The Distribution of the Heat Produced by Electromagnetic Fields on Human Head

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Abstract—Examination of the effect of electromagnetic fields on biological tissues, and studies are undertaken in recent years to understand. Difficult to do experiments on human beings because, in most models used in these studies. Biological tissues, by simulating the electromagnetic waves formed by the textures of various influences on the investigation. In this study, the human head is modeled as a global and various biological structures (brain, bone and skin) with different dielectric constant and conductivity are expressed in concentric spheres. Electromagnetic waves generated by a circular antenna is close to human head formed by the textures on the temperature profiles, and different head models used in mobile communications using frequencies of 900 MHz and 1800 MHz were obtained.

Keywords- Electromagnetic fields; biological tissues; frequency; human head; electrical properties.

I. INTRODUCTION

With the increasing use of magnetic fields in recent five decades, the health effects of nonionized electromagnetic radiation are an important investigation subject. While the magnetic fields are well known, it is difficult to investigate the health effects of radiation, because of the complex metabolism of human body. However, by the experimental and theoretical studies, a lot of significant health effects of magnetic fields have been discovered. But there are probabilities that can have much more adverse health effects. The experimental studies on human tissue exposed to electromagnetic fields are impossible. The experimental studies continue on laboratory animals and the results are explained for humans. But the explained results for humans include indirect knowledge. Because of this reason, preparing the tissue equivalent liquids to analyze expected thermal effects in human tissues exposed to electromagnetic fields is accepted as an important approach. The electrical properties of the equivalent liquid comply with biological tissue, aspect of conductivity and permittivity.

Electromagnetic wave frequencies are emitted by many natural and man made sources and is a fundamental aspect of our lives. Industrial applications, home appliances, communication devices, some natural phenomena, energy generation and transmission systems are created by the nonthermal effects of electromagnetic fields on living beings and is caused by heat. Biological environments and different models of different frequency electromagnetic fields, expressed by many researchers studied the distribution of the heat produced by the human head [1-9]. There is a necessity of tissue equivalent models in research of electromagnetic effects in biologic tissues. Recently, many kinds of tissue models depend on the different aim were proposed. So many studies were carried on the interaction of human head and cellular phone. The most of them are related to numerical models. Owing to difficulty of study on human body, simulation of human tissues is required.

Environmental factors can increase or decrease the effects of electromagnetic radiation on living things. These factors conductivity of soil or the environment, there are metal implants, electromagnetic field reducing material (ferromagnetic material), the field of metal or nonmetal objects, ambient temperature and humidity can be listed as. For example, the biological structure is exposed to radiofrequency radiation exposure to this environment, there are reflective materials can increase the value. All work is carried out in an environment of high temperature operation may be affected by temperature data. Than the ambient temperature or humidity, radiation, biological effects of radiofrequency may be increasing or accelerating. Areas may be reduced with the use of ferromagnetic materials. If the structure of biological metal prosthesis radiofrequency field due to the reflection of the value of metals increases in some regions, some regions may serve to reduce the area [10].

Production and distribution of electricity in case of extremely low frequency of 50 Hz alternating current is carried most of the vehicles running at this frequency. Domestic television, oven, dishwasher, washing machine, hair dryer and electric blanket, as well as in industry and medicine, many vehicles used in the electromagnetic field intensities in the different spreads. Which is one of the two components of the electromagnetic field in the magnetic field, unlike many other weaknesses in the electrical field penetrates deep into the body.
Deep within the body’s electromagnetic field strength of the field strength is almost same as the outside. Therefore, more emphasis on the effects of electromagnetic field component of the magnetic field [11]. Magnetic field effect on biological systems with different methods and purposes, among the issues examined are a few hundred years, researchers report that biological systems are affected by magnetic fields. Which frequencies of magnetic fields, which is the threshold of severity and potential mechanisms of action are still trying to influence [9, 12, 13].

Introduced in recent years and use very different frequencies of electromagnetic field caused by pollution emitting vehicles, the first time can be harmful to human health has been raised by epidemiologic studies. High voltage lines caused leukemia in children exposed to extremely low frequency electromagnetic field is the relationship between the incidence [14, 15]. The relationship between electromagnetic field exposures in adult cancers may have also been determined [16]. Cellular and embryological research, the biological processes are influenced by magnetic fields. 0.2-20 mT magnetic field, even such low levels, and a variety of changing the rate of cell division slow down the speed of the division in tissue cultures. In studies on nerve cells in particular, low electrical conductivity and the low frequency magnetic field induced mitotic cell divisions reported decreases [17]. Magnetic fields, such as muscle and nerve tissues in the inducible changes in the cell membrane ionic currents. Nerve cells of the 10 mT magnetic field intensity, ionic currents and action potential impact on changing the cell membrane potential prevent the formation [18].

Forming of equivalent liquids of human biological tissues is required for electromagnetic dosimetry and hyperthermia studies, because the experimental studies on humans are possible. Required tissue equivalent materials can be obtained using mixtures of some chemical materials. Permittivity and equivalent conductivity change depending on frequency, conductivity increases. Data considerably shows changes depending on a lot of parameters as measurement method and temperature. Tissue models used for tests must be approximate device operation frequency. Body tissues are classified by the rate of included water. The tissues that have high water rate as muscle and skin absorb radiofrequency energy more than the tissues that have low water rate as fat, bone and cranium. The electrical properties of tissues in radiofrequency and microwave frequencies are characterized by permittivity and conductivity at the body temperature that is approximately 37 °C. These tissue parameters are sensitive to temperature.

Electromagnetic waves have the effect of two types of thermal and nonthermal. Level of electromagnetic field application of biological structures that can cause a temperature rise, if the tissue temperature rise to the first, and then brings the temperature rise due to biological changes. This effect is called thermal effects [19]. An increase in temperature may occur depending on the cells may die, or mutagenesis. That caused the death of the cells was determined as the reference temperature 43 °C. Thermal effects, the object to interact with electromagnetic waves, increasing the molecular motion and is due to a rise in temperature due to friction in the system. Dielectric properties are an important parameter [20]. Ionic, molecular, dipole, or electrically charged particles of colloidal particles in motion are always changing areas. Some of the reflected radiofrequency energy when it strikes the surface of the body, by entering a part is absorbed into the body. Electromagnetic wave speed varies depending on the tissue electrical properties over the environment. An electric dipole field which, according to the effect that the general direction of the field, creates a layout. If the area is variable, dipole, which makes the influence of oscillation. This leads to the increase in oscillation to the heat arising from the energy. Increase in frequency, oscillation rate increases and increased losses due to friction occurs when the increase in frequency for the same results. Warm up, the frequency and severity of the increase. Forces act upon them at the effect of charged particles in electric fields, this also leads to changes in the system. Tries out the electric field after a certain time, the system is observed to have become old. This interim period is called the relaxation time. Relaxation time; particle load, and temperature dependent properties of the environment. If you do not increase the effect of heat applied to the area and hence the need to run the body’s heat regulation mechanism will not stay, but it also causes changes in the biological radiofrequency is defined as the nonthermal effects [13, 20]. In addition, activation of nerve and muscle cells and in the event of nonthermal interaction with the observed microwave hearing. Nonthermal mechanisms, the size of the radiofrequency photon energy, radiofrequency stimulation of the areas with the molecular vibration and changes in membrane potential, depending on the place [21].

In this article, the 900 MHz and 1800 MHz frequencies used in mobile communication antenna loop electromagnetic waves produced by the structure of the complex dielectric structure of three concentric spheres with a radius of 10 cm, the heat produced by the profiles were evaluated on a human head.

II. ELECTROMAGNETIC FIELD RADIATION

Earth’s magnetic field, the liquid outer core of the world is caused by convection currents. Convection in the outer movements of the nucleus, over time, creates a magnetic field. This is thought to occur since the formation of convective movements in the world. Earth’s core in the solid, nonthermal motion of liquid iron and creates its own magnetic fields. Sufficient force and displacement of atoms in an orderly manner and steer the world in the shell because it causes permanent magnetization is created a permanent magnetization. Surrounded by a large magnetic field around the world think of as a global magnet.

A moving electric charge produces time varying electric and magnetic fields. According to Faraday’s law of induction electric field leads to a change in the magnetic field, on the contrary, the variable magnetic field generates an electric field. Accordingly, load acting on the electric and magnetic fields affect each other constantly, the fluctuations in these areas; the load is spread outward as an electromagnetic wave.
Electromagnetic energy in biological structures is an important parameter affecting the structure reinforced the position of the electric field vector in space. The polarization of electromagnetic fields in linear, circular, elliptical, or may be random. The structure of the electric field vector of linear polarized wave does not change throughout the motion [22]. Field and wave structures and the surrounding objects depend on the distance from source. Some objects, depending on the dielectric properties of electromagnetic waves are reflected, diffracted, scattered or absorbed. The reflected or scattered waves may increase the severity of the regional area.

The dielectric properties of a biological tissue are a measure of the interaction of electromagnetic radiation with its constituents at the cellular and molecular level. The mechanisms of interaction are well understood, the theory underpinned by experimental data and forming part of a well established classical theory of bioelectrical phenomena [23, 24].

Electromagnetic waves of all frequencies, wavelengths, or energies of the electromagnetic spectrum sorted according to the form (Fig. 1). Electromagnetic fields are located in the interaction with biological organisms, depends on the amount of energy and frequency. For some frequencies the human body is not transparent to others. For example, sunlight only “skin-level” while the magnetic fields penetrate the human body is capable of switching and largely absorbed.

Electromagnetic fields distributions (as shown in Fig. 2 and Fig. 3) in biological tissue depend on electrical properties of the tissue (conductivity and permittivity).

Electromagnetic wave in a medium or tissue to another medium or a portion of the reflective wave is passing through the tissue, or tissue is a part of the other media. Electromagnetic radiation in a tissue and other tissues in a tissue transfer impedance (electrical ε and magnetic permeability μ, conductivity σ) depends on. Touch the dielectric constant, conductivity parameters describing the structure of tissues such as the spread of biological materials, electromagnetic fields and the energy absorbed by the biological structure is important announcement. The higher the dielectric constant of the tissue, the less conductive tissue. Affect the biological structure of the electromagnetic wave energy absorbed in the angle of incidence. Dielectric constant is its own tissues. Dielectric constant decreases, the tissues become more conductive tissues. Tissues showed increasing frequency electromagnetic fields, electrical conductivity and permeability vary [25].

The dielectric properties of materials are obtained from their measured complex relative permittivity ε which, being a relative quantity, has no unit. It is expressed as \( \varepsilon = \varepsilon' - j\varepsilon'' \) where \( \varepsilon' \) is the relative permittivity, measure of the charge displacement and consequent energy stored in the material, and \( \varepsilon'' \) is the out of phase loss factor, a measure of the electrical energy dissipated. In a perfect dielectric material, losses are due to displacement currents and the loss factor \( \varepsilon'' \) can be expressed in terms of a displacement electrical conductivity \( \sigma_d \). Dielectrics in an electric field that can move with the free ads are put into effect when the field is almost negligible loads. So, a current does not pass through dielectrics.

In biological material, an external field will induce ionic as well as displacement currents, ionic currents and corresponding losses are proportionate with the material ionic conductivity \( \sigma_i \). The total conductivity of the material \( \sigma \) is given by \( \sigma = \sigma_d + \sigma_i \) and is related to the loss factor through the expression \( \varepsilon'' = \sigma / \varepsilon_0 \omega \). In practice it is only possible to measure the total conductivity \( \sigma \). Where present \( \sigma_i \), which is frequency independent, can only be obtain from dielectric spectral analysis. In the loss factor expression, \( \varepsilon_0 \) is the permittivity of free space and \( \omega \) the angular frequency of the field. The SI unit of conductivity is siemens per metre (S/m) which presumes that, in the above expression, \( \varepsilon_0 \) is expressed in farads per metre (F/m) and \( \omega \) in radians per second. The dielectric properties are determined as \( \varepsilon' \) and \( \varepsilon'' \) values, or \( \varepsilon' \) and \( \sigma \) values, as a function of frequency. In this report, \( \varepsilon' \) will be referred to as permittivity, and \( \sigma \) as conductivity expressed in S/m.
Scientific study of magnetic field vector is applied to the live environment, or the target tissue is important to know the direction and magnitude. Homogeneous region of this field is applied and the parameters are not changed during the experimental period are also needed to be sure. This type of scientific research in order to create a magnetic field, the Helmholtz coil is frequently used tools. Helmholtz coil mechanism; against each other in a suitable distance between two parallel circular current source of flux density will occur when the magnetic field so that very little will change and is assumed to be homogeneous [6].

High frequency electromagnetic waves are modulated to carry information of different methods. These methods can be summarized as follows:

- Amplitude Modulation: Amplitude is provided with a replacement. The average field intensity modulated signal is amplitude modulated fields depend on the structure and have the same peak amplitude value may be less than a sinusoidal wave.
- Pulse Modulation: Amplitude modulation is a type of special. Discrete source of the signal generated by on and off (for example: mobile phones, radars, base stations...).
- Frequency Modulation: Changing the frequency of the signal provided by the carrier. Average field strength with the same peak amplitude sinusoidal wave with the same value.

Mobile phone antennas very close to the very high measured values. Despite the high field strengths compared to the standards in this area is not far from a homogeneous area that is properly the observed effect of eddy current or heat is not expected to form. Only small parts of the body (ears, etc.) may increase exposure [26].

Biological Tissue

Tissues containing a high percentage of water vary very little impedance at low frequencies, at frequencies exceeding 1 GHz shows a very rapid change. This rapid change in the conductivity of the water to be transformed at high frequencies is the result of very severe. Water with a high content of cell membranes in tissues throughout the interfacial polarization due to a marked increase in conductivity at high frequencies and the decrease in dielectric constant. With low dielectric constants and conductivity of the water content of tissues is low compared to those with high water rates. Exposed to very low and very high frequency electromagnetic fields, the electrical properties of biological tissues, depending on the frequency and rate of exchange are an important cause of the tap water origins from the structure of the membrane capacitance [27].

While permittivity decreases to about 0.5% °C⁻¹ rate in the tissues that have high water level, conductivity increases to about 2% °C⁻¹ rate [5]. Equivalent tissues used specific absorption rate (SAR) investigations are generally similar. These tissues are prepared by equivalent tissue properties at the room temperature. There are several methods to prepare equivalent mixtures of the tissues that have high water rate as brain and muscle. One is equivalent tissue mixture that is like opaque jell (includes: water, salt, polyethylene powder and gelling) and second is formed by mixture of water, sugar, salt and hydroxyethylcellulose (HEC) that is related to fluidity of compound.

Biological Effects of Reactive Oxygen Metabolites and Cellular Damage

Free radicals cause cellular damage by affecting cellular structures (Fig. 4) [28]. Free radicals have very short lifetimes but can react with almost any molecule, like proteins, lipids, carbohydrates and DNA, in their vicinity, etc. Amino acids like prolin, histidin, arginin, cystein and methionine are prone to radical damage. Oxidation of these aminoacids causes the disintegration of proteins, formation of cross bonds, and aggregation.

Hazards of free radicals in cells and tissues can be listed as follows:

- DNA damage,
- Disintegration of coenzymes with nucleotid structure,
- Breakdown of the structure and functions of enzymes that are dependent on thiols, change in the thiol/sulphide ratio of the cell environment,
- Formation covalent bond with lipids and proteins,
- Changes in enzyme activities and lipid metabolism,
- Breakdown of mucopolysakkarides,
- Damage of proteins and increase in protein turnover,
- Lipid per oxidation, change of membrane structure and function,
- Damage of cell proteins, failure in transport mechanisms,
• Aggregation of steroid and age pigments,
• Aterofibrotic changes in capillaries as a result of failure in oxido-reduction reactions in collagen and elastin.

Affects the Blood-Brain Barrier

Radiofrequency and microwave applications of local cerebral blood flow increased in the brains of rats, the increase in the available studies on the blood-brain barrier permeability induced by the exchange. Blood-brain barrier studies, investigations can be done in many methods, which are made in immunohistochemical studies, the observations made with light microscopy, electron microscopy, studies of radioactivity. A study of the dielectric properties of human skin. 300 kHz frequency ultrasound in a clinical study conducted in Germany demonstrated the blood-brain barrier could be exchanged [29]. 2450 MHz, 0.5 to 2600 mW/cm² meters (0.04-200 mW/g), the regions with the exception of microwaves normally pass the blood-brain barrier is not effective in other regions, the value of the 3000 mW/cm² to (240 mW/g) to remove from being out of the brain temperature of 43 °C in case of Evans Blue leakage in the cortex, hippocampus, midbrain regions such as the current was observed [30]. 2800 MHz, 15 mW/cm² pulsed fields 5, 15, 30, 45 or 60 minutes, 500 pulses/sec and 2 µs as the duration of exposure to microwave pulse is applied to rats in thickness than the control group was observed to increase local cerebral blood flow [31]. 2450 MHz, 20 mW/cm² and 65 mW/cm² field values 30 minutes, 90 minutes or 180 minutes of exposure and temperature applied to the outer cortex, hypothalamus, cerebellum, medulla, and temperatures were measured in the colon. Field application of the control group and the outside temperature has led to different values of the high temperature. Long term exposure to mobile phones radiation, such as 2 year event with the blood-brain barrier permeability of albumin in a study that examined under the light microscope, the permeability of the short term applications, such as 60 minutes if the blood-brain barrier permeability changes, but at 2 years was observed that although minimale [32].

The Equivalent Tissue of Human Brain and Muscle

Muscle tissue forms most of the human body. The properties of brain tissue are similar to muscle system. Most of Brain equivalent liquid must have average of electrical properties of these two materials. Dielectric properties of the prepared materials can be reached to desired values. NaCl generally effects material conductivity. Water rate is more effective on dielectric. Limiting of these two materials is independent each other.

To increase fluidity of a lot of water based mixture is used HEC. This material provide fluidity in a large range and it easily mix with water. Fluidity level of the mixture must enable easily moving of the used measurement probe. Because of this reason, liquid or semi liquid mixtures are required for temperature rise and distribution of electric field measurements. More intensive mixtures are obtained without changing of electrical properties, when amount of HEC increases. Another component of muscle materials is sodium chloride (NaCl) that is used to increase conductivity. Sugar is used to decrease conductivity. Bacteriacid used as another component is used to prevent decreasing polymer in bacterial effects. Brain equivalent liquid must have average of electrical properties of these two materials. Dielectric properties of the prepared materials can be reached to desired values. NaCl generally effects material conductivity. Water rate is more effective on dielectric. Limiting of these two materials is independent each other.

III. THE DISTRIBUTION OF THE HEAT

The ever increasing use of cellular phones and increasing number of associated base stations are becoming a widespread source of non ionizing electromagnetic radiation. The immediate biological effect of electromagnetic radiation is the generation of heat in the body and it is generally evident under high levels of electromagnetic energy. However, some biological effects are likely to occur even at low level electromagnetic fields. A global system for mobile communication (GSM) network is comprised of several portions: a mobile radio part, a subscriber information part, a radio network, a switching system and network intelligence (primarily databases), as given in Fig. 5 [36]. The purpose of a GSM base station is to transfer signals between mobile telephones and a network for mobile or normal telephony by means of radiofrequency electromagnetic fields. Since we focus on biological effects of electromagnetic radiation from base station antennas.

Figure 5. GSM components [36]
The electric field measurements were performed using the same type of instruments but this time electric field probe was located at 160 cm above ground. Variation of electric field level with increasing distance from the antennas mast is given in Fig. 6. Result of the measurement show that, at the street level, electric field levels emitted from base station antennas mounted on high masts are below current public exposure limits. Public exposure limits may be exceeded on rooftop antennas when the subject is inside the main beam and at 2-3 m vicinity of the antennas.

The test setup is a general purpose electromagnetic shielded chamber that is suitable to house laboratory animals. In this exposure environment, electromagnetic radiation of specific energy, frequency and wave form can be applied. The main element of the setup is a gigahertz transverse electromagnetic (GTEM) cell (see Fig. 7).

Figure 6. Variation of electric field level with increasing distance from the antenna mast [37]

![Figure 6](image6.png)

Figure 7. Experimental setup for the investigation of biological effects of electromagnetic fields [37]

GTEM cell is a radiated field generation and measurement device that has a single input/output port for electromagnetic immunity and emission test purposes. GTEM cell, in essence, is a transmission line terminated with 50 Ω load. The asymmetrical inner conductor (called “septum”) is designed to match the impedance of a tapered, rectangular wave guide cross section. The outer surface of the GTEM cell is made of metal sheets with an attenuation of around 60 dB at high frequency electromagnetic fields. Note that honeycomb wave guides are installed at the bottom of the GTEM cell for ventilation purposes. Electric field level is directly proportional to the amplitude of the voltage applied to the input port and inversely proportional with the septum height. In order to obtain increased field level with constant input power, cages that contain the test subjects are placed closer to the input port of the GTEM cell for the purpose of biological effect studies.

Some characteristics of GSM digital mobile communication system, frequency band is 890-960 MHz, in general. But base transceiver station downlink is 0.577 μsn. This reduces the average power to one-eighth. The resultant wave from is shown in Fig. 8 to help visualization.

![Figure 8](image8.png)

**Electromagnetic Formulation**

10 cm radius of the configuration used in this article brain, bone and skin of 5 mm thickness is three concentric spheres, the structure of the head by a circular antenna is stimulated with 900 MHz and 1800 MHz electromagnetic radiation. Head model parameters used the complex dielectric values in Table I and Table II. Where the layer radius of 100, 95, and 90 mm are for skin, bone and brain, respectively.

### Table I. Complex Dielectric Properties of Head Model [38]

<table>
<thead>
<tr>
<th>Layer/Tissue</th>
<th>ρ (kg/m³)</th>
<th>σ (S/m)</th>
<th>ε_r</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skin</td>
<td>1080</td>
<td>700</td>
<td>39.5</td>
</tr>
<tr>
<td>Bone (cortical)</td>
<td>1180</td>
<td>170</td>
<td>12.5</td>
</tr>
<tr>
<td>Brain (grey matter)</td>
<td>1050</td>
<td>1100</td>
<td>56.8</td>
</tr>
</tbody>
</table>

### Table II. Complex Dielectric Properties of Head Model [38]

<table>
<thead>
<tr>
<th>Layer/Tissue</th>
<th>ρ (kg/m³)</th>
<th>σ (S/m)</th>
<th>ε_r</th>
</tr>
</thead>
<tbody>
<tr>
<td>Skin</td>
<td>1080</td>
<td>900</td>
<td>38.2</td>
</tr>
<tr>
<td>Bone (cortical)</td>
<td>1180</td>
<td>290</td>
<td>12.0</td>
</tr>
<tr>
<td>Brain (grey matter)</td>
<td>1050</td>
<td>1500</td>
<td>51.8</td>
</tr>
</tbody>
</table>
A mathematical model was developed to calculate the electric field and temperature distribution within the human model [7]. To simplify the problem, the following assumptions were made; electromagnetic wave propagation is modeled in two dimensions over the y-z plane, in which waves and object interact proceeds in the open region, and the computational space is truncated by scattering boundary condition. The propagation of an electromagnetic wave is characterized by transverse electric fields.

The radial coordinate \( R \) at \( \theta \)-direction, \( R_{12} \) distance of the head relative to the center of a circular antenna positioned horizontally,

\[
R = [r\cos \theta - R_{12}]^2 + (r\sin \theta - a_1 \cos \phi)^2 + a_1^2 \sin^2 \phi]^1/2
\]

Where \((r, \theta, \phi)\) in the spheres of a point indicates the global coordinate. Method applied to a circular antenna of electromagnetic radiation in the dielectric structure is the polarization current density and electric current density [2]. These secondary sources of global air space zone within the total electric field inside the dielectric, and the scattering field is obtained by summing the electric field from the source. If the total electric field inside the dielectric structure with dielectric air gap between the global zone is located on the surface using the boundary conditions. Scattering field, are obtained by using multi-pole expansion of the multi-pole fields, scattering coefficients, using state space equations are solved by means of computer software. Total electric field, \( E_{r} \), with the help of dielectric heating in a building located by the formula below.

\[
P(r, \theta, \phi) = \sigma(r) [E_{r}(r, \theta, \phi)]^2 / 2
\]

900 MHz and 1800 MHz frequencies in different angles, the head of the radial temperature distribution of \( \theta \) detractors. \( \theta = 30^\circ \) to 900 MHz in the head from the center outward towards the high heat conductivity increases and reaches maximum at the junction of the brain, bone, bone with a low conductivity decreased, increased again observed that the skin is entered. All the structure of the dielectric maximum temperature, at the junction with the skin, brain, bone, is determined to occur in areas of areas of the head. Here are two things to consider when determining the temperature, radiation length and the size of the conductivity. Where \( \theta \) is large planes, in general, the heat values and the resulting radial axis shows the maximum temperature drop, the brain is hitting the middle of the sphere. However, moving away from the antenna center, i.e., the value of \( R_{12} \) increased heat causes values to fall. Especially when \( \theta = 0^\circ \) the maximum temperature is shifting toward the center of the dielectric structure. 900 MHz 1800 MHz radiation beam for comments also apply to a large extent, but in terms of absolute temperature values observed in 1800 MHz radiation lower heat produced. The reason for this, as shown in Table I and Table II, from 1800 MHz to 900 MHz conductivity of the layers, although larger than the spread due to the high frequency radiation is decisive as to whether exposure to more melting.

The heat transfer analysis is considered only in the human body domain, which does not include parts of the surrounding space as well as the dielectric shield. To reduce complexity of the problem, the following assumptions have been introduced:

- There is no phase change and mass transfer in the human model.
- The human tissues are biomaterial with constant thermal properties.
- There is no chemical reaction occurring within the human model.
- The initial temperature through the human model is uniform.

IV. DISCUSSION

Increasing use of mobile phones and associated base stations are becoming a widespread source of electromagnetic radiation which is the part of nonionizing radiation. Scientific world has focused on the biological effects of electromagnetic radiation for more than 30 years and one of the most important biological effects of electromagnetic radiation is the increase in the permeability of blood-brain barrier. Although, some researchers had found no change, many others found increase in the permeability of blood-brain barrier of rats after electromagnetic radiation exposure. To this end we have aimed to investigate the effects of 900 MHz and 1800 MHz continuous wave mobile modulated electromagnetic field on the permeability of blood-brain barrier of female and male rats. Exposure period was 20 minutes. In electromagnetic fields exposed groups, animals are exposed to about 4.84 V/m electromagnetic field simulating nonthermal exposure levels. Rats were exposed to sham or electromagnetic fields in near field condition.

Including human brain tissue and in tissues, called magnetite (Fe₃O₄), ferromagnetic particles 50 nm in size are small. Higher concentration of magnetite in the outer part of the brain [21]. Magnetic field, magnetic particles and the cell membrane and the mechanical torque generated as a result of the interaction of ionic channels that are activated [39].

900 MHz and 1800 MHz frequencies used in mobile communication by the circular antenna radiation subjected to cyclic structure of the complex dielectric concentric spheres head model, the heat distributions were modeled. 900 MHz small \( \theta \) angles of heat outward from the center of the head, multiplies, the maximum temperature reached at the junction of the layers of brain and bone, bone were decreased and increased again in the skin. Where \( \theta \) is grater as the temperature decreases and the maximum temperatures generally were formed in the mid brain sphere. Circular antenna length increases, the temperature decreases from the center of the head, and in particular for large \( \theta \) the maximum temperature has been observed to occur toward the center of the head. Shows a similar feature from 900 MHz to 1800 MHz thermal behavior was observed, but decreased levels of heat.

So in the most using 900 MHz and 1800 MHz frequencies of telecommunication, recommended tissue models have got.
Especially for the human head, two different tissue models have been created. In interested frequencies, these models can be used in electromagnetic energy absorption (E field and SAR) and on research of thermal effects (heat rise). For other frequencies, mixing ratios can be changed. For different frequencies, studies on the determinations of ratios must be carried on. This is very important for researchers of electromagnetic effects.

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REFERENCES


Dr. Burhan Davarcioglu, Hacettepe University, Ankara-Turkey, Faculty of Engineering in 1978, enters as the Engineer graduated from the Physics, Nuclear Medicine Department in the years 1984-1985 at Hacettepe University, Radiation Physics and Radioisotope Laboratories has participated in the creation work. 1985-1993 Research Fellow in the years of working as a Gazi University, Institute of Science and Technology, Department of Physics, in 1987, “Solid-State Lasers” with his Master’s thesis, and in 1992, “Some Complex and Clathrates Infra-red Spectroscopy Investigation” of the named PhD thesis completed. Faculty Member appointed as Dr. Davarcioglu, Nigde University in 1994, took active part in the founding. Faculty of Arts and Sciences Department of Physics and Institute of Science and Technology the establishment of many administrative tasks found. Turkish National Committee on Clay Science is member and New York Academy of Sciences is an active member. Papers presented at the international level to the majority and the broadcast Dr. Davarcioglu’s many references were made to run. Of interest related to the study of various summer schools participated. Since the year 2000, industrial raw materials quality and quantity of clay, by means of the spectroscopic identification of the work operates. Aksaray University, was appointed in April of 2007 to the relay.