



Faculty of Engineering

**DEVELOPMENT OF THERMAL CONTROL RADIATION TOOL FOR
THE USED WITH SMART DEVICES**

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DEVELOPMENT OF THERMAL CONTROL RADIATION TOOL FOR
THE USED WITH SMART DEVICES

SITI NUR AMMARAH THAQIFAH BINTI ROSLAN

A dissertation submitted in partial fulfillment
of the requirement for the degree of
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To my beloved family and friends

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ABSTRACT

Nowadays, the number of usages in mobile communication is increasing due to the dependency of society to a new and advanced technology driven by wireless communication systems. Almost every people worldwide use mobile phone or smart phone including children. Due to the increased number of users using mobile phone, it may lead to the exposure of the thermal radiation of the mobile phone towards human health. The thermal effects are due to electromagnetic exposure from the smart phone. A human head has been exposed to electromagnetic radiation emitted by the different Global system for Mobile Communication (GSM). A human head, especially skin near ear-skull region is very thin compared to the other part of the human body. When using a smart phone in a long period of time, this region will absorb heat emission from the smart phone/mobile devices. This leads to increasing of temperature around the head and some research would show that this effect would cause severe headache/migrain. An experimental study was conducted by using a volunteer to examine the effect of EM radiation produced when calling and using the smart phone. In this project a smart phone that served GSM 1800MHz are used. The average time of calling and using smart phone is approximately 45 minutes and the data are measured by thermographic methods using FLIR ONE Camera. The result shows that, with a certain period of time, the temperature of the ear skull and human's face region increase due to the absorption of thermal radiation. From the result, a device is develop to alert the user on the temperature increase when using the respective device.

ABSTRAK

Pada masa kini, jumlah kelaziman dalam penggunaan komunikasi mudah alih semakin meningkat disebabkan oleh kebergantungan masyarakat kepada teknologi baru dan maju didorong oleh sistem komunikasi tanpa wayar. Hampir setiap orang di seluruh dunia menggunakan telefon bimbit atau telefon pintar termasuk kanak-kanak. Oleh kerana peningkatan bilangan pengguna yang menggunakan telefon mudah alih, ia boleh membawa kepada pendedahan radiasi haba telefon bimbit terhadap kesihatan manusia. Kesan haba adalah disebabkan oleh pendedahan elektromagnetik dari telefon bimbit. Kepala manusia telah terdedah kepada sinaran elektromagnetik yang dipancarkan oleh sistem *Global system for Mobile Communication* (GSM) yang berbeza. Kepala manusia, terutamanya kulit berhampiran kawasan telinga adalah sangat nipis berbanding bahagian lain pada tubuh manusia. Apabila menggunakan telefon bimbit dalam tempoh masa yang panjang, telinga akan menyerap pelepasan haba dari peranti telefon / mudah alih pintar. Ini membawa kepada peningkatan suhu di sekitar kepala dan beberapa kajian akan menunjukkan bahawa kesan ini akan menyebabkan sakit kepala / migrain. Satu kajian eksperimen telah dijalankan dengan menggunakan sukarelawan untuk memeriksa kesan radiasi EM dihasilkan apabila memanggil dan menggunakan telefon pintar. Dalam projek ini dengan telefon pintar yang berkhidmat GSM 1800MHz digunakan. Purata masa yang memanggil dan menggunakan telefon pintar adalah kira-kira 45 minit dan data diukur dengan kaedah thermografik menggunakan *FLIR ONE Camera*. Hasil kajian menunjukkan bahawa, dengan tempoh masa yang tertentu, suhu pada bahagian telinga dan muka manusia meningkat disebabkan penyerapan sinaran haba. Dari hasil kajian, sebuah alat telah dicipta untuk memberi amaran kepada pengguna mengenai kenaikan suhu apabila menggunakan peranti masing-masing.

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LIST OF ABBREVIATIONS

2D	-	Two-dimensional
Btu	-	British Thermal Unit
CSF	-	Cerebrospinal Fluid
DNA	-	Deoxyribonucleic acid
ELF	-	Extremely Low Frequency
EM	-	Electromagnetic
EMF	-	Electromagnetic field
FCC	-	Federal Communication Commission
FTC	-	Federal Trade Commission
GSM	-	Global System for Mobile Communication
ICNIRP	-	International Commission of Non-Ionizing Radiation Protection
IF	-	Intermediate Frequency
LWIR	-	Long Wave Infrared
MCMC	-	Malaysia Communication and Multimedia Commission
MRI	-	Magnetic Resonance Imaging
MSX	-	Multi Spectral Dynamic Imaging
RF	-	Radio Frequency
RFR	-	Radio Frequency Radiations
SAR	-	Specific Absorption Rate
TV	-	Television

CHAPTER 1

INTRODUCTION

1.1 Overview

Smart devices such as laptop, television (TV) and mobile phone may lead to possible health problems that caused by the electromagnetic (EM) fields. Many investigations have been carried out to determine the effect resulting from exposure to Radio Frequency Radiations (RFR), same as from the smart devices. The effects are cancers, genetic damage, tumors, memory loss, increased blood pressure and weakening of the immune system [1].

The electromagnetic wave transfers the signal through radio frequency and microwave signals. This signal will produce electromagnetic radiation in the form of thermal radiation. Thermal radiation consists of harmful ionizing radiation and harmless, non-ionizing radiation [1]. When using the smart device such as mobile phone, the electromagnetic wave is transferred to the human body. In spite of the fact that the cell phones are low power gadgets, the antenna is near to the head when the telephone is used.

The natural impact of radio frequency fields and living systems can be assessed at different levels, including the sub-atomic, sub cell, organ, or entire body situations. As indicated by [2, 3], bio-effect from radiofrequency fields are characterized into three classifications which is abnormal state impacts (thermal), middle level impacts (athermal) and low-level impacts (nonthermal). Thermal impacts are energy deposition higher than the common human thermoregulatory capacity [4].

In view of figure 1.1, more than half of the radiated energy might be absorbed into the user's head. As an after effect of this, the temperature of the skin and external layers of the brain may increase slightly. In spite of the fact that the expansion of tissue temperature is too small to have any physiological importance, it is conceivable, in principle, that the electric field may, by some obscure nonthermal system, disturb the ordinary cell work [5].

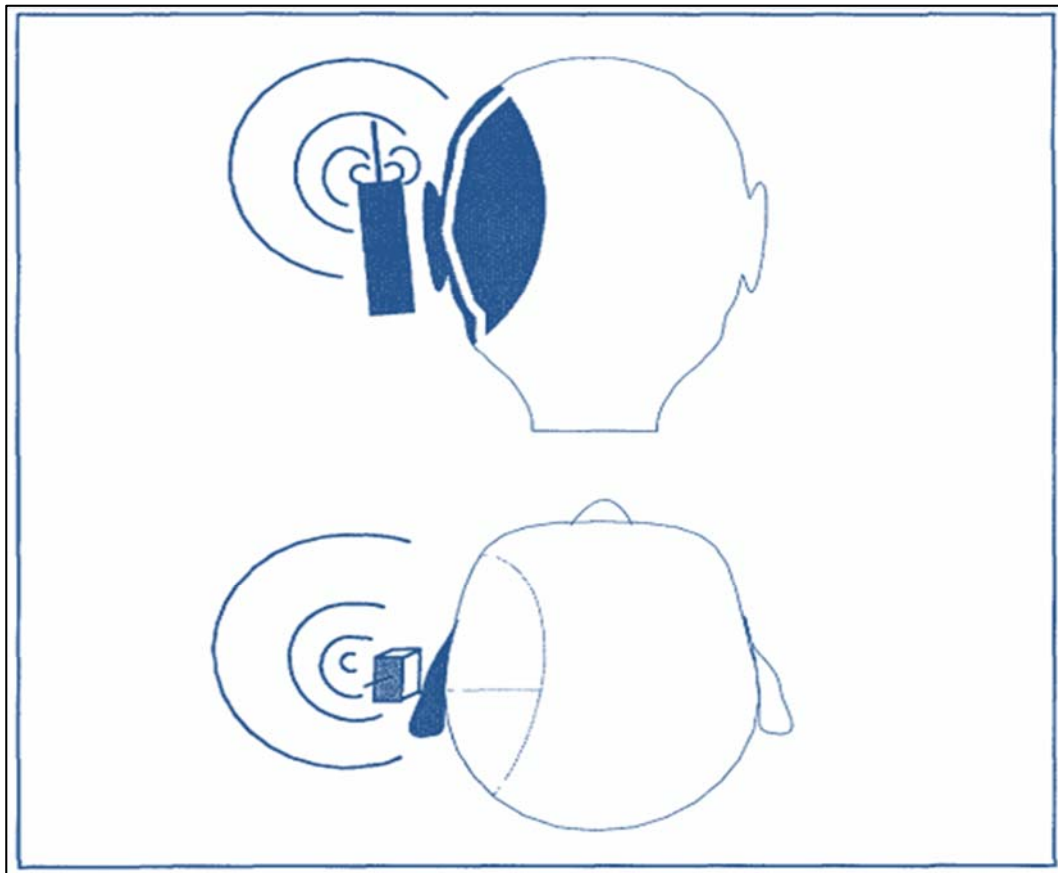


Figure 1.1: A schematic of the absorption of energy radiated by a mobile phone into the user's head [5]

There are a few angles to be considered in order to investigate the effect of thermal radiation of smart devices towards human. The perspectives incorporate the specified absorption rate (SAR), temperature, distance fields, and frequency bandwidth of particular mobile phones and mobile services, for example, Digi, Celcom, Maxis and

Umobile. Moreover, it additionally incorporates the age of the user and time taken utilizing the mobile phone that makes thermal radiation unsafe for the human body.

A thermography procedure is utilized as a part of request to research the impact of thermal radiation of smart devices towards human. Thermal imaging (likewise called infrared thermography) is appropriate to investigate the temperature advancement. For instance the side of the face or the ear-skull district when utilizing handheld cell phone since it can precisely quantifies two-dimensional (2D) temperature fields with high thermal, temporal and spatial resolutions.

Thermal imaging can be utilized to give an indicator of the total exposure related to RF radiation from cell phones. This method does not include any hazard or pain to the user. It is moderately simple to utilize and modest contrasted and other radiofrequency and microwave estimation hardware. The expanding introduction to radiation prompts to neighborhood temperature rises and health risks.

1.2 Introduction

Electromagnetic fields are classified into non-ionizing and ionizing radiation. An ionizing radiation is the radiation with high energy that can remove the bound between the electron and atoms. This radiation can result in tissue damage. A non-ionizing is a radiation that has enough energy to vibrate the atom and molecules. It does not remove the electrons. This non-ionizing radiation occurs at low frequency range. A study by Adair & Black, the electromagnetic radiation in the range from 100 kHz and higher can lead thermal and heating effect [6].

Nowadays, the amount of mobile phone usage is increasing drastically. In 2014, there were 43,248,000 hand phone subscriptions in Malaysia with a penetration rate of 144.2 per 100 populations [7]. Malaysia citizen is exposed to the signal of radio frequency (RF) from their smart phone or other communication services. This lead to the number of absorbed radiation increasing exponentially. This is because, smart phone always be kept close to the human body and is used frequently in daily life.

In this new era of globalization, most of people are depending on their mobile phone. Basically, a mobile phone is a two-way radio, which consists of a radio transmitter and a radio transceiver. The voice is converted into an electrical signal when a person communicates with others using their mobile phone. Then, the signal is transmitted via radio waves to the nearest tower and lastly, it will transmit to the receiver mobile phone. This can be shown in Figure 1.2.

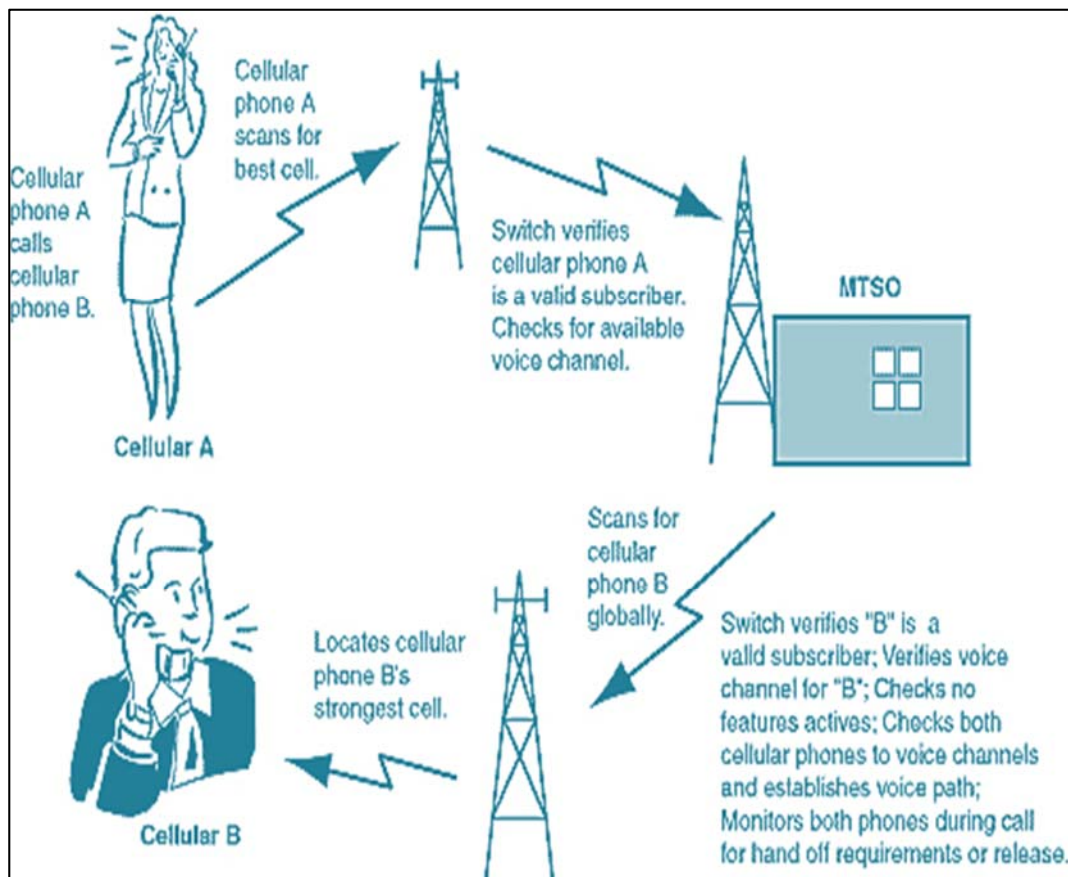


Figure 1.2: Flow diagram of transmit and receive call [8]

An additional function such as web surfing, taking pictures, sending text message and playing games or music is now offered in every smart phone. The usage of mobile phone exponentially increased due to this additional function. This phenomenon has become a big concern as the electromagnetic radiation exposure produce by mobile phone

may effect to the human health. This radiation would lead to thermal radiation that will heat the body tissue at the specific rate.

Thermal radiation depends on the frequency of the energy, the density of the radio frequency field that penetrates the body tissue and lastly, the polarization of the wave. By a research conducted by Professor Om Ghandi, one of the scientists at the University of Utah in 1996, it is stated that the adult human head resonant around 400MHz and baby's smaller head resonates near 700MHz. The increasing of the radio frequency (RF) energy is shown in Figure 1.3 [9].

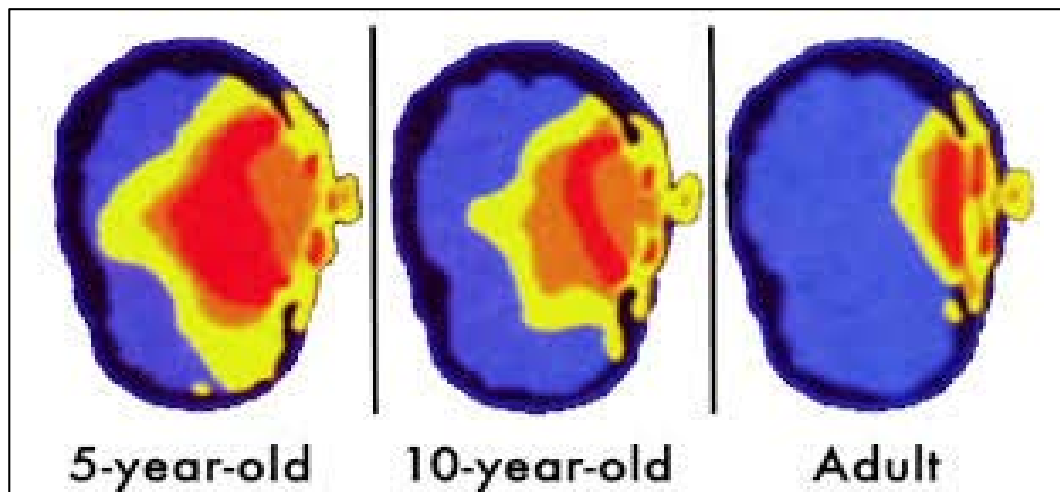


Figure 1.3: Thermal radiation towards different human head size [9]

Based on Table 1.1 and Figure 1.4, both show data collected by Malaysia Communication and Multimedia Commission (MCMC) [10] for the percentage of hand phone distributions by age. It is clearly shown that about 73.1% of all adult users are followed by pre-teens and teens by 12.5% and senior with 4.4% in 2014. The use of pre-teen, adults and senior is increasing throughout the year.

Table 1.1: Percentage distribution of hand phone users by age bands[10]

	2009	2010	2011	2012	2013	2014
Pre-Teen / Teens	14.7	14.3	12.3	13.2	14.7	12.5
Adults	73.4	72.3	74.3	73.3	72.4	73.1
Senior	11.8	13.3	13.4	13.5	12.9	4.4

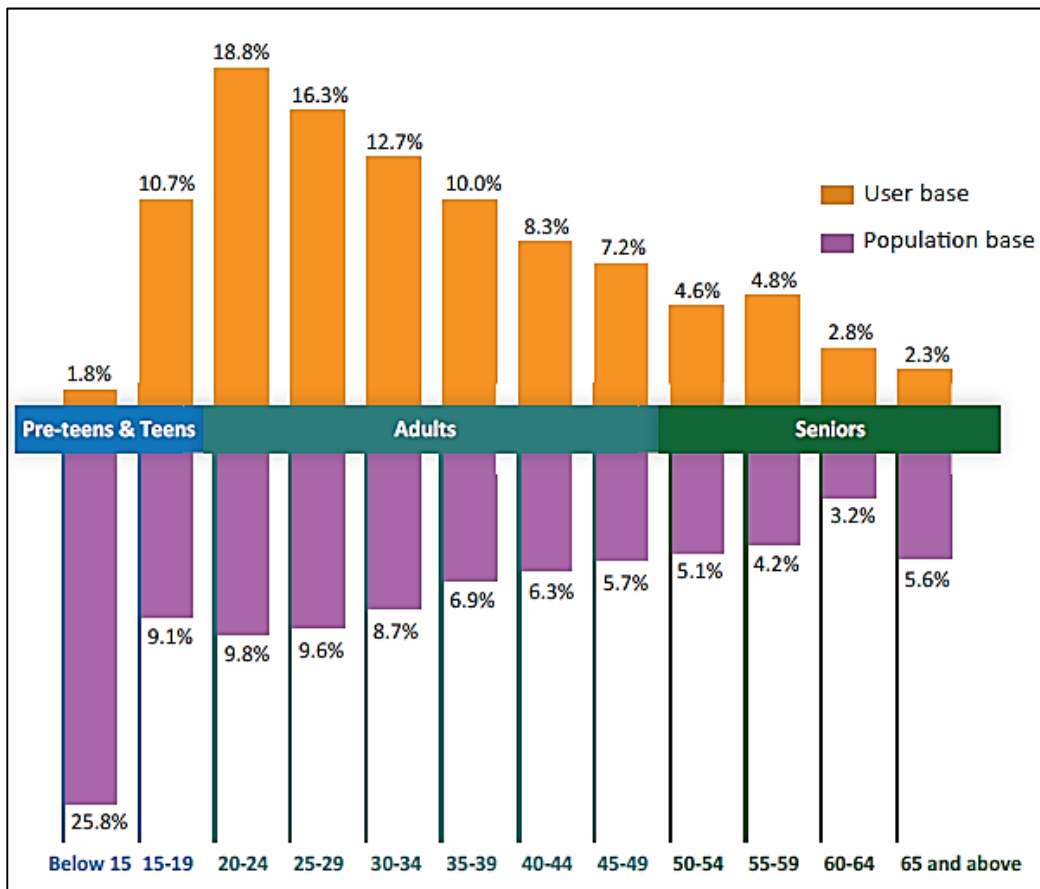


Figure 1.4: Percentage distribution of hand phone users by age category [10]

1.2.1 Absorption of Radiation in Human's Head

The human head can be modeled in six layers of skins, fat, bone, dura, cerebrospinal fluid (CSF) and brain. Table 1.2 concluded the electrical parameter of each layer at 900MHz [11].

Table 1.2: Tissue properties and thickness of six layer human models [11]

Tissue	Permittivity	Conductivity (S/m)	Thickness (mm)
Skin	40.7	0.65	1
Fat	10	0.17	0.14
Bone	20.	0.33	0.41
Dura	40.7	0.65	0.5
CSF	79.1	2.14	0.2
Brain	41.1	0.86	81

The radio frequency electric currents induced in the antenna and on the casing of a handheld mobile phone will induce RF electric fields in tissues of operator. As a result of this a part of the radiated energy will be absorbed into tissue causing an increase in its temperature. The absorption is caused by the power loss involved with dielectric polarizations.

Power loss is defined as Specific Absorption Rate (SAR) which is the unit of measurement for the amount of RF energy absorbed by the body when using a mobile phone. This is because the phone is designed to use the minimum power required to reach the network. Thus, the nearer the user to the base station, the actual SAR will be lower. The SAR can be calculated by using the following formulae:

$$SAR = \left(\frac{dy}{dx}\right) \left(\frac{dW}{dm}\right) = \left(\frac{d}{dt}\right) \left(\frac{dw}{\rho dV}\right) \left[\frac{W}{kg}\right] \quad (\text{Eq. 1.1})$$

$$SAR = \frac{\sigma E^2}{\rho} \quad (\text{Eq. 1.2})$$

where,

E : rms value of the electric field strength in the tissue, in V/m

σ : conductivity of body tissue in S/m

ρ : density of body tissue in kg/m³

In the frequency range from 10MHz to 10GHz, the fundamental exposure limits which are called basic restrictions are expressed as SAR limits. Since most devices are held close to the head and trunk, the limit for these parts is 2W/kg in a 10g of tissue. The whole-body average SAR limit can never be exceeded the devices. Since mobile terminals can be used for periods longer than the averaging time, the limits in Table 1.3 shall always be used [11]. It can be seen from table that the limits of partial body exposure are varying considerably depending on the document and the area of applications.

Table 1.3: SAR Limit for mobile terminals general exposure [11]

Document	Frequency range (GHz)	Limits (W/kg)	Averaging mass (g)	Area of applications
ICNIRP	10-4 – 10	2	10	Head and Trunk
		4	10	Limbs
IEEE	10-4 – 6	1.6	1	Body
		4	10	Hands, wrists, feet, ankles
ENV 50166	10-5 – 300	2	10	Body
		4	10	Hands, wrists, feet, ankles
NRPB	10-4 – 10	10	10	Head, fetus
		10	100	Neck, trunk
		20	100	Limbs

1.3 Project Objective

The objective of the investigation of the thermal radiation of smart device towards human can be summarized as follows:

- i. To study the relationship between the mobile service and thermal radiation.
- ii. To investigate the effect of thermal radiation and the time taken for the device to emits harmful thermal radiation to the human body.
- iii. To develop a solution to reduce the thermal radiation.

1.4 Problem Statement

Nowadays, over 6 billion of people are using mobile phone in worldwide including teenagers and children. The electromagnetic radiation levels has reached quintillion (10^{18}) higher than the natural background levels. This may lead to health problem such as headaches or migraine. The thermal radiation may lead to human biological damage because our body is made up of 65-70% of water, electrolyte and ions [9]. The exponentially expanding of the cell phone client may prompt to the presence of thermal radiation transmitted from the cell phone. Thus, an answer for lessening the impact of thermal radiation toward human should be done at the earliest opportunity. By finding an appropriate length time of calling and utilizing cell phone contingent upon the age is one of the procedures to lessen the radiation.

1.5 Scope of Project

The thermal radiation needs to be reduced as it may lead to serious health problem such as brain cancer and headaches. Basically, in order to achieve the objective of the project, there are two scopes have been outlined:

- i. Investigate the suitable time taken by calling and using a mobile phone depending on their age.
- ii. Developing the best solution to solve the thermal problem as a guideline for people