



The Effects of Electromagnetic Radiation on Human Body Fluids by Simulation Using Replacement Fluids at a Frequency of 900 Mhz

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To cite this article:

Raden Harry Arjadi, Priyo Wibowo, Anita Silvanawati. The Effects of Electromagnetic Radiation on Human Body Fluids by Simulation Using Replacement Fluids at a Frequency of 900 Mhz. *International Journal of Electrical Components and Energy Conversion*. Vol. 7, No. 1, 2021, pp. 1-9. doi: 10.11648/j.ijecec.20210701.11

Received: December 22, 2020; **Accepted:** January 12, 2021; **Published:** January 25, 2021

Abstract: In line with technological developments, cell phones are not only used as a means of communication, but are also used for other activities. However, there is an indirect negative impact caused by the electromagnetic field radiation from this device. As well as disrupting the work system in the human body, including changes in heat energy in the tissues of the human body. Research on the effect of electromagnetic radiation on human body fluids has been carried out with simulations using replacement fluids at a frequency of 900 Mhz. Signal generators are used to simulate the emissivity of a cell phone with a transmit power of more than 3.4 times or 5.34 dB of the power emitted by a cell phone. The results of measurements and calculations in the study showed no significant effect on temperature increases or changes in body fluid color. The result of the calculation of the SAR (Specific Absorption Rate) value of the maximum emissivity signal produced is 109.46 dB μ V - 0.3 V/m, for the conductivity and density of body fluids is 7.46 kg/m³, and shows that it is still below the threshold. the radiation limit permitted by the FCC is 1.6 W/kg, and ICNIRP 2.0 W/kg. It should be noted that the measurement results obtained are the results of measurements including environmental conditions where there is still wave interference from other sources (noise), as well as a relatively short measurement time.

Keywords: Electromagnetic Field Radiation, Human Body Liquid, Cellular Phone Frequency

1. Introduction

Telecommunication technology is developing very rapidly and its development is followed by the growth of a modern society that has high mobility and is always looking for efficiency in all aspects. The need for long distance communication has brought cell phones which are considered more efficient than fixed telephones. From the advantages and convenience of cell phones, there are bad effects that cause concern to experts about the effects of cell phone electromagnetic radiation, which is often considered the cause of various health problems [1, 2]. RF-EMF radiation hazard is measured in a unit known as the SAR (Specific Absorption Rate) radiation exposure rate. The maximum threshold radiation requirement for cellular phones as determined by the FCC (Federal Communications Commission) is 1.6 watts/kg. Meanwhile,

according to ICNIRP (International Commission on Non-Ionizing Radiation Protection), it is 2.0 watts/kg [3, 4]. Regardless of the SAR value of a cellphone, it is not guaranteed to avoid the effects of cell phone radiation, because the RF-EMF radiation energy is cumulative and can be dangerous if used excessively with the intensity of use too often [5].

One of the health problems that occur in humans is related to an increase in the temperature of fluids in body tissues. Research on the effect of electromagnetic radiation on human body fluids by simulating the use of replacement fluids at a frequency of 900 Mhz has been carried out, to determine the negative impact of electromagnetic field radiation on the work system in human body. 900 MHz transmitters are used instead of cell phones, which have more power than cell

phones, in terms of observing the radiation effect of any increased RF power on human body fluids.

2. Theory

2.1. Cellular Phone Work System

Cellular telephone is a wireless communication device. This cell phone is a two-way full duplex communication consisting of a transmitter circuit (Tx) and a receiver circuit (Rx) placed in a packet with access to the user's identity (sim card). The process of sending signals to cellular phones begins with the modulation process of the information data signal with the carrier signal by the RF processor. The modulated data signal is received by the

Base Transceiver Station (BTS), which have distance quite far reaching a distance of about 50 Km., so the signal must be really strong.

The received signals on cell phones from the reception of signals emitted by the BTS will forwarded to the antenna switch, then to the Low Noise Amplifier (LNA), to be strengthened and separated from noise. Fothermore, the RF processor separated the data signal information from the carrier signal, demodulated and then processed by the Digital Signal Processor (DSP) to convert the analog information signal into a digital, then processed by the main processor (CPU). The schematic block diagram of a cellular telephone transceiver system is shown in Figure 1.

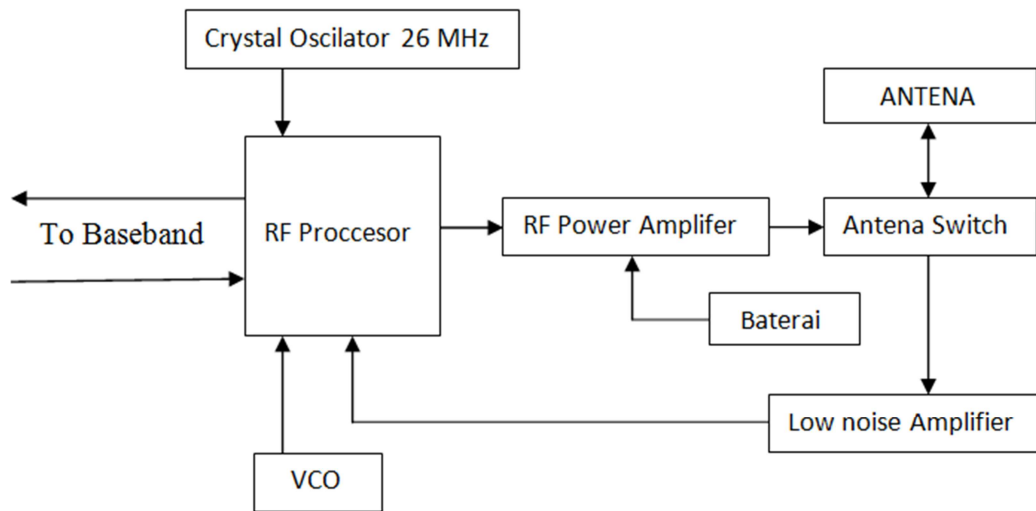


Figure 1. Schematic block diagram of a cellular telephone transceiver system.

2.2. Effects of Cellular Phone Radiation on Health

Cell phones are a potential source of electromagnetic wave radiation, which will generate large photon energy and a greater radiation than other electronic equipment.

Electromagnetic waves used in the communication process on cell phones can cause heating in body tissues, which is caused by rotations of polar molecules by electromagnetic field. Electromagnetic wave radiation produced by cell phones is included non ionic radiation (microwaves). Non ionic radiation, under normal conditions, cannot be felt by the human sense of taste. However, it becomes possible to be captured by the human senses if exposed in high intensity. One of the sensations felt is heat [4].

When communicating with cell phones, a heating effect will occur on the surface of the head and cause an increase in temperature. The brain has the ability to get rid of excess heat through blood circulation. Agitation caused by electromagnetic radiation, if the intensity of electromagnetic radiation is strong enough, will ionize water molecules. Agitation can increase the temperature of water molecules in the cells of the human body and affect the work of the nervous system, glands and hormones and human psychology. The electrical properties of the body,

which depend on the water content in the body, will be absorbed more radiation in media with high dielectric constant such as brain, muscles and other tissues with high water content.

2.3. Composition of Human Body Fluids

The human body consists of fluids and solids. 40% of human body parts are solid substances such as protein, fat, minerals, carbohydrates, organic and non-organic minerals, and the remaining 60% of the human body is liquid. In the human body there are chemical electrolytes that produce electrically charged particles called ions when they are in solution. Fluid and electrolytes enter the body through food and drinks that are distributed to all parts of the body. Body fluids include blood fluid, tissue plasma, synovial fluid in the joints, cerebrospinal fluid in the brain, fluid in the eyeball (aqueous humor and vitreous humor), pleural fluid, and various fluids contained in organs.

2.4. Specific Absorption Rate (SAR)

Specific Absorption Rate (SAR) is the amount at which energy is absorbed by the body when exposed to radiation from electromagnetic waves, although it can refer to the

absorption of other forms of energy by tissue. SAR is defined as the power absorbed per mass of the network and has units of watts per kilogram (W/kg). The SAR value can be calculated from the electric field in the network, using the following formula:

$$SAR = \sigma \frac{|E_1|^2}{2\rho}$$

Where: σ = Liquid conductivity [S/m], E = Electric field [V/m], ρ = Liquid density [kg/m^3]

The magnitude of the conductivity (σ) value of human body fluids for the 900 MHz frequency is 0.17 S/m [5], while the density (ρ) for human body fluids is $1025 \text{ kg}/\text{m}^3$.

3. Research Methods

3.1. Measurement of Transmit Power and Frequency of a Cellular Telephone

In this study the working frequency of the cellular phone measured was at the working frequency of GSM 900 MHz, the block diagram measuring the transmit power of the cellular phone is shown in Figure 2 and Figure 3 below.

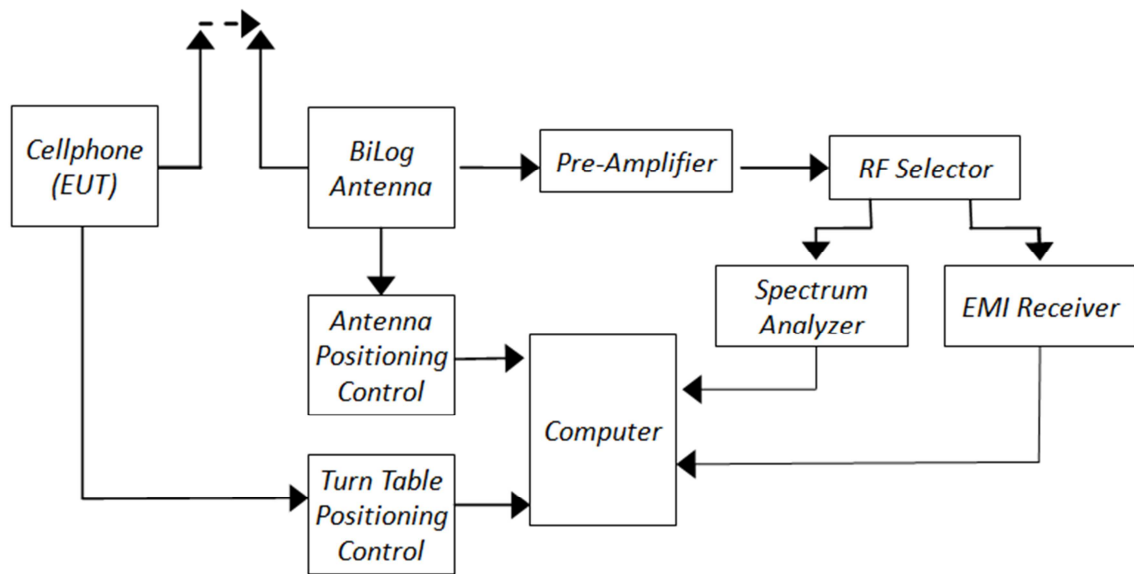


Figure 2. The block diagram measuring the transmit power of the cellular phone in standby state.

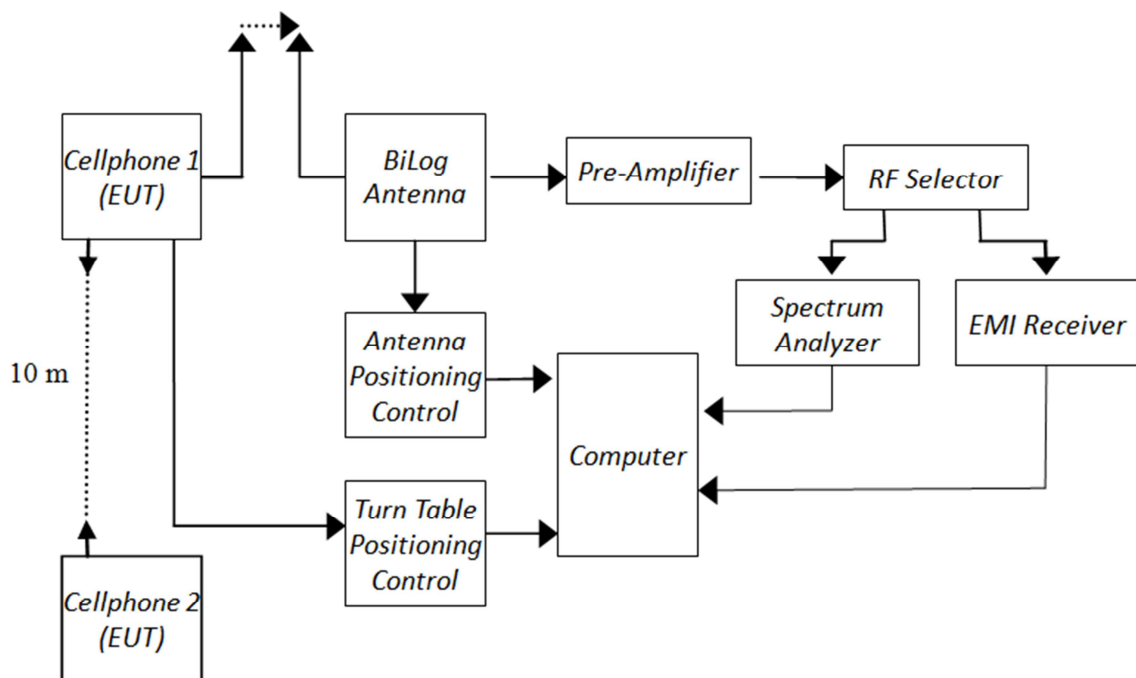


Figure 3. The block diagram measuring the transmit power of the cellular phone in a connected state.

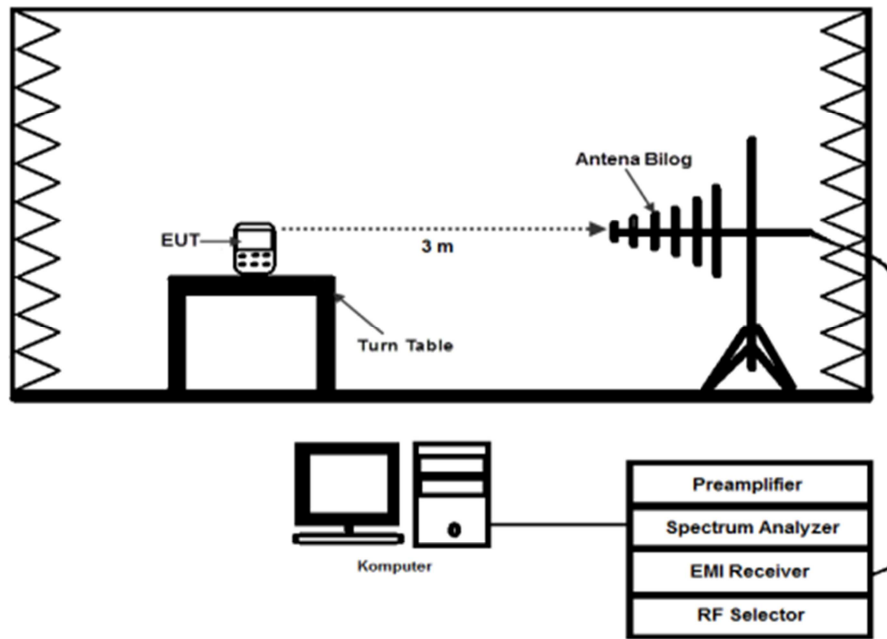


Figure 4. Measurement of the magnitude of cell phone transmit power in an anechoic chamber.

Measurements were made on two mobile phones for two conditions, namely stand by and connected conditions with other cellphones at different distances, namely 3 meters, 2.5 meters, 2 meters and 1.5 meters from the bilog antenna. The measurement results obtained are the EM radiation emitted by the cellphone, which is vertically and horizontally polarized [6-8]. The results of standby measurements are shown in Table 1, while the connected conditions are in Table 2 and Table 3. Measurement of the magnitude of cell phone transmit power in an anechoic chamber is shown in Figure 4. However, the door of the Chamber was partly opened so that communication can occur between the cell phone being measured for transmission power and the BTS.

3.2. Measurement and Observation of EM Wave Radiated Fluids

The data obtained from the measurement of the transmit

power from cell phones and the signal generator, then the observation of human body fluids, which in this study used electrolyte fluids which are considered to be representative of human body fluids. The electrolyte fluid is irradiated by the frequency and transmit power of the cell phone generated by the signal generator and emitted by the hyperLOG 7060 antenna. The distance between the antenna and the electrolyte fluid is adjusted to the real conditions when someone is communicating with a cell phone. Two thermocouples are used, one is attached to the electrolyte liquid to determine the temperature change that is irradiated by EM waves. Other thermocouples is used to determine changes in room temperature. The results are processed using the Fluke 2686A Hybrid Recorder Data logging System and a computer. The measurement block diagram is shown in Figure 5. Observations and measurements were made in the Walk-in Chamber is shown in Figure 6 [9-11].

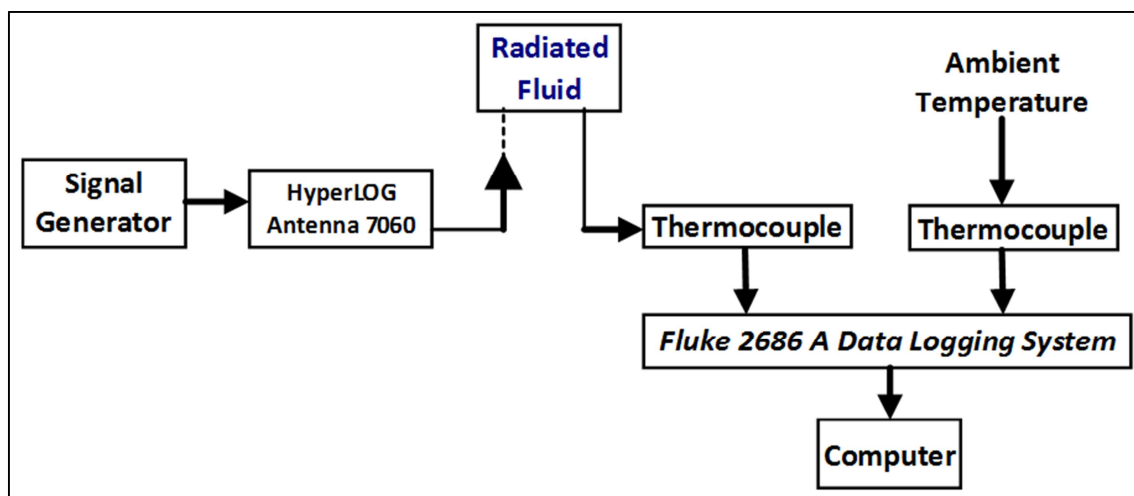


Figure 5. The measurement block diagram.

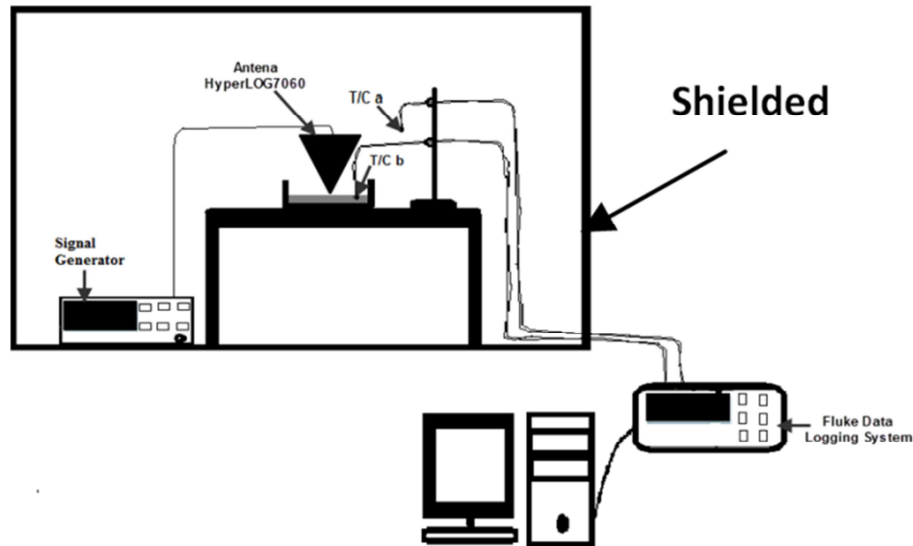


Figure 6. Observations and measurements in the Walk-in Chamber. 3.3. Measurement of Cell Phone Transmit Power (dBμV) in Standby.

The amount of transmit power of the cellphone read by the Toyo EMI software in the Anechoic Chamber is the measurement result when the cellphone is in standby. Then the measurement is done by three times the change in the distance between the cellphone being tested (EUT) and the

receiving antenna. The first measurement of the cell phone transmits power at a distance of 2.5 meters, the second at a distance of 2 meters and finally at a distance of 1.5 meters. The results of measuring the transmit power of a mobile phone in standby state can be seen in Table 1.

Table 1. The results of measuring the transmit power of a mobile phone in standby state.

Frequency (MHz)	Reading (dBμV)	Factor (dB)	Level (dBμV)	Angel (deg)	Jarak (m)
942.576	66.6	8.1	58.5	133.4	2.5
937.183	55.5	8.2	47.3	313.7	2
938.890	65.1	8.2	56.9	316.8	1.5

The GSM used is on the 900 MHz band, where the downlink frequency is 935 MHz - 960 MHz, while for the uplink frequency is 890 MHz - 915 MHz, with a frequency bandwidth for each allocation of 25 MHz.

3.4. Measurement of Cell Phone Transmit Power (dBμV) in a State Connected to Other Cell Phones

The amount of transmit power of the cellphone read by the Toyo EMI software in the Anechoic Chamber is the measurement result when the cellphone was connected to other cellular phones. The distance between the cell phones (EUT) and other cell phones is ± 10 meters. In this measurement there are two brands of cellular telephones that are used as test equipment, both of which are cellular brands that are widely used by the public, this measurement only

uses one provider only.

This measurement uses the EMI Receiver device, the frequency measured by the EMI Receiver device is suspect from the spectrum analyzer. Where the results of the spectrum analyzer measurements will be chosen two frequencies with the highest power for further measurements with the EMI Receiver [12, 13]. Measurements were made by changing the distance between the cell phone (EUT) and the receiving antenna. The first measurement of cell phone transmit power with a distance of 3 meters. Second, with a distance of 2.5 meters. Third, with a distance of 2 meters and Fourth, with a distance of 1.5 meters. The results can be seen in Table 2 for test equipment 1 and Table 3 for test equipment 2

Table 2. Table of mobile phone power measurement results (test equipment 1) in a connected state.

Frequency (MHz)	Polari-zation	Reading (dBμV)	Factor (dB)	Level (dBμV)	Height (cm)	Angel (deg)	Distance (m)
891.864	V	97.9	8.7	89.2	343.2	88.4	1.5
895.017	H	110.2	8.6	101.6	383.4	259.6	
894.978	V	102.1	8.6	93.5	152.2	249.8	2
894.978	H	97.0	8.6	88.4	334.0	335.3	
893.300	V	90.2	8.7	81.5	102.6	234.4	2.5
893.785	H	97.5	8.7	88.8	217.6	58.0	
895.628	V	97.6	8.6	89.0	216.6	329.4	3
892.902	H	93.5	8.7	84.8	225.0	301.1	

Table 3. Table of mobile phone transmit power measurement results (test equipment 2) in a connected state.

Frequency (MHz)	Polari-zation	Reading (dBμV)	Factor (dB)	Level (dBμV)	Height (cm)	Angel (deg)	Distance (m)
894.066	V	100.1	8.7	91.4	317.7	72.8	1.5
891.806	H	95.6	8.7	86.9	361.2	269.2	
894.047	V	98.7	8.7	90.0	182.6	300.3	
892.854	H	98.0	8.7	89.3	338.9	20.0	2
890.341	V	99.6	8.8	90.8	109.9	281.8	
891.758	H	99.6	8.7	90.9	191.3	302.5	2.5
895.211	V	91.7	8.6	83.1	400.0	359.0	
892.281	H	112.9	8.7	104.2	400.0	12.7	3

The measurement data shows the working frequency of connected cellular phones between 890,341 MHz - 895,628 MHz, this frequency is part of the uplink frequency of cellular telephones, and cellular phones function as transmitters that send signals to BTS. So the signal emitted must have great power to be received by the BTS, because the distance between the cellphone and the BTS is quite far. The uplink frequency of the cellular phone itself has a bandwidth of 25 MHz. Not only do cell phones emit one frequency at each measurement angle of the turntable, but they also emit many frequencies ranging from 890 MHz - 915 MHz with different power, or known as frequency hopping. However, the working frequency in the measurement data is the result of frequency hopping measurement from the suspect results by the spectrum analyzer, and two frequencies with the highest transmit power are the results of the suspect spectrum analyzer for each change in the distance between the measured cell phones (EUT) and the antenna receiver. The frequency of the results of the suspect spectrum analyzer was measured again with the EMI Receiver for each 1 m increment of the receiving antenna height and one full turn of the turntable. Measurements were made until the receiving antenna reached a height of 4 m. EMI Receiver functions as a filter, to limit the entry of signals with frequencies that are close to the frequency measured, so that the final data is obtained as in Table 2 and Table 3. From the measurement results table can be seen, the height of the receiving antenna and the measurement angle of the turntable produced different, this is because the antenna height and the size of the rotating table angle in the measurement results table is the selection of the EMI receiver measurements with the highest cell phone transmit power. Also in the Table it can also be seen, the change in the distance between the EUT and the receiving antenna does not affect the amount of

power emitted by the cell phone. The measurement results of the amount of power emitted by test 1 and test 2 are not much different (see Table 2 and Table 3). The amount of transmit power and frequency of work from the results of these measurements will be used as a reference for irradiating electrolyte liquids.

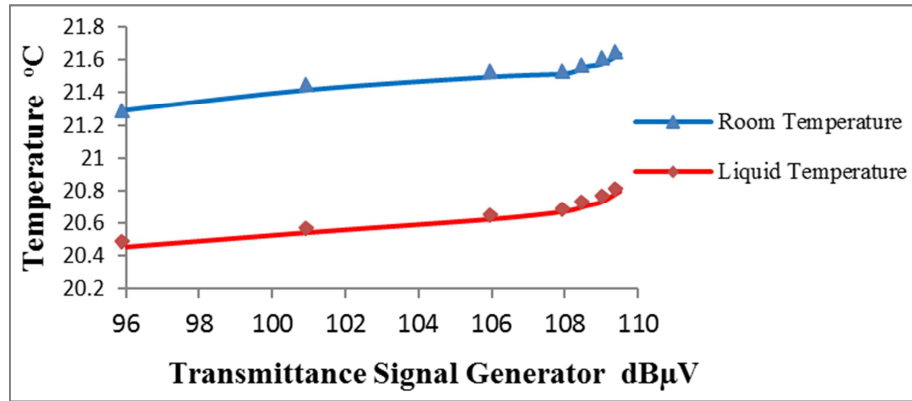
3.5. Measurement of Changes in Electrolyte Liquid Temperature

This section will explain how much the change in temperature of the electrolyte fluid irradiated by the same working frequency and transmit power is even greater than a cellular telephone. The liquid used is electrolyte fluid which has a concentration of electrolyte Cation, and anion electrolyte concentration. The electrolyte fluid container uses a wine glass with an outer circle diameter of 9 cm. When measuring irradiated liquid as much as 10 ml with a liquid diameter of 5.5 cm. The distance of the transmitter antenna and the liquid is conditioned as close as possible, like someone who is communicating with a cell phone. The liquid is irradiated with the frequency and transmit power of the cell phone simulated by a signal generator. Measurements were made for 8 minutes for each increase in power, this measurement was carried out for 7 times the change in power, so that the total time measured for this irradiated temperature change was 56 minutes. This time is longer than 2 minutes, compared to the recommended time of reference which is only 6 minutes. This is done to see and expect that there will be a significant change that occurs in the electrolyte fluid.

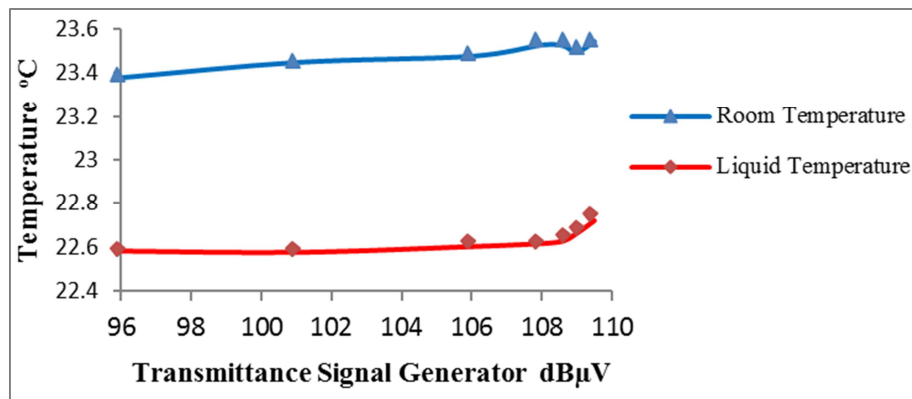
Measurement of changes in electrolyte fluid temperature using a K type thermocouple and Fluke Data Logging System which will be read the results of the Fluke DAQ computer software.

Table 4. Measurement results of changes in temperature of body fluid replacement fluids irradiated with EM waves at a frequency of 890 MHz, for each increase in power per 8 minutes of measurement time.

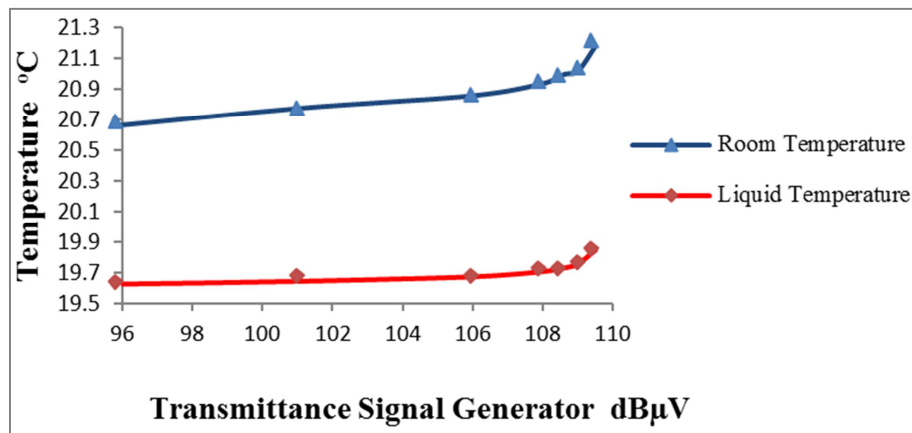
Room Temperature [°C]	Liquid Temperature [°C]	Transmittance Signal Generator [dBμV]
21.292	20.454	96
21.418	20.542	101
21.497	20.624	106
21.517	20.672	108
21.559	20.707	108.6
21.575	20.730	109
21.635	20.796	109.5



a. Irradiated with a frequency of 890MHz



b. Irradiated with a frequency of 895MHz



c. Irradiated with a frequency of 900MHz

Figure 7. Graph of changes in temperature of electrolyte liquid irradiated with a frequency of 890MHz, 895MHz, and 900 MHz.

Table 5. Measurement results of changes in temperature of body fluid replacement fluids irradiated with EM waves at a frequency of 895 MHz, for each increase in power per 8 minutes of measurement time.

Room Temperature [°C]	Liquid Temperature [°C]	Transmittance Signal Generator [dBμV]
23.378	22.582	96
23.447	22.576	101
23.475	22.602	106
23.526	22.616	108
23.523	22.627	108.6
23.494	22.663	109
23.542	22.720	109.5

Table 6. Measurement results of changes in temperature of body fluid replacement fluids irradiated with EM waves at a frequency of 900 MHz, for each increase in power per 8 minutes of measurement time.

Room Temperature [°C]	Liquid Temperature [°C]	Transmittance Signal Generator [dBμV]
20.664	19.624	96
20.775	19.642	101
20.859	19.672	106
20.938	19.706	108
20.997	19.729	108.6
21.020	19.756	109
21.183	19.846	109.5

From the measurement results obtained can be seen, the difference in temperature between the room with irradiated electrolyte liquid where the room temperature is higher $\pm 1^{\circ}\text{C}$. During the observation, there was an increase in room temperature $\pm 0.15^{\circ}\text{C}$ followed by an increase in the temperature of the electrolyte liquid, but the increase in the temperature of the electrolyte liquid was slightly higher, but the increase could not be measured in more detail, even though the transmit power of the signal generator was increased up to 3.4 times greater than cell phone transmit power. This is due to the lack of thermocouple sensitivity used to detect room temperature and the temperature of electrolyte liquids. According to reference [8] the increase in liquid temperature due to electromagnetic wave radiation will not be greater than 1°C . Observations were made for each signal generator frequency of 890 MHz, 895 MHz and 900 MHz, with transmit power ranging from 95 - 127 dBμV. The time for each observation is 8 minutes, this time is 2 minutes longer than the time recommended by the reference. The observations can be seen in Tables 4, 5 and 6, and the temperature changes can be seen in graphs of changes in temperature of electrolyte liquid irradiated with a frequency of 890 MHz, 895 MHz, and 900 MHz as shown in Figure 7 a Irradiated with a frequency of 890 MHz, Figure 7 b Irradiated with a frequency of 895 MHz and Figure 7 c Irradiated with a frequency of 900 MHz.

The increase in liquid temperature that occurred in this study, although the value cannot be determined quantitatively, can be explained in calculations as follows: Maximum cell phone transmit power obtained from measurements (see Table 3), for a frequency of 892,281 MHz, transmission power 104.2 dBμV, equivalent to 0.526 mW/m^2 , while the maximum transmit power of the generator signal (see Table 6), for a 900 MHz frequency, the emission power is 109.46 dBμV, equivalent to 1.8 mW/m^2 . This means that the cell phone transmit power is lower than the signal generator transmit power, or the signal generator power is 3.4 times, equivalent to 5.34 dB of the power emitted by cell phones. This value is still less than the provision of power that can agitate fluids that is equal to 4 mW/cm^2 .

$$0.00018 \text{ mW/cm}^2 < 4 \text{ mW/cm}^2$$

By using the SAR calculation equation, the results of the calculation of the SAR value of the maximum RF transmittance measurement of 109.46 dBμV or equal to 0.3 V/m for the conductivity and density of body fluids are

7.46 kg/m^3 . The calculation results are still below the radiation safe threshold issued by the FCC of 1.6 W/kg and ICNIRP of 2.0 W/kg.

4. Conclusion

From the results of measurements and calculations that have been carried out the signal generator transmit power that is radiated to the body fluid replacement fluid is more than 3.4 times or 5.34 dB of the power emitted by cell phones. However, the power radiated by the signal generator used as a simulation of cellphone transmit power has not significantly impacted the temperature rise or discoloration of body fluids. The results of the calculation of the SAR value, for the maximum transmit power generated by the signal generator is 109.46 dBμV or equal to 0.3 V/m for the conductivity and density of body fluids are 7.46 kg/m^3 . These results are still below the radiation safety threshold set by the FCC of 1.6 W/kg, and ICNIRP 2.0 W/kg, but it should be noted from the measurement results obtained are the results of environmental conditions that still have interference waves from other sources (noise), as well as a relatively short measurement time.

Acknowledgements

The author would like to thank the Indonesian Institute of Sciences, Testing Technology Research Center, Electromagnetic research group, for the opportunity given to conduct research and use existing equipment in the Electromagnetic Laboratory.

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