

Modeling and Analysis of 5G Antenna Radiation Effect on Human Head by Calculating Specific Absorption Rate (SAR) using Adult Brain Model

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ABSTRACT

There has been vast research going on in multiple domains of 5G communication and also the effects of 5G on health [1]. This manuscript proposes the implementation of antenna proposed for 5G cellular communication and measuring the Specific Absorption Rate (SAR) in order to address whether the antennas being proposed for 5G communication could commercially be used according to criteria by Frequency Communication Commission (FCC). In this paper, a compact size dual bands square patch antenna has been modeled on two different software platforms High Frequency System Simulator (HFSS) & Computer Simulation Technology (CST) for 5G cellular communication. The proposed antenna has a compact structure of $19 \times 19 \times 0.787 \text{ mm}^3$ including the ground plane which operates at 10.137 GHz and 28 GHz. The antenna has been designed on Rogers5880 substrate with a thickness of 0.787mm. The proposed design provides a gain of 5.61 dB at 10.176 GHz and 9.485 dB at 28.39 GHz using CST software and a gain of 7.324dB at 10.12 GHz and 9.573 dB at 29.6GHz by using HFSS software. The SAR is calculated at the operating frequency of 10.176 by averaging over a specific volume (typically a 1gram or 10gram area) and the maximum values as 0.8W/kg on 1 gram of tissues and 0.2W/kg on 10 grams of tissues have been calculated. Similarly, at the frequency of 28.39GHz, the maximum values of 1.4w/kg on 1 gram of tissues and 0.3w/kg on 10 grams of tissues are obtained

Keywords: Specific Absorption Rate (SAR), 5G Communication, MMW, Radiation Effects.

Author's Contribution

^{1,2,3,4} Manuscript writing, Data analysis, interpretation, Conception, synthesis, planning of research, Interpretation and discussion, Data Collection

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INTRODUCTION

As the new technologies are increasing rapidly and there is massive growth being perceived in the use of mobile technology, the current generation is unable to fulfill the customer's requirements. So, the world is

moving towards the next generation [2]. 5G will be commercialized approximately in the early 2020s [3]. The 5G technology has great capacity and faster transmission speed as compared to the 4th generation [4]. As 5G is not

yet defined [5] there are many problems which are under research. Some of those include higher data transmission which is the goal for every wireless communication system. The challenge is the use of higher frequency bands to carry high capacity and for all these, it is necessary to have a well-performing antenna. For the performance of the antenna the parameters such as gain, return loss, VSWR, reflection coefficient, directivity, and relative permittivity are merely important which need to be improved in accordance with new standards that are to be set in upcoming 2020 meeting. Along with the parameters, the antenna size, and fabrication, according to the designed devices are also in consideration so far, the mobile antenna must be small, light and fit into the allotted space. Patch antenna meets all these conditions with extra grades of easy fabrication, low cost, multiband properties. The 5G antennas are designed by using different technologies, different feeding techniques, and different dielectric materials but some of the most validate technologies are advanced cell structures, massive Multiple Input Multiple Output (MIMO) implementation and millimeter wave (MMW) system. 5G operates on MMW, also referred to like the extremely high frequency which can be used for this purpose. While 5G is attracting significant research interest, the research is also going on to find the effects on human health due to this technology. The 5G is supposed to create a web of higher frequencies for certain area to be covered, hence several health issues could be expected and reason for uncertainty is scaring investigation in this scenario [1]. This work addresses one of the issues Specific Absorption Rate (SAR) in which the absorption of radiations from the mobile antenna by human head and brain tissues. Based on the implementation of a compact dual bands patch antenna for 5G [6] which is designed using two software platforms HFSS and CST to compare both methods impacts have been discussed.

LITERATURE REVIEW

Some of the paper's reviews are discussed here. The antenna designing, parameters, performance, and applications are discussed leaving the human health and environmental impact of that antenna on the human body. 5G is challengeable in many perspectives; the research is

going on the different areas of 5G network i.e. IOT, security, business but the main focus is on the main element for the 5G network which is antenna designing [7] because antenna performance is affected due to some design issues. Wonbinhong (2014) have designed a low profile 28GHz beam steering antenna for upcoming 5G cellular communication. He proposed a mesh grid antenna array for 5G handsets and its desired coverage [8]. Swarup das (2016) proposed an I-shaped fractal slot multiband microstrip patch antenna with tri-band resonances at frequencies of 2.33, 5.10 and 7.11 for several applications like Bluetooth, WLAN, LTE, and C-band communication [9]. Wei lin (2017) have designed 28GHz compact Omni directional circularly polarized antenna specially for the device to device application [10]. Wonbinhong (2017) gives an overview of mm-Wave 5G antennas for handsets in which he describes the handset effect, gain coverage, field radiation properties, and phased-array design [11]. Weijunzhang (2018) design a dual-band MIMO antenna at 3300-3600 MHz and 4800-5000 MHz for 5G smartphone applications in which he got reflection coefficient less than -6dB and isolation is better than 12dB by using HFSS software [12]. Kim Mey Chew (2014) presents a comparison of the relative permittivity of brain phantom with computer simulation technology (CST) application, the phantom based on real human body dielectric properties with a relative permittivity of 38 and 28 gray matter and white matter respectively at 10GHz frequency [13]. Kim Mey Chew (2012) proposed a human brain phantom model using simple material, for that the aim is to explore clinical results of human brain dielectric properties. The elements used for phantom signify sufficient internal consistency of relative permittivity within 60-80 for a frequency from 1-6GHz. The reason behind affecting the permittivity is the quantity of element sugar [14].

It can easily be observed that the primary focus has been around the best performing antenna for upcoming 5G communication while the segment of other issues specifically related to health is unattended.

ANTEENA DESIGN

The simplest antenna has been selected and modeled. The selection of substrate is the initial step towards antenna designing. There is a significant effect of

substrate parameters. So, in order to increase the bandwidth, substrate height can be increased. Here, Roger5880 has been used for the substrate of the patch antenna. Following table shows the substrate and antenna parameters.

Table I: Substrate Parameters	
Rogers RT5880 (lossy) Parameters	values
Dielectric constant (ϵ_r)	2.2
Substrate thickness	0.708mm
Loss tangent (δ)	0.0009
Dimensions (mm ²)	19 × 19

Table II: Antenna Parameters						
Antenna Dimensions (Unit mm)						
W	L	Lf	Wf	Ws	Ls	Wg= Lg
9	9	4.75	0.7	0.5	2.99	19

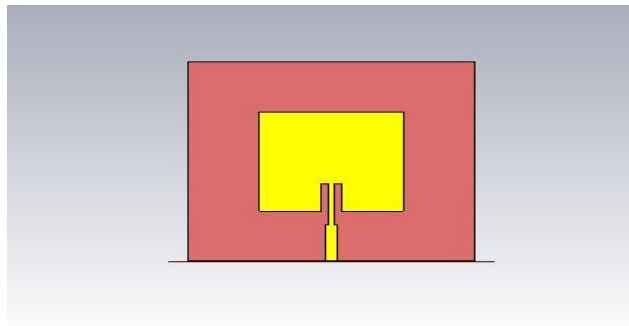


Fig. 1: Square Patch Antenna for 5G Communication

SAR CALCULATION

SAR is the standard used to measure the amount of RF energy characteristics which is absorbed by the human body when using a cell phone to ensure they are within the principle set by the FCC.

FCC is federal communication commission which sets the standard of SAR and ensures antennas installed in mobile phone lie well below FCC's standardized maximum level. The FCC limit for public exposure from cellular telephones is a SAR level of 1.6 watts per kilogram (1.6 W/kg) less than 2.

SAR is defined as the power absorbed per mass of tissues and has a unit of watts per kilogram. The effects of higher SAR on human head and body is due to the higher radiation of radio frequency which causes a sleep disorder, memory loss, headache, the problem of concentration, problem joints, depression, and loss of

hearing. To reduce these types of effects, the user holds the cell phone away from the head and body by using the speaker of phone or hands-free accessory. The SAR is calculated by averaging over a specific volume (typically a 1gram or 10gram area) which is set by FCC. In this work, we took a built-in brain model from CST software, simulate it and analyzed SAR on 1gram and 10 grams of adult tissues by placing square patch antenna near to brain with the operating frequency of 10.176GHz and 28.39 GHz.

SIMULATION RESULTS AND DISCUSSION

The simulations of proposed antenna are performed by using two software platforms computer simulation technology (CST) Microwave studio (CST MS 2018) and High frequency structure simulator (HFSS 13.0) software. For an antenna, the most common quoted parameter is S11 or reflection coefficient which describes the relationship between input and output ports and shows how much power is reflected from an antenna and define the bandwidth. Following figures show the simulation results of the S11 parameter using both software (CST and HFSS)

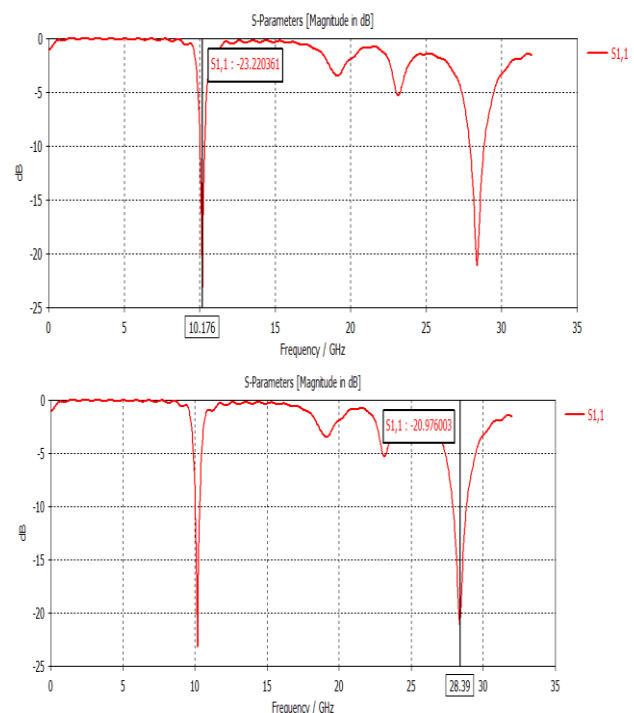


Fig.2: Simulated S11 parameter at 10.176GHz and 28.39GHz using HFSS

In the above figure the result of S11 parameter with the frequency of 10.176 is -23.220 and with the frequency

of 28.39GHz is -20.97 which is within the desired range of 5G.

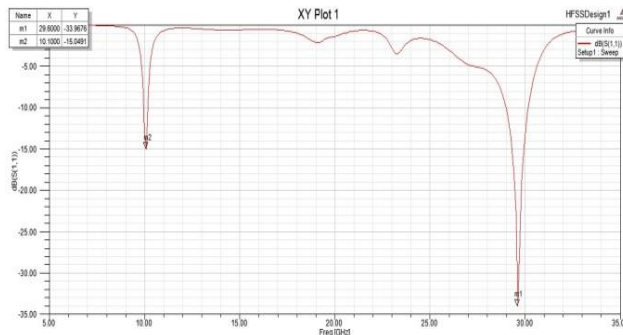
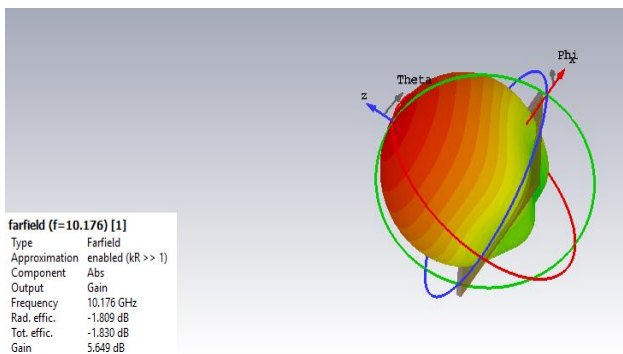


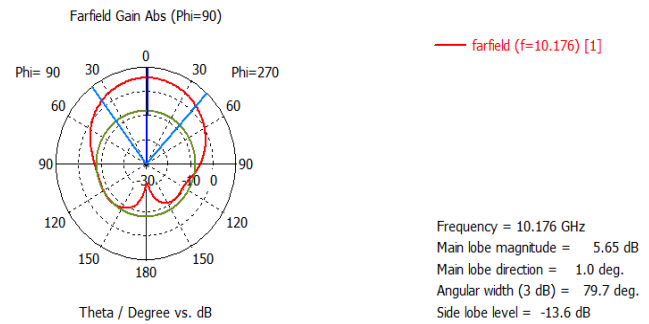
Fig.3: Simulated S11 parameter at 10.12GHz and 29.6GHz using HFSS

In the above figure, the result of the s11 parameter with the frequency of 29.6 is -39.63dB and frequency with 10.12GHz are -15.04dB which are within the desired range of 5G.

Gain and directivity of an antenna are other two important parameters of an antenna, where gain measures the overall efficiency of an antenna, however; directivity is the measurement of how much an antenna concentrates power in a particular direction. For better-performing antenna the gain must be $\geq 6\text{ dB}$. and an antenna may call directive antenna if $D < 1$. The results of gain and directivity after simulating antenna on HFSS and CST shown in figures the gains achieved by using CST is 9.476dB at the frequency of 28.39GHz and 5.649dB at 10.176GHz whereby HFSS the gains achieve as 9.573dB at 29.6GHz and 7.324 at 10.12GHz.

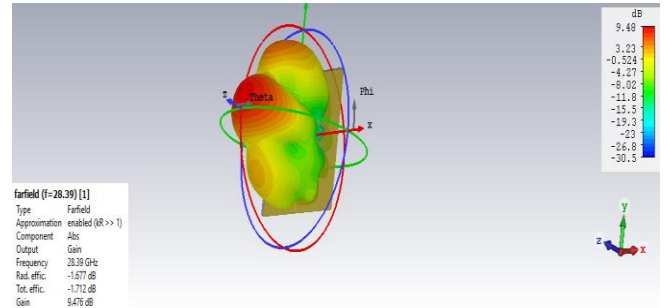


a. The 3D radiation pattern of the square patch at the frequency of 10.176

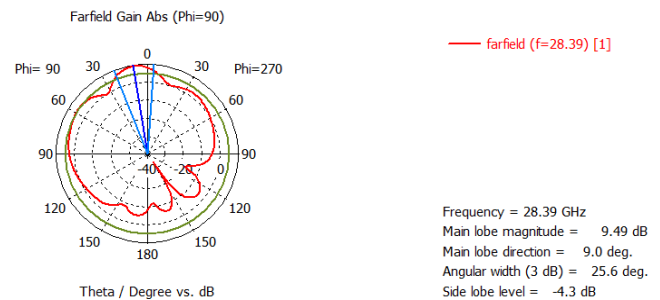


b. 2D radiation pattern of the square patch at the frequency of 10.176

Fig.4: (a) 3D radiation pattern, (b) 2D radiation pattern & antenna gain 6 GHz using CST

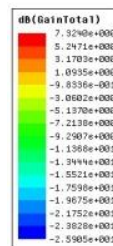


a. 3D radiation pattern of the square patch at the frequency of 28.39

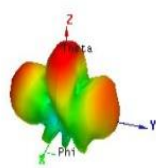
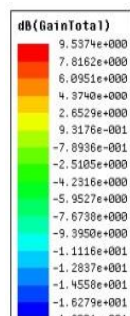


b. 2D radiation pattern of the square patch at the frequency of 28.39

Fig.5: (a) 3D radiation pattern, (b) 2D radiation pattern & antenna gain at 28.39 GHz using CST

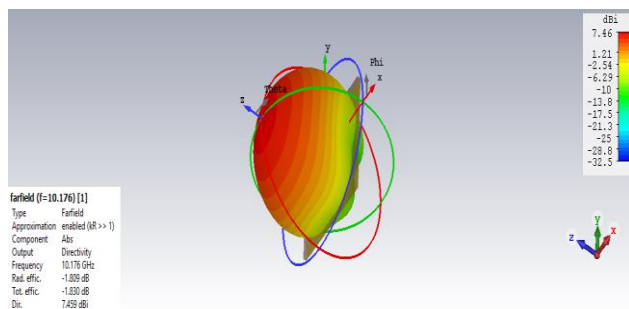


a. 3D radiation pattern of square patch at the frequency of 10.12

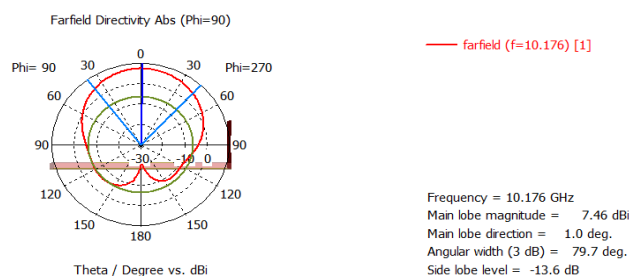


b. 3D radiation pattern of the square patch at the frequency of 29.6

Fig. 6: (a) 3D radiation pattern, (b) 2D radiation pattern & Antenna gain at 10.12 and 29.6 GHz using HFSS

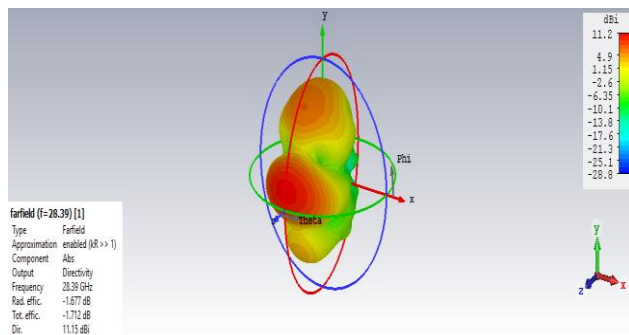


a. 3D Directivity view of square patch at the frequency of 10.176

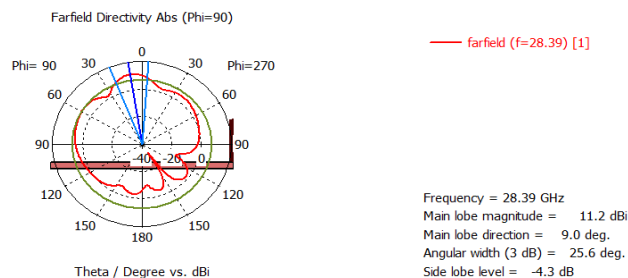


a. Polar view at 10.176GHz

Fig.7: (a) 3D directivity, (b) Polar view & antenna directivity at 10.176 GHz using CST



a. 3D Directivity view of square patch at the frequency of 28.39



b. Polar view at 28.39GHz

Fig.8: (a) 3D directivity, (b) Polar view & directivity at 10.176 GHz using CST

Table II: Summarized simulation results					
Simulator	freq	gain	S11	directivity	VSWR
CST	28.39	9.476dB	-20.976003dB	11.15dBi	1.19643
	10.176	5.649dB	-23.220361dB	7.452dBi	1.14827
HFSS	29.6	9.573dB	-39.63dB	9.413dBi	1.04
	10.12	7.324dB	-15.04dB	7.522dBi	1.58

This work consists of the SAR calculations of designed antenna that how radiations effect on human tissues and body specifically head and brain. The radiations highly effect when we are on call or our phone is near to our body. For an antenna, SAR must be low because if it rises it may dangerously effect on the human body and cause for a disease like headache, cancer and even brain tumor.

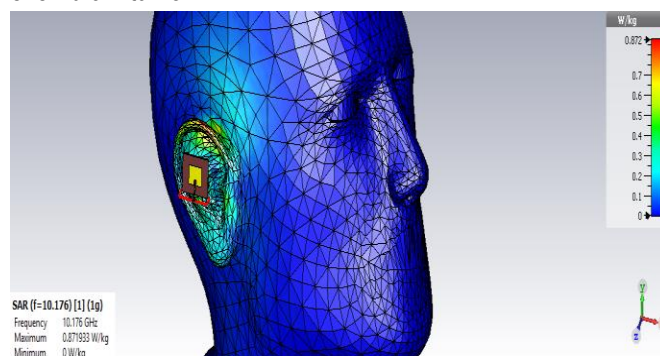


Fig.9: SAR Analysis f=10.176 at 1gram of tissue

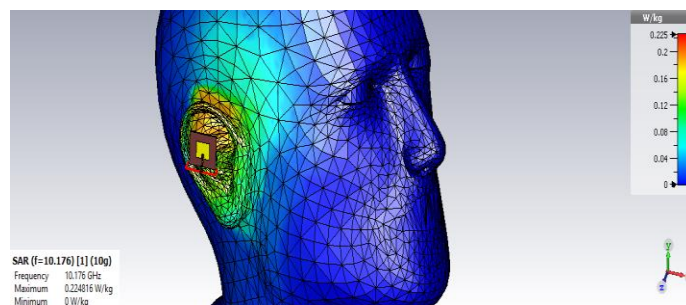


Fig.10: SAR Analysis f=10.176 at 10gram of tissues

In the above figure, SAR analyzed on adult tissues by

placing square patch antenna near to the brain with the operating frequency of 10.176GHz and got the maximum values as 0.8W/kg on 1 gram of tissues and 0.2W/kg on 10 grams of tissues.

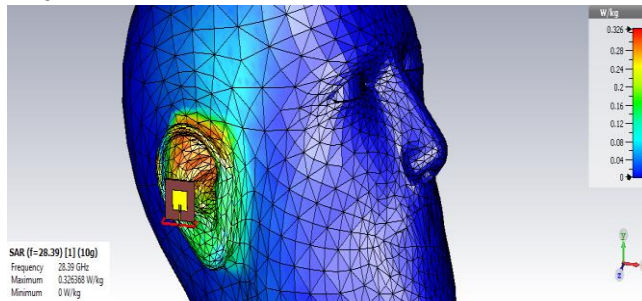


Fig.11: SAR Analysis f=28.39 at 1gram of tissues

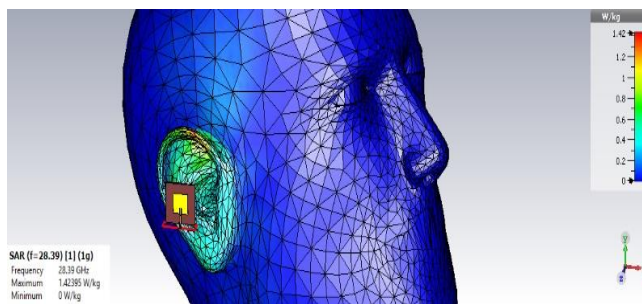


Fig.12: SAR Analysis f=28.39 at 10gram of tissues

Similarly, in the above figure, SAR analyzed by placing square patch antenna near to the brain with the operating frequency of 28.39GHz and got the max values as 1.4w/kg on 1 gram of tissues and 0.3w/kg on 10 grams of tissues.

CONCLUSION

This paper introduces a low-profile antenna for 5G with normal SAR value. An antenna design was presented in this paper that achieved all the desired results and serve as a good option for the 5G network. The antenna's SAR values also satisfy the standard of FCC which shows that this antenna can also be used commercially after approval. Moreover, a test bed is developed in order to check whether the proposed 5G antenna can be used and recognized as health and environment-friendly or not. This work can be extended by taking children's brain. As our new generation using technology in access through which their sensitive tissues can be prone to damage, the SAR has a different impact

on children's brain it is because their tissues structure is different as compared to the adult brain.

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