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The Effect of Sector Antennas On Human Head Model In Term Of Electromagnetic Radiation And SAR Distribution

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دراسة نظرية تبين تأثير إشعاع هوائي المحمول على رأس الإنسان ومعدل الامتصاص النوعي

أطروحة مقدمة لنيل درجة الماجستير في الهندسة من الجامعة الإسلامية

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بسم الله الرحمن الرحيم

(وَقُلِ اعْمَلُوا فَسَيَرَى اللَّهُ عَمَلَكُمْ وَرَسُولُهُ وَالْمُؤْمِنُونَ)

صدق الله العظيم

إهداء

إلى روح والدتي الطاهرة

إلى ابنتي الغاليتين / ليلى ولانا

إلى من أحببت . . . .

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Abstract

The rapid diffusion of wireless communication systems such as cellular phones and wireless local area networks has caused an increased concern for the potential detrimental effect on human health deriving from exposure to EM fields emitted by the antennas of these systems.

In particular, with reference to cellular telecommunication systems, two different exposure condition are present. The first is the exposure of the user's head to the portable phone and the second is the general population exposure to the field radiated by the base station antennas, the researcher in this study will discuss the general population exposure to the field radiated by the base station antennas.

In this study, the exposure of an anatomical model of the human head represented by (skin-bone-brain) to the field radiated by a base station antenna operating around 900MHz has been studied by using the matlab program and FDTD technique.

Numerical method such as FDTD method has been used to study theoretically the biological effect of electromagnetic waves produced from mobile phone base station on human head life tissue.

Specific Absorption Rate(SAR) ,electric and magnetic field has been drawn with respect to time steps ; according to this study the SAR in skin and bone is higher than in other tissue.

المستخلص

لوحظ مؤخرا زيادة استخدام الهواتف اللاسلكية في العالم مما أدى إلى زيادة الاهتمام بالإشعاع الناتج من المحمول والصحة خصوصا موجات المحمول في مدى موجات الميكروويف ونظرا للاستخدامات الكثيرة للمحمول كان لابد من وجود محطات للهوائية في الشوارع والمدن لذا زادت الاهتمامات لمعرفة تأثير الإشعاع الناتج من هذه المحطات على صحة الإنسان.

لذا تم دراسة تأثير المجال الكهرومغناطيسي على رأس الإنسان من خلال استخدام برنامج Matlab ورسم الهوائية الخاصة بالمحمول. تم دراسة تأثير الموجات الكهرومغناطيسية على ثلاث طبقات وهي الجلد والعظم والدماغ حيث أن تأثير كل طبقة يختلف عن الأخرى من حيث القوة ومعدل الامتصاص.

وقد وجد أن التعرض للموجات الكهرومغناطيسية على المدى الزمني الطويل يؤثر على الخلايا الحية بفعل تحول الموجات الكهرومغناطيسية إلى حرارية حيث انه تم وضع دراسة مبسطه من الموجات الكهرومغناطيسية وخصائصها والموجات الناتجة عن محطات الاتصالات الخلوية في الفصل الأول

في الفصل الثاني تم وضع دراسة شامله عن التأثير البيولوجي الناتج عن الموجات الكهرومغناطيسية بصورة مبسطه وتأثيرها على الجسم والرأس تحديدا وتم توضيح أثرها على ثلاث طبقات من الرأس وهي الجلد والعظم وخلايا الدماغ وما هي الآثار المترتبة على ذلك.

أما الفصل الثالث تم فيه تناول أنواع الهوائيات وطريقة توزيع الموجات الكهرومغناطيسية المتعلقة بالزمن.

ومن خلال استخدام برنامج الماتلاب تم رسم علاقات بيانية تبين معدل الامتصاص النوعي SARخلال التعرض للموجات الكهرومغناطيسية الصادرة من محطات المحمول خلال فترات زمنية معينة تم رسم المجال الكهربي المغناطيسي والقدرة على الامتصاص .

من خلال دراسة المنحنيات تبين أن أكثر الطبقات امتصاصا للموجات الكهرومغناطيسية هي الجلد ويليها الدماغ.

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Abbreviation

UV: Ultra Violet Rays

RF: Radio Frequency

IEEE: The Institute Of Electrical And Electronics Engineers

ANSI: American National Standards Institute

MHz: Mega Hertz

ERP: Effective Radiation Power

W: Watt

FDTD: Finite Difference Time Domain

SAR: Specific Absorption Rate

MPa: Mega Pascal's

SCENIHR: Scientific Committee on Emerging and Newly Identified Health Risks

GSM: Global System for Mobile Communication

FCC: Federal Communications Commission .

GHz: Giga Hertz

BBB: Blood Brain Barrier

IARC: International Agency for Research On Cancer

ACRBR: The Australian Centre for Radio Frequency Bio effect Research

ICNIRP: International Commission for Non- Ionizing Radiation Protection.

HFSS: High Frequency Structure Simulator

CHAPTER ONE
Electromagnetic Waves and Antenna Properties

Introduction:

To talk about the radiations emitting from telecommunication stations, it is hard to ignore examining the role of electromagnetic waves.

In this chapter, the researcher focuses on the origin of the electromagnetic waves, radio frequencies, the frequencies used in wireless services, and the different kinds of electromagnetic waves. The chapter also focuses on the feature of ionizing and non-ionizing of these waves.

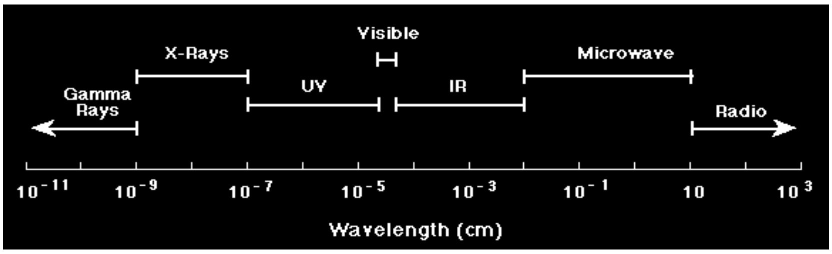
The researcher talk about the different kinds of antenna; including the frequencies of emission with a 120 or 360 degree. Also, focuses on the directed-undirected antenna along with studying the antenna used in the GSM system known as Sector Antenna, this chapter also focuses on the communication cells and the transmission towers.

1.1 Electromagnetic wave

Electromagnetic waves are formed when there is a continuing process of an electric field developing a magnetic field and vice versa. An electromagnetic wave has both, electric as well as magnetic components. The production of magnetism due to electric current is known as electromagnetism. The electromagnetic theory was developed by James Maxwell, whereas Heinrich Hertz demonstrated electromagnetic waves. The electrically charged particles, when in motion, created a magnetic field. This gave rise to electromagnetic waves is observed.

The discovery of electromagnetic waves proved to be revolutionary as these waves have various uses. These waves transmit energy in the form of X-rays, gamma rays, UV rays and infrared radiation[1].

1.2 Electromagnetic Frequency Spectrum



Figure(1.1)

When we talk on mobile phones, the transmitter takes the sound and encodes on to a continuous **"**sine wave**"**. The sine wave radiates out from the antenna and fluctuates evenly through space.

The encoded signals are made up of electromagnetic radiations. These waves are picked up by the receiver in the base station tower. The base station antenna emits radiations continuously to make a link with the subscribers[2].

1.2.1 The Radio Frequency (RF) Standards:

RF standards are expressed in" wave power density" which is measured in mW/cm^2. For antennas that operate around 900MHz, the Institute of Electrical and Electronics Engineers (IEEE) American National Standards Institute(ANSI) exposure standard for general public is $0.57mW/cm^2$ at 1800-2000 MHz with proper design.

A mobile phone base station antenna, mounted 10 meters above public accessible areas and operated at the maximum intensity might produce a power density as high as $0.01mW/cm^2$ in public –accessible areas near the antenna site.

Safety standard for uncontrolled (public) exposure could be exceeded if antennas were mounted in such away that the public could gain access to areas within 6 meter of the radiated surfaces of the antenna themselves, this could arise for units antennas mounted on or near the roof of the building[3].

Hand-held mobile telephones are relatively low power so the RF radiation exposures from them are generally low[4].

1.2.2 Electromagnetic Emitted From Mobile Phone

Non-ionizing radiation have many forms like FM radio waves, microwaves and visible light. They do not cause cancer by directly damaging DNA. RF waves are different from stronger types of radiation such as x-rays, gamma rays, and ultraviolet (UV) light, which can break the chemical bonds in DNA.

At very high levels, RF waves can heat up body tissues, however the levels of energy given off by cell phones are much lower, and the warmth from a cell phone does not damage body tissues[5].

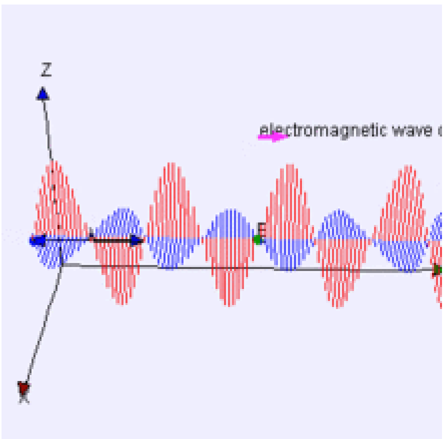
All cell phones emit some amount of electromagnetic radiation. Given the close proximity of the phone to the head, it is possible for the radiation to cause some sort of harm to human head. What is being debated in the scientific and political arenas is just how much radiation is considered unsafe, and if there are any potential long-term effects of cell-phone radiation exposure[5].

1.2.3 Types of Electromagnetic Radiation:

- **Ionizing radiation** - This type of radiation contains enough electromagnetic energy to strip atoms and molecules from the tissue and alter chemical. X- ray as example of ionizing radiation which use in medicine can cause damage to body tissue ,so we wear lead vest when x-ray are taken to ours body.
- **Non-ionizing radiation** - Non-ionizing radiation is typically safe. It causes some heating effect, but usually not enough to cause any type of long-term damage to tissue. Radio-frequency energy, visible light and microwave radiation are considered non-ionizing[6].

1.3 Electromagnetic Wave Properties

The electric field is in a vertical plane and the magnetic field is in a horizontal plane. Electromagnetic waves can be imagined as a self-propagating transverse oscillating wave of electric and magnetic fields. 3D diagram shows a plane polarized wave propagating from left to right as shown in Fig (1.2).



Figure(1.2)

The physics of electromagnetic radiation is electrodynamics. Electromagnetism is the physical phenomenon associated with the theory of electrodynamics. Electric and magnetic fields obey the properties of superposition. Thus, a field due to any particular particle or time-varying electric or magnetic field contributes to the fields present in the same space due to other causes. Furthermore, as they are vector fields, all magnetic and electric field vectors add together according to vector addition.

EM radiation exhibits both wave properties and particle properties at the same time. Both wave and particle characteristics have been confirmed in a large number of experiments[7].

Wave characteristics are more apparent when EM radiation is measured over relatively large timescales and over large distances while particle characteristics are more evident when measuring small timescales and distances. For example, when electromagnetic radiation is absorbed by matter, particle-like properties will be more obvious when the average number of photons in the cube of the relevant wavelength is much smaller than one.

There are experiments in which the wave and particle natures of electromagnetic waves appear in the same experiment, such as the self-interference of a single photon. When a single photon is sent through an interferometer, it passes through both paths, interfering with itself, as waves do, yet is detected by a photomultiplier or other sensitive detector only once[7].

1.4 Mobile phone network

1.4.1 Cellular system

Mobile communication networks are divided into geographic areas called cells, each served by a base station, mobile phones are the user's link to the network. The system is planned to ensure that mobile phones maintain the link with the network as users move from one cell to another. To communicate with each other, mobile phones and base stations exchange radio signals. The level of these signals is carefully optimized for the network to perform satisfactorily. They are also closely regulated to prevent interference with other radio systems used; for example, by emergency services, taxis as well as radio and television broadcasters[8].

1.4.2 Base Stations

Base stations are sometimes called control or fixed stations in US Federal Communications Commission licensing. These terms are defined in regulations inside Part 90 of the commissions regulations. Types of base stations include:

- A **fixed** station is a base station used in a system intended only to communicate with other base stations. A fixed station can also be radio link used to operate a distant base station by remote control. (No mobile or hand-held radios are involved in the system.)

- A **control** station is a base station used in a system with a repeater where the base station is used to communicate through the repeater.
- A **temporary base** is a base station used in one location for less than a year.
- A **repeater** is a type of base station that extends the range of hand-held and mobile radios.

Base stations are broadly divided into the following categories according to cell size:-

- Macro cells – towers, masts and poles providing wide are coverage
- Micro cells – small antennas at street level providing local area coverage
- Pico cells – very small antennas providing dedicated coverage spots

In building systems small antennas inside a building providing dedicated coverage[9].

1.4.3 How a cellular system works

Mobile phones

When a mobile phone is switched on, it responds to specific control signals from nearby base stations. When it has found the nearest base station in the network to which it subscribes, it initiates a connection. The phone will then remain dormant, just occasionally updating with the network, until the user wishes to make a call or a call is received.

Mobile phones use automatic power control as a means of reducing the transmitted power to the minimum possible whilst maintaining good call quality. For example, while using a phone the average power output can vary between the minimum level of about 0.001 watt up to the maximum level which is less than 1 watt. This feature is designed to prolong battery life and possible talk time[10].

1.5 Antenna

Antennae are wires that receive and conduct electromagnetic waves, typically to transmit information[11].

1.5.1Antenna properties:

The most important properties possessed by many antenna are polarization ,radiation pattern, power gain, radiation resistance, band width, effective aperture, power transfer and reciprocity.

Radiation pattern(or **antenna pattern** or **far-field pattern**)

Refers to the directional (angular) dependence of the strength of the radio waves from the antenna or other source[13].

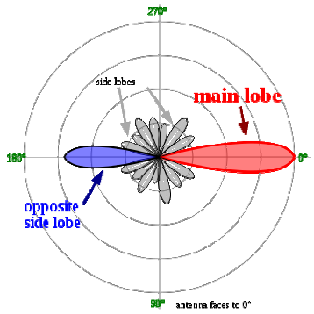


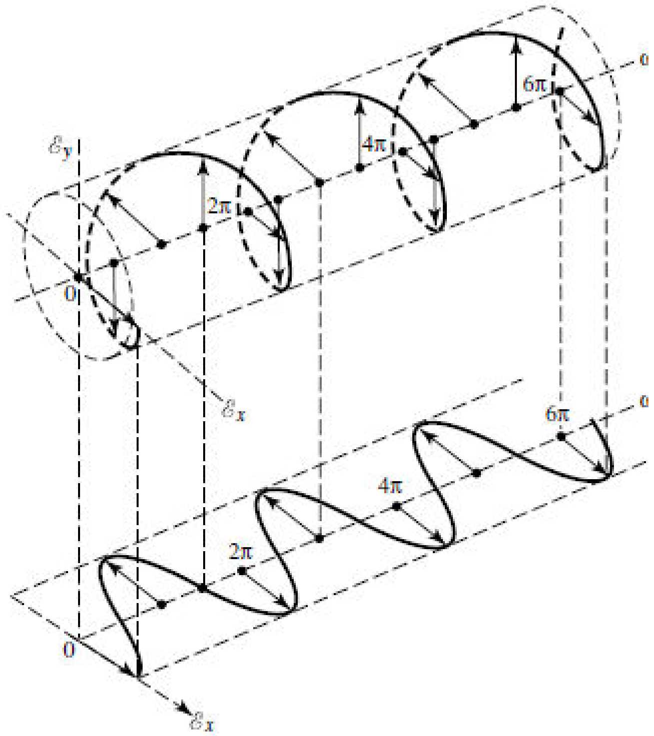
Figure (1.3)

In the case of transmitting antenna, the pattern is a graphical plot of the power or field strength radiated by the antenna in different angular antenna directions. The plot may be obtained for the vertical or horizontal planes and are called the vertical or horizontal polar pattern respectively.

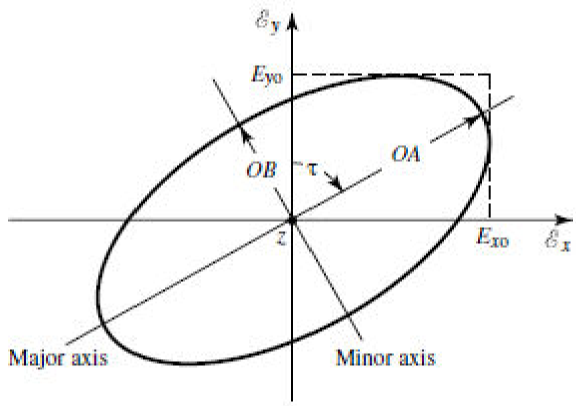
A wide variety of polar pattern are possible, such as the Omni directional pattern in which energy is equally in all directions, the pencil beam pattern in which the energy is concentrated mainly in one direction, the sector pattern, in which energy covers a given sector of space and the multiple-beam pattern in which energy is radiated in several adjacent beams [12].

Polarization

An electromagnetic wave lunched from an antenna may be vertically or horizontally polarized. In the former case, the E vector is vertical and require a vertical antenna to lunch it. Alternatively, if the E vector is horizontal, the wave is horizontally polarized and require a horizontal antenna to lunch it . Vertical or horizontal polarization is also called linear polarization. Sometimes circular polarization is used, which is a combination of vertical and horizontal polarization, Electromagnetic waves are usually vertically polarized [12].



(a) Rotation of wave



(b) Polarization ellipse

Figure(1.4)

Power gain

As a consequence of its polar pattern, power radiated by an antenna may be concentrated in a particular direction. This property is usually expressed in terms of a power gain G which is normally defined in the direction of maximum radiation per unit area as

G= power radiated by an antenna/ power radiated by reference antenna.

The power radiated by an antenna is slightly less than the input power because of losses in the antenna. An alternative definition which assumes the antenna is lossless, is defined as the directive gain D given by

D= maximum power radiated per unit solid angle/ average power radiated per unit solid angle

With G=KD where K<1 and so G is slightly less than D. In practice, the power gain G is commonly used and is expressed as a pure number or in dB by

$$\text{Power gain} = 10 \log_{10} G \text{ dB} \quad [12].$$

Radiation resistance

The radiation resistance is associated with the power radiated by the antenna .if I is the r.m.s (root mean square). antenna current and R_r (radiation resistance) , then the power radiated is I^2R_r watts where R_r (fictitious resistance), which accounts for the radiated power somewhat like a circuit resistance which dissipates heat . The radiation resistance should be large, as the greater R_r is the greater the power radiated by the antenna.

In contrast, for a receiving antenna, its terminal impedance is important. The terminal impedance is defined as the ratio of voltage to current at its terminals and generally it must be matched to the connecting line or cable. The terminal impedance of an antenna may or may not equal its radiation resistance, though in some cases, they are equal[12].

Effective aperture

The power received by an antenna can be associated with a collecting area . Every antenna may be considered to have such a collecting area which is called its effective aperture A_e. If P_d is the power density at the antenna and P_R is the received power available at the antenna terminals, then

$$P_R = P_d A_e \text{ watts}$$

$$A_e = P_R/P_d \text{ m}^2 \quad \text{OR}$$

An antenna with power gain G has an effective aperture A_e at the operating wavelength λ which is given by ;

$$A_e = G \lambda^2/4\pi \text{M}^2$$

The effective aperture A_e may be associated with a physical aperture as in the case of a microwave horn, though it is usually less than the physical aperture. However, even a linear antenna such as a dipole, can be associated with an effective aperture even though it has no physical aperture [12].

Band width

Wide bandwidth are required to meet growing traffic demands and in military applications, where there is a need for frequency agility. In addition, higher operating frequencies tend to be employed, as many antenna structures and waveguide components are more convenient to use at higher frequencies. However, the use of frequencies around 40GHz or more, produce other problems associated with component fabrication, higher attenuation and the generation of high power [12].

Return loss

is the loss of signal power resulting from the reflection caused at a discontinuity in a transmission line or optical fiber. This discontinuity can be a mismatch with the terminating load or with a device inserted in the line. It is usually expressed as a ratio in decibels (dB);

$$Rl(dB) = 10\log_{10\frac{p_i}{p_r}}$$

where *RL*(dB) is the return loss in dB, P_i is the incident power and P_r is the reflected power.

Return loss is related to both standing wave ratio (SWR) and reflection coefficient (Γ). Increasing return loss corresponds to lower SWR. Return loss is a measure of how well devices or lines are matched. A match is good if the return loss is high. A high return loss is desirable and results in a lower insertion loss.

Return loss is used in modern practice in preference to SWR because it has better resolution for small values of reflected wave[14].

Power transfer

For the maximum transfer of power from a receiving antenna to a receiver , the impedance of the antenna should be matched to the input impedance of the receiver, in accordance with the maximum power transfer theorem .As the antenna impedance is normally resistive, this means that the input impedance of the receiver should also be resistive. If Vis the induced r.m.s. voltage in an antenna connected to a receiver with an input resistance R_i, it is shown in appendix B, that the maximum power received is given by $P_R(max)= V^2/4R_i$ watts[12].

Specific Absorption Rate.

SAR stands for specific Absorption Rate, which is the unit of measurement for the amount of RF energy absorbed by the body when using a mobile phone . The SAR is determined at the highest certified power level in laboratory conditions. However, the actual SAR level of the phone while operating can be well below this value .

This is because the phone is designed to use the minimum power required to reach the network. Therefore, the closer you are to abase station, the more likely it is that the actual SAR level will be higher [15] [16].

Theoretical definition

The SAR is an indication that is absorbed into the human body (usually head) when using a handset. The SAR is calculated as the maximum energy absorbed into a unit of mass of exposed tissue. The SAR value is usually expressed in unit of watts per kilogram [w/kg] in either 1g or 10g.There fore SAR is measured using the following formula [17].

$$SAR=\sigma|E|^2/\rho[W/Kg]$$

Where:

σ: conductivity of the tissue[s/m],

E: electric field strength(r.m.s value)[v/m],

P**:** density of the tissue [Kg/m^3]

If the heat diffusion and the exposure time are negligibly small, the SAR is given by

$SAR=c\ \Delta T/\Delta t$

Where:

C: specific heat of the phantom [j/kg.˚c];

ΔT: temperature rise[˚c],

Δt: heating times[18].

Near and Far fields

Not all the energy in the electromagnetic field around the antenna is radiated. Part of the energy called the reactive energy is stored in the field and is recovered and reemitted during successive oscillation. The region where we find reactive energy is called the near field . in the near field, the electric and magnetic field component are not perpendicular to each other. True near field exists only close to the radiator ,and it extends for distance less than one wave length of the radiator.

In the far field, the electric and magnetic field are perpendicular to each other , thus making meaningful measurements of power density . The distance to the start of the far field region from the radiator depends on the size of the antenna and on the wave length of the radiation[19].

Between the end of the near field and the far field is the intermediate region (The Fresnel region) a transition between two regions.

1.6 Types of Antennas

There are many types of microwave antennas, monopole antenna, dipole antenna (the antenna used in mobile communications is dipole antenna), helical antenna, patched antenna. Electromagnetic radiation emerges in the direction in which the aperture is facing . The microwave feed is mounted at the focus of the parabolic reflector. The radiation is then reflected in a parallel beam. However , the beam does spread with the amount of spread being inversely , proportional to the size of the reflector . The measure of beam spread is called the beam width. The beam width is defined as the width of the beam at the half power points and is measured in degrees[20].

1.6.1 Directional Antennas

Directional antennas are designed for use on point-to-point links, or as client antenna in point-to-multipoint applications. Usually, they have the narrowest possible beam width and significantly higher gain than other antenna types.

Essential rule to be applied is the higher the gain, the lower the beam width. Directional antennas are usually constructed in form of grid or parabolic dish antennas[21].

The co-channel interference in a cellular mobile communication system can be reduced by replacing the omni-directional antenna at the base-station with several directional antennas. The use of a directional antenna limits the number co-channel interferers seen by any receiver within the cell. This is true because each directional antenna only radiates within a desired sector. This technique is called sectoring.

1.6.1.1 Sector antenna

A sector antenna is a type of directional microwave antenna with a sector-shaped radiation pattern. The scale of the reduction of co-channel interference depends on the number of sectors used. A cell is commonly partitioned into three 120-degree or six 60-degree sectors, as shown in Figure 1.3. In the case with users evenly distributed within all cells, the amount of co-channel interference is reduced to 1/3 or 1/6 of the omni-directional value if 120-degree or 60-degree sectoring is used respectively.

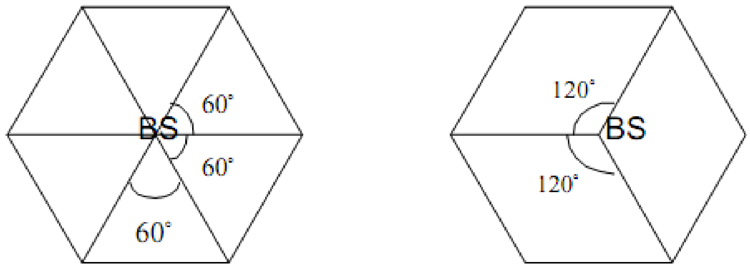
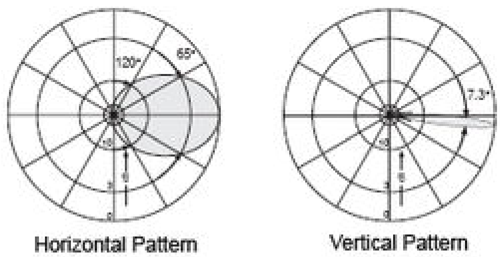


Figure (1.5) 60° and 120° Cell Sectoring

Design



Figure(1.6)

Horizontal and vertical radiation patterns. The antenna radiates a horizontal fan-shaped beam, sharp in the vertical axis so it doesn't spill over into neighboring sectors.

Vertical beam-width is not wider than 15°, meaning 7.5° in each direction. Unlike antennas for commercial broadcast stations AM, FM and Television for example, which must achieve line of sight over many miles or kilometers, there is usually a downward beam tilt or down tilt so that the base station can more effectively cover its immediate area and not cause RF interference to distant cells.

The coverage area which is equal to the square of the sector's projection to the ground can be adjusted by changing electrical or mechanical down tilts. Electrical tilt is set by using a special control unit which usually is built into the antenna case, though different remote control devices are widely produced. Mechanical down tilt is set manually by adjusting an antenna fastener [22].

Figure(1.7)

Figure(1.8) Sector antennas installed on a short mast

To increase or widen the coverage area, and thus the number of served clients, several sector antennas are installed on the same supporting structure. A too-aggressive down tilting strategy will however lead to an overall loss of coverage due to cells not overlapping.

Down tilting can be used to solve specific problems, for example local interference problems or cells that are too large. Electrical tilting slightly reduces beam width.

Note that a more vertical antenna is less visible than a mechanically tilted one , the use of purely electrical tilt with no mechanical tilt is therefore an attractive choice for aesthetic reasons which are very important for operators seeking acceptance of integrated antennas in visible locations[22].

1.7 Physics of Mobile Telephony

The antenna of a handset radiate equally in all direction , but a base station produces a beam that is much more directional . The stations have subsidiary beams called side lobes, into which a small fraction of the emitted power is channeled.

These side lobes are localized in the immediate vicinity of the mast,and despite their low power , density can be comparable with that of the main beam[23].

1.8 Principle of Cellular Radio Network

(wireless communication system)

Most of the people are familiar with the use of radio to permit wireless communication of signals between transmitting and receiving antennas.

The mobile phones communicate by radio signals passing to and from an antenna mounted on the phone antennas connected to the base station . The radio link from the phone to the base station is known as the uplink and carries the speech from the mobile phone user . A separate radio link from the base station to the phone is known as the down link and this carries the speech from the person to whom the phone user is listening.

Transmitted signal strength falls off rapidly with distance from base station and mobile phones, but a certain minimum signal strength is required for adequate reception. This means that a large number of base station is needed to provide coverage of the whole area.

The power radiated by base station has to be carefully controlled in any frequency reuse scheme to limit the distance traveled by signals . operators tend to divide the area around a base station into three sectors and then mount three different sets of antennas of the mast such that each set provides coverage of 120 $^{\circ}$[23].

1.9 General Effect of Radio Frequency Radiation (base station)

First of all, it must be stated that biological effects of the field parameters of cellular phone base stations depend to large extent on the location of emitting source and exposed objects, presence of reflecting article and grounding in the neighborhood [24].

As regards exposure to cell mast radiation, chronic exposure becomes an important factor which may cause serious effects. Intensity and exposure radiation do interact to produce an effect[25].

It found that with extremely low frequency magnetic field that "lower intensity, longer duration exposure can produce the same effect as from "a higher intensity, shorter duration exposure ". Thus, the interaction of exposure parameters , the duration of exposure , whether the effect is cumulative, involvement of compensatory response, and the time of breakdown of homeostasis after long term exposure , play important roles in determining the possible health consequence of exposure to radiation emitted by cell masts [25]

CAPTER TWO

Brief Review of Interaction of EM Waves with Biological Tissue.

2.1 Introduction:

Today the effect of mobile phone radiation on human health become the subject of recent interest and study, as a result of the enormous increase in mobile phone usage in the world. Mobile phone use electromagnetic radiation in the microwave range .

Many scientific studies have investigated possible health symptoms of mobile phone radiation. These studies are occasionally reviewed by some scientific committees to assess overall risks. A recent assessment was published in 2007 by the European Commission Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR)[26].

It concludes that the three lines of evidence, *viz.* animal, in vitro, and epidemiological studies, indicate that exposure to RF fields is unlikely to lead to an increase in cancer in humans.

This chapter represents an important turn in the project. It focuses on the biological effect resulting from the wireless services; particularly the GSM 900MHz.

It examine the human body structure, absorption rate the active cell, and the natural-safe absorption rate for humans based on the principles and measurements of the World Health Organization.

The available literature and previous studies conducted on the topic show the effect resulting from the use of cell phones on human's head depending on the biological structure of brain's cells. These studies also examine the thermal effect on the brain's cell in which changes on the structure of the DNA have been documented.

Another study shows the effect of frequencies resulting from the transmission stations on sleeping habits and the accompanied consequences. Other studies show plain evidence of the effects of the wireless services in causing cancer.

2.2 human body structure

a- Cell : The cell is the structural and the functional unit with which the human body is built.

b- Tissue : Tissues are materials made up of groups of similar cells. Cells are of various types, and tissues vary according to the types of cells in their structure. There are four main types of tissue in the human body:

c- Organs and Systems

Tissues are jointed into larger units called organs, such as the heart, lungs, brain, liver. Each organ is made up of types of tissue, which enable it to do its special work.

A system is a group of organs, which together carry out one of the essential functions of the body. There are nine systems. All of these systems work harmoniously together in a healthy body[27].

2.2.1 Skin tissue

skin is an organ of the integumentary system made up of a layer of tissues that guard underlying muscles and organs. As the interface with the surroundings, it plays the most important role in protecting against pathogens. Its other main functions are insulation and temperature regulation.

Skin is composed of the epidermis and the dermis. Below these layers lies the hypodermis (subcutaneous adipose layer), which is not usually classified as a layer of skin [28].

2.2.2 Bones

Are rigid organs that constitute part of the endoskeleton of vertebrates. They support, and protect the various organs of the body, produce red and white blood cells and store minerals. Bone tissue is a type of dense connective tissue. Bones come in a variety of shapes and have a complex internal and external structure, are lightweight yet strong and hard, and serve multiple functions. One of the types of tissue that makes up bone is the mineralized osseous tissue, also called bone tissue, that gives it rigidity and a honeycomb-like three-dimensional internal structure. Other types of tissue found in bones include marrow, endosteum and periosteum, nerves, blood vessels and cartilage. At birth, there are over 270 bones in an infant human's body, but many of these fuse together as the child grows, leaving a total of 206 separate bones in an adult. The largest bone in the human body is the femur and the smallest bones are auditory ossicles.

The primary tissue of bone, osseous tissue, is a relatively hard and lightweight composite material, formed mostly of calcium phosphate in the chemical arrangement termed calcium hydroxyl apatite (thesis the osseous tissue that gives bones their rigidity). It has relatively high compressive strength, of about 170 MPa (1800 kgf/cm^2) but poor tensile strength of 104–121 MPa and very low shear stress strength (51.6

MPa), meaning it resists pushing forces well, but not pulling or torsional forces. While bone is essentially brittle, it does have a significant degree of elasticity, contributed chiefly by collagen. All bones consist of living and dead cells embedded in the mineralized organic matrix that makes up the osseous tissue.

2.2.2.1 Bone structure

Compact (cortical) bone

The hard outer layer of bones is composed of compact bone tissue, so-called due to its minimal gaps and spaces. Its porosity is 5–30%. This tissue gives bones their smooth, white, and solid appearance, and accounts for 80% of the total bone mass of an adult skeleton. Compact bone may also be referred to as dense bone.

Trabecular (cancellous) bone

Filling the interior of the bone is the trabecular bone tissue (an open cell porous network also called cancellous or spongy bone), which is composed of a network of rod- and plate-like elements that make the overall organ lighter and allow room for blood vessels and marrow. Trabecular bone accounts for the remaining 20% of total bone mass but has nearly ten times the surface area of compact bone. Its porosity is 30–90%. If, for any reason, there is an alteration in the strain the cancellous is subjected to, there is a rearrangement of the trabeculae. The microscopic difference between compact and cancellous bone is that compact bone consists of haversian sites and osteons, while cancellous bones do not. Also, bone surrounds blood in the compact bone, while blood surrounds bone in the cancellous bone[29].

2.2.2.2 Skull

The human skull, scientifically known as the cranium, consists of 22 bones. The skull can be broken into two regions, the cranial section and the facial section. The cranial bones consist of the bones in the top of the skull while the facial bones consist of the bones that make up your face. The skulls primary functions are protection of the brain and support of the face. In the skull, sinal cavities can be found. Although the function of these cavities is still not definitively known, it may be that the sinuses function are to decreasing the weight of the skull while maintaining strength[30].

2.2.3 Brain

The brain is the center of the nervous system in all vertebrate and most invertebrate animals—only a few primitive invertebrates such as sponges, jellyfish, adult sea squirts and starfishes do not have one. It is located in the head, usually close to the primary sensory organs for such senses as vision, hearing, balance, taste, and smell. The brain of a vertebrate is the most complex organ in its body. In a typical human the cerebral cortex (the largest part) is estimated to contain 15–33 billion neurons[31] each connected by synapses to several thousand other neurons. These neurons communicate with one another by means of long protoplasmic fibers called axons, which carry trains of signal pulses called action potentials to distant parts of the brain or body targeting specific recipient cells.

From an evolutionary-biological point of view, the function of the brain is to exert centralized control over the other organs of the body. The brain acts on the rest of the body either by generating patterns of muscle activity or by driving secretion of chemicals called hormones. This centralized control allows rapid and coordinated responses to changes in the environment. Some basic types of responsiveness such as reflexes can be mediated by the spinal cord or peripheral ganglia, but sophisticated purposeful control of behavior based on complex sensory input requires the information-integrating capabilities of a centralized brain.

From a philosophical point of view, what makes the brain special in comparison to other organs is that it forms the physical structure that generates the mind. As Hippocrates put it: "Men ought to know that from nothing else but the brain come joys, delights, laughter and sports, and sorrows, griefs, despondency, and lamentations" [32].

In the early part of psychology, the mind was thought to be separate from the brain. However, after early scientists conducted experiments it was determined that the mind was a component of a functioning brain that expressed certain behaviours based on the external environment and the development of the organism[33].

The mechanisms by which brain activity gives rise to consciousness and thought have been very challenging to understand: despite rapid scientific progress, much about how the brain works remains a mystery. The operations of individual brain cells are now understood in considerable detail, but the way they cooperate in ensembles of millions has been very difficult to decipher. The most promising approaches treat the brain as a biological computer, very different in mechanism from electronic computers, but similar in the sense that it acquires information from the surrounding world, stores it, and processes it in a variety of ways.

2.3 Radiation absorption:

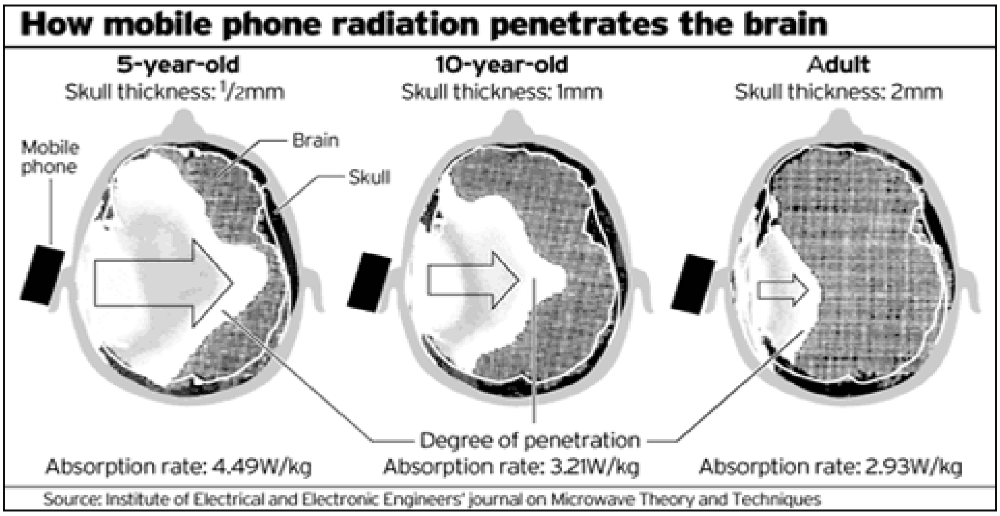
Part of the radio waves emitted by a mobile telephone handset are absorbed by the human head. Digital mobile technologies, such as CDMA2000 and D-AMPS, use lower output power, typically below 1 watt. The maximum power output from a mobile phone is regulated by the mobile phone standard and by the regulatory agencies in each country. In most systems the cell phone and the base station check reception quality and signal strength and the power level is increased or decreased automatically, within a certain span, to accommodate different situations, such as inside or outside of buildings and vehicles. The rate at which radiation is absorbed by the human body is measured by the Specific Absorption Rate (SAR), and its maximum levels for modern handsets have been set by governmental regulating agencies in many countries. SAR values are heavily dependent on the size of the averaging volume. Without information about the averaging volume used, comparisons between different measurements cannot be made[34].

It is worth noting that thermal radiation is not comparable to ionizing radiation in that it only increases the temperature in normal matter, it does not break molecular bonds or release electrons from their atoms.

2.4 Rate of absorption of the human head to radiation

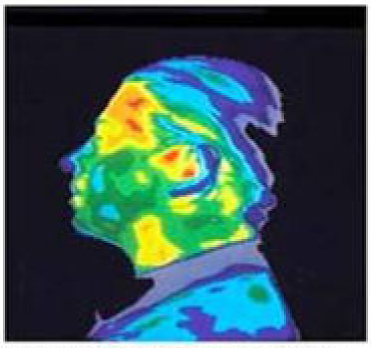
The mobile phone system is referred to as "cellular telephone system" because the coverage area is divided into "cells "each of which has a base station antenna.

Mobile phone technology uses electromagnetic radiation in the Giga hertz range. These radiations are close to microwave range and with similar properties. Part of the radio wave emitted from the mobile phone is absorbed by the human head. The radiation emitted by a GSM handset can have a peak power of 2 watts[35].



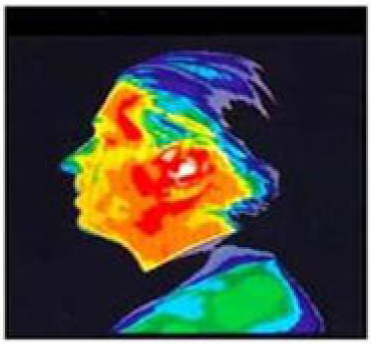
Figure(2.1)

If the SAR level is above the limit, it may cause both thermal and non thermal effects on the body especially on the ear and head since these are at the "Near Field" of the radiation. Thermal effect of microwave is the dielectric heating in which any dielectric material such as living tissue is heated by rotations of polar molecules such as water [36].



Thermographic Image of the head with no exposure to harmful cell phone radiation.

Figure (2.2)



Thermographic Image of the head after a 15-minute phone call. Yellow and red areas indicate thermal (heating) effects that can cause nogative health effects.

Figure (2.3)

In the case of a person using mobile handset for hours in a day, most of the heating effects will occur in the ear pinna, internal ear, head surface and even in the brain. Internal ear has fluid filled structures which are more susceptible to heating effect. Brain tissue is delicate and there is blood-brain barrier system to eliminate excess heat generated [36].

Some of the brain waves that determine mood and alertness resemble the mobile radiation in frequency. So that normal brain functions will be affected even in a few persons using mobile phones continuously. Another structure that can be affected by heating is the cornea of the eye. It is the transparent covering on the front part of the eye. Cornea lacks blood supply, so that the heat generated can not be removed and may cause premature cataract. Non thermal effects include alterations in bio-cycles, cellular metabolism, spermatogenesis, abnormalities in foetal developments, miscarriage etc.

Some users of mobile phones feel several unspecific symptoms during and after the use of mobile phones in the form of burning and tingling sensations, fatigue, sleep disturbances, dizziness, loss of mental concentration etc. All these may be due to the influence of the radiation on the bio magnetic field of the body [37].

2.5 Biological effects of Mobile phone radiation

2.5.1 Thermal Effect

Microwave causes dielectric heating in the human body. Human tissue is rich in water and exhibit dielectric property (+ and – ve ions).

Living tissue heat up through the rotation of polar molecules such as water. This friction causes heating of tissue .Head is in the “near field “ of radiation, so that most of the heating effect occurs in the head. Temperature in the internal ear, brain etc increases to 1 degree or more. This adversely affects the functioning of these organs since these have fluid filled cavities. In short Thermal effect causes

- Burning sensation in the Scalp and Ear pinna
- Mood alteration and lack of concentration
- Lethargy and lack of sleep
- Whistling sound in the ear
- Premature Cataract- the cornea of the eye does not have this temperature regulation mechanism and exposure of 2–3 hours duration has been reported to produce cataracts in rabbits' eyes at SAR values from 100-140W/kg, which produced lenticular temperatures of 41°C. There were no cataracts detected in the eyes of monkeys exposed under similar conditions [38].
- Confusion and loss of memory since the microwaves interfere with the mood controlling brainwaves
- Alters sleep physiology and biological rhythm by changing the level of Dopamine, Serotonin hormones

2.5.2 Non Thermal Effects Non-thermal

In most countries the mobile radiation safety standards are based on the assumption that the only biological effect of microwave (mobile phone) radiation is heating (the so called "thermal effect"). However ample evidence demonstrate that non-thermal effects do exist and may occur at a significantly lower radiation level than what causes heating. This means that present safety standards need to be changed so that they allow considerably lower levels of radiation intensities [39].

Increased cellular responses, Cellular changes demonstrated at non-thermal levels. A Finnish team has found that certain proteins in human cells change due to the radiation at non-thermal intensity levels. This confirms earlier findings of cellular changes in animals. [40][41] Leakage of Albumin from blood into the brain due to increased permeability of BBB

2.5.3 Biological changes

1-Protein Changes in Skin. Ten women volunteered to participate in a study in which radiation (900mH) from GSM cell phones was applied to them for one hour to simulate a phone call. Scientists then screened their skin cells for any stress reactions. They looked at 580 different proteins and found two which were substantially affected.One was increased by 89% and the other was decreased by 32%[42].

2-Excited Brain Cells. Researchers from Fatebenefratelli Hospital in Isola Tiberina, found that the electromagnetic field emitted by cell phones can cause some cells in the brain's cortex (adjacent to the side of phone use) to become excited for about an hour, while others become inhibited[43].
3-DNA Damage. German research group Verum studied the effect of radiation on human and animal cells. After being exposed to cell phone frequencies the cells showed increased breaks in their DNA. These DNA breaks could not always be repaired by the cells. The damage would therefore be passed on to future cells which could predispose them to becoming cancerous[44].

4-Brain Cell Damage. A study of the effects of cell phone frequencies (applied at non-thermal intensity) on rat brains showed damage to the neurons (brain cells) in various brain parts, including the cortex, hippocampus and basal ganglia[45].

Aggressive Growth in Leukemia Cells Researchers at the National Research Council in Bologna, Italy found that Leukemia cells exposed to cell phone frequencies (900MHz) for 48 hours replicated more aggressively[46].

5-Increased Blood Pressure. Researchers in Germany found that one-time use of a cell phone for 35 minutes could cause an increase in resting blood pressure of between 5 and 10mm Hg[47].

6-Role of Blood-Brain Barrier – BBB

The blood vessels in the brain and the surrounding tissue form the BBB that can easily dispose heat. But prolonged heating effect can alter brain functions and hearing ability[37].

Swedish researchers from Lund University (Salford, Brun, Persson, Eberhardt, and Malmgren) have studied the effects of microwave radiation on the rat brain. They found a leakage of albumin into the brain via a permeated blood-brain barrier[48][49].

7-Hearing impairments

• Heating effect in the fluid of internal ear

• Piercing sound from the speaker causes irritability in the ear drum and internal sensory cells of ear Human ear is highly sensitive to waves between 1000 and 6000 Hz[49].

8-Sleep and EEG Effects

Sleep, EEG and waking rCBF have been studied in relation to RF exposure for a decade now, and the majority of papers published to date have found some form of effect. While a Finnish study failed to find any effect on sleep or other cognitive function from pulsed RF exposure,[50]. most other papers have found significant effects on sleep[51]. Two of these papers found the effect was only present when the exposure was pulsed (amplitude modulated), and one early paper actually found that sleep quality (measured by the amount of participants' broken sleep) actually improved.

While some papers were inconclusive or inconsistent,[52][53] a number of studies have now demonstrated reversible EEG and rCBF alterations from exposure to pulsed RF exposure[54]. German research from 2006 found that statistically significant EEG changes could be consistently found, but only in a relatively low proportion of study participants (12 - 30%)[55].

Microwave Auditory Effect

• Clicks and Buzzing sound in the head

• Microwave induces electric current in the hearing centre of the brain and causes Auditory illusion

• This may happen if music is heard using ear phone or Bluetooth for long time

• The human ear has a peak sensitivity of 3000 Hz, which causes a sense of unease. Alarms and Mobile ring tones are designed to sound at 3000 Hz.

• The ear has a very low threshold of hearing for 3000 Hz. A sound of this frequency is very penetrating[56].

Phantom Pain

Pain in the ear without any specific reasons like infection.This may be due to increased stress on the delicate structures of the internal ear or ear drum by the radiation[57].

Electromagnetic Hypersensitivity

Unspecific symptoms during and after the use of cell phone Tingling sensation, fatigue, dizziness, loss of mental attention, reduction in reaction time, memory retentiveness, tachycardia etc[58].

All of these symptoms can also be attributed to stress and that current research cannot separate the symptoms from nocebo effects[59].

2.6 Cancer:

In 2006 a large Danish study about the connection between mobile phone use and cancer incidence was published. It followed over 420,000 Danish citizens for 20 years and showed no increased risk of cancer[60]. The German Federal Office for Radiation Protection (Bundesamt fur Strahlenschutz) considers this report inconclusive[61].

The following studies of long time exposure have been published:

The 13 nation INTERPHONE project – the largest study of its kind ever undertaken – has now been published and did not find a solid link between mobile phones and brain tumours[62].

The International Journal of Epidemiology published[63] a combined data analysis from a multi national population-based case-control study of glioma and meningioma, the most common types of brain tumour.

The authors reported the following conclusion:

Overall, no increase in risk of glioma or meningioma was observed with use of mobile phones. There were suggestions of an increased risk of glioma at the highest exposure levels, but biases and error prevent a causal interpretation. The possible effects of long-term heavy use of mobile phones require further investigation.

In the press release[64] accompanying the release of the paper, Dr Christopher Wild, Director of the International Agency for Research on Cancer (IARC) said:

An increased risk of brain cancer is not established from the data from Interphone. However, observations at the highest level of cumulative call time and the changing patterns of mobile phone use since the period studied by Interphone, particularly in young people, mean that further investigation of mobile phone use and brain cancer risk is merited.

A number of independent health and government authorities have commented on this important study including The Australian Centre for Radiofrequency Bio effects Research (ACRBR) which said in a statement that[65].

Until now there have been concerns that mobile phones were causing increases in brain tumours. Interphone is both large and rigorous enough to address this claim, and it has not provided any convincing scientific evidence of an association between mobile phone use and the development of glioma or meningioma. While the study demonstrates some weak evidence of an association with the highest tenth of cumulative call time (but only in those who started mobile phone use most recently), the authors conclude that biases and errors limit the strength of any conclusions in this group. It now seems clear that if there was an effect of mobile phone use on brain tumour risks in adults, this is likely to be too small to be detectable by even a large multinational study of the size of Interphone

This concludes that currently available data do not warrant any general ecommendation to limit use of mobile phones in the adult population,

Chief Executive Officer, Professor Ian Olver, said findings from the Interphone study, conducted across 13 countries including Australia, were consistent with other research that had failed to find a link between mobile phones and cancer.

This supports previous research showing mobile phones don't damage cell DNA, meaning they can't cause the type of genetic mutations that develop into cancer," Professor Olver said.

However, it has been suggested that electromagnetic fields associated with mobile phones may play a role in speeding up the development of an existing cancer. The Interphone study found no evidence to support this theory.

- A Danish study (2004) that took place over 10 years found no evidence to support a link. However, this study has been criticized for collecting data from subscriptions and not necessarily from actual users. It is known that some subscribers do not use the phones themselves but provide them for family members to use. That this happens is supported by the observation that only 61% of a small sample of the subscribers reported use of mobile phones when responding to a questionnaire[66][67].

- A Swedish study (2005) that draws the conclusion that "the data do not support the hypothesis that mobile phone use is related to an increased risk of glioma or meningioma."[68].
- A German study (2006) that states "In conclusion, no overall increased risk of glioma or meningioma was observed among these cellular phone users; however, for long-term cellular phone users, results need to be confirmed before firm conclusions can be drawn."[69].

Other studies on cancer and mobile phones are:

- A Swedish scientific team at the Karolinska Institute conducted an epidemiological study (2004) that suggested that regular use of a mobile phone over a decade or more was associated with an increased risk of acoustic neuroma, a type of benign brain tumor. The increase was not noted in those who had used phones for fewer than 10 years[70].

- The INTERPHONE study group from Japan published the results of a study of brain tumour risk and mobile phone use. They used a new approach: determining the SAR inside a tumour by calculating the radio frequency field absorption in the exact tumour location. Cases examined included glioma, meningioma, and pituitary adenoma. They reported that the overall odds ratio (OR) was not increased and that there was no significant trend towards an increasing OR in relation to exposure, as measured by SAR[70].

In 2007, Dr. Lennart Hardell, from Örebro University in Sweden, reviewed published epidemiological papers (2 cohort studies and 16 case-control studies) and found that[70]:

- Cell phone users had an increased risk of malignant gliomas.
- Link between cell phone use and a higher rate of acoustic neuromas.
- Tumors are more likely to occur on the side of the head that the cell handset is used.

One hour of cell phone use per day significantly increases tumor risk after ten years or more On 31 May 2011 the International Agency for Research on Cancer classified radiofrequency electromagnetic fields as possibly carcinogenic to humans (Group 2B). The IARC assessed and evaluated available literature and studies about the carcinogenicity of radiofrequency electromagnetic fields (RF-EMF), and found the evidence to be "limited for carcinogenicity of RF-EMF, based on positive associations between glioma and acoustic neuroma and exposure". The conclusion of the IARC was mainly based on the INTERPHONE study, which found an increased risk for glioma in the highest category of heavy users (30 minutes per day over a 10 - year period), although no increased risk was found at lower exposure and other studies could not back up the findings. The evidence for other types of cancer was found to be "inadequate". Some members of the Working Group opposed the conclusions and considered the current evidence in humans still as “inadequate”, citing inconsistencies between the assessed studies[71].

Researchers at the National Cancer Institute found that while cell phone use increased substantially over the period 1992 to 2008 (from nearly zero to almost 100 percent of the population), the U.S. trends in glioma incidence did not mirror that increase[72].

2.7 Conclusion

we found that the electromagnetic radiation that emitted from mobile phone have an affect on human head and human body in general so we must reduce this affect to protect the population living around base stations and users of mobile handsets, governments and regulatory bodies adopt safety standards, which translate to limits on exposure levels below a certain value. There are many proposed national and international standards, but that of the International Commission for Non-Ionizing Radiation Protection (ICNIRP) is the most respected one, and has been adopted so far by more than 80 countries. For radio stations, ICNIRP proposes two safety levels: one for occupational exposure, another one for the general population. Currently there are efforts underway to harmonise the different standards in existence[72].

Here are some recommendations based on all available evidence especially regarding brain tumors:

1. Limit the use of cell phones *...keep calls short*.

2. Children should (not) be allowed to use a cell phone (other than)in..*emergency...* Because of their .. (thin) skulls, the radiation can penetrate much more deeply.

3. Wear an air tube headset (not regular wired headset). The regular wired headset has been found to intensify radiation into the ear canal. The wire not only transmits the radiation from the cell phone but also serves as an antenna, attracting EMFs from the surroundings.

4. Do not put the cell phone in a pocket or a belt while in use or while it is on. The body tissue in the lower body area has good conductivity and absorbs radiation more quickly than the head. One study shows that men who wear cell phones near their groin could have their sperm count dropped by as much as 30%.

5. If (no) headset, wait for the call to connect before placing the phone next to the ear.

6. Do not use the cell phone in enclosed metal spaces such as vehicles or elevators, where devices may use more power to establish connection.

7. Do not make a call when the signal strength is (weak) (1 bar or less), (because much stronger radiation is then emitted by the phone).

8. Purchase a phone with a low SAR. Most phones have a SAR level listed in its instruction manual. The SAR level is a way of measuring the quantity of RF energy that is absorbed by the body.

9. Use text instead of talk.

10. Use landlines.

11. Keep cell phone off most of the time. Let people leave messages and then call them back from a landline.

12. Limit the use of cell phones in rural areas (because the signal is mostly weak there prompting strong radiation from the cell phone)[73].

CHAPTER THREE

Maxwell's Equations and Finite Difference Time Domain (FDTD)

Introduction:

The physics and the distribution of the electromagnetic waves of the Finite difference Time Domain (FDTD) along with the functionality and the general math formula has been discussed. It incorporates the Maxwell equation used to control (FDTD).

Additionally, it examines of specific absorption rate of the active cell SAR and formulating the general mathematical equation of the absorption rate to identify the stimulate propagation in media that have conductivity.

To meet the main goal of the study, human head is approached in this study by examining the effect of the antenna on the skin, the bone, and the brain.

3.1 Finite-Difference Time-Domain (FDTD)

3.1.1 Finite-Difference Time-Domain (FDTD)

FDTD is one of the primary available computational electrodynamics modeling techniques. Since it is a time-domain method, FDTD solutions can cover a wide frequency range with a single simulation run, and treat nonlinear material properties in a natural way.

The FDTD method belongs in the general class of grid-based differential time-domain numerical modeling methods. The time-dependent Maxwell's equations (in partial differential form) are discretized using central-difference approximations to the space and time partial derivatives. The resulting finite-difference equations are solved in either software or hardware in a leapfrog manner: the electric field vector components in a volume of space are solved at a given instant in time; then the magnetic field vector components in the same spatial volume are solved at the next instant in time; and the process is repeated over and over again until the desired transient or steady-state electromagnetic field behavior is fully evolved.

The basic FDTD space grid and time-stepping algorithm trace back to a seminal 1966 paper by Kane Yee in IEEE Transactions on Antennas and Propagation.[74].

The descriptor "Finite-difference time-domain" and its corresponding "FDTD" acronym were originated by Allen Taflove in a 1980 paper in IEEE Transactions on Electromagnetic Compatibility[75].

3.1.2 Using the FDTD method

To implement an FDTD solution of Maxwell's equations, a computational domain must first be established. The computational domain is simply the physical region over which the simulation will be performed. The E and H fields are determined at every point in space within that computational domain. The material of each cell within the computational domain must be specified. Typically, the material is either free-space (air), metal, or dielectric. Any material can be used as long as the permeability, permittivity, and conductivity are specified.

Once the computational domain and the grid materials are established, a source is specified. The source can be an impinging plane wave, a current on a wire, or an applied electric field, depending on the application.

Since the E and H fields are determined directly, the output of the simulation is usually the E or H field at a point or a series of points within the computational domain. The simulation evolves the E and H fields forward in time.

Processing may be done on the E and H fields returned by the simulation. Data processing may also occur while the simulation is ongoing. While the FDTD technique computes electromagnetic fields within a compact spatial region, scattered and/or radiated far fields can be obtained via near-to-far-field transformation[76].

3.1.3 Workings of the FDTD method

When Maxwell's differential equations are examined, it can be seen that the change in the E-field in time (the time derivative) is dependent on the change in the H-field across space (the curl). This results in the basic FDTD time-stepping relation that, at any point in space, the updated value of the E-field in time is dependent on the stored value of the E-field and the numerical curl of the local distribution of the H-field in space[77].

The H-field is time-stepped in a similar manner. At any point in space, the updated value of the H-field in time is dependent on the stored value of the H-field and the numerical curl of the local distribution of the E-field in space. Iterating the E-field and H-field updates results in a marching-in-time process where in sampled-data analogs of the continuous electromagnetic waves under consideration propagate in a numerical grid stored in the computer memory.

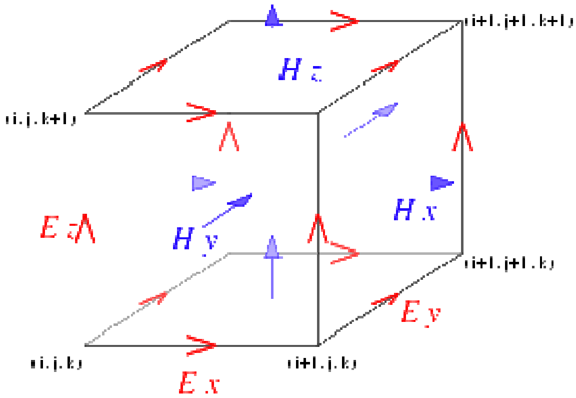


Figure (3.1)

Illustration of a standard Cartesian Yee cell used for FDTD, about which electric and magnetic field vector components are distributed.

Visualized as a cubic voxel, the electric field components form the edges of the cube, and the magnetic field components form the normals to the faces of the cube. A three-dimensional space lattice consists of a multiplicity of such Yee cells. An electromagnetic wave interaction structure is mapped into the space lattice by assigning appropriate values of permittivity to each electric field component, and permeability to each magnetic field component.

This description holds true for 1-D, 2-D, and 3-D FDTD techniques. When multiple dimensions are considered, calculating the numerical curl can become complicated. Kane Yee's seminal 1966 paper proposed spatially staggering the vector components of the E-field and H-field about rectangular unit cells of a Cartesian computational grid so that each E-field vector component is located midway between a pair of H-field vector components, and conversely[78][79].

On the plus side, this explicit time-stepping scheme avoids the need to solve simultaneous equations, and furthermore yields dissipation-free numerical wave propagation. On the minus side, this scheme mandates an upper bound on the time-step to ensure numerical stability[80].

As a result, certain classes of simulations can require many thousands of time-steps for completion.

3.1.4 FDTD formulation

In the FDTD approach, both the space and time are divided into discrete segments. Space is segmented into box-shaped cells, which are small in comparison to the wavelength. The electric fields (E_x(i,j,k), E_y(i,j,k) and E_z(i,j,k)) are located on the edges of the box, and the magnetic fields (H_x(i,j,k), H_y(i,j,k) and H_z(i,j,k)) are positioned on the faces as shown in Figure 1.

This orientation of the fields is known as the Yee cell [14] and is the basis for FDTD The time is divided into small lapses where each step represents the time required for the field to travel from one cell to the next. Given an offset in space of the magnetic fields in relation to the electric fields, the values of the field in respect to time are also offset.

The electric and magnetic fields are updated using a leapfrog scheme where the electric fields come first, then the magnetic ones are computed at each step in time. When many FDTD cells are combined together to form a three- dimensional volume the result is an FDTD grid or mesh. Each FDTD cell will overlap the edges and faces with their neighbours. Therefore each cell will have three electric fields that begin at a common node associated with it. The electric fields at the other nine edges of the FDTD cell will belong to other adjacent cells. .Each cell will also have three magnetic fields originating on the faces of the cell adjacent to the common node of the electric fields .

3.2.1 Maxwell's equations

James Clark Maxwell published the famous Maxwell's equations, which mathematically describe the interdependence of the electric field and the magnetic field. Maxwell suggested the existence of electromagnetic waves, which were discovered later by other scientists. Differential form of time-dependent Maxwell's equations:

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t} \qquad (3.1)$$

$$\nabla \times \vec{H} = \frac{\partial \vec{D}}{\partial t} + \vec{J} \qquad (3.2)$$

$$\nabla \cdot \vec{B} = 0 \qquad (3.3)$$

$$\nabla \cdot \vec{D} = \rho \qquad (3.4)$$

where **E** is electric field intensity ,**H** is magnetic field intensity **D** is electric flux density , **B** is magnetic flux density , **J** is electric current density

The time derivatives can be greatly simplified with the phasor forms as:

$$\frac{\partial \overline{E}}{\partial t} = j \omega \overline{E} \qquad (3.5)$$

$$\frac{\partial^2 \overline{E}}{\partial t^2} = -\omega^2 \overline{E} \qquad (3.6)$$

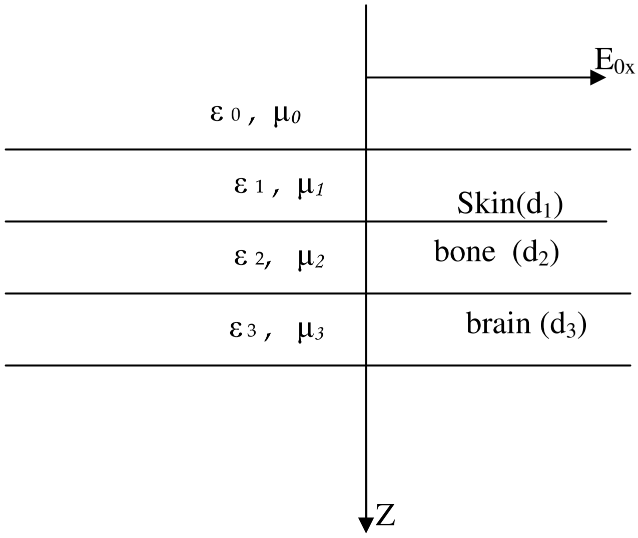
$$\frac{\partial \overline{H}}{\partial t} = j \omega \overline{H} \qquad (3.7)$$

$$\frac{\partial^2 \overline{H}}{\partial t^2} = -\omega^2 \overline{H} \qquad (3.8)$$

3.2.2 **Theory and model**

Mathematical analysis of microwave heating equations in one dimensional skin-layer has been discussed. the effect of microwave heating equations on the thermal states of biological tissues and to predict the effects of the thermal physical properties on the transient temperature of tissues and damage function. This research can be very beneficial in widening the idea of clinical thermal technology and thermal medical practices[13]. analytical formulations in SAR distribution calculations are extremely difficult Computation of specific absorption rate in the human body to base-station antennas using a Hybrid Formulation is found in reference [81]. SAR simulation in wireless communication and safety discussions in the society discussed by M. O. Ozyalcin [82]. A Multi-layered structure representing simplified model of the human head irradiated by plane wave in the frequency range of 100MHz-300GHz was investigated [83], general electromagnetic formulation on the absorption properties of the layered head model is given exact analytical expressions are given for the plane wave complex reflection coefficient as a function of frequency at the interference of the stratified structure, results highlight the position of maximum power absorption values and their dependence on frequency and dielectric parameter. The induced field and the dissipated power distributions in the stratified structure has been obtained by Akram Abdallah (2005).

In this work we consider the effects of electromagnetic waves produced from mobile phone ,a planar three-layer body model has been chosen such as skin ,bone and brain as shown in figure (3.2). It assumed that a plane electromagnetic wave is incident vertically upon the plane-layered slabs of medium in Z direction, which electric field is in X-direction. The model consists of three layer having dielectric properties for each layer differ according the frequency consider .



Figure(3.2) model of layered dielectric slab

In every layer of medium, the electric field and the magnetic field are found to satisfy the equations :

$$(\nabla^2 - \gamma_k^2) E_k = 0, \quad k = 1, 2, 3, \tag{3.9}$$

and

$$(\nabla^2 - \gamma_k^2) H_k = 0, \quad k = 1, 2, 3, \tag{3.10}$$

The general solution of equation above are

$$E_k = A_k e^{-\gamma_k z} + B_k e^{\gamma_k z}, k = 1, 2, 3, \tag{3.11}$$

$$H_k = \frac{A_k}{\eta_k} e^{-\gamma_k z} - \frac{B_k}{\eta_k} e^{\gamma_k z} \tag{3.12}$$

The amplitude of incident wave in vacuum is A_0 , and the reflect wave is not existence in the last slab, that is B_3 =0.founding the solutions of the equations, the amplitudes in every slab A_k and B_k (k = 1,2,3) can be obtained .

3.2.3 FDTD Method and Maxwell's equations

The FDTD method is derived by applying central differences on Ampere's and Faraday's laws:

$$\varepsilon \frac{\partial E_x}{\partial t} = \frac{\partial H_z}{\partial y} - \frac{\partial H_y}{\partial z} - \sigma E_x ,$$
$$\varepsilon \frac{\partial E_y}{\partial t} = \frac{\partial H_x}{\partial z} - \frac{\partial H_z}{\partial x} - \sigma E_y ,$$
$$\varepsilon \frac{\partial E_z}{\partial t} = \frac{\partial H_y}{\partial x} - \frac{\partial H_z}{\partial y} - \sigma E_z \qquad (3.13)$$
$$\mu \frac{\partial H_x}{\partial t} = \frac{\partial E_y}{\partial z} - \frac{\partial E_z}{\partial y},$$
$$\mu \frac{\partial H_y}{\partial t} = \frac{\partial E_z}{\partial x} - \frac{\partial E_x}{\partial z},$$
$$\mu \frac{\partial H_z}{\partial t} = \frac{\partial E_x}{\partial y} - \frac{\partial E_y}{\partial x} \qquad (3.14)$$

The difference equations for $\frac{\partial F}{\partial x}$ and $\frac{\partial F}{\partial t}$ are

$$\frac{\partial F^n(i,j,k)}{\partial x} = \frac{F^n(i+1/2,j,k) - F^n(i-1/2,j,k)}{\partial} \qquad (3.15)$$
$$\frac{\partial F^n(i,j,k)}{\partial t} = \frac{F^{n+1/2}(i,j,k) - F^{n-1/2}(i,j,k)}{\Delta t} \qquad (3.16)$$

The specific absorption rate (SAR) is defined as the power dissipation rate normalized by material density .

It can be shown that :

$$SAR = \frac{1}{\rho}\overline{J}.\overline{E} = \frac{\sigma}{\rho}|E|^2 \qquad (3.17)$$

The SAR distribution within the body is highly inhomogeneous,Tissues dielectric properties change with radio frequency. Many studies have been conducted to determine the relationship between dielectric properties and frequency for different types of biological tissues .

Changing the frequency and running the program, the dielectric properties has been calculated. According to the assumption in research that the layer represents skin, bone, and brain, the conductivity, relative permittivity, wavelength and penetration depth have been evaluated for each layer.

The finite difference time domain (FDTD) method is a full-wave, dynamic, and powerful solution tool for solving Maxwell's equations, introduced by K.S. Yee. The algorithm involves direct discriminations of Maxwell's equations by writing the spatial and time derivatives in a central finite difference form. The time-dependent Maxwell's curl equations in a homogenous dielectric medium are

$$\frac{\partial E}{\partial t} = \frac{1}{\varepsilon_0 \varepsilon_r} \nabla \times H \tag{3.18}$$

$$\frac{\partial H}{\partial t} = -\frac{1}{\mu} \nabla \times E \tag{3.19}$$

The constants ε_0 and μ_0 are known as the permittivity and permeability of free space and ε_r is the relative permittivity of the material.

3.2.4 Curl Equations in Cartesian Coordinates

Expanding the equation (3.18)

$$\frac{\partial E}{\partial t} = \frac{1}{\varepsilon_0 \varepsilon_r} \nabla \times H \tag{3.20}$$

In Cartesian coordinate

$$\hat{x}\frac{\partial E_x}{\partial t} + \hat{y}\frac{\partial E_y}{\partial t} + \hat{z}\frac{\partial E_z}{\partial t} = \frac{1}{\varepsilon_0 \varepsilon_r}\left[\hat{x}\left(\frac{\partial H_z}{\partial y} - \frac{\partial H_y}{\partial z}\right) + \hat{y}\left(\frac{\partial H_x}{\partial z} - \frac{\partial H_z}{\partial x}\right) + \hat{z}\left(\frac{\partial H_y}{\partial x} - \frac{\partial H_x}{\partial y}\right)\right]$$

Equating the vector components, we obtain :

$$\begin{aligned}
\frac{\partial E_x}{\partial t} &= \frac{1}{\varepsilon_0 \varepsilon_r}\left(\frac{\partial H_z}{\partial y} - \frac{\partial H_y}{\partial z}\right) \\
\frac{\partial E_y}{\partial t} &= \frac{1}{\varepsilon_0 \varepsilon_r}\left(\frac{\partial H_x}{\partial z} - \frac{\partial H_z}{\partial x}\right) \\
\frac{\partial E_z}{\partial t} &= \frac{1}{\varepsilon_0 \varepsilon_r}\left(\frac{\partial H_y}{\partial x} - \frac{\partial H_x}{\partial y}\right)
\end{aligned} \tag{3.21}$$

Similarly expanding(3.20)

$$\frac{\partial H}{\partial t} = -\frac{1}{\mu} \nabla \times E$$

We obtain three more equations,

$$\frac{\partial H_x}{\partial t} = \frac{1}{\mu_0}\left(\frac{\partial E_y}{\partial z} - \frac{\partial E_z}{\partial y}\right)$$
$$\frac{\partial H_y}{\partial t} = \frac{1}{\mu_0}\left(\frac{\partial E_z}{\partial x} - \frac{\partial E_x}{\partial z}\right) \qquad (3.22)$$
$$\frac{\partial H_z}{\partial t} = \frac{1}{\mu_0}\left(\frac{\partial E_x}{\partial y} - \frac{\partial E_y}{\partial x}\right)$$

In 1-D, we assume $E_y = 0$ and $E_z = 0$ and no variation in the x-y plane, i.e.

$$\frac{\partial}{\partial x} = 0, \quad \frac{\partial}{\partial y} = 0$$

The equations reduced to

$$\frac{\partial H_x}{\partial t} = \frac{1}{\mu_0}\left(\frac{\partial E_y}{\partial z} - \frac{\partial E_z}{\partial y}\right) = 0$$
$$\frac{\partial H_y}{\partial t} = \frac{1}{\mu_0}\left(\frac{\partial E_z}{\partial x} - \frac{\partial E_x}{\partial z}\right) = -\frac{1}{\mu_0}\frac{\partial E_x}{\partial z} \qquad (3.23)$$
$$\frac{\partial H_z}{\partial t} = \frac{1}{\mu_0}\left(\frac{\partial E_x}{\partial y} - \frac{\partial E_y}{\partial x}\right) = 0$$

$$\frac{\partial E_x}{\partial t} = \frac{1}{\varepsilon_0 \varepsilon_r}\left(\frac{\partial E_z}{\partial y} - \frac{\partial E_y}{\partial z}\right) = -\frac{1}{\varepsilon_0 \varepsilon_r}\frac{\partial E_y}{\partial z} \qquad (3.24)$$

3.2.5 1D-FDTD Solution to Maxwell's Equations .

In a simple one-dimensional case, we will consider the case where only the E_x and H_y components exist. Equations above becomes:

$$\frac{\partial E_x}{\partial t} = -\frac{1}{\varepsilon_0 \varepsilon_r}\frac{\partial H_y}{\partial z} \qquad (3.25)$$

$$\frac{\partial H_y}{\partial t} = -\frac{1}{\mu_0}\frac{\partial E_x}{\partial z} \qquad (3.26)$$

These equations represent a plane wave with the electric field orientated in the x-direction and magnetic field oriented in the y-direction and traveling in the z-direction. In the FDTD formulation, the central difference approximations for both the temporal and spatial derivatives are obtained at $z = k\Delta z$, $t = n\Delta t$ for the first equation:

$$\frac{E_x^{n+1/2}(k)-E_x^{n-1/2}(k)}{\Delta t}=-\frac{1}{\varepsilon_0\varepsilon_r}\frac{H_y^{n}(k+1/2)-H_y^{n}(k-1/2)}{\Delta z} \quad (3.27)$$

And for the second equation:

$$\frac{H_y^{n+1}(k+1/2)-H_y^{n}(k+1/2)}{\Delta t}=-\frac{1}{\mu_0}\frac{E_x^{n+1/2}(k+1)-E_x^{n+1/2}(k)}{\Delta z} \quad (3.28)$$

Numerical error is minimized by making the following change as:

$$\tilde{E}_x = \sqrt{\frac{\varepsilon_0}{\mu_0}}.E_x \quad (3.29)$$

which bring the field quantities to similar levels. Implementing the changing of variables, we obtain :

$$\tilde{E}_x^{n+1/2}(k)=\tilde{E}_x^{n-1/2}(k)-\frac{1}{\varepsilon_r\sqrt{\varepsilon_0\mu}}\frac{\Delta t}{\Delta z}[H_y^{n}(k+1/2)-H_y^{n}(k-1/2)] \quad (3.30)$$

$$H_y^{n+1}(k+1/2)=H_y^{n}(k+1/2)-\frac{1}{\sqrt{\varepsilon_0\mu}}\frac{\Delta t}{\Delta z}[\tilde{E}_x^{n+1/2}(k+1)-\tilde{E}_x^{n+1/2}(k) \quad (3.31)$$

3.2.6 Propagation simulate in media that have conductivity :

There are many media that also have a loss term specified by conductivity . This loss term results in the attenuation of the propagating energy.

Once more we will start with the time-dependent Maxwell equation, but we will write them in amore general form, which will allow us to simulate propagation in media that have conductivity are

$$\varepsilon \frac{\partial E}{\partial t} = \nabla \times H - J \qquad (3.32)$$

$$\frac{\partial H}{\partial t} = -\frac{1}{\mu_0} \nabla \times E \qquad (3.33)$$

J is the current density which can also be written

$$J = \sigma . E$$

where σ is the conductivity., we get

$$\frac{\partial E}{\partial t} = \frac{1}{\varepsilon_0 \varepsilon_r} \nabla \times H - \frac{\sigma}{\varepsilon_0 \varepsilon_r} E \qquad (3.34)$$

$$\frac{\partial H}{\partial t} = -\frac{1}{\mu_0} \nabla \times E \qquad (3.35)$$

The constants ε_0 and μ_0 are known as the permittivity and permeability of free space and ε_r is the relative permittivity of the material.

The equations reduced to

$$\frac{\partial E_x(t)}{\partial t} = -\frac{1}{\varepsilon_0 \varepsilon_r} \frac{\partial H_y(t)}{\partial z} - \frac{\sigma}{\varepsilon_0 \varepsilon_r} E_x(t) \qquad (3.36)$$

Take the FDTD formulation, the central difference approximations for both the temporal and spatial derivatives are obtained at $z = k \Delta z$, $t = n \Delta t$ for the equation:

$$\frac{E_x^{n+1/2}(k) - E_x^{n-1/2}(k)}{\Delta t} = -\frac{1}{\varepsilon_0 \varepsilon_r} \frac{H_y^{n}(k+1/2) - H_y^{n}(k-1/2)}{\Delta z} - $$

$$- \frac{\sigma}{\varepsilon_0 \varepsilon_r} \frac{E_x^{n+1/2}(k) + E_x^{n-1/2}(k)}{2} \qquad (3.37)$$

And for the second equation:

$$\frac{H_y^{n+1}(k+1/2)-H_y^{n}(k+1/2)}{\Delta t}=-\frac{1}{\mu_0}\frac{E_x^{n+1/2}(k+1)-E_x^{n+1/2}(k)}{\Delta z} \quad (3.38)$$

Implementing the changing of variables, equations (3.37) and (3.38) becomes

$$\tilde{E}_x^{n+1/2}(k)=\frac{1-\frac{\Delta t.\sigma}{2\varepsilon_0\varepsilon_r}}{1+\frac{\Delta t.\sigma}{2\varepsilon_0\varepsilon_r}}\tilde{E}_x^{n-1/2}(k)-\frac{1/2}{\varepsilon_r 1+\frac{\Delta t.\sigma}{2\varepsilon_0\varepsilon_r}}[H_y^{n}(k+1/2)-H_y^{n}(k-1/2)] \quad (3.39)$$

$$H_y^{n+1}(k+1/2)=H_y^{n}(k+1/2)-\frac{1}{\sqrt{\varepsilon_0\mu}}$$

$$\frac{\Delta t}{\Delta z}[\tilde{E}_x^{n+1/2}(k+1)-\tilde{E}_x^{n+1/2}(k) \quad (3.40)$$

We use the computer equations and simulates a sinusoidal wave hitting a human body tissue that has a dielectric constant and conductivity according the frequency which considered a s in table (3.1)

Tissue name	Conductivity [S/m]	Relative permittivity	Loss tangent	Wavelength [m]	Penetration depth [m]
Skin Dry	0.86674	41.405	0.41809	0.050714	0.04023
Brain	0.94227	52.725	0.35694	0.045182	0.041536
Bone	0.34	20.788	0.32667	0.072128	0.07211

Table (3.1) Dielectric constant and conductivity according the frequency 900MHz

This knowledge of field values associated with the characteristics of the tissue help to determine the SAR in the tissues without requiring an invasive measure. Now we present the Maxwell's equations in three dimensions. We suppose the absence of magnetic or electric current sources, and the existence of absorbing materials in the space under study.

$$\nabla\times E+\mu\frac{\partial H}{\partial t}=0 \quad (3.41)$$

$$\nabla \times H - \varepsilon \frac{\partial D}{\partial t} = \sigma E \tag{3.42}$$

Where the displacement vector D is related to the electric field through the complex permittivity

$$\varepsilon_r^*(\omega) = \varepsilon_r - j\,\frac{\sigma}{\omega\,\varepsilon_0} \tag{3.43}$$

Where ω is the angular frequency, this gives expressions of the form

$$\begin{aligned} & E_z^n(i,j,k+\tfrac{1}{2}) - \varepsilon_{1z} E_z^{n-1}(i,j,k+\tfrac{1}{2}) \\ & -\varepsilon_{2z}\left(\frac{H_y^{n-\frac{1}{2}}(i+\frac{1}{2},j,k+\frac{1}{2}) - H_y^{n-\frac{1}{2}}(i-\frac{1}{2},j,k+\frac{1}{2})}{\Delta x}\right) - \varepsilon_{2z}\left(\frac{H_x^{n-\frac{1}{2}}(i,j+\frac{1}{2},k+\frac{1}{2}) - H_y^{n-\frac{1}{2}}(i,j-\frac{1}{2},k+\frac{1}{2})}{\Delta y}\right) \end{aligned} \tag{3.44}$$

$$\begin{aligned} & E_z^{n+\frac{1}{2}}(i+\tfrac{1}{2},j+\tfrac{1}{2},k) = H_z^{n+\frac{1}{2}}(i+\tfrac{1}{2},j+\tfrac{1}{2},k) \\ & -\frac{\Delta t}{\mu}\left(\frac{E_y^n(i+1,j+\frac{1}{2},k) - E_y^n(i,j+\frac{1}{2},k}{\Delta x}\right) + \frac{\Delta t}{\mu}\left(\frac{E_y^n(i+\frac{1}{2},j+1,k) - E_y^n(i+\frac{1}{2},j,k}{\Delta y}\right) \end{aligned} \tag{3.45}$$

The various components of the fields are evaluated on the basis of neighboring components for each lapse of time and each cell in the modeling area. This method works in the time domain and allows direct visualization of electromagnetic fields.

CHAPTER FOUR

Results And Analysis

Introduction:

In this study, the researcher conducted a thorough research on the antenna used by wireless telecommunication company operated by the frequency 900MHz. The researcher adapted infinite models of the antenna and designed a new antenna using the HFSS software. It is worth to mention that the researcher used the same design utilized by the Palestinian Telecommunication Company JAWAL.

We visited Jawal Company the Engineering Department which is specialized in installing the Antenna for Safety and security .during this round we made a field visit for some stations to measure the signal amplitude coming out of the station accounting some different distances for the Antenna radiation to the around Houses .
The distances were as follow:

Distance	Signal Strong
11m	0.016mw
13m	0.019mw
15m	0.023mw

Table (4.1) distance according the signal strong

We got these results and created simulation on Mat lab program as a signal hits human's head which is three layers

The designed antenna consists of a dipole shaped antenna: 14.2cm, radius of 0.5 cm, and a gap between the two parts of the dipole estimated by .25 cm.
The distance between the antenna and the reflector is about 6.5 cm.

The length of the reflector is about 20 cm and 15 cm of width with a curve of 2 cm on both right and left side.

4.1 The work

MATLAB is used to make virtual simulation for the effect of electromagnetic signal which radiate from GSM Base Station to user equipment (900 MHz) on the human head . the simulation study the signal properties in free space and the change of the signal after hit human head and go through head layer (skin, bone and brain). MATLAB Program make virtual environments for free space and head layers, then show the different shape of GSM signal inside each of them. The metrology of work begin with take random reading for signal power in different distance from base station they used them as input to MATLAB program. MATLAB study signal electromagnetic , power density and SAR in the different dimension (one, two and three) . the MATLAB code use FDTD Method as main class on it analysis. The next sections show electromagnetic, power density and SAR at the different distance that we take on one dimension and how the signal will arrive to zero at brain to provide that its safety for human then certain this result in two and three dimension.

The general idea of the program show the electromagnetic of GSM signal in free space and after strikes the human head interface, which must propagates more slowly, and amplitude must decrease through skin, bone until arrived to zero in brain. The same concepts for power density and SAR with variation on amplitude

The present approach focuses on the investigation of GSM radiofrequency electromagnetic fields effects of two different specific absorption rate (SAR) distributions on human head and power density. Matlab script used Finite-Difference Time-Domain (FDTD) to calculate SAR and power density.

1-D FDTD code in Matlab

This part contains a code script written in Matlab, in which the 1-D FDTD algorithm is implemented. An electromagnetic pulse is radiated from a source located in free space. The source waveform is a sinusoidal shaped pulse, where implementation by Matlab as directional dipole model. This wave travelling in free space and strikes human head. When the wave strikes the interface, a fraction of the incoming wave is reflected, and a fraction is transmitted into the head layers. The amplitude of the reflected and transmitted waves, relative to the incident wave, is described by the reflection coefficient ρ and the transmission coefficient τ, which relate the amplitudes of the E field waves. The fields Ez, Hz, Power density and SAR are simulated along the line X =Y = 0, i.e. propagation along the ˆz axis during free space and the 3 head layers l (skin, bone, brain). The next section shoe that the computational results which meet the international safety guidelines for human health.

2-D FDTD code in Matlab

Matlab simulation shows the 2-D wave in free space hitting a head surface (right side), with the source at the centre. The results were supportive to the result in one diminsion.

3-D FDTD code in Matlab

Its provide Analysis of specific absorption rate (SAR) generated by half wave radiating dipole antenna inside a spherical inhomogeneous human head model at the frequency range 900 MHz using finite difference in time domain (FDTD) method. The human head is modeled consisting of a uniform core representing human brain, surrounded by two spherical shells representing skin and bone. Also the effect of Electromagnetic field and power density is studied. Simulation in the next sections shows that the absorption of electromagnetic energy into the human head depends on the operating frequency, polarization and the distance of the radiating antenna from the human head, but in general GSM signal meet the international safety guidelines for human health as approve in one and two dimension.

4.2 One-Dimensional Simulation with the FDTD Method At Distance 11m

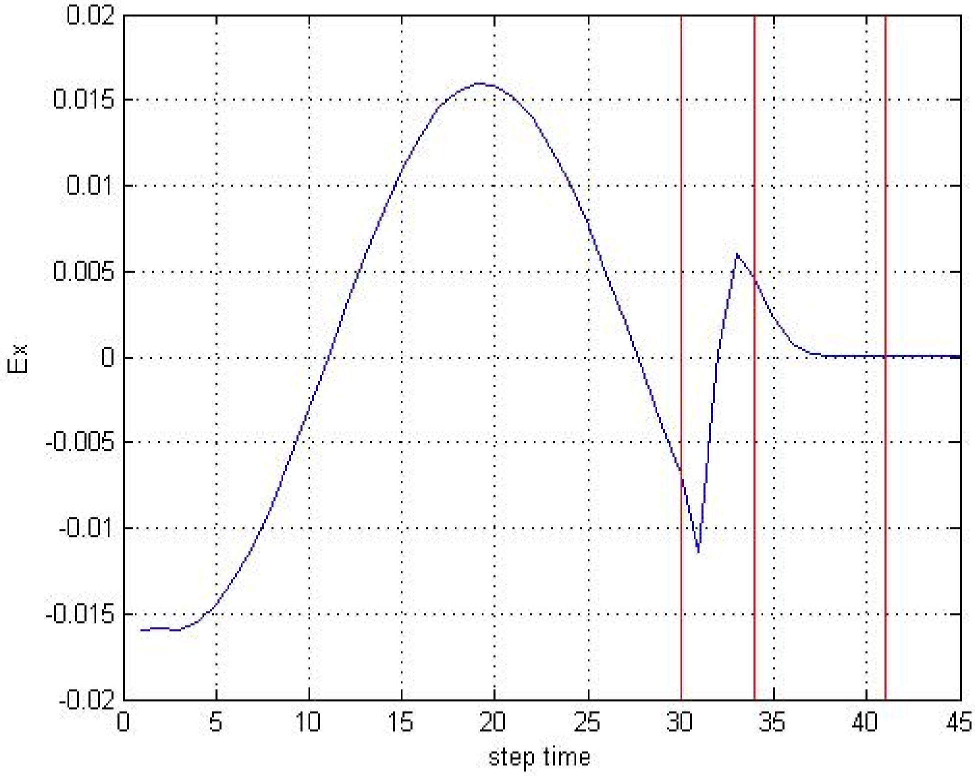


Fig. 4.1 Relation between electric field and time steps through human body.

This graph shows, the rang from 0 to 30 it represent free space, from 30-34 represent skin, from 34-41 it represent bone and 41-45 it represent brain. The graph show that an electromagnetic pulse is radiated from a source located in free space, where amplitude equal .016 mW/cm^2 , but when the pulse strikes the human body interface the wave propagates more slowly, and the pulse length is shorter, skin amplitude decrease to .006, bone cancellous amplitude is .002 and pulse amplitude will arrive zero at brain grey matter.

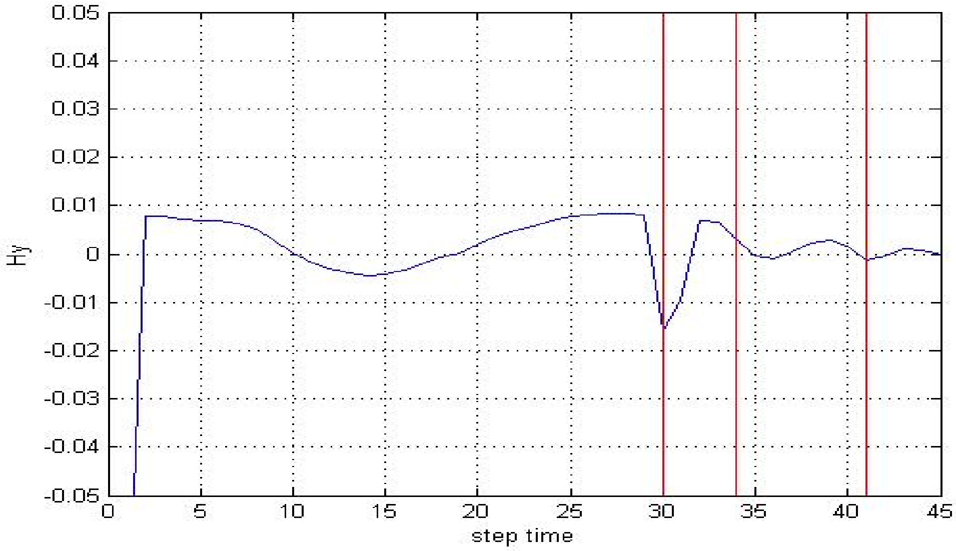


Fig 4.2 Relation between magnetic field and time steps through human body.

According to the Figure 4.2, the rang from 0 to 30 it represent free space, from 30-34 represent skin, from 34-41 it represent bone 41-45 it represent brain. and show relation between Magnetic in y-dimension and time step where signal amplitude is decrease when it strikes the human body and go through the skin, bone until reached zero at brain.

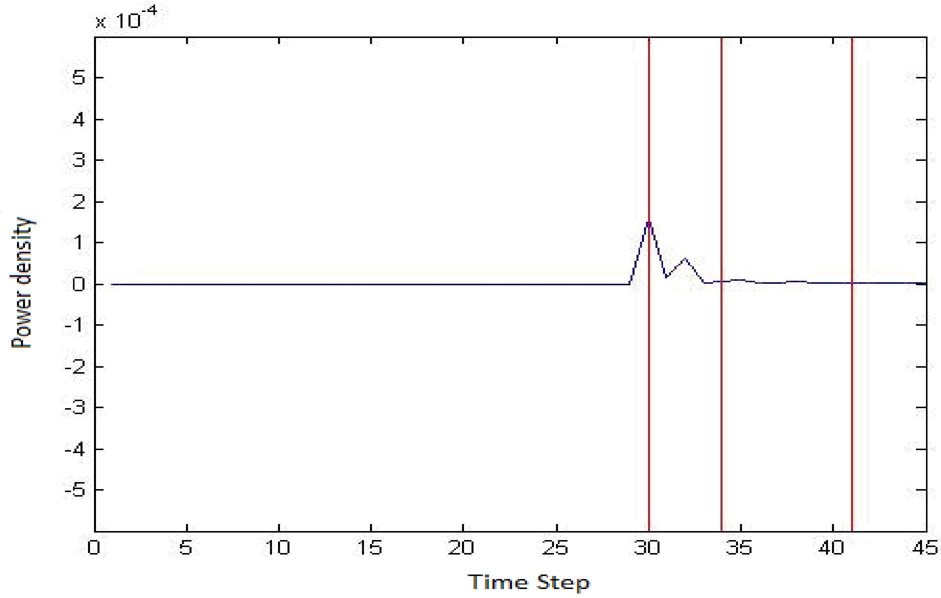


Fig. 4.3 Relation between power density and time steps through human body

Figure 4.3 explain the rang from 0 to 30 it represent free space, from 30-34 represent skin, from 34-41 it represent bone and 41-45 it represent brain. Also it show that Power density is zero in free space and increase to maximum at skin equal .0001 and decrease in bone to .00005 and finally reached zero in brain.

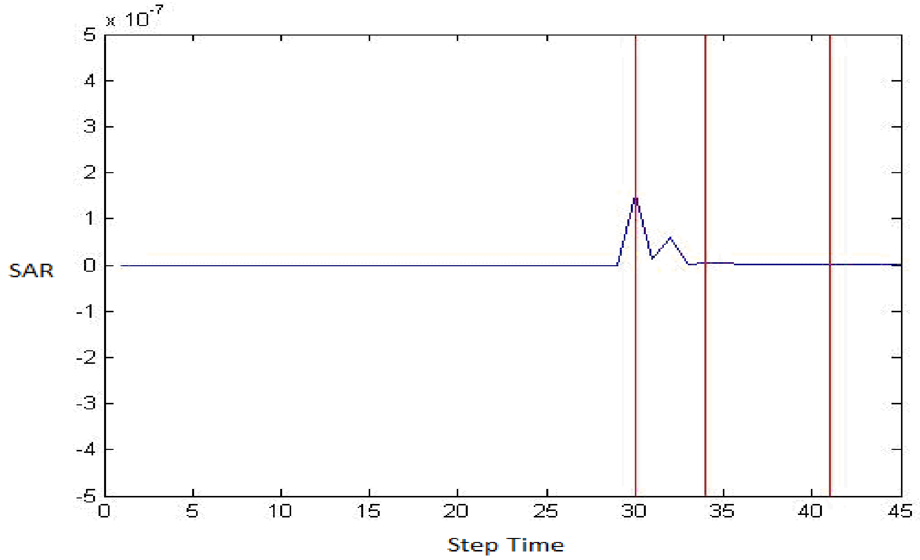


Fig. 4.4 Relation between SAR and time steps through human body.

The rang from 0 to 30 it represent free space, from 30-34 represent skin, from 34-41 it represent bone 41-45 it represent brain. The relation between SAR versus time step show that it increase from zero at free space to.0000016 at skin and decrease again to .00000005 at bone until back to zero again in brain grey matter.

At Distance 13m

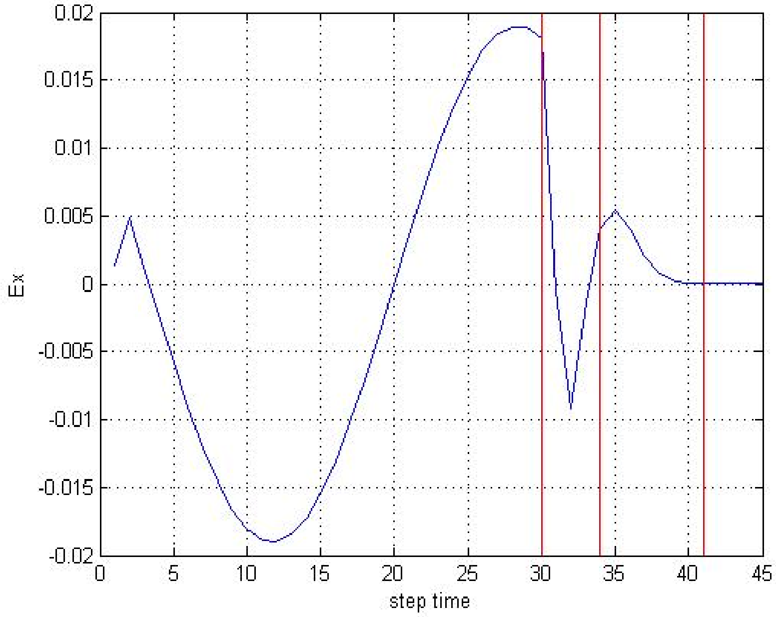


Fig. 4.5 Relation between electric field and time steps through human body.

Electromagnetic pulse is increase at distance 13m, that when measured is taken it achieve line of sight where signal amplitude begin with .18 in free space and decrease until be zero in brain through skin and bone.

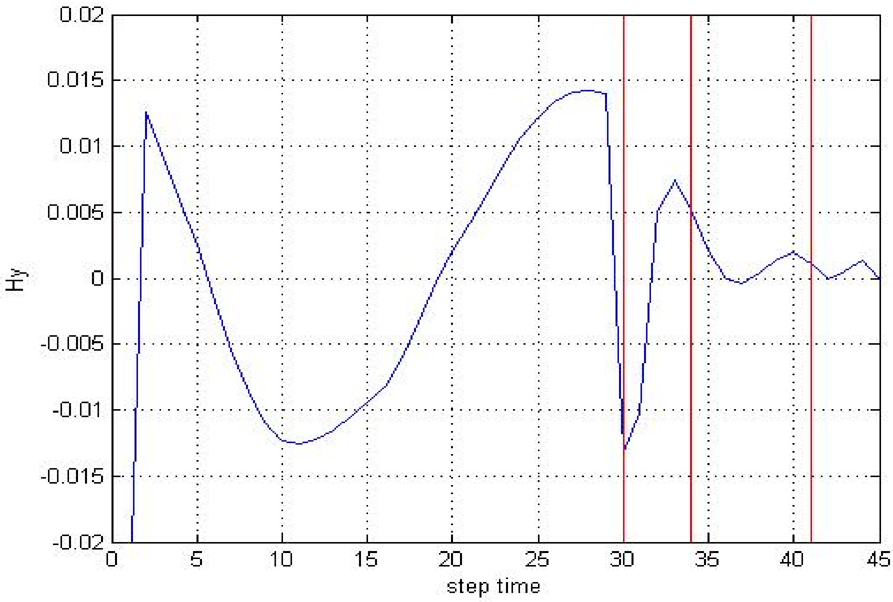


Fig 4.6 Relation between magnetic field and time steps through human body.

Magnetic is increase as it happen in Electromagnetic as happened in electromagnetic.

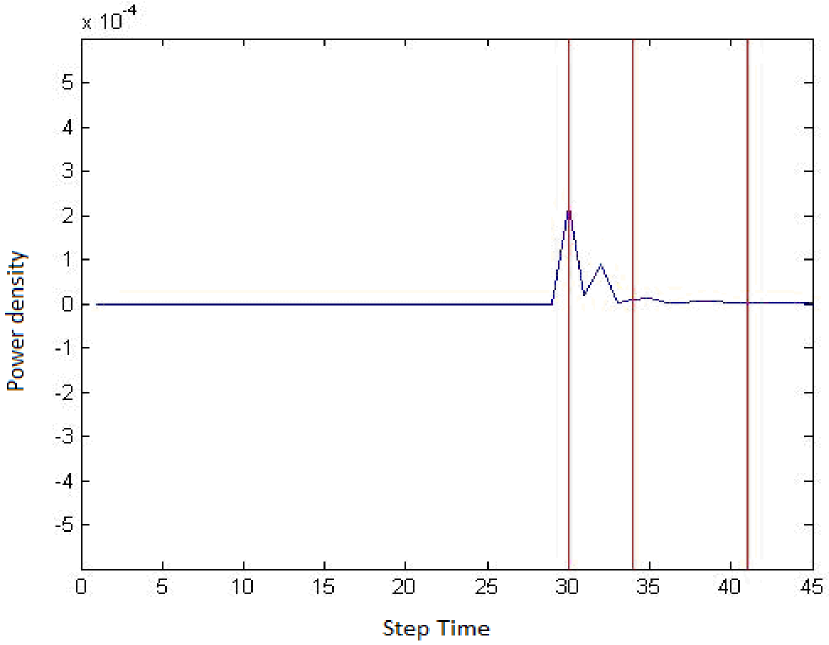


Fig. 4.7 Relation between the power density and the time steps through human body.

SAR is increase more than measured taken at distance 11m. it reached .0002 in skin and decrese to .00019 in bone and finally become zero at brain.

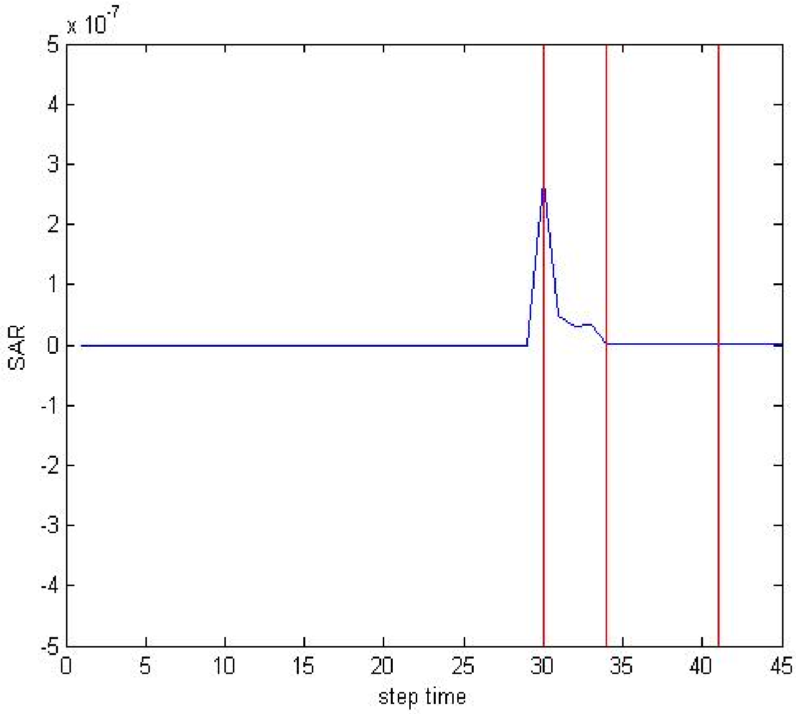


Fig. 4.8 Relation between SAR and time steps through human body where become .0000003 in skin.

SAR here is increase more than measured taken at 11m where become 0.0000003.

At Distance 15m

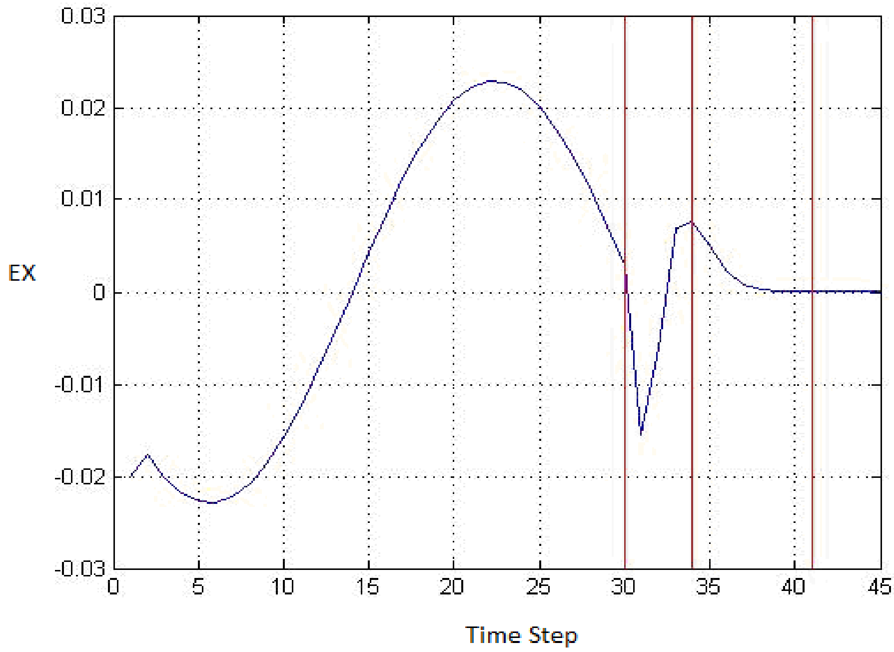


Fig. 4.9 Relation between electric field and time steps through human body.

From the above illustrator electromagnetic is increase because measured achieved an efficient line of sight. Signal amplitude here .025 in free space and become zero in brain after hit human body.

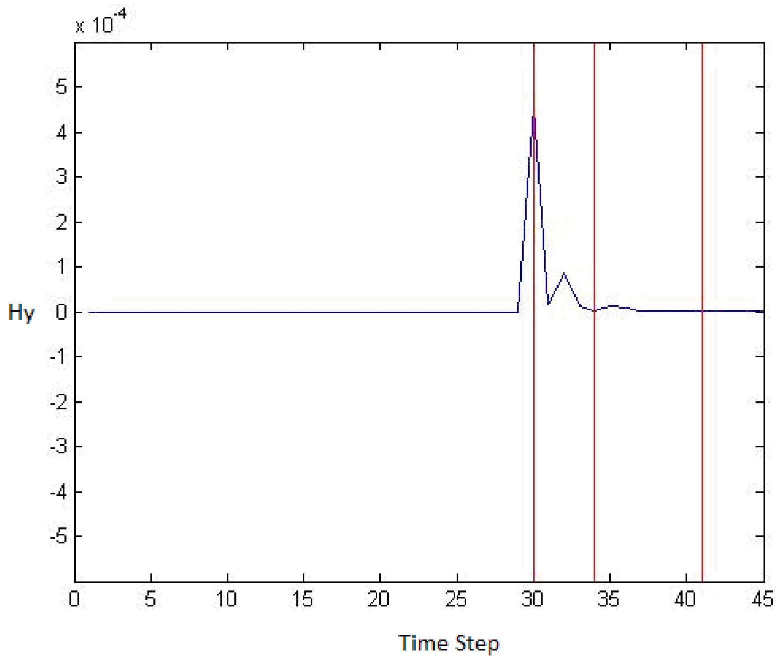


Fig. 4.10 Relation between power density and time steps through human body.

This illustrator show that power density is increase because it depend on electromagnetic plus which increase as shown before.

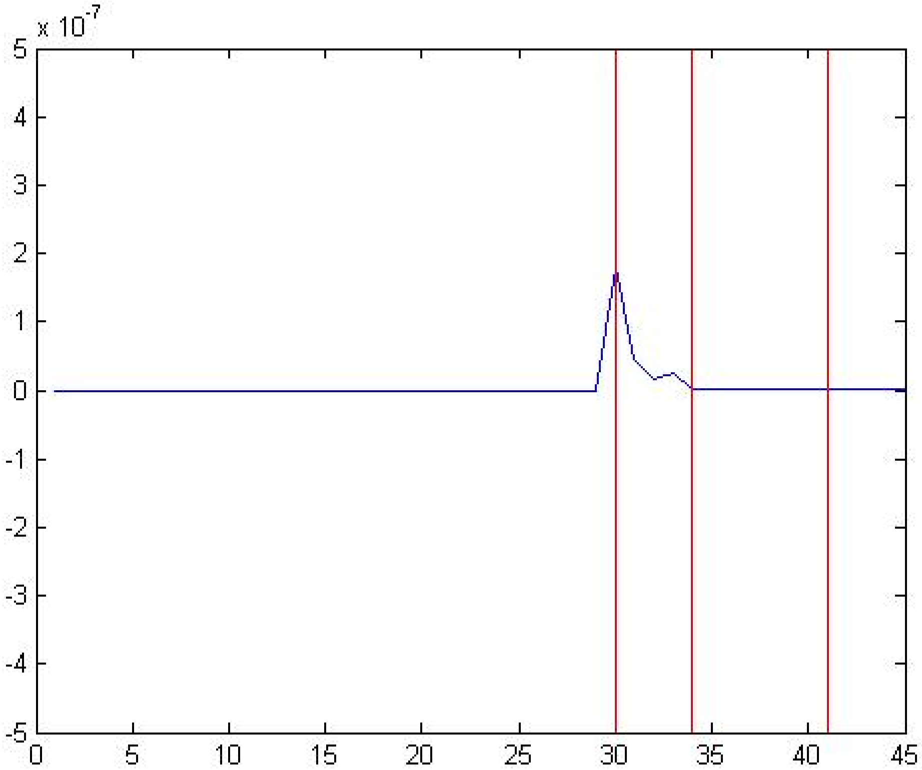


Fig. 4.11 Relation between SAR and time steps through human body.

Its seen here that SAR increased as explained before

4.3 Two Dimensional Simulation with the FDTD Method

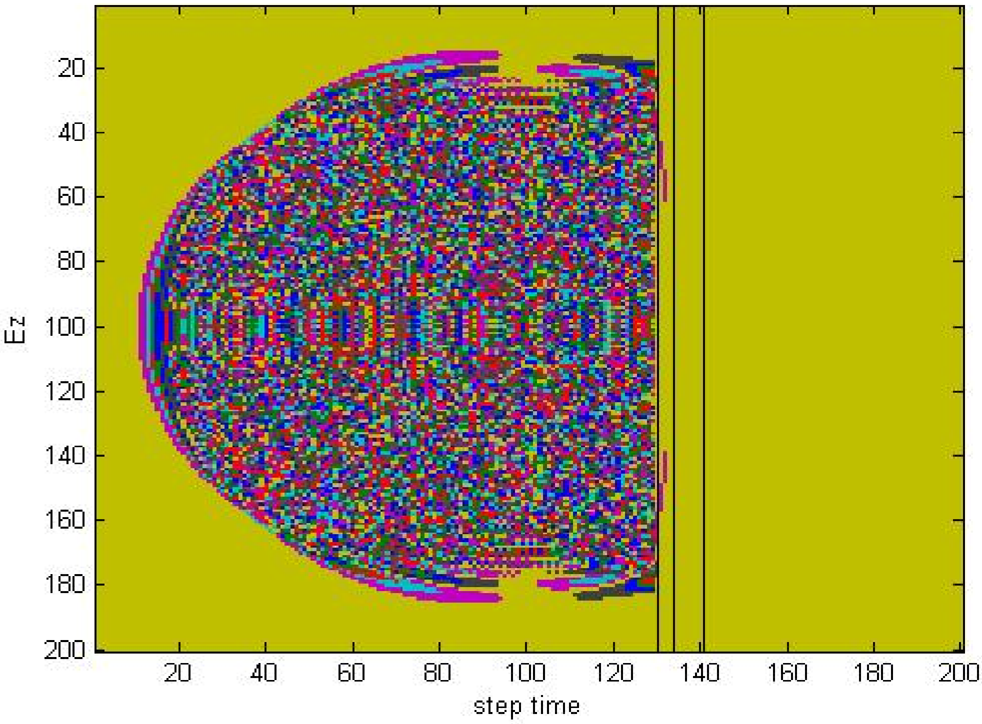


Fig. 4.12 Relation between electric field and time steps through human body at distance 11.

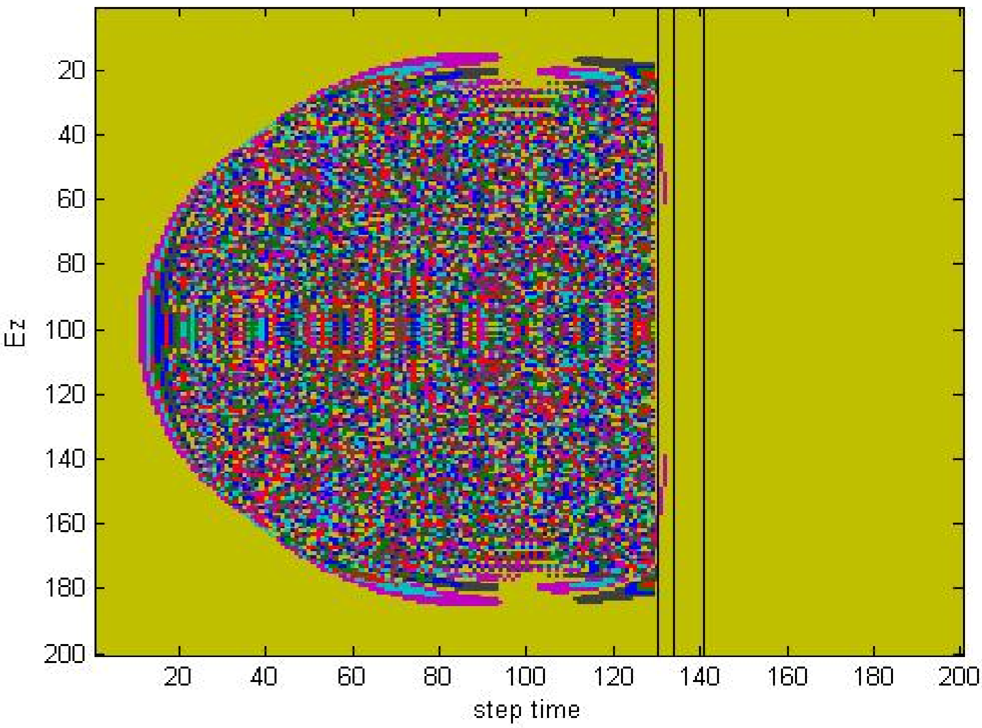


Fig. 4.13 Relation between electric field and time steps through human body at distance 13m

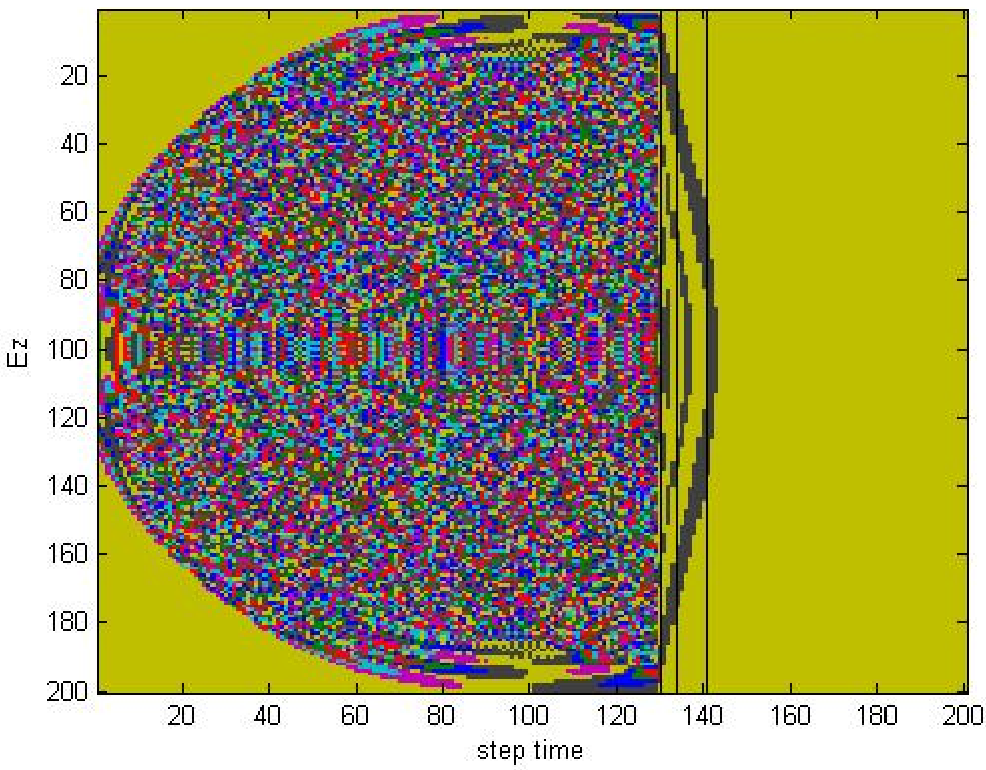


Fig. 4.14 Relation between electric field and time steps through human body at distance 15m.

According to the above graphs, the rang from 100-130 it represent free space, from 130-134 represent skin, from 134-141 it represent bone 141-145 it represent brain. These graphs shows that An electromagnetic pulse is radiated from a source located in free space, but when the pulse strikes the human body interface. Notice that the wave propagates more slowly, and the pulse length is shorter.

4.4 3-Dimensional Simulation with the FDTD Method

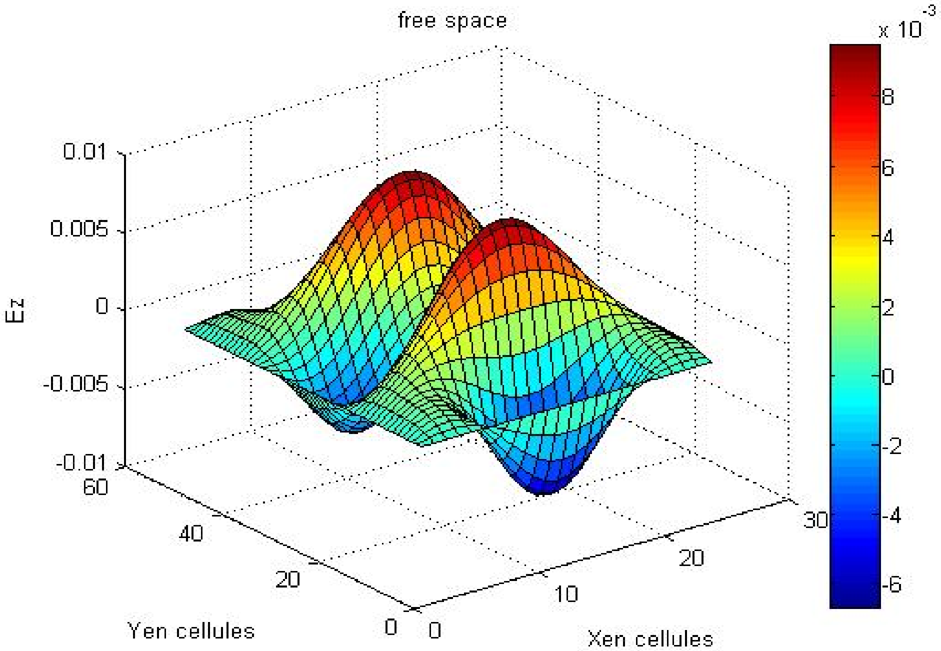


Fig 4.15 Relation between Electric field in free space and time steps through human body at distance 11m

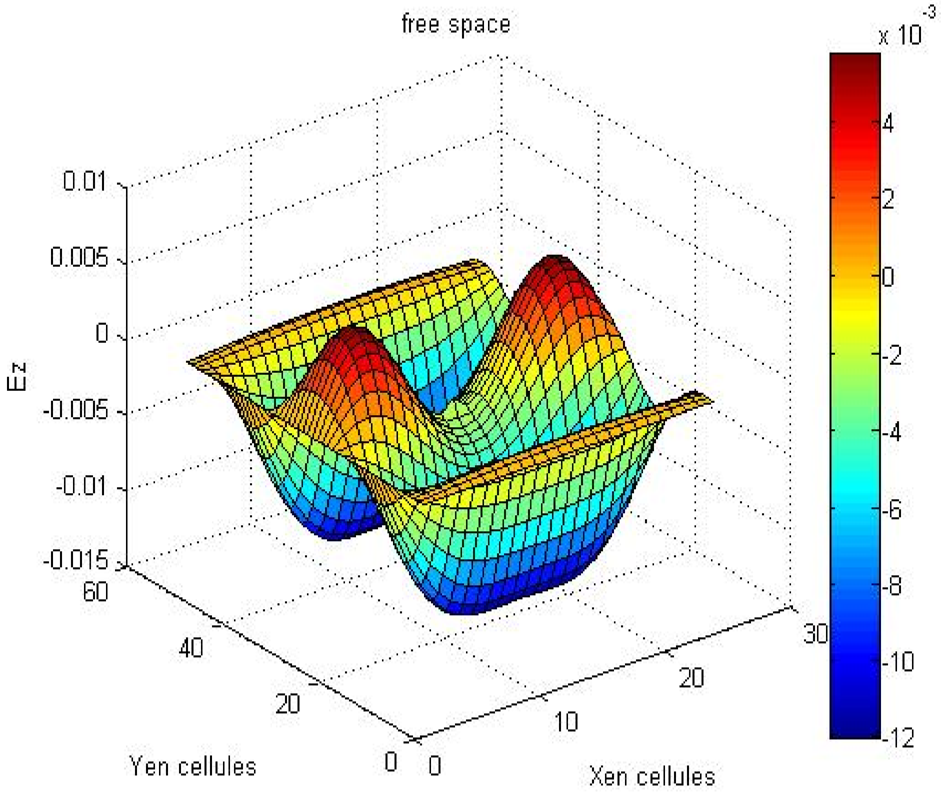


Fig 4.16 Relation between Electric field in free space and time steps through human body at distance 13m

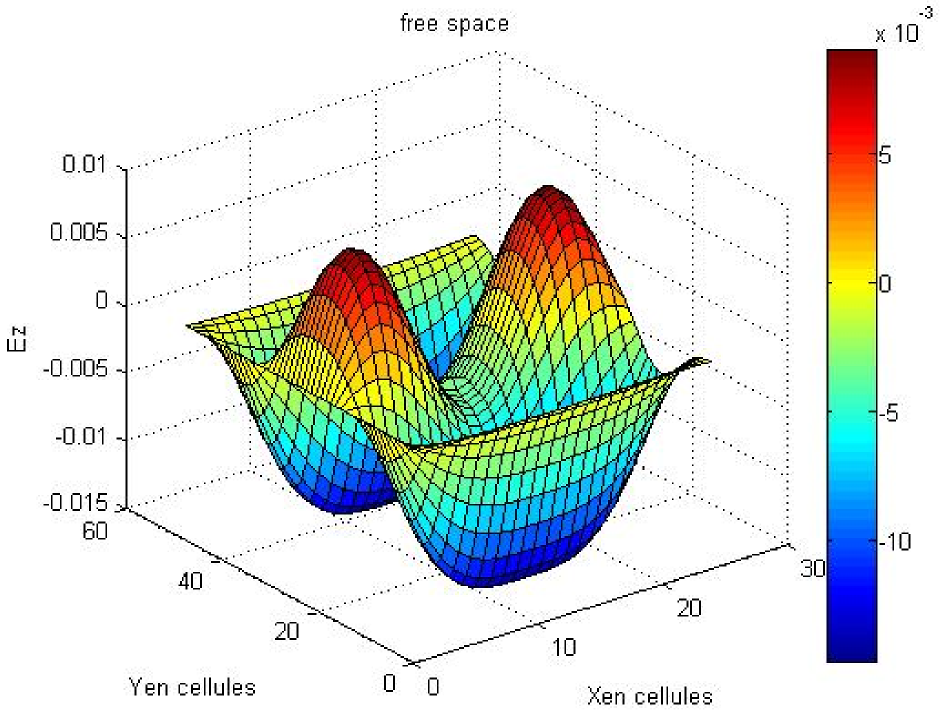


Fig 4.17 Relation between Electric field in free space and time steps through human body at distance 15m.

Fig 4.15,4.16,4.17 compare the electromagnetic in free space at three different distance

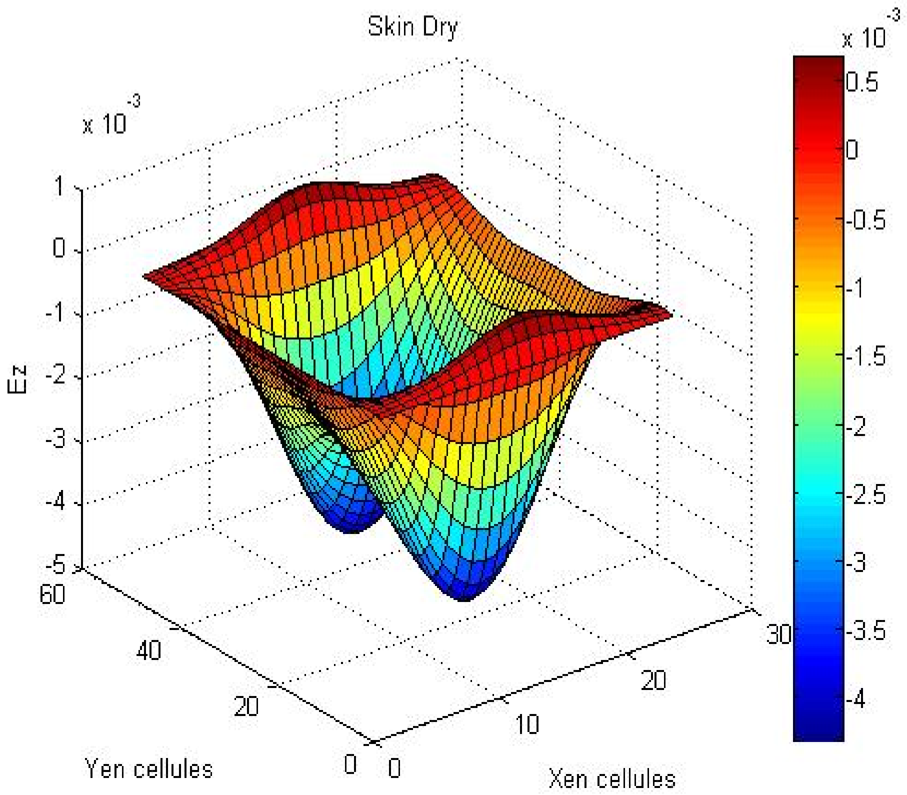


Fig 4.18 Relation between Electric field in skin and time steps through human body at 11m.

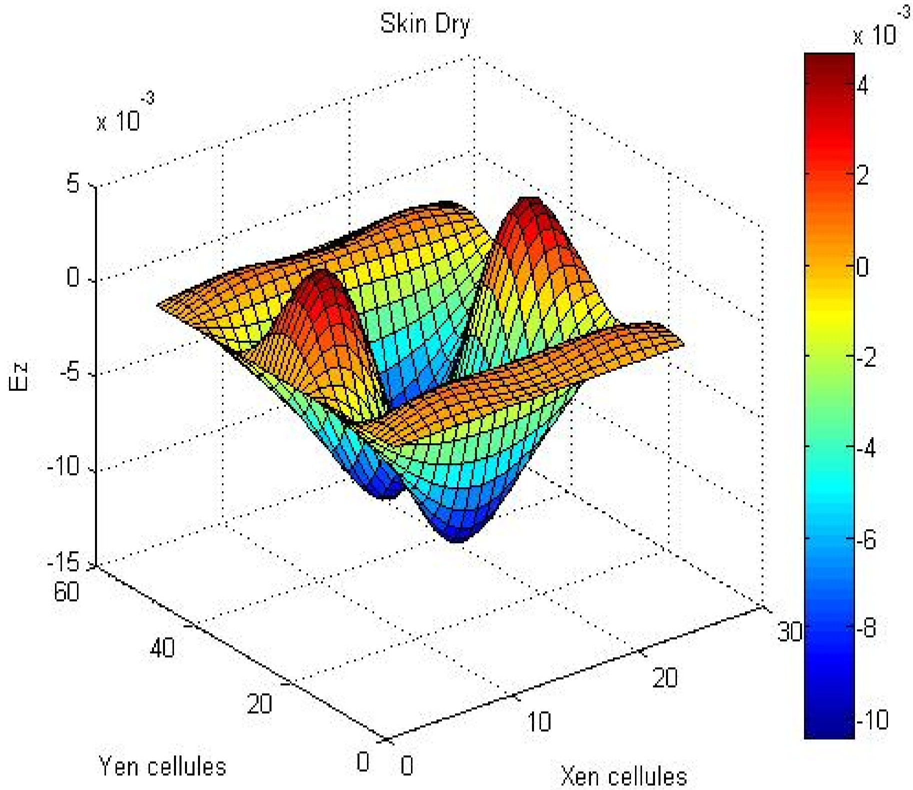


Fig 4.19 Relation between Electric field in skin and time steps through human body at 13m.

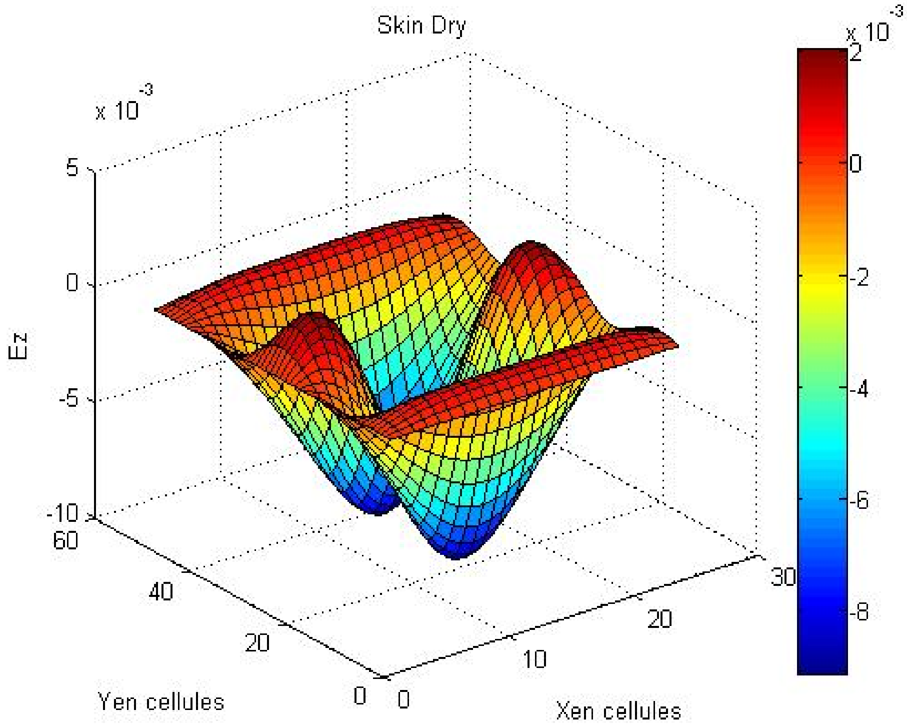


Fig 4.20 Relation between Electric field in skin and time steps through human body at 15 m.

Fig 4.18,4.19,4.20 compare the electromagnetic inside skin at three different distance

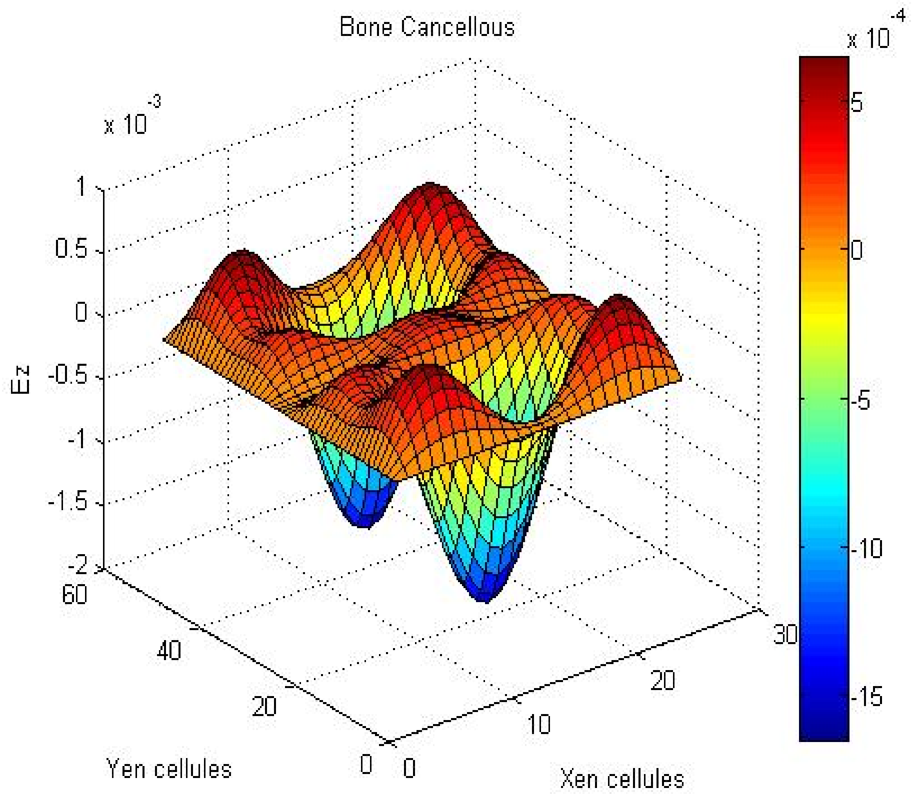


Fig4.21 Relation between Electric field in bone cancellous and time steps through human body at distance 11 m.

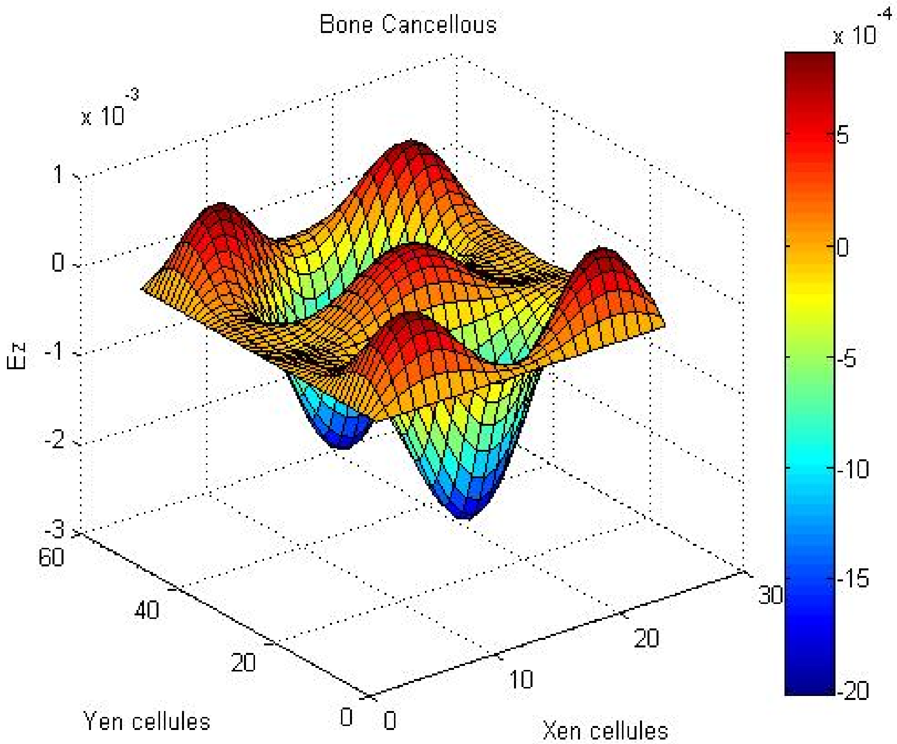


Fig4.22 Relation between Electric field in bone cancellous and time steps through human body at distance 13 m.

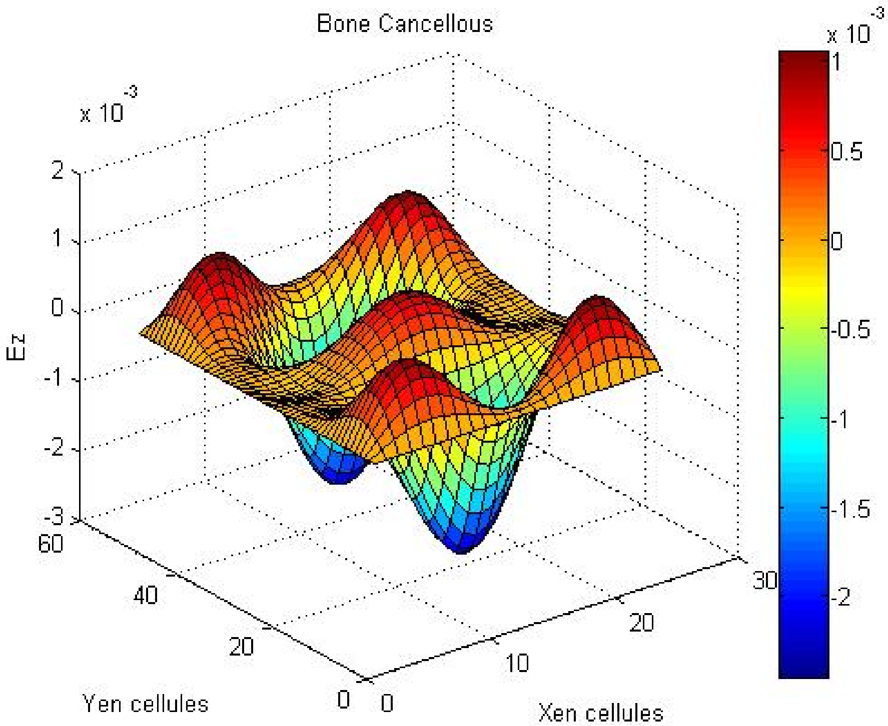


Fig4.23 Relation between Electric field in bone cancellous and time steps through human body at distance 15 m.

Fig 4.21,4.22,4.23 compare the electromagnetic dimensions inside bone at three different distance

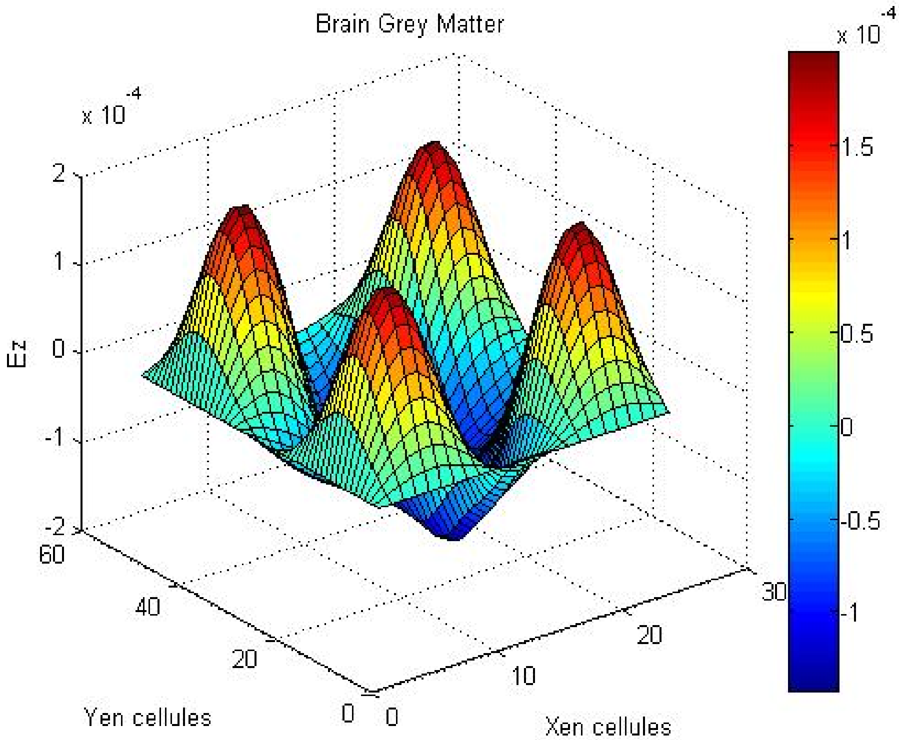


Fig 4.24 Relation between Electric field in brain grey matter and time steps through human body at distance 11m.

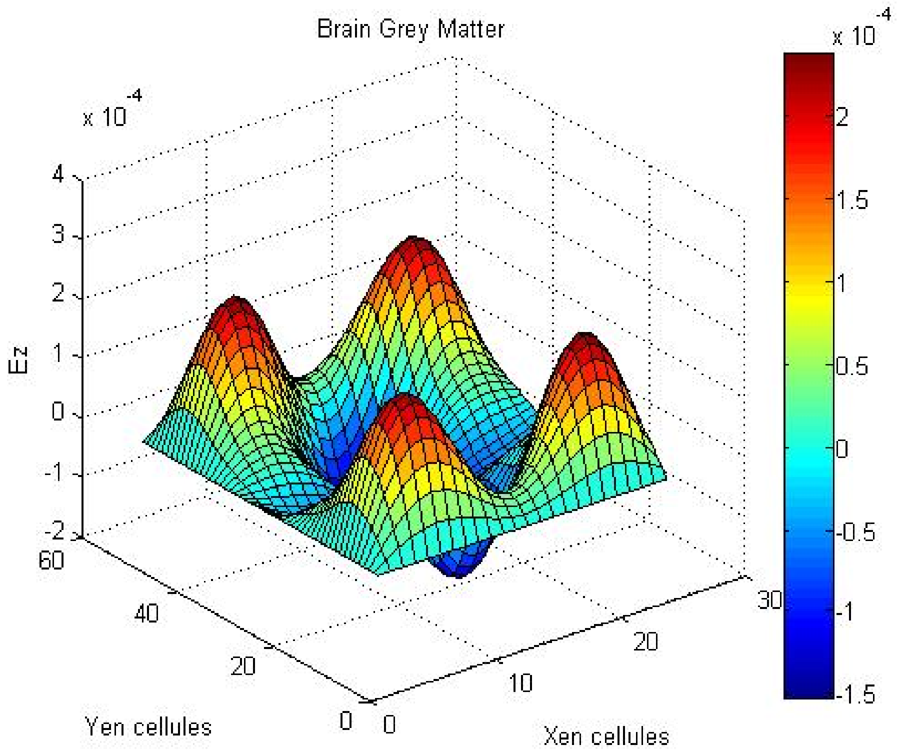


Fig 4.25 Relation between Electric field in brain grey matter and time steps through human body at distance 13m.

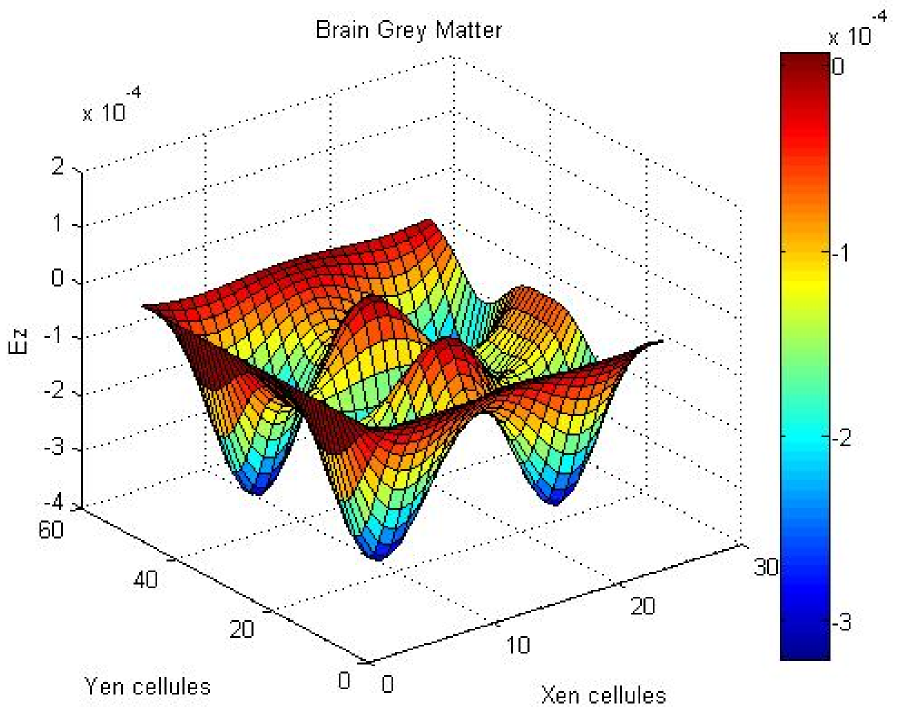


Fig 4.26 Relation between Electric field in brain grey matter and time steps through human body at distance 15m.

Fig 4.24,4.25,4.26 compare the electromagnetic dimensions inside brain at three different distance

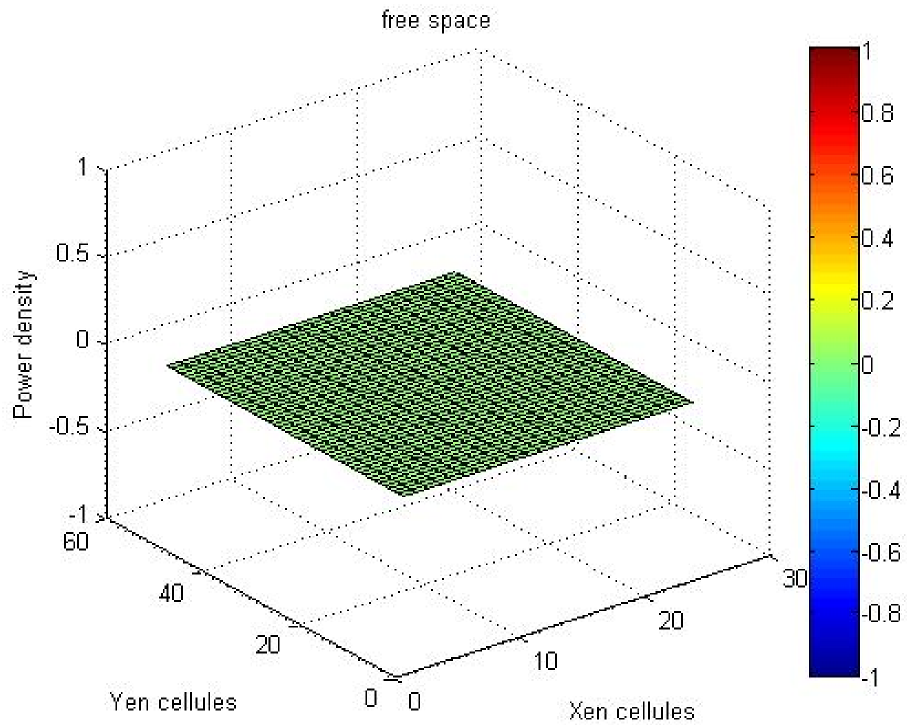


Fig 4.27 relation between power density in free matter and time steps through human body at distance 11m.

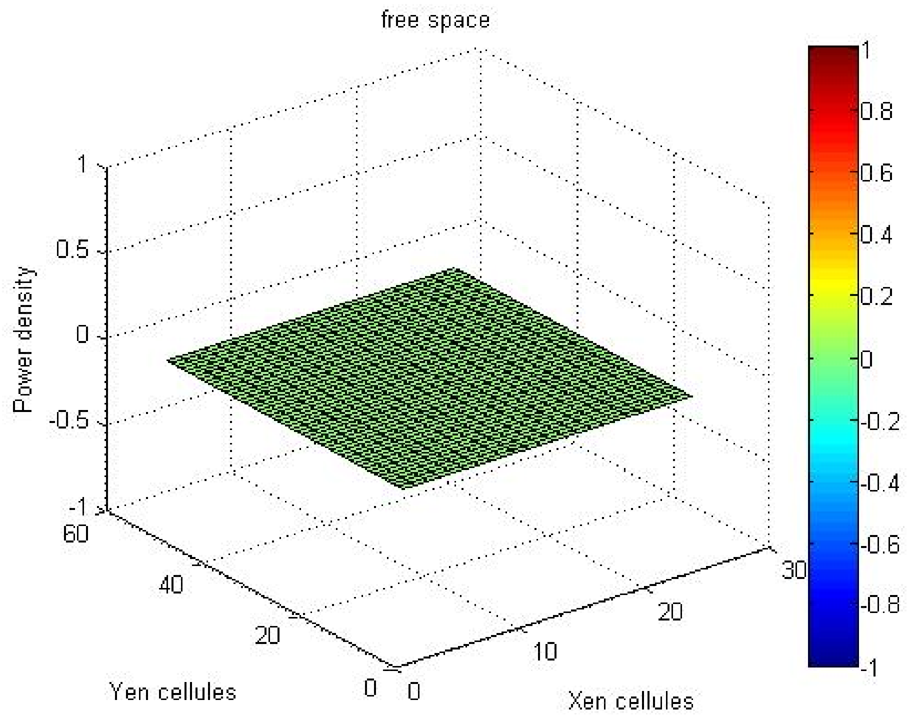


Fig 4.28 Relation between power density in free matter and time steps through human body at distance 13m.

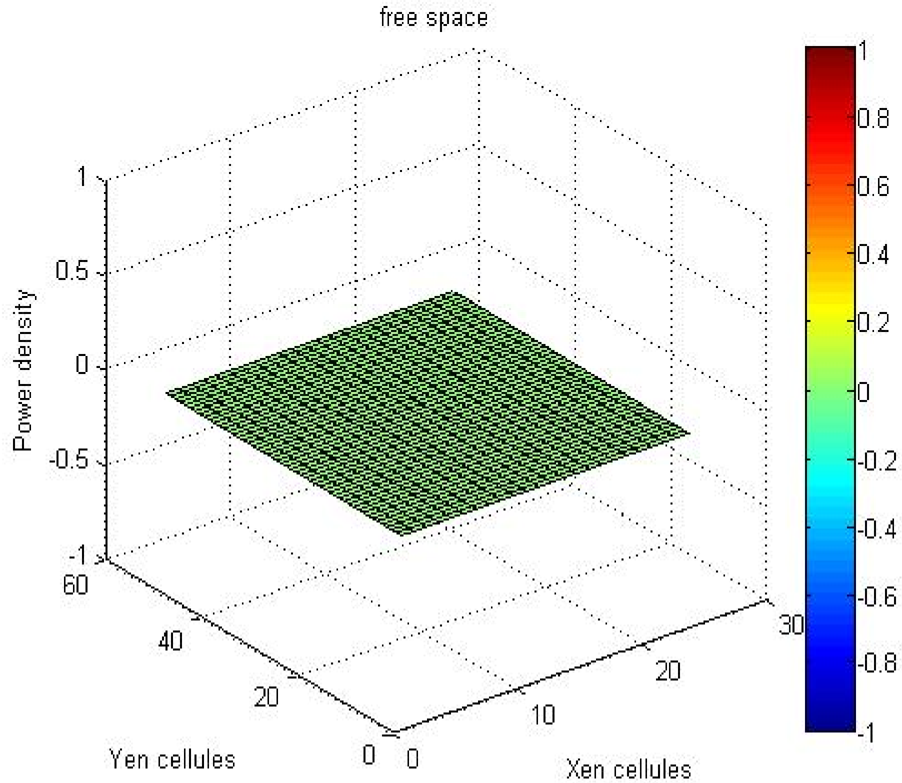


Fig 4.29 Relation between power density in free matter and time steps through human body at distance 15m.

Fig 27,28,29 show the power density in third dimensions where strength pulse equal 1 zero.

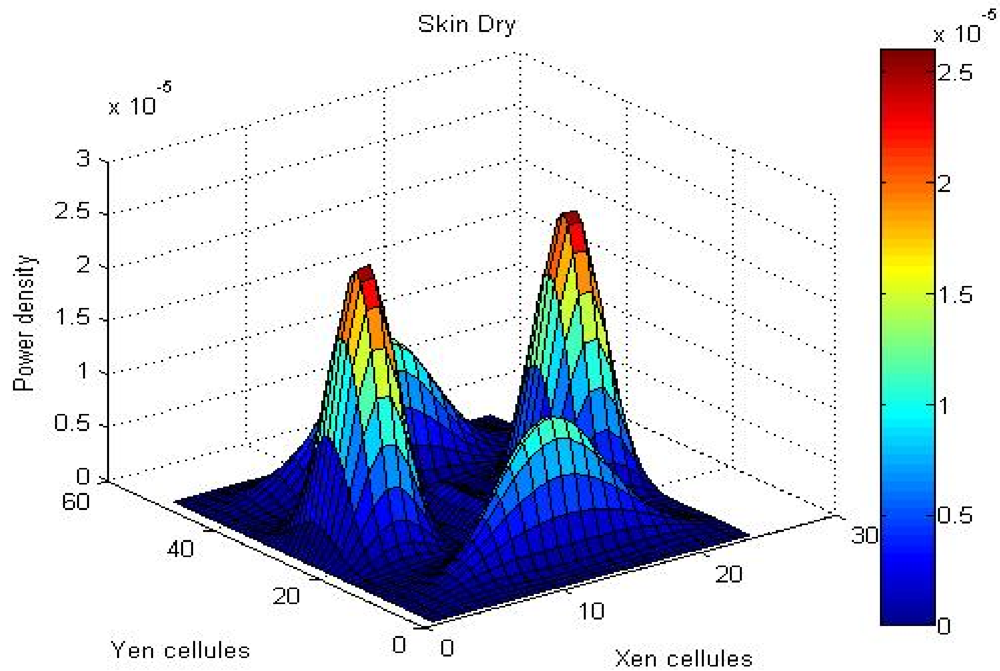


Fig 4.30 Relation between power density in skin and time steps through human body at distance 11m.

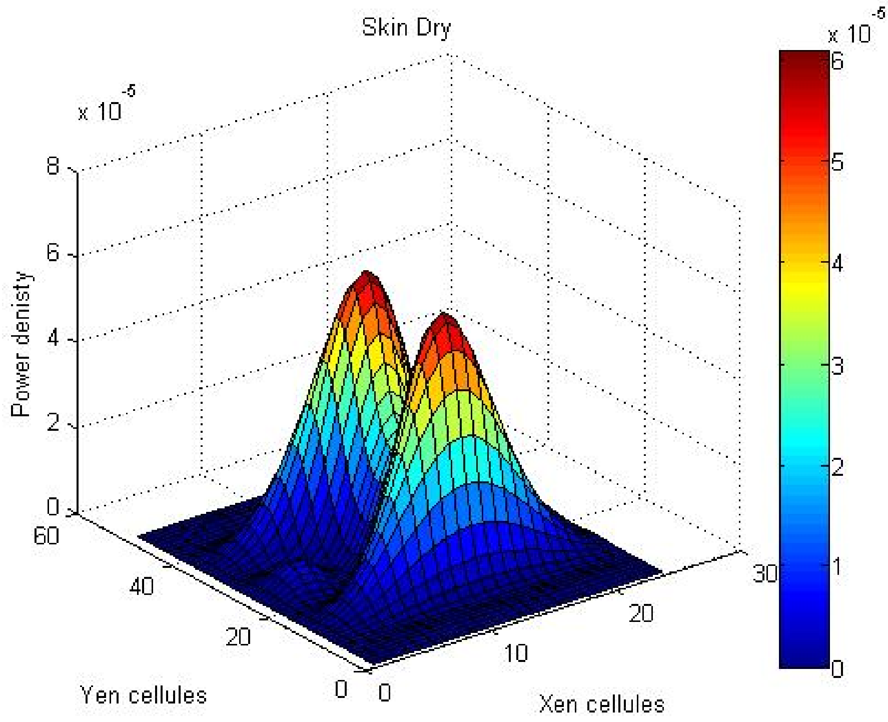


Fig 4.31 Relation between power density in skin and time steps through human body at distance 13m.

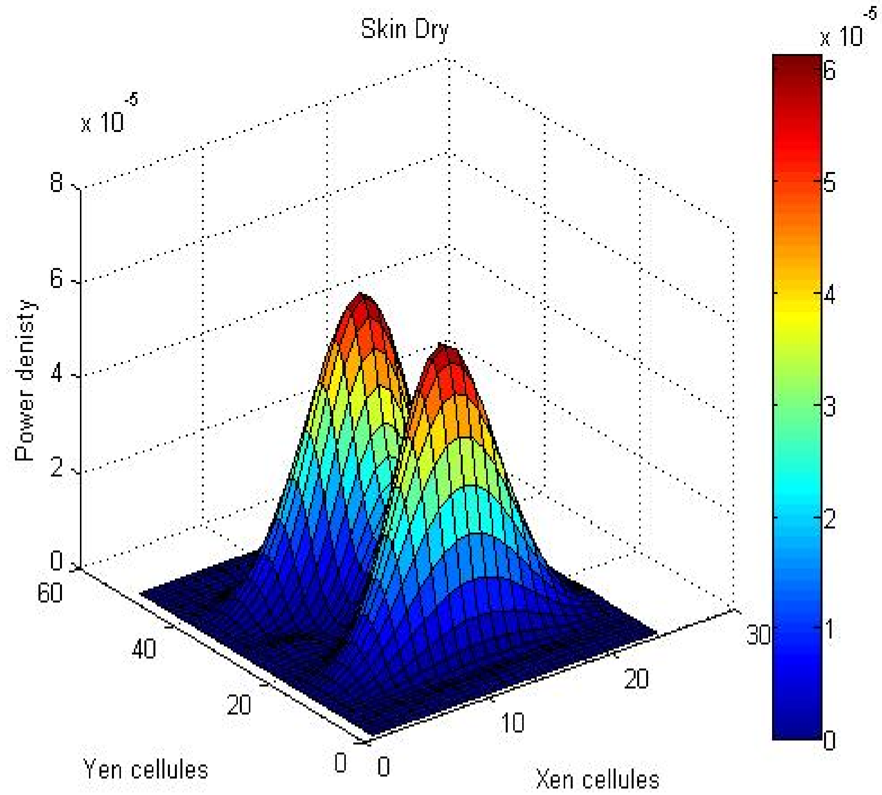


Fig 4.32 Relation between power density in skin and time steps through human body at distance 15m.

Fig 4.30,4.31,4.32 compare the power density inside skin at three different distance

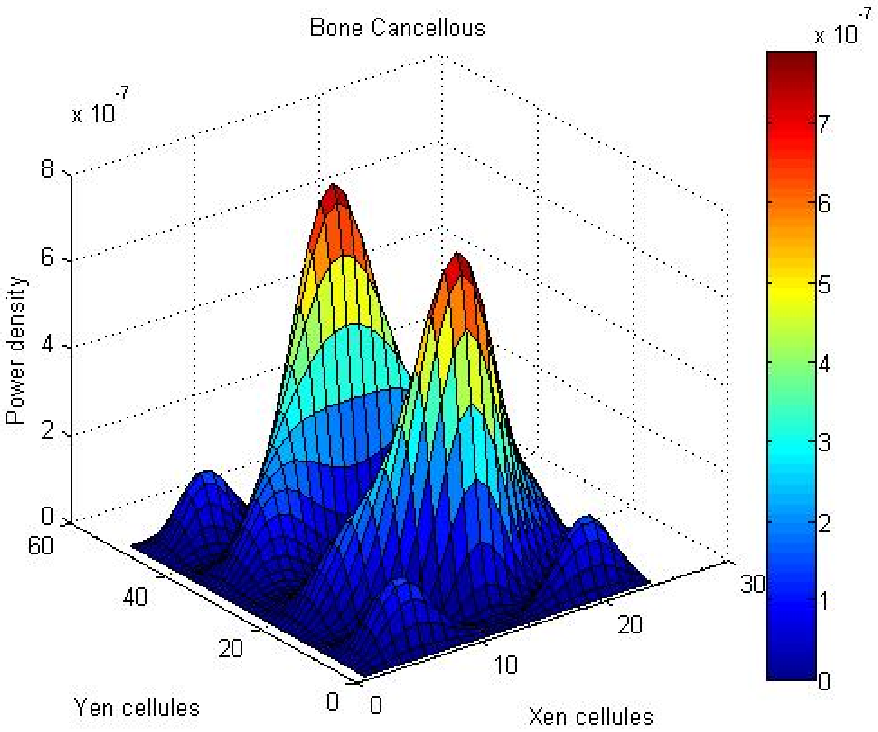


Fig 4.33 Relation between power density in bone cancellous and time steps through human body at distance 11m

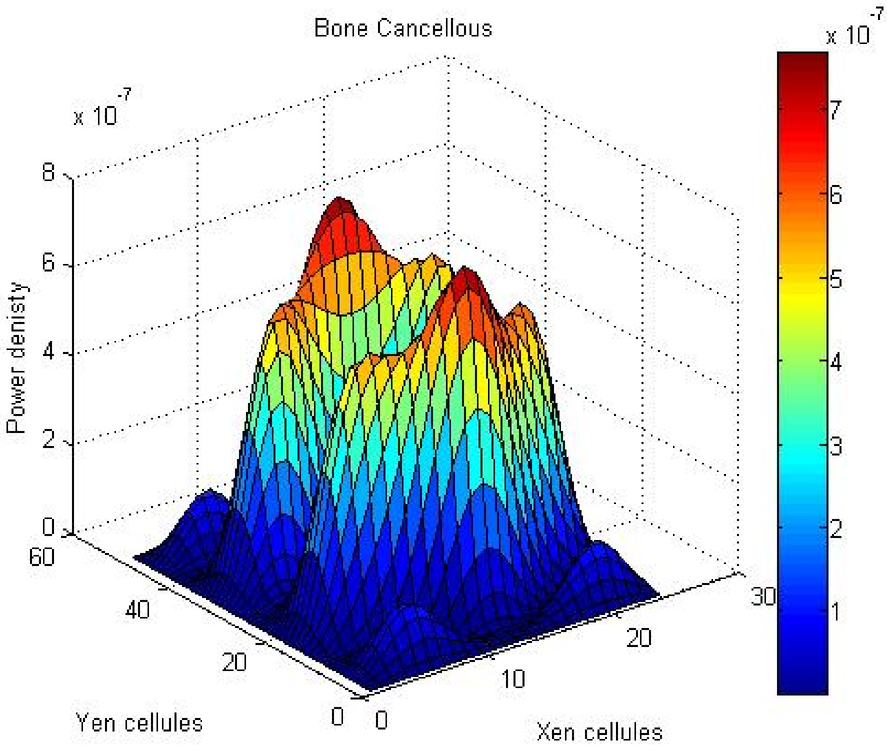


Fig 4.34 Relation between power density in bone cancellous and time steps through human body at distance 13m

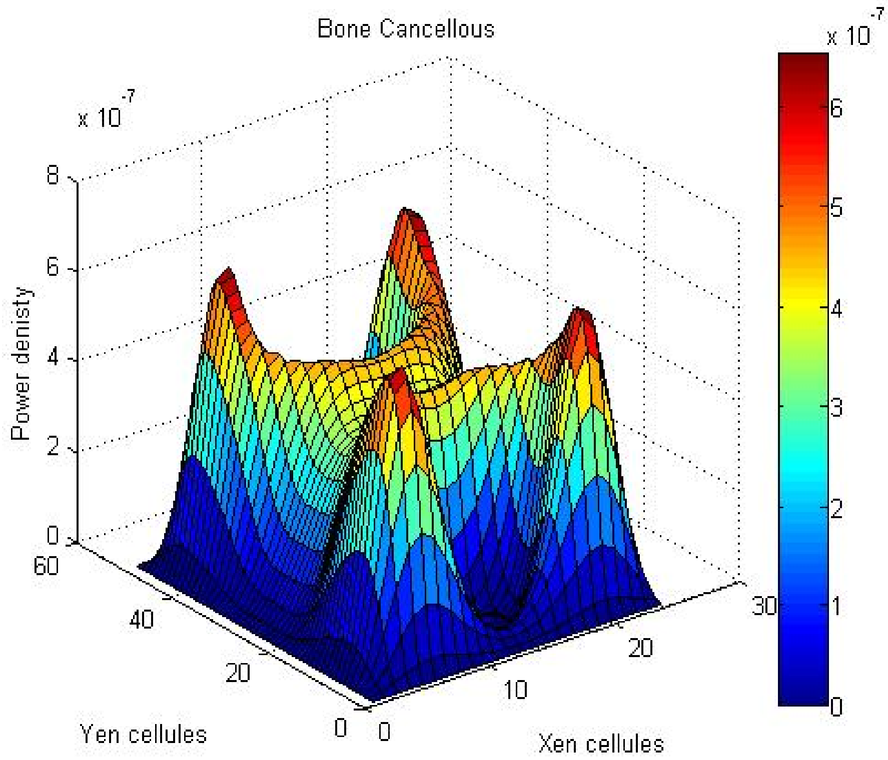


Fig 4.35 Relation between power density in bone cancellous and time steps through human body at distance 15m.

Fig 4.33,4.34,4.35 compare the power density inside bone at three different distance

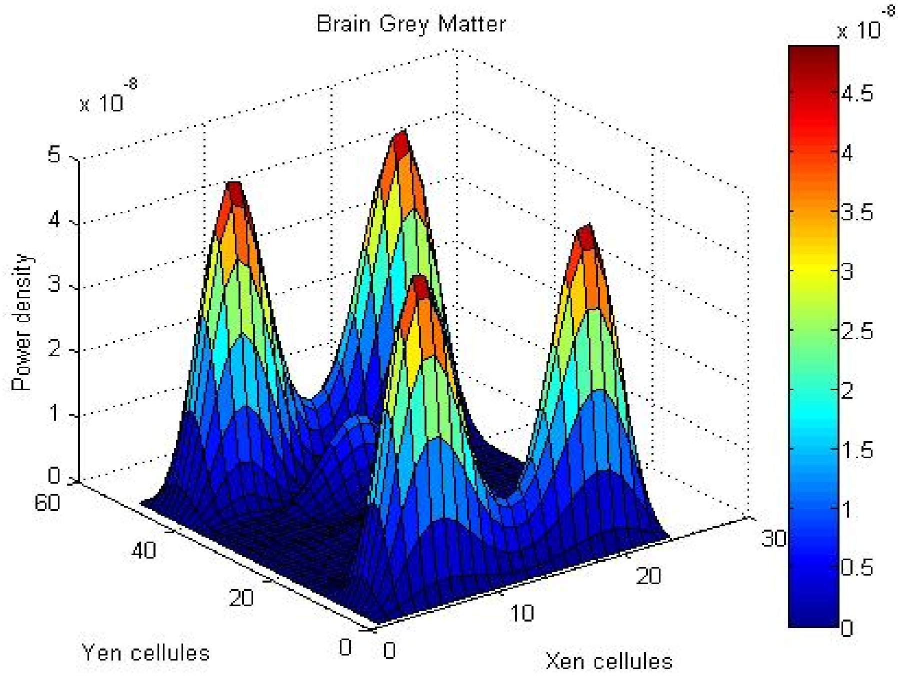


Fig 4.36 Relation between power density in brain grey matter and time steps through human body at distance 11m

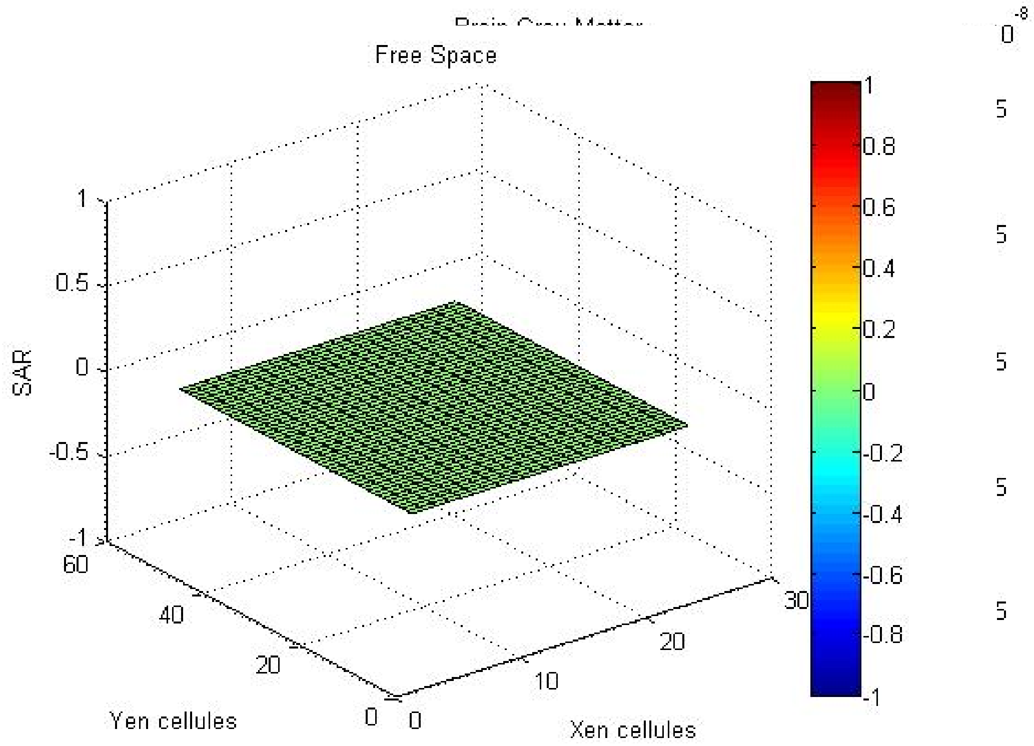


Fig.4.37 Relation between power density in brain grey matter and time steps through human body at distance 13m**.**

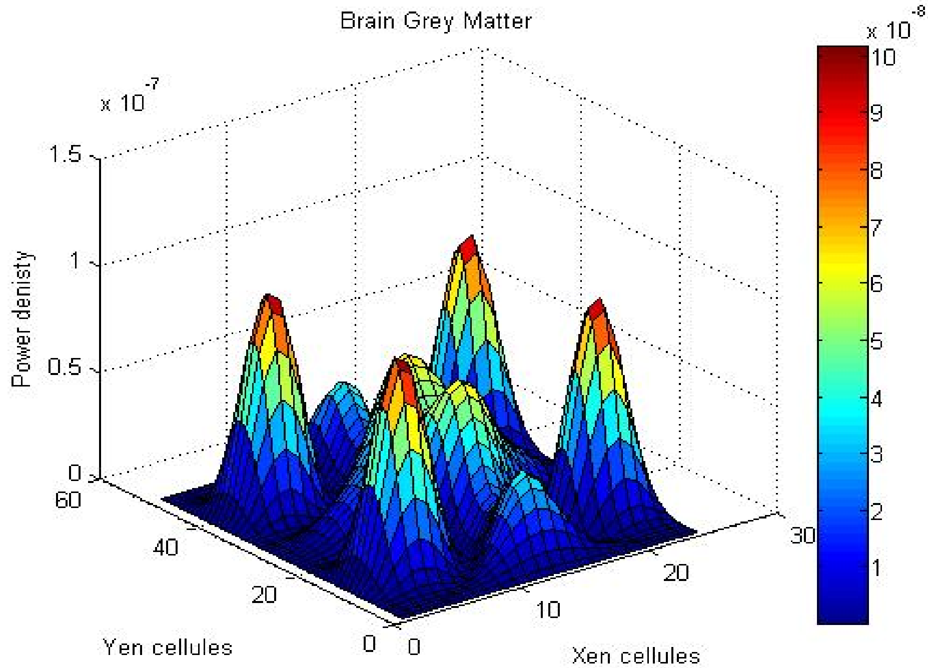


Fig 4.38 Relation between power density in brain grey matter and time steps through human body at distance 15m.

Fig 4.36,4.37,4.38 compare the power density inside brain at three different distance

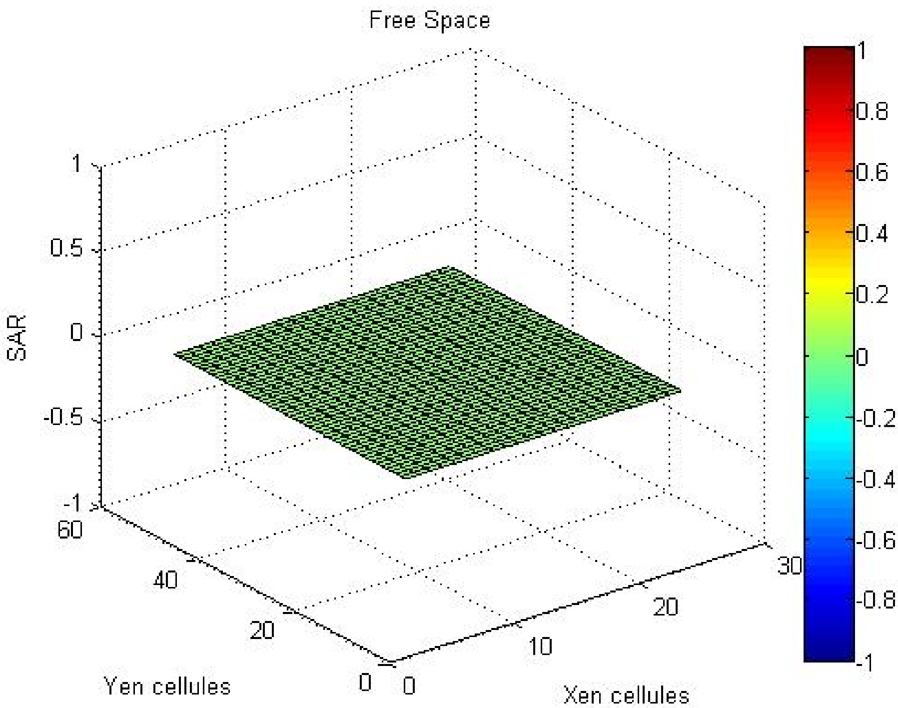


Fig 4.39 Relation between SAR in free space and time steps through human body at distance 11m,13m and 15m

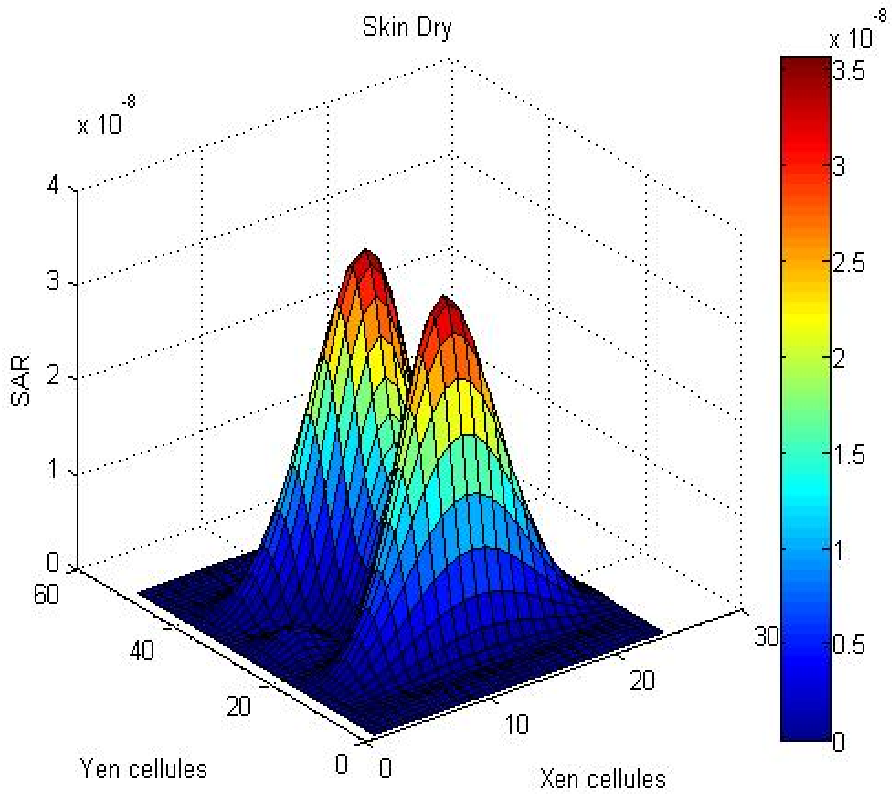


Fig 4.40 Relation between SAR in skin dry and time steps through human body at distance 11m.

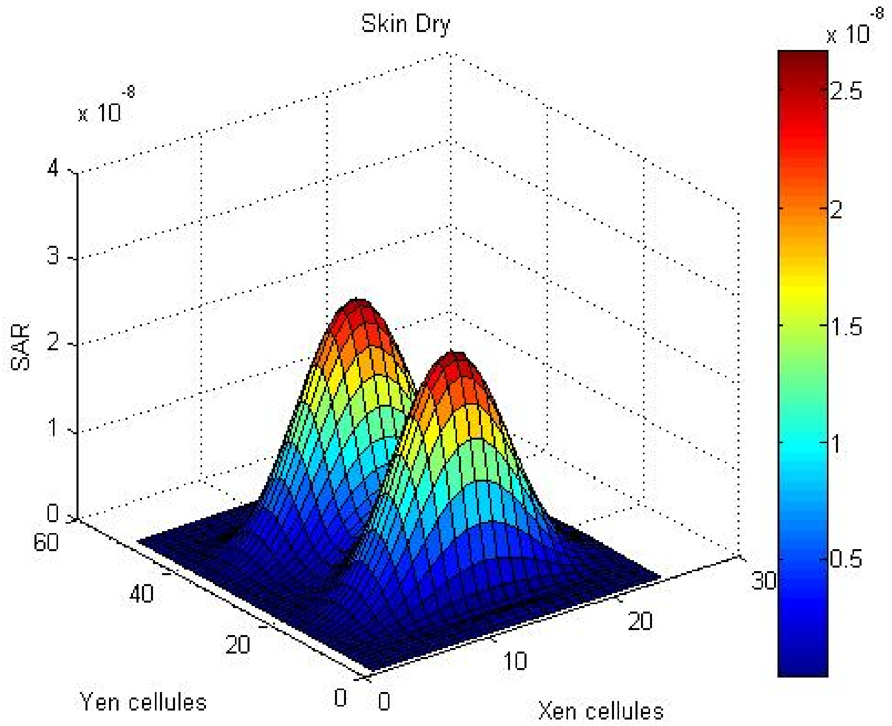


Fig 4.41 Relation between SAR in skin dry and time steps through human body at distance 13m.

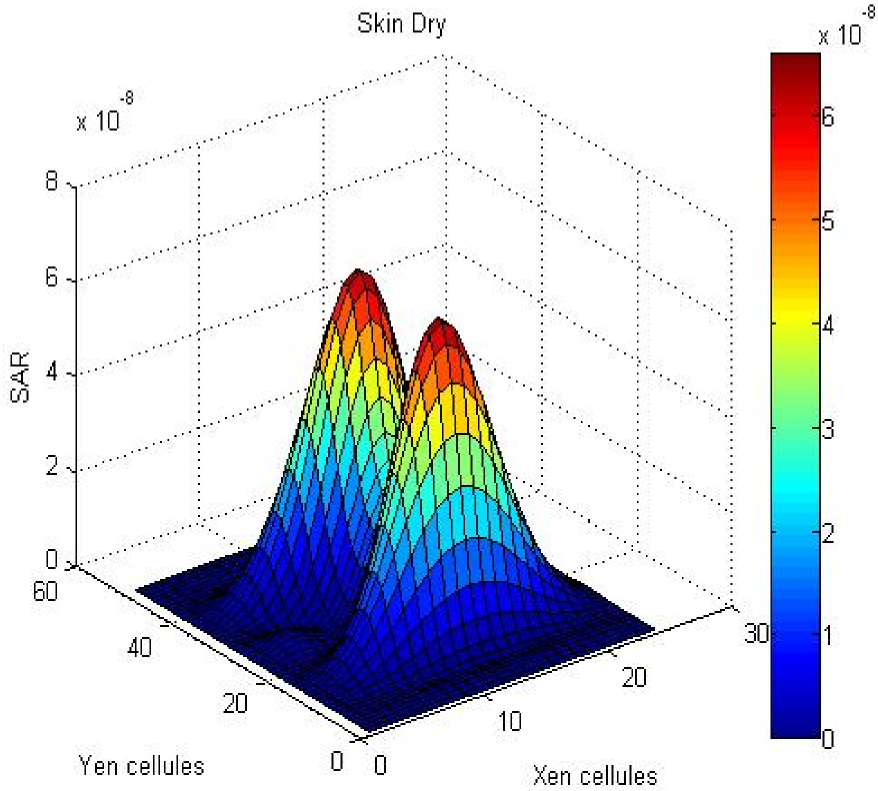


Fig 4.42 Relation between SAR in skin dry and time steps through human body at distance 15m.

Fig 4.40,4.41,4.42 compare the SAR inside skin at three different distance

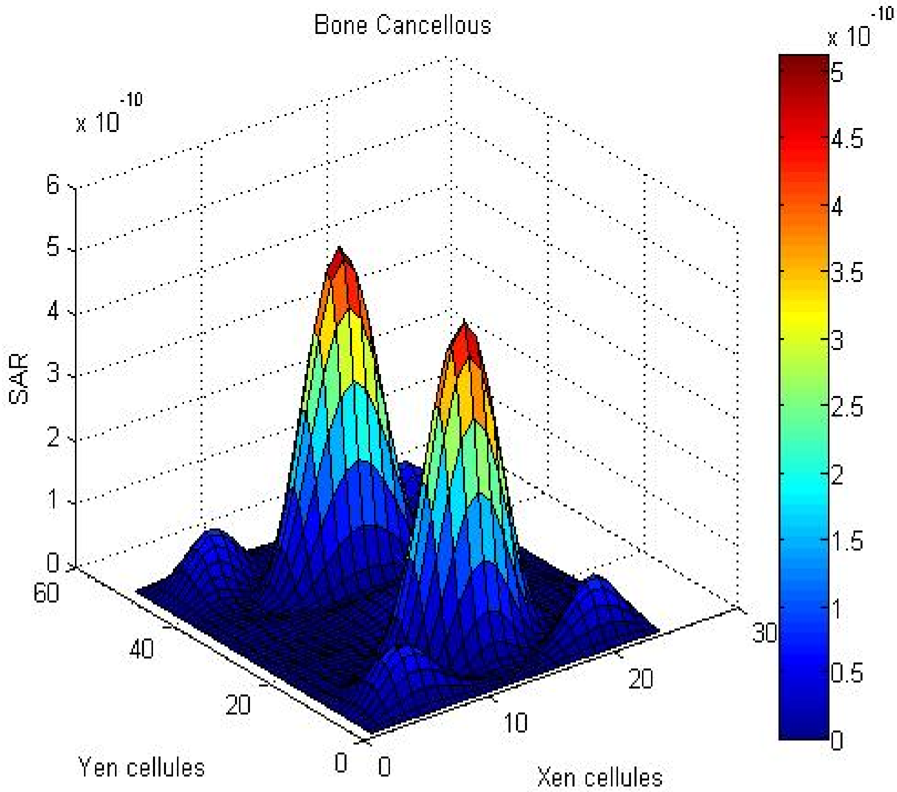


Fig 4.43 Relation between SAR bone cancellous and time steps through human body at distance 11m.

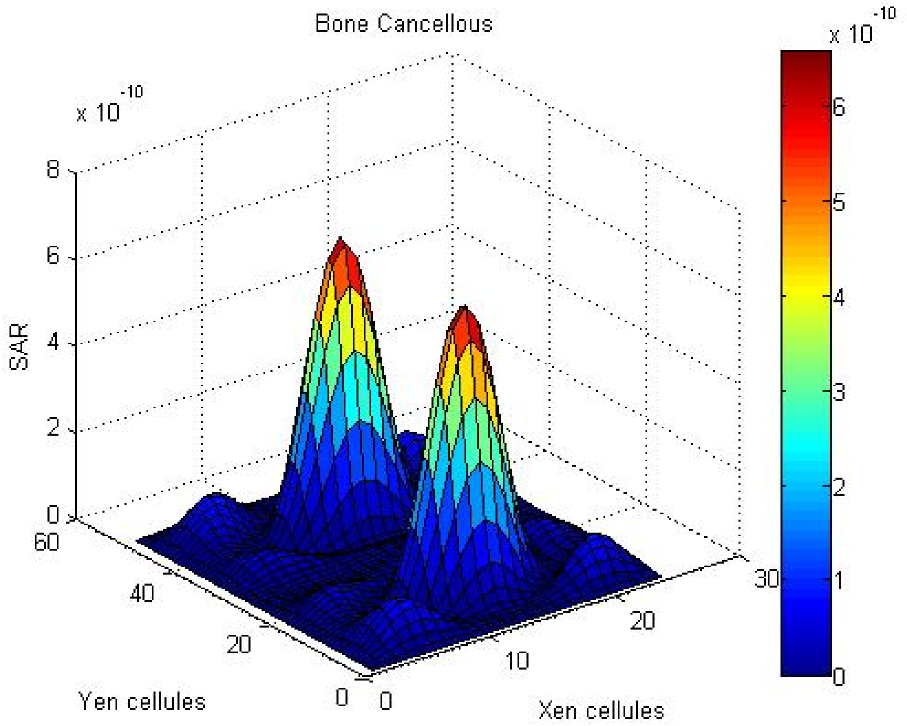


Fig 4.44 Relation between SAR bone cancellous and time steps through human body at distance 13m.

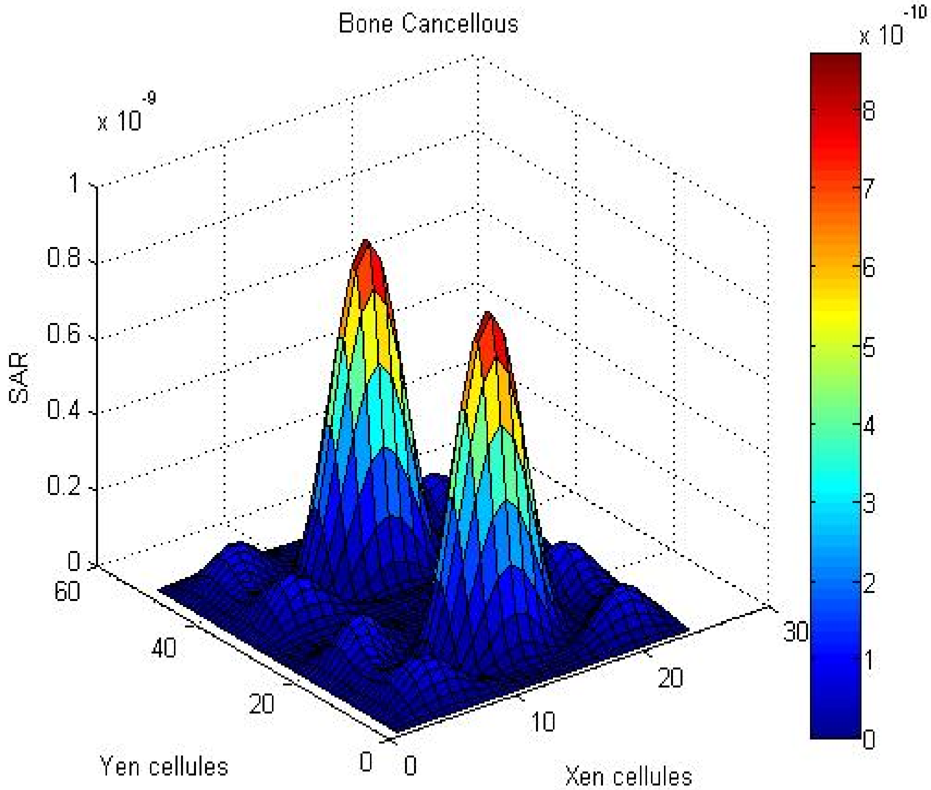


Fig 4.45 Relation between SAR bone cancellous and time steps through human body at distance 15m.

Fig 4.43,4.44,4.45 compare the SAR inside bone at three different distance

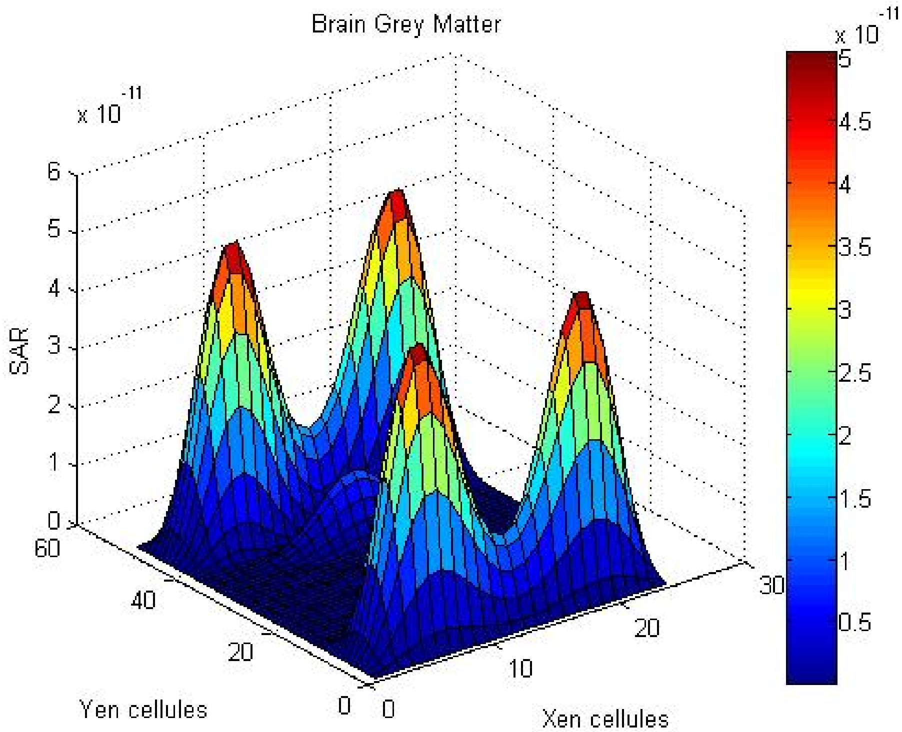


Fig 4.46 Relation between power SAR bone cancellous and time steps through human body at distance 11m.

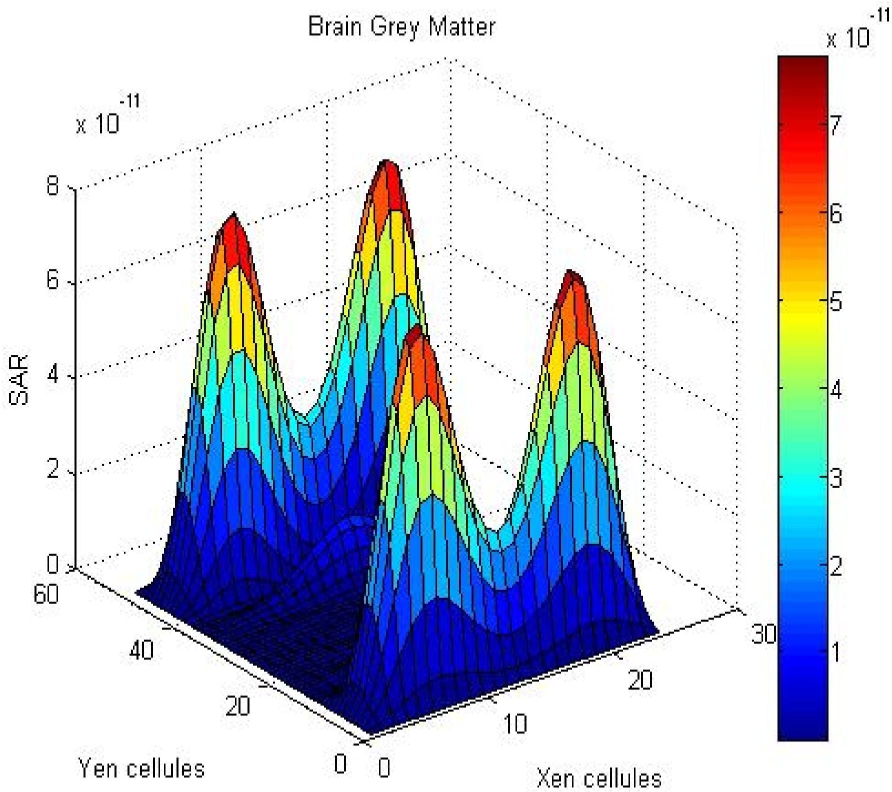


Fig 4.47Relation between power SAR bone cancellous and time steps through human body at distance 13m.

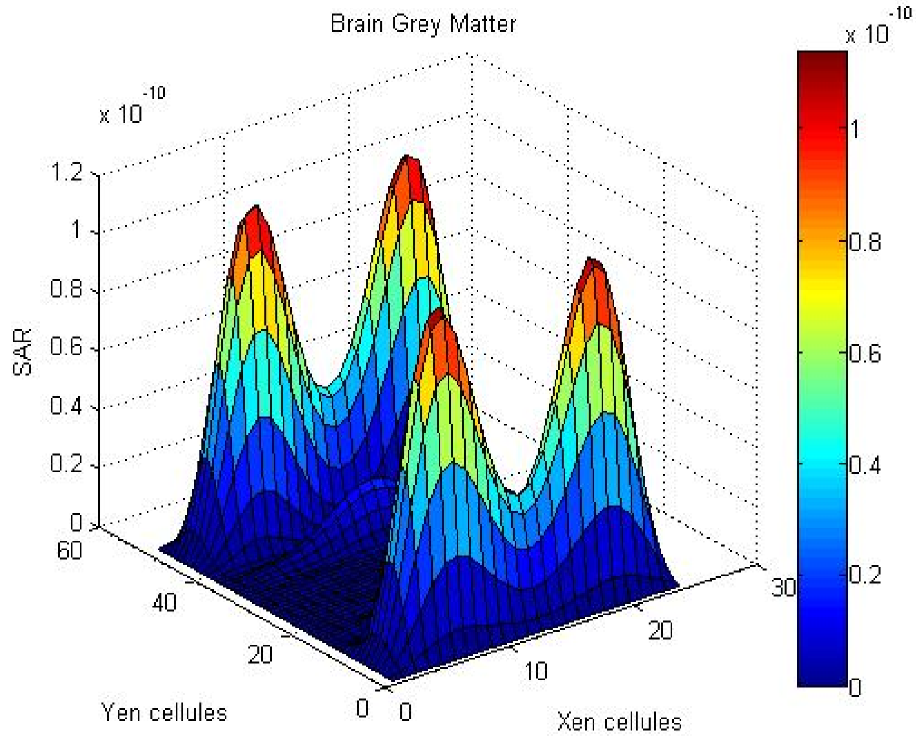


Fig 4.48 Relation between power SAR bone cancellous and time steps through human body at distance15m.

Fig 4.46,4.47,4.48 compare the SAR inside brain at three different distance

4.5 Discussion

4.5.1 One dimension simulation with the FDTD

An electromagnetic pulse is radiated from a source located in free space , but when the pulse strikes the human body interface. Notice that the wave propagates more slowly, and the pulse length is shorter, skin amplitude decrease, bone cancellous amplitude is also decrease and pulse amplitude will arrive zero at brain grey matter.

Figures 4.1,4.5,4.9 show the electric signal distribution at various layers obtained inside the human head model in XY plane at frequency 900MHz from the figure ,it is seen Bone tissues until decays at brain tissue.

Power density

Figures 4.3,4.7,4.10 show that Power density is zero in free space and increases to maximum at skin and decrease in bone and finally reached zero in brain.

That's mean power density distribution at human head layers have higher values in skin and bone and lower values in the core of the head "brain".

SAR

The relation between SAR an time step show that it increases from zero at free space ,at skin and decrease gain at bone until back to zero again in brain grey matter.

Fig. 4.8 shows SAR distribution at human head layers (skin, bone, and brain), which have higher values in outer section of head consisting of skin and bone that because they nearer to the antenna source. On the side it have lower values on the core region of head which represent by bone.

4.5.2 Three dimension simulation with FDTD

Figures 4.15,4.16,4.17 show the Electric z in third dimensions where strength pulse equal and decrees with distance in free space.
Figures 4.18,4.19,4.20 show the Electric z in third dimensions where strength pulse inside skin is decrease, when the pulse strikes the human body interface.
Figures 4.21,4.22,4.23 show the Electric z in third dimensions inside bone where strength signal is decrease than skin.
Figures 4.24,4.25,4.26 show the Electric z in third dimensions inside brain where strength signal around zero.

A large amount of energy transfer from antenna to head but because there mismatching between free space region and skin most of the signal reflected and some of it transmitted ,also we have the same principle between skin-bone and bone-brain as shown in the figures from free space to brain.

SAR

Figures 4.40,4.41,4.42 show the SAR in third dimensions
Figures 4.43,4.44,4.45 show the SAR in third dimensions inside skin where strength signal is decrease.
Figures 4.46,4.47,4.48 show the SAR in third dimensions inside bone where strength signal is more decrease
Figures 4.49,4.50,4.51 show the SAR in third dimensions inside brain where strength signal equal approximately zero

shows that power absorbed by skin have maximum values comparing to the value in bone as illustrated in bone and core of the head in brain figures, that come from the fact that SAR have linear relation with electric field and conductivity which the highest value in the skin as illustrated in brain figures. also SAR have inversed linear relation with mass density which have the highest value in the brain.

Power density

Figures 4.27,4.28,4.29 show the power density in third dimensions where strength pulse equals zero.
Figures 4.30,4.31,4.32 show the power density in third dimensions inside skin brain where strength signal around zero.
Figures 4.33,4.34,4.35 show the power density in third dimensions inside bone where strength signal is decrees than skin.

Figures 4.36,4.37,4.38 show the power density in third dimensions inside bone where strength signal equal approximately zero.

So power density will have the same response of SAR with different in the amplitude that because its part of SAR function.

CHAPTER FIVE

Discussion and Conclusion

5.1 Results:

The effect of electromagnetic waves have been examined concerning the one dimensions, two dimension, and three dimensions using Matlab software. Through simulating electromagnetic waves emitting from antenna about 30 cm away from human's head, the behavior of the wave from the moment of emission to the moment of infiltrating the scalp then the brain is examined. Following that, the researcher identifies the absorption rate in each single layer (skin, bone, and the brain) with the following findings: the highest level of absorption takes place right in the skin layer and then the brain layer given the biological structure of the cells.

The energy density emitted from the transmission stations and the human capacity is also studied.

5.1.1 One dimension simulation with the FDTD method

Electric field in x direction

Fig.4.1 shows the electric signal distribution at various layers obtained inside the human head model in XY plane at frequency 900MHz from the figure, it is seen Bone tissues until decays at brain tissue.

Power density

Fig. 4.3 shows power density distribution at human head layers, which have higher values in skin and bone and lower values in the core of the head "brain"

SAR

Fig. 4.4 shows SAR distribution at human head layers (skin, bone, and brain), which have higher values in outer section of head consisting of skin and bone that because they nearer to the antenna source. On the side it have lower values on the core region of head which represent by bone

5.1.2 Three dimension simulation with the FDTD method

Electric field in x direction

A large amount of energy transfer from antenna to head but because there mismatching between free space region and skin most of the signal reflected and some of it transmitted ,also we have the same principle between skin-bone and bone-brain as shown in the figures from Fig. 4.8 to Fig.4.20.

SAR

Fig 4.22 shows that power absorbed by skin have maximum values comparing to the value in bone as illustrated in fig. 4.23 and core of the head in fig 4.24, that come from the fact that SAR have linear relation with electric field and conductivity which the highest value in the skin as illustrated in Fig 4.8.also SAR have inversed linear relation with mass density which have the highest value in the brain.

Power density

Power density will have the same response of SAR with different in the amplitude that because its part of SAR function

5.2 Conclusion

The evaluation of human exposure to new telecommunication systems, which are becoming more and more widespread, has become an important issue. In fact, these new systems usually operate a rather complex environment where many field sources and scattering objects are present. In this situation, accurate investigations are needed to assess if human exposure can give rise to health risks and to verify if existing protection standards are still adequate.

In this study, the exposure of human head to the electromagnetic waves radiated by abase station antenna.the exposure has been analyzed coupling the FDTD method and with using matlab program.

In analytical assumption, three-layered structure representing simplified model of human body tissue irradiated by mobile phone base station, is investigated. The layers represent the skin, bone and brain.

FDTD is used to study the distribution of EM field in the body tissue, the absorbent power, and SAR distribution. it is found that the fields penetrates the skin and attenuates rapidly till they reach zero at the organs layer. Absorbent power and SAR have maximum values at the skin layer.

5.3 Future work

Throughout this study, the researcher examines the effect resulting from the GSM 900MHz sector antenna in the wireless services. It is the hope of the researcher to present an a noticeable advancement in the study of the effect of the fourth generation electromagnetic antenna in the wireless services. It is also the hope of the researcher to find ways to reduce the risks resulting from the frequencies emitted from transmission stations in wireless services.

Study the effect of EM waves produced from mobile phones base station on life tissue by using rate as experimental study.

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