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Short Communication

Comment on "numerical analysis of heat transfer in multilayered skin tissue exposed to 5G mobile communication frequencies" by Jagbir Kaur and S.A. Khan

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ABSTRACT

Kaur and Khan have published a simulation study demonstrating that a 5G device should cause only minimal temperature variations in the skin layer. For this they use a 4 - layer skin model and the Pennes' bioheat equation. The comment points out some differences between the 4 layered model they used and those of the groups of Abdulhalim and Feldman, who also incorporated the presence of the human sweat duct in the model. Furthermore, the comment notes that theoretical work by Neufeld and Kuster that takes into account the disparity between the time constants for electromagnetic absorption and thermal perfusion will lead to significantly higher temperature spikes that those found by the authors. Finally, new research by Gultekin and Siegel is noted that does indeed confirm temperature spikes in biological tissues for 5G frequencies.

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COMMENT

The paper [1] by Kaur and Khan addresses the thorny question of how much heat will be generated in the skin as a result of absorption of electromagnetic radiation arising from transmissions by a nearby 5G enabled device. Their skin model is a simplistic 4 layer model with dielectric parameters drawn from Ney and Abdulhalim [2]. Using Comsol and the Pennes bioheat equation they calculate the expected temperature rise in the skin. The SAR value is also calculated by the excepted equation, , where σ is the conductivity of the layer, ρ is the mass density and E is the electric field. The frequencies addressed in this paper are 28 GHz, 38 GHz and 60 GHz, relevant for the upcoming 5G and 6G standards. While there is little to criticize in the methodology of the paper, it does raise some points to be considered.

One notices that the authors reference the model of Ney and Abdulhalim as the source of dielectric parameters for the skin layers (table 1 of their manuscript) and

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while they are broadly comparable there is one glaring difference. The model of Ney and Abdulhalim also considers the presence of the human sweat duct as an integral component of the layer and something that is electromagnetically relevant. In this Ney and Abdulhalim follow an earlier model proposed by Feldman et al. [3, 4] that also considers the implication of the sweat duct. Furthermore both of these authors felt that it has a major contribution in terms of ac conductivity, due to the presence of heightened proton hoping in the region of the lipid/water boundary in the water filled interior of the duct [2, 3]. As the density of such ducts can be between 300-600 per cm^2 [5], one must assume that their effect on the absorption cannot be ignored. In fact Betzalel et al. [6] demonstrate at least a factor of 2 increase due to the presence of the sweat duct in the frequency region of interest. One feels that the authors have overlooked an important element of the skin, rendering their simulation limited.

Accepting the limitations of the simulation as they stand, one notes that the authors predict a minimum local SAR value of 43 W/kg and a maximum value of more than 700 W/kg. While it is to be understood that these values are not averaged over 6 minutes , as demanded by the safety definition of ICNIRP [7] and the FCC [8], they still represent values far in excess of 1.6 W/kg as considered safe by those same safety definitions. One notes that these values are similar to those derived by Alekseev et al. [9]. As the ICNIRP limit is considered to be the "safe" limit in this frequency range, the authors should question these results too.

Coming back to the simulation it must be pointed out that the solutions to the Pennes' bioheat equation are a quasi-static solutions with the external heat source, Q_{ext} , a function of frequency but constant in time. This condition does not reflect the reality of 5G transmissions, where the signal is pulsed. Other authors have considered this condition, in particular Neufeld and Kuster [10]. They demonstrate that the disparity between the time constants for electromagnetic absorption, less than 1 ns for water in the skin [4], and heat perfusion (500 seconds according to [10]) in the skin, causes non-negligible temperature spikes in the skin layer. This leads them to call for a reassessment of the ICNIRP and, consequently, FCC standards for 5G.

As a final point, one draws the Author's attention to a recent article by Gultekin and Siegel [12]. In this work they directly measured the temperature increases in recently culled calf brains arising from transmissions up to 38 GHz with power densities equivalent of most modern 5G devices (1 mW- 2000 mW). The temperature measurements were made for both continuous wave and pulsed signals. Pulsed signals at low power densities produced temperature spikes of 10 °C. Due to differing water contents one would expect less for skin (although the dermal layer can approach 75 % water content [13], similar to that in calf brains). Consequently, one questions the Authors' assertion that *"The results indicate that the mmWs cannot cause thermal injuries in skin and may be considered safe for 5G mobile communications"*. It is patently not correct.

DATA AVAILABILITY STATEMENT

The authors confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

ETHICS

There are no ethical issues with the publication of this manuscript.

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