ELECTROMAGNETIC ABSORPTION IN MULTILAYERED CYLINDRICAL MODELS OF MAN

[redacted]

ABSTRACT

An important question in docimetry is whether the skin-fat muscle layers and other inhomogeneities in the body are important factors in calculating the specific absorption rate (SAR), or is a homogeneous model adequate.

To help answer this question, the absorption characteristics of multilayered cylindrical models of man irradiated by a normally incident electromagnetic plane wave are described in this paper. Numerical calculations for a specific skin-fat-muscle cylindrical model of man predict a layering resonance at 1.2 GHz with an average specific absorption rate (SAR) about double that calculated for the corresponding homogeneous model. The layering resonance frequency is found to be the same for incident waves polarized parallel and perpendicular to the cylinder axis. The effects of layers on whole-body absorption by man are determined by averaging the effects obtained for many combinations of skin and fat thicknesses. Absorption effects due to clothing are also investigated.

SUMMARY

The absorption characteristics of multilayered spherical models of the human head exposed to electromagnetic (EM) plane waves have been investigated by Joines and Spiegel [1], and by Weil [2]. They have shown that there is a layering resonance in the specific absorption rate (SAR) versus frequency curve for the multilayered spherical model that occurs at frequencies higher than the geometrical resonance. The SAR is the average absorption in W/kg or mW/cm^3 assuming a tissue density of 1 g/cm^3. A multilayered planar model has recently been utilized by Barber, *et al.* [3] to examine the dependence of whole-body power absorption of the configuration of surface layers. They found that:

a. A planar model can accurately predict the layering resonance frequencies for a nonplanar geometry.

b. The resonance due to the gross geometry of the body and the resonance due to the layers are independent of one another if the layers are a small fraction of the maximum dimension.

c. Calculations for a multilayered planar model of an average man predict a whole-body layering resonance at 1.8 GHz with a SAR 34 percent greater than that predicted by a homogeneous model.

Since the layering effect appears to be significant, and since it occurs in the frequency range where a cylindrical model gives good results for the homogeneous case [4], the effect of skin-fat-muscle layering, as well as the effect of clothing, on the average SAR in a multilayered cylindrical model of man have been investigated. Previous SAR calculations for homogeneous models of man have been modified to include the effects of layers on absorption. The results are summarized in Fig. 1, which shows the average SAR in a typical layered model compared to that of a homogeneous model.

The calculated SAR values, for different models of man, lead to the following conclusions:

a. The effect of layers is generally to change the average

SAR values in the frequency range of 0.4-8 GHz. The effects are not large, since the greatest increase, which occurs at about 2 GHz, is approximately double that of the homogeneous model, and the greatest decrease, which occurs at about 5 GHz, is approximately half that of the homogeneous model. At frequencies below 400 MHz, the layers are so thin compared to a wavelength as to have a negligible effect, and at frequencies above 10 GHS, the depth of penetration is so low that the transmitted power is all absorbed in the surface skin layer, which has the same permittivity as that of muscle material of the homogeneous model.

b. The location of the layering resonance and the enhancement of the absorption due to layers are found to be almost identical for planar and cylindrical models.

c. The frequency of the layering resonance is found to be independent of the polarization.

d. For given permittivities of the layers, the layering resonant frequency is inversely proportional to the thickness of the layers.

e. For frequencies below 2 GHz, the clothing has very little effect on the SAR value. However, for higher frequencies, some secondary peaks have been found in the average SAR values for the model with lossy clothing.

REFERENCES

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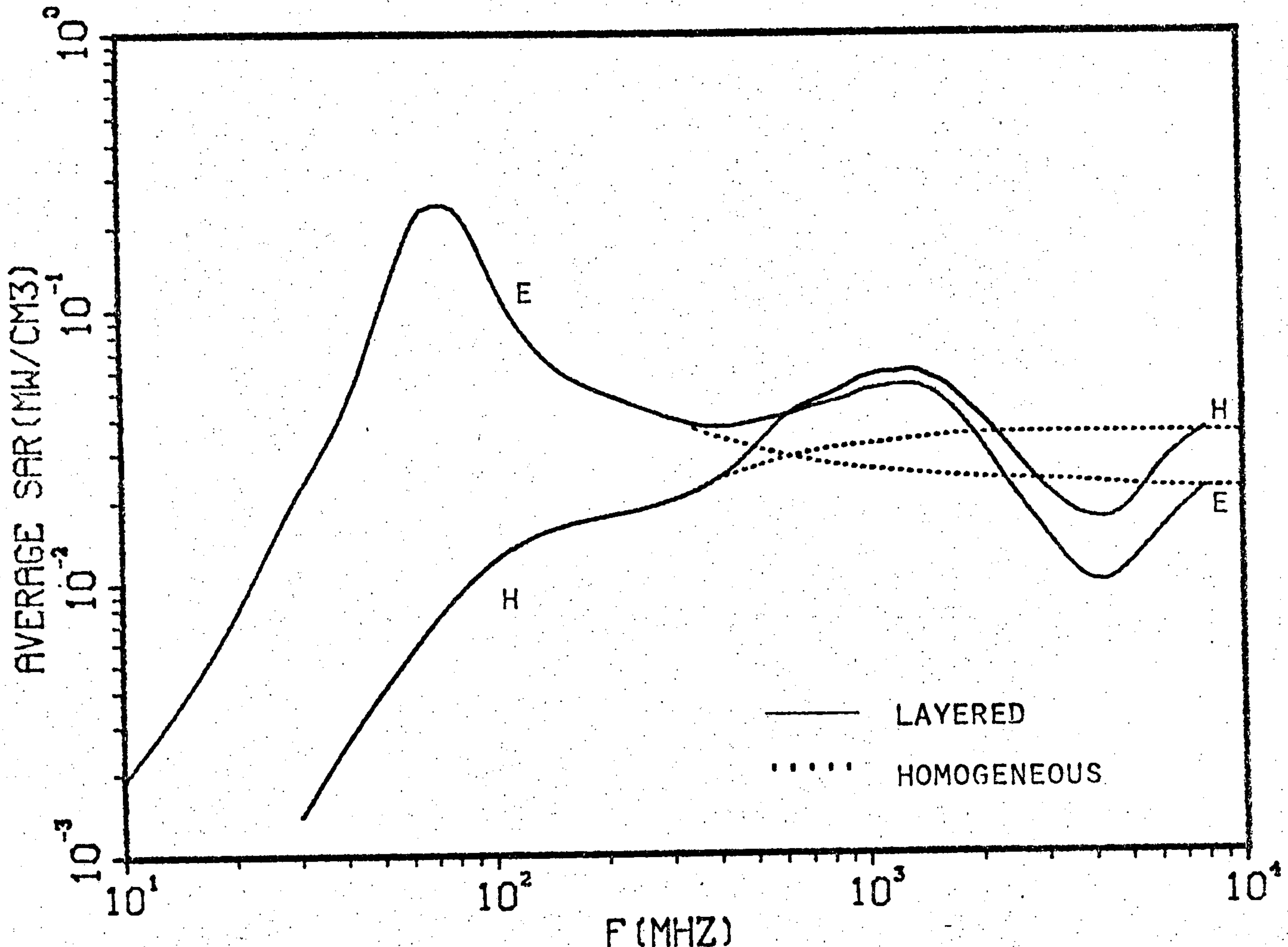

Fig. 1. Average SAR in homogeneous and multilayered models of an average man for an incident power density of 1 mW/cm^2 for two polarizations.