SPECIFIC ABSORPTION RATE IN THE PRESENCE OF CONDUCTIVE METALLIC OBJECTS WITH CLOSE PROXIMITY RADIATING SOURCE

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A thesis submitted in fulfilment of the
requirements for the award of the degree of
Master of Engineering (Electrical)

Faculty of Electrical Engineering
Universiti Teknologi Malaysia

MARCH 2015

To my beloved mom & dad,

Rosadah Abu Bakar & Othman Puteh

my dearest husband,

Aizat Azmi

my supportive sister & brother

Syazwani & Mohd Nizam

ACKNOWLEDGEMENT

Alhamdulillah, Praise to Allah S.W.T for HIS blessing and guidance have helped me in completing my thesis. I would like to take this opportunity to express my deepest gratitude to my supervisor, Dr Noor Asmawati Samsuri and my co-supervisor, Professor Dr. Mohamad Kamal for their advice, guidance, motivation, suggestions and ideas throughout my study from the beginning to the end of this research.

My utmost thanks also go to my family, especially my father, my beloved mother, and my dearest husband to whom I owe my love and gratitude for their support every moment I need them. I can never thank them so much and tell how much I appreciate their encouragement.

To all my friends and P18 members who have helped and supported me along the way, I thank you from the bottom of my heart. Thank you; the most suitable words for those who keep supporting and be there all the way through my years in Universiti Teknologi Malaysia.

ABSTRACT

This thesis identifies and evaluates the effect of human body and conductive metallic objects in the vicinity of portable handheld electronic devices on antenna radiation pattern, antenna performance and Specific Absorption Rate (SAR). The presences of electronic devices in the vicinity of human body especially close to the human sensitive part (when the antenna is left inside the trousers pocket) allow the radiated electromagnetic wave to penetrate inside human tissues. Homogeneous and realistic body models have been considered in the simulation. The excitation is provided by means of a simple dipole and PIFA antennas as the radiating source at four different frequencies (0.4, 0.9, 1.8 and 2.4 GHz). In order to characterize the variation of SAR due to metallic items, the external metallic item and implanted medical item are used and modelled as conducting objects with their sizes chosen in order to coincide with typical sizes available. The results have shown that the presence of human body near to the antenna detuned the resonant frequency and significantly distorted the antenna radiation pattern. Nevertheless, the presence of conductive objects do not have any profound effect on antenna radiation pattern due to their size which is relatively small compared to the size of human body. Additional metallic objects close to the human leg could alter the SAR and the effect varies depending on the size and the position of the objects. In addition, the zip could significantly increase SAR inside the testicle by 50% at 0.9 GHz due to the position of zip that is close to the human sensitive organ. Nevertheless, the presence of conductive medical implant inside the leg could increase the maximum SAR by more than 400 times at 0.4 GHz. However, the medical implant has only minor effect on SAR inside the testicle. The simulation results have been validated through measurement using homogeneous body model at 2.4 GHz.

ABSTRAK

Tesis ini mengenal pasti dan mengkaji kesan kehadiran tubuh manusia dan objek bersifat konduktif yang berhampiran dengan elektronik mudah alih pada corak radiasi antena, prestasi antena dan Kadar Penyerapan Spesifik (SAR). Kehadiran alat-alat elektronik berhampiran badan manusia terutama berdekatan dengan bahagian sensitif manusia (apabila antena ditinggalkan di dalam poket seluar) menyebabkan gelombang elektromagnetik menembusi tisu badan manusia. Model homogen dan model realistik telah digunakan dalam kajian ini. Dwipolar antena dan PIFA antena digunakan sebagai sumber radiasi pada empat frekuensi yang berbeza (0.4, 0.9, 1.8 dan 2.4 GHz). Objek luar dan implan yang bersifat konduktif digunakan dalam simulasi berangka untuk mencirikan kesan objek tersebut terhadap SAR dengan mengubah saiz objek tersebut berdasarkan saiz yang terdapat di pasaran. Keputusan kajian menunjukkan bahawa kehadiran badan manusia berhampiran dengan antena menyebabkan perubahan pada frekuensi dan corak radiasi antena. Walau bagaimanapun, kehadiran objek bersifat konduktif berhampiran dengan antena tidak memberi sebarang kesan kepada corak radiasi antena kerana saiz objek adalah lebih kecil berbanding saiz badan manusia. Kehadiran objek bersifat konduktif berhampiran kawasan kaki manusia boleh mengubah SAR dan perbezaan kesan bergantung kepada saiz dan kedudukan objek. Selain itu, kehadiran zip bersifat konduktif juga boleh meningkatkan SAR di dalam testikel sebanyak 50% pada 0.4 GHz adalah disebabkan oleh kedudukan zip yang terletak berhampiran dengan testikel. Tambahan pula, kehadiran implan bersifat konduktif boleh meningkatkan SAR maksima lebih daripada 400 kali ganda pada 0.9 GHz. Walau bagaimanapun, kehadiran implan hanya menyebabkan perubahan SAR yang kecil dalam testikel. Keputusan simulasi berangka telah disahkan melalui pengukuran menggunakan model badan homogen pada 2.4 GHz.

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LIST OF ABBREVIATIONS

EM	-	Electromagnetic
RF	-	Radio Frequency
ICNIRP	-	International Commission on Non-Ionizing Radiation Protection
SAR	-	Specific Absorption Rate
ELF	-	Extremely Low Frequency
UHF	-	Ultra High Frequency
SAM	-	Specific Anthropomorphic Mannequin
FDTD	-	Finite Difference Time Domain
DASY	-	Dosimetric Assessment System
MRI	-	Magnetic Resonance Imaging
FIT	-	Finite Integration Technique
MOM	-	Method on Moment
CST	-	Computer Simulation Technology
PIFA	-	Planar Inverted–F Antenna
PEC	-	Perfect Electric Conductor
FCC	-	Federal Communications Commission

LIST OF SYMBOLS

ρ	-	mass density of the materials
ε_r	-	relative permittivity
σ	-	tissue conductivity
η_{tot}	-	total efficiency
η_{rad}	-	radiation efficiency
d	-	antenna-body distance
r	-	radius of coin and ring
l_r	-	length of intramedullary nail

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CHAPTER 1

INTRODUCTION

1.1 Introduction

The extremely fast development in mobile and wireless technologies, along with the use of radio frequency (RF) as the channel for data transmission has led to the increase of public concern on the possible adverse health effects due to the electromagnetic (EM) wave radiated by the antenna while in used. The antenna periodically emits the EM radiation although it is in standby mode. Generally, a mobile phone is usually being placed close to the human head when it is in used, while it is left inside the trousers pocket (especially front trousers pocket) for longer duration when it is not being operated. In this case, the mobile phone is left in standby mode and in very close proximity to the human body (waist area). In 2005, research in [1] has found that 57% of man out of 419 left their mobile phone inside the trousers pocket. This condition has raised the public concerned due to the vicinity of the human sensitive organ to the radiation source. Researches in [2-4] have shown that EM wave could significantly affect the male reproductive system due to the thermal and non-thermal effects especially on human spermatozoa.

In normal practice, there are some conductive metallic items such as coin, ring, zip, and belt placed inside and in close proximity to the trousers pocket, hence they have become very close to the mobile phone antenna. Besides, patients who suffer from bone fracture are having orthopedic implant such as bone plate, screw, pins, rods implanted inside their body. These metallic implants when exposed to the radiation source could enhance the current density in nearby body tissue when compared to the body model without any implant [5]. The finding in [5] has shown that the significant increase in current density however exceeded the restriction recommended by International Commission on Non-Ionizing Radiation Protection (ICNIRP). In recent years, numbers of studies have focused on the effect of metallic implant inside the head [6-8] and body [9-12]. Research in [6] has found that the conductive metallic implant notably increases the Specific Absorption Rate (SAR) inside the head by 162% for 1g SAR and 64% for 10g SAR.

Besides, numerous studies have examined the interaction between the EM fields radiated by the mobile handset with the human head [13-19], the human head and hand [19-21], and also with additional conductors such as external objects (wire-framed spectacles, braces, ring, bangles, hands-free, earring, zip, coin) [22-27] that may also have effects on the amount of the EM field radiated by the antenna. Researches [19, 22-26] have found that the presence of additional external conductors may change the amount of energy absorption inside the human body. Moreover, researchers in [25] who have investigated the effect of common metallic items placed inside the trouser pocket (zip, coin, and ring) on SAR suggested that the small increment of SAR values in the testicles could be very important than the same increase in the leg.

1.2 Problem Statement and Significance of the Research

In recent years, there have been considerable research efforts devoted to the effect of human head on antenna performance especially for mobile phone and wireless devices [28-32]. These published researches reported that the presence of human head in close proximity to the antenna has significantly detuned the antenna resonance. Part of the energy radiated by the antenna is absorbed by the body hence modifying the antenna efficiency and radiation pattern. In addition to that, some researches [6, 26, 33, 34] have shown that the presences of additional metallic objects near the antenna and the human body have notable effect on the amount of energy absorbed by the body. Therefore it is expected that this condition will further modifies the antenna performance. However the effect of human body on antenna performance in the presence of metallic object has received limited attention in the literature. Therefore, this research aims to further investigate the effect of additional metallic items (such as coin, ring and zip) on antenna performance at 0.4 GHz, 0.9 GHz, 1.8 GHz and 2.4 GHz. These frequencies are chosen to represent the frequency for walkie-talkies, GSM band and ISM band where the operating devices are used in close proximity to the human body.

In addition, rapid development and usage of mobile devices has raised the public concern on any possible health effect due to the amount of energy absorbed by the body. The condition is further worrying as some researchers [22, 26] have found that the common metallic items worn on the human head enhances the energy absorbed by 25%. In practice, the mobile phone is placed near the head while in used, but left for longer duration inside the trousers pocket while not in used. Therefore, the effect of antenna radiation on the waist part of the body is placed in doubt, especially when it could consequently affect the human sensitive organ (testicle). Besides, study in [4] has demonstrated that the presence of EM radiation increases the temperature inside the testicle and affect the behavior of the normal sperm.

The issue complicates further by the presence of additional metallic items inside the trousers pocket. The additional metallic items such as key, coin and keychain ring that are usually left inside the trousers pocket may enhance the energy radiated by the antenna and thus increases the temperature and the amount of energy absorbed by the body and the sensitive organ. Very little works have been done on the effect of EM field on human sensitive organ (testicular) in the presence of any additional metallic objects [25]. Therefore, this research will further investigate the effect of common metallic items on the amount of energy absorbed by the body, focusing on the waist area including the testicle tissues.

On the other hand, as the presence of external metallic objects is expected to further enhances the energy absorbed by the body and affecting the testicle tissues, the presence of additional metallic items implanted inside the waist area are also another concerning matters. Previous researches have shown that the presence of conductive implant has increased the current distribution and SAR inside the human body [5, 9, 35]. Research in [9] focuses on small size metallic implant and the results demonstrated that the effect on SAR is less significant. However, larger size of conductive implant is expected to have significant effect on SAR. To date, there is no available research investigating the effect of medical implant near the reproductive organ. Therefore this research will examine the effect of larger size conductive implant (bone plate and intramedullary nail) on antenna performance and SAR focusing on the waist area including the men sensitive organ.

Moreover, most researches have been focusing on the far-field interaction of the human body in the vicinity of additional metallic objects [11, 16, 26, 36-38]. To the best of our knowledge, there are very limited number of researches that focused on the near-filed effect of external metallic objects [25] and conductive metallic implant [35, 38] especially in the waist area. Such work is crucial and worth further investigations since the implants, particularly near to the leg area is typically very close to the human sensitive organ. The presence of the conductive implant in the near-field exposure is expected to significantly increases the SAR in the testicle since the position of the testicle is considerably close to the mobile antenna when it is left inside the front trousers pocket. Hence, this research aims to investigate and analyse the effect of human body, external metallic objects and medical implant on antenna performance and SAR in near-field exposure.

1.3 Objectives

The main objective of this research is to evaluate the effect of human body on antenna performance and energy absorbed by the human body in the presence of metallic objects (common external metallic objects and medical implants). The effect on human sensitive organ (testicular) will also be addressed in this research. This research involves numerical simulation and also measurement for validation purposes.

The objectives can be summarized as follows:

- To evaluate the effect by the presence of human body close to the antenna on antenna performance and SAR at 0.4 GHz, 0.9 GHz, 1.8 GHz and 2.4 GHz

- To determine and analyse the effect by the presence of external metallic objects and metallic implant closed to the human body on the antenna performance and SAR

- To construct simple measurement set-up in order to measure and validate SAR in the waist area at 2.4 GHz

1.4 Scope of Research

The evaluations on antenna performance and SAR due to conductive metallic items involve a series of research work. This research is done based on the following scope:

- Literature review on the interaction between the human body and antenna performance and also the factor that possibly affect the SAR.

- In order to study the effect of different dielectric properties of body model on antenna performance and SAR, three types of body models are considered in this research which are: simple cylindrical homogeneous body model, realistic Voxel body model and homogeneous Voxel body model.

- Simulate two types of antenna ($\lambda/2$ dipole and PIFA) in freespace condition at four frequencies; 0.4 GHz, 0.9 GHz, 1.8 GHz and 2.4 GHz.

- Then, the body model is included in the simulation and the antenna is place next to the leg. The orientation of the antenna is varied to vertical and horizontal orientation with respect to the body in order to study the effect of human body on antenna performance.

- Additional metallic items (coin, keychain ring and zip) made of copper and conductive medical implant (bone plate and intramedullary rod) made of stainless steel are then introduced in the simulation. The antenna performance and SAR with and without the presence of conductive items are compared.

- Further investigation and evaluation on the factor that affect the SAR distributions by varying the radius of ring, r, the length of intramedullary rod, l_r and bone plate.

- Measurement system is constructed for validation purpose using body phantom made of fiberglass. The body phantom is filled with muscle equivalent liquid at 2.4 GHz . Then, simulations and measurements results are compared and examined.

- Simulated and measured results are analyzed and discussed the in terms of S_{11}, antenna radiation pattern, SAR and current density.

1.5 Organization of Thesis

This thesis consists of seven chapters:

Chapter 1 presents a brief introduction of the thesis including the problem statement, the significance of the research, the objectives, and the scope of research.

Chapter 2 is an overview on the previous work related to this research. The basic concept of EM wave, the interaction between the EM wave and the human body with and without the presence of metallic object, the energy absorption by the human tissues is also discussed in this chapter.

Chapter 3 presents the methodology and the project flow involved in this research. This project includes simulation and measurements that will be explained in details in this chapter.

In chapter 4, the effect of external metallic items on antenna performance and SAR are discussed. The metallic items are designed as a coin, ring and zip. The size of the ring is varied as well as the homogeneity of body model (homogeneous and inhomogeneous). The results are presented in the form of antenna performance and SAR.

Chapter 5 analyses the simulation results on the effect of human body in the presence of medical implants. In order to identify the factors that affect the energy distribution and absorption, two types of medical implants (intramedullary nail and bone plate) with different length are considered in this research. The effect of using different types of body model also have been investigated and discussed in this chapter.

Chapter 6 discusses the measurement results. All measurements are conducted at 2.4 GHz using dipole antenna as the radiation source. The measured results are compared and further validate the simulation results.

The conclusions and summary on the research work are stated in Chapter 7 together with the recommendation for additional study.

References are listed at the end of this thesis.

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