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Mobile Phone Radiation Effects on Action Potentials in Brain-Arm Nerve Fibres of Human

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Abstract- The common use of Global System for Mobile Communications (GSM) phones has initiated research regarding the possible biological hazardous effects of exposure to electromagnetic radiation (EMR). Therefore, it is essential to study the extent of interaction of GSM phone radiation towards action potentials (AP) in nerve fibres. In order to investigate the effects of GSM phone radiation towards human arm AP, human brain-arm nerve fibres were modeled as wire-type transmission lines; two wires and one wire. Both models with and without interference source from the radiation were simulated and the output waveforms have been analysed to detect any existence of interference. The interference source value was obtained by finding electric and magnetic fields in nerve layer of simulated human arm model that been exposed by GSM phone radiation. Simulation results show the radiation is capable of disturbing the normal AP by introducing bursting spikes on it when distance of the phone from the human arm model is 9 mm with phone radiation power as low as 0.02 W. Furthermore, large nerve fibre radius with huge exposure area to the EM waves also adds on to the effect of radiation on the AP. The altered AP might disturb the normal functions of human arm and hence lead to potential health hazard.

Keywords: Action potentials (AP), nerve fibres, GSM phone radiation, transmission lines (TL).

Introduction

Nowadays, people are frequently exposed to EMR in their daily life due to increasing usage of wireless communication device such as mobile phones and base stations which are widely placed in human environment. As a result, human body will continuously expose to the EMR from those devices. Even though, EMR form those devices is categorised as non-ionizing EMR which does not alter atomic structure [1], but it still have multiple effects on the human body especially the nervous system. Many studies [2-4] over the years have positively reported thermal or heating effects and non-thermal effects that cause from non-ionizing EMR. Whilst thermal effect can have adverse health effects due to heating of the tissue, the consequences of non-thermal effects such as neuro-stimulation, cells interaction and behavioural changes are still subjected to differences of opinions amongst researches, governments and industries.

Nervous system acts as a command system that coordinates other systems in human body. The nervous system can conduct such robust task because its contain nerve fibres that carry electrical pulses known as AP that initiate other systems functionality. It is possible for the EMR to interact with AP and hence disturbing the functionality of human body systems. Some of the researcher did in depth studies on effect of GSM phone radiation towards nervous system. Bawin et al. [5] reported that since GSM phone operates in a pulse mode and its signal is categorised as modulated EMR, the radiation may cause neurological effects even at low average power. Luria et al. [6] did a study on the cognitive functions of humans when exposed to GSM phone radiation. 48 healthy right-handed males were given a specific task and their responding times were recorded. The study confirmed the existence of an effect of the EMR exposure on the responding time and has correlation with exposure time and location of the phones. Guy and Chou [7] reported that a rat which exposed to a very high-intensity microwave pulses has a temperature rise in its brain and seizures occurred to the rat and followed by unconsciousness for 4 to 5 minutes. Post mortem revealed damage at myelin sheaths of the rat nerve fibre.

Therefore, in this study, we are concentrating on the effects of GSM phone radiation towards the AP in nerve fibres of nervous system. Human arm is important in handling a mobile phone. Somehow, it become severs part in human body due to the EMR of GSM phone. As a result, it is essential to model the human arm nerve fibres into transmission lines (TL) that can be observe and analyse in order to obtain results which then can be logically relate to the actual human arm behavior towards EMR.

Methods

A. Human arm modelling

Obtaining an equivalent TL circuit that represent the human arm nerve fibres involved steps of process with usage of several softwares. First step is to model the simplest form of the actual human arm with it corresponding radiation source in a three dimensional simulation software package known as CST Microwave Studio. This step is very important in order to know how much intensity of electric and magnetic fields are being absorbed by the nerve fibres. Then, electric and magnetic field intensities are converted into radiation sources or also known as induced sources for the TL circuit.

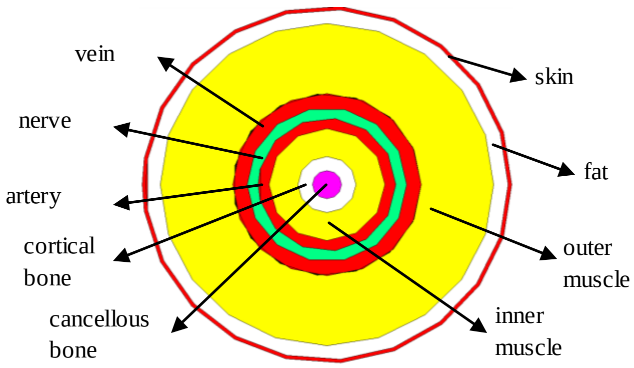

Fig.1. Simplest form of human arm in axial view

Human arm axial view shows layers of organs and tissues that create a human arm. In general, along the human arm, outermost layer of human arm is skin and then followed by outer muscle, blood and nerve networks, inner muscle and lastly bone as innermost layer [8]. Therefore, it can be said that human arm simplest form is just like a cylindrical solid. Inside it, contain layers of smaller cylindrical as shown in Figure 1 with each layer represent different organs. Properties of the organs are summarized in Table 1.

TABLE.1. Human arm organ properties

Organs	Thick (mm)	Relative permittivity at 900 MHz [9]	Conductivity at 900 MHz (S/m) [9]
Skin	1	41.405	0.86674
Fat	4	5.462	0.051043
Outer Muscle	20	55.032	0.94294
Vein	4	44.775	0.69612
Nerve	3	32.531	0.57369
Artery	3	44.775	0.69612
Inner Muscle	8	55.032	0.94294
Cortical Bone	4	12.454	0.14331
Cancellous Bone	4	20.788	0.34

Figure 2 shows free view of the constructed human arm model. Beside the human arm model is a GSM phone model that operate at carrier frequency of 900MHz, which is modulated at frequency of 217Hz with modulation index equal to 0.5. The GSM phone radiation power is at 0.02W. The phone model is placed as near as possible to the human arm model without overlapping each other which has produce a distance of 9mm between them. Figure 2. setup has produced a near field region scenario because the human arm is located in the near field of radiated GSM phone signal. This setup is considered because this paper concentrating on a worst case scenario of GSM phone radiation effects towards human arm nerve fibres.

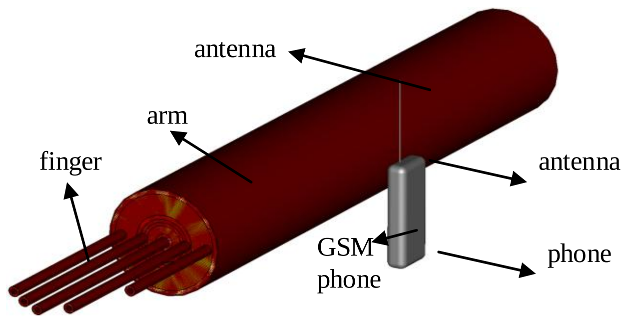

Fig.2. Human arm model with a GSM phone

B. Brain-Arm Nerve Fibres Modelling

Nerve fibre is closely related to human arm movement because it carried signal so called AP from brain to arm in order to initiate finger muscles either to reflex or extend. Therefore, it is understood that brain represents as a voltage source, nerve fibre as a TL, finger muscle as a load and AP as signals in the circuit. Furthermore, one of important AP characteristic is it can propagate without attenuating [10]. Therefore, current advanced simulation software like PSpice has its own lossless TL tools that allow signals to propagate without attenuating. Hence, this tool is fully utilized in modelling the nerve fibres TL.

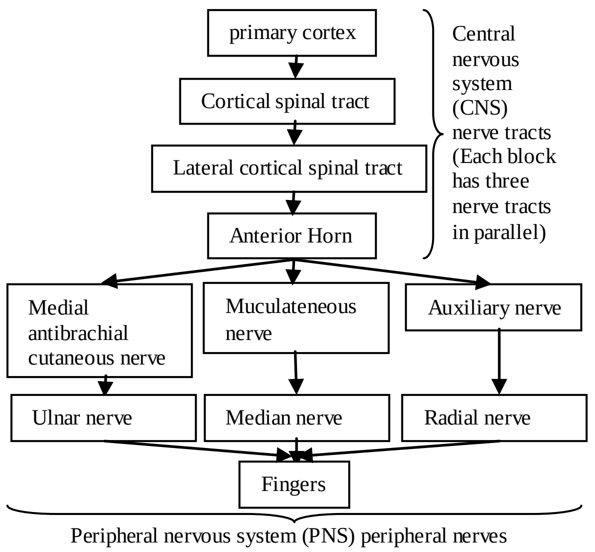

Fig.3. Anatomy flow of human brain-arm nerve fibre

Further study in anatomy field shows that nerve fibre tract from brain to arm involved more than one nerve fibre [11]. Figure 3 shows the propagation tracts of the AP from brain to fingers of human arm. Furthermore, the study also discovers there are two types of tracts from brain to arm. First type is that nerve consists of parallel bundles of nerve fibres which are motor and sensory nerve fibres [11]. Therefore, those nerve fibres represent two wires TL with motor nerve fibre as a path for signal travel down to load and sensory nerve fibre as a path for signal return to source. Second type is that motor nerve fibre is surrounded by extracellular fluids [11].

Considering the the GSM phone radiation interaction within the nerve layer of human arm model plus with the knowledge of anatomy flow of human brain-arm nerve fibre, more accurate two wires and one wire TL models with induced sources effect has been produced. Figure 4 and Figure 5 show two models of brain-arm nerve fibres according to the anatomy flow presented in Figure 3.

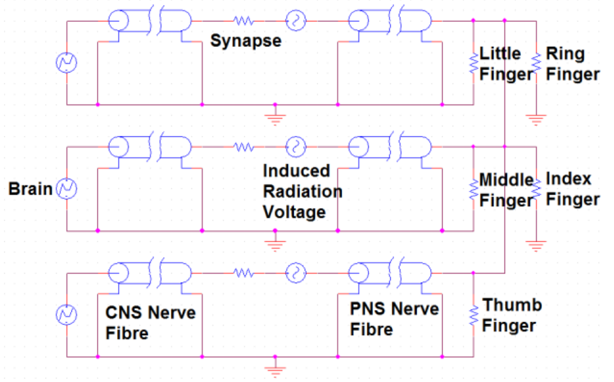

Fig.4. Brain-arm nerve fibres with radiation voltage factor for both two and one wires TL

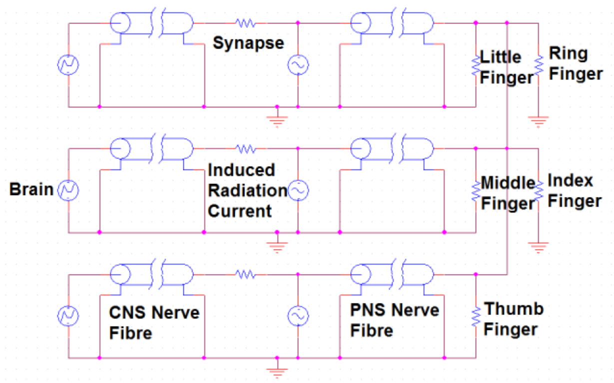

Fig.5. Brain-arm nerve fibres with radiation current factor for both two and one wire TL

Simple model of spiking neurons by Izhikevich [12] is used as the voltage source for both models. Value for both types of induced sources are obtained by substituting magnetic field and electric field intensity at nerve layer from CST simulation into induced voltage source, VsL and induced current source, IsL formulae respectively as in [13]. Those TL have uniform plane wave propagation by having characteristic impedance, Z0 and time delay, td as in [13]. Resistance of each finger is also calculated by using formula in [13] with each finger has its own specific length. All used and calculated parameters are summarized in Table 2. Finally, the severity of the EMR induction are analysed in Pspice time domain in order to verify EMR induction effects on the original AP properties.

Table 2. Summary of defined and calculated parameters

Parameter (unit)	Value
Muscle relative permittivity at 200 Hz, ε_{rm}	0.291 [9]
Thumb finger and nerve fibre length, L_{tf} (m) and L (m)	0.12 & 0.56 [14]
Thumb finger resistance, R_{tf} (Ω)	30311
Middle and index finger resistance, R_{mf} (Ω) and R_{inf} (Ω)	35110 & 32444
Distance between nerve fibre and natrium ion, h (μm)	10.01 [15]
Synapse gap, L_s(nm)	20 [11]
Extracellular relative permittivity, ε_r	74.3 [9]
Inductor of one wire TL, l_1(nH)	8.943
Capacitor of one wire TL, c_1(μF)	0.1232
Characteristic impedance of one wire TL, Z_{o1}(Ω)	0.2695
Magnetic field in nerve fibre, |H|(A/m)	0.144
Induced voltage of one wire TL, V_sL_1(mV)	11.456
Induced current of one wire TL, I_sL_1(mA)	46.718
Little and ring finger length, L_{lf} (m) and L_{rf} (m)	0.17 & 0.19 [14]
Middle and index finger length, L_{mf} (m) and L_{inf} (m)	0.2 & 0.185 [14]
Little and ring finger resistance, R_{lf} (Ω) and R_{rf} (Ω)	29777 & 32888
Neuron radius, r_w(μm)	10 [15]
Distance between two neurons, s(μm)	50 [15]
Synapse resistance, R_s(Ω)	42.16
Time delay of one wire and two wires TL, t_d(ms)	4.658
Inductor of two wire TL, l_2(μH)	0.627
Capacitor of two wire TL, c_2(nF)	1.758
Characteristic impedance of two wire TL, Z_{o2}(Ω)	18.883
Electric field in nerve, |E|(V/m)	5.994
Induced voltage of two wire TL, V_sL_2 (mV)	28.612
Induced current of two wire TL, I_sL_2(mA)	1.665

Simulation Results

A. Radiation effects on brain-arm nerve fibre's AP

Figure 6 and Figure 7 show the waveform of source AP from the brain (solid traces), load AP without any radiation effects at the muscle finger (dash traces) and load AP with an induced current source radiation effects at the muscle finger (dot traces). Meanwhile, Figure 8 and Figure 9 show the waveform of source AP from the brain (solid traces), load AP without any radiation effects at the muscle finger (dash traces) and load AP with an induced voltage source radiation effects at the muscle finger (dot traces).

TL models simulated without any induced source has shown no effect in magnitude of the load AP (dash traces) which still has the same magnitude as the source AP (dot traces). That means information from brain is transferred accurately to muscle fingers in order to make any movement as instructed. Appearance of either induced sources for both TL models has altered the AP by introducing an interference signal like some sort of bursting spikes that appear like riding on the original output AP (solid traces). Interference of EM radiation sources has altered the shape of original output and this might lead to disturbance in the human arm function to conduct accurately some specific movement instructed by the brain.

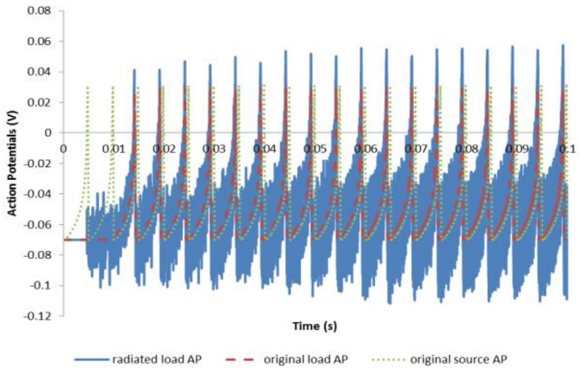

Fig.6. Interference of an induced current source on one wire TL model

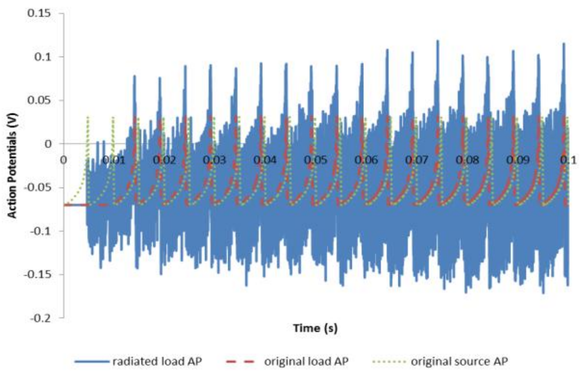

Fig.7. Interference of an induced current source on two wires TL model

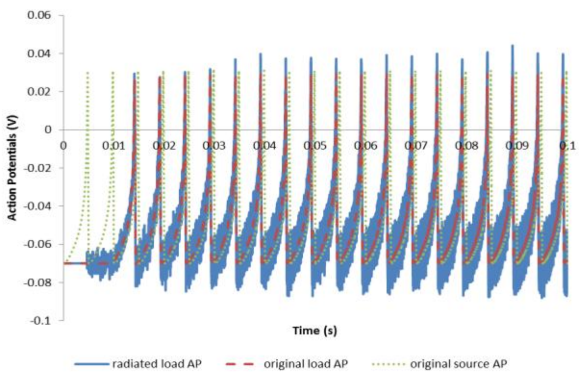

Fig.8. Interference of an induced voltage source on one wire TL model

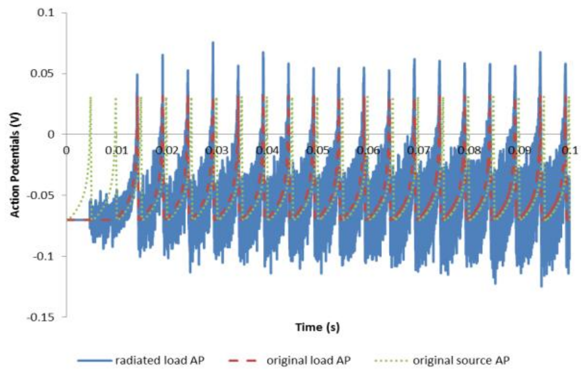

Fig.9. Interference of an induced voltage source on two wires TL model

B. Nerve fibre radius effect on AP disturbance

Figure 10 and Figure 11 show the interference effects of an induced current source towards the AP for both TL models by variiying the radius of nerve fibre (rw). Meanwhile, Figure 12 and Figure 13 show the interference effects of an induced voltage source towards the AP for both TL models by variiying radius of nerve fibre.

Results show as the radius of nerve fibre increases from 2.5 μm to 5 μm and eventually to 10 μm, interference towards the AP also increases. This scenario indicates that motor nerve fibre is easily affected by the radiation source rather than sensory nerve fibre. Motor nerve fibre is really important in coordinating any human body movement. This motor nerve fibre is the main focus in this research as the human arm does do a lot of movement in our daily life. Therefore, it is essential to know the radiation effects towards the AP in the motor nerve fibre as the AP is signal that controls the arm movement.

When the energy information is lost the problem become worse as node energy level may go below the threshold value and due to inefficient gathering of energy information from head node to the sensor the delay will be more ,because until new cluster head selected the sensor cannot get the information of nodes. Thus an decision coordination priority technique has been proposed where the sensors gives first priority to the cluster head than the normal nodes.

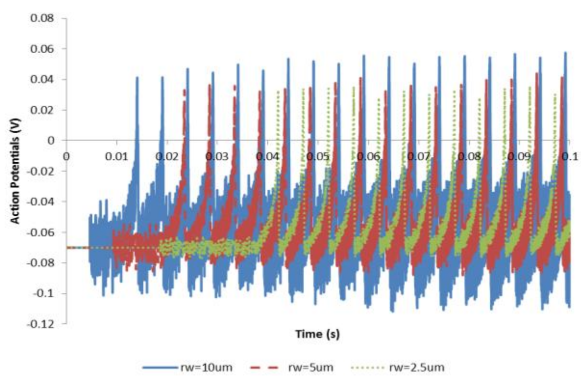

Fig.10. Interference of an induced current source on one wire TL model with varied fibre radius

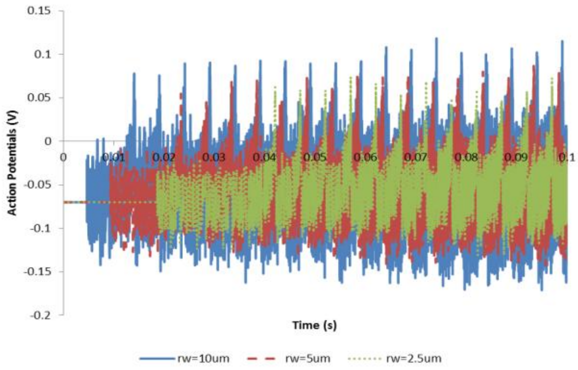

Fig.11. Interference of an induced current source on two wires TL model with varied fibre radius

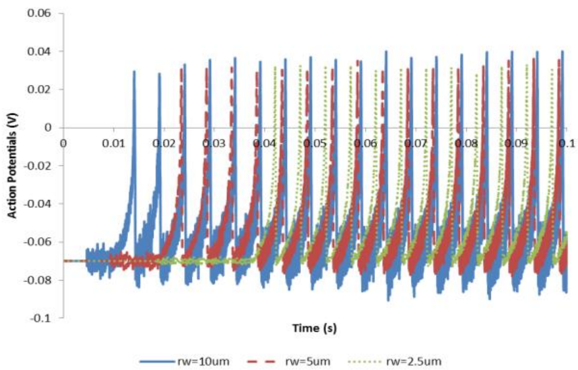

Fig.12. Interference of an induced voltage source on one wire TL model with varied fibre radius

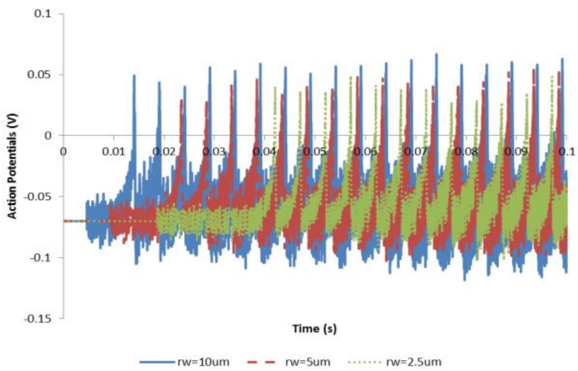

Fig.13. Interference of an induced voltage source on two wires TL model with varied fibre radius

C. Discussion on simulation results

Results from both TL models show the induced current source are dominant in affecting the AP because bursting spike interference riding on the original AP is large in amplitude compared to when induced voltage source as the source of interference in the TL models. This happen due to human arm organs has high relative permittivity at 900 MHz and therefore it easily affected by electric field radiation which induced the current source. Furthermore, from results obtained one wire TL model shows more reasonable result compared to two wire TL model. This is because bigger interference spike magnitude either from induced current source or induced voltage source might cause severity to human arm function even if it's exposed for a short period. Therefore, it is not logical for human arm to get movement disorder with just short exposure of a mobile phone near to human arm. It was clearly seen from all AP results above, one wire TL model is effected less by the radiation effect in term of interference spike magnitude rather than two wires TL model regardless of which interference source applied to those models.

Conclusions

The modeling of the simplest human arm model in layers of cylindrical solid has been successfully achieved. The model can give brief results on the electric field and magnetic field magnitudes absorbed by the nerve layer and hence assisted in identifying the induction sources value introduced by GSM mobile phone. Investigation in motor nerve fibre of human brain-arm anatomy has produced actual nerve fibre tracts which can be presented as two wires and one wire TL model. The tract almost resembles the real human brain-arm neuronal system. The effects of GSM mobile phone radiation has proven to alter the AP as shown in time domain simulations. This alteration might interfere with the human arm harmonious function. The one wire TL model is the most suitable model to resemble the nerve fibre tracts in the human brain-arm nervous system as spikes introduce in the AP is in a right magnitude so that it does not bring severity to human arm function even if its exposed for a short period.

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