Heating Effect of Mode of Operations of Mobile Phones

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Abstract- Bluetooth is a technology that has been widely used for transferring data and files within a short distance range using electromagnetic energy. Hence, it has raised public awareness on the radiation of the Bluetooth devices. This study quantifies the thermal effect by investigating electromagnetic field exposure during and after a call is made using three different mobile phone models, with three different modes of operation. An infrared thermal camera was used to obtain thermal images of the right ear-face region of a human during and after a call is made. It is shown that mobile phone usages with Bluetooth connection contribute the lowest to the right ear-face region surface temperature rise compared to wired hands free and direct contact modes. The right ear-face region temperature rise is found to be the highest using wired hands free. Also, it is demonstrated that exposure to radio frequency electromagnetic field due to the usages of Bluetooth and direct contact modes for all the three mobile phone models are generally below the ICNIRP considered safe levels, while the usage of wired hands free mode is on the contrary.

Keywords- Bluetooth, wired hands free, thermal images, RF EMF, ICNIRP.

I. INTRODUCTION

MOBILE phone usages are indispensable in today's world. Some users of this technology experience warming sensations and itching on the side of the face and headaches. These complain and the search for convenience has made the mobile manufactures to come up with alternatives in making and receiving calls using mobile phones. Nowadays, people use Bluetooth hands free (BTHF) and wired hands free (WHF) in addition to the direct contact between their ear-face regions and the mobile phones.

The word Bluetooth is taken from the 10th century Danish King Harald Bluetooth who was very influential in uniting Scandinavians. The founder of the Bluetooth has felt that the name Bluetooth was fitted as it is meant to unite different devices such as computer and mobile phones [1]. Fig. 1 shows the logo for the Bluetooth. Bluetooth SIG introduced Bluetooth formally to public with its logo designed by a Scandinavian. In the shown logo, it keeps the original name of Bluetooth. The logo unites the runic alphabetic characters "H", which look similar to an asterisk, and a "B", which are the initials for Harald Bluetooth [1].

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Fig. 1 Bluetooth Logo

Bluetooth is an open wireless protocol for exchanging data over short distance from fixed and mobile devices, creating PANs. It was originally conceived as a wireless alternative to RS232 data cables. As it can connect several devices, Bluetooth is able to overcome problems of synchronization [1]. For example, a BTHF can be simultaneously connected to two mobile phones. While, for any WHF, it can only be connected to one mobile phone at once. Nowadays, most people in the world own more than one mobile phone. Hence, it is inconvenient for them to use the WHF. A BTHF will enable them to connect to all mobile phones at once. In other words, they can answer any call from any of the phone while wearing the same BTHF. They can use this while driving as well as it is safe and not against the law.

Bluetooth uses a radio technology called frequency-hopping spread spectrum. It can achieve a transfer data rate of 1Mbps. Bluetooth provides a way to connect several types of Bluetooth devices through a secure, globally unlicensed industrial, scientific and medical (ISM) 2.46 GHz short-range RF band width [2].

Regulations and reports as in [2, 3] and [4, 5], respectively, acknowledged evidences suggesting that increasing human exposure to electromagnetic field (EMF), will in turn increase the local temperature of the body. The extent to which this rise in temperature result has not been investigated using wired and Bluetooth technology. Therefore, this study was designed to quantify the heating effect of radio frequency (RF) EMF due to the usages of BTHF, WHF and direct hand held mobile phones using infrared thermal imaging instrument.

An infrared thermographic camera (IRTC) was chosen due to the fact that it is noninvasive and can be used to quantify the temperature within a biological system without coming in contact with it. Though no direct investigation of exposure due to BTHF and WHF mobile phones mode of operation, similar studies on thermal effect using IRTC on hands and heads were reported in [6, 7]. Other studies that use thermographic principles to investigate thermal effects using animals as surrogates were reported by [8-13].

II. THERMOGRAPHIC PROCEDURES

A noninvasive IRTC (IR SnapShot® Model 525, Infrared Solutions, Inc.) that operates in the wavebands 8-12 mm with a thermal resolution of 0.1°C was used. The

thermographic images were analyzed in SnapView Pro 2.1 software (Infrared Solutions, Inc.).

The subject used in this work was allowed to sit down on a chair in a relax position and acclimatize for 30 minutes before the RF EMF exposure is started. At each mode, the thermographic image of the object was taken before, during and the end of the exposure. The only restriction imposed on the subject was to position his head approximately perpendicular to the cameras fixed viewing direction just before any image was taken. This is to ensure the right ear-face region where the BTHF, WHF and direct contact with the phone could be imaged as in [6]. Several images were taken during the acclimatization period in order to determine the reference temperature level. Note that the average right ear-face region temperature for reference is found to be 36˚C. The average temperature and humidity monitored throughout the experiment using HC520 digital thermometer and hygrometer is 27˚C. Thereafter the thermographic experiment is done by the following steps:

1. The thermographic is taken during and after a 2 minutes call is made. There is 60 minutes rest after each mode. Fig. 2 illustrated the arrangement for the human thermographic experiment, where *d*=1m is the distance between the camera and the human. This experiment involves three modes, which are calling using BTHF, calling using WHF, and direct phone call.
2. Then, the three modes are repeated using another two mobile phone models.

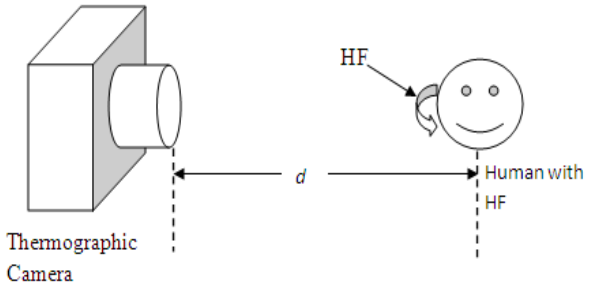

Figure 2 Arrangement for human thermographic experiment

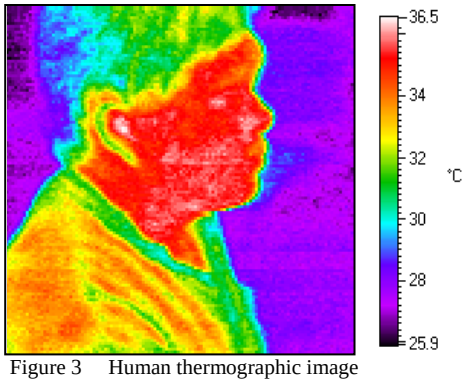

Figure 3 Human thermographic image

III. RESULTS AND DISCUSSION

Fig. 3 shows a sample human thermographic image captured with the IRTC. The concentration of this thermographic image is focused at the right ear-face region temperature.

Three different modes were investigated using human in relax sitting position. In each mode, three mobile phone models were used. The three modes considered are named as Modes 1, 2, and 3 where a call is made using BTHF with the phone, WHF with the phone and directly with a phone, respectively. Fig. 4 to 6 represented the right ear-face region temperatures for during and after a call is made for Modes 1, 2 and 3, respectively. Also, Fig. 7 and 8 demonstrated the right ear-face region temperatures for during and after a call is made, respectively, for comparison purposes between Modes 1, 2 and 3.

The right ear-face region temperature rise as a result of exposure to BTHF, WHF and direct phone calls are evident as in all the three modes the temperature recorded during and after a call is made are higher than the reference. In Fig. 4, the highest ear-face region temperature recorded using the BTHF in Mode 1 after a call is made is 37˚C as been demonstrated by phone model C with the difference between this temperature and the reference is 1˚C. In Fig. 5 it is shown that phone model B recorded the highest temperature increase after a call is made, i.e. 39.3˚C and 3.3˚C in difference with the reference. While in Fig. 6, the highest temperature rise for right ear-face region is illustrated by phone model A with 37˚C and 1˚C in difference with the reference.

In Fig. 7, it is shown that Mode 2 has the highest temperature recorded for all the three mobile phone models while a call is made. Again, Mode 2 demonstrated the highest recorded temperature after the 2 minutes call is made for all the three mobile phone models as exhibited in Fig. 8. Therefore, it could be concluded that using a WHF is not the best option while making a call using mobile phones compared to usages of a BTHF or direct contact.

Available experimental evidence indicates that exposure of resting humans for approximately 30 min to EMF producing a whole body SAR of between 1 and 4 W/kg results in a body temperature increase of less than 1˚C [2] which according to [14], there will be no adverse health effects expected with an increment of 1˚C of the whole body temperature. In normal conditions, local temperature at head, trunk and extremities should be limited to 38˚C, 39˚C and 40˚C, repectively [15]. Note that in this work, 36˚C is taken to be the right ear-face region reference temperature, i.e. when the subject is at rest. Also, according to ICNIR [16] local SAR for head, trunk and extremities at normal condition are given as 10 W/kg, 10 W/kg and 20 W/kg, respectively, with the temperature rise to be limited to 1˚C.

Many laboratory studies with rodent and human were reported to have broad range of tissue damage resulting from either partial body or whole body heating producing temperature rises in excess of 1 to 21˚C. It is shown from the results of this study that some mobile phone models under some mode of operations are capable to heat up tissues above the recommended temperatutre that ICNIRP stipulate

as safe level. Note that the localised SAR is considered rather than the whole body SAR in this study.

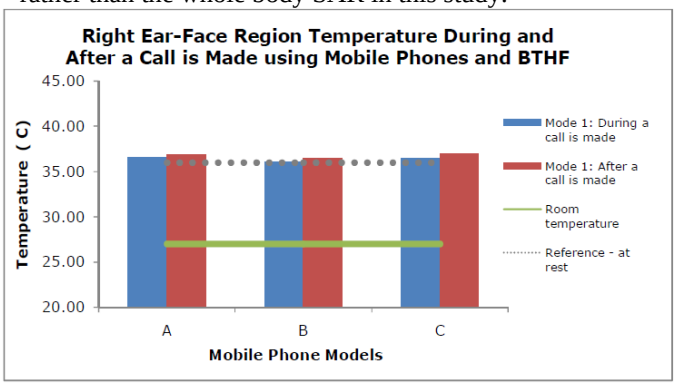

Figure 4 Right ear-face region temperature for during and after a call is made for Mode 1

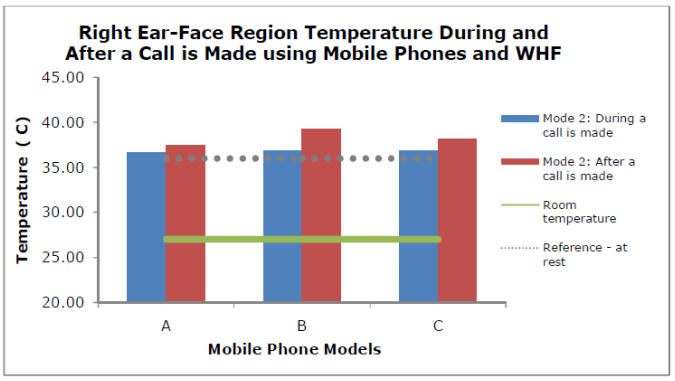

Figure 5 Right ear-face region temperature for during and after a call is made for Mode 2

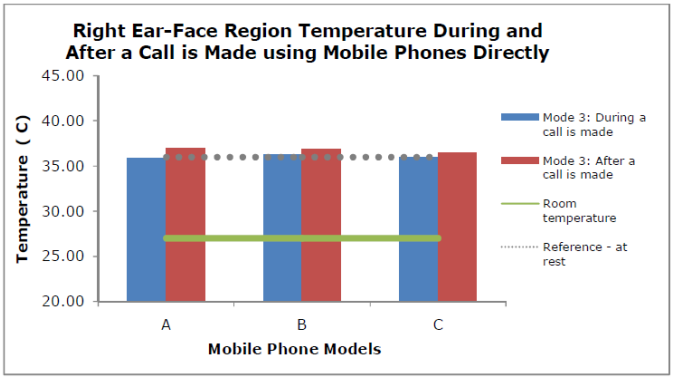

Figure 6 Right ear-face region temperature for during and after a call is made for Mode 3

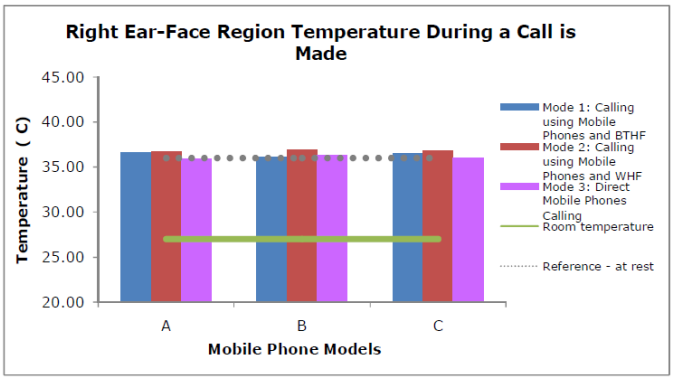

Figure 7 Right ear-face region temperature during a call is made

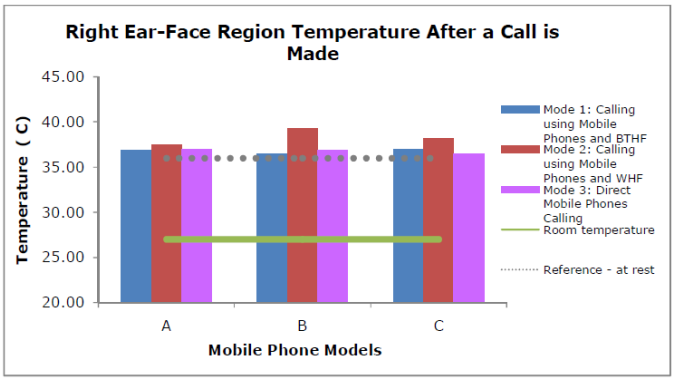

Figure 8 Right ear-face region temperature after a call is made

For Mode 1, i.e. when BTHF is applied, mobile phone models C and A has the highest and lowest percentage differences of the right ear-face region compared to the reference, respectively. While, after a call is made in Mode 1, the percentage differences with the reference of the ear-face region temperature are given as 2.2%, 1.4%, and 2.8% for mobile phone models A, B, and C, respectively. For Mode 2 where WHF is used while a call is made, the highest and lowest percentage differences of the ear-face region temperature compared to the reference during a call is made are demonstrated by mobile phone models B and A, respectively. Note that, the highest and lowest percentage differences of the ear-face region temperature with the reference after a call is made for Mode 2 are also demonstrated by mobile phone models B and A, respectively. For Mode 3, the highest and lowest percentage differences of the ear-face region temperature with reference during a call is made using direct phone are given by mobile phone models A and C with 0.28% and 0.00%, respectively. And, the highest and lowest percentage differences of the ear-face region temperature compared to the reference after the 2 minutes call is made in Mode 3 are given by mobile phone models A and C with 2.8% and 1.40%, respectively.

Therefore, it can be concluded that the WHF mode can cause high temperature increases compared to the other two modes where BTHF and direct phone mode are used while making a call. Due to that, WHF phone calling is not recommended and BTHF is a better choice for both safety and convenience purposes of having more than one phone.

The high temperature obtained when using WHF may not be unconnected to the fact that in this mode the WHF serves as a wave guide to channel all the electromagnetic energy with minimum loss to the ear-face region, this is contrary to the direct phone call mode where the human hands that hold the phones serve as a good conductor. With the hand holding the mobile phone during a call is made, sufficient amount of heat energy will be absorbed by the hands from the mobile phone. This is the contributing factor to the low temperature recorded during and after a call is made as compared to the other modes. In BTHF mode, some part of the RF EM waves are absorbed in the air before reaching to the BTHF device. The body-cloth boundary between the phone and the BTHF device can also serves as absorbers.

Several considerations are made during the thermographic experiments. As stated earlier, the room temperatures are monitored and the average at all time is 27°C. Also, the

reference ear-face region temperature was taken to be 36°C. Additionally, similar BTHF and WHF are being used for all the three mobile phone models. Furthermore, similar person is taken to be the subject. Therefore, the effect of having different set up and different mobile phones should give appropriate effect for the comparison purposes only.

VI. CONCLUSION

RF EMF using BTHF, WHF and direct phone contact in three mobile phone operations were investigated where the thermographic results obtained shows that not only for the sake of convenience and having more than one phone to be used simultaneously, the BTHF ear-face region temperature also demonstrated the safest mode to be used compared to the other two modes. The right ear-face region temperature during and after a call is made in direct contact mode was also found to be lower compared to the WHF mode. The study shows that exposure to RF EMF using BTHF and a direct contact mode of operations for all the three mobile phone models are generally found to be below the ICNIRP considered safe levels, while the ear-face region temperature rise during and before the exposure using WHF is on the contrary.

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