Effect of Direct Contact Use of Selected Mobile Phones on Skin Temperature

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***Abstract*—This study was carried out to investigate the possible temperature rise in the skin surface of the ear region as a result of a continuous exposure to electromagnetic radiations fromfour selected mobile phones. Temperature measurements were taken with an infrared thermometer on the side of the ear and outer pinna surface of the volunteers, with the phones in soft contact, at an interval of 30 seconds for 30 minutes call duration. Analysis of the measured skin temperature gotten showed that at the end of the call, Techno S1, Lenovo A3300-HV, SiccooP100 and Infinix hot 7 recorded temperature 35.3^{o}C, 36.9^{o}C, 35.4^{o}C and 37.0^{o}C showing a rise of 1.1^{o}C, 2.9^{o}C, 1.2^{o}C and 3.2^{o}C respectively. In a bit to investigate further the skin surface temperature, calls beyond 30 minutes' experimental time, prediction models were developed for temperature/call duration assessment with respect to the selected phones used. Considering the fact that skin temperature above 38^{o}C possesses a health concern, the findings from the analysis of the prediction models' results show that Infinix hot 7 and Lenovo A3300-HV cannot be used continuously for more than 2 and 3 hours respectively.**

Keywords—Skin surface temperature, direct contact, mobile phones, electromagnetic radiation

I. INTRODUCTION

Safety is a legitimate concern of users of wireless devices, particularly, in regards to possible hazards caused by electromagnetic (EM) fields. There has been growing concern about the possible adverse health effects resulting from exposure to radio frequency (RF) radiations, such as those from mobile communication devices. Different scientists have argued that the mobile phone radiation is too bad for human health [1 - 3].

Two possible effects of electromagnetic fields have been identified [4]. They are thermal effect and non-thermal effect. Thermal or non-ionizing radiation effect is caused by tissue warming that occurs mainly in the range between 30 MHz and 300 GHz radio waves frequency. Non-thermal effect, also known as non-ionizing radiation, is not associated with increase in tissue temperature, but with tissue changes caused by the frequency, wavelength, amplitude and electric or magnetic field.

The effect of electromagnetic waves on living creatures has been controversial due to studies with contradicting results [5]. Many of the controversies on studies regarding RF-EMF exposure, focused on genetic damage [6, 7], cancer [8], immune dysfunction [9, 10], neurological disease [11, 12], kidney damage [13, 14], reproductive disorders [15, 16], as well as electromagnetic hypersensitivity [17], and cognitive effects [18].

Considering the fact mobile phones are mostly placed next to the ear, and several reports of health hazards such as deafness, hot and itchy ears, high blood pressure, burning skins, migraines, headaches and fatigue after calls have been made. Studies have linked high temperature in the ear-skull region as one of the possible causes of the aforementioned observed health effects [19]. Any temperature above 38^{o}C is considered to be dangerous to human health [20]. In an effort to address the situation, international and regional agencies have developed safety measures to guide the manufacturing and use of the mobile phones.

Owing to the several advantages offered by mobile communications, the demand for mobile phones has risen to an unprecedented level in recent times. As such many cheap and substandard smartphones have found their way into our markets without being subjected to quality assessment by the regulatory authorities, through the instrumentality of smugglers and dubious businessmen. There is a possibility that the use of these substandard phones might be a source of health concern to the users.

In this work, an attempt is made to establish the possibility of an increase in skin temperature in the human ear region as a result of a prolonged use of mobile phone placed next to the ear. Four commonly used phones are considered in this study.

II. MATERIALS AND METHOD

In this work an experimental approach was adopted. The experiment was carried out in the city of Uyo, South-South, Nigeria. It involved four human volunteers, the use of four mobile phone models (Tecno S1, Lenovo A3300-HV, Siccoo P100 and Infinix hot 7) and an infrared thermometer as shown in Fig. 1.

The temperature of the skin (ear region) was measured directly as call progressed from initiation to 30 minutes duration. The mobile phone was placed in soft contact with the skin surface during the call period (see Fig. 2) while the skin temperature was measured at 30 seconds intervals through the call period.

The experiment was done inside a room with all doors and windows closed in order to prevent wind interference from the outside environment. Electric fans and air-conditioners were also not used within the room throughout the period of the experiment.

This was to maintain as much as possible still air within the room environment. Before the start of the experiment, the volunteers were made to rest for a minimum period of 30 minutes so as to be acclimatized with the atmospheric conditions of the site.

The temperature measurements obtained from the experiments for a period of 30 minutes (1800 seconds) of 30 seconds intervals are presented in Appendix I. The values are presented on mobile phone basis for easy presentation.

III. MODELLING OF SKIN SURFACE TEMPERATURE

From the plots of the measured temperature values shown in Fig. 3, it is observed that there exit a sort of logarithmic relationship between the measured values and time, which describes a non-linear system. In order to proceed with this type of modelling, the non-linear will first be linearized; thereafter linear regression modelling will be employed.

Fig. 1: Equipment used in the experiment

Fig. 2: A mobile phone held in soft contact with the ear region

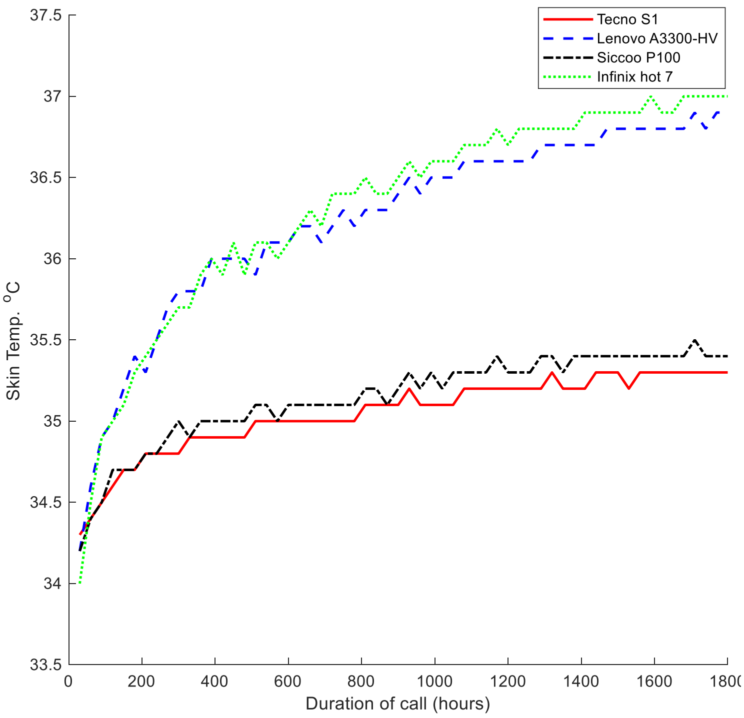

Fig. 3: Plot of the measured skin surface temperature of selected mobile phones

The measured data are linearized by logarithmic transformation of the predictor (t) variable given in (1).

$$\theta_i = m * \ln(t_i) + c \quad \text{for } i = 0,1, \dots\dots, 60 \qquad (1)$$

where θ_i is the temperature value and t_i is the time at i^{th} measurement; m and c are the slope and intercept of the plots of θ vs. $\ln(t)$.

A big challenge arises in using (1) as the $\ln(t_0)$ is undefined as $t_0 = 0$, i.e. the beginning of measurement. To take care of this, the change in temperature values with respect to the initial value is used. This is given in (2).

$$\theta_i - \theta_0 = m * \ln(t_i) + c \text{for } i = 1,2 \dots, 60 \qquad (2)$$

where θ_0 is the temperature value at $t_0 = 0$.

Expressing (2) as a linear regression model,

$$y = mx + c \qquad (3)$$

where $y = \theta_i - \theta_0$ and $x = \ln(t_i)$.

In order to have an approximate the line of best fit for the dataset, the correct values for weight (m) and bias (c) must be learned training and optimization of the cost function. For linear regression, the cost function is the mean square error (MSE). MSE measures the mean squared difference between the measured and predicted values as given in (4)

$$MSE = \frac{1}{N}\sum_{i=1}^{N}(y_i - (mx_i + c))^2 \qquad (4)$$

where N is the total number of data points, $\frac{1}{N}\sum_{i=1}^{N}$ is the mean, and y_i is the actual measured value and $mx_i + c$ is the prediction.

The output is a value representing the cost associated with the current sets of weights and biases. The target is to minimize the MSE so as to improve the accuracy of the model. This is achieved through training using gradient descent learning algorithm.

For this study, the dataset in Table 1 was divided into two sets: 48 datasets for model training and 12 datasets for model validation. The regression models obtained for the four phones considered are given in equations 5 - 8.

For Techno S1:

$$y = 0.2565x - 0.8266 \qquad (5)$$

For Lenovo:

$$y = 0.6641x - 2.1015 \qquad (6)$$

For Siccoo P100:

$$y = 0.3021x - 1.0281 \qquad (7)$$

For Infinix hot 7:

$$y = 07483x - 2.3824 \qquad (8)$$

Rearranging (2) to express the predicted value of skin temperature (θ_p) as the function of time:

$$\theta_p = m * \ln(t) + c + \theta_0 \qquad (9)$$

where θ_0 is the measured temperature value at $t_0 = 0$.

Substituting y for $mx + c$ with $x = \ln(t)$ into (9) gives

$$\theta_p = y + \theta_0 \qquad (10)$$

Rewriting the regression models in equations (5) – (8) in form of (10) give

For Techno S1:

$$\theta_p = 0.2565 * \ln(t) + 33.3734 \qquad (11)$$

For Lenovo:

$$\theta_p = 0.6641 * \ln(t) + 31.8985 \qquad (12)$$

For Siccoo P100:

$$\theta_p = 0.3021 * \ln(t) + 33.1719 \qquad (13)$$

For Infinix hot 7:

$$\theta_p = 07483 * \ln(t) + 31.4176 \qquad (14)$$

IV. RESULT

From the measured temperature of the ear region in Appendix I, it is observed Lenovo and Infinix hot 7 recorded a temperature value of about 36.9^{o}C and 37^{o}C respectively after 30 minutes of call, and a temperature rise of 2.9^{o}C and 3.2^{o}C. Techno S1 and Siccoo P100 gave a value of about 35.3^{o}C and 35.4^{o}C after 30 minutes of call, and a temperature rise of 1.1^{o}C and 1.2^{o}C.

The plots of regression models of the training and validation datasets are shown in Figs. 4 and 5 while the corresponding root mean square error (RMSE) and coefficient of determination for the mobile phones considered are presented in Table 1. Lenovo phone type gave the highest RMSE of 0.0603 and 0.0583 for training and validation datasets respectively, while Siccoo P100 phone type gave the least R-squared values of 0.9698 and 0.9861 for training and validation datasets respectively. This shows a good correlation between the measured and predicted skin temperature values.

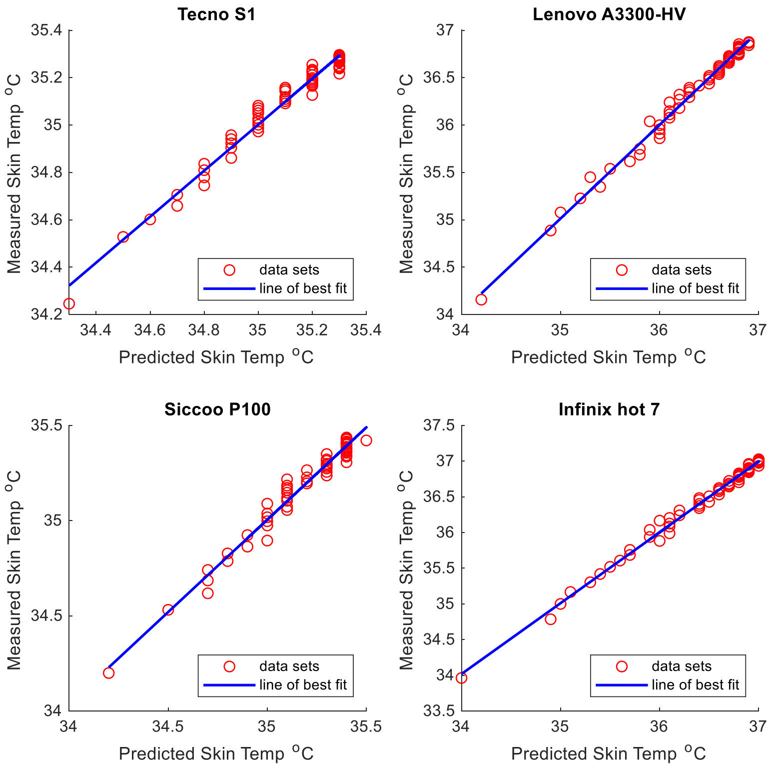

Fig. 4: Regression plot of the training dataset for four different mobile phones

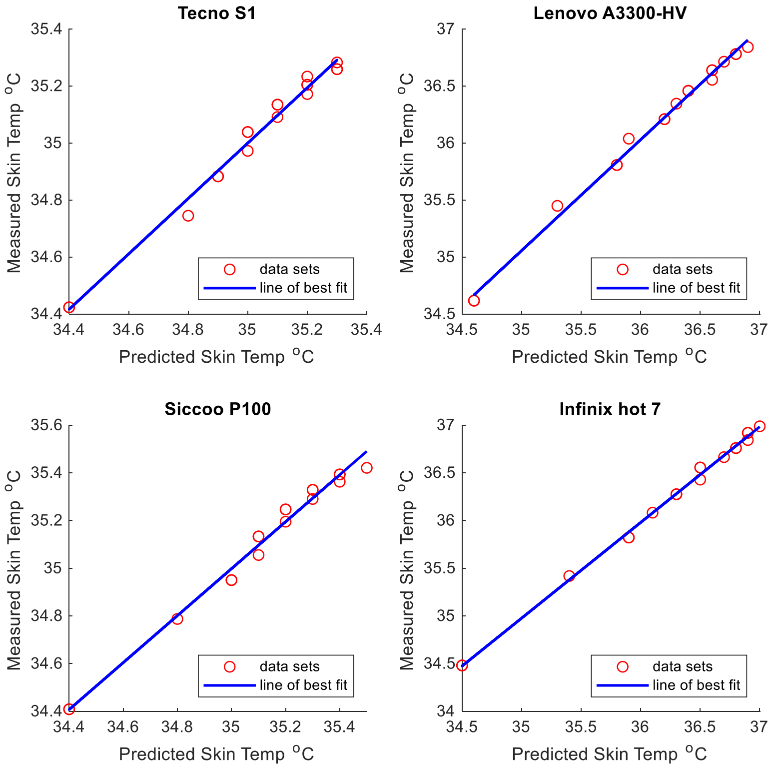

Fig. 5: Regression plot of the validation dataset for four different mobile phones

Table 1: RMSE and coefficient of determination values for training and validation datasets

Mobile Phone Type	Training Dataset		Validation Dataset	
	RMSE	R^2	RMSE	R^2
Techno S1	0.0383	0.9710	0.0303	0.9868
Lenovo	0.0603	0.9891	0.0583	0.9946
Siccoo P100	0.0461	0.9698	0.0360	0.9861
Infinix hot 7	0.0585	0.9919	0.0438	0.9972

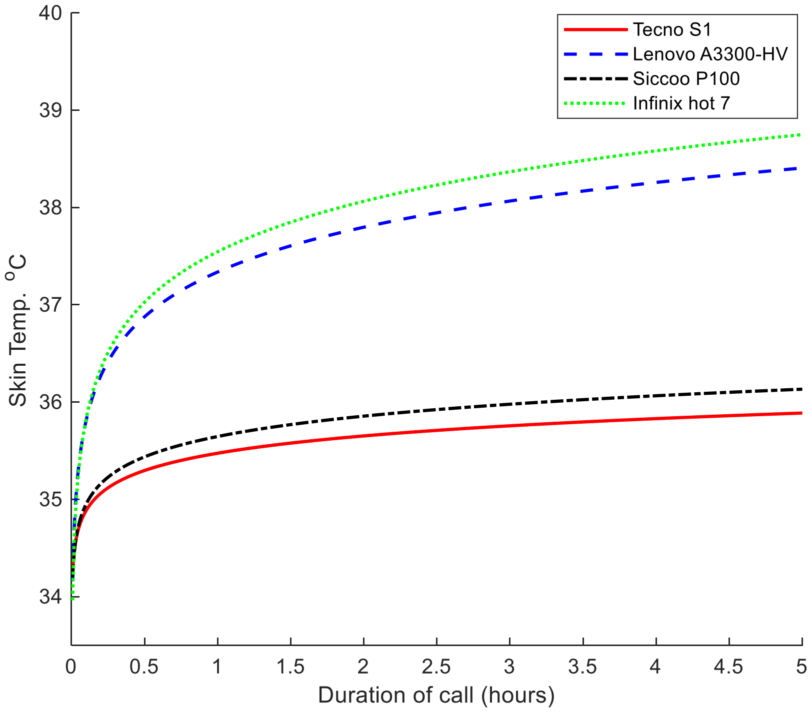

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Fig. 6: Skin temperature 5 hours call predictions

Table 2: Hourly skin temperature predictions for the selected phones

Phone Type	1 Hour	2 Hours	3 Hours	4 Hours	5 Hours
Techno S1	35.5	35.7	35.8	35.8	35.9
Lenovo A3300-HV	37.3	37.8	38.1	38.3	38.4
Siccoo P100	35.6	35.9	36	36.1	36.1
Infinix hot 7	37.5	38.1	38.4	38.6	38.7

Using the developed models for the four selected mobile phones, skin temperature predictions were made for call duration of five hours. The prediction plots are shown in Fig. 6, while the temperature on hourly basis is presented in Table 2. Considering the fact that skin temperature above 38^{o}C possesses health concern, the findings from the analysis of the prediction models shows that Infinix hot 7 and Lenovo A3300-HV cannot be used continuously for more than 2 and 3 hours respectively.

V. Conclusion

In this paper, experiments were conducted to investigate the temperature effects as a result of the use of selected mobile phones on the skin of the ear region. The results gotten showed that long duration calls might have the capacity to cause thermal effect, particularly when the phones are indirect contact with the skin. A further prediction analysis confirmed an increasing skin surface temperature with longer call durations. Mobile phones like Lenovo A3300-HV and Infinix hot 7 gave skin temperature of above 38^{o}C after 3 and 2 hours of use respectively. Thus, they are potential health threats, and should not be used for more than 2 hours' continuous call especially when in direct contact with the skin.

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Appendix I: Temperature measurement of the ear region

Time (sec)	Skin Temperature (^oC)			
	Techno S1	Lenovo	Siccoo P100	Infinix hot 7
0	34.2	34.0	34.2	33.8
30	34.3	34.2	34.2	34.0
60	34.4	34.6	34.4	34.5
90	34.5	34.9	34.5	34.9
120	34.6	35.0	34.7	35.0
150	34.7	35.2	34.7	35.1
180	34.7	35.4	34.7	35.3
210	34.8	35.3	34.8	35.4
240	34.8	35.5	34.8	35.5
270	34.8	35.7	34.9	35.6
300	34.8	35.8	35.0	35.7
330	34.9	35.8	34.9	35.7
360	34.9	35.8	35.0	35.9
390	34.9	36.0	35.0	36.0
420	34.9	36.0	35.0	35.9
450	34.9	36.0	35.0	36.1
480	34.9	36.0	35.0	35.9
510	35.0	35.9	35.1	36.1
540	35.0	36.1	35.1	36.1
570	35.0	36.1	35.0	36.0
600	35.0	36.1	35.1	36.1
630	35.0	36.2	35.1	36.2
660	35.0	36.2	35.1	36.3
690	35.0	36.1	35.1	36.2
720	35.0	36.2	35.1	36.4
750	35.0	36.3	35.1	36.4
780	35.0	36.2	35.1	36.4
810	35.1	36.3	35.2	36.5
840	35.1	36.3	35.2	36.4
870	35.1	36.3	35.1	36.4
900	35.1	36.4	35.2	36.5
930	35.2	36.5	35.3	36.6
960	35.1	36.4	35.2	36.5
990	35.1	36.5	35.3	36.6
1020	35.1	36.5	35.2	36.6
1050	35.1	36.5	35.3	36.6
1080	35.2	36.6	35.3	36.7
1110	35.2	36.6	35.3	36.7
1140	35.2	36.6	35.3	36.7
1170	35.2	36.6	35.4	36.8
1200	35.2	36.6	35.3	36.7
1230	35.2	36.6	35.3	36.8
1260	35.2	36.6	35.3	36.8
1290	35.2	36.7	35.4	36.8
1320	35.3	36.7	35.4	36.8
1350	35.2	36.7	35.3	36.8
1380	35.2	36.7	35.4	36.8
1410	35.2	36.7	35.4	36.9
1440	35.3	36.7	35.4	36.9
1470	35.3	36.8	35.4	36.9
1500	35.3	36.8	35.4	36.9
1530	35.2	36.8	35.4	36.9
1560	35.3	36.8	35.4	36.9
1590	35.3	36.8	35.4	37.0
1620	35.3	36.8	35.4	36.9
1650	35.3	36.8	35.4	36.9
1680	35.3	36.8	35.4	37.0
1710	35.3	36.9	35.5	37.0
1740	35.3	36.8	35.4	37.0
1770	35.3	36.9	35.4	37.0
1800	35.3	36.9	35.4	37.0