‘REPORT SUBMISSION’

ON

“BIOLOGICAL ELECTROMAGNETIC EFFECTS OF MOBILE PHONE EXPOSURE ON HUMAN HEAD BY MEASURING SAR USING CST”

DISSERTATION-II

Submitted in partial fulfillment of the
Requirement for the award of the
Degree of

MASTER OF TECHNOLOGY
IN
(Electronic and Communication Engineering)

By
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Under the Guidance of

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PHAGWARA (DISTT. KAPURTHALA), PUNJAB

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TOPIC APPROVAL PERFORMA

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PROPOSED TOPIC : Biological electromagnetic effects of mobile phone on human head and hand models by measuring SAR using CST

Qualitative Assessment of Proposed Topic by PAC		
Sr.No.	**Parameter**	**Rating (out of 10)**
1	Project Novelty: Potential of the project to create new knowledge	7.50
2	Project Feasibility: Project can be timely carried out in-house with low-cost and available resources in the University by the students.	8.00
3	Project Academic Inputs: Project topic is relevant and makes extensive use of academic inputs in UG program and serves as a culminating effort for core study area of the degree program.	7.50
4	Project Supervision: Project supervisor's is technically competent to guide students, resolve any issues, and impart necessary skills.	8.00
5	Social Applicability: Project work intends to solve a practical problem.	7.50
6	Future Scope: Project has potential to become basis of future research work, publication or patent.	7.00

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PAC Member 2 Name: Lavish Kansal	UID: 15911	Recommended (Y/N): Yes
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Overall Remarks: Approved

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CERTIFICATE

This is to certify that Deepika Sahu is bearing Registration no. 11204340 has completed objective formulation of thesis titled, **"Biological electromagnetic effects of mobile phone on human head models by measuring SAR using CST"** under my guidance and supervision. To the best of my knowledge, the present work is the result of her original investigation and study. No part of the thesis has ever been submitted for any other degree at any University.

The report of dissertation-II is fit for submission and the partial fulfillment of the conditions for the award of Masters in Technology in electronics and communication engineering.

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DECLARATION

I, Deepika Sahu, student of communication system engineering under Department of Electronics and communication engineering of Lovely Professional University, Punjab, hereby declare that all the information furnished in this thesis report is based on my own intensive research and is genuine.

This thesis does not, to the best of my knowledge, contain part of my work which has been submitted for the award of my degree either of this university or any other university without proper citation.

Date : Signature and Name of the student

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ABSTRACT

Communication applications are growing revolutionary era by era with improved performance using high frequency bands of EM spectrum. EM spectrum consists of electro-magnetic wave which travel with a constant velocity of 3×10^8 ms^{-1} in vacuum and also carries important properties like polarized in nature, can propagate without any medium and is not even deflected by any medium so it is used in some specific technologies. One of such technology is Mobile communication in which frequency ranges for 2^{nd} G (800MHz-1900MHz), 3^{rd} G (850MHz, 900MHz and 2.1GHz), 4^{th} 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 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. Some of the studies of the adverse effects of electromagnetic radiation are drawn in this report to show the biological effects, SAR and thermal effects of mobile communication performed by prominent researchers earlier.

Some standards and guidelines of EM consumption is introduced by IEEE standards and other organizations like European research, FCC, ICNIRP, other organizations like Russian and East European Countries research organizations, European and UK universities etc to avoid the encounter of hazards of radiation. Here the main objective is to design Rectangular micro strip patch antenna and triangular micro strip patch antenna of 2.4GHz resonant frequency with 50Ω and calculation of SAR value on human head model using CST simulator. Then comparison between output SAR of Triangular micro strip patch antenna and rectangular micro strip patch antenna is performed. After performing the simulation using CST I analyzed that SAR was more for Rectangular Microstrip patch antenna than Triangular Microstrip patch antenna. It was also analysed that after maintaining distance (1mm, 2mm etc.) between antenna and human head SAR exposure get reduced.

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CHAPTER 1

INTRODUCTION:

Communication is interchanging of information between two or more parties. Electromagnetic band is reserved for such communication system those are Radio, Radar communication, FM, satellite communication and mobile communication etc that are under wired and wireless communication system. Mobile communication is now a day popular because of certain applications of it like voice call, internet surfing, video call, E-mail services, social networking applications etc.

1.1 Electromagnetic radiation (EM radiation or EMR): This is radiation that is consists of perpendicular wave forms arrangement of electric and magnetic field. Some bands of EM spectrum are shown in the figure 1.

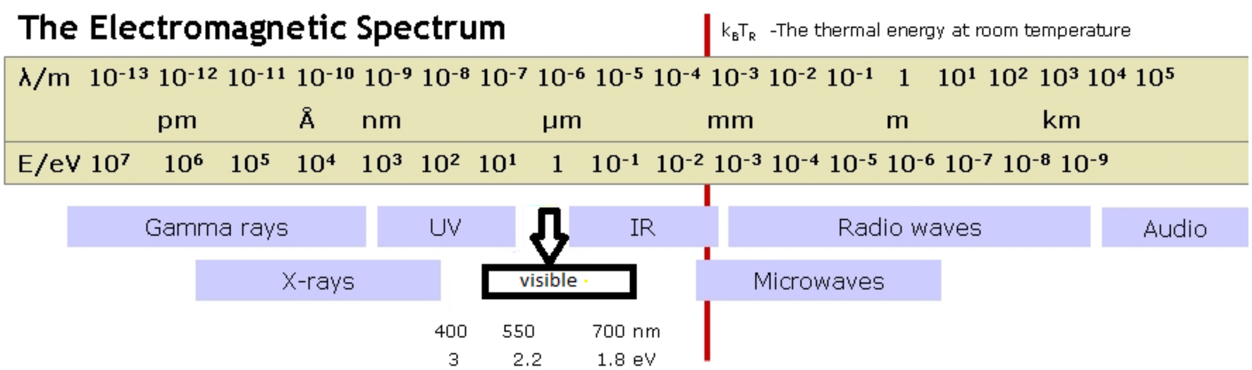


Figure 1: Electromagnetic spectrum scale

1.2 MAJOR APPLICATIONS OF EM SPECTRUM:

a) Applicable in a microwave, for communications, especially for extending TV signals to larger distances, radar applications.

b) EM waves are used in biomedical instruments like MRI, EEG etc.

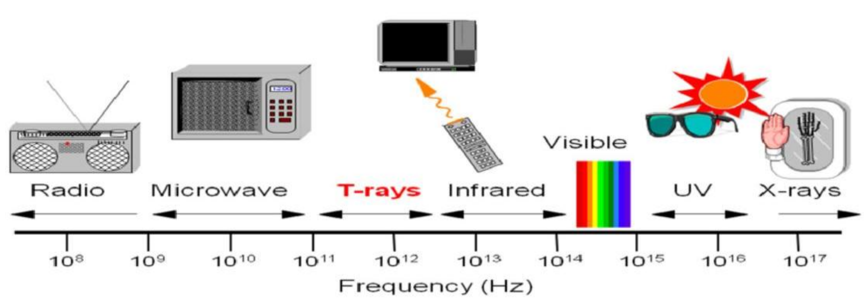


Figure 2: Electromagnetic wave in different fields

Table 1: Some frequency ranges that were used in communication system earlier are:

SEQUENCE NO.	GENERATION	FREQUENCY RANGES
1.	1st Generation	Approximately 150MHz
2.	2nd Generation	800MHz to 1900MHz(GSM frequency)
3.	3rd Generation	850MHz, 1900MHz, 2.1GHz
4.	4th Generation	2GHz to 8GHz

In communication system from few years for better throughput and performance the reinforced and extraordinary use of EM spectrum as per above frequency ranges used in advance technologies like cell phones, cellular and cordless phones, house hold remote controlling, electric vehicles, FM/GSM antennas are going on which are the foremost cause of unexpected exposure of the EM radiation. This radiation is creating harmful effects on sensitive organs of human like eye sights, brain tumour, memory loses, reproductive system of women, blood pressure uncertainty etc. The main part of the human body is head because it is directly connected to the device when we are talking while using mobile phone. In this paper some adverse effects of EM wave exposure is studied by several researchers by calculating SAR exposure and thermal effects on human head along with its different layers (brain, bone, fat, skin, ear etc).

In the 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 and thermal effect was also observed over there at that particular region of head where exposure was more. By using CST suite simulator the process of designing of Rectangular Microstrip patch antenna[23], Triangular Microstrip patch antenna[24], human head model and calculation of SAR on human head using both the antennas has been performed.

1.3 SPECIFIC ABSORPTION RATE: It is also defined as SAR level that is the rate of absorption of energy or power by human body especially human head tissues when human body or any other biological system falls under mobile phone exposure or radiation by antennas used for other communication system technologies.

SAR can be envisioned at small part of the human body or whole body. Whenever a mobile phone is modelled, at that time SAR measurement is the one of the most important parameter that must be take care so that radiation or exposure level must not exceed above its standard value defined by different safety organizations. In mobile phones it is calculated for 1g or 10g of mass density of the tissues. It is measured in W/Kg means energy absorbed per unit mass density of tissue. For long term environmental exposure it is defined as 0.8W/Kg and for short term environmental exposure it is 0.4W/Kg.

The FCC limit for public exposure of SAR from mobile phones is defined as 1.6W/Kg for 1g of tissue mass density and 2.0W/Kg of tissue mass density. Expression for SAR is defined in equation (1).

CHAPTER 2

LITERATURE REVIEW:

Electromagnetic wave is the backbone in transformation of information in mobile communication and as per the advancement in the technologies for mobile and radio communication, the frequency ranges has been increased.

EM radiation is having numerous adverse effects on human health and biological systems. The major concern here is the effects on Human head and SAR exposure level calculation. SAR is specific absorption ratio, i.e. defined as absorbed EM exposure level by biological system as per 1g and 10g of tissues due to mobile phone radiation and other communication technique.

By experiments and simulations that have been performed by different researchers in earlier years are mentioned in this paper. Literature survey of those researches is described here along with the experimentation, tabulation of the SAR exposure on different parts of human head (brain, skin, fat, bone etc) performed by the researchers. Some literature surveys are overviewed here in this paper.

1. TOPIC: Temperature Increase in the Human Head Due to a Dipole Antenna at Microwave Frequencies [1].

1.1 Work and Description: Temperature increase and SAR calculation is performed in paper this in the frequency of 900MHz to 2.45GHz. Temperature increase of 3.5^0 doesn't show any effect on head. The human head model was consists of different layers along with the blood. FDTD method is preferred to analyze the relationship between SAR calculation and thermal increment that are defined in equation number 1, 2 and 3.

1.2 RESULT: 1) As per the increase in frequency, SAR exposure and Thermal distribution also increases i.e. shown in diagram-2 along with the SAR absorption in human head at 900MHz, 1.3 GHz and 2.45GHz of frequencies and diagram 3 shows temperature distribution. Peak SAR absorption for 1g and 10g is shown in graph 4 and 5. Figure number 7 shows maximum absorption at high frequency. Thermal increase is shown for different levels of human are 10^0c in skin, 3.5^0c in brain. Thermal increment on Head and its Brain layer are also shown in the graph 9 (a, b) in which temperature is increasing with the increase in power and frequency. In the paper it was observed that average thermal increase in tissue was 0.5^0c or 1.5^0c was more than specified value.

2) Relationship in between average SAR and thermal increase also determined in the paper. Maximum temperature increase is defined as: $Tmax=a*SAR_a$ that is calculated by using FDTD method. Table III shows temperature increase on head with auricle, without auricle and on brain. After experimentation it was observed that temperature increase depends upon frequency used

and SAR ranges too. It is mentioned by safety standards that for 1g of tissue over 65W/kg increase in the temperature must be 10^0 excluding auricle.

2. TOPIC: Modeling of Electromagnetic Wave Penetration in a Human Head due to Emissions from Cellular phone. [2]

2.1 Work and description: The study is to calculate EM effect and SAR calculation on human head at operating frequency of cellular phone.
Work- whole process is performed in two ways; first is mathematical study and second defined as simulation. Experiment is performed in 2D head model using FDTD method. In this research CST is used for simulation purpose that measures electromagnetic properties such as Far fields, Thermal loss, return loss, gain, SAR etc and the research paper considered measurement about electric field and SAR only.

2.2 RESULT: Table 1 is defined for Peak SAR for 1g and 10 g tissues. Electric field distribution is defined for 1g and 10g of tissues with 900 and 1800MHz (GSM frequencies). Diagram 3.2 defines following results-
1) Red colour place is most affected point i.e. defined as region of feed point of wave to the antenna.
2) Electric conductivity and permittivity is higher in case of 1800MHz exposure than 900 MHz exposure in both 1g and 10g tissues.
3) Value of SAR max is different for each case. Here(δ) Dp is defined which tells about depth of penetration .The notable point is that SAR for 1g and 10g is defined as 1.6W/Kg and 2.0W/Kg respectively (by ICRIP) and in this paper the value is below the SAR value that can be considered as safe condition. SAR is also calculated by considering angles 30 degree and 90 degree with 900 MHz freq.

2.3 CONCLUSION: After result it was clear that if frequency increases then SAR increases but by keeping distance from the head we can reduce the effects. Thus, for safety purpose, the must use their hand free or turn ON the speaker at the time use of the phone. Thus by incrementing the distance between head and antenna may cause less exposure on human head.

3. TOPIC: Development of the First Chinese Electromagnetic Human Model and Its Use for SAR Calculations. [3]

3.1 WORK AND DESCRIPTION: Human head model created by considering Chinese EM model i.e. used for study of SAR exposure in this paper. This model is female human head model that is based on Chinese visible human (CVH) data set. The virtual resolution of electromagnetic field was provided to the CEHM in this paper is 0.17x 0.17x 0.5 mm3 for body and 0.17x 0.17 x

0.25 mm^3 for head. The SAR was calculated for different segments from top to bottom of the head model.

3.2 RESULT: It was found that result in vector cross section configuration there was Saw tooth like structure in tissues. The SAR is calculated for SAM model and CEMHM model in table [1] for different tissue density.

4. TOPIC: Evaluation of SAR Reduction for Dipole Antenna Using RF [4].

4.1 WORK AND CONCLUSION: RF shield is used for SAR reduction rate by using ferromagnetic material. The rate was decreased while used ferromagnetic material that is also used as RF absorber. SRF fielding is defined for 1g, 10g, and for total values of SAR values which shows that if the value is more than effective shield is more.
Experiment-In the exp they have taken bone tissues with 10cm and brain tissues with 9cm is used and the dipole antenna wavelength is l/2 used at 900MHz. Table I and table II shows all the parameter measured while experiment was performed for both bone and brain tissues at 900 MHz .
SAR reduction mechanism was used based on suppression of current over the metal/surface of the mobile phones by metallic loss and heat formation on the surface of mobile.

4.2 NUMERICAL RESULTS AND ANALYSIS: According to the analysis it was defined that by ferrit3 we will get reduced absorption rate 80.02%, when used Ferrite4 and Ferrite2 the reduced SRF was 78.94% and 47.20% in decreasing order. The most reduced SRF can be obtained by using Ferrite1 i.e. 14.21%. Figure 1 shows SAR without and with distances, higher SRF declares larger SAR reduction. When the measurement was carried out with distance (between human head and antenna) of 5mm, 10mm, 15mm then it was observed that ferrite3 was more capable to restrain the effects of exposure. Figure 3 shows comparison between SAR total for all. Figure 4 shows comparison for RMS value of SAR for ferrite materials, figure5 shows SRF for 1g and 10gm of SAR and so on the measured graph is shown for all the conditions. SRF was increased as per change in thickness of Ferrite 1 i.e. from 1mm to 2.5mm in steps of 0.5mm. Total SRF (total) was decreased according to the increase in thickness of Ferrite 1.

5. TOPIC: Biological Effect of 900MHz and 1800MHz Mobile Phones in SAR weight [5].

5.1 Work and description: The survey is performed in this paper to analyze human biological effects at 900MHz and 1800MHz frequency ranges by using FDTD method. Distance between head and antenna is taken 10mmwith radiated power 0.6W. IEEE, FCC and IEC standards are kept in mind to design the head model for which in table-1 relative permittivity (45.8055), mass density (0.7665) and conductivity (1010) is defined. By Fidelity’s study the specification of mobile is defined in the table-2 where permittivity (1), mass density (4.9e7) and conductivity (1000) are shown.

5.2 RESULT: Figure 1 and 2 are showing external and internal radiation pattern at 900MHz of frequency and figure 3 and 4 are showing the same at 1800MHz of frequency. Table 3, 4, 5 and 6 is showing SAR calculation with both the frequency while considering 1g of tissue that denotes that absorption at 1800MHz is more (because of more penetration depth) than that of absorption at 900MHz. Depth of penetration depends on the distance of the antenna from the head means internal monopole antenna is more closer than external monopole antenna. The main conclusion drawn in this paper is that no any hazardous effects are found but temperature increase in the head was analyzed that may be the cause of fatigue, headache, fuzziness etc.

6. TOPIC: Estimation of human exposure in some electromagnetic environments [6].

6.1 Work and description: A spherical SAM homogenous human head model and Complex human head model is recommend in the experimentation of SAR and Relative exposure calculation on head. In this four different head models (two homogenous spherical model, SAM model and proposed head model) are used so that can determine exposure in every head according to the different frequency. Virtual proposed head model (figure-2) was created by MRI of real human and consists of muscle, bone, and brain and eye part. For calculation of SAR, parameters are given are: a=0.15m, a=0.08m (for two homogenous models), electric permittivity $\varepsilon_{\rho,}$ conductivity is σ,magnetic permittivity μ_ρ density ρ. In table-2 SAR values are shown after calculation. In table-3 comparison of SAR between SAM model and Virtual proposed model is shown along with SAR in brain, muscle, brain and eye.

6.2 RESULT: After experiment it was observed that SAR for average of 1g of tissue was more than that of 10g of tissue. Also SAR exposure in every level of brain was defined after experiment. In table-3 RSAR and RE are shown while considering only electric field with different houses situated in certain distance. By analyzing table it is clear that RE was larger than R-specific absorption rate or we can say field reference level is more than basic restriction in the result.

7. TOPIC: Analysis of the Correlation between Antenna Gain and SAR Levels inside the Human Head Model at 900MHz [7].

7.1 Work and description: In this paper SAR and thermal effect determination is performed due to exposure of EM wave. For implementation of this experiment was performed in two categories. First was volumetric interpolation by using MRI, was used for assessing the properties of the tissues at absorption rate and another category was related to different layered architecture of human head model i.e. brain, fat, bone, skin by considering brain's EM properties.

Calculation was based on Finite integration method and Finite element method. A 3D model of human head whose properties are much similar to real human head along with its EM properties, designed in this research process while frequency used is 900MHz. Table-1 is introducing different EM parameters (conductivity, electric and magnetic permeability and tissue density) to calculate SAR in different layers of human head. Research has been completed by taking care of boundary conditions of EM to get more accurate result over the experiment. Model A 3DS max is used to make more realistic head model and COMSOL simulator is also used in designing of human head. Model B was designed by using CST simulator. Different phones like mono block mobile and flip-flop mobile phone models are also used in this paper to determine the actual result by setting power of operation at 0.25W. By using finite element method it was observed after experiment that more exposure was around the radiated field (Fig-4 shows). Fig-5, 6 and 7 show the absorption above the

7.2 RESULT: By analyzing figure 8, 9, 10 it is clear that according to the cross section of the model-A, mouth level is having dark red color that means this region is more affected by absorption. So it can be say that skin, brain, fat all may be affect by the exposure according to distance of mobile from user. For the frequency 900MHz SAR is calculated and shown in the figure 11, 12, 13 and 14. Figure 15 and 16 is showing thermal distribution on head model. By visualizing graph 17 we can see thermal distribution according to the distance of mobile phone from the user. It was analyzed that small increase in heat in hypothalamus was the reason of changes in thermoregulatory system of human body.

8. TOPIC: Specific Absorption Rate in the Human Head due to Different Far Field Exposure Sources [8]

8.1 WORK AND DESCRIPTION: In this paper SAR is calculated for GSM frequency (i.e. 900MHz to 1800MHz) on human head model for different Far field radiation by using CST simulator. Numerical method for calculation of SAR has been derived by whole volume in far field and scattered field region formed by cells. Complete experimentation was performed in Electrical lab where filed values were found on the air that was above from ground level at 1.5m of distance.

Calculations done in the paper was performed by using Rohde & Schwarz FS300 spectrum analyzer, with frequency 9 KHz to 3GHz, horn antenna with frequency range 0.8 to 5GHz. SAR calculation was performed in two different situations. 1) Polarization between Far field plane and incident electric field. 2) Complex Far field exposure on human head in all the four directions. SAM phantom head model was kept at same distance from all the four antennas. In the CST it was observed that there was not much fluctuation in the frequency.

Now monopole antenna with length $\lambda/4$ was placed in the distance of 1m from the head to calculate the exposure of SAR for frequencies 938MHz and 1818MHz.

8.2 RESULT AND CONCLUSION: In figure 4 and 5 graphical representation of electric field vs. frequency is shown which show spectrum analysis for SAR calculation. In the polarized far field the SAR was observed more. Table II shows SAR max in 10g of tissue for frequency 938MHz and 1818MHz in both the electrical lab. Table III and IV show SAR in 10g for different angles. In complex far field the SAR level was more than polarized far field. When observed for different angles at 90^0 absorption was more. Front side exposure in human head put more affects to SAR value.

9. TOPIC: Effects of human head on frequency reconfigurable PIFA antenna performance and SAR calculations [9].

9.1 Work and conclusion: In this paper defined that PIFA(Planer inverted F antenna) is having simple design, light weight, low cost and good radiation pattern, type of specification that is the cause of maximum preferable antenna. It also reduces backward radiation towards user and SAR as well. Also improves performance of wireless/radio communication. By using CST software PHANTOM head model and PIFA is designed. By placing antenna 30degree horizontal SAR has been measured for that formula of SAR has been used by considering ρ, σ, $\mu$and E. The antenna operates at six different frequencies 810 MHz, 850 MHz, 1.47 GHz, 2.45 GHz, 2.62 GHz and 3.35GHz.

9.2 RESULT AND CONCLUSION:- Table-II defines SAR with 1g and 10 g tissues with different freq and distances. Fig 5 shows gain and efficiency of the antenna with respect to the different distances that are measured as decreased values.
This paper considers result as under SAR standard because the value measured for SAR is maximum 0.81 that is under ICNRIP standard.

10. TOPIC: SAR Analysis of Resonant Cavity Applicator Using Dielectric Bolus with Anatomical Human Model by Finite Element Method [10].

10.1 WORK AND DESCRIPTION: In this paper for reducing SAR exposure and its effects one dielectric material is used that is bolus using 3-D FEM. Human head is kept in electromagnetic field and bolus is attached with the human head. The human anatomy of human head model consist of layers skull, brain white matter, brain gray matter, centricle spinal fluid (CSF), ventricle, eyeball, and lens and so on are shown in figure 3 and accordingly all physical properties are listed in table 3 by considering 300MHz of frequency.

10.2 RESULT: Because of use of dielectric material exposure wave was moved towards upper part of head that was removable or reducible by bolus dielectric material. It was helpful in decreasing temperature in the human head.

11. TOPIC: Influence of Circular Patched EBG Substrate on SAR and Far-Field Pattern of Dipole Phase-Array Antenna [11].

11.1 Work and description: Circular patched with two element dipole array antenna, electromagnetic band gap (EBG) is used in the research and experimentation for analyzing the effects on SAR as well as on human head. An antenna designer can use high impedance EBG structure for getting better performance and gain by antenna that will also helpful in decreasing exposure into human body. In figure-2 antenna is designed that is kept 10mm away from human head where length and radius of dipole antenna are 36mm and 0.2mm respectively. Formula for dimension setting is shown. Human head is designed by 150, 150, 35 mm of the (l, w, h). In diagram 3 complete EBG array structure with two dipole antennas are shown.

11.2 RESULTS: In this paper CST simulator is used with implementing FDTD and hexahedral mesh for getting exact and accurate outcome. While using CST 3.3GHz to 3.5GHz is considered as frequency range, averaging mass is 10gm, and for post processing IEEEC95.3 averaging standard is used. Along with the phase difference (0^0, 90^0, 180^0) EBG for circular, square patched and SAR reduction factors are calculated in table-1. SRF value is calculated for SAR in 10gm of tissue. The observation was that SAR was reduced from 21% to 31% according to the change in the phase. At 90^0 SAR was max in both the antennas. Far field component for E-field in different phase is defined in table 2 and drawn in diagram-6 in which highest gain got in 0^0 phase. Efficiency was 95.83% and loss 22.37dB

12. TOPIC: SAR in Human Head due to Mobile Phone Exposure [12]

12.1 Work and Description: In this paper SAR calculation has been performed different frequency ranges 900MHz, 1800MHz and 2400MHz for near field and far field model (Fraunhofer model). Head in this experiment is placed at 55mm distance from the antenna.

a) Near field SAR calculation: Figure 2 shows SAR distribution in head model at 900MHz freq. figure 3a, 3b, 3c show the graph of SAR distribution in head with respect to increase in the frequencies.

b) Far field SAR calculation: In this also figure 4 is 3D diagram of SAR distribution and figure 5a, 5b, 5c show graphical representation.

12.2 RESULT: In the table II comparison between SAR distribution in Far field and near field is drawn that shows more SAR value in near field. Table III show SAR_{max} for reactive near field and radiated near field along with the distances. In graph 6a, 6b, 6c SAR is drawn for 900MHz, 1800MHz and 2400MHz of frequency ranges and the conclusion found after observation was that SAR was more in case of 2400MHz frequency.

13. TOPIC: Computation of Effective Dielectric Constant and Electric Field in the Human Head: A Preliminary Study for Electromagnetic Wave Effect [13]

13.1 Work and description: In this paper the hazardous effect of exposure is defined for E-field, absorbed power density and SAR value in human head. Thermal energy, that is absorbed by tissue act with EM energy and creates kinetic energy. E field distribution must be known to find out SAR, APD and dielectric constants. The mathematical formulation is display for calculating dielectric constant as equation1 by using Debye method. In table 1 for different layers of the human brain along with the various frequencies ranges from 100MHz to 6GHz with the calculation of SAR values at those parts is shown.

Dosimetry calculation methods-1) Multilayer method: By considering semi infinite model all the values are calculated in 6 main layers of brain (Debye standards in table-1). Table-II is showing dosimetry for different layers of the model. 2) Method: Derivative parts are derived in the paper to calculate the dosimetry while multilayer of brain is being taken into consideration along with E and H field of EM. Thus the formula for ADP and SAR is derived in this.

13.2 RESULT: After all the calculation (in graph-4) it was defined that ADP at radial difference r=-0mm was at center of line. At r=-0.7mm it was below it, at -2.3mm conductivity is less and at r=26.3mm it is exactly in center of line. Similarly for SAR values at r=-0mm, -0.7mm, -2.3mm and -26.3mm density value was at center line, below the center line, less density and in the center line.

14. TOPIC: Walls Effect over the Specific Absorption Rate in the Human Head due to Mobile Phone Exposure [14].

14.1 WORK AND DESCRIPTION: In this paper a monopole antenna with l/4 wavelength is placed in the distance of 1m form head for SAR calculation. GSM frequencies of communication that are defined as 900 and 1800 MHz have been taken in concern so that exposure level can be realized. Communication vendors must take care of the standards introduced by different safety institutes like IEEE, ICNIRP standards into account to avoid from this problem.

The antenna was placed in 45 degree tilted and effect of conducting metallic wall effect is the main study.SAR= $(\sigma|E|^2)/2\rho$ that is defined for 10g of tissue of SAM phantom human head model with frequency ranges 900 MHz and 1800 MHz (GSM frequencies in the near field). For getting the result metallic field was being changed by its distance from head.

14.2 RESULT AND DISCUSSION: The SAR level after simulation in CST simulator using mesh properties was obtained 1.051 W/kg and 2.995 W/kg for 900MHz and 1800MHz of frequency respectively. Along with the graphs and tables it is shown the result of SAR exposure with respect to distances and frequency ranges while open space, elevator is used and frequency bands are 900MHz and 1800MHz correspondingly.

14.3 CONCLUSION: The maximum SAR average over 10g mass of tissue is increasing about 27% when one or two walls for 900MHz and 1800MHz are absent. When antenna turned bow at 45^0 then SAR was increased by 64% and 30% more for 900 MHz and 1800 MHz frequencies while one wall was absent at near field.

15. TOPIC: Analysis of the effects of Distance between Head and Mobile Phone on SAR. [15]

15.1 Work and description: Dual band GSM (800MHz AND 1800MHz) frequency is taken in this paper for experimentation. Antenna is designed with L, W, D as 100mm, 40mm and 8mm respectively to deal result same as real head phone antenna exposure. A numerical anthropomorphic mannequin (SAM model) is used here for observation. Table-1 is showing properties of SAM model with different frequency ranges.

15.2 RESULT: In figure-3 at 900MHz and 1800MHz of frequency SAR value is shown with respect to distance of phone from human head. For 900MHz SAR value is increasing at right hand side of head and decrease in 1800MHz at every instant of the time with increase in the distance of phone from head. It was also analyzed that radiation loss decreases with the increase in the distance. By showing graph 3 and 4 it can be realized actually. Mobile with cover case reduces the SAR absorption rate.

16. TOPIC: IMPACT of human hair configuration on human head absorption rate.[16]

16.1 WORK AND CONCLUSION: The basic motive of the study is to measure the propagation of EM wave through human head. In this daig-1 point of average SAR calculation in head model and integrated loss cube are defined.

CST simulation-Real life practical exposure is not possible so numerical method is used to calculate the SAR values and for that CST has been used in this paper. In this experiment patch antenna of 2.5GHz specification is used that is placed 5mm away from human head. The values for calculation of SAR are taken ε_{ρ}=42, μ_{ρ}=1, σ=0.99 S/m, ρ=1030kg/m3. It is studied that our hair is having capabilities to decrease the power absorption due to exposure. The presence of hair is the cause of reflection, refraction and scattering of the wave and was causing increase in SAR value firstly. At second time the specifications of the hair was changed. Now by considering different length of hair 35mm and 65mm experiments were done (diag-8,9) .

16.2 RESULT AND CONCLUSION: Longer the hair more is the absorption which is defined in diag-9. Other main parameters studied were water, gel and other things added to hair that was the cause of change in permittivity. Example-water is having permittivity of 78 so it was the cause of change in SAR value. This type of model is defined here as shell model. Because of reflection, refraction like incidents was factors of SAR increase and harm increase. It was realized that central part of head was more affected in this case.

17. TOPIC: Specific Absorption Rate (SAR) Reduced Mobile Phone Antenna Designs [17]

17.1 Work and description: In this paper SAR has been calculated for antennas used for communication purpose. The different type of channels are used here that are Dipole antenna and Rectangular patch antenna with different measurement of ε values and head model is kept at distance of 1cm from the antennas. Figure 2 and 7 shows SAR distribution with head and without head kept in from of dipole antenna and rectangular patch antenna respectively. Figure 3 and 8 show SAR distribution. SAR with 6 layers of human head is calculated in this paper along with the SAR calculation in antennas. The experiment is performed by using HFSS simulator in which 6 different levels of human head is designed with Box model in which bone, brain, fat, dura, skin, CSF are drawn.

17.2 RESULT: It was observed that SAR was more when dipole was useful and when EBG (electromagnetic band gap) was being used then it was drastically reduced. It means that EBG is beneficial for reduction of SAR exposure. Figure 15 shows SAR in dipole antenna and dipole with EBG. Other thing was that return loss in Dipole with EBG was reduced from -1.8447dB to -11.404Db. Table 1 also shows the reduction in SAR while using EBG.

18. TOPIC: Relationship between Spatial-Averaged SAR and Temperature Elevation in Human Head Models from 1−10 GHz [18].

18.1 WORK AND DESCRIPTION: In this paper the relation between peak mass SAR_{max} exposure and thermal elevation in human head and on pinna of the ear. 4.5^0 C temperature was allowable level for human head that might be considered as protected temperature limit without any adverse effects. Pricking temperature is defined as 45^0 C, causes skin pain. For the frequency range 3-10GHz SAR value was calculated in this paper for 10g of tissue. MRI of whole body is used here of every age, gender and races. Different human head model is used here segmented with 51-70 anatomical tissues. Different lengths of antenna are taken with respect to the frequency ranges for checking the dosimetry. Thermal elevation on human head is clarified by Bio Heat equation.

18.2 RESULT AND CONCLUCION: In figure 2 SAR and thermal increment is defined in TARO type head model (Chinese head model) at 6GHz frequency. It was observed that most of energy was absorbed by the pinna with increase in frequency. At 2GHz penetration depth was about 15mm in tissues of muscles. It was also observed that a 6GHz heating factor for DUKE model was more than HANAKON model. Figure 5 shows heat for different human head model with change in the frequency ranges.

19. TOPIC: Impact of SAR on Human head modeling in Elevators using IFA[19].

19.1 WORK AND DESCRIPTION: This paper consist of effects of EM wave on human head and SAR inside elevator while half opened elevator, fully closed elevator and free space using FEKO software and head is designed by considering all the dielectric constants and all other parameters with IFA handset. Because of metallic surface due to scattering, reflection and refraction, resonance occurs that are responsible for hot spot creation. Inverted F antenna (IFA) is designed for experimentation that is shown in the figure1. Human head model of 3mm radius is designed using FEKO simulator by considering all conductivity, mass density, electric permittivity etc defined in table3 for 900MHz and 1800MHz of frequency ranges. IFA under free space propagation with antenna and head model is designed in figure 4 in which head model is kept 5mm away from antenna. In figure5 radiation phenomena is shown that shows maximum radiation at nearest part of head from antenna (more reddish part). In second term half open elevator is shown in which resonance has been observed. In fully closed elevator structure frequency ranges from 1800MHz to 2.1GHz is considered. In this case resonance is more because of reflection from wall of the elevator.

19.2 RESULT AND CONCLUSION: SAR in 1g and 10g tissue is calculated while using 800MHz and 1800 MHz of frequencies. The result is shown in table II. After calculating overall SAR and analyzing all the graphs it was concluded that half open elevator was having SAR more than free space but in fully closed elevator it was the most means 20-60% SAR was more absorbed in this case for 1g of tissue. For 10g of tissue it was 10-30% more.

20. TOPIC: Radiation Performance and Specific Absorption Rate (SAR) Analysis of a Compact Dual Band Balanced Antenna.[20]

20.1 WORK AND DESCRIPTION: In this paper dipole dual band antenna using meander line is taken here for calculation of s-parameter, SAR and average SAR with frequency 3.78GHz and 4.29GHz. Human head model and antenna design is shown in a, b, figure2 with complete specifications and figure 3 with six layer of head model using HFSS.

20.2 RESULT AND DESCRITPION: Isolation mode was managed by using HFSS and s-parameter was measured for those areas on which radiation was directly being exposed. Return loss was observed 25dB for 3.78GHz and 18db for 4.29GHz. S-parameters are shown in figure5, 6. Figure 8, 9 show electric field distribution and SAR on human skin at 4.29GHz of frequency. Electric field distribution is more at nearest point of the antenna and maximum SAR exposure is 0.405W/kg that is less than the standard given by ICNIRP (1.6W/kg). It was also considered that skin absorbed more electrical field than brain tissue. By balanced antenna design approach ground plane current can be reduced and thus other exposures can be reduced.

21. TOPIC: Interaction of a human head model with the antenna of mobile terminal [21]

21.1 WORK AND DESCRIPTION: For optimization of SAR is explained in this paper. For this purpose equivalent current surface model and method of volume current polarization is used using FEKO software. Planner antenna is used here for examining that is rectangular plated metal structure. For determining exposure level three layers of head is taken that are brain, bone, skin. To determine exposure level permittivity, conductivity and mass density is considered by formulation.

Table 2: Shows all the specifications for bone, brain and skin while 3GHz of frequency is used:

Substance	Thickness in mm	E	S	D	R
Brain	Filling	46	1.7	0.369	1030
Bone	3	8	0.1	0.125	1800
Skin	1	44	1.216	0.41	1100

It was assumed that large dielectric material was kept in near field of antenna.

21.2 RESULT: When head was kept in 0mm distance from antenna, it was observed that SAR exposure was increased 1.5 times. At frequency of 2.5GHz it was 1.49W/kg and above this frequency SAR level increased by 17.5%. SAR and power loss result is shown in the table 2 with respect to the distance of Head from antenna.

22. TOPIC: Design Considerations to Calculate SAR in Multiband MIMO Antenna for Mobile Handsets [22].

22.1 WORK AND DESCRIPTION: For the calculation of exposure flat phantom is used while mobile is placed closer to human head i.e. 'body worn mode' and another was while voice call is in on condition i.e. 'talking mode'. Adaptive Beam forming technique increases SIAR (signal interference to noise ratio). For understanding the coincidence effect while two antennas are kept near to each other here experiment is performed that technique is known as SAR to peak location ratio (SLPR). Where SLPR is defined as: SPLSR=(SAR1+SAR2)/D W/Kg. D is value of distance between antenna elements i.e. 5cm. SPLSR is defined 0.3 by FCC.

22.2 SIMULATION AND RESULTS: Phantom model (with SAR defined by FCC) is considered here and condition is when user is carrying mobile in his pocket. In talking mode SAR exposure is more due to less distance of antenna form head while hotspot is near the head. SAR is reduced 50% in talking mode than flat phantom mode. According to frequency increase accepted power will decrease and thus result also found that at 1.9GHz, power was 0.13W. Literature survey is shown in table 3.

Table 3: Tabulated analysis of SAR and Thermal effects on human head:

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.[2]	900-1800MHz	Human brain	Most affect at near feed point of antenna
Ke-Li Wu[3]	100KHz-10GHz	Human head	SAR measured with respect to mass density
L. K. Ragha and M. S. Bhatia[4]	900MHz	Human head	SAR for 1g of tissue was more than 10g in this frequency
M. H. Hussain et al[5]	900MHz	Human head, face, ear	Mouth level was more affected and thermal effect was more
C. Lazarescu[6]	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[7]	900MHz, 1800MHz, 2400MHz	Human head	SAR more in near field and at 2400MHz frequency.
M. H. Mat[8]	900MHz	Human head	Increase of heat absorption on hypothalamus of the ear.
M. A. Rahman[9]	800, 1.47, 2.45, 3.35GHz	Human head	SAR is 0.81 that is under standard by ICNIRP
Y. Iseki *et* al[10]	300MHz	Human head	Use of dielectric material reduced SAR and thermal effect
K. T. Kaharpardeshi[11]	3.3GHz-3.5GHz	Human head	At 90^0 elevations angle SAR exposure was more on human head.
C. Lazarescu[12]	ISM band	Human head	It provides exposure on human head and result was high exposure level at high frequency as well thermal increment on head.
V. Mishra et al.[13]	100MHz-6GHz	Human head	SAR varies according to change in density of mass.
M. I. Hossain, M. R. I. Faruque and M. T. Islam[14]	1800MHz	Human head	SAR was more in open elevator at 1800MHz

A. Tharakan et al.[15]	800MHz, 1800MHz	Human head	Central part of head was more affected by exposure
A. Hirata, S. Ohta, I. Laakso and O.Fujiwara[16]	2.5GHz	Human head and EBG	By using EBG SAR value was reduced
A.Tharakan [17]	1-10GHz	Human head	After simulation it was found that SAR was more at 10GHz of frequency.
S. Jemima Priyadarshini et al.[18]	0.8GHz, 0.835GHz	Head and ear	Pinna absorbed more heat and radiation than brain skin.
A. If7ikhar et al.[19]	1-10GHz	Head	For fully closed elevator SAR was 20-60% more for 1g tissue and 20-30% more for 10g tissue.
M. B. Protsenko et al.[20]	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[21]	1.9GHz	Human head	Hot spot formation was observed near ear at near field of antenna.

CHAPTER 3

OBJECTIVES OF THE RESEARCH:

1) To design a Rectangular Microstrip patch antenna and Triangular Microstrip patch antenna in which substrate is made up of ‘FR-4 lossy’ i. e. having ε_r=2.2 and loss tangent tanδ=0.02 using CST simulator generating mobile band frequencies i.e. ISM band at 2.4GHz frequency.

2) To design a spherical head model (skin) by considering its conductivity, mass density, electric and magnetic permittivity in accordance to the Bio-Heat equation of tissue.

3) To measure values of SAR on human head model for both of the antennas and perform comparison between simulation results.

4) To analyze the effect on SAR exposure at certain distance gap between antennas and human head at 2.4GHz and 3.5GHz.

CHAPTER 4

ANTENNA DESIGN USING CST SIMULATOR:

4.1 CST MICROWAVE STUDIO SIMULATOR: CST is defined as computer simulation technology microwave studio used for performing Electromagnetic/ SAR exposure calculation as well as designing of Antenna for any type of applications of any range. It provides 3D modeling of the objects as well as graphical representations of the output result. After completion of model creation wave guide supply and simulation engine are started to get results.

After designing the prototype by using transient solver, frequency/Time domain solver, integral setup solver, mesh etc we can design a complete model and can simulate it and can get all the different parameters like S-parameter, VSWR, SAR, thermal distribution etc. My aim is to get simulation results for SAR level and Thermal distribution on human head model while working with two different antenna designs of same resonant frequency i.e. 2.4GHz, impedance, bandwidth etc.

Dimensions and measurements in CST simulator: At the inning of the software when we choose for a new project file then a dialog box appears in which we can define those parameters that are going to be use in the making our project means our antenna and head model. Those parameters are like frequency, length, time, temperature, conductivity, permittivity, tangent loss etc.
Field Monitor: When we are interested in calculating S-parameter, SAR level, Thermal loss etc on human head due to radiation then there is need of defining frequency for all the fields. Those fields are E field, H field, power flow, power loss density, magnetic loss and electric loss density etc. After defining frequency we can run the simulator using either by setup solver or by simulation.

4.2 ANTENNA: According to IEEE a physical medium by which exchange of information via EM transmitting wave is known as antenna. Antenna design can be originate by considering parameters like return loss, gain, VSWR, radiation pattern, directivity, antenna efficiency, effective area, input impedance, beam width and bandwidth.

4.2.1 Return Loss: It is defined as parameter required match between transmitter and receiver for perfect reflection of signal between these antennas.

VSWR: This defined as the ratio of maximum voltage of standing wave over minimum voltage of standing wave. Formula:- VSWR = V_{max}/V_{min} and value of VSWR must be 1 always for perfect reflection of signal.

4.2.2 Antenna gain: It is ability of antenna to provide maximum directional radiation or main lobe at desired direction as output. An ideal isotropic radiator is analyzed as 100% efficient. Formula: $S = P_0/4\pi r^2 = |E|^2/\eta$

4.2.3 Directivity: It is defined as direction of maximum information.

Cross polarization and co polarization directivities are defined as below
Directivity $_{c} = U_{cmax}/U_0$ Directivity$_x = U_{xmax} / U_0$

4.2.4 Effective Area: Defined as the area where power captured and delivered will be more. The power supplied to the terminals is defined as the product between effective area and S. $P_d = S\ A_{eff}$

4.2.5 Input Impedance: It is defined as the ratio between voltage and current of the electric and magnetic field component.
$Z_{in} = R_{in} + jX_{in}$

4.2.6 Bandwidth: It tells us about the frequency range over which the antenna can receive and transmit the waves properly.
I am doing my experimentation on EM radiation effects on SAR level and thermal effects on human head model i.e. defined in terms of skin layer. For radiation purpose I used Microstrip patch antenna. I have designed two different types of antennas operating frequency 2.4GHz i.e. also known as ISM band. Parameters for Microstrip patch antenna are defined below:

4.3 MICROSTRIPPATCH ANTENNA: Microstrip antenna is defined as antenna with inset line feed or co-axial cable that leak from their edges and provide radiation. It plays vital role in today's wireless communication system. Fabrication of Microstrip patch antennas is very easy by using conventional fabrication technique. Patch of the Microstrip patch antenna can be in triangular shape, rectangular shape, circular shape, elliptical shape etc. Substrate with higher dielectric constant must be used for accurate efficiency and return loss with narrower band width.

Due to excitation negative charges produced at feed point and positive at another part of patch. These charges create electric field that helps in radiation of the wave through the antenna.
The basic architecture of Microstrip patch antenna consist of dielectric substrate, patch, ground plane, feed point, slot (if want to operate antenna in multiband). Patch in an antenna act as radiating plane of the wave that is made up of copper or gold etc materials. The feed lines used to provide wave guide to the antenna.

The diagram of Microstrip patch antenna is shown below:

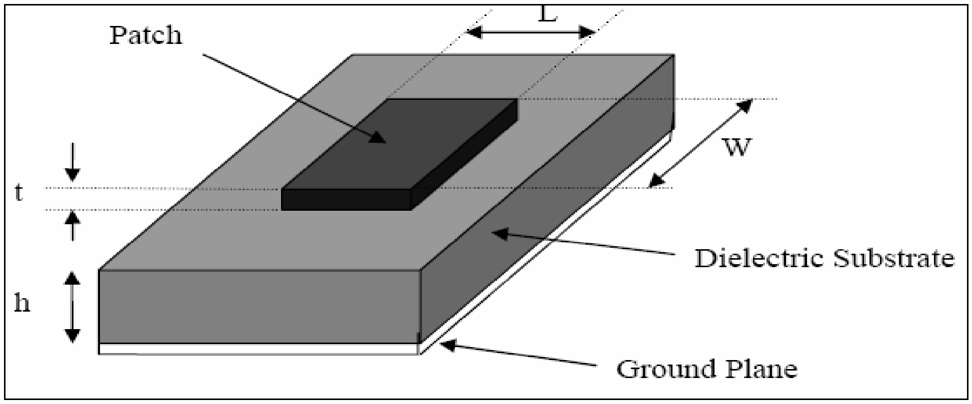


Figure 3: Microstrip patch antenna

The design of Microstrip patch antenna using CST Microwave studio is shown in below figure in 3D plane. Antenna consists of different modules which are after combine all is making a complete antenna. The different specifications given to the antenna are as follows:

4.3.1 Design of Rectangular Microstrip patch antenna [24],[26]:-

1) **SUBSTRATE:**

a) Rectangular substrate is designed by considering length, width, height with the dimension 75×60×1.85(in mm).

b) This substrate also used for ground plane for the antenna.

c) Material used for this is Aluminum or Cupper because of any structure formation by these materials.

2) **PATCH:**

a) It is made up of copper material and dimension is 42.4×42×0.05(in mm)

b) Patch is the main part of the Microstrip patch antenna.

c) It is made up of FR4 lossy material.

d) FR4 lossy material is used in designing because of its lossy nature.

3) **FEED LINE**:

a) The dimension of the feed line is defined as W_f = 4.82mm and h=0.05mm

b) In this a conducting line/strip made up of copper or PEC material is connected to the patch of the antenna.

c) Feed can be co-axial feed point, inset line feed. I have preferred inset line feed that is having smaller width as compared to patch and other elements of antenna.

d) It is made up of copper material.

e) It is the plane in which we can expose waveguide so that we can transmit signal through the antenna.

4). **CAVITY:**

Cavity is designed for creating cavity in patch of the antenna. Dimension of cavity is h=0.05mm, W_c=6.5mm.

The complete design of rectangular Microstrip patch antenna is shown in figure 4.

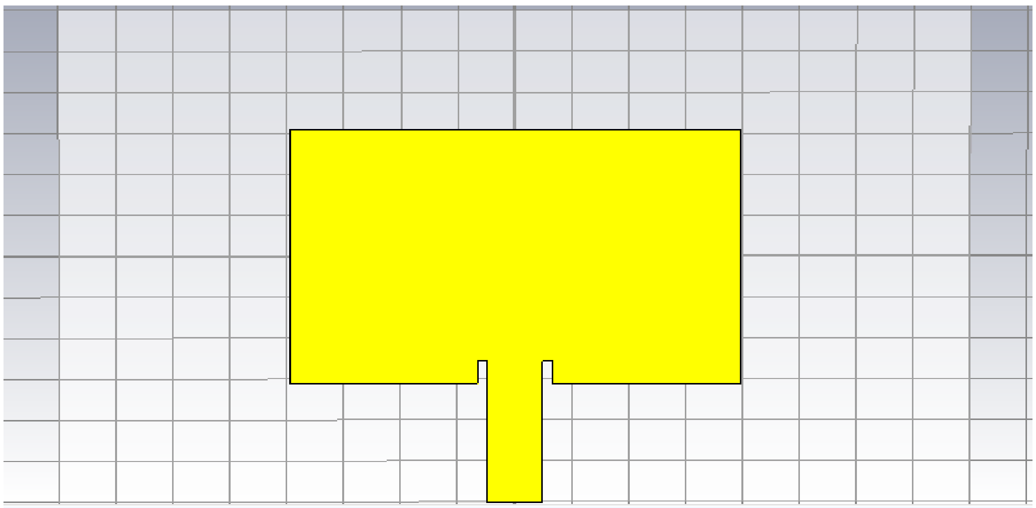


Figure 4: Rectangular Microstrip patch antenna

4.3.1.1 Formulae used for designing Rectangular Microstrip patch antenna:

4.3.1.1.a For calculating effective length of the antenna:

$$f_0 = \frac{c}{2L\sqrt{\epsilon_r}}$$

Here c=speed of light in free space, L=effective length of antenna, ε_r=dielectric permittivity of substrate and f_0= resonant frequency

4.3.1.1.b For calculating width of the antenna:

$$W = \frac{v_0}{2f_r}\sqrt{\frac{2}{\epsilon_r}}$$

Here W= width of antenna, f_0 or f_r=resonant frequency, ε_r=dielectric permittivity of antenna

4.3.2 Design of Triangular Microstrip patch antenna [25]:-

1) **SUBTRATE:** Substrate used in Triangular Microstrip patch antenna is made up of FR-4 lossy and dimension of it is: 80×60×2.5(in mm).

2) **PATCH:** Patch is made up of copper annealed. The dimensions of patch are: a=54.9 and h=0.05.

3) **CAVITY:** Cavity is made up of Vacuum. Dimension of it is defined: l=7.5, h=0.05.

4) **GROUND:** Ground is made up of PEC material whose dimension is same as of substrate and height of it h=-0.05.

5) **FEED LINE**: Feed line is for wave guide transmission through the antenna. It is made up of copper material. Dimension is defined as: W=4.82,h=0.05.

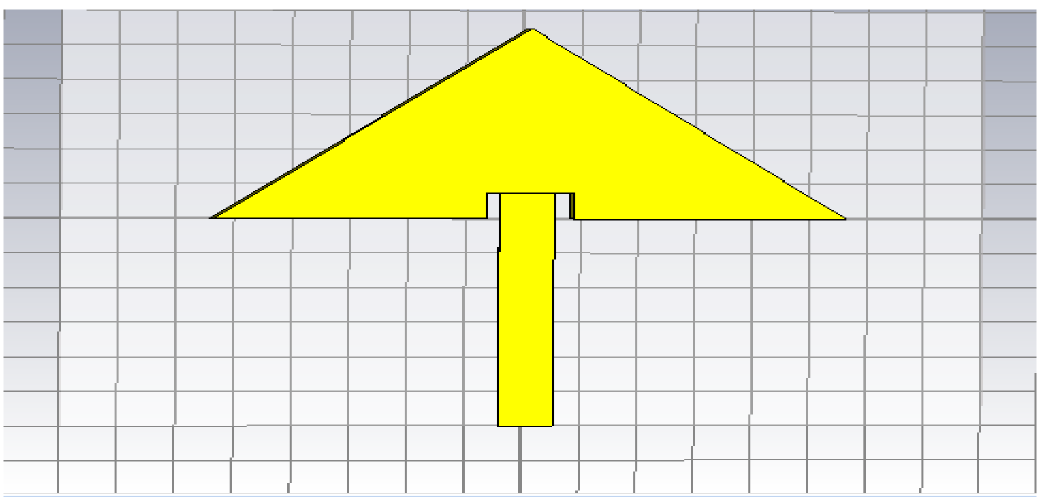


Figure 5: Triangular Microstrip patch antenna

4.3.2.1 Formula used for designing Triangular Microstrip patch antenna:

$$f_0 = \frac{2C}{3a\sqrt{\epsilon_r}}$$

Here f_0= resonant frequency of antenna, C=speed of light in space, a=side of triangle,
ε_r=dielectric permittivity of antenna
Above equation is for calculating value of side of the triangle.

The objective of the inset feed is to get maximum impedance with respect to the position of the feed line with the edge of the patch. The input impedance can be reduced while using feed at centre of the edge of patch. Inset matches impedance between feed line and patch. This is easy to design this feed because of its simplicity for impedance matching. As per the thickness of the substrate of dielectric material increases surface waves and also increases radiation and thus changes in bandwidth of the antenna.

4.4 HUMAN HEAD DESIGN USING CST: By using AUTO CAD design software a 3D Human head model was created. The head was created by considering all the specifications those are similar to the real human head mentioned in table 4.

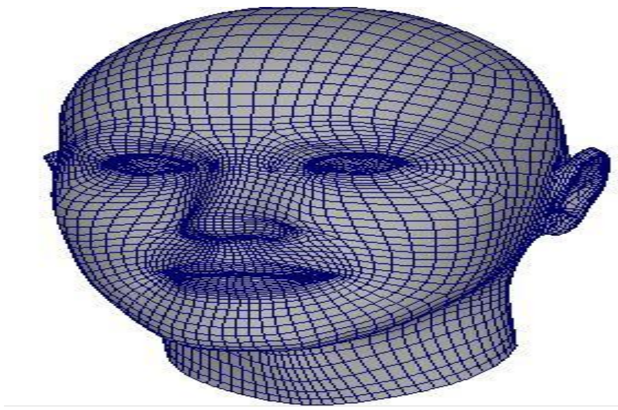


Figure 6: CAD design of human head model

Specifications like conductivity, mass density, dielectric permittivity (electric and magnetic). Firstly head model was kept at distance of 0mm away from Microstrip patch antenna and then SAR and Thermal loss was calculated. Then later on at 1mm, 2mm, 3mm, 4mm distance was introduced between human head and both the antennas. When head was kept aside of antenna, radiation face was towards the brain and ear of the head model. The radiation was showing the maximum power distribution on human head at a particular position.

Human head model in this research work created is in spherical shape that consists of Skin layer of the human head. 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 [23]

Table 4: Specifications of skin of human head model

Substance	ε	σ(S/m)	tangent, δ	ρ(kg/m^3)
Skin	38.4	1.216	0.42	1100

Human head model is designed that is related to Bio-Heat equation (1) that tells about above values as well as Blood flow in Skin layer of the human head.

Bio Heat equation is defined as:

$$\rho_c \frac{dT}{dt} = \Delta(K\Delta T) + \rho C_b w_b (T_b - T) + Q_{met} + Q_{ext}$$ [2]

Here Q_{met}=energy deposition on metabolism, Q_{ext}=energy deposition due to external hypothermia, K= Boltzmann constant, T=temperature, ρ_C=mass density of tissue, w_b=width or thickness of layer.

The above mentioned equation tells about the heat loss, energy deposition and blood flow through the human head model.

Human head designed using CAD design was not compatible with CST simulator so I created spherical model of human head that is created by using above specifications and Bio-Heat equation. Human head model is created by taking Skin layer into consideration.

Skin layer of human head is the uppermost layer that is direct in connection with the mobile phone when one talking by phone. SAR value on human head model at different frequencies and distance between human head and antennas has been calculated. The SAR values on human head show that how much power radiated by antenna has been observed by the human head.

Spherical model is shown in figure 7 i.e. created by using CST microwave studio.

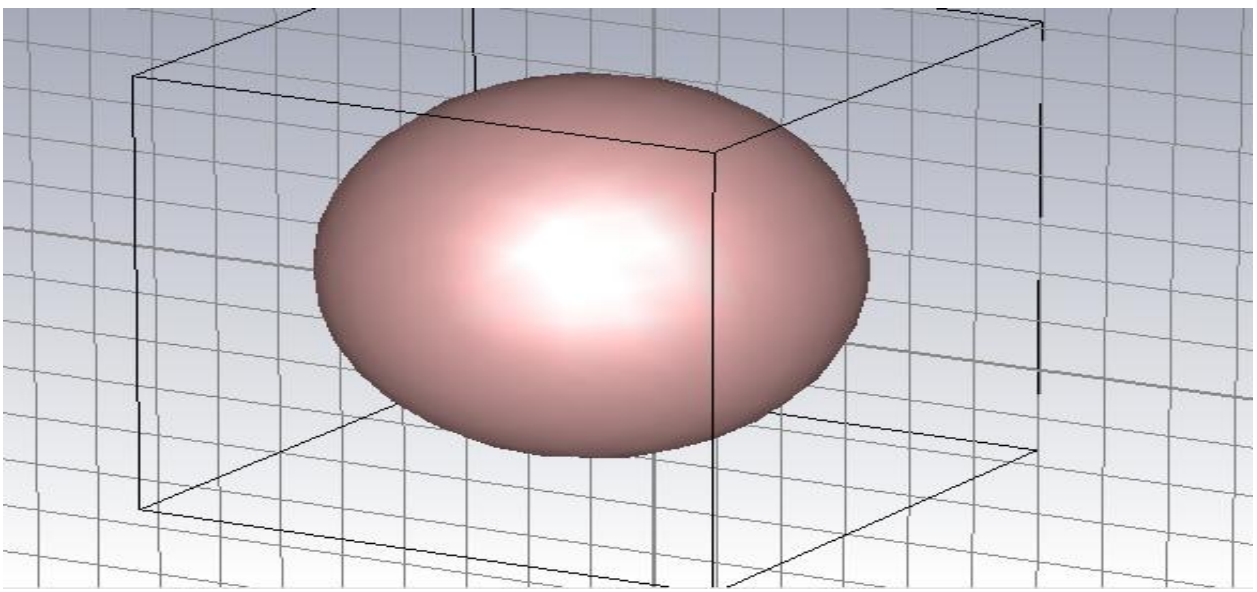
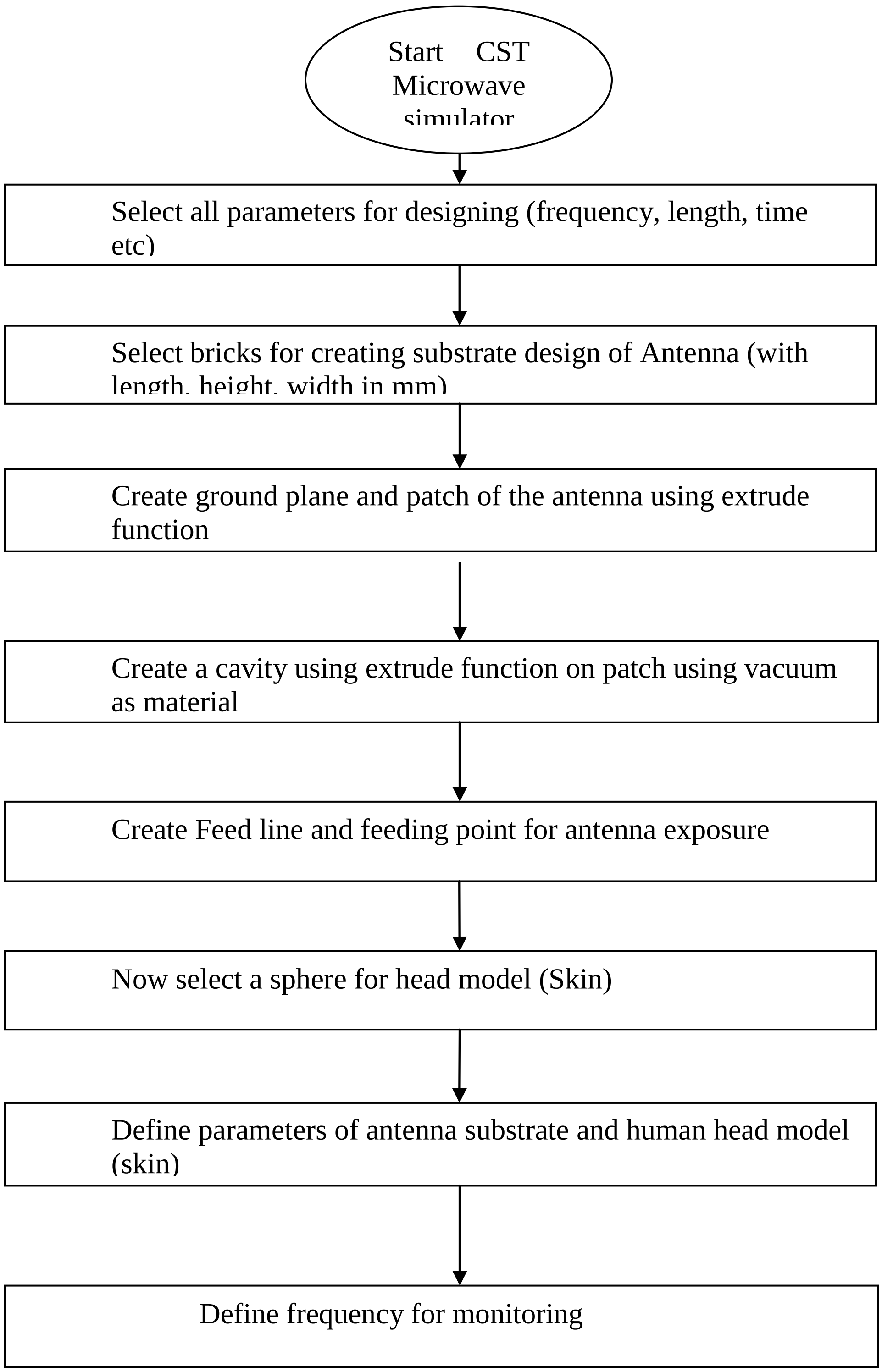
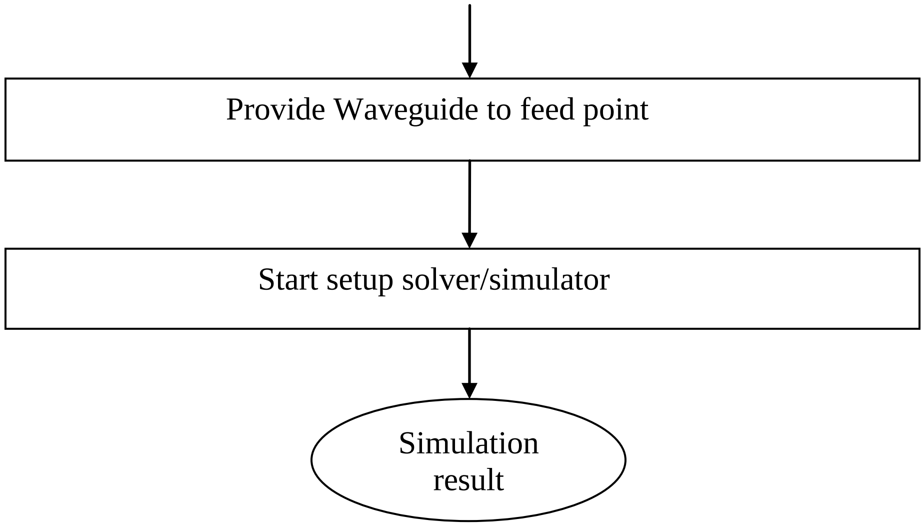


Figure 7: Spherical human head model (skin layer)

CHAPTER 5
RESEARCH METHODOLOGY:

For experiment, I have used CST simulator by designing antenna and performing exposure of it on human head model. In this I have calculated SAR level and thermal distribution too. The complete simulation is performed in the following steps:





5.1 Diagrammatic representation of human head model:

After step number 4 we will get 3D model in the CST studio simulator as given in the diagram 7 and 8. Rectangular Microstrip patch antenna and human head model arrangement is shown below:

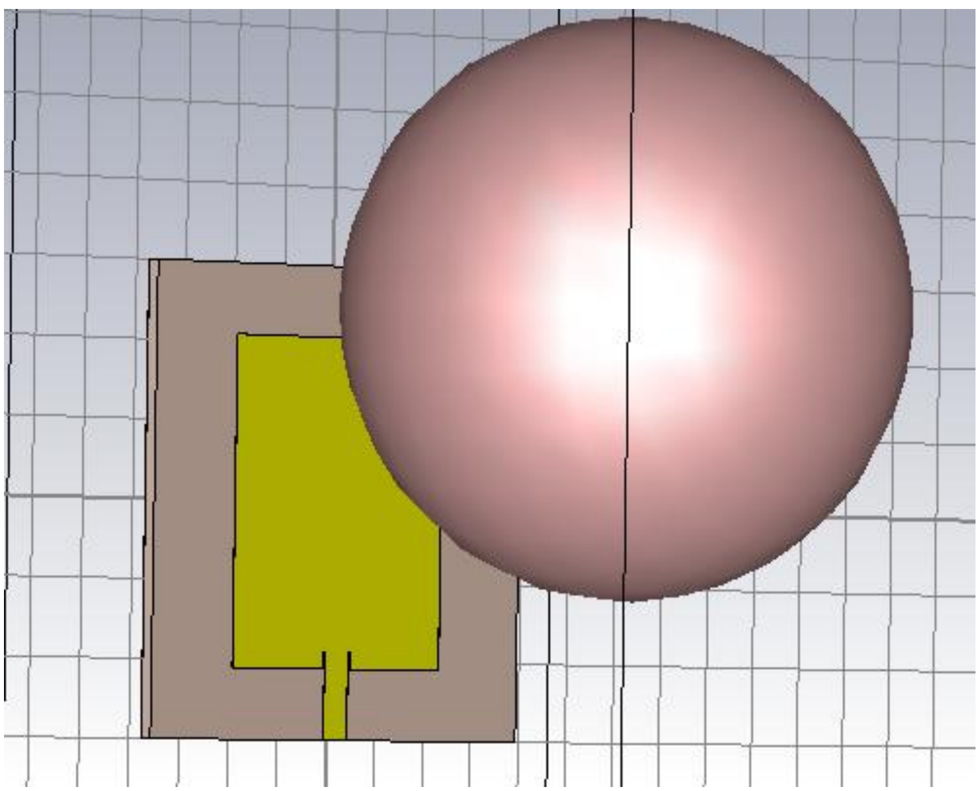


Figure 8: Rectangular Microstrip patch antenna and Human head using CST

Triangular Microstrip patch antenna and human head model arrangement is shown below:

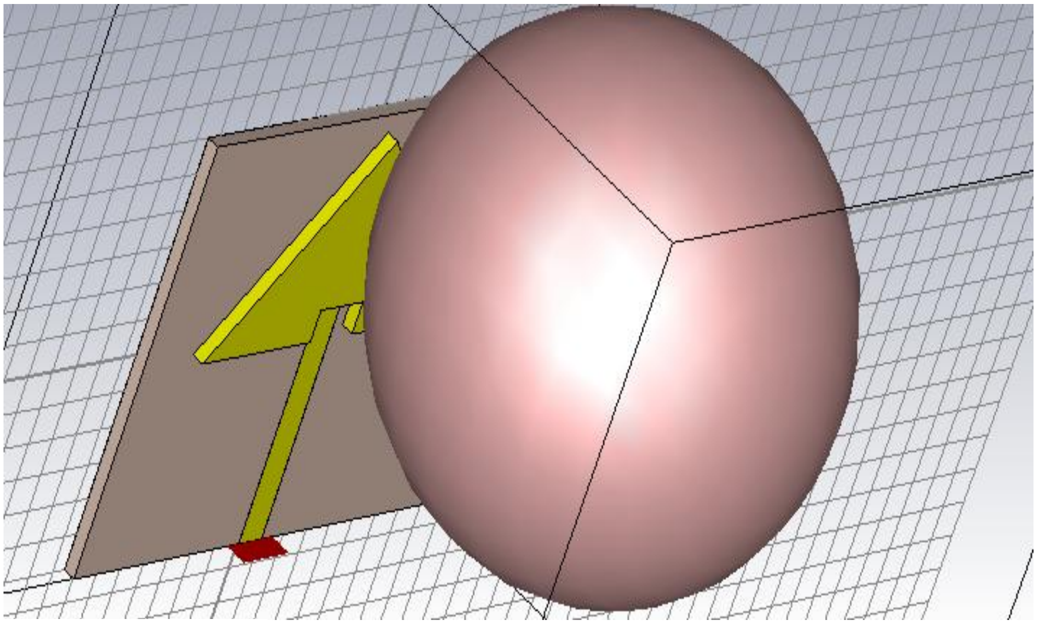


Figure 9: Head model and Triangular Microstrip patch antenna 3D model in CST

In the above diagram the complete arrangement is shown after designing antenna as well as human head model. Feed line has been provided the feed point so that EM wave can be imposed on to the antenna and thus we can calculate SAR level and thermal distribution.

5.2 Parameterizations of antenna and human head model: Parameterization of antenna can be considered as- ε, ρ, tanδ, σ like parameters of substrate material used in designing antenna. Here are some of the parameters that are defined using CST microwave simulator:

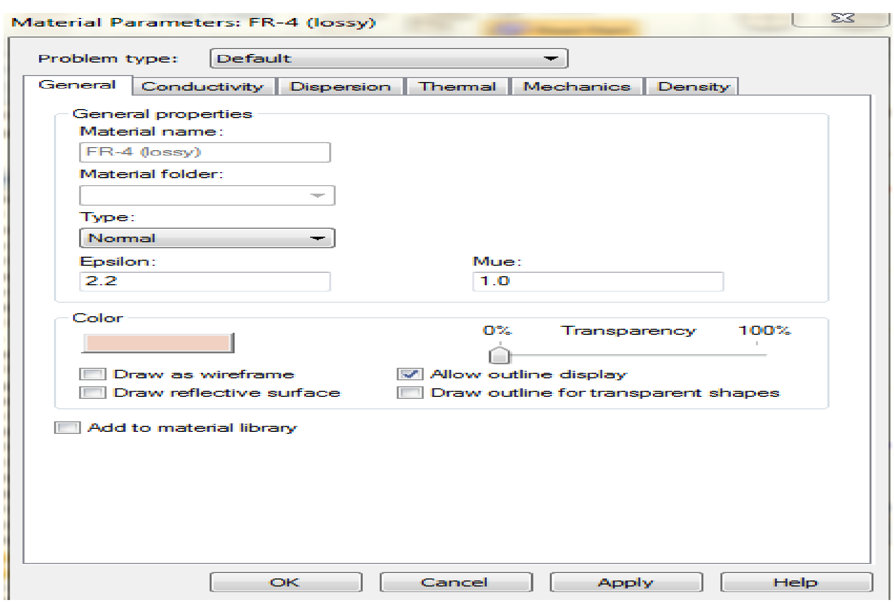


Figure 10: Parameterization of dielectric permittivity of substrate (FR-4 lossy)

Defining conductivity and tangent loss:

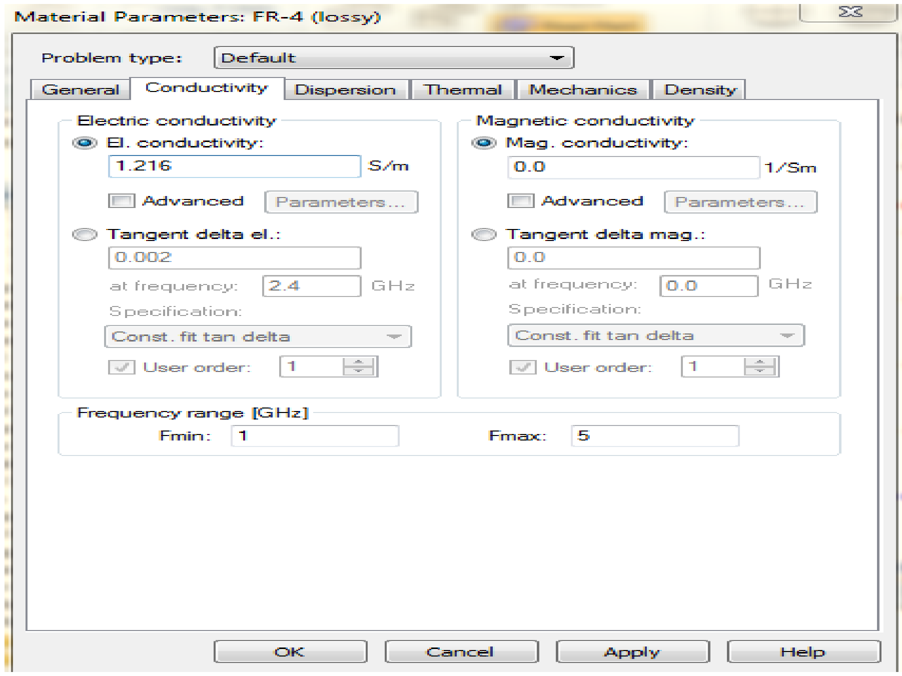


Figure 11: parameterization of conductivity and tangent loss of the substrate material

Defining parameters electric permittivity of head model (skin layer):

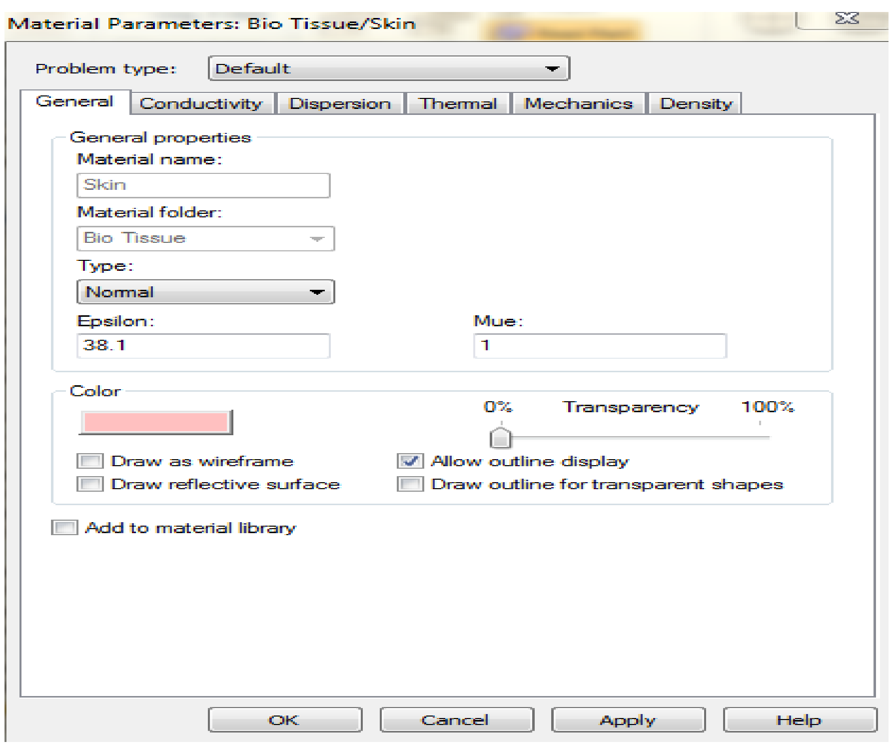


Figure 12: Parameterization of electric permittivity of human head (skin layer)

Defining conductivity and tangent loss of human head model (skin layer):

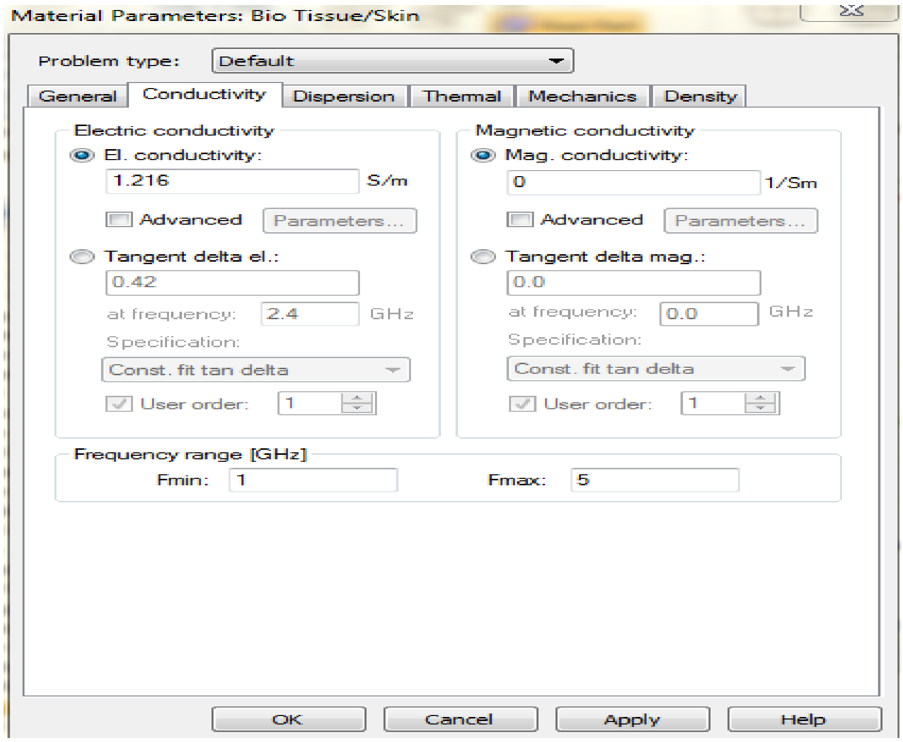


Figure 13: Parameterization of conductivity and tangent loss of human head (skin layer)

Defining mass density of human head model (skin layer):

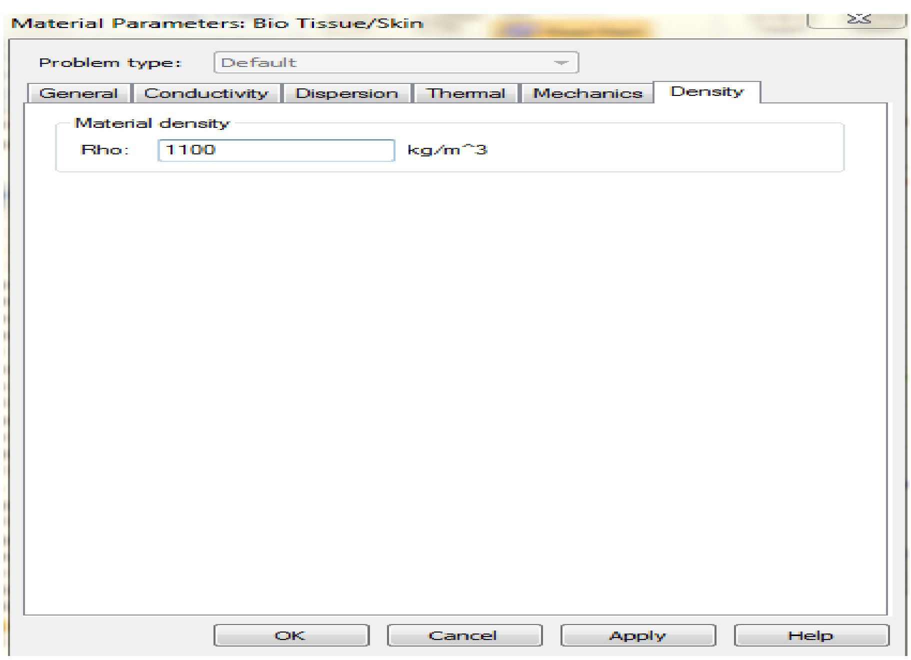


Figure 14: Parameterization of mass density of human head model (skin layer)

CHAPTER 6
SIMULATION AND RESULT:

Simulation results are categorized in different parts like Antenna performance and SAR measurement. Antenna performance can be achieved by measuring resonant frequency, Reference Impedance of antenna, Bandwidth, S-parameter graph etc for both the antennas i. e. Rectangular Microstrip patch antenna and Triangular Microstrip patch antenna.

The other category of simulation result is based on SAR exposure on human head model at resonant frequencies 2.4GHz and 3.5GHz (obtained in both of the antennas).

6.1 S-PARAMETER PRESENTATION:

Simulation results of antennas in terms of resonant frequency and bandwidth measurement along with the gain of the antennas.

A). S-parameter graph for Rectangular Microstrip patch antenna:

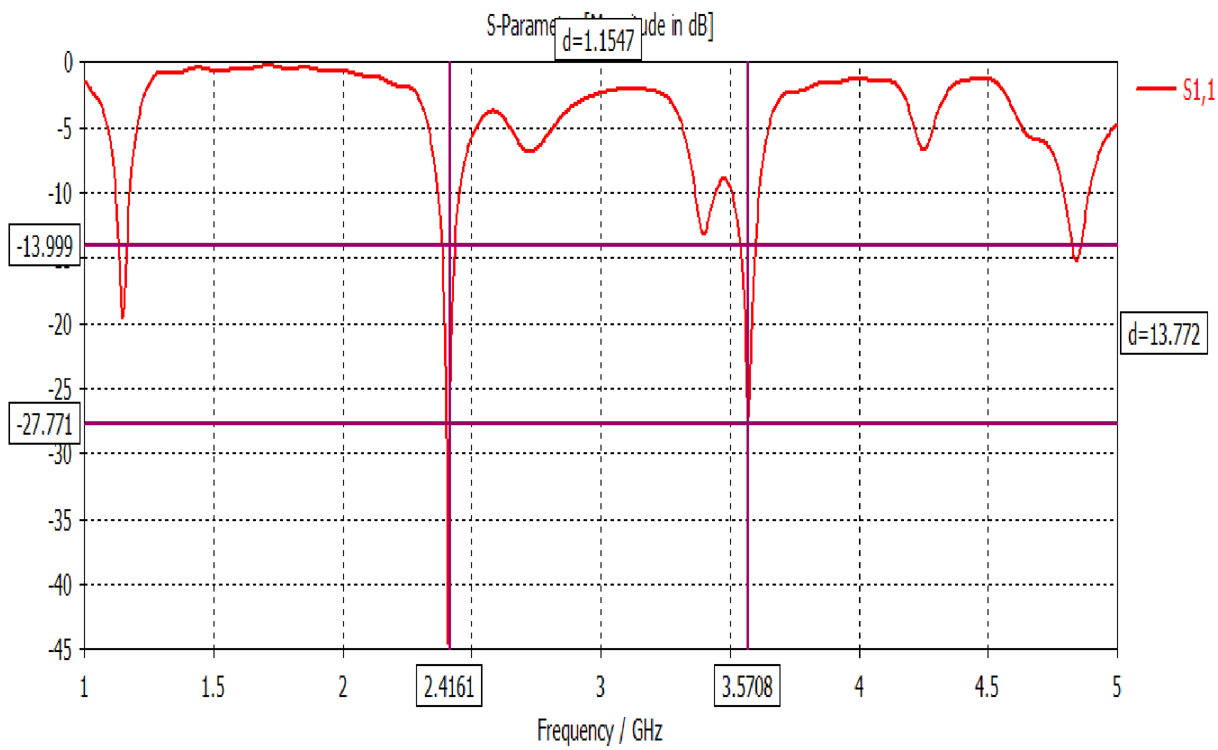


Figure 15: S-parameter graph Rectangular Microstrip patch antenna

B). S-parameter graph for Triangular Microstrip patch antenna:

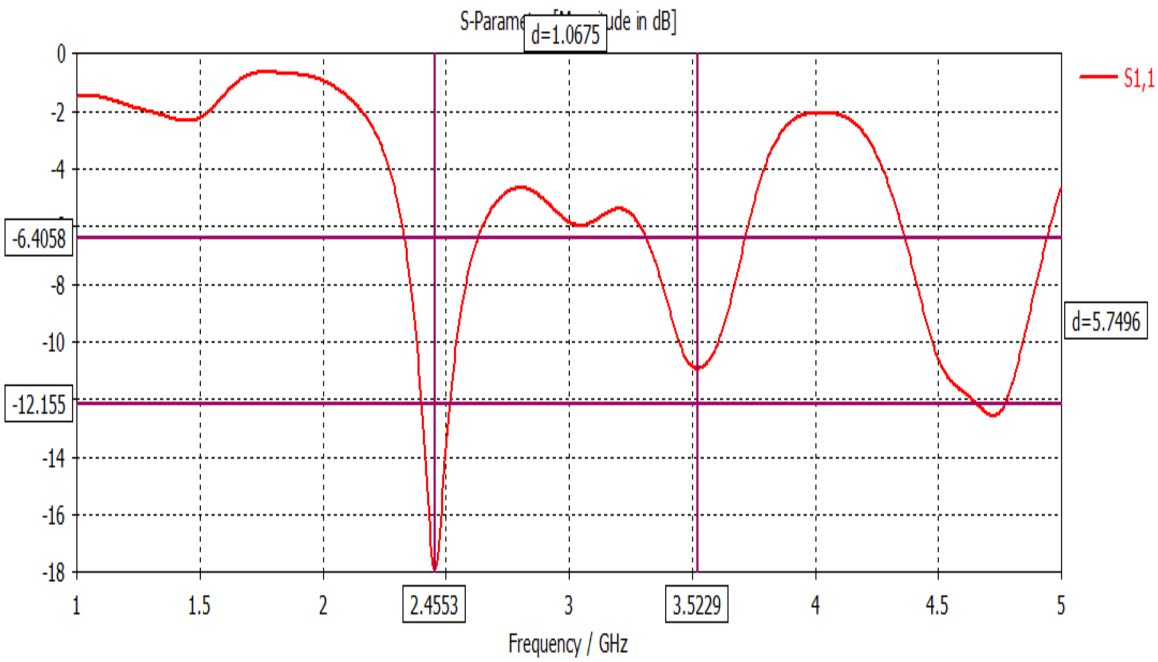


Figure 16: S-parameter graph Triangular Microstrip patch antenna

6.2 Resonant frequency and bandwidth of antennas:

Table 5: Simulation results of Rectangular Microstrip patch antenna and Triangular Microstrip patch antenna:

Type of antenna	Resonant frequency(in GHz)	f_1(in GHz)	f_2(in GHz)	Band width(in GHz)
Rectangular Microstrip patch antenna	2.4GHz	2.36GHz	2.46GHz	2.41
	3.5GHz	3.49GHz	3.61GHz	3.5
Triangular Microstrip patch antenna	2.4GHz	2.38GHz	2.54GHz	2.46
	3.5GHz	3.45GHz	3.6GHz	3.5

6.3 Radiation pattern and Directivity of the antenna: It is defined as variation in the power radiated by antenna at a specific direction. Radiation pattern is defined in three categories- a) Omni directional, b) Directional, c) Isotropic.

a) Omni directional radiation pattern: For an actual antenna, the radiation pattern is isotropic in a plane. It can be seen in dipole antenna and slot antenna.

b) Directional radiation pattern: In this radiation pattern the complete power radiated will propagate in a particular direct for most and radiation power can be seen at single peak direction. It can be seen in slotted waveguide antenna and dish antenna.

c) Isotropic radiation pattern: In this radiation pattern power radiated in all the direction will be same. In practice antenna with isotropic radiation doesn't exist in practical.

6.3.1.1 Directivity of Rectangular Microstrip patch antenna at 2.4GHz frequency:

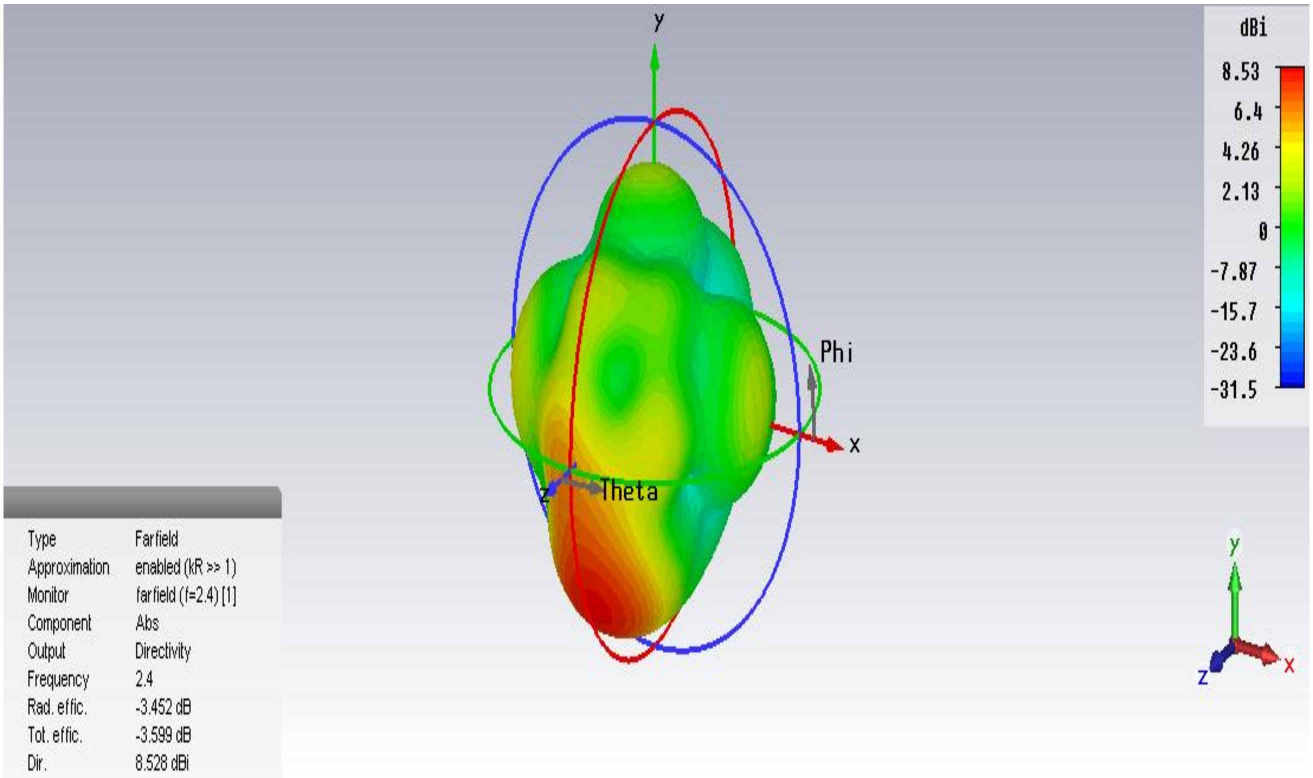


Figure 17: Directivity of Rectangular Microstrip patch antenna at 2.4GHz

6.3.1.2 Directivity of Rectangular Microstrip patch antenna at 3.5 GHz frequency:

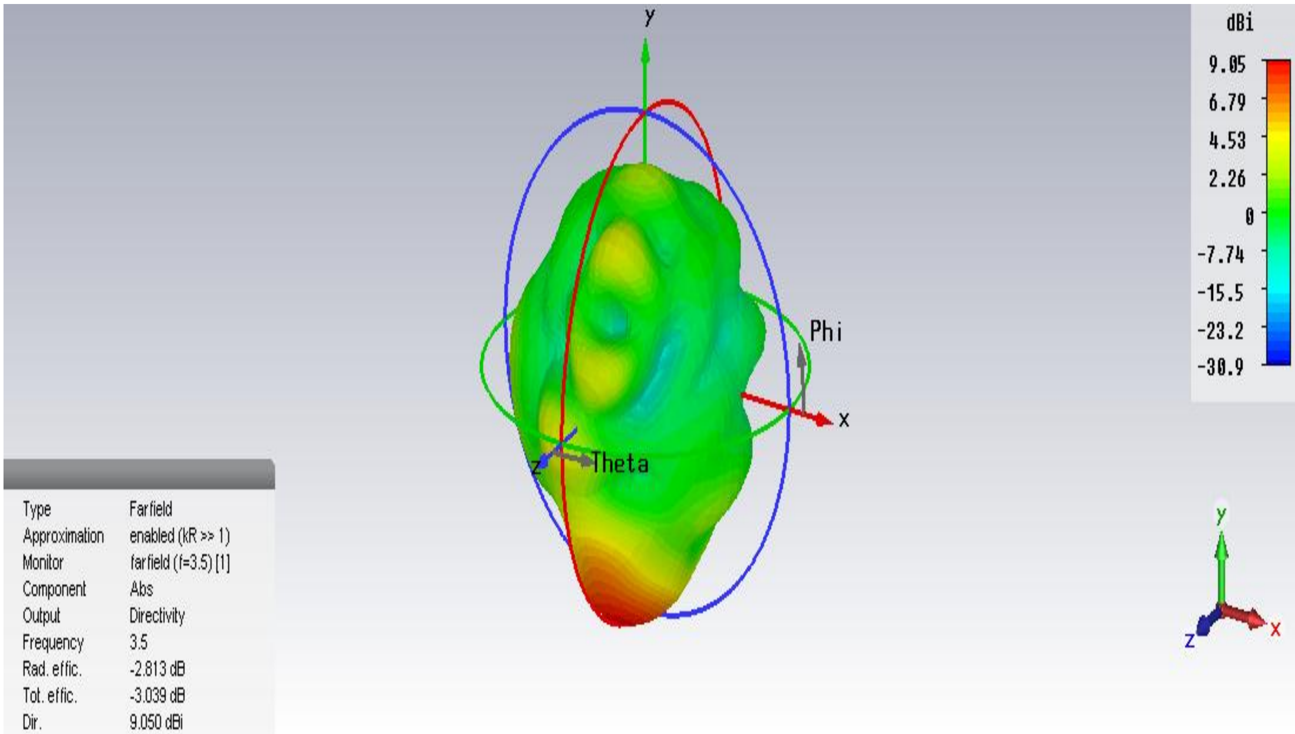


Figure 18: Directivity of Rectangular Microstrip patch antenna at 3.5GHz frequency

6.3.1.3 Directivity of Triangular Microstrip patch antenna at 2.4GHz frequency:

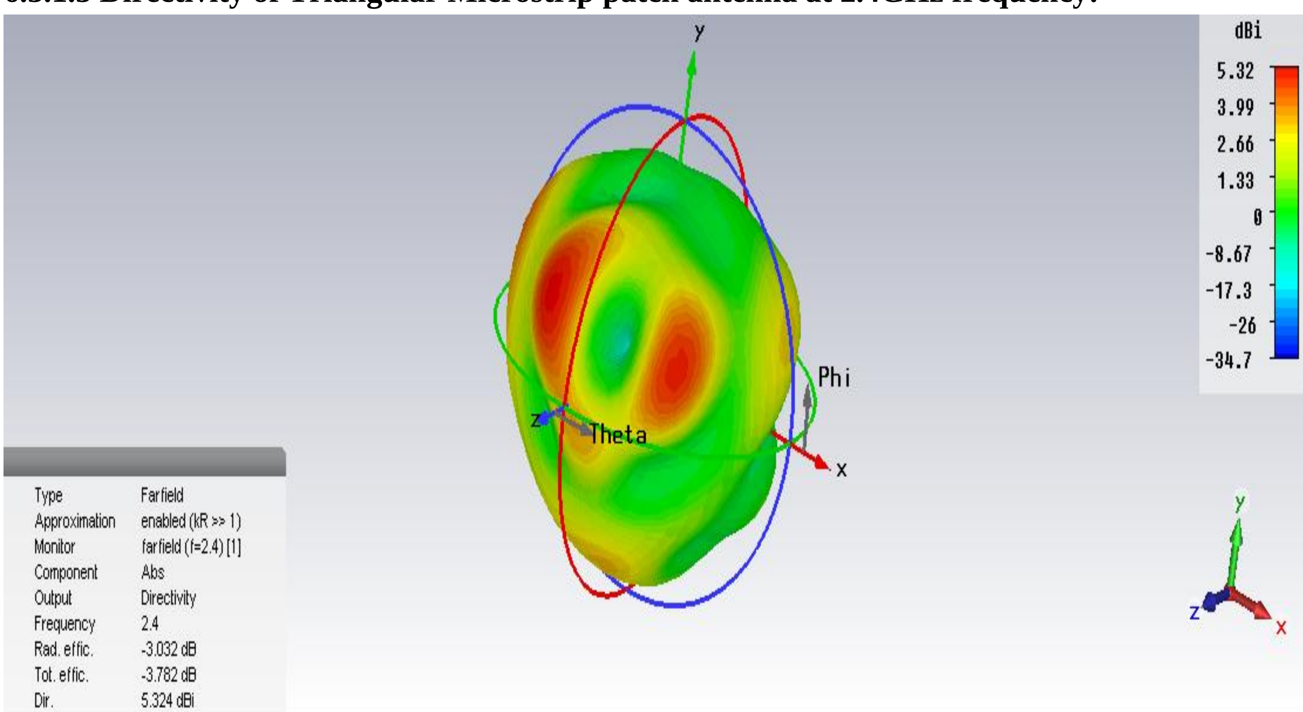


Figure 19: Directivity of Triangular Microstrip patch antenna at 2.4GHz frequency

6.3.1.4 Directivity of Triangular Microstrip patch antenna at 3.5GHz frequency:

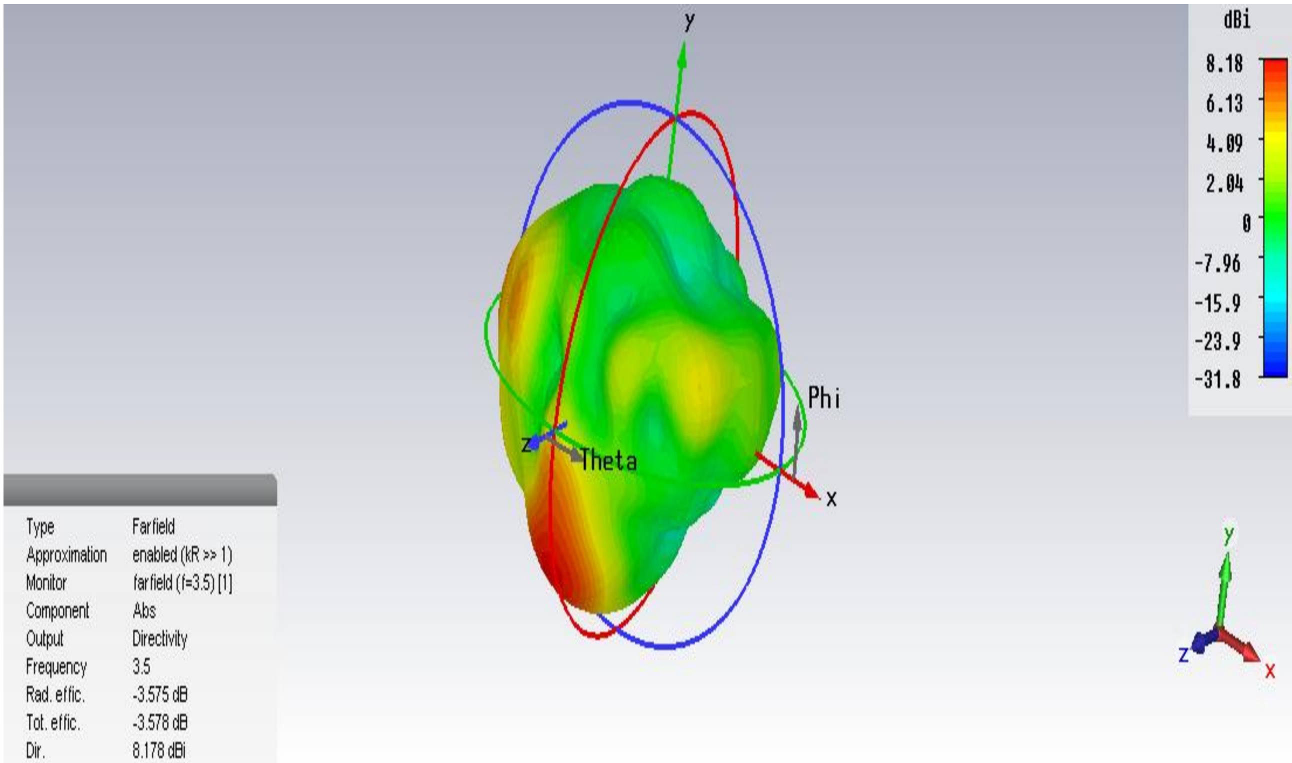


Figure 20: Directivity of Triangular Microstrip patch antenna at 3.5GHz frequency

6.4 RADIATION PATTERN: It is defined as the maximum radiation at a particular direction.

6.4.1 Radiation pattern of Rectangular Microstrip patch antenna at 2.4GHz:

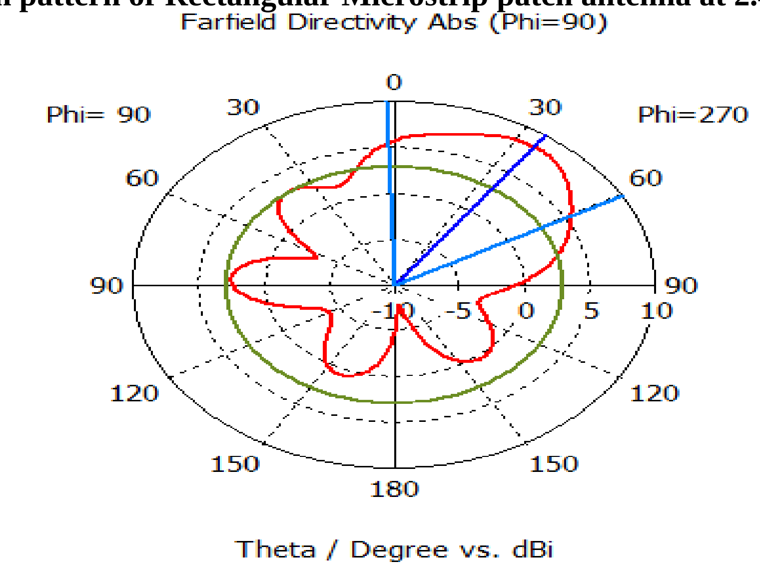


Figure 21: Radiation pattern of Rectangular Microstrip patch antenna

6.4.2 Radiation pattern of Rectangular Microstrip patch antenna at 3.5GHz:

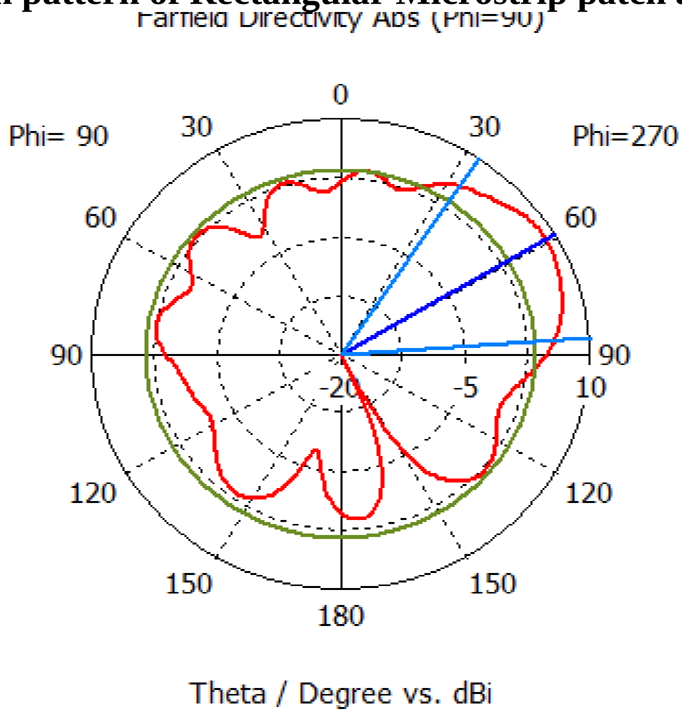


Figure 22: Radiation pattern of Rectangular Microstrip patch antenna

6.4.3 Radiation pattern of triangular Microstrip patch antenna at 2.4GHz:

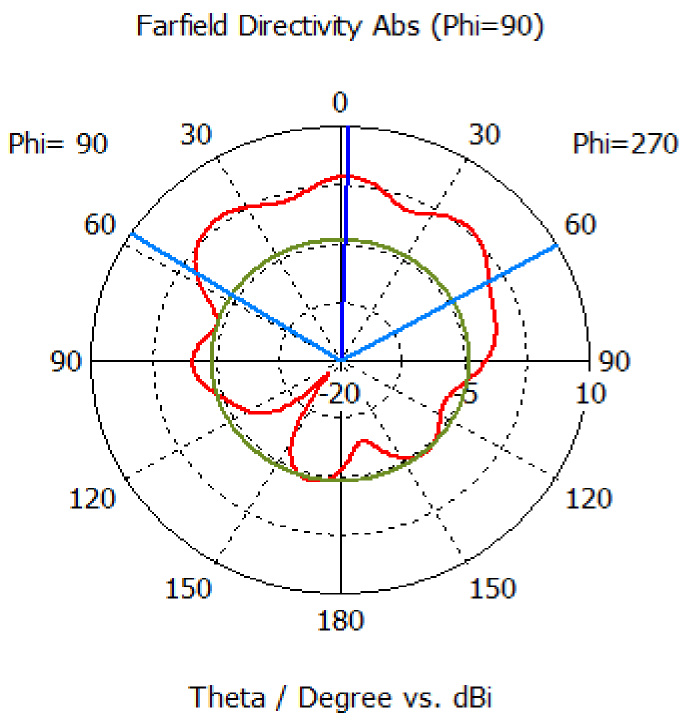


Figure 23: Radiation pattern of triangular Microstrip patch antenna

6.4.4 Radiation pattern of triangular Microstrip patch antenna at 3.5GHz:

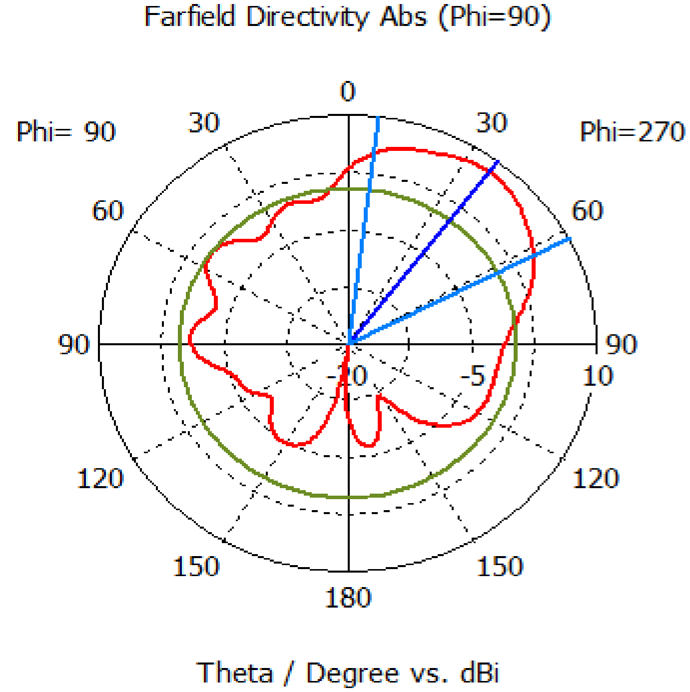


Figure 24: Radiation pattern of triangular Microstrip patch antenna

6.5 SAR exposure on human head due to exposure of EM wave by Rectangular and Triangular Microstrip patch antenna:

6.5.1 SAR on human head for Rectangular Microstrip patch antenna at 2.4GHz:

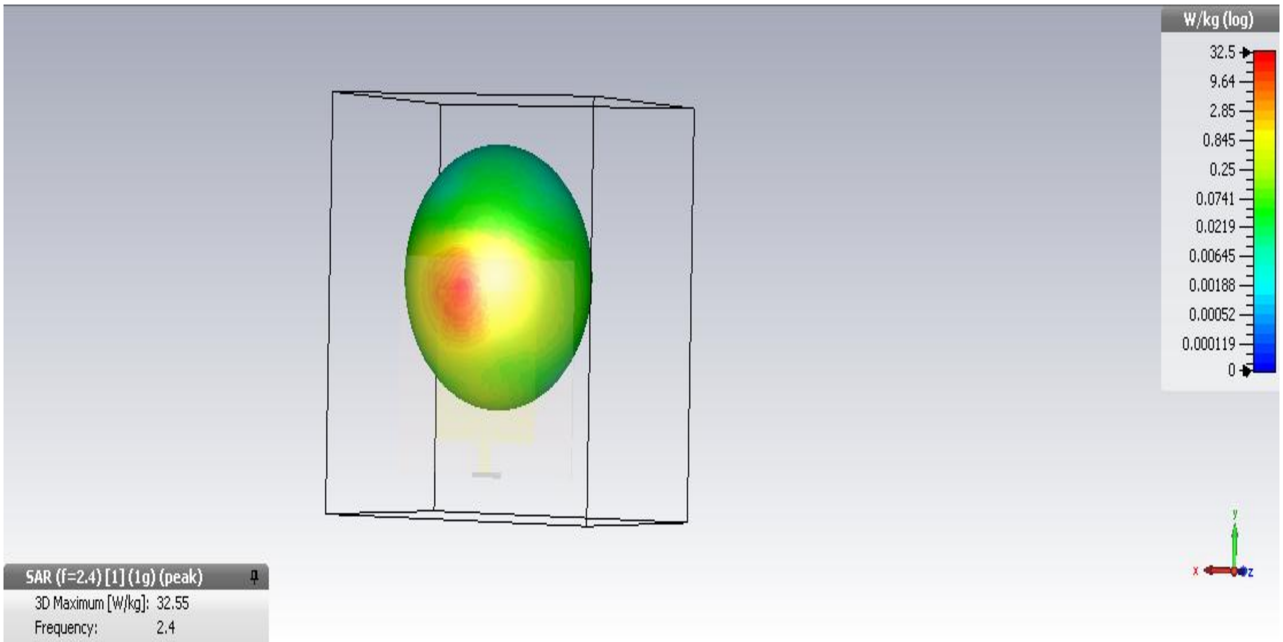


Figure 25: SAR=1.5W/kg at operating frequency=2.4GHz

6.5.2 SAR on human head for Rectangular Microstrip patch antenna at 3.5GHz:

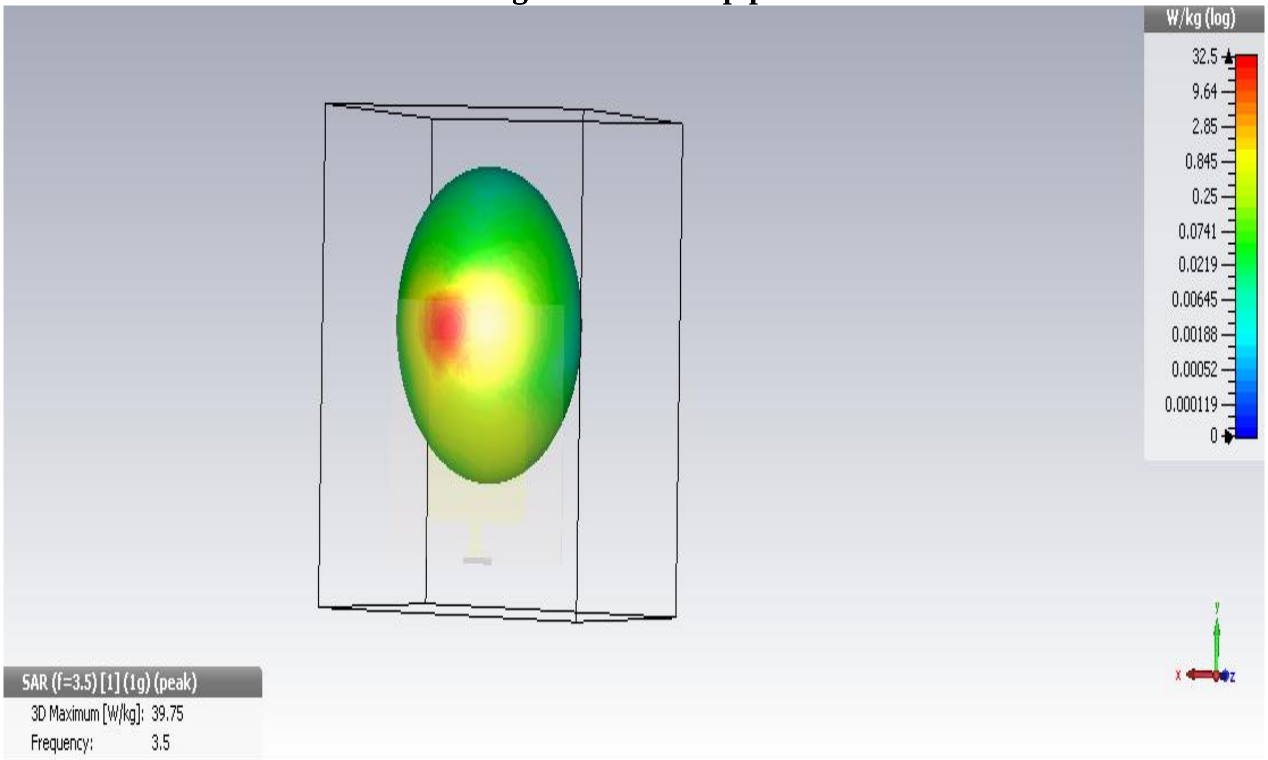


Figure 26: SAR =1.59W/kg at operating frequency= 3.5GHz

6.5.3 SAR on human head for Triangular Microstrip patch antenna at 2.4GHz:

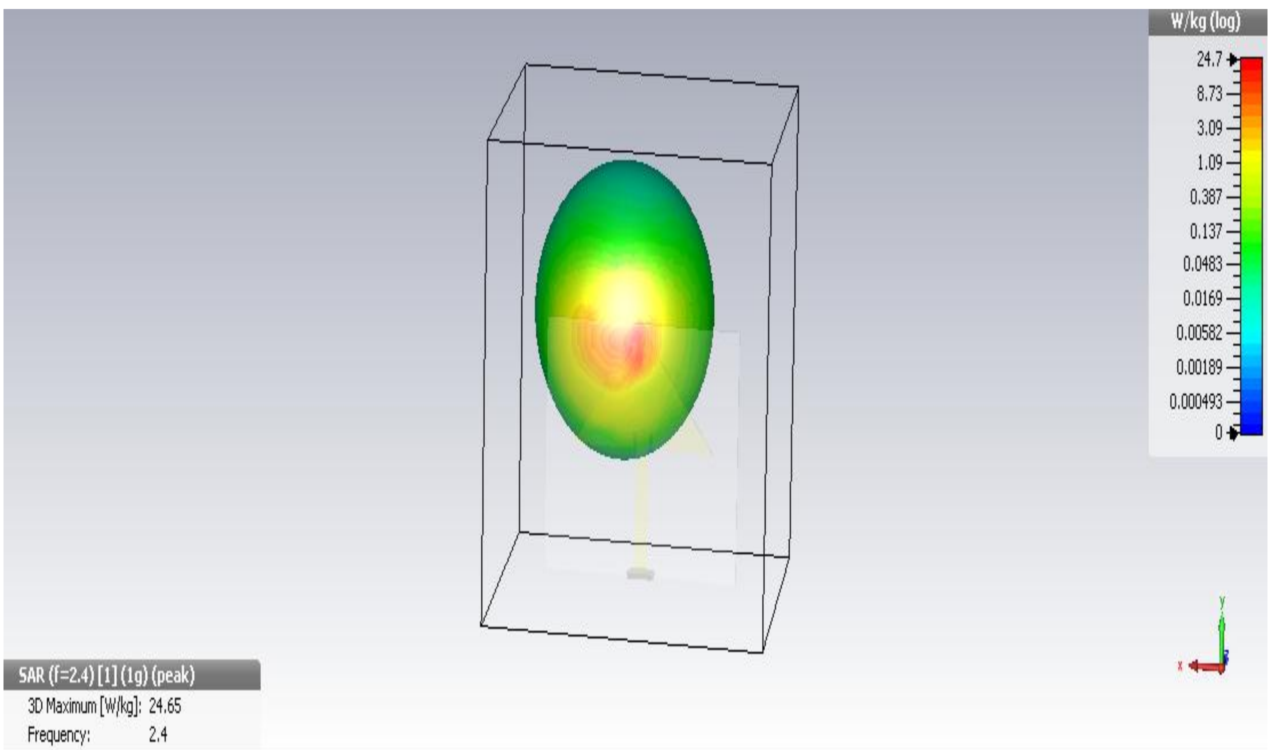


Figure 27: SAR=1.39 at operating frequency =2.4GHz

6.5.4 SAR on human head for triangular Microstrip patch antenna at 3.5GHz:

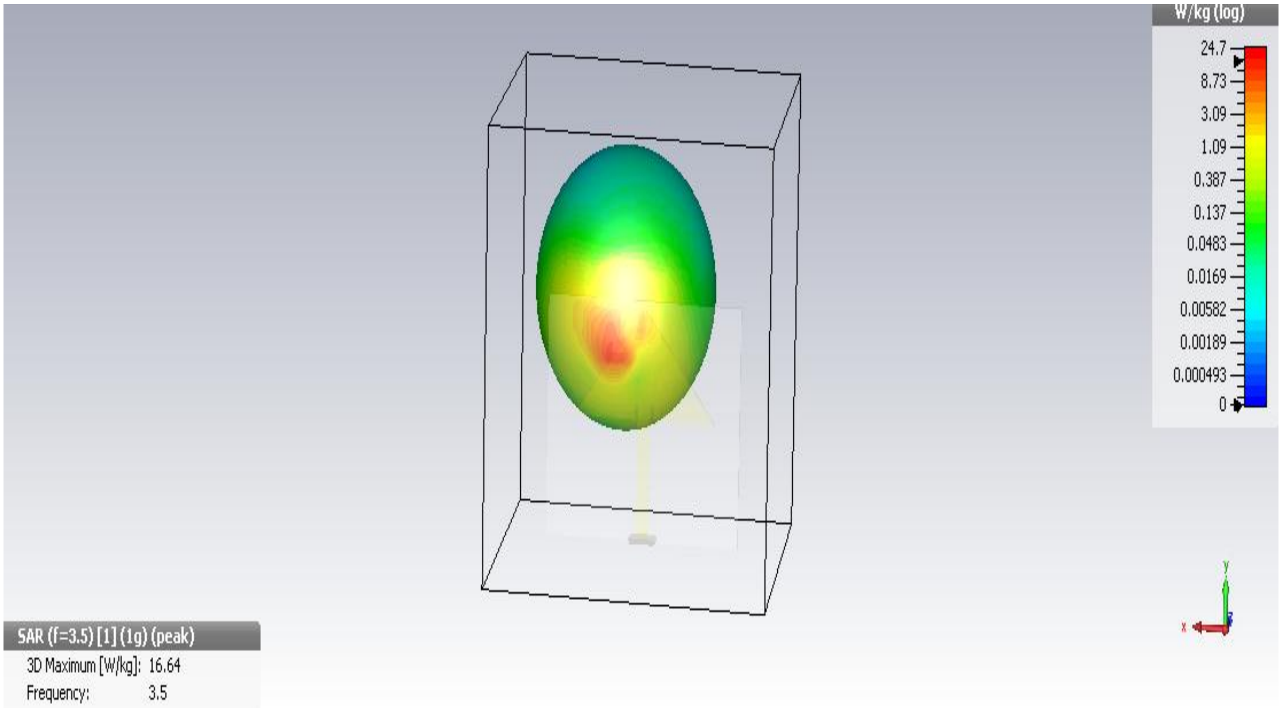


Figure 28: SAR=1.22W/Kg at operating frequency 3.5GHz

Table 6: Comparison of the simulation result the antennas according to the SAR exposure level and thermal distribution:

Antenna type	**Operating frequency(GHz)**	**SAR on head(W/Kg) for 1g tissue**	**Thermal distribution (^{0}F)**
Rectangular Microstrip patch antenna	2.4GHz	1.5	1.28
	3.5GHz	1.59	1.18
Triangular Microstrip patch antenna	2.4GHz	1.39	0.76
	3.5GHz	1.22	0.69

6.6 Calculation of the SAR exposure on human head due to EM wave exposure by antenna while certain distances are introduced between head model and antenna is shown in the diagrams.

6.6.1 When Rectangular Microstrip patch antenna is kept at 4mm distance way from human head:

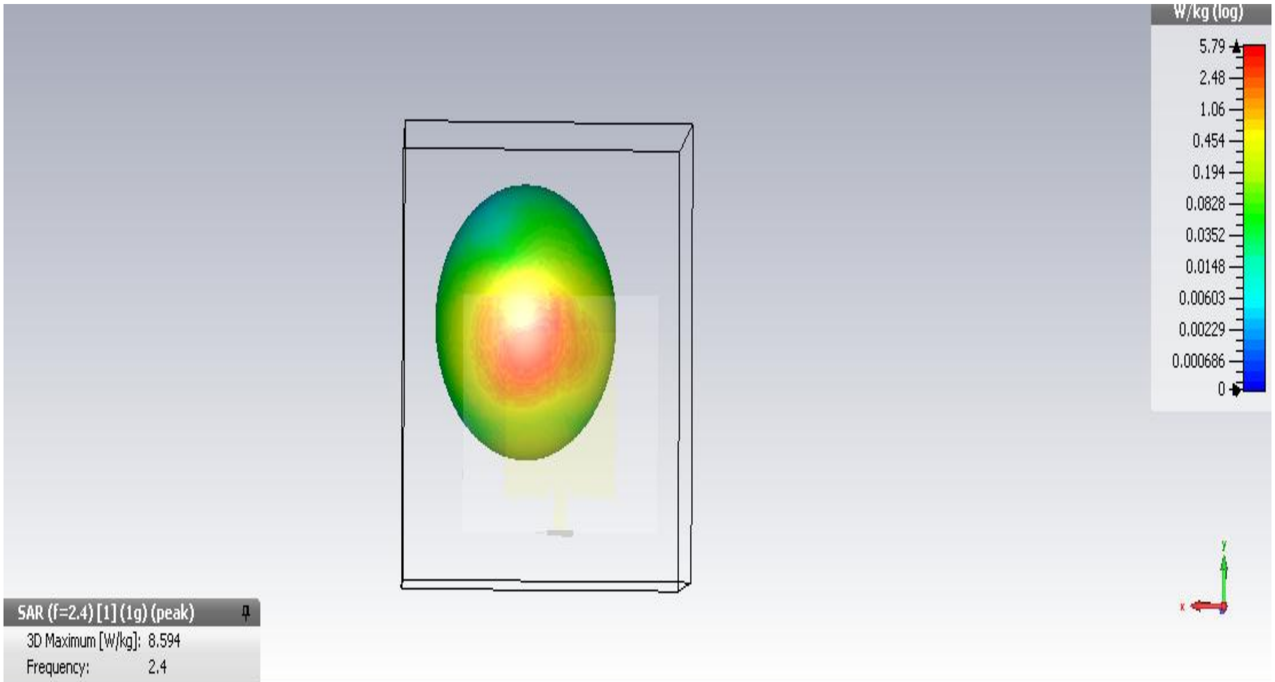


Figure 29: SAR=0.93 at distance=4mm and operating frequency=2.4GHz

6.6.1 SAR For 3.5GHz of frequency for Rectangular Microstrip patch antenna:

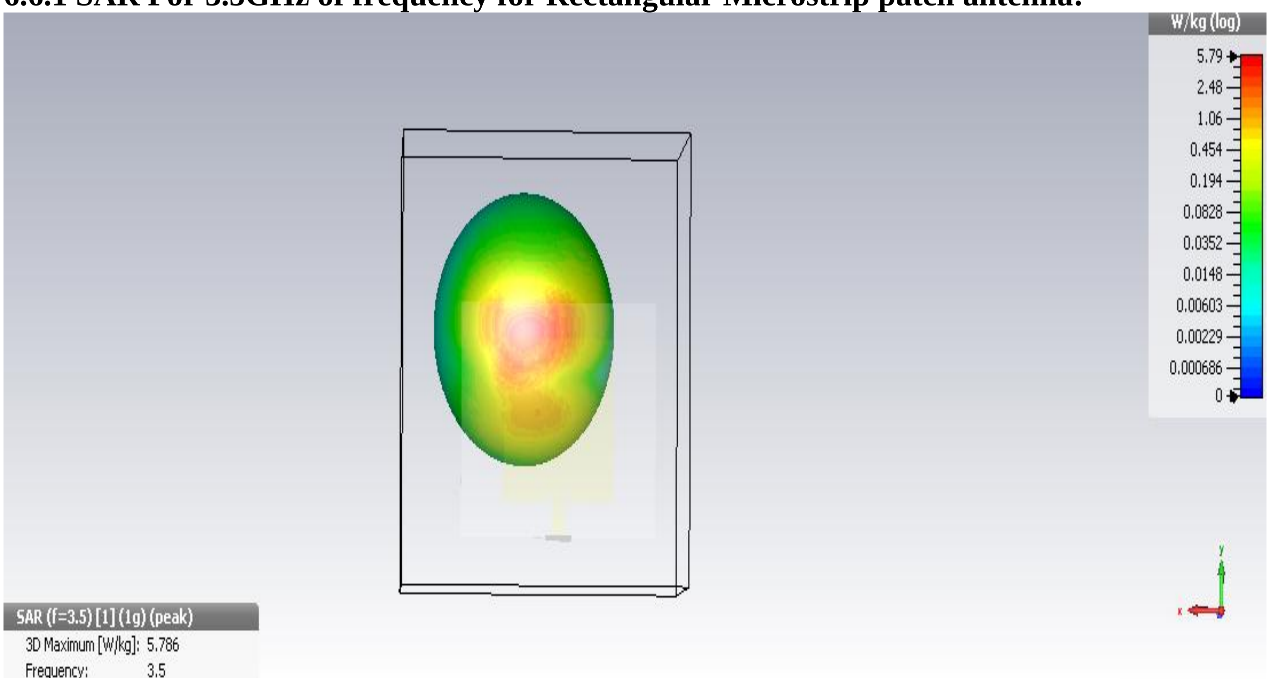


Figure 30: SAR=0.76, at distance=4mm and operating frequency=3.5GHz

6.6.3 When Triangular Microstrip patch antenna is kept at 4mm distance way from human head:

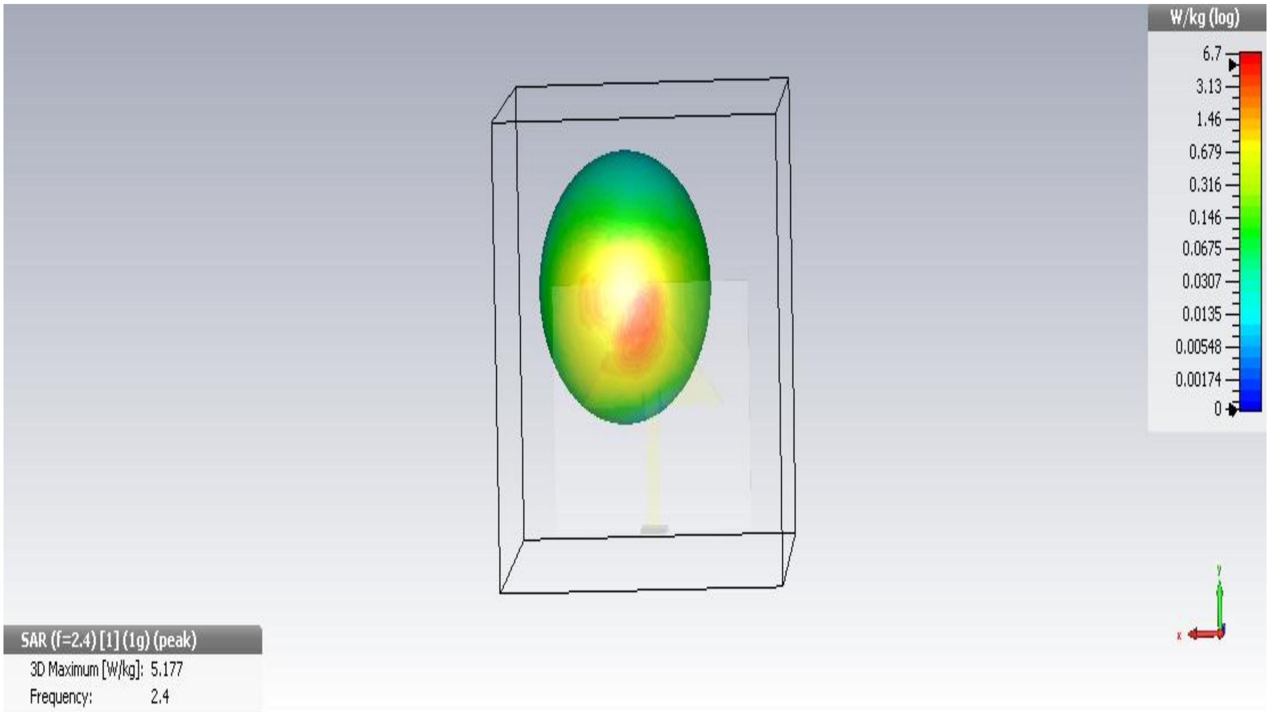


Figure 31: SAR=0.70 at distance=4mm and operating frequency=2.4GHz

6.6.4 SAR at certain distance for Triangular Microstrip patch antenna:

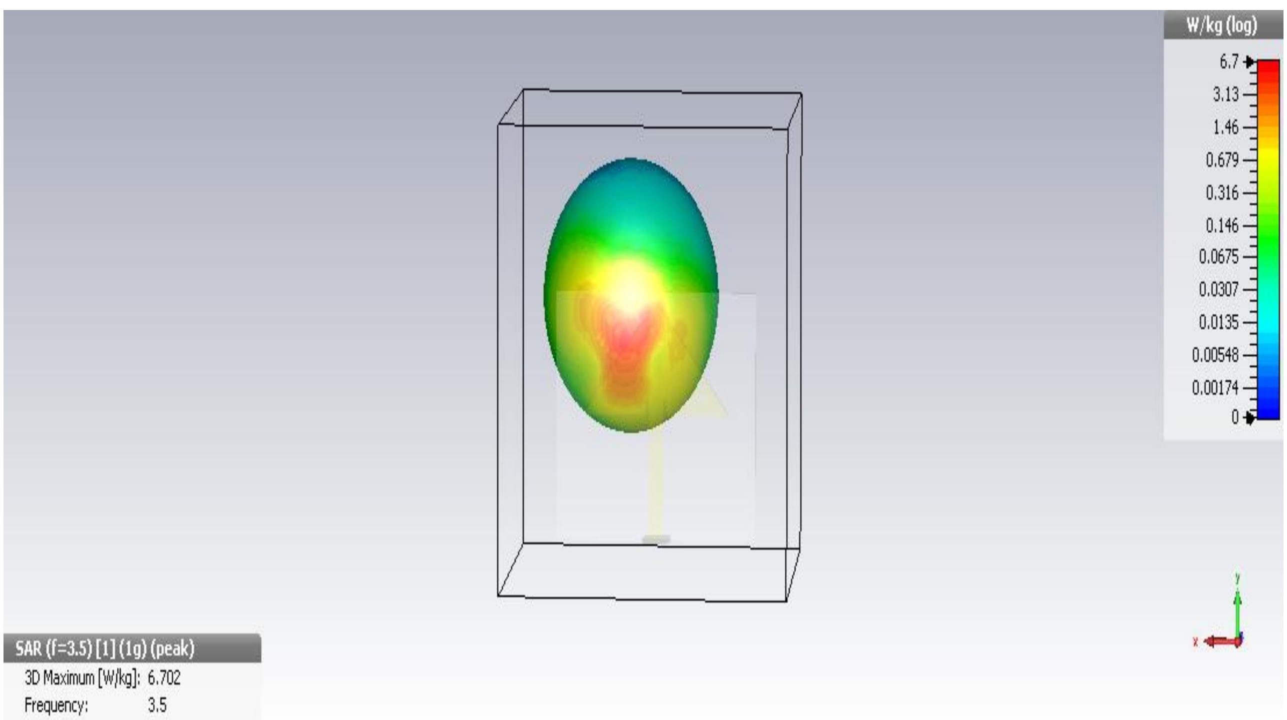


Figure 32: SAR=0.82 at distance=4mm and operating frequency=3.5GHz

Table 7: Comparison between SAR exposure level at different distances between human head and antenna:

Antenna type	Distance(mm)	Operating frequency(GHz)	SAR exposure for 1g tissue(W/Kg)
Rectangular Microstrip patch antenna	1mm	2.4GHz	1.18
		3.5GHz	1.16
	2mm	2.4GHz	1.07
		3.5GHz	0.99
	3mm	2.4GHz	1.01
		3.5GHz	0.90
	4mm	2.4GHz	0.93
		3.5GHz	0.75
Triangular Microstrip patch antenna	1mm	2.4GHz	1.30
		3.5GHz	1.22
	2mm	2.4GHz	0.86
		3.5GHz	0.96
	3mm	2.4GHz	0.78
		3.5GHz	0.91
	4mm	2.4GHz	0.71
		3.5GHz	0.82

CHAPTER 7

CONCLUSION: As per the development of technologies and high quality of communication services provided by the service provider, increased the mischief level regard EM radiation. With the increment of facilities, hazards also increased simultaneously. FM, GSM towers (in communication environment), cell phone microwave field are cause of most of the radiation that are causing severe problems in human head and human health too. In above review of different studies and researches along with experiments done by the researchers to make us come to know about the SAR level and thermal distribution on the human head. 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 use of mobile phones is mainly produced the heating effects especially to the human head. These heating effects contributed to the temporary effects such as fatigue, headache, fuzziness and nausea. In this paper two main operating frequencies have been considered to calculate the SAR exposure and Thermal distribution over head model of human.

From simulation it is clear that Rectangular Microstrip patch antenna is having more level of SAR exposure while Triangular Microstrip patch antenna is having lesser SAR exposure level compared to Rectangular. Thermal distribution is also more for Rectangular Microstrip patch antenna than triangular Microstrip patch antenna. It is noticeable that simulation results of SAR exposure on human head for 1g of tissue at both the operating frequencies are under safety levels which are proposed by safety organizations.

When distance between head model and antenna is introduced it can be clearly seen that SAR exposure level also decreased as per the increase in the distance. So it can be say that by maintaining certain distance with the mobile phone while talking on it, will protect from unwanted exposure.

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.

CHAPTER 8

FUTURE SCOPE:

1). Further scope of research can be perform using additional specific materials in mobile phone cover design that reduces back radiation by antenna used in mobile, on human body and head.

2). Designing of an antenna for mobile communication system that should be able to reduce EM radiation and SAR exposure level.

CHAPTER 9

PUBLISHED WORK

1). Biological Effects of Electromagnetic Waves: Case Studies and Safety Standards. It has been published on Indian Journal of Science and Technology. [27]

2). Biological Electromagnetic Effects Of Mobile Phone Radiation On Human Head By Measuring SAR Using CST. The paper has been accepted for Scopus indexed journal “International Journal of Control Theory & Applications” in conference ICSELM 2017.

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