SPECIFIC ABSORPTION RATE AND HISTOPATHOLOGICAL EVALUATION FOR MOBILE PHONE APPLICATION

by

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LIST OF ABBREVIATIONS

CAD	Computer-Aided Design
CENELEC	European Committee for Electrotechnical Standardization (*Comité Européen de Normalisation Électrotechnique*)
CTIA	Cellular Telecommunications Industry Association
DNA	Deoxyribonucleic acid
EM	Electromagnetic
FCC	Federal Communications Commission
FDTD	Finite-Difference Time Domain
FEM	Finite Element Method
FIT	Finite Integral Technique
FPBA	Fast Perfect Boundary Approximation
FR-4	Flame Retardant 4
GSM	Global Systems for Mobile Communications
ICNIRP	International Commission on Non-Ionizing Radiation Protection
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineering
LCD	Liquid Crystal Display
MCMC	Malaysian Communications and Multimedia Commission
MoH	Ministry of Health
MoM	Method of Moments
MPE	Maximum Permissible Exposure
PCB	Printed Circuit Board
PIFA	Planar Inverted-F Antenna
RF	Radio Frequency

SAM	Specific Anthropomorphic Mannequin
SAR	Specific Absorption Rate
SIM	Subscriber ID Module
SPEAG	Schmidt and Partner Engineering AG
TIS	Total Isotropic Sensitivity
TSL	Tissue Simulating Liquid

LIST OF SYMBOLS

°C	Degree Celsius
cm	Centimeter
dB	Desibel
e’	Dielectric constant
f	Frequency
f_c	Center frequency
F_{max}	Maximum frequency
F_{min}	Minimum frequency
g	Gram
GHz	Gigahertz
Hz	Hertz
J	Joule
K	Kelvin
kg	Kilogram
m	Meter
MHz	Megahertz
mm	Millimeter
S	Siemens
SAR_{1g}	SAR averaged over 1 gram
SAR_{10g}	SAR averaged over 10 gram
S_{11}	Reflection coefficient
V	Voltage
W	Watts
μm	Micrometer/microns
σ	Electrical conductivity

KADAR SERAPAN KHUSUS DAN PENILAIAN HISTOPATOLOGI BAGI APLIKASI TELEFON BIMBIT

ABSTRAK

Laporan ini menerangkan tentang pembikinan model kepala dan tangan orang Asia menggunakan perisian rekabentuk terbantu komputer (CAD) dan menganalisis kadar serapan khusus (SAR) pada 900 MHz hingga 1800 MHz dengan pelbagai posisi tangan. Motivasi untuk kajian ini telah diilhamkan oleh kekurangan sumber penyelidikan mengenai kesan-kesan SAR terhadap pengguna di Asia kerana kebanyakan kerja dilakukan dengan menggunakan model bersaiz Eropah. Untuk terus menyumbangkan maklumat berkaitan Asia, model tangan bersaiz orang Asia direkabentuk, dijalankan simulasi menggunakan antenna satah F-terbalik (PIFA) dan melakukan siasatan terhadap pengagihan SAR dengan kewujudan model tangan tersebut. Kesan radiasi di frekuensi 1800 MHz diuji pula pada tikus jenis Sprague-Dawley menggunakan pendekatan histopatologi. Rekabentuk model tangan orang Asia dimulakan dengan model geometri mudah berserta ciri-ciri tisu manusia yang dibentuk pada dua gerakan biasa mod berbual bersama-sama dengan model kepala patung antropomorfik khusus (SAM) untuk kajian perbandingan dan seterusnya berkembang menjadi model tangan separa realistik berdasarkan bancian yang dijalankan. Tangan wanita Asia dipilih selepas mengutip data saiz tangan kebiasaan orang Asia untuk kedua-dua lelaki dan wanita berumur di antara 19 hingga 25 tahun. Saiz purata menunjukkan bahawa tangan lelaki adalah sama dengan piawaian model tangan SAM yang biasa digunakan untuk siasatan SAR sedangkan tangan wanita didapati lebih kecil daripada itu. Siasatan SAR dijalankan dengan menggunakan saiz purata model tangan wanita dalam perisian CST Studio Suite bersama telefon mudah alih jenis petak dan lipat yang menggunakan pancaran dari PIFA pada kedua-dua frekuensi terhadap model kepala bersaiz orang Asia. Hasil menunjukkan bahawa model tangan dengan lapisan tisu kebiasaan di dalam tangan manusia - kulit, tulang, otot dan tendon, memberi nilai SAR yang tinggi pada 1800 MHz dengan pola sebaran yang kecil tetapi lebih tertumpu ke arah dalam bahagian telinga dan pipi. Kepelbagaian model tangan telah membantu memberikan pemahaman yang lebih baik tentang gaya memegang telefon yang boleh mengurangkan penyerapan radiasi semasa mod berbual. Kajian ini diteruskan dengan pengujian terhadap 100 tikus Sprague-Dawley berumur dalam lingkungan 2 hingga 3 bulan yang didedahkan secara menyeluruh menggunakan isyarat 1800 MHz dari Antenna Hon Gandaan selama tempoh satu bulan dan dua bulan. Sampel yang diambil daripada tikus tersebut adalah otak, kulit, otot dengan tendon dari tangan tikus. Sampel dihiris dengan ketebalan mikron dan dilihat pada mikroskop sebarang perubahan sel. Terdapat perubahan yang ketara dalam sampel kulit yang diperolehi, dan beberapa penemuan tompokan dalam sampel otak yang memerlukan analisis yang terperinci. Kesimpulannya, kajian ini menawarkan alternatif mudah untuk merekacipta model tangan yang sesuai mengikut kumpulan sasaran siasatan, sebagai contoh seperti maklumat berkenaan orang Asia ini. Berbanding dengan model tangan piawai, model tangan yang lebih kecil dan sesuai dengan saiz purata kumpulan sasaran ini adalah lebih sesuai digunapakai dan ujian terhadap haiwan juga banyak membantu dalam memahami kesan secara biologi pada tahap sel.

SPECIFIC ABSORPTION RATE AND HISTOPATHOLOGY EVALUATION FOR MOBILE PHONE APPLICATION

ABSTRACT

This report describes the development of Asian head and hand model using computer-aided design (CAD) software and the analysis of specific absorption rate (SAR) at 900 MHz to 1800 MHz with various hand positions. The motivation for this work has been inspired by the lack of research contributions on the effects of SAR towards Asian users since most work is done using European-sized model. To further contribute for the Asian database, Asian-sized hand models are designed, simulated with a planar inverted-F antenna (PIFA) and investigated for the distribution of SAR with the inclusion of the hand model. The radiation effect at 1800 MHz is tested on Sprague-Dawley rats using histopathology approach. The Asian hand model design development begins with simple geometrical model with human tissue properties posed at two common talk-mode positions together with a Specific Anthropomorphic Mannequin (SAM) head model for comparative study and further evolved into a semi-realistic hand model based on a conducted survey. The female Asian hand was chosen after collecting data of the size of typical Asian hand for both male and female ranging from age 19 to 25 years old. The mean size shows that the male hand is similar to the standard SAM hand model commonly used for SAR investigation whereas the female hand is found smaller than that. The SAR investigation is carried on with the average size of female hand model in Computer Simulation Technology (CST) Studio Suite using a candy-bar and clamshell type mobile phone with PIFA radiating at both frequencies in the vicinity of Asian-sized head model. The result have shown that the hand model with layers of common tissues in human hand – skin, bone, muscle and tendon, gave a high value of SAR at 1800 MHz with the spreading pattern smaller but deeper into the ear and cheek part. The various hand models has help to provide a better understanding in hand grip styles that may reduce absorption while in talk-mode. This research continues on animal testing of 100 Sprague-Dawley rats aged 2 to 3 months old exposed whole body to 1800 MHz signal generated by a Standard Gain Horn Antenna for one month and two months duration. The samples taken from the rats are the brain, the skin, the muscle with tendon from the hand of the rat. The samples is sliced in six micron thickness and put under microscope to observe any cell changes. Significant changes in skin samples are obtained, with some patchy appearance found in brain that needed more analysis. As a conclusion, this work offers simple alternative for developing suitable hand model according to the target group of investigation, in this case for Asian database. Compared to the standard hand model, a smaller hand that suits the averaged size of this target group is more reliable and the test on animal has help a lot in understanding biological effects at the level of the cells.

CHAPTER 1

INTRODUCTION

1.1 Background

Early mobile communication started off with simplex radio communications used by the militaries, police units, rescue teams or even among construction workers to children combat games which is a one-way communication using a short range device called walkie-talkie. Today's handheld mobile communications evolved to a duplex radio communications that is a two-way communications without delay with a wider range of distance, the whole world.

In Malaysia as in 2011, there were 36,123,300 hand phone subscriptions to a population of 28,477,600 with the mainstay of the subscriber base were young adults in the '20 - 24 years old' age group, followed by the '25 – 29 years old' age group from a group survey range of below 15 until above 50 years old (MCMC,2012a). By the year 2014, the penetration rate per 100 inhabitants was 143.7% which is already over than 100% due to multiple subscriptions and number of device possession per person (MCMC, 2014). The survey conducted in 2012 (MCMC, 2013) in terms of hand phone ownership shows that 63.3% of users owns only one mobile phone, 29.6% carries two, another 5% uses three hand phones while 2.1% have four or more in possession. These summarizes that mobile phone are nowadays an important gadget in daily life especially for the youngsters and definitely all users will be exposed to the radiation emitted from the device for the entire day ever since it was purchased.

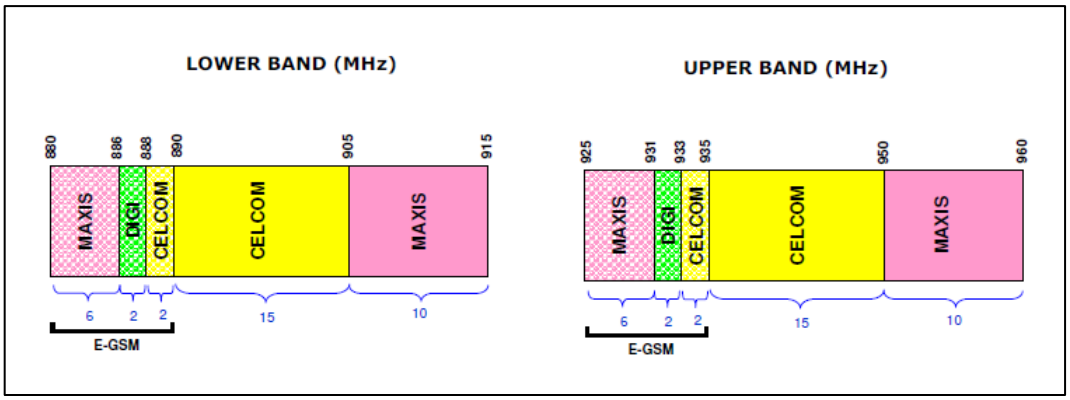
The spectrum allocation in Malaysia is guarded by a government body that manages frequency bands from 3kHz to 420THz, the Malaysian Communications and Multimedia Commission (MCMC). Mobile phone service providers mainly request for allocation in the GSM bands at 900 MHz and 1800 MHz, and the latest were allocated in UMTS band at 2000MHz (MCMC, 2012b). The exact frequency range applied by the major service providers in Malaysia are shown in Figure 1.1. However, research on mobile phone radiation mostly focuses on GSM bands since these are the earliest frequencies allocated for the service providers to the general public.

The effect of being exposed to electromagnetic waves can be assessed from two categories; mathematically or biologically. In terms of mathematics, the time rate of RF energy being absorbed into a specific averaged mass of tissue from human or animals are measured as the Specific Absorption Rate (SAR) (Habash, 2006). The mathematical model of SAR is defined as,

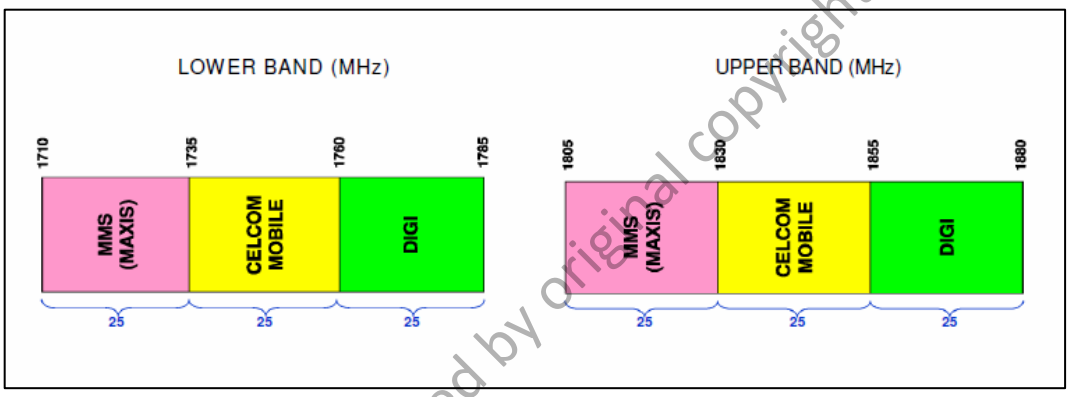
$$\text{SAR} = \frac{\sigma|\text{E}|^2}{\rho} \tag{1.1}$$

where |E| is the root mean square (RMS) value of the induced electric field (V/m), σ the electrical conductivity of the tissue (S/m), and ρ the density of the tissue (kg/m^3) (Yelkenci et al.,2008).

Since 1990s, the Finite Difference Time Domain (FDTD) method based on Maxwell's time-domain equations became the most widely accepted means for SAR calculation. In applying the FDTD method for numerical dosimetry calculation, the Yee cells correspond completely to the voxels in biological models by assigning the corresponding permittivity and conductivity to each voxel; one can easily model the anatomical tissues and organs, and calculate the internal electric and magnetic field (Watanabe et al., 1996).



(a)



(b)

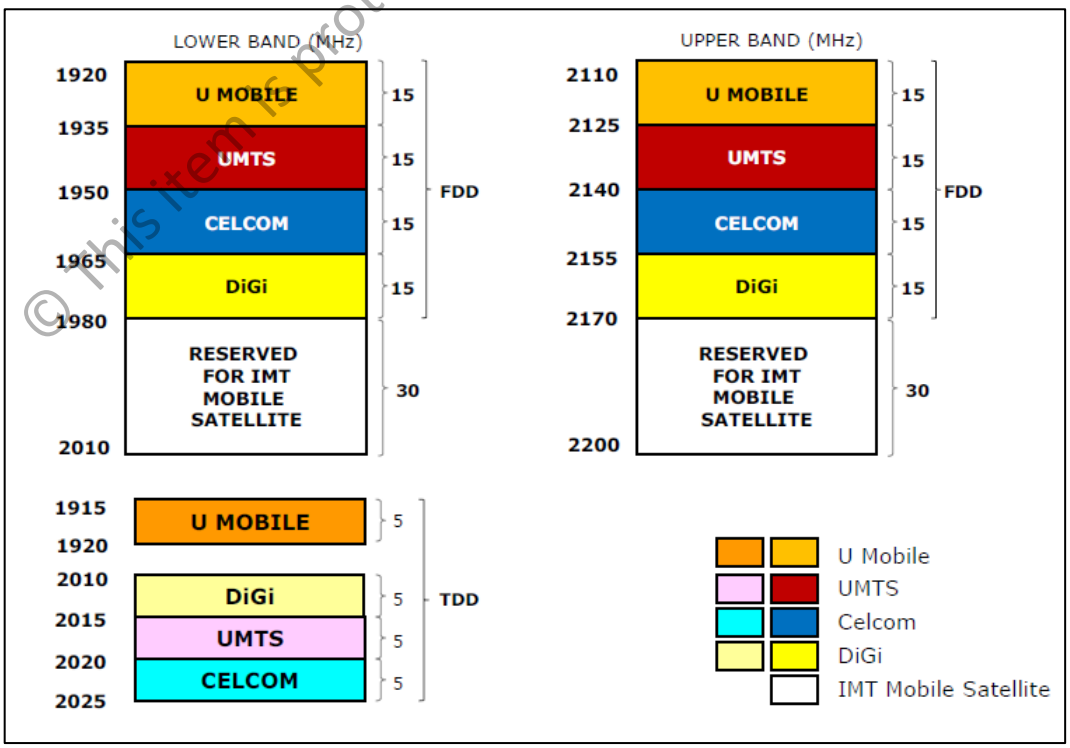


Figure 1.1: Spectrum bands in Malaysia (a) GSM900, (b) GSM1800 and (c) IMT2000 bands (MCMC, 2012b)

As for the permittivity and conductivity values of each tissue, the parametric models using 4-Cole-Cole equations based on measured data from 10 Hz to 20 GHz by Gabriel (Gabriel et al., 1996a; Gabriel et al., 1996b) constitute the most widely accepted biological tissues database.

Malaysia is one of the countries in the world that adopts the SAR safety limit guidelines from the International Commission on Non-Ionizing Radiation Protection (ICNIRP). This organization's activities include determining the exposure limits for electromagnetic fields used by devices, for example, mobile phone and it also specialized in non-ionizing radiation protection. ICNIRP standards are being used widely in Europe, Africa, South America, Middle East and some Asia countries.

Besides ICNIRP, there are other safety regulators in the world such as the Federal Communications Commission (FCC) which is under the Institute of Electrical and Electronics Engineering (IEEE) adopted by North America, Bolivia and Korea, and also the Maximum Permissible Exposure (MPE) with no accessible research data being used by Russia only. In 1982, IEEE C95.1-1982 was the first national standard in which field limits were derived from frequency dependent dosimetry quantity SAR (Mason et al., 2001). Recommended safety limits guideline of SAR from two leading regulators as mentioned are listed in Table 1.1.

All of the SAR values shown in Table 1.1 are values from measurement time averaged over any 6 minutes period, while the survey done by MCMC annually shows increment in mobile phone possession, hence a longer period of usage. These are the group that were exposed to the near field RF energy more than the time of exposure used when determining the safety limit guidelines by the ICNIRP (1998, 2009).