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ELECTROMAGNETIC MODELLING OF ARTIFICIAL PACEMAKER

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ELECTROMAGNETIC MODELLING OF ARTIFICIAL PACEMAKER

EMELIA ANAK GUNGGU

This project is submitted to
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in partial fulfilment of the requirements
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Dedicated to my beloved family

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ABSTRAK

Pacemaker tiruan diimplan ke dalam tubuh seseorang yang mengalami degupan jantung yang lemah. Ia mengantikan fungsi *pacemaker* dengan mengawal kelemahan dengupan jantung. Alat elektronik yang kecil itu mengandungi sistem *lead electrode*, *pacemaker* dan *connector*. Operasi telefon bimbit menghasilkan kesan elektromagnetik (EM) pada peralatan elektronik yang lain kerana Radio Frekuensi (RF) yang dimilikinya. Pendedahan elektromagnetik yang berlebihan ke atas *pacemaker* tiruan mungkin akan menyebabkannya gagal berfungsi, ketidakselesaan dan kesakitan kepada penggunanya. Bagi menilai darjah interferen elektromagnetik pada *pacemaker* yang dihasilkan oleh sumber EM seperti telefon bimbit, adalah lebih baik untuk memahami operasi *pacemaker* dan litarnya terlebih dahulu. Justeru itu, kajian ini dilakukan untuk membentuk model EM bagi *pacemaker* tiruan dan mengira radiasi *impedance*, yang diinduksikan oleh sumber voltan dan juga voltan dan arus interferen yang terhasil pada *connector pacemaker*. Simulasi keputusan yang diperoleh daripada pemprogramman dalam perisian Microsoft Visual C++, digunakan untuk menganalisis model *pacemaker* ketika kapasitor *pacemaker* dicas dan dinyahcaskan. Proses pengecasan dan penyahcasan kapasitor *pacemaker* yang berterusan, menggalakan denyutan jantung.

ABSTRACT

Artificial pacemaker is implanted into the body of one whom encounters heart beat failure. It replaces the function of heart pacemaker by controlling heart beat ineffability. The tiny electronic device consists of the lead electrode system, pacemaker itself and connector. The operation of mobile phone produces electromagnetic effects to other electronic devices due to its Radio Frequency (RF). Excessive exposure of electromagnetic (EM) on the artificial pacemaker may cause failure to it and discomfort and illness to its user. In order to evaluate the degree of electromagnetic interference (EMI) on the pacemaker due to EM source such as mobile phone, it is best to understand the operation of pacemaker and its circuitry. Hence, this research is carried out to develop EM modeling of an artificial heart pacemaker and to determine the radiation impedance, induced by the source voltage and also the interference voltage and current which exist at the connector of the pacemaker. Simulated results obtain from programming in Microsoft Visual C++ is used to analyze the EM modeling of artificial pacemaker when the capacitor of the pacemaker is charging and discharging. As the continuous process of charging and discharging of pacemaker's capacitor will stimulate the heart beat of the user.

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CHAPTER 1

INTRODUCTION

Broad application of microwave and radio frequency (RF) devices such as in telecommunication, radio, radar and biomedical is due to today's rapid development of electronics industry. The risk of microwave and RF devices to human health and other electronics devices is questioned through out the study of electromagnetic radiation (EMR) and human health.

Ability of using mobile phone at wide coverage, timelessly led to its necessary used in daily life. Attached or integrated antenna in the mobile phone produced RF exposure through its transmission and reception data.

Excessive exposure to RF fields can caused adverse health consequences while the electromagnetic interference (EMI) due to RF energy may cause malfunction to electronics devices such as implanted pacemaker. EMI level from mobile phone towards the implanted pacemaker depend on the strength of the electromagnetic field, duration of exposure, frequency of the source and distance. Malfunction of implanted pacemaker can caused irritation, discomfort and illness to its user.

1.1 Project Objectives

This research is done to develop the EM modelling of an artificial heart pacemaker due to its exposure to electromagnetic (EM) field i.e. exhibited by mobile phone. Based on the modelling of artificial heart pacemaker, the radiation impedance, the level of voltage and current interference are determined.

1.2 Statement of Problems

Contraction between electromagnetic source i.e. mobile phone with implanted pacemaker may caused interference to the pacemaker. For a better understanding on the pacemaker operation, the modelling of artificial pacemaker need to be develop to calculate the radiation impedance, the level of voltage and current interference of the pacemaker. In order to determine the degree of electromagnetic interference of the pacemaker it is suggested to implement FDTD method.

1.3 Project Approach

The electromagnetic radiation (EMR) on the pacemaker is calculated based on the formulas develop from the modeling of artificial pacemaker. Simulation results are obtained from the programming in Microsoft Visual 6.0 C++ software.

1.4 Expected Outcomes and Contributions

The modelling of the pacemaker is expected to be developed, which can be implemented to determine the radiation impedance at the connector of the pacemaker and as well the voltage and current interference due to electromagnetic field.

1.5 Project Outlines

Chapter 1 is the introduction which plainly describes the effects of mobile phone towards the implanted pacemaker operation. Project objective, project approaches, expected outcomes and contributions and also project outlines is included in the chapter.

The overall system of implanted pacemaker, its advantages to human health is written in Chapter 2 Literature Review. User of implanted pacemaker is advisable to keep distance from electric and magnetic sources, to avoid interruption to the pacemaker. Hence, in this chapter explanation is carried out on the types of electromagnetic (EM) sources and surroundings, implanted pacemaker's users should avoid. The characteristics of material for each of the implanted pacemaker component are also described. Moreover, the pacing impedance of the pacemaker is being explained on this chapter.

The suggested approach to develop this research is briefly discussed in Chapter 3 Methodology. Finite-difference time-domain (FDTD) method is used to obtain the EMI level of the mobile phone towards the pacemaker. Related equations and algorithm is

written for better understanding of the method which includes Taylor's series, Maxwell's equations, Yee's algorithm, transverse magnetic mode in z-direction for two-dimension (TM_Z). Meanwhile, the EM modelling of the pacemaker when it is being charged and discharged is being discussed in order to evaluate the radiation impedance (Z_R), the level of voltage (V_I) and current interference (I_I) of the pacemaker with time.

Result of the research is included in Chapter 4 and as well analysis and discussion for the results. The results consist of graphs of radiation impedance (Z_R), voltage and current interference (V_I and I_I) when the capacitor of pacemaker modelling is in the state of charge and discharge.

The last chapter (Chapter 5), conclude the outcomes of the research and recommendations is added for future reference. Problems encounter in the process of accomplishing this project is also being explained.

CHAPTER 2

LITERATURE REVIEW

This chapter describes what is pacemaker, advantages of pacemaker, pacemaker and surroundings and material characteristics for each pacemaker components. Moreover, the basic concept of pacemaker circuitry is being explained in this chapter.

2.1 Pacemaker

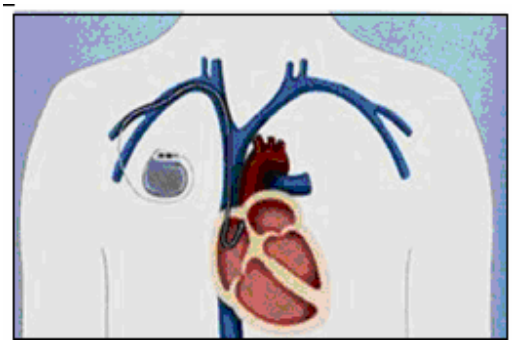

Figure 2.1: Location of pacemaker [1]

Inappropriate heart rate can be normalized by implanting a small battery-operated device underneath the skin near the shoulder of cardiovascular patients which is known as artificial pacemaker. This device utilizes electrical impulses transported by electrodes which contacting the heart muscle, to regulate the beating of the heart.

The weight of a pacemaker is about 20 to 50 grams [2]. It is implanted under the collar bone and consists of one or more leads which are located into the heart via a vein. There are three types of pacemakers which are single-chamber pacemaker, dual-chamber pacemaker and biventricular pacemaker, at which they differ in numbers of lead.

Single-chamber pacemaker contains one lead which is implanted either in atrium or ventricle, depends on the cause and nature of *Bradycardia*. The single-chamber pacemaker receives signals from and pace only the specified area (ventricle or atrium).

However for dual-chamber, it consists of two leads which pace both atrium and ventricle. It coordinates the signals and contractions of the atria and ventricles for efficient function.

Moreover, biventricular pacemaker owns three leads where one in the right atrium, one placed in the right ventricle, and one placed in the left ventricle via the coronary sinus vein.

2.2 Advantages of Pacemaker

In order to carries oxygen and nourish our cells, our heart pumps bloods to the cells of our body. The heart beats due to electrical impulses generate by *sinus node* or *sinoatrial* (the heart's natural pacemaker). Disease or age related process; can cause one to suffer *Bradycardia*, rhythm disorders- problems in the conduction system or possible blockage of the pathways [1].

However by the implantation of artificial pacemaker on the body of *Bradycardia* patients, they will no longer encounter rhythmic pace disorder anymore.

When the body's demand could not conduct an amount of oxygen to body, it can caused dizziness, extreme fatigue, shortness of breath, confusion or fainting and etc, which are symptoms of abnormal heart beat. This sickness can be reduce and ended by implantation of artificial pacemaker.

2.3 Pacemaker and Surroundings

One who is wearing an artificial pacemaker must be alert to his surroundings and electronic devices in order to avoid interference on the pulse generator of pacemaker

2.2.1 Home appliances

Electric shavers, microwave ovens, vacuum cleaners, radios and televisions do not affect pacemaker pulse generator by altering the pacing rates. However, power generator, arc welding equipment and powerful magnets as in medical devices, heavy equipment or motor can inhibit pulse generators.

2.2.2 Cell phones

Digital cellular phones can interfere with pacemaker [3]. Hence, it is advisable that the users of pacemaker placed there cellular phone held their phone opposite from the side of pacemaker and do not carry the phone in the pocket near their chest.

2.2.3 The Pacemaker and medical equipment

Magnetic Resonance Imaging (MRI scan) can interfere the pacing and inhibit the output of pacemaker as it apply strong magnetic field in order to produce the images of internal organs and functions. Hence, the users of pacemaker should not carryout MRI scanning without discussion with doctor. Diagnostic scanning (such as X-ray) does not totally inhibit pacemaker output. But therapeutic radiation which is for threatening cancerous tumors can damage the pacemaker's circuit. Adversely, dental equipment does not effect pacemaker operation. For most users of pacemaker, Extracorporeal Shock-Wave Lithotripsy (ESWL) to dissolve kidney stone is a safe treatment with some reprogramming of the pacing. But patients with certain kinds of pacemaker implanted in