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# The effects of dielectric shield on specific absorption rate and heat transfer in the human body exposed to leakage microwave energy ☆

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A B S T R A C T

This paper proposes a numerical study to simulate the effects of dielectric shield on the specific absorption rate (SAR) and the temperature increase in the human body exposed to leakage microwave energy. In this study, the effects of shield dielectric properties on distributions of SAR and temperature increase within the human body at various operating frequency are systematically investigated. Based on the obtained results, the installed dielectric shield strongly affects the SAR and the temperature increase in human body. The SAR and the temperature increase in human body can be reduced simultaneously by setting the appropriate dielectric properties of the dielectric shield. The appropriate dielectric properties of the dielectric shield greatly depend on the operating frequencies. These fundamental data for the implementations of the radiation protection shielding materials, with focusing on the human organism, are provided as well.



## 1. Introduction

Microwave is a form of electromagnetic wave with wavelengths ranging from 1 m down to 1 mm, with frequencies between 0.3 and 300 GHz. Microwave energy has proven to be an efficient and reliable form of heating for a wide range of industrial processes such as heating process [1], curing process [2], and melting process [3]. As applications of microwave energy become widespread, adverse effects caused by the leakage microwave energy are increasingly a subject of concern [4,5]. In many countries, various studies on biological effects have been made and many results have been reported. There has been an intensive model analysis of the SAR of the human body [6,7]. The protection is serious for researchers who work with high-power electromagnetic waves. In connection with research on human protection from electromagnetic field exposure, some researches have been carried out on how effectively the human body is protected from unwanted electromagnetic waves [8]. Furthermore, fundamental analysis of shielding effects of lossy dielectric materials located in front of a human body have also been carried out by some researchers [9,10]. However, the heat transfer model has not been included in the modeling analysis.

The computation of the temperature increase is one of the main tasks in the evaluation of the risk related to the exposure of humans to electromagnetic fields [11]. Nevertheless, most studies of human protection from electromagnetic field exposure have not considered the temperature increase within the domain of the human body especially in the human organism. There are few studies on the temperature and electromagnetic field interaction in a realistic physical model of the human body due to the complexity of the problem, even though it is directly related to the thermal injury of tissues [7,12,13]. Therefore, in order to provide information on protection of the human body against electromagnetic fields adequately, it is essential to simulate the coupled electromagnetic field and heat transfer models to represent an actual process of shield protection from possibly harmful effects of electromagnetic fields. This research is a pioneer work on human protection from electromagnetic field exposure that simulates the SAR distribution and temperature distribution over an anatomically based human body.

This work is extended from our previous work [7] in which the human body exposed to leakage electromagnetic field is investigated. This paper mainly analyzes the shielding effect of a dielectric shield being placed in front of a human body. Specifically, lossy dielectric media are chosen as the dielectric shield material. The local SARs and temperature increase of human model are calculated for various operating frequencies. Three shield dielectric properties at microwave frequencies of 300, 915, 1300, and 2450 MHz are selected for the shielding investigation. The system of governing equations, as well as initial and boundary conditions are solved numerically, using finite element method (FEM). Moreover, this research is also focusing on the interaction between electromagnetic field and organs in the human trunk.

## 2. Formulation of the problem

Fig. 1 depicts a physical model of the problem. The incident plane wave (TE wave) with a microwave power density of 5 mW/cm$^2$ is

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