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SAR Variations in the Face Due to Semi-Rimmed Spectacles and Polarized Sources at GSM900 and GSM1800

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***Abstract*—This paper presents experimental and simulated results from a study looking at the effects of semi-rimmed spectacles on the specific absorption rates (SAR) inside the head. Measurements were carried out using a modified specific anthropomorphic mannequin (SAM) phantom head incorporated into a DASY4. 1g SAR was recorded for 14 different semi-rimmed spectacles using CW dipole sources at 900MHz and 1800MHz. Simulations have also been conducted using the digitised SAM head and a pair of spectacles.**

I. Introduction

The health effects of using mobile communication equipment (MCE) at the side of the head have been studied widely in the past [1]-[3]. Consequently, mandatory safety limits for RF energy absorption inside the human body have been adopted throughout the world [4]. With the arrival of 3G, applications have been developed where the MCE are required to be held in front of the face, thus changing the origin of the RF radiation. In such radiation conditions, metallic objects found on the face such as studs, labrets and spectacles may influence the RF energy absorbed in the head.

At Loughborough University, we have developed a modified SAM phantom head for measuring the SAR in the facial area when the RF source is placed in front of the face [5]. In the past, we have shown that external metallic pins of resonant lengths placed at specific distances from the SAM head can increase the 1g SAR inside the head by a factor of more than 5 [6]. In that study, metallic pins were used to represent the crossbars of semi-rimmed spectacles.

II. Methodology

This study examines the applicability of the pins simplification to contemporary spectacles by investigating the effect on 1g SAR of a random sample of 14 semi-rimmed spectacles, 5 of which have plastic arms. The spectacles vary in size, shape and lens material. All the spectacles' semi-rimmed frames were metallic.

A. Measurement setup

The Loughborough SAM head was used in conjunction with a DASY4 SAR measurement system [7] at 900MHz and 1800MHz. The CW dipole sources were positioned in front of the face with the centre of the dipoles aligned to the midpoint between the two eyebrows. The perpendicular separation distance between the tip of the nose and the dipoles were maintained at 80mm. The dipoles were aligned both horizontally (from ear to ear) and vertically (from chin to forehead). The experimental setup is shown in Fig 1. All measured results were normalised to 1W transmitted power.

Fig 1 SAR measurement setup showing 900MHz dipole in horizontal alignment and a pair of semi-rimmed spectacles mounted on the SAM head

B. Measured Results and Discussion

Fig 2 shows the 1g SAR inside the head at 900MHz for horizontal dipole alignment when different spectacles were mounted on the SAM head. The SAR measurements were taken in the area between the eyebrows as any resonance of the spectacle crossbars would have increased the SAR in this region. For each spectacle, the total length of the front metallic frame from the left arm hinge to the right arm hinge was measured and converted into free-space wavelengths. The 1g SAR values measured between the eyebrows were then plotted against the spectacles' lengths measured in wavelengths.

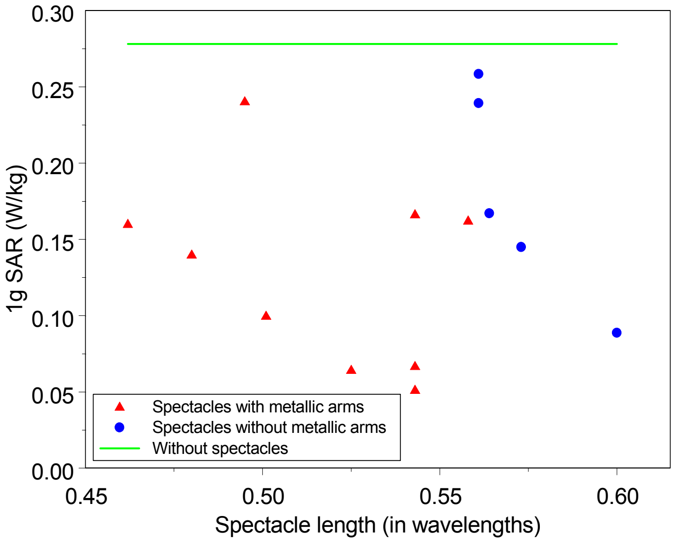

Fig 2 Measured localised 1g SAR inside the SAM head due to spectacles at 900MHz for horizontal dipole alignment

Previous work on the effect of metallic pins on SAR showed that at both 900MHz and 1800MHz, pins between ~0.40λ and ~0.45λ long had an increasing effect on the SAR when positioned 0.06λ from the head [6]. With resonant metallic pins, the maximum SAR regions in the head were located directly behind the pins in the midpoint between the eyebrows. Fig 2 shows that all the semi-rimmed spectacles actually decreased the 1g SAR in the central eyebrow region when the dipole was horizontally aligned.

An increase in the 1g SAR is not observed for any of the tested spectacles because their lengths are all outside the 0.40λ to 0.45λ range required for resonance at 900MHz. Even though some of the spectacles with metallic arms appear close to 0.45λ, the metallic arms themselves increase the actual electrical length making them non-resonant at 900MHz. This result has been verified through simulations in CST's Microstripes 2009 [8]. The presented results for the metallic armed spectacles indicate that these spectacles reduce the 1g SAR in the region between the eyebrows by shielding this region. Largest measured SAR values for all spectacles were in fact located at the base of the nose offset to one side. This is further indication that none of the tested spectacles resonated because resonance increases the SAR between the eyebrows and not in the nose. Although the DASY4 was able to measure inside a small part of the nose, due to the limited space inside the phantom and the requirements for positioning of the probe, the system was unable to measure sufficient points for a representative 1g SAR average inside the nose. Therefore, measured maximum 1g SAR values cannot be presented. It is important to note that the results in Fig 2 are not maximum 1g SAR values, but are the 1g SAR values found in the region behind the spectacles between the eyebrows.

In Fig 2, the dots indicate the 1g SAR resulting from the spectacles without metallic arms; the arms were plastic from the hinge onwards. Although these spectacles were outside the resonant length range, it can be seen that as the length decreased towards 0.45λ, the measured 1g SAR between the eyebrows increased. Therefore, we expect shorter length spectacles to increase the 1g SAR at 900MHz and this hypothesis will be tested through simulations later on in this paper.

In the vertical dipole alignment (Fig 3), some of the spectacles increased the 1g SAR whilst others decreased the 1g SAR. Simulations with a straight metallic pin showed that when the dipole was rotated by 90° to the vertical position, very little radiation coupled from the dipole to the pin and so there was negligible difference in 1g SAR with and without the pin. However, the measured results here suggest there was added coupling between the source and the spectacles, most likely caused by the complexities of the metallic frames near the nose pads. Whereas pins are cross-polar to the source, the spectacles have some co-polar metallic sections.

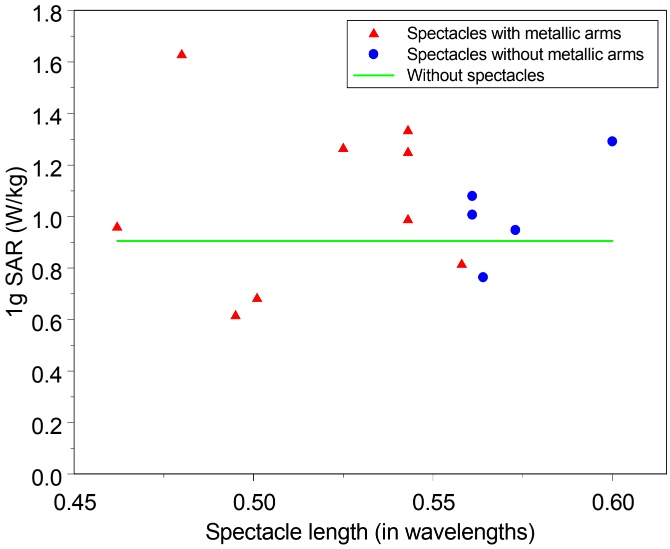

Fig 3 Measured maximum 1g SAR inside the SAM head due to spectacles at 900MHz for vertical dipole alignment

The measured 1g SAR values in the region between the eyebrows for all the spectacles with a horizontally aligned 1800MHz dipole source are given in Fig 4. All the metallic armed spectacles decreased the 1g SAR in this region. In most cases, the maximum SAR value recorded was inside the nose, and so it was not possible to measure sufficient points to calculate the maximum 1g SAR. For two of the spectacles without metallic arms, the maximum 1g SAR was located between the eyebrows, indicating some resonance and there was an associated increase in the recorded 1g SAR. Simulations with a λ pin indicated that there was only a minor resonance at this length and so the 1g SAR was not expected to increase substantially.

With the 1800MHz dipole in vertical alignment, all the maximum SAR locations for the spectacles were located between the eyes towards the top of the nose. Therefore, it was possible to calculate maximum 1g SAR values for all of the spectacles. These results are presented in Fig 5. They are higher than the localised 1g SAR results obtained in the horizontal dipole position because the in the horizontal dipole position, the maximum 1g SAR was located in the nose where it could not be measured. Spectacles with metallic arms generally reduce or have little effect on the maximum 1g SAR.

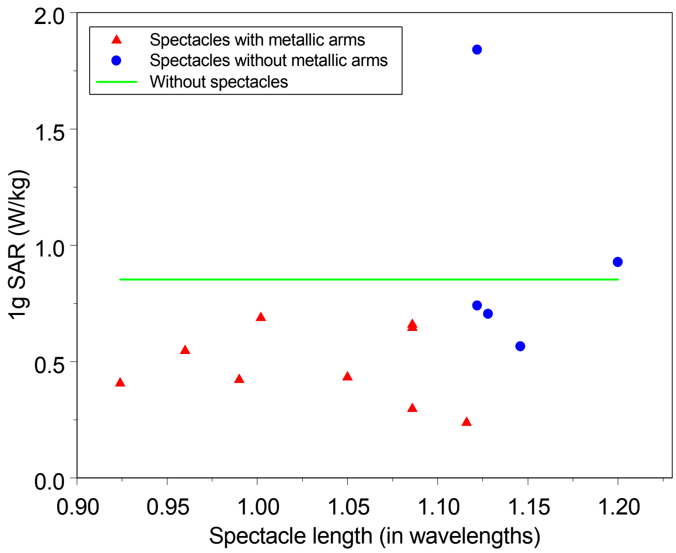

Fig 4 Measured localised 1g SAR inside the SAM head due to spectacles at 1800MHz for horizontal dipole alignment

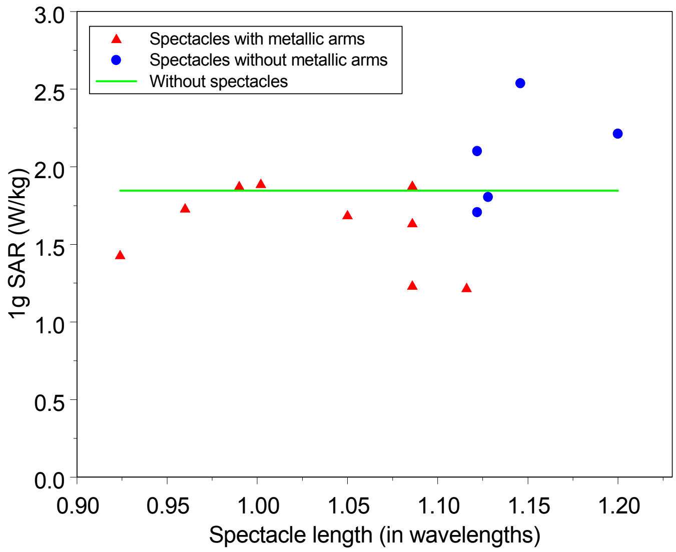

Fig 5 Measured maximum 1g SAR inside the SAM head due to spectacles at 1800MHz for vertical dipole alignment

C. Simulation Setup

A planar 3D digital model of one of the semi-rimmed spectacles with plastic arms was constructed and imported into Microstripes in order to ascertain its resonant frequency. This was positioned, as shown in Fig 6, on a digitised SAM head to replicate normal spectacle wear. The simulation model had a resolution of 2mm. The frontal part of the spectacle was a planar structure but short curved metallic stubs were added at both ends to better represent the metallic hinges. As can be seen in Fig 6, the plastic sections of the arms were omitted from the model. This also ensured the overall length of the metallic frame in the model (~200mm) matched the physical structure.

The SAM head was given a permittivity of 41.5 and a conductivity of 0.97 S/m, which are standardized values at 900MHz for SAR measurements. The metallic frames were defined as perfect electrical conductors. The lenses had a permittivity of 2.56 and were defined as lossless.

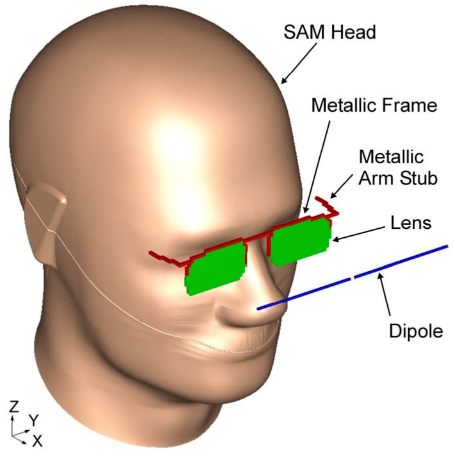

Fig 6 Simulation setup showing the spectacles with stubs positioned on the SAM head with the CW dipole source in front

The location of the dipole was the same as that used in the measurements; 80mm from the tip of the nose and the centre of the dipole was aligned with the mid point of the eyebrows.

D. Simulated Results and Discussion

With the same SAM head and spectacle combination, maximum 1g SAR inside the head was calculated between 500MHz and 1200MHz with appropriately sized dipole sources. These results are presented in Fig 7. The maximum 1g SAR results without the spectacle are also shown for comparison.

The results for the spectacle with stubs clearly indicate a strong resonance at 660MHz. At this frequency, the maximum 1g SAR increased by 6.7 times from 0.27 W/kg to 1.80 W/kg. A similar result was observed in the previous study with straight metallic pins placed in front of the SAM head [6]. In that study, a 150mm pin resonating at 900MHz (0.45λ in length) increased the 1g SAR by ~5.8 times in simulations and by ~7.7 times in measurements with the SAM head shown in Fig 1. The 200mm long spectacle used here has a free-space wavelength of 0.44λ at 660MHz which was previously shown to be close to the length required for resonance. In a similar fashion to the pins study, the maximum 1g SAR with the spectacle in place was located at the midpoint between the eyebrows.

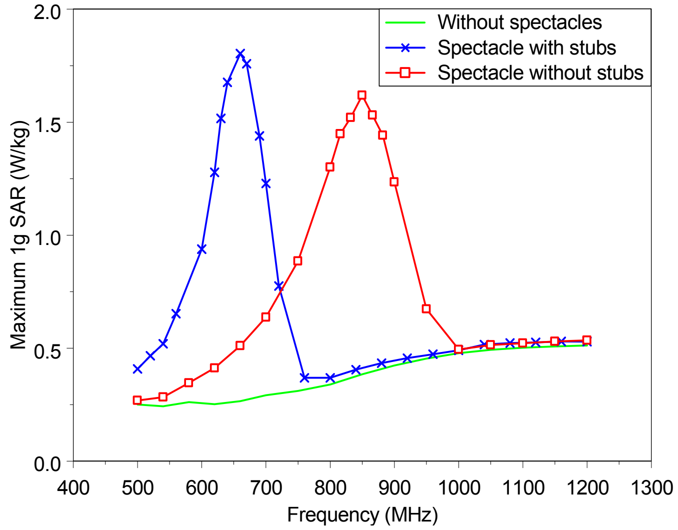

Fig 7 Maximum 1g SAR inside the SAM head for a horizontally aligned source with and without the spectacles

The graph also shows that the spectacle with stubs did not resonate at 900MHz. There was negligible difference in the maximum 1g SAR with and without the spectacle with stubs. Simulations showed that the maximum 1g SAR location in both cases was inside the nose. This correlates with the observed experimental results for horizontal dipole alignment where none of the 5 plastic armed spectacles increased the 1g SAR at 900MHz.

Since all 5 plastic armed spectacles tested were longer than 0.45λ, it has not been possible to demonstrate experimentally spectacle resonance at 900MHz. However, through simulations we have shown that plastic armed metallic spectacles can resonate at the lower frequency of ~660MHz. To move this resonance frequency up to 900MHz, we have shortened the length of the spectacle by removing the two metallic stubs at both ends. The new spectacle model without stubs is shown in Fig 8. This resulted in the full length of the frame reducing to ~148mm. The simulated maximum 1g results with this spectacle are also given in Fig 7. The largest effect was observed at 850MHz where the spectacle increased the 1g SAR by a factor of 4.2. At 850MHz, the spectacle is ~0.43λ long which is within the previously mentioned resonant length range.

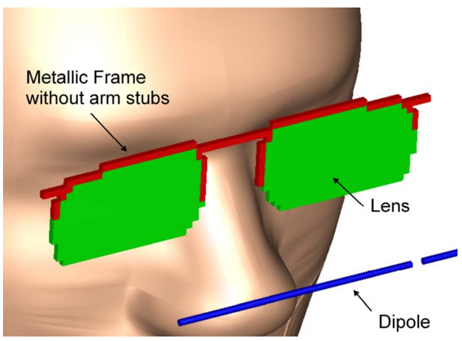

Fig 8 Simulated spectacles without metallic arm stubs.

III. Conclusions

In this paper, 14 different semi-rimmed spectacles were tested on a SAM phantom using 900MHz and 1800MHz dipole sources in two orthogonal alignments. Almost all the spectacles did not resonate when the dipoles were in horizontal alignment. This was shown to be because the length of the metallic frames were outside the 0.40λ to 0.45λ range required for resonance. We can conclude that semi-rimmed spectacles with metallic arms are unlikely to resonate at 900MHz and 1800MHz and are more likely to reduce the 1g SAR between the eyebrows. However, we have shown through simulations that semi-rimmed spectacles without metallic arms can resonate at ~900MHz if the total frame length is ~144mm, increasing the maximum 1g SAR by 4.2 times. The front portion of the frames are generally of resonant length but the addition of the hinges makes the spectacles longer than the resonant length for 900MHz

When the source was vertically aligned, the maximum 1g SAR locations with all of the spectacles were in the region between the eyes towards the top of the nose. With some spectacles increasing the 1g SAR and others decreasing it, there was no obvious pattern to the measured results. The metallic structure supporting the nose pads may play some role in modifying the 1g SAR.

In future studies we plan to create 3D CAD models by optically scanning the spectacles. These will then be simulated on a heterogeneous head model. We anticipate the varying properties of the different constituent tissues will effect the increase in SAR caused by resonating spectacles. We also intend to study the effects on SAR and the resonance frequency of spectacles in contact with the skin.

Acknowledgment

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