A STUDY OF CHANGES TO SPECIFIC ABSORPTION RATES IN THE MUCOUS MEMBRANE CLOSE TO PERFECTLY CONDUCTING SPECTACLES WITHIN THE RADIO FREQUENCY RANGE 0.8 TO 2.6GHZ.

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Abstract—this paper investigates the effects of metallic spectacles on the Specific Absorption Rates (SAR) in the mucous membrane in the human head, using the FDTD method. The excitation is a vertically polarised plane wave traveling from the front of the face to the back of the head. The frequency range considered is 0.8 to 2.6GHz. Metallic spectacles were found to significantly change the SAR in the mucous membrane.

A. Introduction

The mucous membrane lines many of those passages in the head that are exposed to air. Typically it is associated with congestion, the production of mucus and has functions related to the body's protection mechanisms. Inflammation of the mucous membrane can cause rhinitis. The mucous membrane produces mucus and acts as an air filter, warming, moistening and removing toxins from the air. If too much mucus is produced sinusitis can develop. A more detailed description is beyond the scope of this paper. However, we can say that the bulk of the mucous membrane is located towards the front of the head, in-between and below the eyes. Fig.1 shows that the mucous membrane is situated in the mouth, nose, around the sinuses and that there is relatively little lining the passageways near the ears. The mucous membrane is a reactive tissue and often lies close to or on the surface. It has a high conductivity (σ=1.2S/m at 1.8GHz) and is therefore likely to have higher 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.

There is public and scientific interest in any effects of electromagnetic waves emanating from mobile devices on humans. In recent years some work has been written up regarding mobile phones positioned near the ear [1] [2]. The head has also been irradiated by a source in front of the head using realistic mobile phone models [1] [2]. Metallic objects near the human body have been found to increase the SAR in the head [3] [4]. In fact, [3] contains a comprehensive review of bioelectromanetics. This paper investigates the effects of metallic spectacles on the SAR in the mucous membrane with a CW source positioned in front of the head.

Previously the authors have reported that metallic spectacles were found to significantly increase the SAR in the eyes [5]. That paper used a Genetic Algorithm (GA) to search for the metallic spectacles that produced the maximum and minimum SAR in the eyes at 1.8GHz. 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. The length of the strut from the frame to the arm was 18mm. The pair that produced the lowest SAR in the eye had rectangular frames 46x38mm, positioned 28mm in front of the eye with a 6mm thick glass lens. The strut to the arms was 6mm. These two pairs of spectacles will be used to investigate the SAR in the mucous membrane in the frequency range 0.8 to 2.6GHz. This range covers the range used in Europe (0.9 and 1.8GHz), USA (0.8 and 1.9GHz), Japan (1.5GHz) and Bluetooth devices (2.4GHz). In this paper we have used these same spectacles but have looked instead at effects in the mucous membrane.

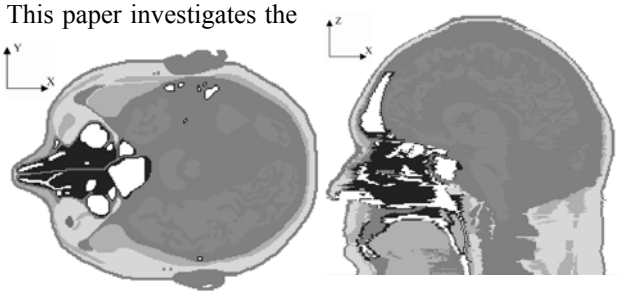

Fig. 1. Two cross sections through the head. The XY cross section is at the bottom of the eyes and the XZ cross section is at the center of the head. The mucous membrane is shown in black.

B. Description of Model

The details of the 3D FDTD code used in this paper are provided in [3] [5]. 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 for orientation of the axes. The power density used was 10W/m², the ICNIRP maximum permissible exposure limit for the general public [5].
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. Fig. 1 shows two cross sections of the head. It also shows that the mucous membrane (marked in black) is predominantly located towards the front of the head and in between the eyes. The size of the Yee cell was 2mm, equal to the resolution of the head. The lowest number of cells per wavelength was always greater than seven, and reasonable results have been obtained with only four [3]. The spectacles were modelled using metallic Yee cells, by setting the conductivity of the cells equal to the conductivity of copper [5]. In each case the centre of the lens was positioned at the centre of the eye in the Y – Z plane. The cells between the frames were assigned a relative permittivity of 5.0; thereby including realistic glass lenses in multiples of 2mm in thickness.

C. Results

The effect of symmetry on the SAR in the mucous membrane was considered as a way to reduce the computational run times. To examine the effects of metallic spectacles, four metrics were investigated; the maximum local SAR in a single cell, the average SAR in the mucous membrane, the SAR_{1g} averaged over one gram and the SAR_{10g} averaged over ten grams. The SAR_{1g} and SAR_{10g} have been averaged over a cubic volume containing no air [5].

1) The symmetry of the mucous membrane

In previous work, the computational requirements have been reduced by assuming the head is symmetrical [5] [6]. This assumption has been shown to produce negligible errors when the SAR in the eye is investigated. However, the mucous membrane lies across the central boundary of the head and is only approximately symmetrical as shown in Fig.1. The results of the maximum SAR averaged over a 1g cube containing at least 50% mucous membrane (by volume) are shown in Fig.2. In this case, the use of symmetry does not produce reliable results when the SAR in the mucous membrane is considered. Therefore, in this paper, results are calculated using the whole head and not a mirrored half head.

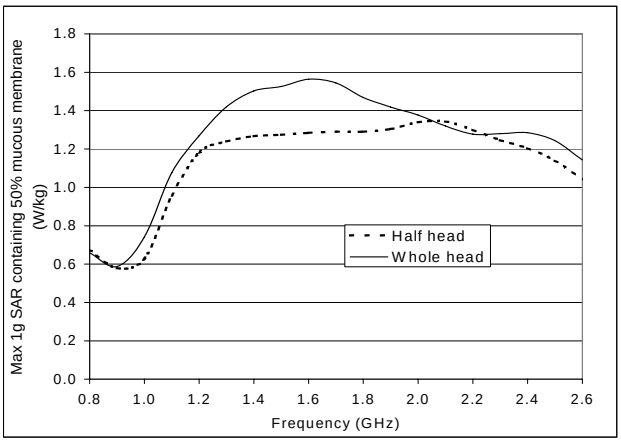

Fig. 2. The effects of symmetry on the maximum SAR_{1g} in the mucous membrane. Note the 1g cube consists of at least 50% mucous membrane.

2) Maximum SAR in an individual Yee cell of mucous membrane

The SAR in one Yee cell is extremely sensitive and is thus only an indicative measure of the SAR in the head. The results not included in this paper to save space show that the 36x38mm spectacles have a much larger effect on the maximum SAR in a Yee cell of mucous membrane than the 46x38mm pair. The maximum SAR in one cell of mucous membrane is increased by 205.2% to 1.5W/kg with the 36x38mm spectacles at 1.8GHz. The largest increase in SAR due to the 46x38mm pair is 61% at 2.6GHz. Above 1.6GHz the presence of spectacles can reduce the maximum SAR in one cell of mucous membrane. The maximum SAR in one Yee cell in any tissue in the head is generally increased with the addition of spectacles. At certain frequencies the presence of metallic spectacles can cause insignificant decreases to the maximum SAR in any cell in the head. The maximum SAR in one cell of mucous membrane is considerably smaller than the maximum SAR in the whole head. The maximum SAR in the head without spectacles is 4.2W/kg and 7.1W/kg with spectacles. This shows that although the mucous membrane is located towards the front of the head and often exposed to the air, the skin absorbs the highest amount of energy in any individual Yee cell.

3) Average SAR in the mucous membrane

Referring again to Fig.1 we see that the bulk of the mucous membrane is situated between the eyes and towards the front of the head. 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. Both pairs of metallic spectacles have a significant effect on the SAR in the mucous membrane, see Fig. 3. At 1.8GHz, the 36x38mm pair of spectacles, that previously produced the maximum SAR in the eye [5], increased the average SAR in the mucous membrane by 47.7% compared to the case without spectacles. The 46x38mm pair of metallic spectacles, that decreased the SAR in the eye at 1.8GHz [5], marginally decreased the average SAR in the mucous membrane at 1.8GHz. However, the same pair increased the average SAR by 57.7% at 1.6GHz. Both spectacles increased the average SAR at frequencies below their resonance and decreased it at higher frequencies. The 36x38mm spectacles increase the average SAR in the whole head by 14.9% at 1.8GHz and the 46x38mm pair increase it by 12.0% at 1.6GHz.

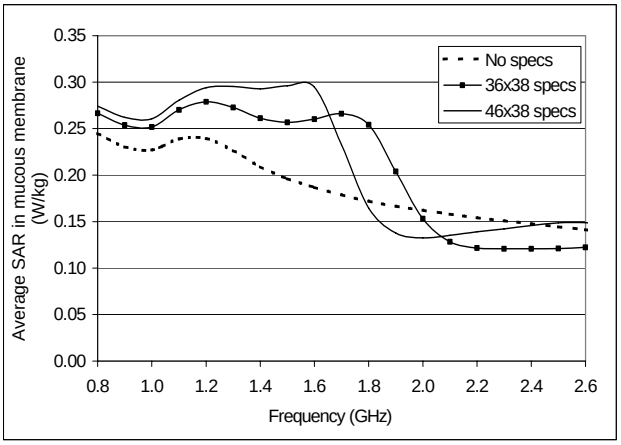

Fig. 3. The average SAR in the mucous membrane with and without metallic spectacles.

4) Maximum SAR averaged over 1g of mucous membrane

The maximum SAR_{1g}, is comparable with the ANSI/IEEE standards of 1.6W/kg [3]. 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. 4 are for 1g cubes containing at least 50% mucous membrane by volume. At 1.8GHz, the 36x38mm spectacles increase the SAR_{1g} by 56.8% and the 46x38mm pair reduce the SAR_{1g} by 27.0%. However, the 46x38mm pair increase the SAR at 1.6GHz by 53.0%. At lower frequencies neither pair of spectacles had a significant effect. Although, the maximum SAR in a single cell of mucous membrane was several orders of magnitude smaller than the maximum SAR in a single cell of the head, this was not the case with the 1g averaged values. The SAR_{1g} values containing at least 50% mucous membrane were always greater than 83% of the maximum SAR_{1g} values in the head. For the case without spectacles, the locations of the maximum SAR_{1g} in the both the mucous membrane and in the head were the same at all frequencies. For the results with metallic spectacles; at approximately 2/3 of the frequencies considered here, the maximum SAR_{1g} in the head and the SAR_{1g} in the mucous membrane were equal and were located at the same position in space. This result shows that the maximum SAR_{1g} in the head occurs in a region of mucous membrane. 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 SAR_{1g} results, shown in Fig. 4, by approximately 80%. These results give an indication to the density of mucous membrane in the head.

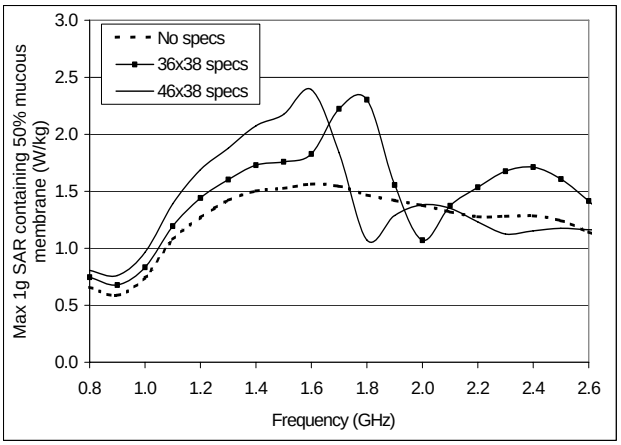

Fig. 4. The maximum SAR averaged over 1g of mucous membrane with and without metallic spectacles. Note the 1g cube consists of at least 50% mucous membrane.

5) Maximum SAR averaged over 10g of mucous membrane

The SAR_{10g} is comparable to the ICNIRP safety standard of 2W/kg [3]. The 10g results for the mucous membrane are similar to the 1g results and are shown in Fig. 5. At 1.8GHz, the 36x38mm spectacles increase the SAR_{10g} in the mucous membrane (at least 50% by volume) results by 77% and the 46x38mm pair increase the SAR_{10g} by 78.1% at 1.6GHz. The SAR_{10g} mucous membrane results are approximately 85% of the maximum SAR_{10g} results for all tissues. Again, this shows that the mucous membrane is particularly at risk when the excitation is from the front. When the 10g results were calculated using cubes containing 70% mucous membrane, the SAR values were reduced by half compared to the 50% by volume results. The Brooks head contains no 10g cubes that contain at least 90% mucous membrane.

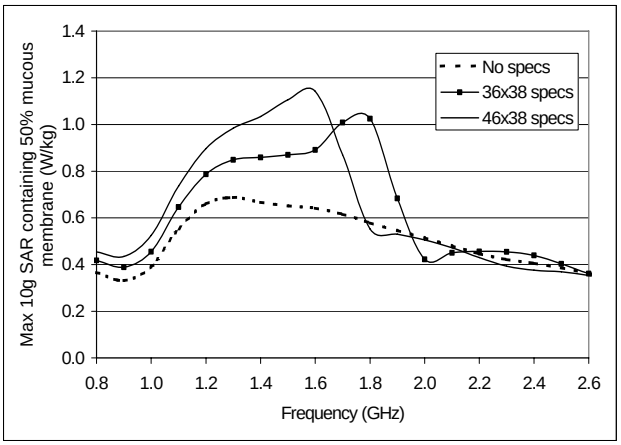

Fig. 5. The maximum SAR averaged over 10g of mucous membrane with and without metallic spectacles. Note the 10g cube consists of at least 50% mucous membrane.

D. Conclusions

This paper has shown that the mucous membrane has a high degree of interaction with RF energy when the excitation is from the front of the head and that the maximum 1g and 10g mucous membrane results were very close to the maximum 1g and 10g values in the whole head. However, the maximum SAR in any single Yee cell in the head was much larger than in the mucous membrane. This paper has shown that metallic spectacles can significantly increase the SAR in the mucous membrane as well as in the head. Spectacles increased the SAR_{1g} and SAR_{10g} in the mucous membrane by approximately 55% and 77% respectively. The spectacles had different effects at different frequencies and the pair with the larger circumference resonated at a lower frequency. Note that the spectacles were designed by a GA to find the maximum and minimum SAR in the eye. This means other spectacles may cause even larger increases to the SAR in the mucous membrane, particularly around 1.6GHz as the spectacles that resonated at that frequency were only designed to have a low SAR at 1.8GHz. The spectacles had little effect to the SAR at frequencies below 1.0GHz and around 2.4GHz, but significantly increased the SAR in the range 1.5 to 1.9GHz.

E. References

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