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INITIAL RESULTS ON MEDIUM FREQUENCY ELECTROMAGNETIC FIELD PENETRATION IN BIOLOGICAL SOFT TISSUE

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Abstract. Therapy is among the oldest medication technique in maintaining the health of the body especially from bad blood circulation, stroke and several others. This technique includes acupuncture, guasa and also massage. There are also modern therapy techniques like colour therapy, water therapy, ozone therapy, drug therapy and others. This paper will highlight electromagnetic therapy generator, a device which has the potential of therapy application in medical field. This device produce medium frequency magnetic field as a therapy source. This small scale medium frequency and low cost hardware that has been developed was tested on the biological tissue for the purpose of measuring the magnetic field penetration. The testing has proven that the generated magnetic field is able to penetrate the soft tissue up to 2 cm with distance from the source up to 7 cm. The capability of the system penetrations through the soft tissues provide the bright future of this research since magnetic field have shown the potential as being part of the therapy for curing migraine, stroke, cramp and several others besides the application in the magnetic induction tomography imaging.

Keywords: Electromagnetic therapy, magnetic field, penetration, soft tissue; medical applications

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Abstrak Terapi merupakan antara teknik perubatan tertua dalam mengekalkan kesihatan badan terutama daripada aliran darah yang tidak baik, strok dan beberapa penyakit yang lain. Teknik ini termasuklah akupuntur, guasa dan juga urutan. Terdapat juga teknik terapi moden seperti terapi warna, terapi ozon, terapi dadah dan banyak lagi. Kertas kajian ini akan mengetengahkan penjana terapi elektromagnet, satu alat yang mempunyai potensi aplikasi terapi dalam bidang perubatan. Alat ini menghasilkan medan magnet berfrekuensi sederhana sebagai sumber terapi. Perkakasan yang berskala kecil berfrekuensi sederhana dan berkos rendah ini telah dibangunkan dan telah diuji pada tisu biologi bagi mengukur tahap ketembusan medan magnet. Ujian ini telah membuktikan bahawa medan magnet yang telah dihasilkan mampu menembusi tisu lembut bersaiz sehingga 2 cm dengan jarak 7 cm daripada sumber. Kebolehan penembusan sistem ini terhadap tisu lembut memberikan peluang yang cerah kepada kajian ini memandangkan medan magnet telah menunjukkan potensi sebagai sebahagian daripada terapi untuk memulihkan migraine, strok, kekejangan dan beberapa yang lain selain boleh diaplikasikan dalam pengimejan tomografi induksi magnet.

Kata kunci: Terapi elektromagnet, medan magnet, penembusan, tisu lembut, aplikasi perubatan

1.0 INTRODUCTION

The applications of electromagnetic in therapy have been studied for several years and have been proven to give good results to human health. Electromagnetic therapy is part of the electromagnetic techniques which apply electromagnetic fields to treat and prevent diseases besides promoting health and longevity as extend *in vitro* cellular proliferative life span as well as delay and reverse some of the age-dependent changes in both replicative and non-replicative cells [1]. Although the electricity itself remains confined within the wire, the induced magnetic fields move outside in direction. The fact that makes this treatment so remarkable is that living tissue is essentially transparent to magnetic fields. When a varying electromagnetic field is placed close to a conductive medium such as the human body, it will induce electrical current, also known as Eddy current which then will produce its own electromagnetic field. This field may then interact with the cell surface membrane where through this interaction may lead to the changes of cell internal ion concentration. This phenomenon may trigger production or synthesis of certain enzyme or special products that helps in maintaining, improve or cure Alzheimer [1], certain metabolism problem [2]. Other than that, electromagnetic therapy also has been proven successfully in the management of postsurgical pain and edema, the treatment of chronic wounds, and in facilitating vasodilatation and angiogenesis [3], treating osteo-artritis [4], does prevent bone loss adjacent to the distraction gap [5], promote healing of chronic arterial and venous leg ulcers [6], reduce pain during migraine [7], help fighting cancer cells [8], treatment of acute stroke [9] and several others.

1.1 Difference Between Magnetic Theraphy and Electromagnetic Therapy

Even though the name is quite similar to each other, the operation and applications of magnetic and electromagnetic are different. A magnetic therapy normally uses a permanent magnet as a source of static magnetic field [10, 11] with permanent field strength. This static field does not vary over time. While for electromagnetic therapy, it normally uses pulses for generating time varying field [12] which may produce field at different frequencies or wavelengths depend on the source applied. These two parameters (frequency and wavelength) will characterize each electromagnetic field since it is directly related to each other: the higher the frequency the shorter the wavelength.

The biological effects of electromagnetic fields is hypothesized to be due to electrical rather than magnetic forces, which are different for static magnetic field where the effects on the biological tissues are not due to electrical current in nature. This hypothesis is based on the theory that magnetism generates a voltage in tissue according to the equation:

$$V = n \times a \times \frac{dB}{dt} \tag{1}$$

Where;

V = Voltage
n = number of turns in the electromagnetic coil
a = area of the loop
$\frac{dB}{dt}$ = The rate of change of magnetic field with respect to time

Based on this equation, a static magnetic field cannot generate an electrical voltage, as the $\frac{dB}{dt}$ component of the equation, is zero, as is the voltage induced by the field [13].

1.2 Electromagnetic Fields and Biological Effects

Human and animal organisms consist of a large number of cells which function electrically. If there is no electrical potential left in the cell, it is no longer viable. These cells have a basic (or rest) potential that is necessary for normal cellular metabolism [13]. There is ample evidence that electrical activity exists in the body at all times. For example, electrical currents can be measured in the beating heart

and are also generated in the production of bone. Endogenous electrical current densities produced by mechanical loading of bone under physiologic conditions approximate 1 Hz and 0.1-1.0 micro A/cm2 [14].

Since blood vessel is almost everywhere in our body, this make electromagnetic therapy healing process promise a good result. When a magnetic field with a series of alternating North and South poles is placed over a blood vessel, the influence of the field will cause positive and negative ions (for example, Na^+ and Cl-) to bounce back and forth between the sides of the vessel, creating flow currents in the moving blood not unlike those in a river. The combination of the electromotive force, altered ionic pattern, and the currents causes blood vessel dilation with a corresponding increase in blood flow [15]. However the penetration of magnetic field depends on the temperature and the frequency, since the frequency is related to wavelength λ [16] where:

$$frequency, f \propto \frac{1}{wave\ length, \lambda}$$

The low-frequency magnetic field will penetrate every single cell being exposed to the pulsing field. This in turn influences the ions within the cell to enhance ion exchange which will improve the oxygen utilization of the cell. This is important for every healing and regeneration process [17].

Anyhow extracellular matrix synthesis and repair are subject to regulation both by chemical agents (such as cytokines and growth factors) and physical agents, principally mechanical and electrical stimuli. The precise nature of such electromechanical signals is not known, however. In bone, mechanical and electrical signals may regulate the synthesis of extracellular matrix by stimulating signaling pathways at the cell membrane [18-19].

Another interesting part is as Shiba. K. *et al.* [20] did report that, there is absorption of transmitted energy in biological soft tissue surrounded his developed artificial heart. This finding may help us in explaining the pattern of measured magnetic field value during penetrating the biological soft tissue. Another thing that needs to take into consideration is, the generation of secondary magnetic field by the cells when primary field from the source penetrate them. The combination of these two fields will produce a slightly higher value at the receiver (detector) during measurement [21-22].

2.0 EXPERIMENTAL SETUP

In this experiment several important components have been used such as inductor with maximum current capacity of 3 A, MOSFET to drive the flow current and also heat sink to reduce the generated heat. Before PCB design process happens, circuit as in Figure 1 is designed and simulated and tested using MULTISIM. The output as shown in Figure 2 will display the generated frequency and at the same time through the simulation we can determine whether circuit is working properly. The real circuit on the fabricate PCB is shown in Figure 3. In this simulation, motor is used to represent magnetic coil, since in MULTISIM magnetic coil is not in the list.

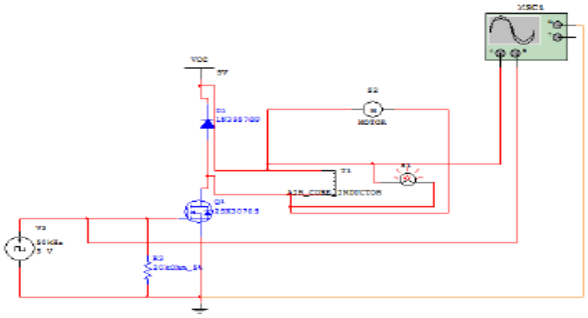

Figure 1 Constructed circuit using MULTISIM

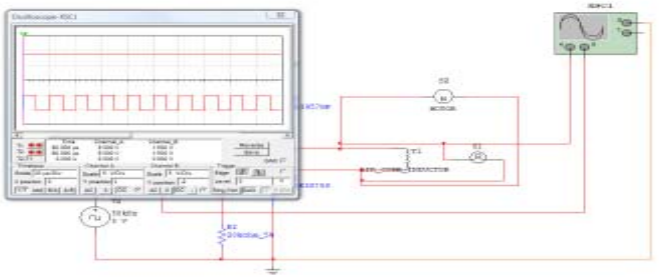

Figure 2 Simulation result using MULTISIM

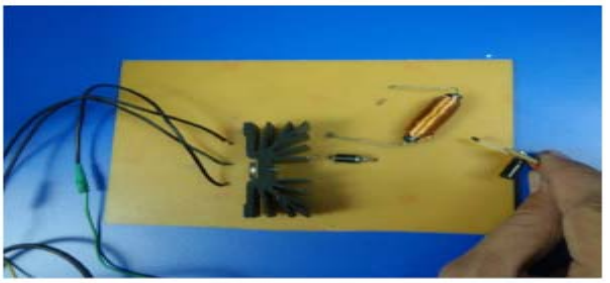

Figure 3 Real circuit of electromagnetic therapy board

3.0 RESULT AND DISCUSSION

In the measurement sessions, the magnetic strength at different distances was measured using gauss meter and Hall Effect sensor. Since the value of magnetic field depends on the current that flows in the coil and distance, current of 1.0 A has been tested. The testing of the soft tissue is shown in Figure 4.

Figure 4 Measuring of magnetic field penetration on soft tissue

In this experiment beef tissues have been selected as the subject. The thickness of the tissue is increased up to 2.0 cm. Table 1 shows the results of the testing and Figure 5 shows the graph the magnetic flux density versus the thickness of tissue.

Table 1 Result of penetration in soft tissue at different frequencies with 1.0A current

Thickness of soft tissue	Magnetic field value		
	10.7 kHz	50 kHz	200 kHz
0	2.11	5.05	10.32
0.5	6.26	15.37	14.53
0.7	21.47	14.11	12.63
1.0	5.89	8.84	7.79
2.0	3.58	6.74	6.74

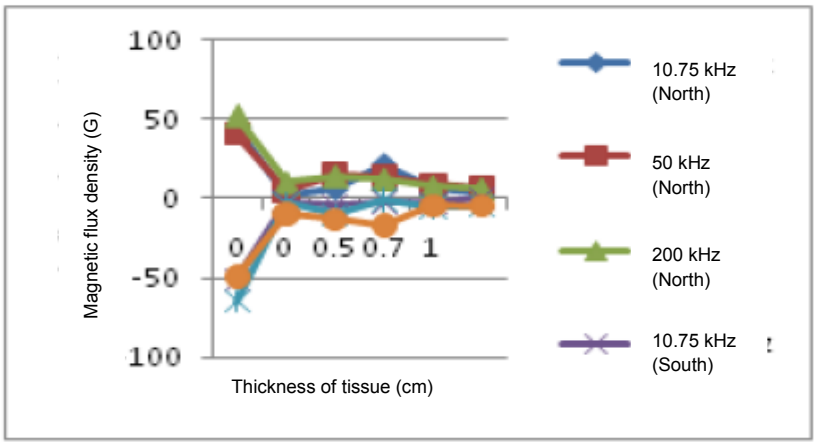

Figure 5 Magnetic field penetration pattern with different values of frequency

From the result, all three frequencies have shown the same pattern of magnetic field strength starting from minimum then increased to maximum at thickness of 0.7 cm (for 10.7 kHz) while at thickness 0.5 cm (for both 50 kHz and 200 kHz). All magnetic field strength then decreased after these sample thickness. These results mean that, source with frequency 10.7 kHz will penetrate deeper into the tissue compare to other higher frequencies (50 kHz and 200 kHz). At this maximum penetration, the primary magnetic field (from the source) may penetrate almost all the biological cells of the tissue sample, and these cells will generate their own field (secondary field). The combination of primary field and secondary field will produce higher reading of magnetic field value when detected by hall effect sensor. The absorption happened when thickness of the sample exceeded the mentioned value, and this is the reason why there are reductions of the magnetic field value when exceeding this sample thickness.

4.0 CONCLUSIONS

In conclusion this electromagnetic therapy prototype device is capable to operate at medium frequency with 2 cm tissue penetration capabilities, where 2 cm penetration depth is suitable to be applied at hand, leg muscle, knee and arm especially for wound injury. Lower applied frequency will make the penetration more deep into the tissue compare to the higher applied frequency value while working at this lower frequency will minimize the potential of magnetic radiation to the patient during the therapy sessions. Within this range of penetration, it has the potential to be applied to human body as one of the low cost therapy source.

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