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Indicative SAR levels due to an active mobile phone in a front trouser pocket in proximity to common metallic objects

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INDICATIVE SAR LEVELS DUE TO AN ACTIVE MOBILE PHONE IN A FRONT TROUSER POCKET IN PROXIMITY TO COMMON METALLIC OBJECTS

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Abstract: This paper investigates Specific Absorption Rates (SAR) in the human body with a realistic mobile phone source positioned in a 'front trouser pocket' of a truncated male heterogeneous anatomical body model. A Finite-Difference Time-Domain (FDTD) code was used to analyse the SAR in the body in the mobile communication frequency range 0.9 to 4GHz. Realistic everyday metallic objects, including a coin, a ring and a zip were added to the model. These objects increased the SAR in the body at different frequencies. The cumulative effect of the three objects generally increased the SAR in the waist section over the frequency range considered.

1. Introduction

There has been public and scientific comment that the radiation from mobile communications devices may adversely affect human health. Recent estimates suggest there are 40 million mobile phones users in the UK. Mobile phones spend the majority of their time in a trouser pocket and are therefore in close proximity to the testicles. Even when not in use, mobile phones emit radiation periodically as they communicate their position with base stations. Mobile phones are also left in the pocket when used with a hands-free device whether it is via a wire or a Bluetooth link. In many systems, in order to conserve battery life, a phone's power level may be dynamically negotiated with a base station to be at a minimum level whilst maintaining a reasonable signal to noise ratio. However, since a phone in a pocket is generally less efficient than a phone held to the ear, the average power from the phone may in some circumstances be higher. Note, neither the wire of a hands-free microphone or additional CW source for a Bluetooth link are considered in this paper.

A survey of 419 people showed that 57% of men put their mobile phone in their trouser pocket [1] with an additional 15% using a belt attachment, whereas 66% of women keep their phone in a bag. Men tended to put their phone in the front right pocket. This was particularly true for men under 30.

A mobile phone located on the belt and used with a hands-free wire has been reported at 1.8GHz [2]. That paper used a 5mm resolution cell size and concentrated on the efficiency of the phone and the maximum SAR. The SAR in the body and the testicles has been investigated with different sources including a dipole near the torso and a WLAN card on a laptop computer [3]. A wrist-watch type phone has also been modelled with the hands held by the waist [4]

In previous works, the authors [5, 6] have found that metallic objects close to the human body can significantly increase the SAR. Please see [5, 6] for a more complete literature review of bioelectromagnetics and the effects of metallic objects on SAR. Recently, the authors showed that metallic rings approximately one wavelength in circumference [7] and metallic pins 0.4λ long [8] can increase the SAR by several times in both homogenous and heterogeneous heads.

We have also hypothesized that metallic objects in close proximity to the waist could increase the SAR. Typical metallic objects close to or inside a front trouser pocket may include metallic zips, coins, keys, key rings and pens. This paper will present results for a metallic coin, a ring and a zip as well as the combination of all three. The testicles are considered to be sensitive organs [9, 10] and are located close to the outside of the body. They are vulnerable to heating, however, [11] concluded that the testes of mice were naturally capable of regulating their temperature. In terms of size they may be similar to eyes which have been shown to resonate at some mobile phone frequencies [5, 6, 12].

2. Description of model

An independent 3D FDTD code [5, 6] has been written. Perfectly Matched Layers (PML) absorbing boundary conditions are used to terminate the grid. The PML is eight cells thick and is positioned at least twelve cells from

the source and the body. The Yee cell size used throughout this paper is 2mm. The lowest number of cells per wavelength was always greater than five, and reasonable results have been obtained with only four [2].

The excitation in this paper was a monopole positioned at the centre of the top face of a PEC box. The box was 80mm high, 40mm wide and 20mm deep. The monopole was Z directed and fed with a sinusoidal CW source. The tangential E-field components are set to zero along the length of the monopole and surface of the PEC box [5]. The box was surrounded with a layer of plastic 2mm thick ($\sigma=0\text{S/m}$, $\epsilon_r=2.56$) with a 2mm gap surrounding the excitation location. All results in this paper are normalised to 1W input power at all frequencies. Please note that an output power of 1W may be higher than for many mobile phones. However the results in this paper may be scaled. The SAR is calculated with the twelve-field approach [5]. The geometry and location of the phone are shown in Figure 1.

An anatomically accurate human body model provided by Brooks Air Force was used. The body phantom used is based on the Visible Human Project, has 40 tissues and a 2mm resolution. To reduce the considerable runtimes and excessive memory requirements, the body was truncated in the Z direction, so that only the waist was modelled; see Figure 1 (a). This truncated section of the body contained 19 different tissues.

In this model, the testicles have a density of 1040kg/m^3 and a combined mass of 22.85g. The tissues are frequency dependent [13]. The testicles have the following electrical properties: ($\sigma=1.06\text{S/m}$, $\epsilon_r=62.45$ at 0.5GHz; $\sigma=1.69\text{S/m}$, $\epsilon_r=58.61$ at 1.8GHz; $\sigma=3.68\text{S/m}$, $\epsilon_r=55.13$ at 5GHz). Therefore, energy absorption is more superficial at higher frequencies where not only is the wavelength reduced but the conductivity is higher.

The metallic objects were modelled using metallic Yee cells, by setting the conductivity of the cells equal to the conductivity of copper [5] and were 2mm thick (1 Yee cell). The metallic zip was 142mm long and 6mm wide. The coin had a diameter of 20mm and was 2mm thick and was positioned in the XY plane level with the base of the phone. The ring had a diameter of 20mm, was 2mm thick and was positioned between the phone and the body. Please see Figure 1 for the exact locations of the metallic objects.

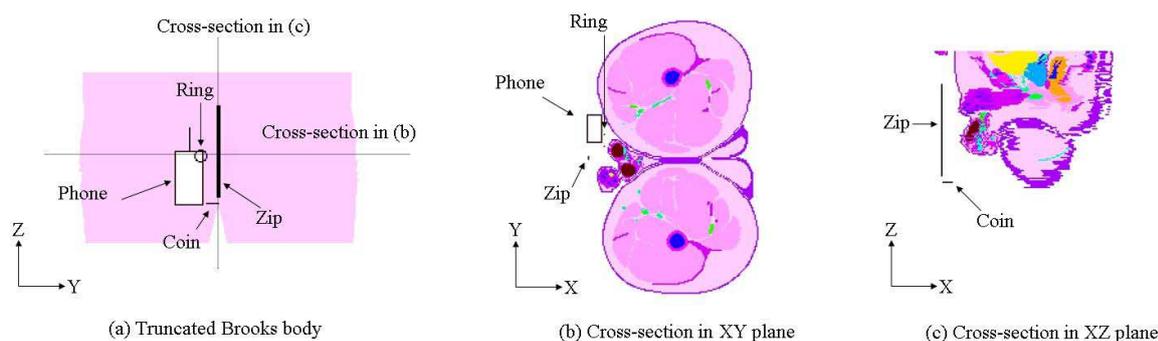


Figure 1. The geometry of the Brooks waist: (a) truncated Brooks body with phone as seen from the front, (b) and (c) show two cross-sections through the model.

3. Results

The maximum 10g SAR values in all tissues in the waist section are shown in Figure 2. The coin has negligible effect below 2.8GHz and a small effect upto 4GHz. The zip increased the 10g SAR at approximately 2 and 3.3GHz. The ring increased the SAR at all frequencies considered below 3.9GHz. However, the largest effect was found when all three metallic objects were added to the Brooks waist. The combination of zip, coin and ring increased the 10g SAR between 1 and 4GHz. The 10g SAR was nearly doubled at 1.8GHz and 3.2GHz. The increase in SAR due to the three objects was roughly but not exactly related to the increase in SAR of the three objects when considered individually. The 1g SAR values in all tissues had a similar shape to the 10g SAR values, except the 1g SAR values were approximately 3 times higher.

The average SAR in the (right) testicle closest to the phone was also considered and the results are shown in Figure 3. The testicle in the model, without metallic objects, showed a slight resonance at 1.1GHz. The average SAR in the left testicle, which has a similar mass but a different shape, decreased with frequency. Hirata [12] showed that eyes of different sizes resonated at different frequencies, so different models or people may be different. Adding metallic objects produced similar results to the SAR in the right testicle as to the 10g SAR. Above 1.1GHz, the addition of all three objects increased the SAR averaged over the testicle. At 0.9GHz, the three objects significantly reduced the SAR in the testicle. At 1.8GHz the average SAR was increased by 70%. Note the right testicle has a mass of 11.63g and is comparable with the 10g SAR results in Figure 2. Above

1.1GHz, the average SAR value in the right testicle was less than the maximum 10g SAR as the maximum 10g SAR occurred in the leg which was closer to the source.

The maximum 1g SAR in the testicles was also considered and the results, shown in Figure 4, were found to be similar to the average SAR in the right testicle shown in Figure 3, except the 1g SAR results were roughly twice as large. The smaller 1g SAR volume had a larger effect at around 3.3GHz, where the energy absorption is more superficial. The 1g SAR values in the testicles were approximately half the 1g SAR values in all tissues.

4. Conclusions

The FDTD method was used to investigate the SAR in the waist section of the human body. Realistic metallic objects added in close proximity to the model both increased and decreased the SAR. When all three objects were added, the SAR in both the leg and in the testicles was generally increased and approximately doubled at 1.8GHz. The addition of extra metallic objects was roughly cumulative but not exactly. This shows that the system is more complicated with multiple objects interacting with each other. Note, that the location of the phone and metallic objects was arbitrarily chosen and based on realistic sizes. No attempt was made to find the worst case scenario or to choose a range of objects that resonate at the same frequency. The testicle closest to the phone showed a slight resonance but the SAR values were generally lower than in the leg. However, it is hypothesized that lower SAR levels in the testicles could be more concerning than the same values in the leg.

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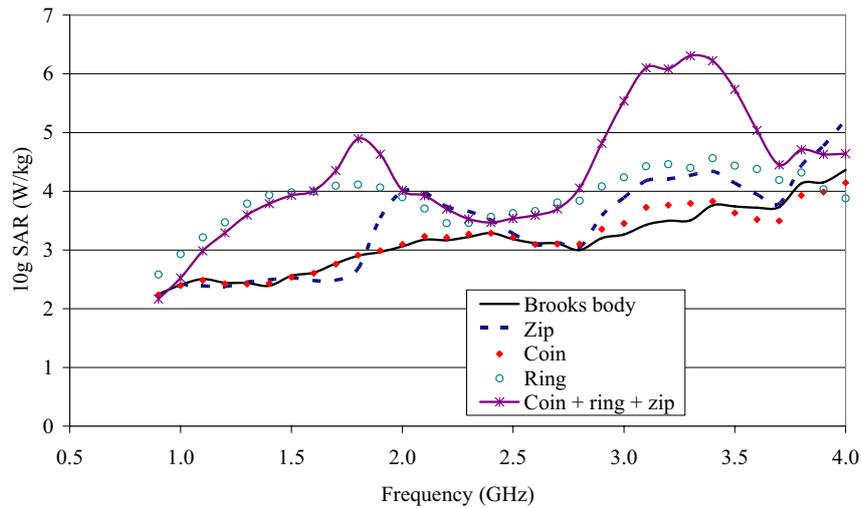


Figure 2. The 10g SAR in the Brooks waist as a function of frequency.

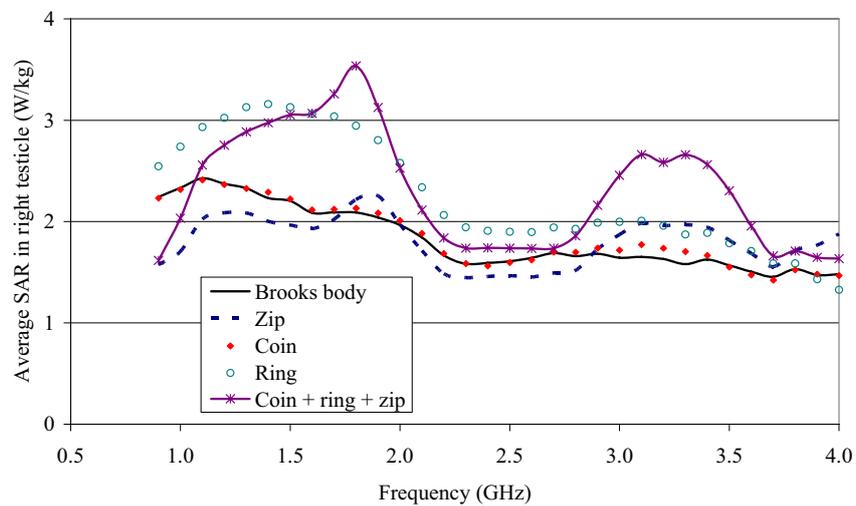


Figure 3. The average SAR in the right testicle as a function of frequency.

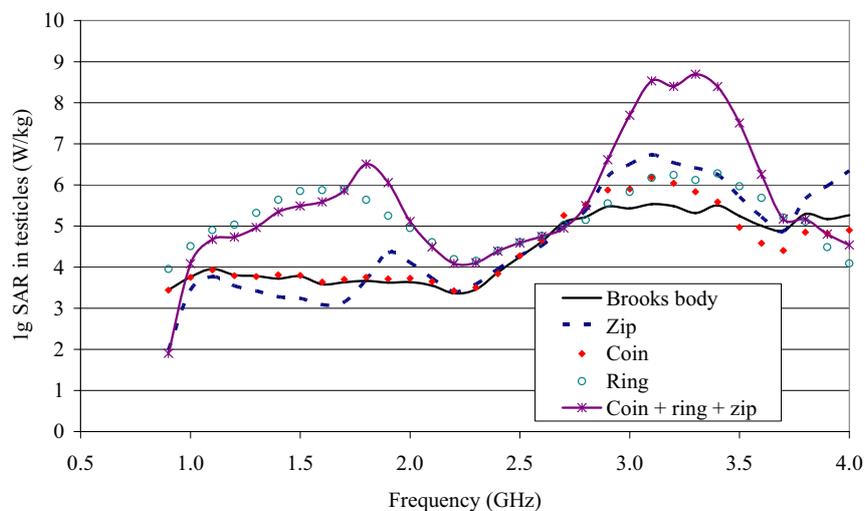


Figure 4. The maximum 1g SAR in the testicles as a function of frequency.