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RESEARCH ARTICLE - ENGINEERING

Dual-Band MIMO Antenna Design for 5G Smartphones Mobile Communications

Atta Ullah[1*], Naser Ojaroudi Parchin[2], Mohamed Abdul-Al[1], Waqas Manan[1], Abubakar Salisu[1], Ibrahim Gharbia[1], Chan Hwang See[2], Raed A. Abd-Alhameed[1]

[1] Faculty of Engineering and Informatics, University of Bradford, Bradford BD7 1DP, UK

[2] School of Computing, Engineering and the Built Environment, Edinburgh Napier University, Edinburgh, UK

[*] Corresponding author E-mail: A.Ullah5@Bradford.ac.uk

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Abstract

In this research, an innovative L-shape slot that is fed by F-shape dual-band six-Elements multiple-input multiple-output (MIMO) antenna for mobile phones that operate in a 5G spectrum is demonstrated. This proposed antenna has six antenna elements that can operate in dual band sub-6 GHz for 5G band spectrums at 3.42–3.77 GHz and at 5.30–5.63 GHz. Every antenna element has an L-shaped slot in the ground fed by the same feedline that support the matching of the F-shaped microstrip lines. Important features of the anticipated layout are examined. It provides excellent efficiency at the operation band, appropriate isolation, adequate radiation coverage, and good S-parameters. Ant 3's provided the maximum return loss at 3.6 GHz which is -35 dB, whereas Ant 5 and Ant 6 provide the highest return losses at 5.4 GHz which is -38dB of the suggested dual-band frequency of 5G smartphones. To validate the exactness of the constructed MIMO antenna performances, the sample prototyping and experimentally measured outcomes were carried out in the Lab. Both simulated and measure result assessments revealed an extremely excellent understanding of both results. satisfactory input impedance and mutual coupling characteristics. Future smartphones can leverage the proposed design for high data-rate cellular connectivity because of these appealing properties.

Publisher : Middle Technical University

Keywords: MIMO Array; 5G Communication; Future Smartphones; Dual-Band Antenna.

1. Introduction

Since the fifth generation (5G) communication technology is presently preparing for an exponential growth with the announcement of fifth Generation (5G) New Radio (NR) designs in June 2018 [1-2], it is projected that there will be a substantial need for a new design of a 5G antenna. The range of applications for wireless technology and the range of its uses has rapidly expanded in unison with the rapid development of mobile and communication technologies. Artificial intelligence, mobile video streaming, and the Internet of Things (IoT) are the driving reasons behind this huge expansion in wireless communication [3-4]. Fifth-generation mobile networking is the most up-to-date crucial bandwidth elucidation that advances radio transmission technology and satisfies the growing requirement for cell phone communication setups in the coming years [5-8]. However, once 6G becomes available, fifth-generation mobile networking will be rendered obsolete. To accomplish the superior data rate and low latency, 5G is the definitive answer for wireless communication technology [9-10].

Presently, the 5th generation of cellular phone communication (5G) of the band is recognized as dual frequency bands in 3.42 – 3.77 GHz and 5.30 – 5.63 GHz. It is possible to obtain a total bandwidth of 700 MHz [11-14]. Multiple-input multiple-output (MIMO) techniques can then ominously progress the range operation and channel capabilities in communication systems without boosting transmit power and adding extra transmission bandwidth. On the other hand, as the miniaturization and prospect of wireless appliances turn out to be the distinctive mainstream, the manageable clusters for the antenna are beyond insufficient [15-16]. Consequently, it is exceptionally vital to launch an effective MIMO antenna. To assume the repeatedly applied wireless technologies, dissemination MIMO antenna is a supplementary choice. Conversely, there is intense mutual coupling while the area amongst MIMO antenna mechanisms is incredibly near composed. Though, there is powerful mutual coupling when the space amongst MIMO antenna components is very close together. It is perverse to the aspiration for sharper isolation and lowers envelop correlation coefficients. Therefore, it is crucial to diminish the mutual coupling among the antenna components [17-18].

On the other hand, the available window for antennas becomes more constricted as the efficiency and reliability of wireless machines become more widespread. As a consequence of this, the development of a miniature MIMO antenna is of the utmost importance. In order to adapt to widely used wireless devices, the decision to use printed MIMO antennas is an essential component [19]. In spite of this, there is a high mutual coupling, and the space between MIMO antenna systems is extremely close. It is resolute in its insistence on the requirement for greater isolation and a reduction in envelope correlation coefficients. As a consequence of this, it is absolutely necessary to lessen the reciprocal coupling that exists between the elements of the antenna [20].

Nomenclature & Symbols

MIMO	Multiple-Input Multiple-Output	5G	Fifth Generation
IoT	Internet of Things	NR	New Radio
FR-4	flame retardant	CST	computer simulation technology

In the planned layout, a dual-band six aspects MIMO antenna array is available which covers 3.42 – 3.77 GHz and 5.30 – 5.63 GHz. The transformation of the decoupling suggestion predicted in this research paper does not purely upsurge the partings proficiently, but additionally generates an innovative prosperous refrain in another occurrence band, which covers 5.30 – 5.63 GHz to achieve a dual-band occupied presentation, thus it can competently improve astronomical use in mobile devices [21-23]. The introduced MIMO squeezed antenna array's specifications are approved, and the S-parameter, maximum gain, user effects, radiation, and overall MIMO antenna array efficiency results are also presented.

2. Antenna Design

Through the use of the electromagnetic simulation program CST Microwave Studio, the design of this condensed mobile MIMO F-Shape six-element antenna array is recognised [24-25]. An FR4 substrate with a relative permittivity of 4.3 and a dielectric loss tangent of 0.019 served as the foundation for the intended project. The front-side and back-side views of the smartphone antenna are shown in Figs. 1 and 2, respectively, and the dimension of the central substrate is 140×70 mm2. which almost exactly mirrors the mainboards of modern mobile phones of today era's. Table 1 demonstrates the inclusive measurements of the antenna parameters.

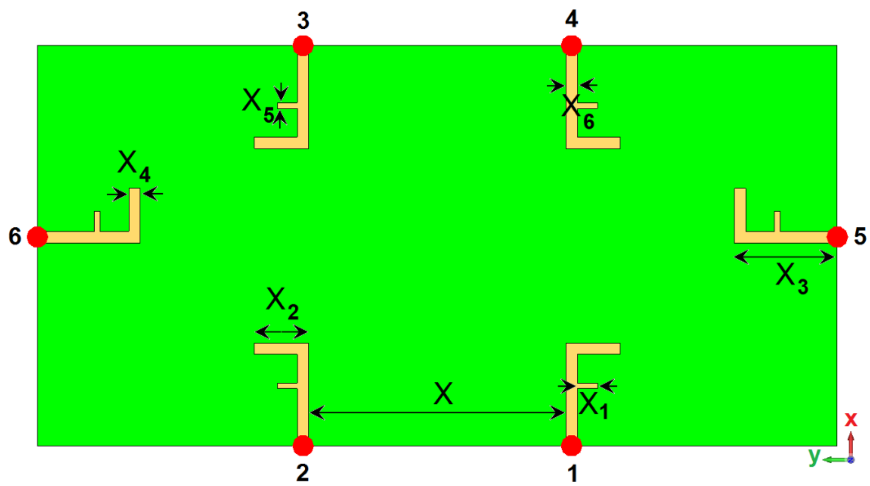


Fig. 1. Front view of the smartphone antenna's

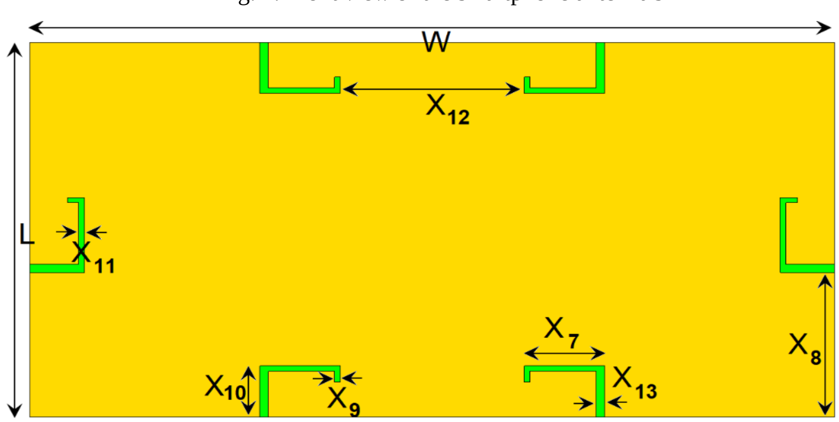


Fig. 2. Bottom view of the smartphone antenna's

Table 1. Final measurements of the antenna parameters in mm

Parameter	W	L	h_{sub}	X	X_1	X_2	X_3	X_4	X_5
Measurements	140	70	0.8	48	4	8	18	2	1
Parameter	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	
Measurements	2	11.5	41.5	1	9.5	1	32	1.5	

3. Result and Discussion

As in this article, Utilizing CST software, the characteristics, and effectiveness of the proposed 6-terminal MIMO antenna arrays are examined [26]. Each section is committed to a 50-ohm SMA connector to achieve sufficient S-parameters and the antenna was motivated on achieving the complete polarisation return loss, radiation pattern, resonant frequency, and gain are the constraints that will be addressed in this research article.

The proposed 6-element MIMO array operates at the dual-band from 3.42 – 3.77 GHz and 5.30 – 5.63 GHz covering the sub 6 GHz frequencies for 5G mobile communications. The suggested antenna's return loss (Snn) is shown in Fig. 3 while it is mutual coupling (Smn) is shown in Fig. 4. These are the main graphs to illustrate the energy-efficient power consumption and the interference that could be caused by the MIMO antenna in terms of the self and mutual scattering parameters. Generally speaking, we are looking for a minimum of 10 dBs of reflection and insertion losses between the port's terminals. The computer-generated S_{11}, S_{22}, S_{33}, and S_{55} are fewer than -21 dB at 5.45 GHz while the computed S_{55} and S_{66}, as seen, are lesser than -20 dB respectively as shown in the figure. Al-though, the Snn values for antenna components 1, 2, 3, and 4 are fewer than -35 dB at 3.6 GHz, although the Snn for antenna elements 5 and 6 are fewer than -40 dB is the outcome at 5.45GHz. The position of the antenna fundamentals [27–31] is primarily to blame for this. According to Fig. 4, the basics of the antenna express respectable mutual coupling consequences that are superior to -15 dB and -12 dB at double operating bands.

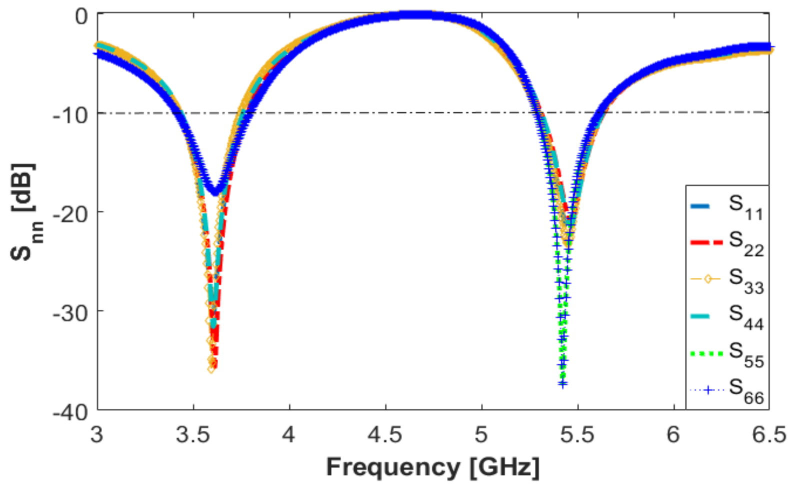


Fig. 3. Simulation of the MIMO antenna array's return loss (Snn)

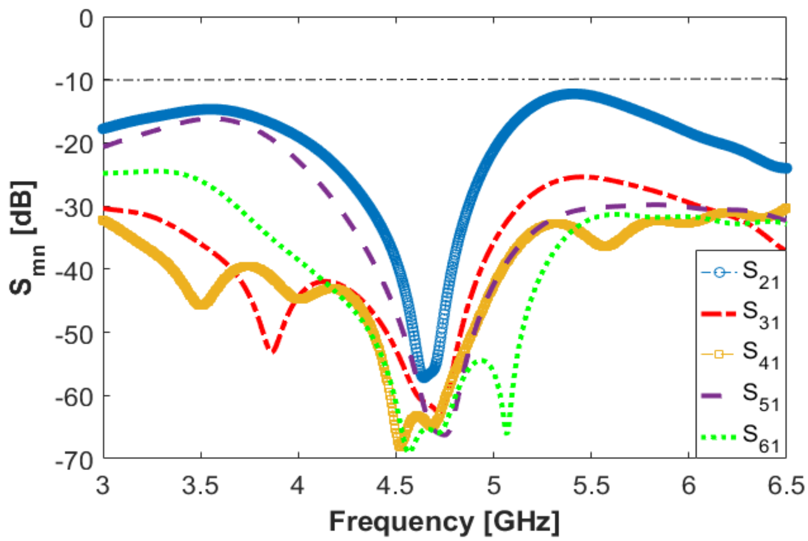
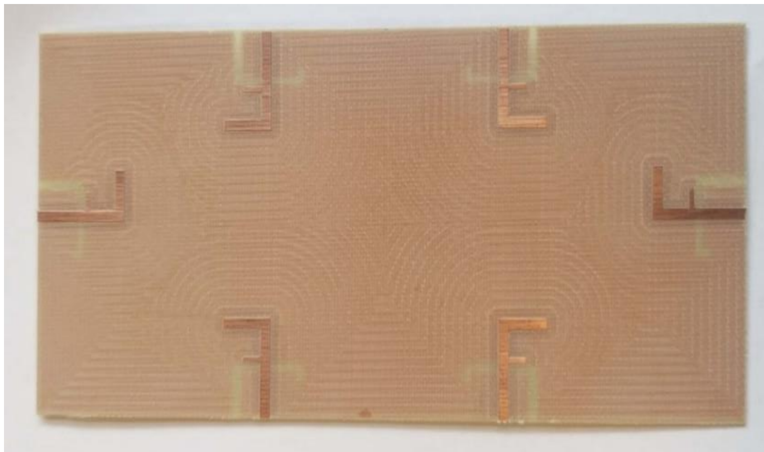


Fig. 4. Simulated result of MIMO antenna array's mutual coupling (Smn)

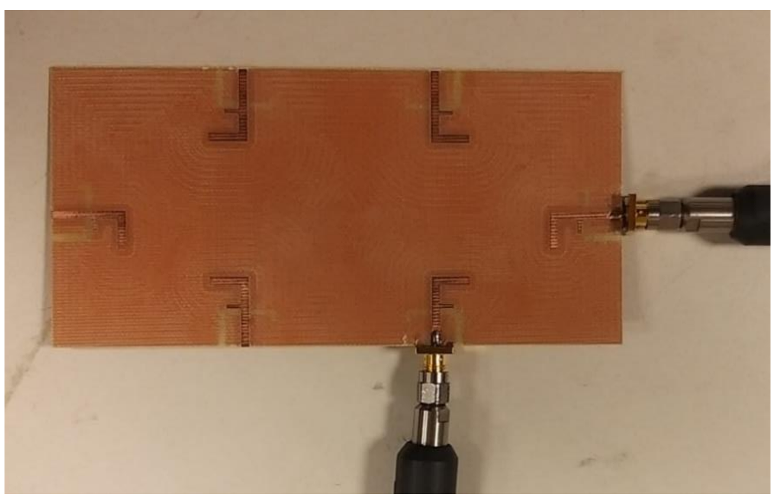
The suggested MIMO scheme has been prototyped and verified by the network analyzer and in the Anechoic chamber. Fig. 5 (a) and (b) demonstrate the top layer and bottom layer of the manufactured sample. Additionally, Fig. 6 (a) shows the prototype's combined SMA feeding mechanism and measurement setup with network analyzer while Fig 6 (b) shows the measurement setup in anechoic chamber. In Figs. 7(a) and (b), correspondingly, the measured and cyber reflection/transmission coefficients (S11 and S21) of the faithfully spaced antennas (Ant. 1 and Ant. 2) have been associated and explained. As revealed, the confirmed antenna resonators impair various effects, as was made clear. In total, the measurements and simulations concur fairly well, with acceptable impedance bandwidth and square couplings ≤-10 dB. A very slight minor difference has been perceived which might be due to the predictable inaccuracies in prototyping, feeding the antennas, and also the experimental setup.



(a) Top layer

(b) bottom layer

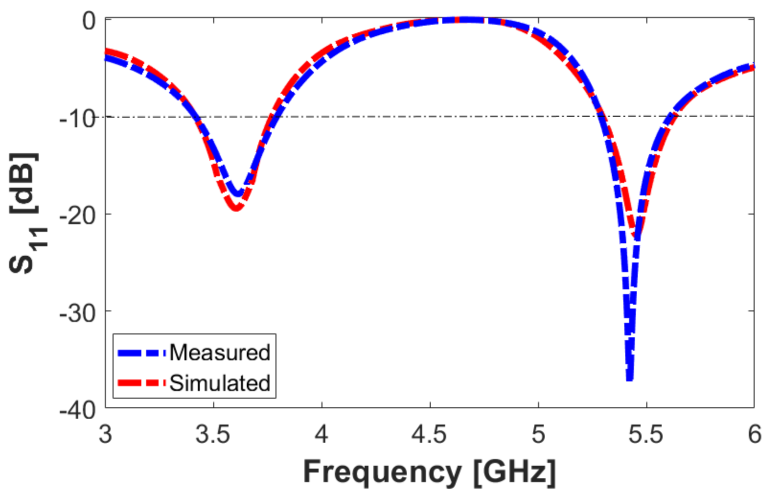
Fig. 5. Fabricated prototype of Proposed MMO Antenna



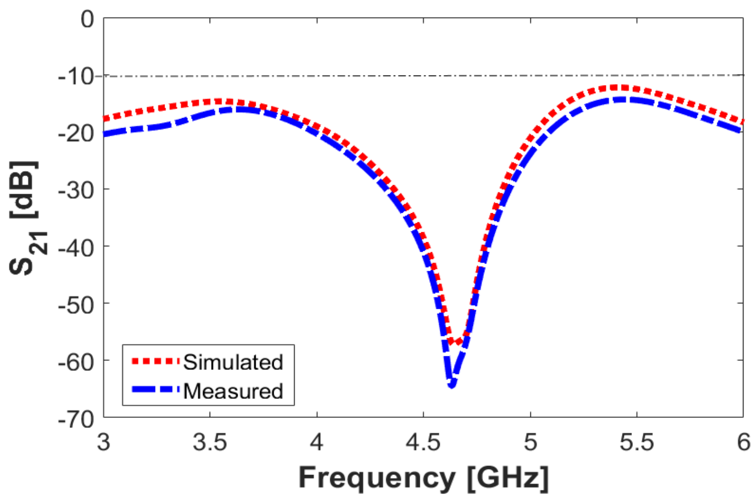
(a) Setting with Network Anaylzer

(b) Measurement in Anechoic chamber

Fig. 6. Feeding/measurement mechanism of the Proposed MIMO antenna



(a)



(b)

Fig. 7. Measured and simulated; (a) S_{11} (operation bands) and (b) S_{21} (mutual couplings)

Figures 8 and 9 show the 3D radiation patterns for the six major design components at both operation frequencies, having 3.6 GHz & 5.45 GHz, individually. It can be seen that the 6-component MIMO antenna can provide enough radiation coverage for every single radiator. As explained, 3.6 GHz, the IEEE gain level of the scheme contrasts from 3.1 to more than 4.1 dB. Although, at the additional operation band (5.45 GHz), the fundamentals display persistent gains of 5.8 dB.

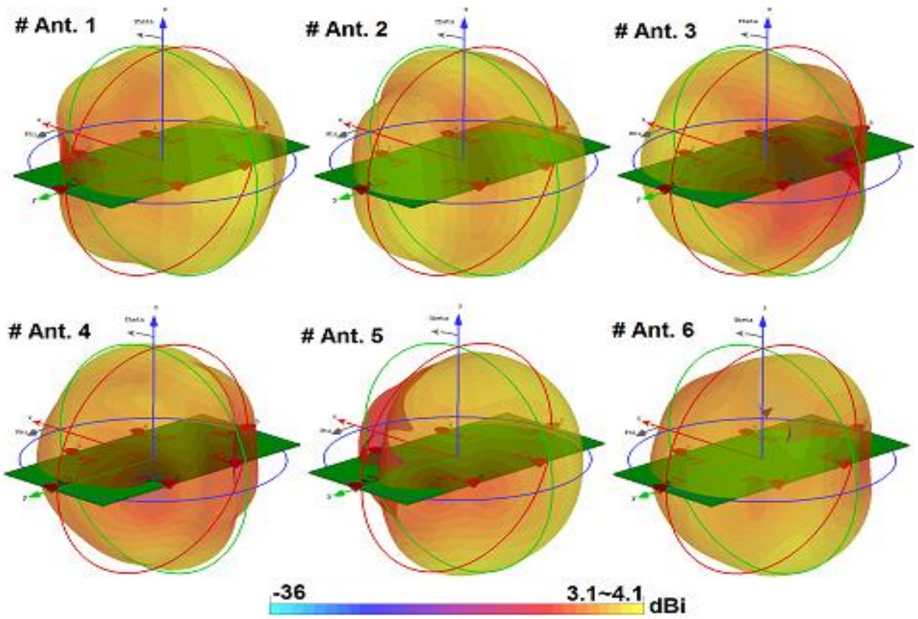


Fig. 8. The proposed MIMO antenna's 3D radiation patterns are at 3.6 GHz

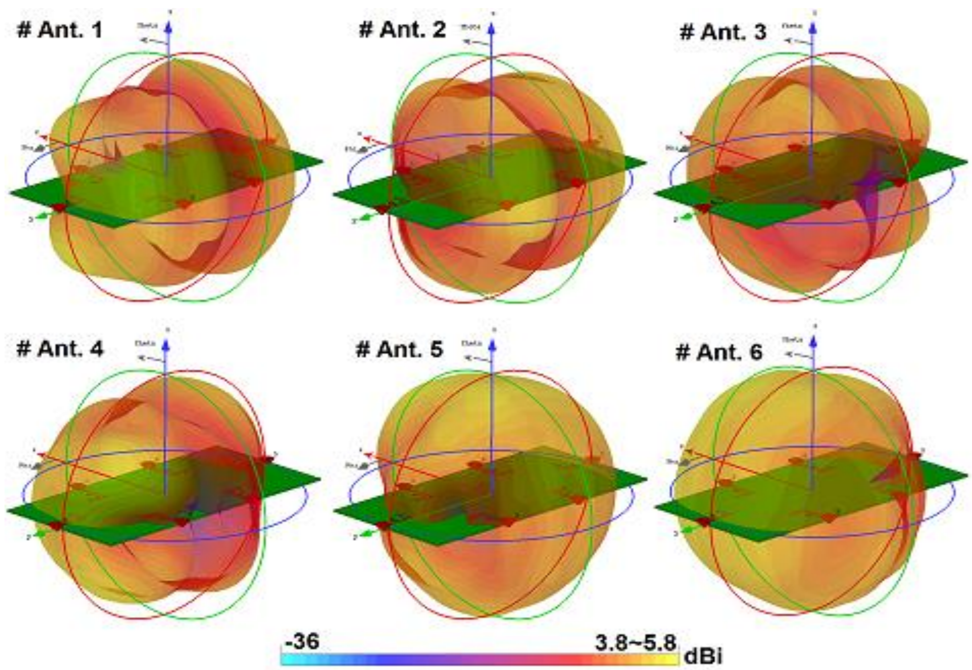


Fig. 9. The proposed MIMO antenna's 3D radiation patterns at 5.45 GHz

Figures 10 & Figure 11 correspondingly provide the antenna efficiencies (Radiation and Total) of the antenna resonators respectively. Within the operational band zones, high efficiencies with insignificant variations are accomplished. It is well noted that the variations of the reduced total efficiency (even if it is bigger than 80%) belong to the loss consistent with the array antennas and handset. At the first and second operation bands, it was found that the components of the suggested MIMO design had radiation efficiencies of more than 95% and 90%, respectively. Additionally, as depicted in Fig. 8, the antenna elements offer overall efficiencies between 75% and 80%.

The maximum gain models and experimental results for the antenna are shown in Fig. 12. All antenna elements show maximum gains of over 3 dBi and up to 6.5 dBi across a wide range of frequencies. In contrast to the first function band's base frequency of 3.6 GHz, the peak gains of the antenna at the succeeding resonance are practically constant by a rate of 6 dBi.

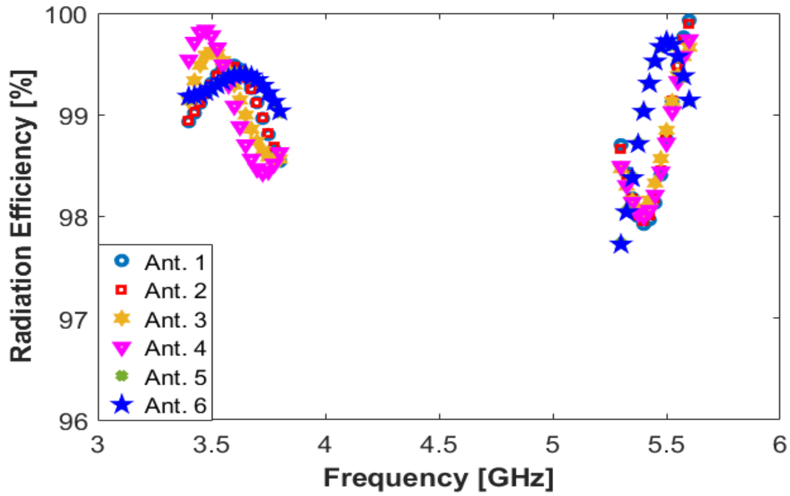


Fig. 10. MIMO antenna's radiation efficiency over its operating band

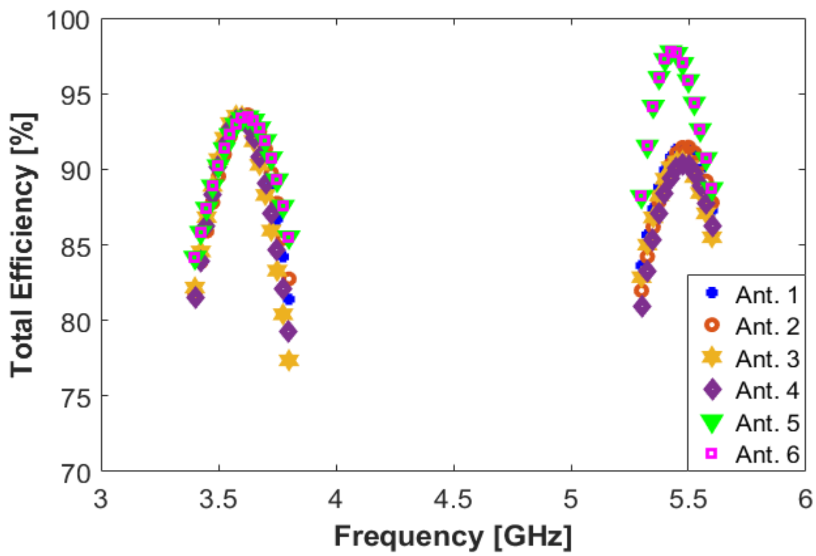


Fig 11. Overall MIMO antenna efficiency across its operating band

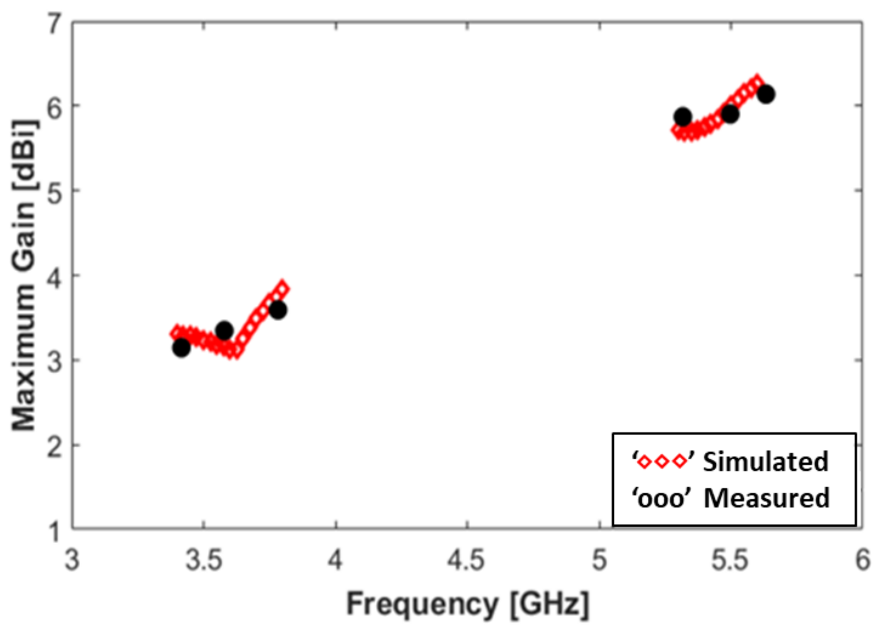


Fig. 12. Measured and simulated Maximum gains of the MIMO antenna over its operation band

Table 2 compares the fundamental properties of the proposed MIMO antenna with MIMO antenna arrays recently reported in the literature [32-38]. As can be seen, the proposed antenna can support three different operation bands with very similar radiation and MIMO performances in terms of bandwidth, efficiency, and isolation. In contrast to the reported designs, each radiator of our design can cover dual band 5G frequency operation bands of sub6 Ghz simultaneously.

Table 2. Comparison between the presented and reported mobile handset antennas

Reference	Bandwidth (GHz)	Efficiency (%)	Overall Size (mm^2)	Isolation (dB)
[32]	2.55-2.68	48-63	136 x 68	12
[33]	3.4-2.38 5.15-5.92	41-84 47-79	150 x 80	12
[34]	2.55-2.6	48-63	136 x 68	11
[35]	3.4-3.6	62-78	140 x 70	10
[36]	3.4-3.8	55-70	150 x 75	15
[37]	3.55-3.65	52-76	150 x 75	11
[38]	1.88-1.92 2.30-2.62	50-70	138 x 68.8	10
Proposed	3.42–3.77 5.30–5.63	80-90	170 x 70	15

4. Conclusions

In this work, an F-shape dual-band 6-port MIMO antenna array for 5G applications is presented. Utilizing a part of the copper edge as a radiation branch, the antenna array can work appropriately in a metal-frame smartphone. The effects reveal that the working frequency band of the offered mobile antenna array can cover 3.42 – 3.77 GHz and 5.30 – 5.63 GHz. Within the operational bandwidth, the antenna radiation and overall efficiencies are greater than 80% and 90%, respectively. According to all results in this paper, the mentioned MIMO antenna array is a strong contender for the upcoming 5G enormous MIMO mobile communication systems.

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