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Terahertz Electromagnetic Communication for In-Vivo Wireless Nanosensor Networks

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The engineering community is witnessing a new frontier in the communication industry. Among others, the tools provided by nanotechnologies enable the development of novel nanosensors and nanomachines. On the one hand, nanosensors are capable of detecting events with unprecedented accuracy. On the other hand, nanomachines are envisioned to accomplish tasks ranging from computing and data storing to sensing and actuation [1]. Recently, in vivo wireless nanosensor networks (iWNSNs) have been presented to provide fast and accurate disease diagnosis and treatment. These networks are capable of operating inside the human body in real time and will be of great benefit for medical monitoring and medical implant communication [2]. Despite the fact that nanodevice technology has been witnessing great advancements, enabling the communication among nanomachines is still a major challenge. Classical communication paradigms need to undergo a profound revision before being used in nanonetworks. One of the mechanisms being comprehensively investigated is molecular communication [3], which is based on the exchange of molecules to transmit information. However, there are still many fundamental challenges to address, including the development of mechanisms to overcome the very long latency in molecular systems or the potential interference with biological molecular processes. Ultrasonic communication, based on the use of very high frequency acoustic signals, has also been recently proposed [4]. Nonetheless, for the time being, the size and power limitations of ultrasonic acoustic transducers pose a major challenge in their integration with biological nanosensors. From the electromagnetic (EM) perspective, the miniaturization of a conventional metallic antenna to meet the size requirements of a nanosensor results in very high resonant frequencies, in the order of several hundreds of terahertz (THz or 1012 Hz). Accordingly, novel plasmonics have been recently proposed for wireless communication among nanodevices [5] [6]. These nanoantennas enable the wireless interconnection amongst nanosensors deployed inside and over the human body resulting in many bio-nanosensing applications [7]. For the time being, several works exist pointing to both the Terahertz Band (0.1-10 THz) as well as the infrared and optical transmission windows [8] [9]. While the majority of (nano) biosensing applications rely on the use of light, the propagation of THz signals within the human body remain largely unknown. While the THz-band radiation is non-ionizing, the propagation of THz-band waves inside the human body is drastically impacted by the absorption of liquid water molecules [10]. As a result, the authors in [11], advocated the use of the optical window for intrabody wireless communication among nanosensors with plasmonic nanoantennas. This is due to the fact that the absorption from liquid water molecules is minimal in the so-called optical window, roughly between 400 THz and 750 THz [12]. In addition, plasmonic nanodevices at optical frequencies have already been utilized in several in vivo applications [13]. In this paper, we present a full-wave electromagnetic communication channel model for iWNSNs in the THz band as well as optical window is presented. In particular, a mathematical framework is developed to compute the path loss by taking into account the spreading of the propagating wave, absorption from different types of molecules, as well as scattering of both the cells and the medium background. The results provided illustrate the design principles of iWNSNs.

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