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A Study of Biomagnetic Stimulation for Transcranial Application

A Study of Biomagnetic Stimulation for Transcranial Application

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Abstract. Biomagnetic stimulation is a treatment uses the application of magnetic field principle for a therapeutic purpose. This non-invasive therapeutic technique use low frequency electromagnetic field which is less than 10 MHz. In transcranial application, electromagnetic field is use to stimulate the brain tissue for the people affected by weaken neurologic and psychiatric disorders. This paper discusses the modelling and simulation of Transcranial Magnetic Stimulation using Comsol Multiphysics software. In this research four designs have been simulated. The overall analysis indicates that a single coil design has the best performance in stimulating the area of interest at the frequency of 5MHz.

1. Introduction

The human brain is made up of biological tissues with a specific value of conductivity that is different than others biological tissues in human body. Any electrical abnormality that happens to human brain can leads to a neurological disorder such mental illnesses and ischemic [1]. Transcranial Magnetic Stimulation is basically based on Faraday electromagnetic induction principle where a pulse of electric current with a high intensity is applied near a patient head through a coil, non-invasively. The current in the coil in turn will generate a electromagnetic field which penetrates the scalp and skull and the brain tissue. The energy form the field is transferred to the brain tissue and trigger the metabolism of the brain cells and activates the brain activities through depolarising the neurons which eventually producing a different neurophysiological responses and behavioural changes at the targeted region [2].

In the case of glioma which is the interest of this project, it is found that 40% of glioma located in the frontal lobe, 29% in temporal lobe, 14% in parietal lobe, and 3% in occipital lobe and with 14% in the deeper structures. Glioma is a kind of tumor that occurs in brain and spinal cord [3],[4].

2. Modelling and Simulation procedure

COMSOL Multiphysics is used to design the biomagnetic stimulation coil for transcranial which involves brain tissue. The coil that will be used is a circular type coil with 1A [5] and the radius is set up to 25mm with 10 number of turns [6]. The brain model is a 66 years old human head with a radius of 100mm [7]. The distance of stimulating coil from the scalp is fixed to be 5mm [8]. The depth of a cortical surface from the surface of the head is assumed to be 15 mm [9]. Hence, the radius of cortical region of the brain will be 85mm. The conductivity and permittivity value for the brain tissue is set to be 0.292 S/m and 320 respectively [10]. In this project, the frequency is set to be fixed at 5MHz. The material of the coil is made up of copper. The flow chart of methodology is shown Figure 1.

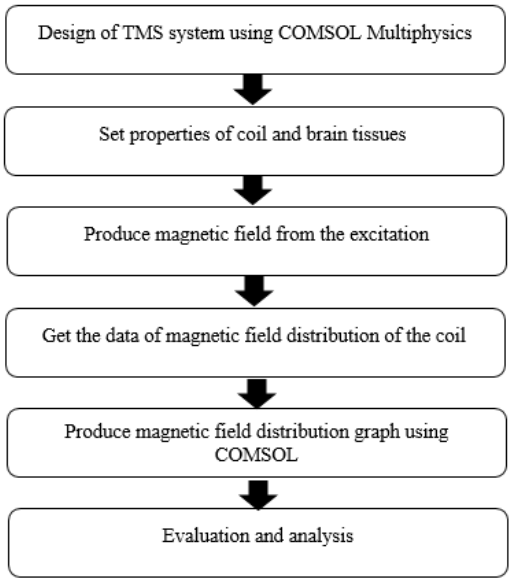


Figure 1. Flowchart of the procedure

3. Result and Discussion

3.1. The modelling of biomagnetic stimulation effect on transcranial application.

Figure 2 shows the model design in Comsol and the magnetic flux density after stimulation. Figure 3 shows a graph for magnetic density versus distance. From this graph, we can conclude that as the distance increase, the value of magnetic density decreases. Hence, this system is valid for a normal size of human brain.

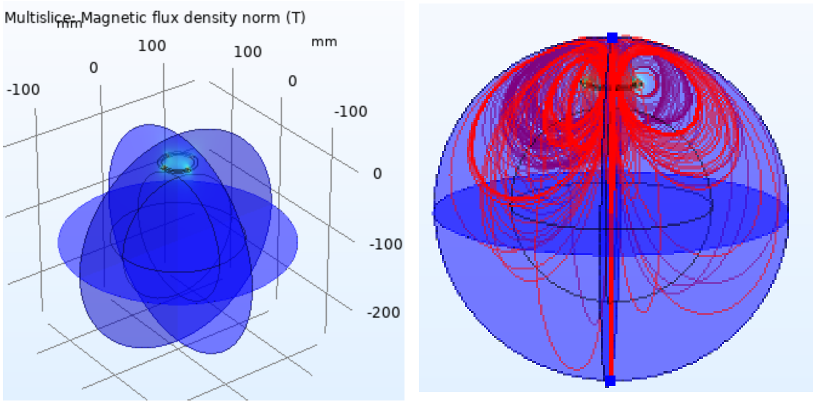
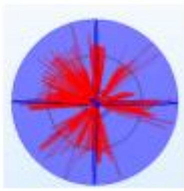
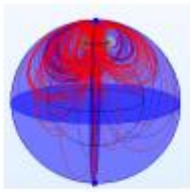
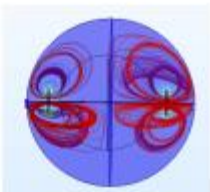
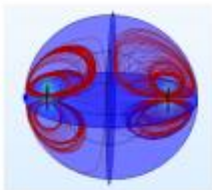
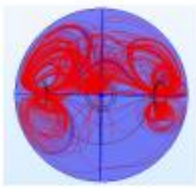
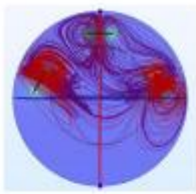
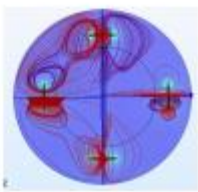
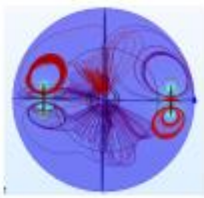


Figure 2. Coil design and magnetic flux density stimulation using COMSOL Multiphysics

3.2. The modelling and stimulation of four different design of coil placement

Table 1. Four different designs of coil placement

DESIGN	TOP VIEW	FRONT VIEW
1 COIL		
2 COIL		
3 COIL		
4 COIL		

3.3. The evaluation of simulation result

Table 2 shows the graph for magnetic field distribution produced for each design.

Table 2. Magnetic Flux Density (T) vs Distance (mm)

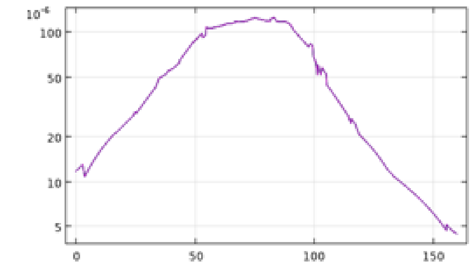
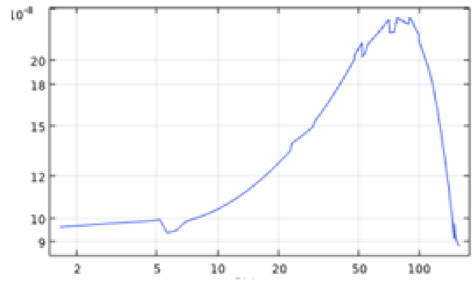
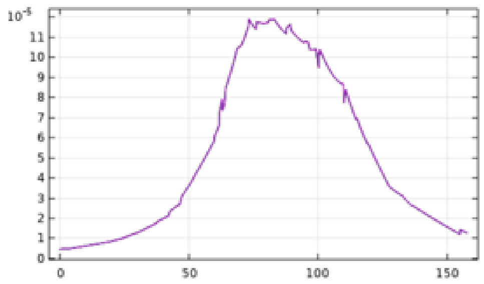
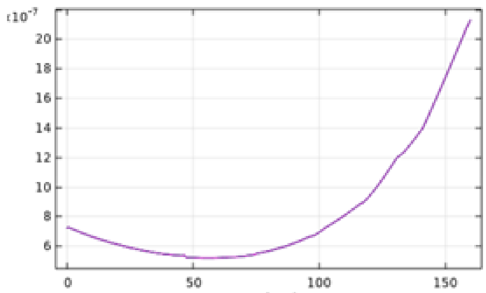
One coil	Two coil
	
Three coil	**Four coil**
	

Table 1 show One-Coil and Three-Coil design has distribution of electromagnetic field at the central of brain area whereas for Two-coil and Four-coil design the distribution are towards the end of the line. In term of maximum strength, approximately $120x10^{-4}$ T, $30x10^{-4}$ T, $12x10^{-5}$ and $22x10^{-7}$ T for One-Coil, Two-Coil, Three-Coil and Four-Coil respectively.

4. Conclusion

The results show that One-coil design has been the best option which produce focus central electromagnetic field distribution and with the highest maximum amplitude.

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