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ON SPECIFIC ABSORPTION RATES IN THE HUMAN MUCOUS MEMBRANE WITH CONDUCTING SPECTACLES AT MOBILE PHONE FREQUENCIES BY FDTD SIMULATION

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ABSTRACT
An anatomically correct FDTD head phantom was used to study SAR levels in the mucous membrane found in the lining of the nose, sinuses and ears. The membrane is found to absorb significant levels of energy when illuminated by a plane wave from the front of the head. The frequency range considered is 0.8 to 2.6GHz. Metallic spectacles were found to significantly change the SAR in the eyes and mucous membrane.

KEY WORDS
FDTD, SAR, metallic spectacles, mucous membrane

1. Introduction

The mucous membrane consists of reactive tissue that is found in humans close to or on the surface of the head. In general, it may be in close proximity to handheld mobile communications devices particularly mobile phones held to the ear; Bluetooth type devices in and around the ear and Personal Digital Assistants (PDA) type devices held toward the front of the face. It produces mucus and acts as an air filter, warming, moistening and removing toxins from the air [1]. Fig. 1 shows that in the Brooks digital head, the mucous membrane (highlighted in black), is situated towards the front of the head; in the mouth, nose, around the sinuses and that there is relatively little lining the passageways near the ears. It has a high conductivity (σ=1.2S/m at 1.8GHz) and is therefore likely to have higher Specific Absorption Rates (SAR) than other tissues with lower conductivities. It is hypothesized that because of its location, the membrane will show a greater degree of interaction with RF energy when the illumination is from the front, as might be the case with a communications enabled PDA type device compared to when illuminated by emissions from a typical mobile phone held to the ear. Previously little attention has been given in the literature to the mucous membrane and it is often completely missing from numerical phantoms of the type commonly used for Finite-Difference Time-Domain (FDTD) simulations. Note, other head models may contains larger amounts of mucous membrane in the passageways near the ears.

There is public and scientific interest in any effects from microwave energy from mobile communications devices on humans. In recent years, work has been presented regarding mobile phones positioned near the ear [2] and sources in front of the head [2]. Metallic objects near the human body have been found to increase the SAR in the head [3]. In fact, [3] contains a comprehensive review of bioelectromanetics.

Previously, the authors have reported that metallic spectacles significantly increased the SAR in the eyes [4]. The pair that produced the highest SAR had rectangular frames 36mm wide and 38mm high (exterior dimensions) and were positioned 26mm in front of the eye. The lens was 4mm thick and made of glass (εr=5.0). More comprehensive details can be found in [4]. Two pairs of spectacles from [4] are used here to investigate the SAR in the eyes and the mucous membrane in the frequency range 0.8 to 2.6GHz.

2. Description of Model

The details of the 3D FDTD code used in this paper including validations against published controls are provided in [3] [4]. The excitation is a Z polarised plane wave propagating in the X direction (from the nose to the rear of the head), see Fig.1. The power density used was 10W/m², the ICNIRP maximum permissible exposure limit for the general public [4].

A realistic heterogeneous head with 25 different tissue types was provided by Brooks Air force, USA, and is based on The Visible Human data set, see Fig. 1. The implementation of the head into the FDTD code and the plane wave excitation have been validated in [5]. The Brooks head contains approximately 3% mucous membrane and it is the 9th commonest tissue type by volume. As a comparison both eyes in the Brooks head contribute 0.3% to the volume of the head. The size of the Yee cell was 2mm, equal to the resolution of the head. Previously, the authors have reported that for certain types of experiment it may be possible to use the symmetrical properties of the head and use the results form one half head mirrored across the central plane [4]. However, the mucous membrane in the head is not symmetrical [1] and therefore the whole head was used.

3. Results

Both pairs of metallic spectacles have a significant effect on the SAR in the eyes and the mucous membrane. Fig. 2 shows the maximum 10g SAR, with and without spectacles, in the mucous membrane is larger than the average SAR in the eyes (mass of one eye is 8.37g [3]). The spectacles had little effect on the SAR at frequencies below 1.0GHz, but significantly increased the SAR in the range 1.5 to 1.9GHz. At 1.8GHz, the 36x38mm pair of spectacles, that previously produced the maximum SAR in the eye [4], increased the 10g SAR in the mucous membrane (at least 50% mucous membrane by volume) results by 77% compared to the case without spectacles. Note there are no 1g or 10g cubic regions in the Brooks head which contain 100% mucous membrane. The 46x38mm pair of metallic spectacles, that decreased the SAR in the eye at 1.8GHz [4], marginally decreased the 10g SAR in the mucous membrane at 1.8GHz. However, the same pair increased the 10g SAR in the mucous membrane by 81% at 1.6GHz. The 36x38mm spectacles increased the average SAR in the whole head by 14.9% at 1.8GHz and the 46x38mm pair increased it by 12.0% at 1.6GHz. Both spectacles increased the SAR at frequencies below their resonance and decreased it at higher frequencies.

The maximum 1g SAR, is comparable with the ANSI/IEEE standards of 1.6W/kg [6]. Note that the power density of the plane wave excitation is likely to be larger than that produced by a mobile device. The results shown in Fig. 3 are for 1g cubes containing at least 50% mucous membrane by volume. The results are similar to Fig. 2 except the 1g SAR values are approximately double the 10g values. For the case without spectacles, the locations and values of the maximum 1g SAR in both the mucous membrane (50% by volume) and in the whole head were the same at all frequencies. For the results with metallic spectacles; at roughly 2/3 of the frequencies considered here, the maximum 1g SAR in the head and the 1g SAR in the mucous membrane were equal and were located at the same position in space. This result shows that the maximum 1g SAR in the head occurs in a region of mucous membrane.

The 1g and 10g SAR values containing at least 50% mucous membrane were always greater than 83% of the maximum 1g and 10g SAR values in the head. This confirms the hypothesis that the mucous membrane may be particularly vulnerable when the excitation is from the front. When the maximum SAR averaged over 1g was calculated using 70% mucous membrane, the results fell to approximately 85% of the values of the 50% mucous membrane cube. However, using a 90% mucous membrane averaging 1g cube reduced the 50% by volume 1g SAR results, shown in Fig. 3, by approximately 80%. These results give an indication to the density of mucous membrane in the head.

Fig. 4 shows the difference in SAR with spectacles compared to without spectacles through two cross sections of the head at 1.8GHz. The 36x38mm spectacles increased the SAR in the nose, the eyes and the mucous membrane. The effect of the spectacles is reduced towards the back of the head. The 46x38mm spectacles reduced the SAR in the eyes and generally increased it in the mucous membrane. However, the maximum 1g and 10g SAR in the mucous membrane is reduced by the 46x38mm spectacles - see Fig. 2 and Fig. 3. Comparing Fig. 4 with Fig. 1 shows that the region in the head where the SAR is increased is closely related to the mucous membrane location.

4. Conclusion

This paper has shown by simulation that the mucous membrane interacts significantly with RF energy when the excitation is from the front of the head and that the maximum 10g SAR in the mucous membrane results were very close to the maximum 10g values in the whole head. This is important and topical since this concludes to a greater emphasis being placed on the mucous membrane when considering inclusion into numerical phantoms. The mucous membrane may be considered as being of more importance when illumination is from the front of the face.

Metallic spectacles significantly increased the SAR in the eyes and in the mucous membrane as well as in the head. The configuration of spectacles used in this paper caused a larger percentage increase to the SAR in the eyes than in the mucous membrane. However, the SAR in the mucous membrane was higher. The spectacles had different effects at different frequencies and the pair with the larger circumference resonated at a lower frequency.

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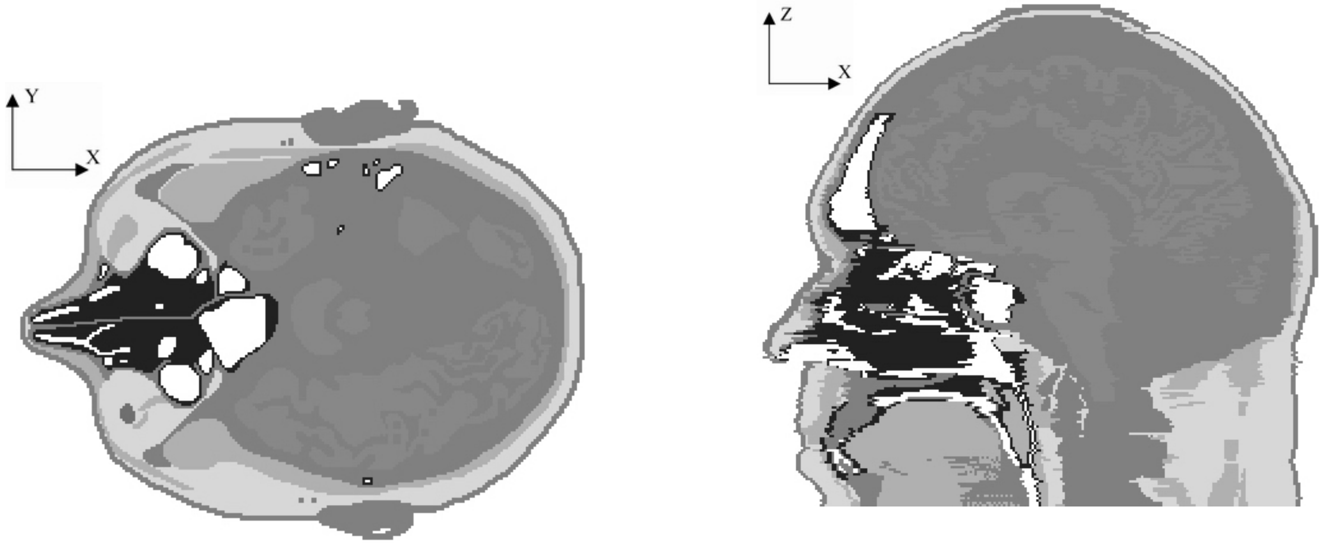

Figure 1. Two cross sections through the Brooks head. The XY cross section is at the bottom of the eyes and the XZ cross section is at the center of the head. The mucous membrane is shown in black

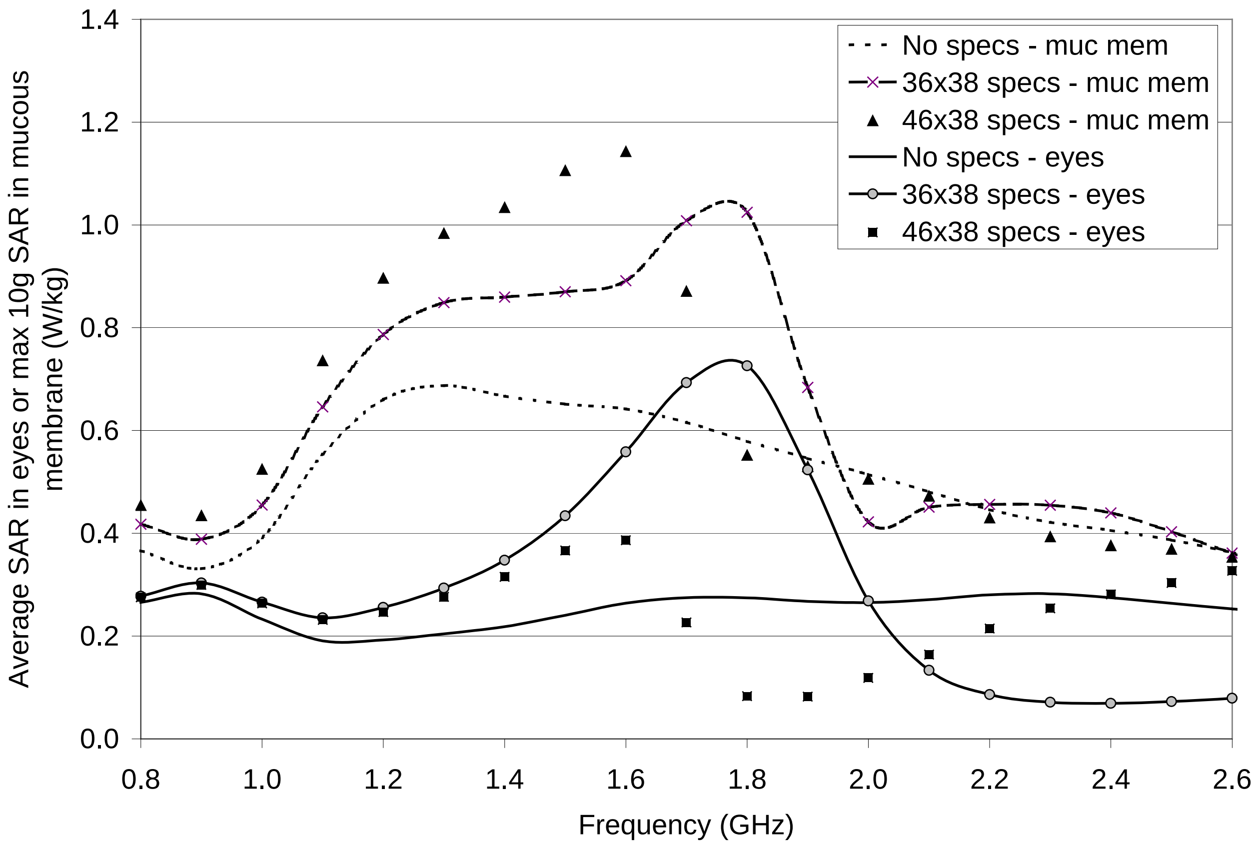

Figure 2. The maximum SAR averaged over 10g of mucous membrane and the average SAR in the eyes with and without metallic spectacles. Note the 10g cube consists of at least 50% mucous membrane.

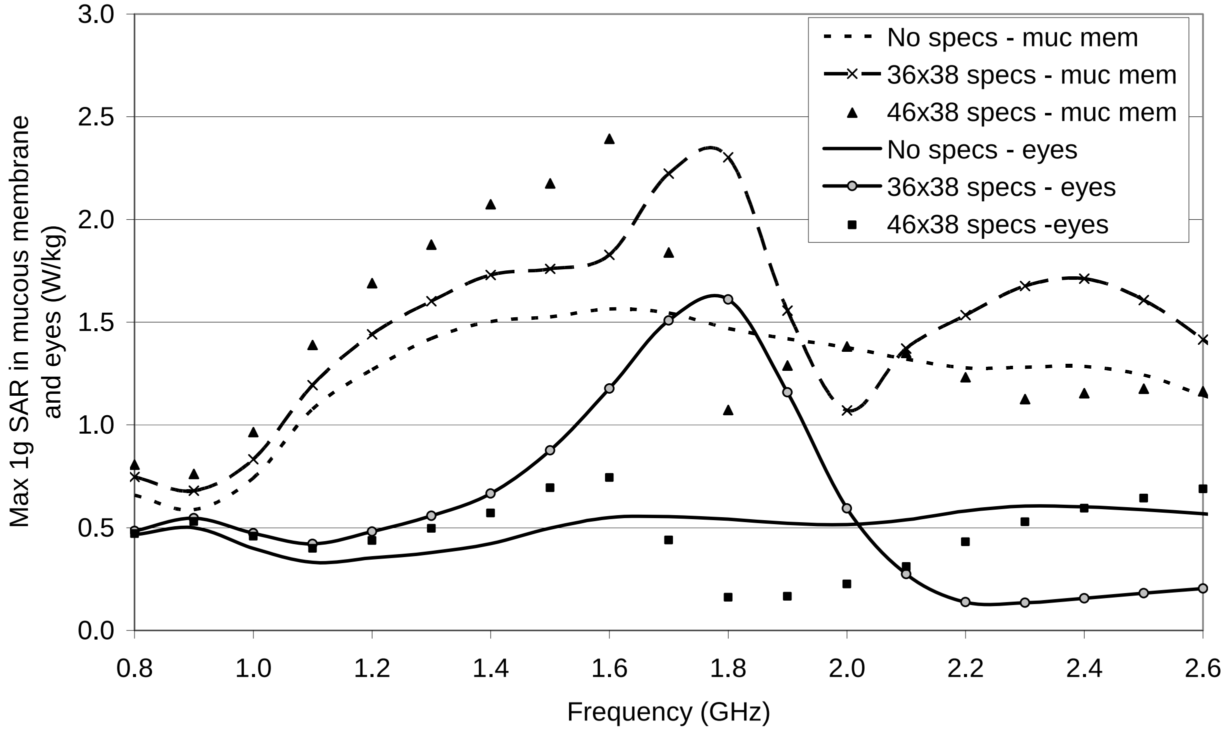

Figure 3. The maximum SAR averaged over 1g of mucous membrane and the 1g SAR in the eyes with and without metallic spectacles. Note the 1g cube consists of at least 50% mucous membrane.

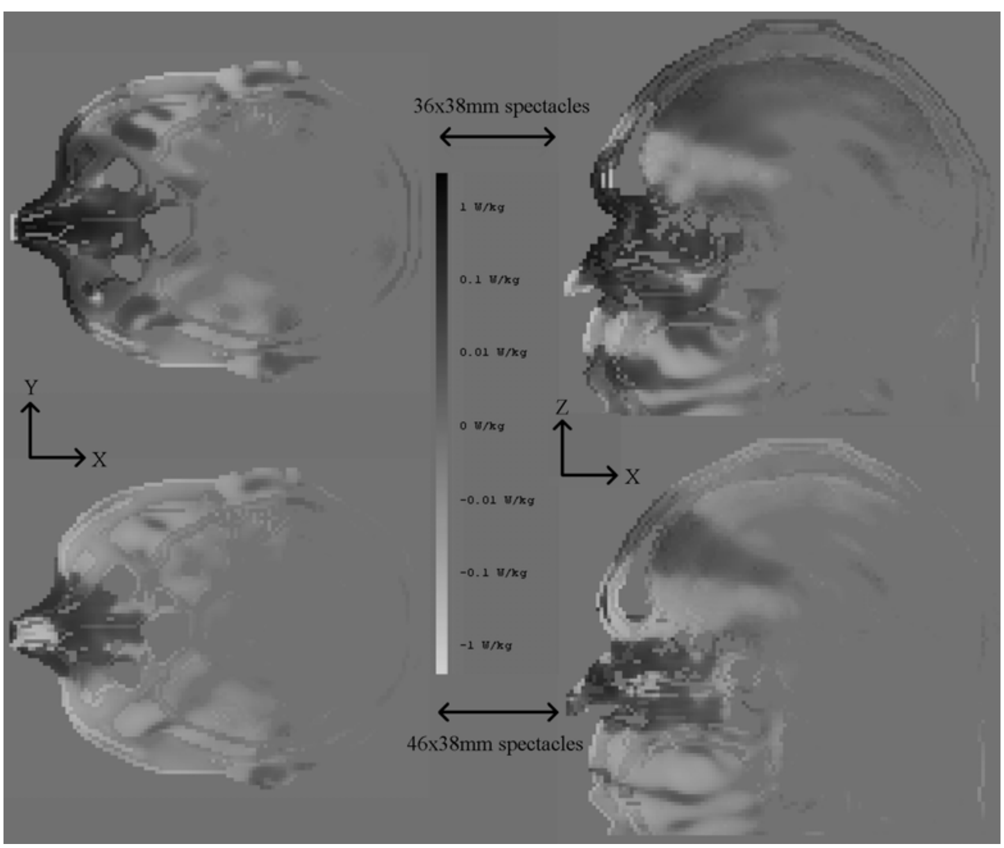

Figure 4. SAR difference with spectacles compared to without spectacles (SAR specs – SAR no specs).