# SAR Analysis at 900MHz of Layered and Homogeneous Phantoms Incorporating Variations to the Thickness of Fat and Muscle Tissues, at Multiple Dipole Distances

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ABSTRACT

This paper discusses results from a study conducted into the effects of SAR (Specific Absorption Rate) when comparing homogeneous and heterogeneous models against a dipole which was positioned from 10mm up to 200mm in distance form the centre of the dipole to the tissue boundary. Typical methodologies were employed [1, 2, 3] with regards the reference homogeneous simulation models which followed the accepted methodologies for defining reference SAR values used for experimental SAR system validation and calibration [1, 2]. Further studies utilized a heterogeneous model based on skin, fat and muscle. The purpose of the study was to investigate the possible effects of distance and model layering on SAR. The intent of the study was to establish if the accepted homogeneous model was conservative at the typical GSM band.

Index Terms: Dosimetry, SAR, Validation, radio frequency exposure, GSM, Homogeneous and Heterogeneous.

## I. INTRODUCTION

As part of this study it was decided to assess the conservative SAR for homogeneous and heterogeneous phantom models and a series of problems were created and run within the Remcom Inc XFDTD [5] numerical software package. The intention of this study was to investigate the effect of multiple tissue layers on final evaluated SAR and compare against the established conservative homogeneous model so as to determine if the intention of the accepted measurement standard(s) [1, 2, 7] of performing conservative SAR analysis were being met at the GSM frequency [6]. Numerical problems were run with variations to the skin, fat, and muscle thicknesses so as to identify the parameters where the conservative SAR can be found within a layered heterogeneous model.

When the conservative model was identified and defined further numerical problems were run where changes to the dipole separation distance from 10mm up to 200mm were made and conservative SAR was assessed. Further numerical problems were then ran using the IEEE 1528 [1] homogeneous phantom specifications and protocols so as to compare the heterogeneous [7, 8, 9] findings for conservative SAR against accepted global practices. All problems were run using a commercially available FDTD program (Remcom Inc XFDTD) [5, 6].

## II. HOMOGENEOUS PHANTOM

The Flat Phantom test geometry from IEEE 1528 (
Figure 1) is used with the dielectric parameters defined (eps=41.5, sig=0.97, rho=1000). The antenna is a simple (two cylinder) half-wave dipole at 900MHz spaced 10, 25, 50, 100, and 200mm from the phantom.

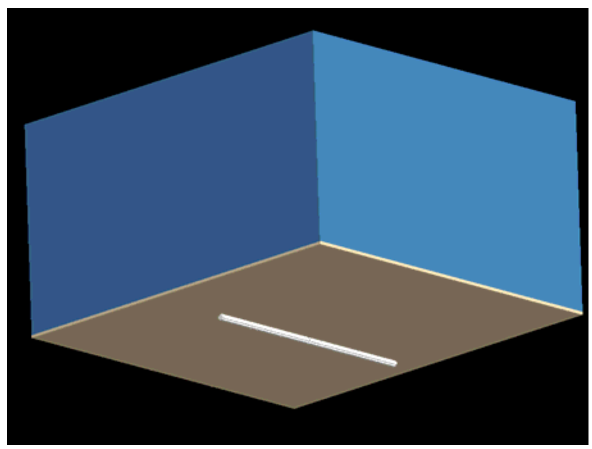

Figure 1: The homogeneous phantom shown with the dielectric shell and simulating liquid above the dipole.

## III. LAYERED PHANTOM

A flat, layered, rectangular phantom comprising of skin, fat and muscle has been used (Figure 2). The skin layer thickness has been varied from 1 to 3mm in 1mm steps. The fat layer is set at four thicknesses values: 20mm, 30mm, 40mm, and 50mm. The fat layer is followed by a muscle layer of 100, 90, 80, and 70mm thickness, depending on the fat thickness selected for the problem. Dielectric parameters used are fat: eps=11.33, sig=0.11, rho=916; skin: eps=41.41, sig=0.87, rho=1125; muscle: eps=55.03, sig=0.94, rho=1046.9.

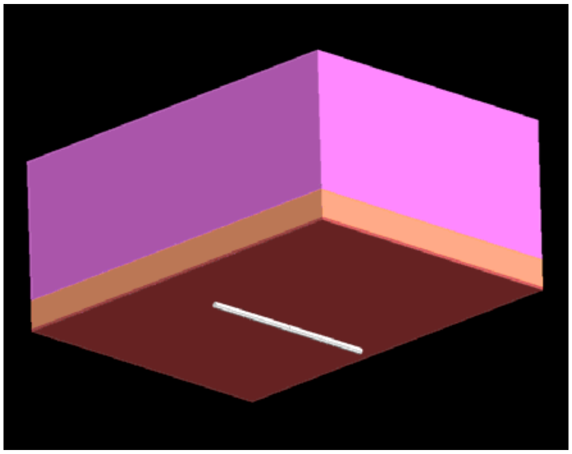

Figure 2: View of the layered phantom showing the skin, fat, and muscle layers above the dipole.

## IV. Results

Plots are shown for comparison of SAR (1g averaged, and 10g averaged) in the homogeneous phantom and layered (skin/fat/muscle) phantom cases. The results are intended to identify any effect that may result from an increase to antenna separation. It has been previously presented in other scientific studies that the layered phantom is more conservative than the homogeneous phantom as distances between the dipole to the boundary are increased.

The details of the phantom models in the previous work are unknown at this time with regards to the skin thickness and the overall phantom size and as such direct comparisons can not be made. It has been observed within this study that the skin thickness has a significant effect on the calculated SAR values. Figures 3 and 4 show the actual calculated SAR values (normalized, W/kg) for various antenna separations. Figures 5 and 6 show the layered phantom SAR normalized to the homogeneous phantom SAR (peak layered SAR/peak homogeneous SAR).

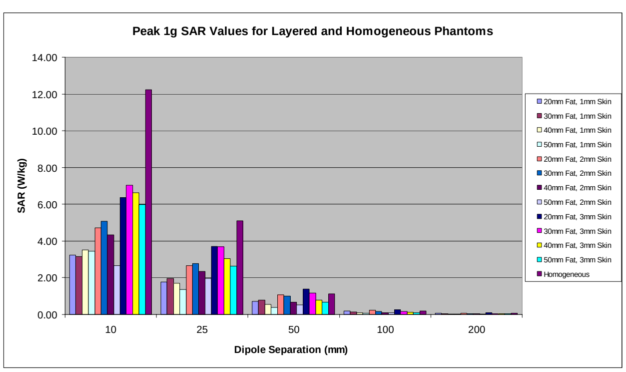


Figure 3: Peak 1g SAR vs dipole separation for half-wave dipole at 900MHz above homogeneous and layered phantoms.

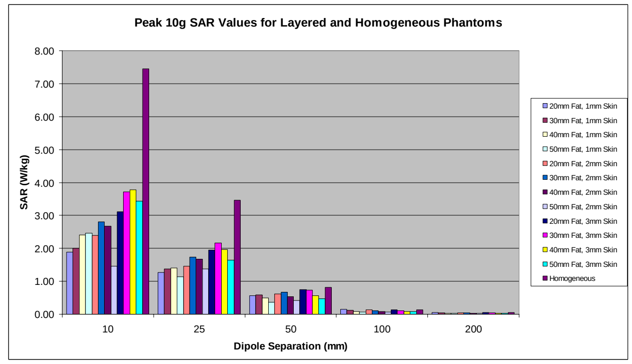


Figure 4: Peak 10g SAR Averaged SAR vs dipole separation for half-wave dipole at 900MHz above homogeneous and layered phantoms

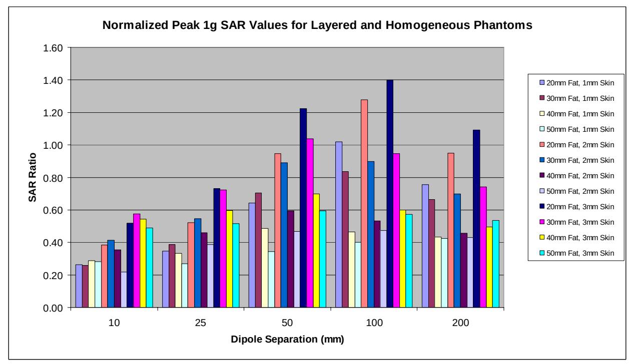


Figure 5: Normalized (Layered/Homogeneous) Peak 1g Averaged SAR vs dipole separation for half-wave dipole at 900MHz above homogeneous and layered phantoms

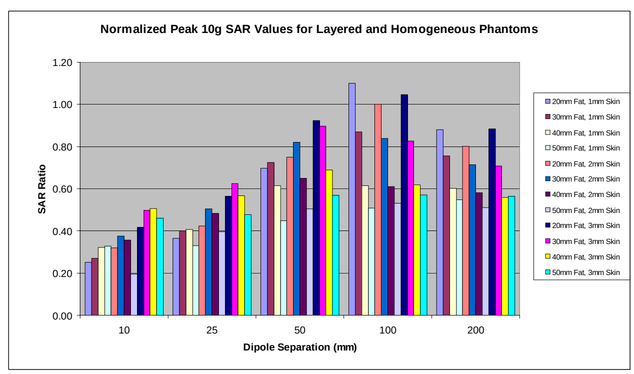


Figure 6: Normalized (Layered/Homogeneous) Peak 10g Averaged SAR vs dipole separation for half-wave dipole at 900MHz above homogeneous and layered phantoms.

In most cases the homogeneous model has yielded the highest averaged SAR when comparing against the conservative heterogeneous model.

It has been observed from the results of this study some averaged SAR data with 20mm fat thickness show a more conservative assessed SAR value compared to the conservative homogeneous model. Where the SAR within the heterogeneous model becomes greater, it can be assumed that this may not be indicative of the greater percentile of the populace.

## V. CONCLUSIONS

The data suggests that for large dipole to phantom separations, the 20mm fat layer has some impact on the computed average SAR results, possibly due to some resonance effects between the higher conductivity muscle and skin layers.

An observation has been made that it is possible to create a heterogeneous model which could be "tuned" for distance specific scenarios of dipole to tissue boundary conditions, and that it may be possible to create a model which is significantly more conservative than the accepted homogeneous model. Caution should be taken though when applying this logic as it needs to be verified physically against scientifically correct anatomical models. At this time there is a need for more data to be published which provides further information on anatomical studies of complex tissue and layering structures which can be used for more accurate studies.

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