Impacts of RF Radiation on the Human Body in a Passive Wireless Healthcare Environment

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Abstract—**In this paper, we identify the most significant problems involving the impacts of radio frequency (RF) radiation on the human body. The coming pervasive healthcare environment will rely heavily upon wirelessly communicating devices to provide the information visibility and communication capabilities required to achieve these ambitious systems. The impact of significant and continuous RF radiation exposure must be understood to ensure that we first do no harm with our new environments. The Specific Absorption Rates (SAR) is a dosimetric measure that has been widely adopted as a method for quantifying radiation absorbed by the human body. This tool is both simple and useful. We investigate the factors that affect RF absorption in human tissues to identify the physical and biological factors that impact RF absorption. Similarly, we investigate the factors that influence biological responses to the effects of absorbed and incident RF radiation. We focus specifically on low power and passive communicating systems that will form the vast majority of the wireless devices in a pervasive healthcare environment.**

I. Introduction

THE impacts of RF radiation incident on human bodies and biological tissues are a consequence of the complex interactions of numerous parameters [1]. These parameters affect the electromagnetic wave absorption in the human body and influence the biological responses to the absorption. To understand the details regarding the propagation and absorption in human bodies, a complex model that describes both the electric and magnetic field propagation and Specific Absorption Rates (SAR) must be studied. A model describing and quantifying the internal fields in an exposed body is an important tool in understanding the factors that affect RF absorption. In turn, the factors that affect absorptions are important in analyzing the influences on biological responses from the human body for the specific absorption rates.

In this paper, we identify current research focuses in addressing the impacts of RF radiation on the human body in a pervasive wireless healthcare environment. Section II presents a background on RF radiation on the human body. Here, the SAR is described as an experimental dosimetric measurement that is simple to use but conceptually limited and therefore insufficient as a complete model. This section introduces the classification of RF radiation as pertaining to the healthcare domain. The factors that affect RF absorption in human bodies are also presented here. Similarly, this section also describes the factors that influence biological responses to the SAR. Section III discusses open areas of research currently being conducted to study the impacts of RF radiation on human bodies for passive wireless technologies in the pervasive healthcare environment. Here a conclusion is presented on specific problems involving low power wireless and passive communication systems.

II. Background

Exposure to an electromagnetic field induces a current in the human body similar to the case of an imperfect conducting wire [2]. The magnitude of the maximum induced current can be measured and its limit is used as the criterion in safety guidelines by organizations such as the International Commission for Non-ionizing Radiation Protection (ICNIRP) [3]. These induced currents in the human body cause thermal (or heat) and non-thermal (or a-thermal) effects in the localized area of the human body. In turn, these effects influence the biological responses. When the human body is exposed to low frequency (LF) radiation, the non-thermal effects dominate and are often related to cellular levels [3]. However, at high frequencies (HF), thermal effects dominate the impact on the body through the point of depositions, disturbance of specific bio-chemical reactions and interference of electron transport flows [2, 4, 5, 6].

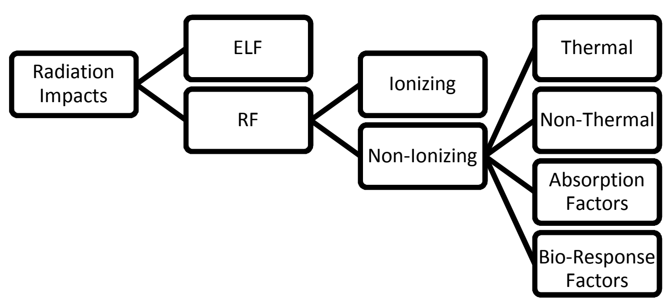

Figure 1: Classification of radiation sources, impacts and factors

Figure 1 presents the classification of radiation sources, impacts, and mitigating factors. Radiation impacts are grouped at the higher level into the extremely low frequencies (ELF) and RF groups. Notice that the RF

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category in Figure 1 is divided into non-ionizing and ionizing radiation. Ionizing radiations are energetic waves that have potential to ionize an atom through atomic interactions. RF radiations from passive wireless systems are non-ionizing radiation because of the longer wavelengths. Similarly, thermal and non-thermal effects exist for the RF radiation on human bodies. These effects today are described using a dosimetric measure called the SAR [7].

Table 1: Factors that affect RF absorption [1]

Physical Parameters	Biological Parameters	Artifacts	Environmental Parameters
Frequency	Tissue dielectric properties	Ground plane	Temperature
Polarization	Size, geometry	Container	Humidity
Modulation	Animal orientation relative to polarization	Metal implants	
Power density	Spatial relations among animals	Shielding materials	
Field pattern		Metal or non-metallic objects in the field	
Field uniformity			
Type of transmitting or radiating equipment			
Chamber material			
Chamber dimensions			

The SAR is typically described using effect-based parameters such as the physical and biological parameters, artifacts and environmental factors such as given in Table 1. Similarly, the factors that influence the biological responses to the same SAR are a sub-category to both the thermal and non-thermal effects. These factors are denoted instead in Table 2, where it is categorized into the subject, concomitant, environmental and experimental variables. The specific absorption rate caused by the factors in Table 1 is denoted by the electric field as described in Equation 1.

Table 2: Factors influencing biological responses to the SAR [1]

Subject Variable	Concomitant Variables	Environmental Variables	Experimental Variables
Species: sex; age; weight	Genetic predisposition	Temperature; humidity	Acclimation procedures
Sensitivity	Base line of the response	Air flow	Duration of exposure
Number of subjects	Functional and metabolic disorders	Lighting	Number and schedule of exposures
Interventions: anesthetics; drugs; electrodes; lesions		Noise	Mode of exposure: partial or whole body
Animal husbandry		Odor	Sampling technique
			Time between exposure and sampling
			Time of day of exposure
			Restraint devices
			Investigator-animal interaction

$$SAR = \frac{d}{dt}\left(\frac{dW}{dm}\right) = \frac{d}{dt}\left[\frac{dW}{\rho(dV)}\right] = \frac{\sigma}{2\rho}|\boldsymbol{E}|^2 = \frac{\omega\epsilon}{2\rho}|\boldsymbol{E}|^2 \quad (1)$$

Here we see that the electric field ($\boldsymbol{E}$) plays a crucial role alongside the density of the matter (ρ) and the tissue conductivity (σ). This definition of the SAR, is the rate at which the body or tissues absorbs RF energy when exposed to an electric field. Notice that parametric influences such as direction of the internal electric field and interactions caused by the magnetic field are not considered. Therefore, SAR does not provide full quantitative information, which yields the present concept insufficient. In the following section, open areas of research for passive wireless technologies in the pervasive healthcare environment are presented.

III. Open Research Problems

Open research areas for passive wireless healthcare environments include topics that study the impacts on cell growth, infants, pregnant women, cell recovery, long term adaptation and DNA mutations. The impact of RF exposure by passive wireless devices must be studied as they growingly contribute towards the power density of the electromagnetic spectrum in the healthcare environment. Issues such as adaptability and recoverability of living materials or cells from long term radiation of passive systems must be studied. In a study of such, subject variables such as the species may play a more crucial role. Similarly, these impacts must be understood for the cell growth and the human reproduction process. When considering these pressing problem areas, a clear motive is essential to quantify the self recoverability that exists for living beings, when compared to biological materials. Finally, there is a huge need for the unification of ideas and research to study these impacts in the pervasive healthcare environment. These efforts must be directed towards the pressing problem areas as denoted here and dealt with swiftly to derive and unify theory with experimentation.

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