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Biological Electromagnetic Effects of Mobile Phone Radiation on Human Head by Measuring SAR using CST

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Abstract: The purpose of the study is to investigate the adverse effects of electromagnetic waves coming out from mobile phone devices on human head. For to examine the same SAR and thermal distribution values are measured for different frequencies on human head and comparison is done between the previous research results as well as with the safety standards given by the International health organizations. To achieve the objective the CST microwave simulator is used for designing antenna as well as to create the model of human head. Several research papers and reports are reviewed to know about the safe SAR value standards and possible biological effects for unsafe SAR values. In this paper, software experimental approach is followed for measuring the SAR values and thermal distributions, under exposure of frequencies 3GHz, 3.78GHz, 4.29 GHz and 5GHz. The results are showing that there is increment in SAR and thermal distribution as the frequency gets increased. The standard values of SAR have been defined 1.6W/kg and 2.0W/kg for 1g and 10g of tissue respectively by many organizations like ICNIRP, FCC, WHO etc. The practical findings have been compared with the standards and possible biological health effects found like fatigue, memory loss, headache etc with increased in SAR.

Index Terms: Mobile phone Radiation, Specific absorption rate (SAR), Thermal distribution, Safety exposure limits of SAR, Bio-heat equation, Biological health effects.

1. INTRODUCTION

Communication applications are growing revolutionary era by era with improved performance using high frequency bands of EM spectrum **"one of such technology is Mobile communication"** in which frequency ranges for 2nd G (800MHz-1900MHz), 3rd G (850MHz, 900MHz and 2.1GHz), 4th G (2-4GHz) frequency ranges were utilized for communication purpose with remarkable accessing speed, better throughput, and resolved delay problems. It is well known that the mobile communication systems are providing us a lot of comfort in P2P communication, internet connectivity with services like voice calling, SMS, video calling etc. and making our life easier as compare to earlier days. With such easiness and comfort of mobile technology, it has some adverse effects too. The electromagnetic radiations are not useful to the human body, as it causes certain side effects which are unfavorable for proper functioning of the biological entity of the human body and head.

In this paper survey is drawn that were performed by different researchers to analyze whether exposure of EM wave is harmful or not. They focused on SAR exposure on human head as well on different layers of the human head. Researchers studied that at different frequency ranges (in increasing order of frequency) the SAR exposure also increased as well as thermal values [1][9][24]. The same effect is observed over here on the particular region of human head where exposure is more i.e. near by the region of ears as shown in Figure 1 [25].

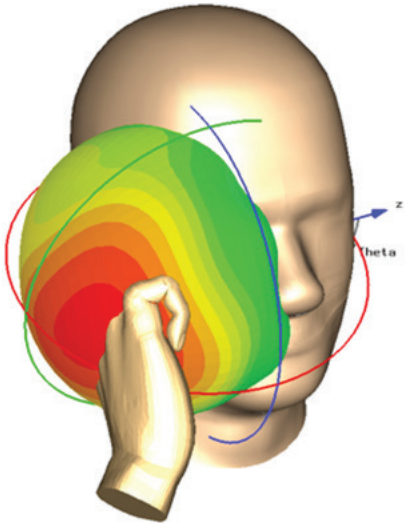

Figure 1: Mobile Phone Radiation And Human Head

2. THERMAL AND SAR CALCULATION

The SAR exposure and Thermal distribution on the human head has been calculated in the paper by referencing the below formulae:

A. Thermal Value Calculation

When we calculate SAR on human head we also concern with the Bio-heat Transfer equation (1) that propose mathematical model to represent Metabolism and Blood perfusion on the energy balance within the tissue of the human head [2].

$$\rho_c \frac{dT}{dt} = \Delta(K\Delta T) + \rho C_b w_b (T_b - T) + Q_{met} + Q_{ext} \quad (1)$$

where, ρ = Tissue density, C_b = Specific heat capacity, K = Thermal conductivity coefficient, Q_{met} = Heat source of Metabolism (W/m^3), Q_{ext} = External heat source

B. Specific Absorption Rate (SAR) Calculation

The SAR value can be calculated with respect to the internal E-filed distribution on human body or human head. SAR is defined as [3]:

$$SAR = (\sigma |E|^2)/2\rho \quad (2)$$

where, σ = conductivity (Sm^{-1}), ρ = mass density ($kg\ m^{-3}$) and E = rms value of electric field strength (Vm^{-1}).

The SAR value will also depend on the mathematical shape of the part of the body which is exposed to the RF energy.

$$\text{SAR} = \int \frac{\sigma(t)\left|\,\mathrm{E}(r)\,\right|^2}{\rho(r)}\,dr \tag{3}$$

Thus tests have to be on each specific RF sources, such as a mobile phone and at the proposed position of use.

SAR is also described in relation to the temperature increment at a spot by

$$\text{SAR} = \frac{c\Delta\mathrm{T}}{\Delta t} \text{ at } (t = 0) \tag{4}$$

where, ΔT = temperature change (°C), Δt = exposure duration (sec), c = specific heat capacity (J/Kg°C).

For exploring exposure level and its threats, some of the literature surveys have been performed.

3. LITERATURE SURVEY

It is well known that Electromagnetic wave is the backbone in propagation of information in wireless communication with advancement in the technologies for mobile and radio communication; but there are some critical health related hazards also. To define SAR and Thermal distributions with their health effects on human head a literature survey is summarized in Table 1.

Table 1
Literature Survey

Author	*Exposure Frequency*	*Body Parts*	*Results and Analysis*
A. Hirata, M et. al., [1]	1.3GHz, 2.45GHz	Human head, skin, brain, bone	Temperature increase 0.5^0 and 1.5^0 in skin and bone was observed.
N. b. Ismail et. al., [5]	900-1800MHz	Human brain	Most affect at near feed point of antenna
Ke-Li Wu[6]	100KHz-10GHz	Human head	SAR measured with respect to mass density
L. K. Ragha and M. S. Bhati [7]	900MHz	Human head	SAR for 1g of tissue was more than 10g in this frequency
M. H. Hussain et. al., [8]	900MHz	Human head, face, ear	Mouth level was more affected and thermal effect was more
C. Lazarescu[9]	9khz-3ghz	Human head	In complex far field SAR level was more and at 90^0 it was more
C. Lazarescu, I. Nica and V. David[10]	900MHz, 1800MHz, 2400MHz	Human head	SAR more in near field and at 2400MHz frequency.
M. H. Mat[11]	900MHz	Human head	Increase of heat absorption on hypothalamus of the ear.
M. A. Rahman[12]	800, 1.47, 2.45, 3.35GHz	Human head	SAR is 0.81 that is under standard by ICNIRP
M. A. Rahman, A. Thakur and M. O. Goni[13]	1.8GHz	Human head	Decrement in antenna loss while interaction with the human head.SAR level is also under safety level i.r. 1.5W/Kg for 10g of tissue and 0.9 average for 1g of tissue.
Y. Iseki *et. al., [14]*	300MHz	Human head	Use of dielectric material reduced SAR and thermal effect
K. T. Kaharpardeshi[15]	3.3GHz-3.5GHz	Human head	At 90^0 elevations angle SAR exposure was more on human head.
V. Mishra et. al., [17]	100MHz-6GHz	Human head	SAR varies according to change in density of mass.

Author	*Exposure Frequency*	*Body Parts*	*Results and Analysis*
M. I. Hossain, M. R. I. Faruque et. al., [18]	1800MHz	Human head	SAR was more in open elevator at 1800MHz
A. Tharakan et. al., [19]	800MHz, 1800MHz	Human head	Central part of head was more affected by exposure
A. Hirata, S. Ohta, I. Laakso and O. Fujiwara[20]	2.5GHz	Human head and EBG	By using EBG, SAR value was reduced.
S. Jemima Priyadarshini et. al., [21]	0.8GHz, 0.835GHz	Head and ear	Pinna absorbed more heat and radiation than brain skin.
A. If7ikhar et. al., [22]	1-10GHz	Head	For fully closed elevator SAR was 20-60% more for 1g tissue and 20-30% more for 10g tissue.
fM. B. Protsenko et. al., [23]	2.54GHz	Human head	SAR increased 1.5 times at distance of 0mm from antenna and head.
G. P. Kumar, N. Agarwal, P. Kranthi and S. S. Babu[24]	1.9GHz	Human head	Hot spot formation was observed near ear at near field of antenna.

4. SAFE EXPOSURE LIMIT OF SAR

Many International organizations have proposed some safety level of SAR exposure on human head / body and those are World Health Organization (WHO), International Commission on non-ionizing radiation protection (INIRP), Standard Association of Australia (SAA), National Council on radiation protection and measurement (NCRP), Federal Communications Commission (FCC), concluded that exposure level should be kept below or under 1.6W/Kg for 1g of tissue and 2.0W/Kg for 10g of tissue.

SAR exposure limits are drawn in below Table 2 that are proposed by ICNIRP, US, FCC, and Health organization of CANADA [3].

Table 2
Sar Radiation Limit For Head Model

Organizations and Guidelines	*SAR Limits (for Head)*
ICNIRP	2.0W/Kg average over any 10 g of tissue*
FCC, US OET 65, Health Canada Safety code 6	1.6 W/kg averaged over 1 g of tissue*

Specification for human head model is specified in Table 3 for designing skin layer structure of the human head [4].

Table 3
Specifications of Skin of Human Head Model

Substance	Thickness (mm)	ε	σ(Sm/m)	tg, δ	ρ(kg/m^3)
Skin	1	44	1.216	0.42	1100

5. ANTENNA AND HUMAN HEAD DESIGN USING CST SIMULATOR

CST MICROWAVE STUDIO is a full-featured software package for electromagnetic analysis and design in the high frequency range. It simplifies the process of inputting the structure by providing a powerful solid 3D modeling front end Strong graphic feedback. By using this simulator the design of Human Head model and slotted micro strip patch Antenna is created. For designing of this antenna, the dimensions are taken in terms of Length × Breadth × Height as for substrate 30mm × 40mm × 4mm, for Patch 20mm × 22mm × 4.05mm and Slot 10mm × 10mm × 4.05mm.

Specifications for skin layer of human head are mentioned in Table 3. Head model is designed by considering Skin as material that is modeled using sphere and dimensions are defined **(a) Center radius** = 74.75mm, **(b) X Center** = 25mm, **(c) Y Center** = 50mm, **(d) Z Center** = 77mm. Parameterization of the specific values is defined in Figure 2 and 3.

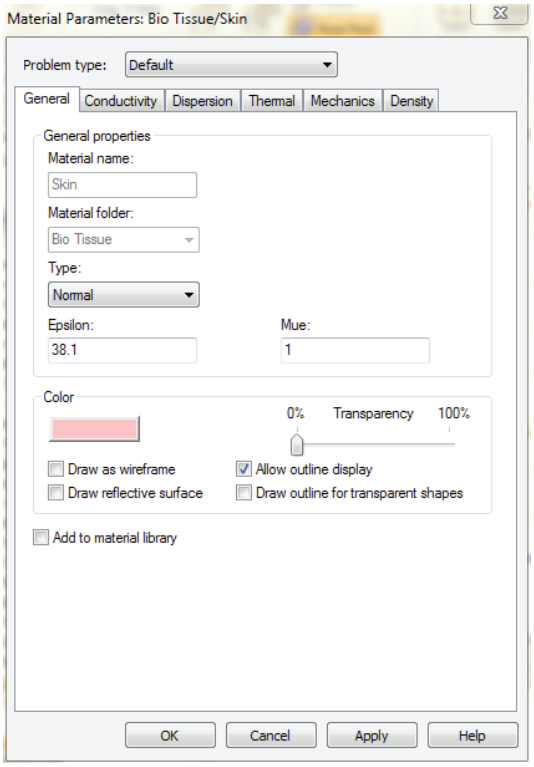

Figure 2: Skin Tissue Permittivity (μ = 1)

The arrangement of slotted micro strip patch antenna and human head model is shown in Figure 4 and Figure 5. The antenna is designed by considering different important parameters of antenna so that can calculate SAR exposure as well as Thermal loss on human head model. Those parameters are: Electric and Magnetic Permittivity are taken $\varepsilon_\rho = 42$, $\mu_\rho = 1$ respectively.[16]

6. MEASURED SAR AND THERMAL DISTRIBUTION

The SAR and Thermal distribution have been calculated by considering different frequencies like 3GHz, 3.78GHz, 4.29GHz and 5GHz is mentioned in Table 4. The result has been compared with the previous results calculated by different researchers.

Table 4
Comparison of the simulation result and safety standards

Frequency range	*SAR_{max} w/kg previous results (for 1g issue)*	*SAR_{max} w/kg present result (for 1g tissue)*	*Thermal distribution previous result (°F)*	*Thermal distribution present result (°F)*
3GHz	1.48	1.14	0.369	0.779
3.78GHz	1.40	1.25	1.2	0.915
4.29GHz	1.8	1.14	1.28	0.703
5GHz	1.95	1.16	1.39	0.788

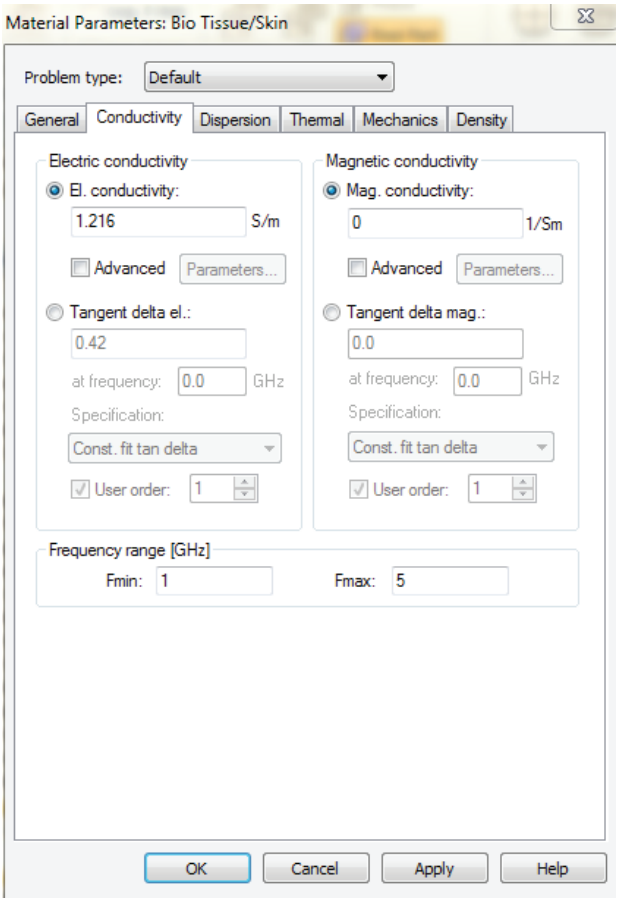

Figure 3: Skin Tissue Magnetic Conductivity and tan δ

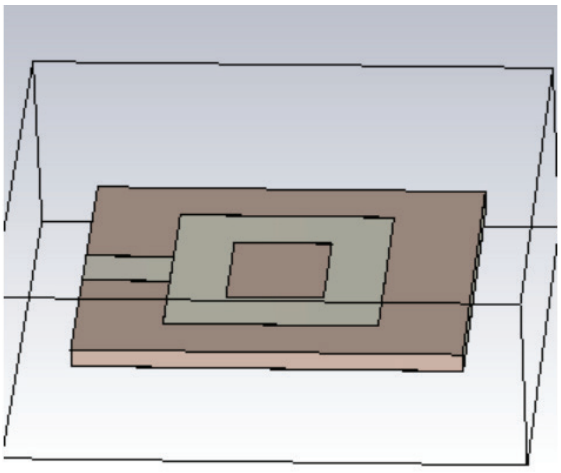

Figure 4: Slotted Micro strip patch antenna

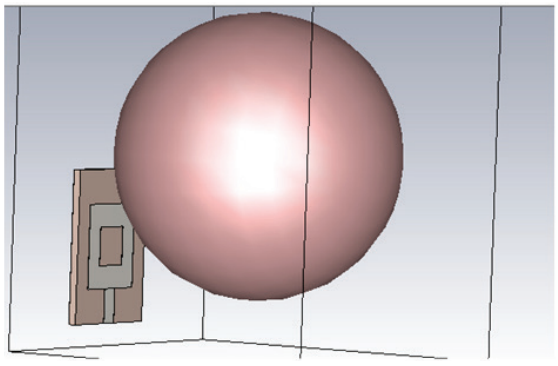

Figure 5: Antenna and Spherical Head model of Human

A. SAR Distribution at Different Frequency Ranges

SAR has been calculated for different frequency ranges that are shown in the Figure 6, 7 that also shows thermal distribution on human head model after exposure of EM wave on it. It is observed that much thermal distribution is seen at near filed of the antenna after exposure of EM wave.

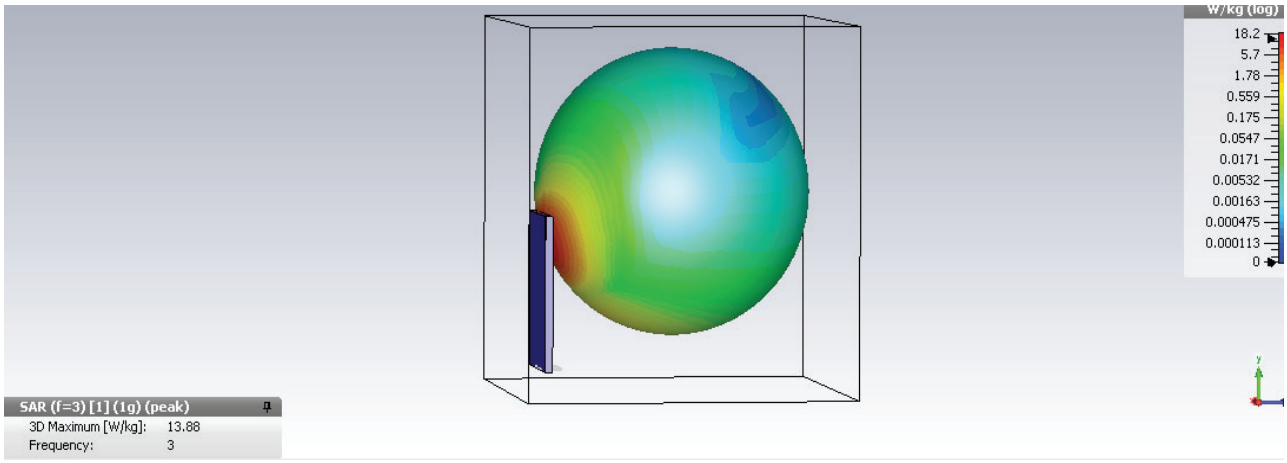

Figure 6: SAR = 1.14 W/Kg at 3GHz (in log scale SAR = 13.88 W/Kg)

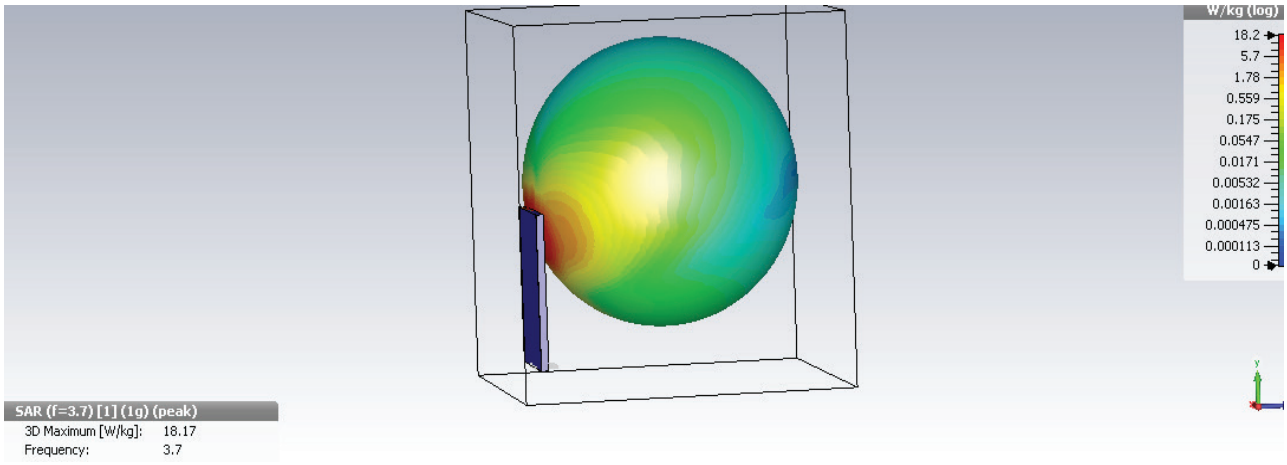

Figure 7: SAR = 1.25 W/Kg at 3.78 GHz (in log scale SAR = 18.17 W/Kg)

B. Return Loss Diagram

The graph of return loss is drawn as below that tells about gain and resonant frequency too.

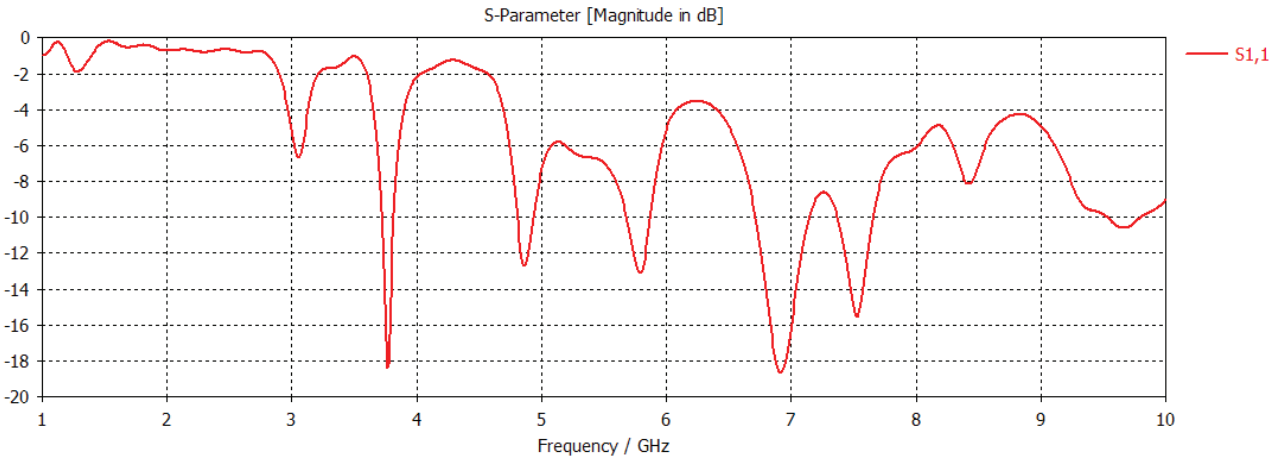

Figure 8: S-Parameter Graph

C. Radiation Pattern

Radiation pattern of the antenna is shown below:

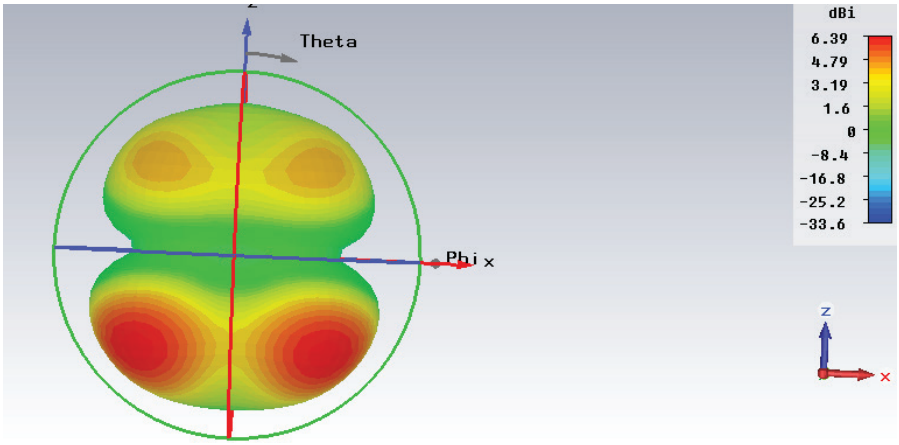

Figure 9: Radiation Pattern at 5ghz Frequnecy

7. COMPARISON OF THE REVIEWED RESULTS AND SAFETY STANDARDS WITH THE PRESENT RESULT

In the above described review of different research papers also defined SAR level and thermal distribution in different levels of head like brain, skin, bone, fat etc. The excessive use of mobile phones produces the thermal effects notably to the human head (basically on skin layer of the head). From the simulation it is clear that when frequency range from 3GHz to 5GHz are being imposed on human head, SAR value for the frequencies are considerably good. The SAR values are under safety standard that is good for biological health and human head.

8. CONCLUSION

The excessive use of mobile phones mainly produces the thermal effects especially to the human head and its different layers. These thermal effects confer to the alternate effects like as fatigue, headache, fuzziness and nausea. From the simulation it is clear that when frequency ranges from 3GHz to 5GHz are being imposed on human head i.e. within 4G band gap (used for mobile phone assessment now days), SAR values for the frequencies are increasing accordingly. Field penetration strength was more at frequency 3.3 and 4.29GHz. Thermal distribution is more in case of 5GHz of frequency range. The above mentioned dimensions used for designing the antenna is providing good resonance frequency as well as reference impedance is also 52.3Ω that provides better outputs. After comparing simulation results with previously simulated results of other researches, it is found that they are coming under safety standard. Some standards and guidelines are declared by some organizations so that people must know about the cause of adverse effects, prevention method of exposure of EM radiation and must follow the standards given by the WHO, environmental health safety organizations, Russian and East European Countries research organizations, European and UK universities, ICNIRP etc.

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