EFFECTS OF METALLIC SPECTACLES ON SAR WHEN USING COMMUNICATIONS ENABLED PDAs IN FRONT OF THE FACE

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Abstract This paper presents simulated and measured results of a study examining the effects of metallic spectacles on the Specific Absorption Rate (SAR) inside a modified Specific Anthropomorphic Mannequin (SAM) head when using various RF sources. We consider dipole sources resonating at 900MHz and 1800MHz as well as three communications enabled PDAs operating in the GSM900 band.

1. Introduction

With new advances in electronics and communications, there has been a merger between mobile communications and Personal Data Assistant (PDA) type devices. This new breed of device is intended to deliver multimedia applications, 3G video calls, internet browsing and email access among others, all of which require the device to be held in front of the face rather than to the side of the head. Current mobile phone safety standards are based on side of the head use and all testing protocols are designed accordingly [1]. With the increase in front of face radiation sources, the effects of facial jewellery on the SAR inside the head has become an important area of study. Simulation studies of spectacles on heterogeneous head models have been conducted in the past [2 - 4] but studies using the SAM [5] head phantom are less common.

Previously, the authors have modified a SAM head phantom for use in a DASY4 SAR measurement kit [6 7]. The rear of the head has been removed and the phantom fixed face down, allowing the E-field probe to scan the area behind the face (see Figure 2). The measurement system has been successfully validated against FDTD simulations [7]. The authors have also studied the effects of simple metallic objects, such as pins and rings on the SAR inside the newly developed modified SAM head. The authors showed that metallic rings approximately one wavelength in circumference [8] and metallic pins approximately 0.4λ long [9] can increase the SAR by several times in both homogenous and heterogeneous heads. SAM phantom measurements were verified against simulated SAR values using in-house FDTD code. In all cases, a CW dipole source was used. In this study, we extend the investigation by using actual metallic spectacles and popular communications enabled PDAs working at GSM900.

2. Description of model

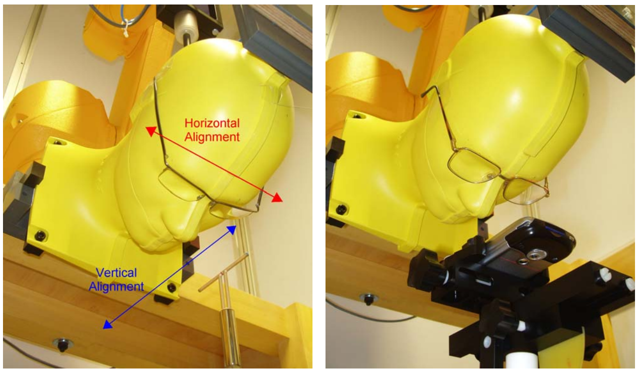
This study used six different spectacles, four of which were standard fully-rimmed metallic spectacles (see S3 – S6 in Figure 1). The remaining two were semi-rimmed (see S1 and S2), i.e. only the top half of the rim is present in the design. SAR measurements were carried out using the modified SAM head and the DASY4. Each spectacle was positioned in turn with the upper most part of the spectacle rim in line with the point on the eyebrow that protrudes the most. On the SAM head, this point is 54mm vertically up towards the top of the head from the tip of the nose.

S1 S2 S3 S4 S5 S6

Figure 1 - Six different metallic rimmed and semi-rimmed spectacles used in the study

For the first set of measurements, CW dipoles were used at 900MHz and 1800MHz. The dipoles were positioned at a distance of 80mm away from the tip of the nose but the centre of the dipole was always in line with the centre of the eyebrow (and also the top most part of the spectacle rim). Figure 2(a) shows Spectacle 1

(S1) positioned on the SAM phantom with a vertically aligned 1800MHz dipole. For each spectacle, measurements were made with both horizontally and vertically aligned dipoles at 900 and 1800MHz. Horizontal alignment is from ear to ear whilst, vertical alignment is from the chin to the top of the head.



(a) (b)

Figure 2 - SAM head with (a) S1 and vertical 1800MHz dipole and (b) S6 and Xda IIi PDA

A further set of measurements were made within the GSM900 band using three different communications enabled PDAs. Figure 3 shows the three PDAs used. They are the Xda IIi, Nokia E61i and the Samsung SGH-i600. Positioning of the Xda in front of the face is shown in Figure 2(b). The PDA screen is 80mm in front of the tip of the nose whilst the centre of the screen is aligned with the centre of the eyes.

The effects of the spectacles have also been simulated. An independent 3D FDTD code [10] 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 head. The Yee cell size used throughout this paper is 2mm. The lowest number of cells per wavelength was always greater than ten, and reasonable results have been obtained with only four [10]. The FDTD code models spectacles as copper Yee cells 2mm in size in a 2D plane. The lenses are modelled as 2mm thick Perspex cells with a relative permittivity of 2.56. Spectacle arms and nose rests are not modelled. Each spectacle was positioned such that the top most part of the rim was aligned with the eyebrow, 54mm vertically up from the tip of the nose, similar to the location used in the measurements. A CW dipole source was used in the simulations. All simulation and measured results are normalised to 1W transmitted power.

(a) (b) (c)

Figure 3 - Three communications enabled PDAs used in the study (a) Xda IIi (b) Nokia E61i (c) Samsung SGH-i600

3. Results

Figure 4 shows the measured and simulated 1g SAR values inside the head for the six different spectacles when using a horizontally aligned dipole source at 900MHz and 1800MHz. 1g SAR results without spectacles are

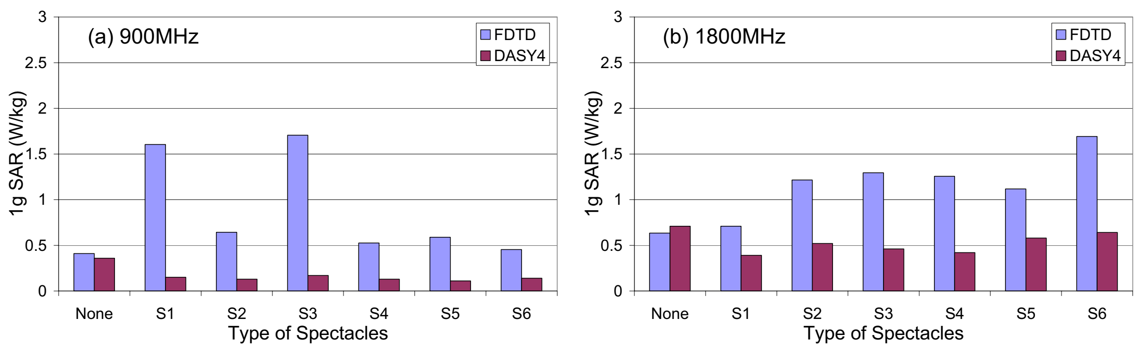


Figure 4 - 1g SAR inside the SAM head caused by six different spectacles when radiated by (a) 900MHz and (b) 1800MHz horizontal dipole sources

also presented for comparison. There is good agreement between FDTD and DASY4 results when there are no spectacles in place but the agreement is poor when spectacles are included. Without spectacles, the peak SAR region was on the central axis of the SAM head between the eyebrows, which was easily measured and duly verified by similar FDTD results. When the spectacles were included, the peak SAR region moved to the inside of the nose. This region can be easily summed for a 1g cube in the FDTD code but cannot be accessed by the e-field probe of the DASY4 kit. The probe must be able to approach the surface of the phantom within 30° of the normal, if not, that particular measurement point is abandoned. Due to the steep sloping shape of the nose, the probe cannot access this area without colliding with the rear of the SAM head. Therefore, all the 1g SAR DASY4 measurements shown in Figure 4 are maximum values obtained by excluding the nose region.

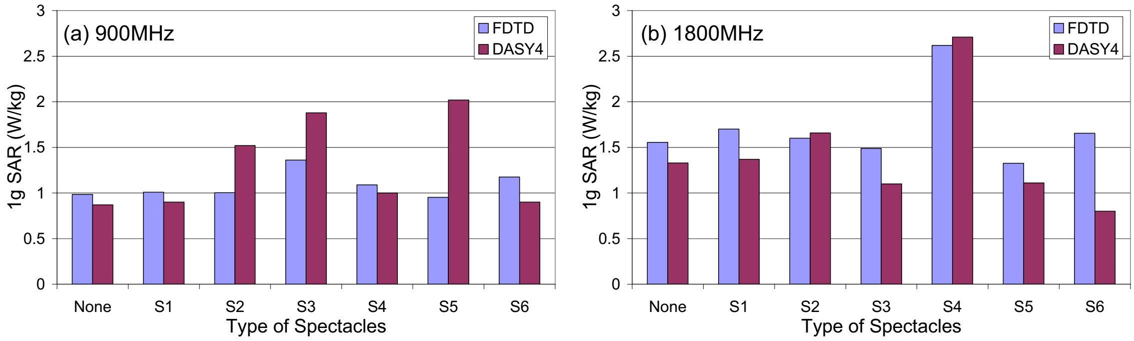


Figure 5 - 1g SAR inside the head caused by six different spectacles when radiated by (a) 900MHz and (b) 1800MHz <u>vertical</u> dipole sources

A previous study showed that a 150mm metallic pin placed horizontally along the eyebrow 8mm from the surface caused a five times increase in the 1g SAR at 900MHz [9]. The 1g SAR was particularly sensitive to the length and location of the pin. The semi-rimmed spectacle S1 has a similar horizontal metallic bar and the FDTD simulation shows a four times increase at the same frequency. However, this is not reproduced in the measurements. We believe this is due to the separation distance between the spectacles and phantom surface not being the same in the simulation and measurement. It is difficult to accurately match the positioning in the measurements and simulations when spectacles are three dimensional in the measurements but only two dimensional in the simulations. The physical spectacles also have curving lenses, metallic arms and metallic fixtures for the nose pads, all of which are not included in the simulations. This may suggest why in the physical model, maximum SAR for S1 is not behind the eyebrow but inside the nose making it impossible to measure. From the FDTD results, it can be seen that at 900MHz, S1 and S3 increased the 1g SAR by four times where as the other spectacles had very little effect. At 1800MHz, all the spectacles except for S1 double the 1g SAR.

Figure 5 shows the measured and simulated 1g SAR values inside the head for the six different spectacles when using a vertically aligned dipole source at 900MHz and 1800MHz. In this alignment, the maximum SAR point was normally found on the central axis of the SAM head between the two eyes. This area can be measured by the DASY4 and so the measurements and simulations generally show better agreement. At 900MHz, simulations suggest all spectacles have limited effect on the 1g SAR whilst, the measurements show a two times increase for S3 and S5. At 1800MHz, the simulations show a similar effect; little change in the 1g SAR except for S4. The measurements at this frequency shows a general trend of reduced SAR except for S4 which approximately doubles the 1g SAR.

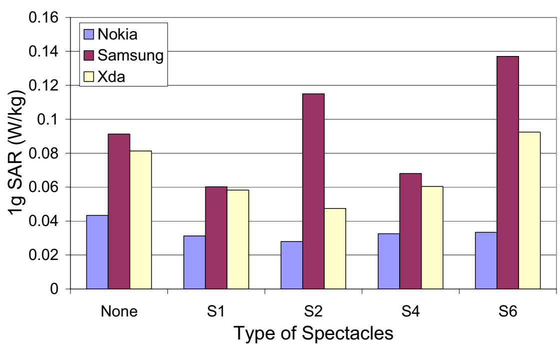


Figure 6 - 1g SAR measured inside the head caused by four different spectacles when radiated by GSM 900 PDA sources

As a general rule, the vertically aligned dipole gives a higher 1g SAR at both frequencies. The exceptions are S1 and S3 at 900MHz, where the horizontal aligned dipole has a much bigger effect in the simulations.

Figure 6 shows the measured 1g SAR inside the SAM head for four different spectacles when using three PDAs in front of the face. In all configurations, the Nokia has the lowest SAR followed by the Xda and finally by the Samsung. In all cases, the 1g SAR cube is located on the central axis of the SAM head between the eyes. All four spectacles reduced the 1g SAR when the Nokia was used. Measurements with the Xda also followed this general trend. With the Samsung, S2 and S6 increased the 1g SAR whilst S1 and S4 reduced the 1g SAR. Different antenna configurations within the body of the PDAs will give rise to unique antenna radiation patterns with differing levels of vertical and horizontal E-field components. As already seen in the dipole study, spectacles behave differently depending on the polarisation of the E-field. In all cases, the measured 1g SAR values are very low due to the large separation distance between the phantom and the source, and so are well within the IEEE's 1.6W/kg limit. Whereas the earlier dipole measurements were normalised to 1W, at GSM900, a 1/8th duty cycle is used and so the energy absorbed over any given time period will be less than a CW source.

4. Conclusions

The modified SAM head has been used to study the effects of spectacles on the SAR inside a SAM head at 900 and 1800MHz. Vertically aligned dipoles have generally produced a higher SAR compared to horizontally aligned ones at both investigated frequencies. The main exception has been Spectacle 1, which most resembled a 0.4λ metallic pin. It caused the biggest 1g SAR increase of a factor of four when radiated by a horizontal dipole. Due to the existing system's inability to measure inside the nose, some results have not been experimentally verified. Nevertheless, the study has highlighted the possibility of resonance of semi-rimmed spectacles and therefore merits further study. Future work will involve developing a method to scan inside the nose so that the entire face region is accessible.

5. References

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