A 4D Immersive Platform to Visualize RF Propagation in BAN

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***Abstract*—Recent advances in micro-electronics technology to build small radio-enabled implantable and wearable medical sensors have sparked considerable interest in body area networks. Understanding the characteristics of radio frequency propagation inside and around the human body requires obtaining sufficient amount of data for different scenarios via physical experiment with human subjects. This is either difficult or in the case of implants, nearly impossible. In addition, the body motion could significantly impact the quality of wireless communication links (i.e. the propagation channel) among implants or wearable medical sensors. To address these issues, we have developed an immersive platform capable of emulating physical experiments. The platform includes a dynamic (i.e. 4D) human body model that can emulate various human motion e.g. walking. This 4D immersive platform can be used as a scientific instrument to study various Radio Frequency communication channels inside or on the surface of a human body. It can also be used to identify the best scenarios for limited physical experimentation and measurements.**

***Index Terms*—radio frequency propagation; immersive platform; body area networks**

I. INTRODUCTION

Inhomogeneity and complexity of the propagation medium along with possible propagation paths from any direction necessitate a three-dimensional environment to better capture, visualize, and understand RF propagation from/to implants or wearable body sensors. The complexity of the propagation environment surrounding a medical implant would also imply that an appropriately designed immersive platform would be very helpful in better understanding the radio frequency channel characteristics inside the human body. Lack of a detailed human body model and realistic wearable/implantable antennas are usually among the shortcomings of previous simulation studies in this area. Also, as body motion could significantly impact the wireless communication between implants and wearable medical sensors [1], a dynamic (i.e. 4D) human body model capable of emulating typical human motion (such as walking, rolling in a bed, twisting/turning, and bending) would be a valuable tool to study and understand this impact. The 4th dimension here refers to the dynamic nature of the model i.e. the time axis. In this paper, we present an immersive environment that allows data visualization and interaction with the objects under study. Our objective is to use this platform to better understand the complicated phenomenon associated to RF propagation in & around human body.

Figure 1 shows a user in our immersive visualization environment interacting with the 4D human body model. The body model includes frequency dependent dielectric properties of 300+ parts of a male human body. These properties are also user-definable if custom changes or modifications are desired. The human body model has a resolution of 2 mm. Using our immersive platform, a researcher is able to place a customized antenna at the desired location of the human body and study the RF propagation at the target frequency for a variety of scenarios or medical applications [2,3,4]. The 4D body model that has been developed allows for capturing variations of RF signal from implants & wearable nodes in more realistic scenarios where human motion is involved (see Fig. 2).

Figure 1. A user in the NIST immersive visualization environment interacting with the 4D human body model

Other components of the immersive platform include: a visual display consisting of three large screens, stereoscopic glasses that are motion-tracked, and an input device that is also motion-tracked. The three large video projection screens are arranged edge-to-edge in a corner configuration; these are used as a single 3D stereo display. The 3D scene is updated for the position of the stereo glasses given by the motion tracker. This enables the immersive platform to present a virtual three-dimensional world within which the user can move and interact with the virtual objects. A hand-held three button motion-tracked wand with a joystick is the principal interaction device. The platform also includes a propagation engine (i.e., HFSS[1])

[1] HFSS is registered trademark of ANSYS Corporation. HFSS has been used in this research to foster understanding. Such identification does not imply recommendation or endorsement by the National Institute of Standard and Technology, nor does it imply that this product is necessarily the best available for the purpose.

which is three-dimensional full-wave electromagnetic field simulator.

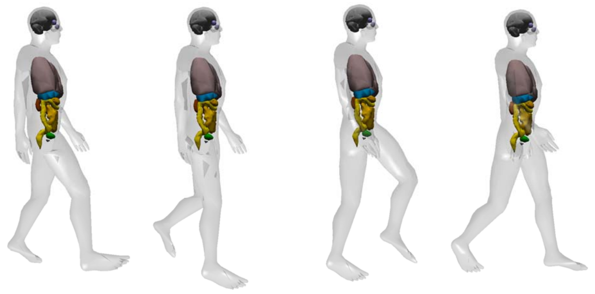

Figure 2. Emulating human walking motion in the immersive platform

II. SAMPLE RESULTS

In this section, we briefly highlight few of our current research results that can be obtained using the immersive platform. Other results have been omitted due to brevity.

The antenna is an essential component of body area networks and has to be carefully designed given the intended application. Unlike other applications, the design process for a BAN antenna has to consider the environment where it is supposed to operate. The immersive platform is an ideal environment to evaluate the performance of such antennas. We have developed tools to visualize the 3D antenna gain patterns in any direction and distance. Fig. 3 demonstrates a virtual plane that can be controlled by the user and show the signal intensity (i.e. proportional to gain) from the antenna. The antenna is shown by the gray square located on the chest as observed in Fig. 3. The figures also highlight the body surface signal intensity at the same time. Using such tools, an antenna designer can visually observe how much of the signal energy is propagated off-body and how much is directed on the body surface. This is an important issue as the particular application could require different antenna design for off-body versus body-surface communication. The antenna designer can immediately evaluate how the antenna performs on off-body versus body-surface links.

A very interesting phenomenon in body surface propagation is the existence of surface diffracted creeping waves. This phenomenon greatly impacts the fading characteristics of radio waves for on-body communication. Visualization of such creeping waves would be a very helpful insight and could allow the antenna designer to exploit this characteristic for more efficient designs. Poynting vector is a quantity that describes the magnitude and direction of the flow of energy in electromagnetic waves. The small vectors on the body surface shown in Fig. 4 represent the Poynting vector direction and its magnitude. With creeping waves, the direction of the Poynting vector will be parallel to the surface on which the wave is propagating. Using the immersive platform, we have developed tools to further observe this property, and circumstances under which it occurs. These tools involve geometrical and computational techniques to calculate the direction of the Poynting vector with respect to the body surface at a given distance away from the body.

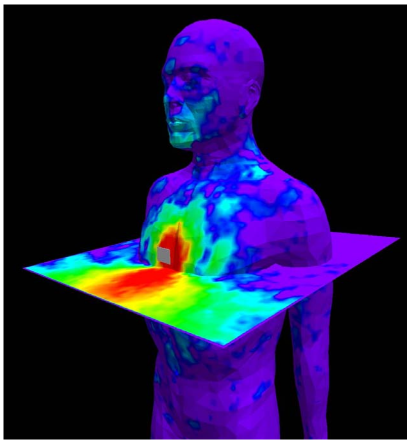

Figure 3. Horizontal view of off-body and on-body signal intesity

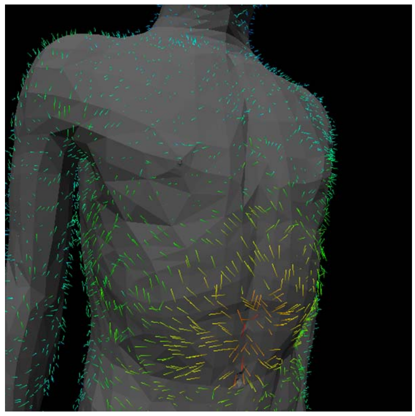

Figure 4. Poynting vector direction on the body surface

III. CONCLUSION

The technology for networking various medical implants and body sensors is rapidly evolving with many novel applications. As these human body area networks are envisioned to pervasively be part of our daily life, the evaluation of their operational reliability has to be performed in more realistic scenarios. The 4D immersive platform discussed in this paper will allow communication engineers to better study and understand RF propagation in body area networks. Further research is required to evaluate the accuracy of the results obtained by this platform.

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