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Measurement of Electromagnetic Field Effect on 900 MHz Head Fluid Replacement Liquid Temperature Using Thermocouples

Harry Arjadi, Priyo Wibowo

Electromagnetic Research Group, Research Center for Testing Technology and Standard, National Research and Innovation Agency (BRIN), Tangerang Selatan, Indonesia

Email address:

r.harry.arjadi@brin.go.id (H. Arjadi), priyo.wibowo@brin.go.id (P. Wibowo)

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Abstract: As it is known that electromagnetic fields have been used for various life activities, a study was conducted to measure the electromagnetic field effect on 900 MHz head fluid replacement liquid temperature using thermocouples. This research was conducted to determine the effect and consequences of electromagnetic wave radiation on the temperature of the replacement liquid when the emitted electromagnetic field is absorbed by the replacement liquid during communication activities. J-pole antenna is used to emit electromagnetic waves as a simulation of the electromagnetic field of mobile phones. This study shows that the change in the average head fluid replacement liquid temperature is 1.43 ± 0.136°C after being exposed to a 900 MHz electromagnetic field at a level of 23 dBm, and an average temperature change of 1.46 ± 0.147°C with a field level of 33 dBm. for 10 minutes. The effect of exposure to electromagnetic fields around the head, with a certain period of time, will cause the temperature of the head fluid to increase and the electrical characteristics of the head fluid to change which can have an impact on the healthy functioning of the head.

Keywords: Electromagnetic Effect, Electromagnetic Waves, K-type Thermocouple, 900 MHz Head Fluid Replacement, J-Pole Antenna

1. Introduction

The most visible impact of technological developments in the use of electronic components is the effect of electromagnetic field radiation (EMF) caused by these electronic devices. In general, any form of electromagnetic field radiation can affect the function of the human body in particular, including the function of the human head and brain [1-3]. The cells in the head are the most susceptible to field radiation. The head is mostly composed of water molecules which are also easily ionized by electromagnetic field radiation including heat changes caused by electromagnetic waves [4-6].

Electromagnetic exposure in terms of type, frequency, and level is allegedly triggering and affecting human health. Various studies have been conducted regarding the negative effects that can be caused by exposure to electromagnetic fields. Epidemiological, animal, experimental human, in vitro, clinical, and also cell-level studies have been carried out regarding exposure effect on human health and safety. Evaluating the electromagnetic absorption energy distributions in human tissue is a complex task. The rate of temperature increase in a tissue-equivalent liquid using anthropomorphic models is a safe way to study the effect of electromagnetic exposure on a human head [7–15].

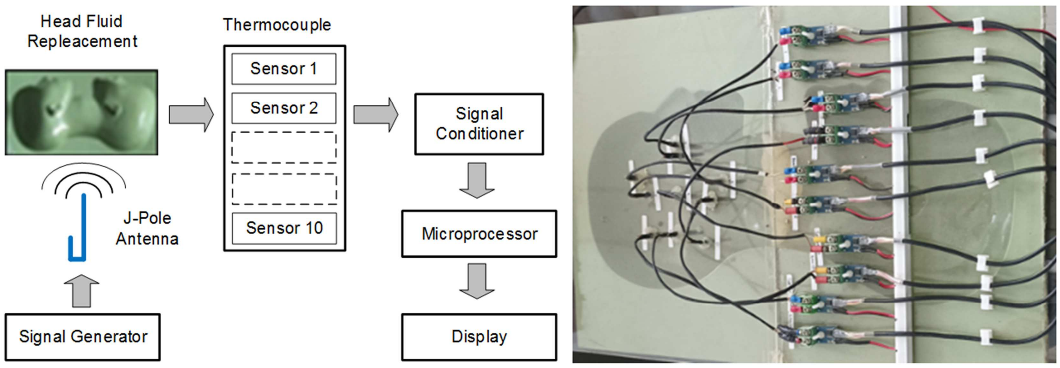
This research was conducted to determine the influence of the electromagnetic field on the temperature of 900 MHz fluid head replacement using K-type thermocouples, including how the level of the field source affects the fluid head. A special liquid whose characteristic is the same as the human head is used as a fluid replacement of a fluid head [16, 17].

2. Methodology

The focus of this research is to determine the effect of electromagnetic fields on the fluid in the head by providing a simulation of electromagnetic waves on a human head mannequin filled with fluid as a substitute for head fluid [16, 17]. Exposure to electromagnetic waves will affect the temperature of the replacement fluid. The measurement system consists of 10 K-type thermocouple sensors which function to measure temperature changes at several measurement points on the head model. The temperature will be measured depending on the level of electromagnetic waves emitted by the signal generator through the J-type antenna which simulates the electromagnetic field from a mobile phone to a head model filled with replacement head fluid. The output from the temperature sensor in the form of a very small voltage is amplified using a differential amplifier circuit and a buffer circuit before being processed by the Arduino Mega 2560 microprocessor. The temperature changes generated by each thermocouple sensor are displayed using an LCD (liquid crystal display) which is used to display temperature information from the Arduino Mega 2560 microprocessor, namely information on the influence of electromagnetic waves emitted on the mannequin head. The diagram block of the measurement system can be seen in Figure 1. Measurement of the electromagnetic field effect on head replacement fluid, as to represent head liquid, is carried out to find out how temperature changes due to the effect of the electromagnetic field on it.

2.1. Temperature Sensor

The thermocouple used in the design of this measurement system is a K-type thermocouple. Referring to the basic principles of thermal sensors and their use [18, 19], there are several characteristics of several types of thermocouples. The K-type is an economical thermocouple designed for high and low temperatures, which is why the K-type is called a multipurpose thermocouple. The K-type thermocouple sensor consists of a positive conducting metal made of Nickel-Chromium and a negative conducting metal made of Nickel-Aluminium. Thermocouples are used to detect changes in the temperature of the head fluid replacement after being exposed to an electromagnetic field. The measurement system and K-type thermocouple setup are shown in Figure 1.



(a) Measurement diagram (b) K-type thermocouple setup

***Figure 1.** Measurement system.*

K-type thermocouple responds very quickly to changes in temperature and also has a wide operating temperature range, which ranges from -200°C to 1200°C. The thermocouple is also resistant to shock or vibration. The working principle of the k-type thermocouple sensor is basically as shown in Figure 2.

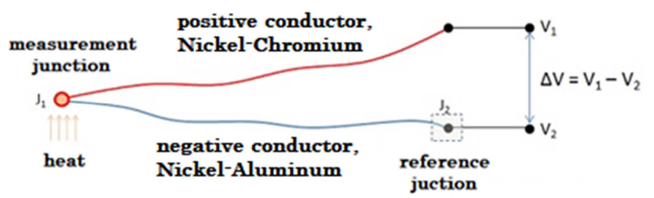


***Figure 2.** Working principle of K-type thermocouple.*

When both junctions have the same temperature, then the potential difference and electric voltage through the two junctions is "Zero" or $V_1 = V_2$. However, when the junction connected in the circuit is given a hot temperature or connected to the measurement object, there will be a temperature difference between the two junctions which then produces an electric voltage whose value is proportional to the heat it receives or $V_1 - V_2$. The relationship between the temperature difference and the voltage produced by the thermocouple is not a linear function but a polynomial interpolation function. For smaller temperature measurements, the voltage changes are relatively linear [19]:

$$v = \alpha(T - T_{ref}) \tag{1}$$

where

v = measuring voltage (V),
T = Measuring Temperature (K),
T_{ref} = Reference temperature (K),
α = Seebeck coefficient.

The use of a K-type thermocouple requires an additional circuit to be able to measure temperature properly. It needs a signal conditioning circuit that has a filter to reduce the effect of high-frequency noise and also has a burn-out detector to detect any cable disconnection and a linearization compensation formula [20].

2.2. Electromagnetic Source

The antenna used as an electromagnetic source in this study is a J-Pole antenna. The antenna was designed for work at frequency 900 MHz as same as mobile phone working frequency. The antenna is made of copper rods with a diameter of 3.2 mm and a length of 333.1 mm. Vector Network Analyzer (VNA) was used to find out the antenna bandwidth, return loss, and antenna impedance. The antenna radiation pattern was measured using a semi-anechoic chamber. The J-pole antenna and the measurement of its characteristics are shown in Figure 3. The most expected performance for the return loss value is below -10dB because it indicates a small power-loss value.

(a) J-Pole Design (b) Measurement using VNA

Figure 3. *J-Pole Antenna design and its characteristic measurement.*

Electromagnetic radiation has a broad spectrum ranging from very low-frequency electromagnetic waves to very high-frequency electromagnetic waves. The difference in frequency, wavelength, and photon energy of each electromagnetic radiation turn out to cause different radiation effects [2]. Electromagnetic radiation is divided into 2 groups, namely: non-ionizing radiation, radiation that will not be able to induce the ionization process with matter because it does not have sufficient energy to cause the ionization process. Electromagnetic waves included in non-ionizing radiation are ultraviolet rays, infrared rays, microwaves, radio waves, and very low frequency electromagnetic fields. Ionizing radiation, namely the emission of energy when passing through a medium and an absorption process occurs, which can cause the process of releasing electrons from atoms or molecules so that an ionization process occurs [1, 2]. Gamma rays and x rays are very high-energy electromagnetic waves called ionizing radiation because they ionize molecules in the paths they travel. Exposure to large uncontrolled ionizing radiation is known to cause illness and even death in humans. Radiation generated from any source of electromagnetic waves has energy. According to Max Planck, the amount of quantum radiation energy of an electromagnetic wave is proportional to its frequency.

Electromagnetic fields exist in the around of transmission, distribution, or electrical equipment. This field then spreads to the environment and causes electromagnetic wave pollution. The electromagnetic field will have an impact on the environment and health. Low-frequency electromagnetic fields can affect the body's biological systems which harm human health. However, exposure to electromagnetic fields can also have a positive impact on humans too [9].

Frequency 850 - 1800 MHz is the frequency range of electromagnetic fields emitted from mobile phones. This range is included in the microwave area. Cell phones use electromagnetic waves to send and receive messages and other information. These electromagnetic waves can cause the heating of body tissues. The rotation of polar molecules caused by electromagnetic fields heats body tissues. The heating sensation will happen on the surface of the head and induce an increase in temperature when a person is on a phone call even though the brain has the ability to dissipate excess heat through blood circulation.

Another observation regarding the impact of electromagnetic radiation from cell phones is the effect of electromagnetic energy on the human body, the occurrence of agitation in the body. When the level of electromagnetic radiation is strong enough, the water molecules are ionized. Agitation can increase the temperature of water molecules in the cells of the human body and this can affect the work of the nervous system, work of glands and hormones, and affect human psychology.

The human body consists of liquids and solids. 40% of the human body is solid substances such as proteins, fats, minerals, carbohydrates, organic and non-organic minerals and the remaining 60% of the human body is in the form of fluids. Fluids in the human body consist of blood and blood plasma, Cytosol, Cerebrospinal fluid, Vitreum Corpus, Vitreous Humor, Serum, Aqueous Humor, Lymph fluid, Pleura fluid, Amnion fluid. Each of these fluids has a different function and place in the body.

Of all human body fluids, several body fluids are in the head, namely, Cerebrospinal fluid (in the brain), Vitreous Corpus (in the eye), Vitreous Humor (in the eye), Serum (in the ear), Aqueous Humor (in the eye), blood plasma, (in flowing blood) and cytosol (on every cell in the human body).

An antenna is a device that functions to transfer electromagnetic wave energy from the cable medium to the air or vice versa. Because it is an intermediate device between the cable and air media, the antenna must have the appropriate properties (match) with the cable media feeder. The J-Pole antenna is a type of antenna that receives and emits electromagnetic waves with a beam angle of 360-degree perpendiculars to the top. So, the electromagnetic waves emitted by this antenna expand over a short distance. Figure 4 shows the basic design of the J-Pole Antenna. The function of this antenna is to serve a wide coverage area but within a short-range. The advantage of this antenna, at least theoretically, is equivalent to a quarter-wave radiator over the perfect ground. The J-Pole also corresponds to the highest impedance at the end of a half-wave radiator to a low input impedance suitable for the coaxial input [21-23].

There are some advantages of the J-Pole antenna such as it does not require a radial or ground plane, it does have DC Grounded, so it doesn't have to worry about being struck by lightning. Its radiation pattern is an Omnidirectional pattern. The gain is 3 dB above the antenna's Ground Plane and The SWR of the J-Pole antenna is fairly flat and <1.5 dB along with the band, and the wind resistance is very low. A J-pole is composed of a radiator and a matching stub where each operates as an end-fed half-wave antenna even though the radiator and the stub are respectively three-quarters and one-quarter of the wavelength as shown in Figure 4 [23].

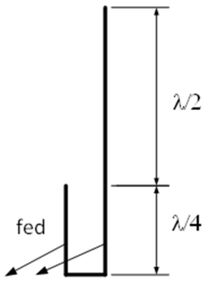


Figure 4. *J-pole antenna basic design.*

2.3. Head Liquid 900

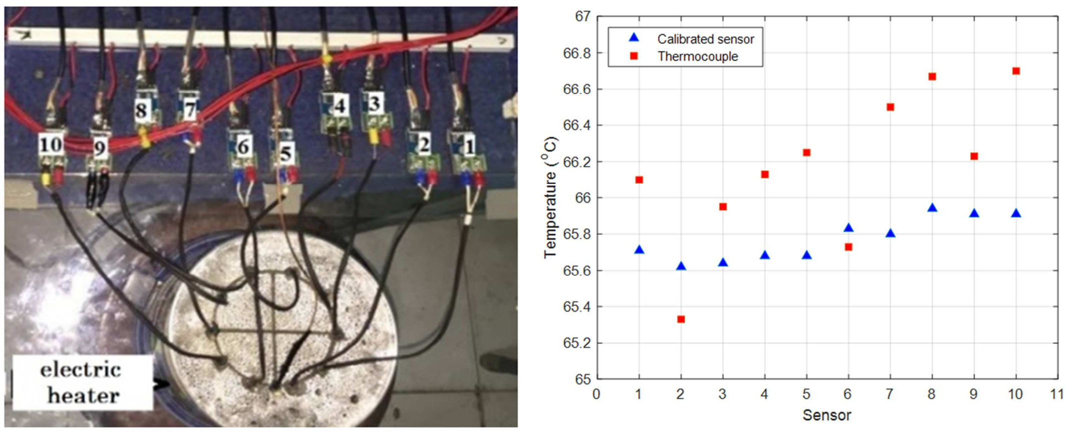
Head Liquid 900 is a fluid replacement for head fluid which is 98% the same properties as human head fluid. The content of this liquid is in the form of 1-2 Propanediol, H_2O, and NaCl. When communicating using cellphones, exposure to electromagnetic waves can change the temperature of the head liquid. Its temperature can increase when getting the electromagnetic waves radiation frequency 900 MHz [16, 17].

3. Result and Discussion

3.1. Testing of K-type Thermocouples

The performance of the sensor used in this study was determined by conducting a thermocouple sensor testing activity. The performance of this thermocouple is needed in research to find out the real temperature elevation. The test is carried out by comparing the results of the sensor measurements being tested with the results of the calibrated sensors. Ten sets of thermocouples and a calibrated sensor are arranged in a circle to measure the temperature of an electric heat source as shown in Figure 5(a).

The results of the average test data of K-type thermocouple sensors used and the calibrated sensor as shown in Figure 5(b). The measurement results show that there is not much difference between the average results of 10 K-type artificial thermocouples compared to the measurement results obtained from the calibrated sensor. The temperature differences between the thermocouples and a reference sensor are 0.10°C to 0.769°C.



(a) Thermocouple setup (b) Temperature reading

Figure 5. *Test method for verifying the temperature readings.*

3.2. Testing of J-pole Antenna

The J-pole, which is a simple design antenna, is used as a device for transmitting electromagnetic fields that are exposed to head fluid replacement. Therefore, it is necessary to conduct a test to determine the performance of the J-pole, especially to determine the radiation pattern of the electromagnetic field it emits. Measurement of the performance of the J-Pole is carried out in a semi-anechoic chamber. The signal generator is used to provide wave signals to be transmitted on the J-Pole antenna, and it is supported by several other measuring instruments, such as a spectrum analyzer and a receiver. J-pole antenna testing was carried to get the largest radiation pattern, to find out the antenna bandwidth, return loss, and impedance of the J-Pole antenna. The test is carried out by providing an electromagnetic field with a center frequency of 900 MHz. The return loss of the J-pole can be seen in Figure 6 and the radiation pattern can be seen in Figure 7.

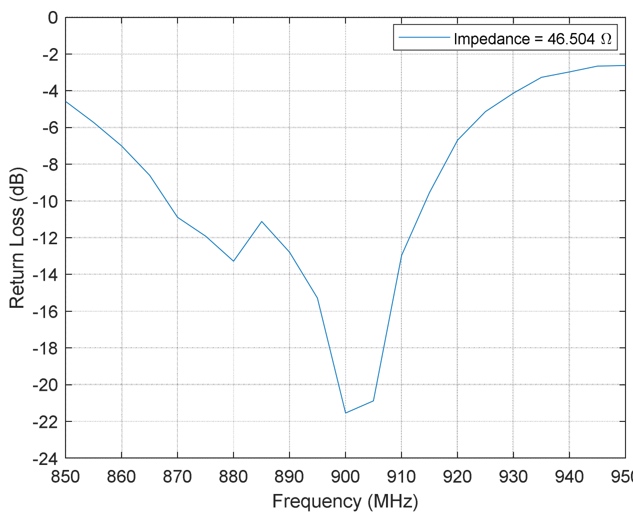
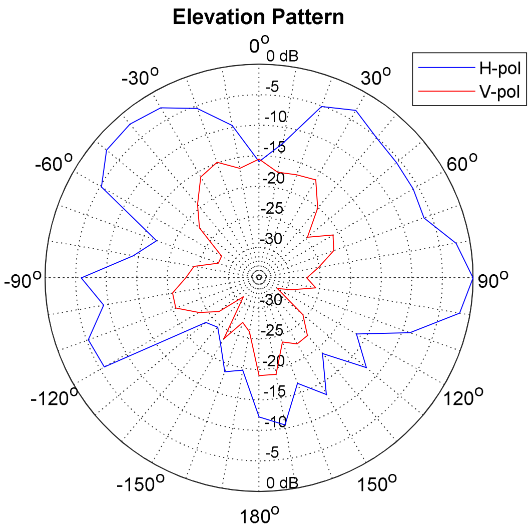
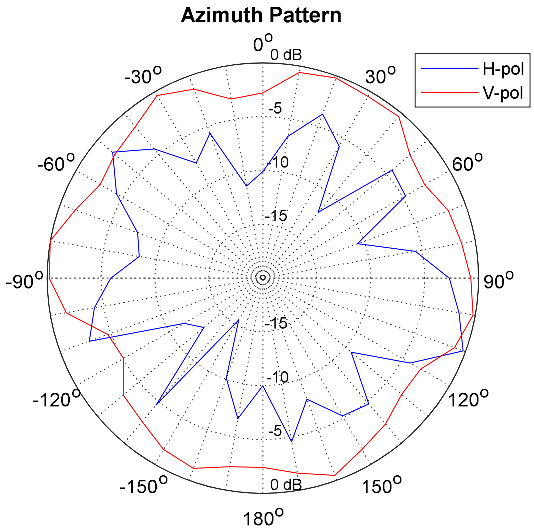


Figure 6. *The return loss of the J-pole antenna.*



(a) Azimuth angle θ = 0°



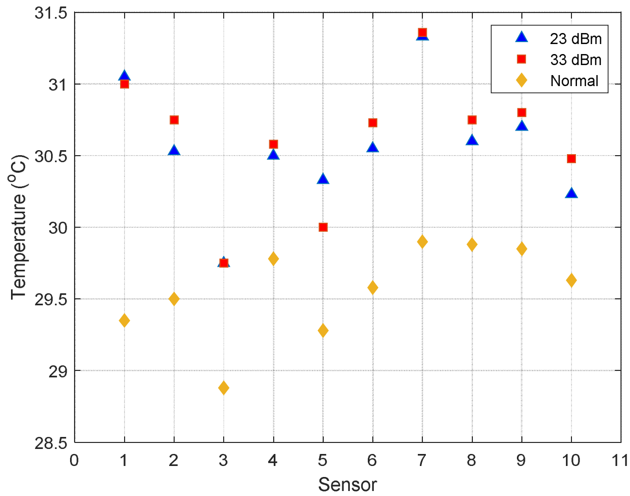
(b) Elevation angle ϕ = 0°.

Figure 7. *J-pole antenna pattern.*

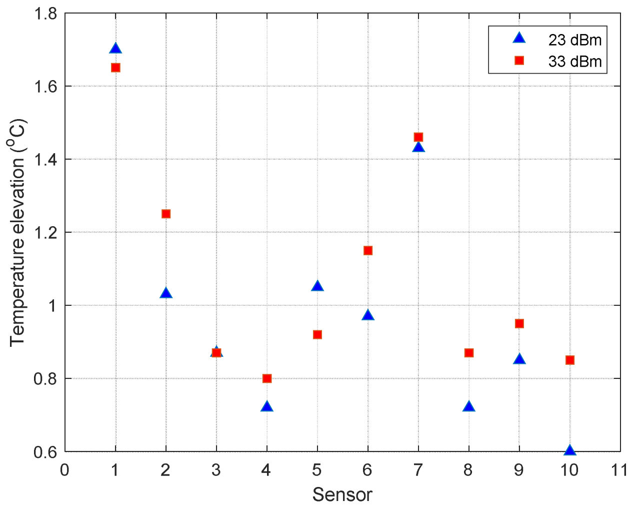
3.3. Head Fluid Replacement Temperature

The measurement of the influence of the electromagnetic field on the fluid replacing the fluid head is done by exposing the electromagnetic field generated by the signal generator whose output is a signal with a frequency of 900 MHz to emit an electromagnetic field level of 23 dBm and 33 dBm. The comparison between the temperature of the fluid head that is not exposed to an electromagnetic field of 900 MHz and the temperature of the fluid that is exposed to 23 dBm and 33 dBm is shown in Figure 8.

The uncertainty of temperature measurement, at a working frequency of 900 MHz and a level of 23 dBm, is calculated based on the assumption that factors other than the measurement data are considered zero. So that the uncertainty value is obtained from the temperature condition at the frequency of 900 MHz with a level of 23 dBm is 30,56 ± 0,136°C. While the uncertainty of temperature measurement at a working frequency of 900 MHz with a level of 33 dBm is 30,61 ± 0,1467°C.



(a) Temperature comparison



(b) Temperature elevation

Figure 8. *The temperature change of head fluid replacement due to the electromagnetic field exposure.*

This study was conducted to determine the effect of the electromagnetic field on the fluid head, including how the level of the field source affects the fluid head. In increasing confidence in the measurement results, the infrastructure used in this study is very supportive. Testing the K-type thermocouple will also affect the assessment of the field effect on the head fluid. By assuming the uncertainty of other factors other than the measurement data is considered zero, the average temperature head fluid replacement that does not expose to electromagnetic wave is 29,56 ± 0,102°C. The average temperature when it is exposed for a certain time is 30.56 ± 0.136°C for a field source level of 23 dBm, and 30.61 ± 0.147°C for a field source level of 33 dBm. The highest temperature of head fluid replacement is detected on sensor 7 when the fluid is exposed to an electromagnetic field at 23dBm and also 33dBm. The temperature rises 1.43°C at level 23 dBm, while at level 33 dBm it increases 1.46°C. This is due to the exposure of the electromagnetic field from the J-pole antenna which simulates the waves emitted from the cellphone when it is used to communicate.

The head liquid replacement is sensitive to electromagnetic waves with a working frequency of 900 MHz. When expose to electromagnetic waves from the J-pole antenna, the head liquid replacement will experience heat changes. This will change the viscosity of the head fluid replacement. The function of the original human head fluid is to protect the central nervous system from impacts and external pressures and to maintain appropriate humidity for the brain. So, if the fluid in the head changes its thickness or viscosity, it will cause damage and disrupt the function of the cerebrum and cerebellum of the human head. However, the interaction of electromagnetic fields and head liquid in living bodies are not uniform. The actual mechanism of temperature increase in the living bodies due to electromagnetic field exposure may vary.

4. Conclusions

The study to determine the influence of the electromagnetic field on the temperature of 900 MHz fluid head replacement using K-type thermocouples has been carried out. The temperature increase by 1.43°C and 1.46°C due to the exposure of the electromagnetic field from the J-pole antenna which simulates the waves emitted from the cellphone when it is used to communicate respectively at 23 dBm and 33 dBm. The head liquid replacement is sensitive to electromagnetic waves. So, if there is exposure to electromagnetic fields, it will be a change in the temperature of the head fluid and there is a possibility of a change in the electrical characteristics of the fluid.

It should be considered that the effect of exposure to electromagnetic fields around the head, with a certain time it will cause the temperature of the head fluid to increase. Therefore, there is a possibility of changes in the electrical characteristics of the head fluid which will have an unfavorable impact on the health of the head function even mechanism of temperature increase in the living bodies due to electromagnetic field exposure may vary.

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