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DESIGN OF 5G MIMO AERIAL WITH NON-IONIZING RADIATION PROTECTION

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Abstract

Novel antenna designs that utilize antennaarrays to provide improved coverage, minimize interference, and boost data-carrying capacity are needed to meet 5G targets.This paper provides an approach for designing an inverted-L 5G MIMO antennas with SAR (Specific Absorption Rate) calculation. The designed antenna will be resonating at5.84GHz, with optimal parameters like reflection coefficient, gain and voltage standing wave ratio (VSWR). The measured bandwidth is in the range of 3.07GHz to 6.6GHz. The simulatedhuman body SAR values are 0.925 W/kg, which is less than the ICNIRP-recommended SAR safety limit of 2 W/kg. The user- friendly CST Microwave Studio Software is used for all simulations and design.

Keywords: Inverted L-antenna, 5G MIMO antenna, SAR value, CST Microwave Studio, S11 parameter

1. INTRODUCTION

Modern wireless communication technologies are advancing at a breakneck pace and operate over a widefrequency range. The new 5G radio access networks are projected to handle a sizable number of connections at a sametime. The FCC has separated the most spectrums into three bands: frequency up to 1GHz as low band, below 6 GHz as medium band and mm waves as high bandwidth to enable 5G. The millimeter-wave band provides data rates of over 2 Gbps and high capacity, while the low-bandwidth band provides outstanding 5G coverage, therefore the medium bandprovides a mix of both. The usage of the 5G millimeter wave spectrum to provide superfast data rates are definitely desirable.

However, some significant obstacles must be overcome before millimeter wave mobile communication can be widelyadopted. Millimeter waves are also sensitive to air attenuation and can't travel great distances. Sub-6 GHz waves, on the other hand, can travel larger distances than millimeter wavesand are thus a less expensive option for long-distance, high- data-rate communication networks. Because 5G connectivityat frequencies below 6 GHz can transfer high data rates overgreat distances, it can be used in both urban and rural locations. When users use communicating devices (e.g., mobile phones) to transmit data, EM waves are constantly exchanged between the base station and the device.

When exposed to electromagnetic waves, the humanbody can absorb and dissipate EM wave’s energy since most tissues are dissipative media. Health will be adversely harmed once absorbed electromagnetic radiation surpasses aparticular safety limit, like organ dysfunction, aberrant hormone system, and so on [1]. As a result, the problem of electromagnetic radiation safety produced by wireless devices is attracting increasing attention from people from allwalks of life.

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As mentioned above, tissues can absorb radiation and how radiation affect human body has to be characterized. Forsuch reasons, SAR (Specific Absorption Rate) is introduced to quantify the absorbed electromagnetic energy by biological tissues. Many international organizations have setSAR value safety standards, including two of the most generally used guidelines. The International Commission on Non-Ionizing Radiation Protection (ICNIRP) sets the maximum SAR value at 2 W/kg averaged over any 10 gramsof tissue, while the Institute of Electrical and Electronics Engineers (IEEE) and thus the United States Federal Communications Commission (FCC) set the maximum SARvalue at 1.6 W/kg averaged over any 1 g tissue. Because all mobile phones must comply with the aforementionedrequirements, there is a strong engineering need for low SARantenna design theories and techniques.

2. LITERATURE SURVEY

In paper [1], Lu, Bao et.al, proposed a method to reducethe antenna radiation. Here, SAR is reduced by directlyadjusting the antenna surface current using the rectangular slot in PIFA. Simulation results show that the obtainedbandwidth is in the range of 2.4 – 2.49 GHz and the reflection coefficient is 6 dB. The obtained SAR value is 0.184 W/kg. Manufacturing inaccuracy and dielectric loss are disadvantages, and antenna modeling and test reports are notidentical.

In paper [2], Yan, Kuixi et.al, proposed an approach in which the components of the T-ship open slot antenna are symmetrically mirrored along the frame's long side edge. The aim is to get good isolation for dual-band with the wide ranges is observed. Even so, the return loss is found to be 7 dB. The designed antenna is complex and also, imparting an antenna all over a mobile may increase radiation.

In paper [3], Yang, Peng et.al, designed a small-sized antenna and wide operating bandwidth. They developed a folding slot structure to achieve the antenna's compactness and low ground clearance. The obtained bandwidth ranges from 800 to 900 MHz, 1700 to 2700 MHz, 3300 to 3700 MHzand 4800 to 5000 MHz and the return loss of 7 db. The reconfigurable antenna uses a switching mechanism; hence the design is complex.

In paper [4], Zhang et.al, proposed an antenna withbandwidth ranging from 3300 to 3600 and 4800 to 5000 MHzand the return loss is -6 dB, isolation is -12, and the obtainedSAR value is 0.54 W/kg. The limitation of this design is thatcomplex feed structures require high performance arrays.

In paper [5], Jan et.al, proposed a planar monopoleinverted L shaped antenna with a parasitic element shorted toground is presented. The multiband widths of 0.2 GHz (2.3 to 2.5 GHz), WLAN band, covering the HIPERLAN band andWLAN band is observed with better gain and efficiency.

3. PROPOSED ANTENNA DESIGN

The following design parameters are used to calculate the proposed antenna specifications [7].

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$$W = \frac{0.5}{f_r(\sqrt{(\epsilon_o \mu_o)}}\sqrt{2/(\epsilon_r + 1)} \quad (1)$$

$$\epsilon_{reff} = ((\epsilon_r + 1)/2) + (\epsilon_r - 1/(\sqrt[2]{(1 + 12d)/W}) \quad (2)$$

$$\Delta L = \frac{0.412d(\epsilon_{reff}+0.3)(\frac{W}{d}+0.264)}{(\epsilon_{reff-0.258})(\frac{W}{d}+0.8)} \quad (3)$$

$$w = \frac{7.84*d}{e^{(z_o\frac{(\epsilon_r+1.41)^{0.5}}{87})}} - 1.25 * t \quad (4)$$

$$L = \frac{0.5}{f_r\sqrt{\epsilon_{reff}\epsilon_o\mu_o}} - 2\Delta L \quad (5)$$

where W-width of the patch; ε_r-the relative permittivity; L - the length of the patch; d - the thickness of the substrate; w - the width of the feed line.

Designed inverted L antenna dimensions are mentioned as in Fig. 1. An inverted L parasitic wire connected to ground with shorting pin as in Fig. 1. b. [5]. The length (L) and width (W) of the driven element is calculated from the antenna design parameters for centre frequency of 5.7GHz are W=8mm and L=3mm [6].

On the substrate (FR-4) of relative permittivity 4.4 with dimensions 120mmx30mm and thickness of 1.6mm, the driven element is placed. On top of the driven element, parasitic element is placed 1mm away and D=5mm of distance towards the right side of driven element. The parasitic element is introduced, which is dependent on the driving patch element. It has no feed of its own. It is used in this sort of array to assist increase the radiation indirectly. This element is connected to ground plane using the shorting pin.

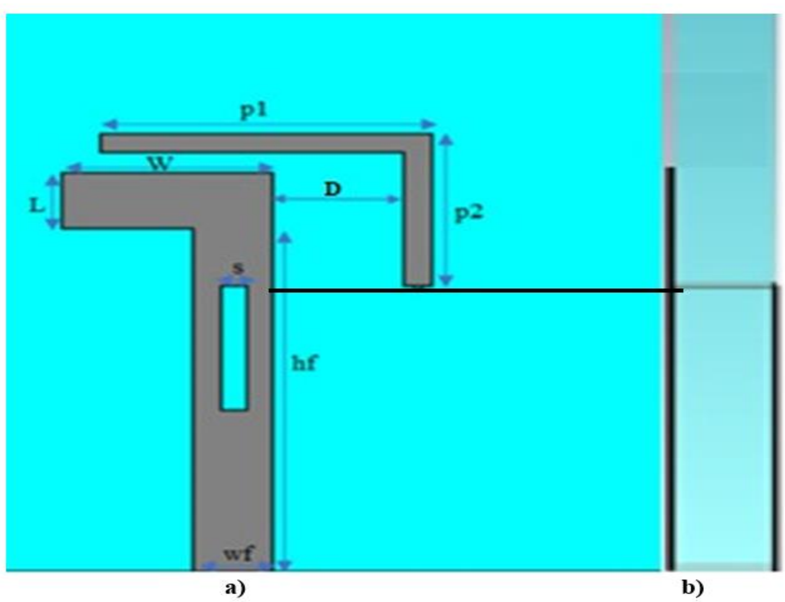

Fig. 1: Layout dimensions of the design (a) Front view; (b) Side view

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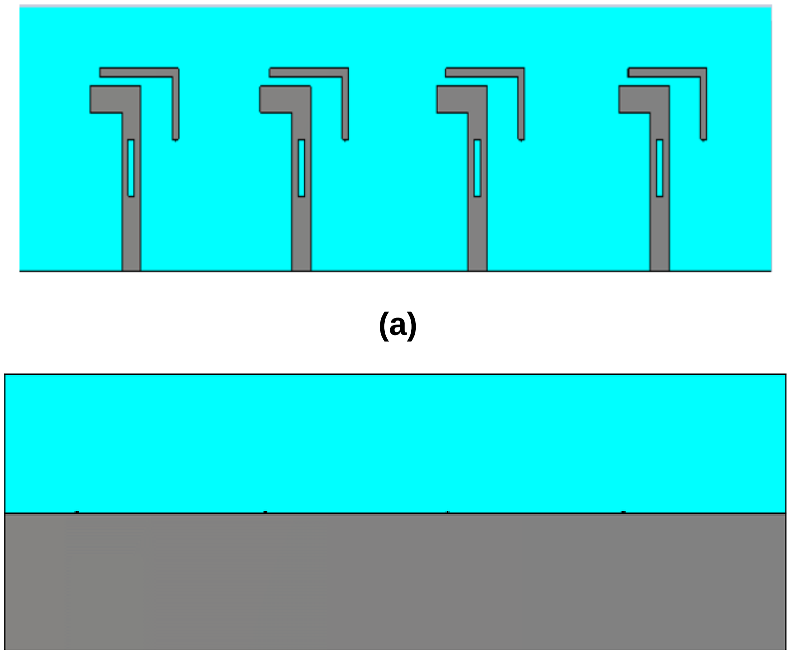

(a)

(b)

Fig. 2: MIMO antenna array (a) Front view; (b) Rear view

A 50Ω micro strip feed line of width w=3mm and height hf=18mm, which provides good impedance matching is used in this design. An additional slot of 1x8mm is inserted on feed line providing the additional electrical length to the design as shown Fig. 1. b. [5]. Below the micro strip, on the other side of antenna the ground of dimensions 120mmx15mm is printed as shown in Fig. 2. b.

4. SIMULATED RESULTS AND DISCUSSION

CST microwave studio 2019 is utilized for designing and simulating a proposed antenna. The optimal parameters such as return loss, VSWR and gain are calculated.

A. Return loss and VSWR

Over a range of frequencies, the return loss plot shows how closely the connection and channel's impedance match their rated impedance. A high value of return loss indicates a great rated impedance match, which indeed results in greater

The Voltage Standing Wave Ratio is a measurement of how well RF power is carried from port to the antenna through transmission line. VSWR is a function of reflection coefficient (Γ). VSWR and reflection coefficient relation is as shown in the Equation (6). Difference between the reflected and transmitted signal powers.

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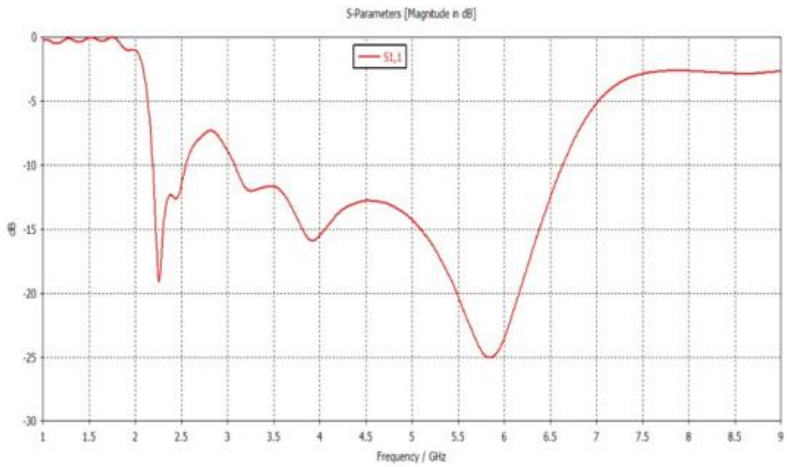
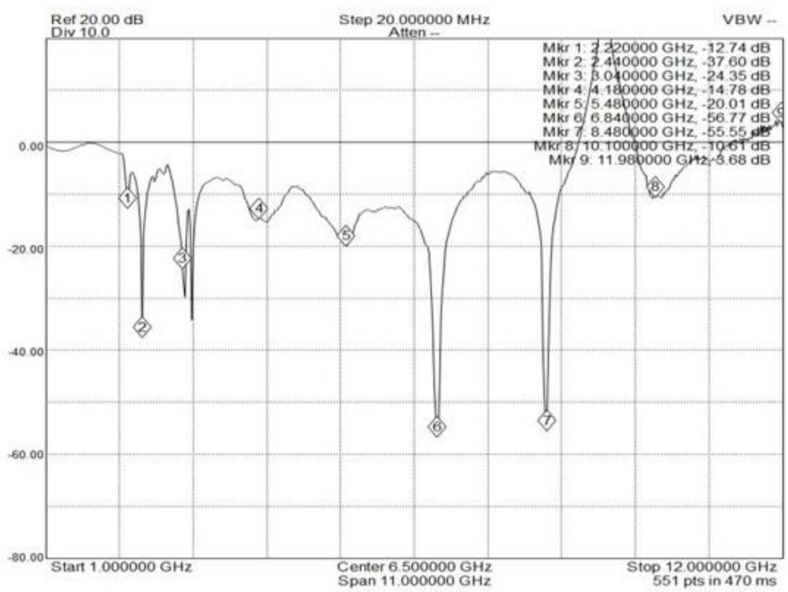
$$VSWR = \frac{1+|\Gamma|}{1-|\Gamma|} \qquad (6)$$

The proposed antenna's simulated and measured through analyser results for return loss (S11) are as shown in Fig. 3. The bandwidth of about 3.6GHz determined. The desirable band of 3.06GHz to 6.63GHz is covered under -10dB of return loss.



(a)



(b)

Fig. 3: S11 Parameter (a) Simulated; (b) Measured using analyser

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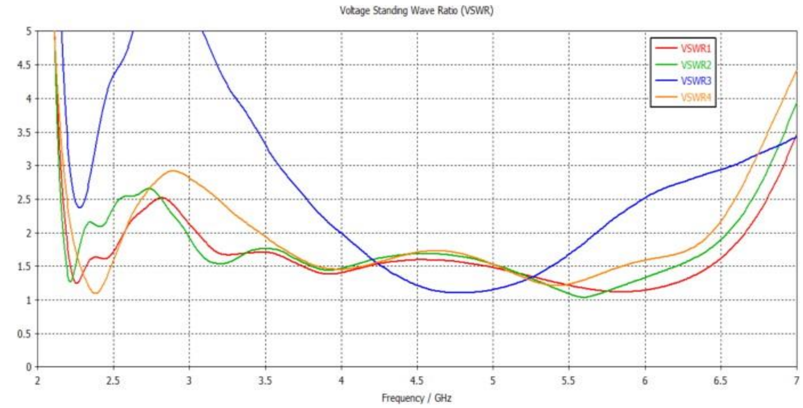
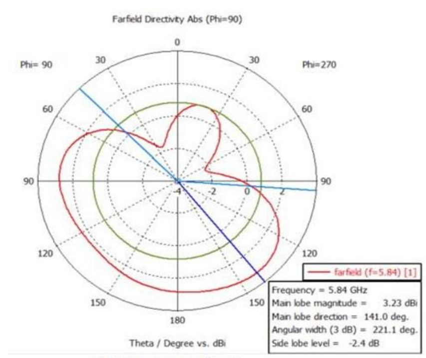


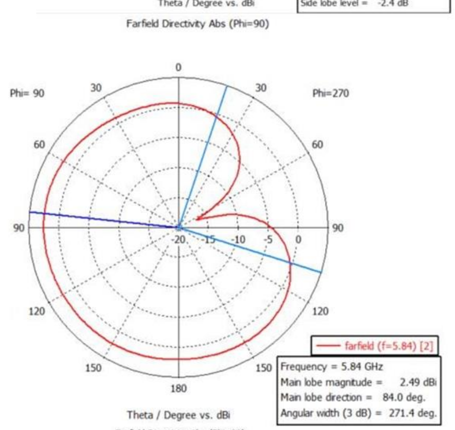
Fig. 4: VSWR

Fig. 4. Shows the VSWR for all ports. The return loss of antenna is around -25dB at 5.84GHz for VSWR of 1.3. The simulated plots indicate the antenna can cover wider range of frequencies 3.07GHz to 6.6GHz of band width 3.6GHz which is suitable for WLAN and other such applications.

B. Radiation pattern

Analysing return losses, while taking into account the antenna's efficiency performance, there is another important attribute to examine when determining antenna vitality is the radiation pattern.





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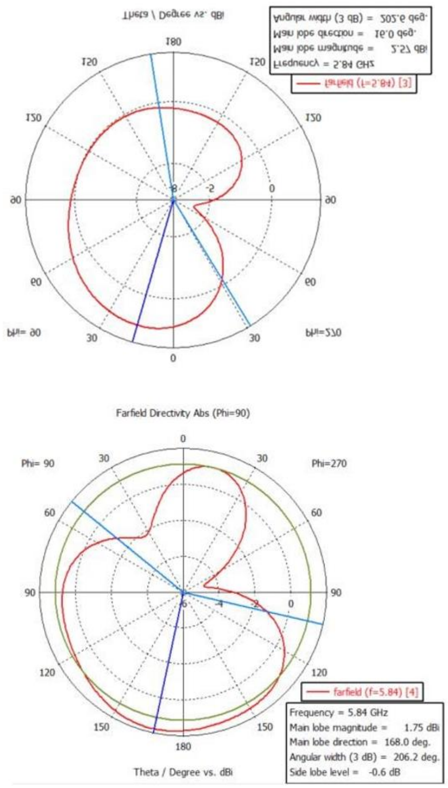

Fig. 5: Far field patterns

Proposed antenna's radiation pattern operating at 5.84GHz is shown in 2D pattern view in Fig. 5. Observed pattern of the radiation is nearly unidirectional which is suitable for Wireless LAN (WLAN) application. The electric field intensity dropped little in the direction of the antenna's two ends. Because of that, even though the pattern is unidirectional but radiation is not fully occupied by 360˚ region in far field radiation pattern.

C. Gain

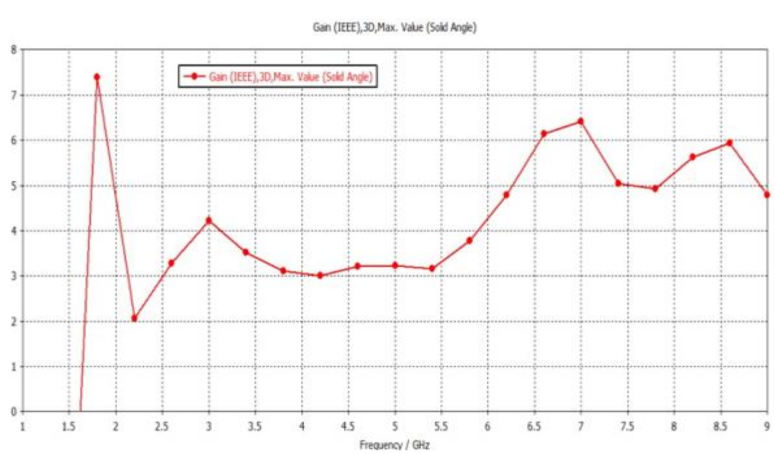

Fig. 6: Gain

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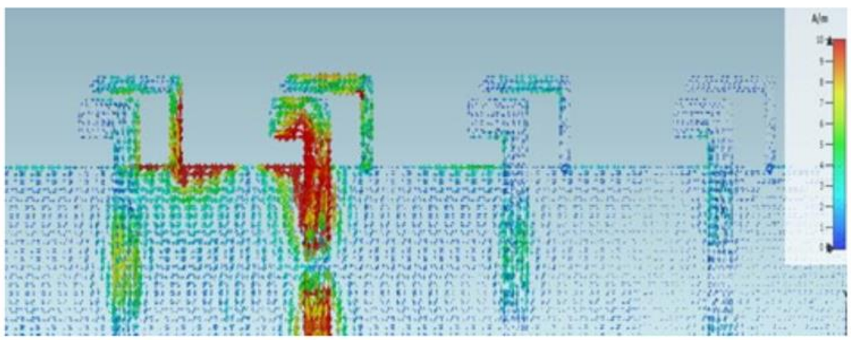
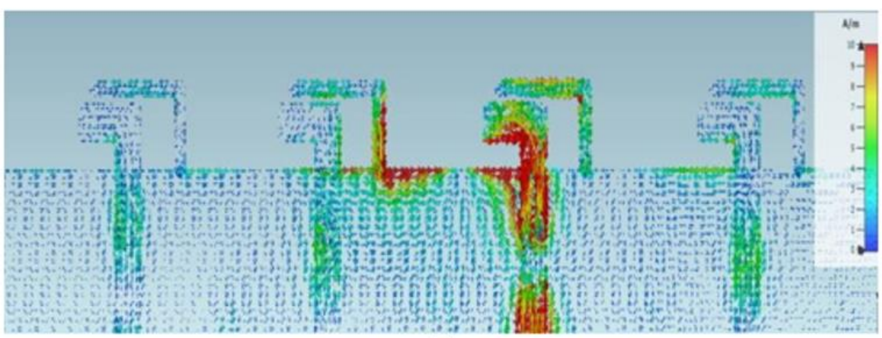
The antenna gain is the ratio of power transmitted in the peak radiation direction to that of an isotropic source. A 3 dB gain transmitting antenna receives 3 dB more power (twice as much) than a lossless isotropic antenna with the same input power. The proposed antenna gain is as shown in the Fig. 6. This is observed to have a maximum of 6dBi in the obtained bandwidth.

D. Surface Current distribution

The surface current in metallic antennas is an actual electric current caused by an applied electromagnetic field. The simulated surface current distribution for each port excitation is shown in the Fig. 7.



a)



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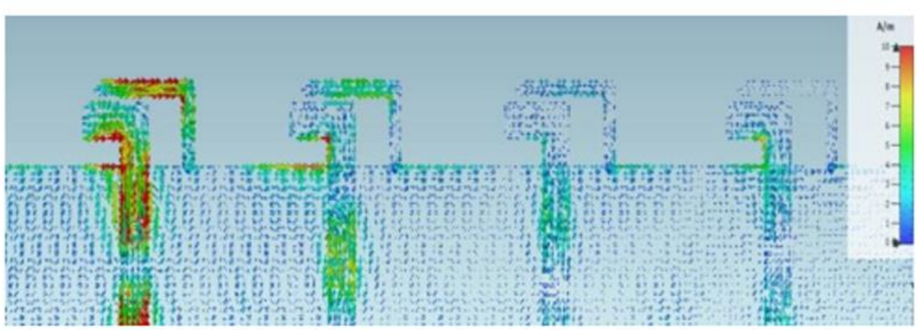

c)

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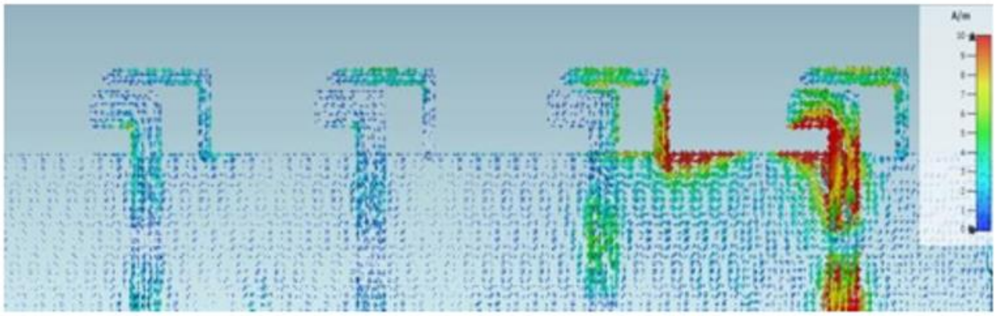

d)

Fig. 7: Surface Current distribution at (a) Port 1; (b) Port 2; (c) Port 3; (d) Port 4

E. Specific Absorption rate (SAR)

Due to the dissipative nature of the human body, an antenna's efficiency is impaired when placed in close proximity to it. A four-layered body phantom, consisting of muscle, fat, and skin, is created in the CST Microwave studio for this purpose, as shown in Fig. 8. At 5.84 GHz, the relative permittivity and conductivity of the layers are: skin (ε_r = 35.08; σ = 3.75), fat (ε_r= 4.95; σ = 0.295), muscle (ε_r = 48.933; σ = 5.25), skull (ε_r = 12.51; σ = 1.66) as shown in Fig. 8, and antenna is put in front of the human head phantom as shown in Fig. 9.

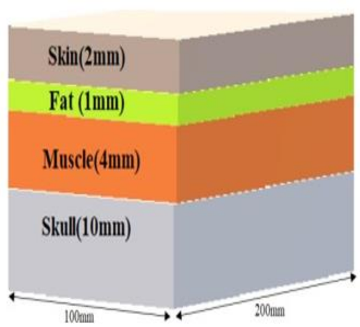

Fig. 8: Human head phantom layers

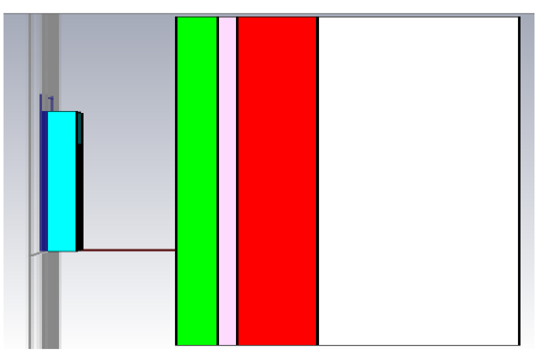

Fig. 9: Antenna placed in front of phantom layers

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In this simulation, the transmitted power is 0.5W continuous signal, and the SAR analysis is performed using the IEEE/IEC 62704-1 averaging method in CST MW Studio. SAR calculations were performed on a volume of 10-gram tissue. The standard safety limit over 10 grams of tissue is 2 W/kg.

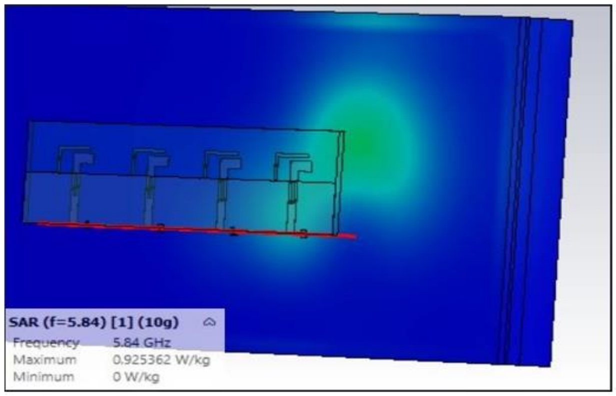
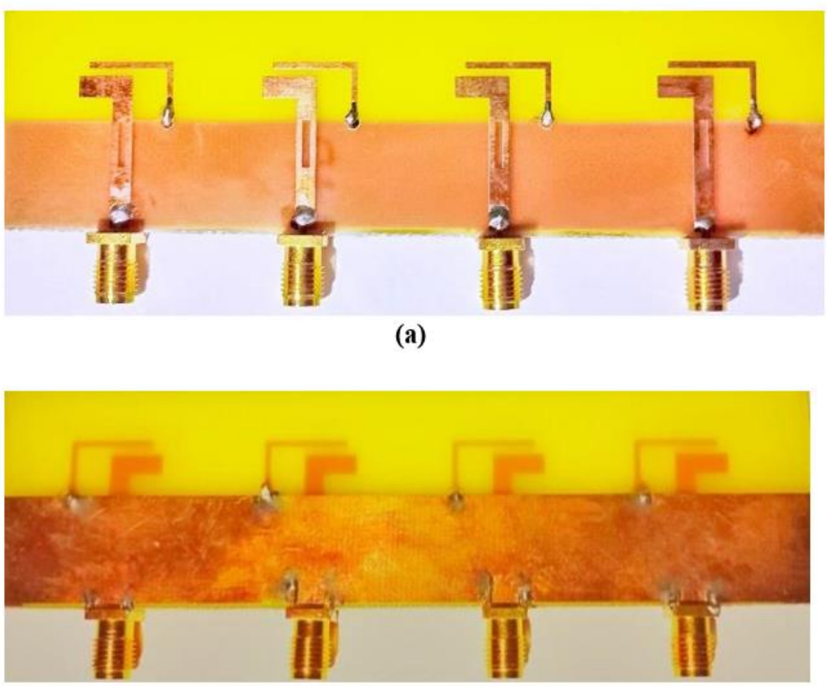


Fig. 10: Distribution of SAR over a head phantom layer

The SAR of the proposed antenna over the human head phantom is as shown in Fig. 10. The maximum 10gm averaged SAR of the proposed design is 0.925 W/kg.

5. FABRICATED ANTENNA



(a)

(b)

Fig. 11: Fabricated antenna (a) Front view; (b) Rear view

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6. CONCLUSION

A compact MIMO antenna for 5G communication is designed, which operates in the sub-6 GHz band and the designed inverted L MIMO antenna shows the bandwidth of 3.56 GHz (3.07 GHz – 6.63 GHz). The proposed antennas provide good gain of 6dBi at the desired resonance frequencies and the simulated SAR value is 0.925 W/kg per 10g of tissue. The antenna could be perfectly suitable for the WLAN applications because of its radiation pattern and good bandwidth range.

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