Study of Effects of Commercial Shielding Products Attached to Mobile Phone on Human Body with Implanted Medical Device

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***Abstract*—There are many commercial shields for 3G and 4G mobile phones re-emerging onto the market, claiming specific absorption rate (SAR) reduction; however their effectiveness is questionable. In this paper, their SAR and induced electric field (E-field) are measured, and the corresponding induced E-field inside the human body with and without implanted medical devices is analyzed. Results have indicated that the SAR values, either with and without the shields have shown no particular impact, and the induced E-field on a human body with and without any implanted pacemaker are similar.**

Keywords—specific absorption rate (SAR); mobile phone; pacemaker

I. INTRODUCTION

Much attention has been paid to the possible adverse effects due to electromagnetic (EM) exposure from mobile phones to the 1G and 2G generations in the past [1], [2]; their impact has been much discussed and safety guidelines have been developed for occupational and public exposure to electromagnetic field in general [3], [4]. While many specific absorption rate (SAR) reduction products are re-emerging back onto the market for the 3G and 4G mobile devices, this paper examines the induced electric field (E-field) to a human body with and without any implanted pacemakers.

Applying an external ground plane to mobile phones is one of the most common methods for SAR reduction. Chan [1] investigated the effects of using conductive materials for SAR reduction purposes. The effectiveness of using other materials has also been assessed by various researchers. Hirata [5] analyzed the radiation efficiency and the effectiveness of peak SAR reduction of a folded-loop antenna using a reflector at 2 GHz. Chou [6] investigated using a resistive sheet in order to reduce the peak SAR for handset application. Islam [7] studied the SAR reduction effectiveness by attaching a ferrite sheet to the mobile phone.

Fung [2] studied the SAR reduction effectiveness of such shielding products with different attach positions in the GSM900; an experimental study of the SAR reduction effectiveness of various commercially available products and shielding materials for mobile devices has been carried out.

IEEE Standard 1528 [8] and EN 62209-1 [9] specify the measurement instruments and procedures of the peak spatial average SAR, induced by exposure to radio frequency fields from hand-held and body-mounted wireless communication devices. The assessment of the induced SAR of a device can be carried out by measuring the E-field in the shell phantoms filled with tissue-equivalent liquid. The relationship of the SAR and the E-field at any specific point is expressed by

$$\text{SAR}=\frac{\sigma E_i^2}{\rho} \tag{1}$$

Where E_i is the root-mean-square E-field strength induced in the tissue-simulant (V/m); σ is the conductivity of tissue-simulant (S/m), and ρ is the mass density of tissue (kg/m^3). For general public exposure, the basic restriction for a time varying EM field of 10 MHz-10 GHz is 2 W/kg for any 10g of contiguous tissue, according to the ICNIRP guidelines[3].

Pacemakers have been commonly considered as EM field sensitive devices. Previous studies [10], [11] have evaluated the electromagnetic interference (EMI) on pacemakers from wireless communication devices. Wang [12] numerically compared the EMI reduction effectiveness of using conductive and magnetic sheets. Some recent studies [13], [14] investigated the SAR distributions in the human body with a pacemaker, and reported the SAR enhancement around the pacemakers.

Fig. 1 illustrates some commercial products available on the market for SAR reduction, as discussed in this paper. Fig. 1a) shows a card which is to be carried together with the mobile devices; Fig. 1b) and c) show two stickers for attaching to the mobile devices, and Fig. 1d) shows a shielding bag where the mobile devices are to be placed.

This paper first experimentally studies the SAR reduction effectiveness of various commercially available SAR reduction products for mobile phones. Then the HFSS [15] is adopted to conduct the EM simulations in the study of the effects of using shielding products on the E-field and SAR distributions around pacemakers.

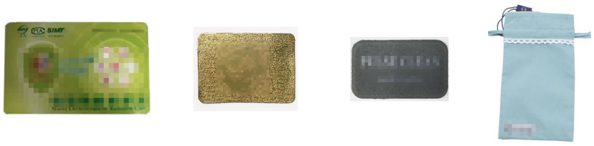


Fig. 1 a) Fig. 1 b) Fig. 1 c) Fig. 1 d)

Fig. 1. Commercial SAR reduction products.

II. METHODOLOGY

A. SAR Measurement Setup

The SAR measurement is conducted in WCDMA band 1, and a commonly available mobile phone is used as the radiation source in this study. A 2201 ProLock Phone Tester is used to control the nominal maximum radiated power of 0.25W at 1900 MHz, transmission band of the 3G system. Fig. 2 shows the SAR measurement in this study.

Fig. 2. The SAR measurement system - APREL ALSAS 10U.

The dielectric constant of the tissue-equivalent liquid is 40.0, and the conductivity is 1.40 S/m for the human head, while ε_r=53.3 and σ=1.52 S/m are used for the human body, at 1900 MHz, in accordance with the tissue-equivalent liquid requirement in EN 62209-1 [9].

An isotropic SAR probe was used to measure the induced E-field. The results for the averaging SAR over 1g of tissue and for the averaging SAR over 10g of tissue were computed by the software.

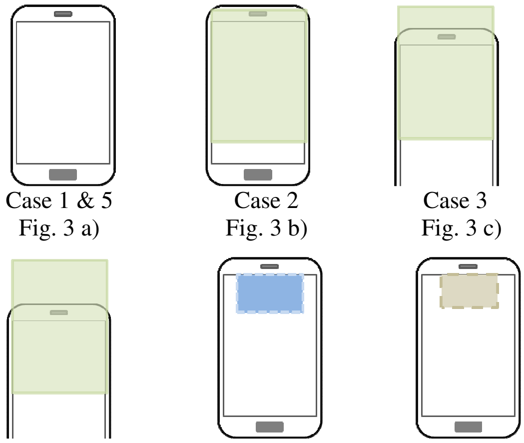
The mobile phone was tested in the touch position; three SAR reduction products were selected from the market, which were a card and two stickers as in Fig. 1a), b) and c). The body phantom was used with product A (the card), the head phantom was used with products B and C (two stickers). Table I and Fig. 3 illustrate the seven cases that were measured and their relationship to the different products and different attachment positions.

As the variation of the SAR in the human head due to the handedness is only about 1% [16], only right head phantom is used in the SAR measurements in this study.

Each situation was tested three times, and the tested maximum 10g avg. SARs were selected for analysis due to the uncertainty of the SAR measurements.

TABLE I. SAR REDUCTION PRODUCTS & POSITIONS

Case	Product	Phantom	Position
1	-	Body	No attachment
2	A	Body	Attached to the display screen
3	A	Body	Moved 2 cm upward from Case 2
4	A	Body	Moved 4 cm upward from Case 2
5	-	Head	No attachment
6	B	Head	Attached to the back of mobile phone
7	C	Head	Attached to the back of mobile phone



Case 1 & 5 Fig. 3 a) Case 2 Fig. 3 b) Case 3 Fig. 3 c)

Case 4 Fig. 3 d) Case 6 Fig. 3 e) Case 7 Fig. 3 f)

Fig. 3. Summary of the cases for SAR measurments.

B. Simulation Analysis

To quantitatively evaluate the effectiveness of common SAR reduction products to the E-field and SAR distributions in human body with implanted pacemaker, numerical evaluation of the effectiveness of SAR reduction products was conducted.

Fig. 4 illustrates the antenna and body model in the simulation. The human body was represented by a three layer rectangle torso model with the dimensions of 400mm x 250mm x 70mm. The torso model consists of three tissues: skin, fat, and muscle. The dielectric properties for different tissues are listed in Table II [17].

TABLE II. DIELECTRIC PROPERTIES OF BODY TISSUE

Tissue	Dielectric Constant	Conductivity (S/m)	Thickness (mm)
Skin (dry)	38.71	1.22	2.5
Fat	5.34	0.08	10
Muscle	53.42	1.40	57.5

A half wavelength dipole antenna working at 1900 MHz was used as the radiation source. The length of the dipole antenna was 69.6mm, the radius was 1mm, and the separation distance between the antenna and the torso was set to be 20mm. A perfect conductive sheet was inserted just between the antenna and the torso, to represent a shielding product. Two different dimensions of the sheet were considered in this study and these were 50mm x 30mm and 65mm x 40mm. The unipolar pacemaker model had previously been adopted in [18], and it was inserted 15mm deep [10] into the torso as shown in Fig. 4.

Four configurations were studied:

a) Without shield, without Pacemaker
b) Without shield, with Pacemaker
c) With shield, without Pacemaker
d) With shield, with Pacemaker

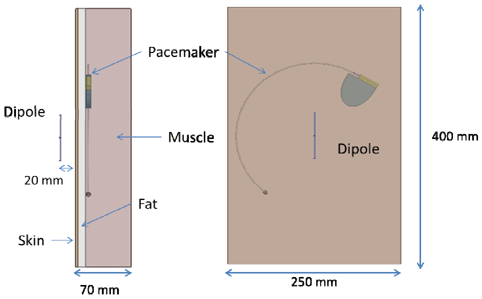


Fig. 4. Unipolar pacemaker and torso model.

III. Results

A. *SAR Measurement Results for Different Products*

TABLE III. SAR Reduction Effectiveness

Case	Maximum 10 g avg. SAR	Reduction Effectiveness
1	1.077 W/kg	-
2	0.932 W/kg	13.5%
3	0.925 W/kg	14.1%
4	0.435 W/kg	59.6%
5	0.396 W/kg	-
6	0.440 W/kg	No (11.1% of increase compared to case 5)
7	0.443 W/kg	No (11.9% of increase compared to case 5)

The SAR measurement results and the corresponding SAR reduction effectiveness for those products are shown in Table III. A maximum SAR reduction effectiveness of 59.6% for 10g avg. SAR can be found, and when the product is moved upward from case 2 to case 4, the reduction effectiveness increases from 13.5% to 59.6%. However, in some cases, applying such products with a specific position or direction might even cause an increase of the peak spatial average SARs, as in cases 6 and 7.

Fig. 5a) to d) show the SAR distributions for cases 1 to 4, for product A. One can find that SAR distribution is affected by the position of attachment. In case 1, the hot spot locates near the top edge of the mobile phone, and after product A is attached and moved upward from case 2 to 4, the hot spot is gradually being covered by the product A, results in the decrease of the peak spatial average SAR and the change of the SAR distribution. Fig. 5e) to g) show the effects of applying products B and C to the SAR distributions corresponding to cases 5 to 7 respectively. The differences of the SAR distribution with and without products B and C are relatively small. A slightly higher peak SARs are found after applying the latter two SAR reduction products.

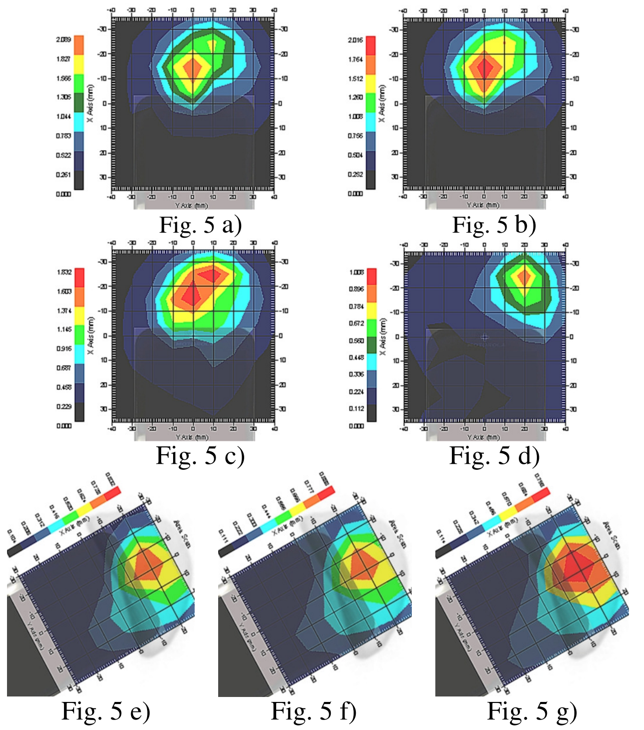


Fig. 5 a) Fig. 5 b) Fig. 5 c) Fig. 5 d) Fig. 5 e) Fig. 5 f) Fig. 5 g)

Fig. 5. SAR distributions for different shields.

B. *Simulation of The Induced E-Field and SAR in The Human Body with/without Implanted Device*

Table IV shows the maximum E-field strength and 10g avg. SAR in the muscle layer for the 6 cases. The differences between cases with and without pacemakers are much smaller. The S_{11} of the dipole antenna in open space is -13.5dB at 1900 MHz. When applying the shield of 50mm x 30mm, a slight increase in the peak E-field strength and SAR in muscle layer could be found; and when applying a shield of 65mm x 40mm, the 10g avg. SAR is reduced by about 20%, but the S_{11} of antenna decreases to -9.4 dB for the shield of 50mm x 30mm, and -4.2dB for the shield of 65mm x 40mm. In all cases, the maximum 10g avg. SARs in muscle layer is lower than the basic restrictions in ICNIRP guidelines [3].

Fig. 6a) to f) show the SAR distributions on the surface of the torso for the six cases in Table IV respectively. When applying the small shield of 50mm x 30mm as in Fig. 6c) and d), the SAR distributions are quite similar to those without a shield; when applying the larger shield as in Fig. 6e) and f), a change in the SAR distributions could be observed.

TABLE IV. MAX. E-FIELD AND SAR IN MUSCLE LAYER

Case	Max. E-field (V/m)	Max. 10g avg. SAR (W/kg)
No shield, no pacemaker	51.0	0.8598
No shield, with pacemaker	51.2	0.8598
Shield(50mm x 30mm), no pacemaker	54.6	1.0288
Shield(50mm x 30mm), with pacemaker	54.4	1.0286
Shield(65mm x 40mm), no pacemaker	44.5	0.6861
Shield(65mm x 40mm), with pacemaker	44.1	0.6885

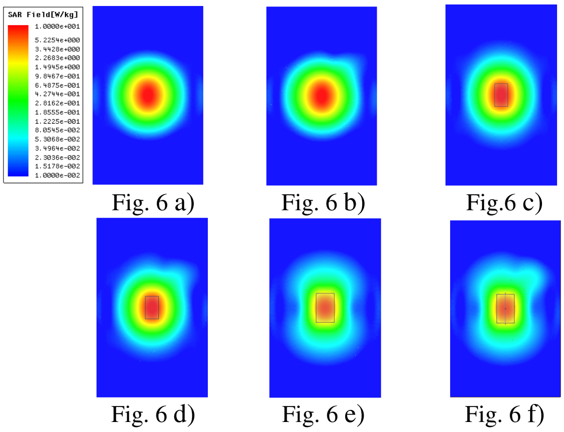


Fig. 6. SAR distributions on torso surface.

IV. CONCLUSIONS

In this paper, the effectiveness of several commercially available SAR reduction products has been assessed. Results have shown that the effectiveness of the selected commercial SAR reduction products is not consistent and as significant as claimed. It can be concluded that the SAR reduction effectiveness highly relies on the relative positions of the product to the mobile devices. Results have shown that by applying the conductive shield between the antenna and body would affect the SAR distributions, but the effects strongly depend on the position and dimension of the shield, and it may cause much deterioration of the antenna performance.

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