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P2_4 Electromagnetic radiation from Mobile Phones

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Abstract
This paper demonstrates a method to quantify the energy absorbed by the human head from using a mobile phone. Our results show the energy absorbed per second per unit area by a human brain is $P_{Absorbed}$ = 1.37 x 10^{-5}J.s^{-1}.m^{-2} and by a human head is $P_{Absorbed}$ = 2.64 x 10^{-5}J.s^{-1}.m^{-2}.

P2_2 General Physics

Introduction

In recent years there has been a large increase in the amount of wireless devices used in our daily lives. This rapid increase raises serious questions about the effects on human health.

Although a lot of research has been done in this area, it is very difficult to find quantitative information with regards to the amount of energy absorbed by a human head or brain, which makes it difficult to define new EU guidelines.

Here we quantify the amount of energy absorbed by both the brain and brain for a given time, T.

Method

We start by defining the radiative transfer equation for a uniform medium.

$$\frac{dI_f}{d\tau_f} = S_f - I_f \quad (1)$$

Where $S_f = j_f / \alpha_f$, j_f is the emission coefficient, α_f is the absorption coefficient and I_f is the specific intensity. Equation (1) is then multiplied by an integrating factor, e^{τ_f} and integrated between the limits of 0 and τ_f (wrt. τ_f), where τ_f is the optical depth (unitless).

$$I_f(\tau_f) - I_f(0) = S_f(e^{\tau} - 1) \quad (2)$$

In this case the emission coefficient, j_f =0 as we assume the brain to emit no radiation in the shortwave-radio/microwave range. Therefore

$$\lim_{s_f \to 0} I_f(\tau_f) = I_f(0)\, e^{-\tau_f} \quad (3)$$

For a signal originating at the handset to reach the brain it must first pass through a thin layer of skin and cranial bone, as illustrated below.

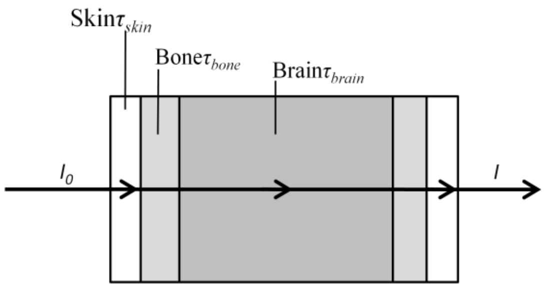

Figure 1 shows an illustration of a beam with initial intensity I_0 beam passing through the brain.

The drop in intensity of the beam corresponds to the intensity absorbed, given by

$$I_{absorbed} = I_0 - I$$

$$I_{absorbed} = I_0 - I_0 e^{-\tau} \quad (4)$$

where

$$\tau = \tau_{skin} + \tau_{bone} + \tau_{brain} \quad (5)$$

The source of the radiation is known to be isotropic. But due to the distance of the

source to the brain we approximate it as a beam passing directly through the brain.
The peak power for radio waves emitted by a GSM handset is 2W [1]. As the source radiates equally in all directions we approximate $I_0 \leq P_{Peak}/2A \approx$ 1Wm^{-2} as ~1/2 radiation travels in the opposite direction to the head (where A is the cross-sectional area of the head).

Mobile phones emit radiation in two frequency ranges [2]. Here we look at an average emission frequency within the range of 1400MHz.

Optical Depth (At 1400MHz)	Value (3 s.f.)
τ_{skin}	1.16×10^{-7}
τ_{bone}	62.3×10^{-7}
τ_{brain}	137×10^{-7}

Figure 2. Optical depth values [3].

Results
Using equation (4) and the values from figure 2, the intensity absorbed by the 3 layers is $I_{Absorbed}$ = 2.00×10^{-5} J.s^{-1}.m^{-2} (0.002% of the original beam) giving $P_{Absorbed}$ = 2.00 x 10^{-5}J.s^{-1}.m^{-2} (6).

Subtracting the amount of energy absorbed by the layer of skin and bone, $I_{absorbed} = I_0\left(1 - e^{-(\tau_{skin}+\tau_{bone})}\right)$ (7), from (6) gives the power absorbed by the brain to be $P_{Absorbed}$ = 1.37 x 10^{-5}J.s^{-1}.m^{-2} (8).

Substituting for the condition $\tau = 2\tau_{skin} + 2\tau_{bone} + \tau_{brain}$ (9) in equation (4), the power absorbed by the head was calculated to be $P_{Absorbed}$ = 2.64 x 10^{-5}J.s^{-1}.m^{-2} (10).

Discussion
These figures only account for radiation absorbed from a single device. It is realistic to assume numerous wireless signals of varying strengths passing through us at any given time, however we assume that as they drop off as a function of $1/r^2$ and will be attenuated by everything in the local environment, that their effects are likely to be negligible.

Using $\Delta T = \frac{\Delta E}{mc}$ we found the rate of dielectric heating of a human brain to be 5.95 x 10^{-10}K.s^{-1}.m^{-2} (3 s.f.) (approximating a human brain as a sphere comprising of water, *r*=15cm).

Conclusion
It has been shown that the energy absorbed by a human head can be quantified in quite a simple, efficient fashion.

The power absorbed by the brain per unit area was calculated to be $P_{Absorbed}$ = 1.37 x 10^{-5}J.s^{-1}.m^{-2}and the power absorbed by the head per unit area was calculated to be $P_{Absorbed}$ = 2.64 x 10^{-5}J.s^{-1}.m^{-2}.

These values can now be compared to known energy thresholds at which absorbed energy causes damage to human tissue so new guidelines can be defined for the peak power output of mobile phones. Dielectric heating to a human brain from a mobile phone can therefore be seen to be negligible.

The cellular response to the resulting increase in temperature would be a good area of further investigation as well as the effects (if any) to the blood-brain barrier.

We have assumed the effects of other devices to be negligible in our calculations. With the continued growth in the number of wireless devices used, the effects of local sources of radiation will require more consideration when setting maximum power outputs of wireless devices (i.e. those within a distance r and those which are not strongly attenuated when they reach a human receiver).

References
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[2] Radiofrequency Fields from Mobile Phone Technology, *www.iegmp.org.uk/documents/iegmp_4.pdf*
[3] Attenuation Coefficients and Mass Energy-Absorption Coefficients, *http://www.nist.gov/index.html*