FDTD Simulation Of Wave Propagation And Coupling For Body Area Networks

Jonathan Bringuier¹, Raj Mittra¹, Joe Wiaart²

¹Electromagnetic Communication Laboratories, 319 Electrical Engineering East, Pennsylvania State University, University Park, PA 16802. jnb170@psu.edu, mittra@engr.psu.edu

²France Telecom, France, jow.wiart@orange-ftgroup.com

Abstract

The ubiquitous presence of personal computing devices has naturally led to extension of wireless networks that can be implemented on the human body. A detailed study of the propagation mechanisms for wireless communication involving body mounted antennas has been carried out in this effort using an accurate human body phantom to characterize the coupling between these antennas. Finally, the antennas are placed in various positions on the body so as to develop an understanding of the coupling relation between space, surface and creeping waves.

1. Introduction

The interaction of electromagnetic energy with biological tissue has long been an area of study, both for health purposes as well as wireless communication. Until recently, most studies have involved specific absorption rates (SAR) without further research into how energy propagates along the tissues interface. However, in recent works [1]-[6], it has been shown that a promising technology, termed body area networks (BAN’s), has the potential to allow personal wireless computing devices to communicate with each other through electromagnetic coupling via space, surface and creeping waves. Currently, most of the literature is concerned with wave propagation through and around the human head, and very few works have studied the phenomenon of wave propagation on the body. Most attempts to study body-mounted antennas have led to real time measurements. However, this approach can be both costly and time-consuming; furthermore, it provides little physical insight. Therefore, a computational approach to studying BAN’s can substantially aid in the design of these systems.

Only recently have computational resources become available to enable us to perform a meticulous study of wave propagation for body mounted antennas. In previous works, the present authors have used a parallel FDTD to study line of sight (LOS) coupling, where both antennas were mounted on the front of the torso [6]. The coupling in the LOS study was found to be primarily due to surface waves, where the body can be approximated by a planar slab. In the first part of this paper we extend that study by placing two antennas on opposite sides of the torso, front and back, respectively. It was shown in [2] that antennas mounted on opposite sides of the head couple primarily through creeping waves. In this paper we show that the behavior is similar for antennas mounted on opposite sides of the torso.

In the second part of this paper we have placed several receiving nodes on various parts of the body and calculated the coupling in order to characterize the channel of BAN’s. The results can be classified by either LOS, NLOS, or intermediate LOS coupling. As expected, NLOS and intermediate LOS coupling is found to be due to creeping/surface waves. Furthermore, the results found herein are consistent with those measurements found in the literature [3]-[5].

The simulation parameters in this study involved an accurate homogeneous human phantom [7], [8], for which the material dispersion properties were taken into account (see Table 1 and Fig. 1), and two monopole antennas having a resonant length of 2.45 GHz in accordance with WLAN, etc. The frequency range of interest was from 1-5 GHz. It is evident that monopole antennas do not provide the required efficiency over this bandwidth; nevertheless, for numerical simulations, they provide simple and useful test to characterize the channel due to their uniform pattern in their respective azimuthal planes.
1. Figures and Tables

![Figure 1 Transmit and receive antennas placed on human body phantom](image1)

**Figure 1** Transmit and receive antennas placed on human body phantom

<table>
<thead>
<tr>
<th>Frequency band [MHz]</th>
<th>1450</th>
<th>1610</th>
<th>1800</th>
<th>1950</th>
<th>2450</th>
<th>3000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uses</td>
<td>PDC</td>
<td>mobile satellite</td>
<td>(*3)</td>
<td>PHS W-CDMA</td>
<td>Wireless LAN etc.</td>
<td>radar</td>
</tr>
<tr>
<td>Relative Permittivity (*1)</td>
<td>54.00</td>
<td>53.80</td>
<td>53.30</td>
<td>53.30</td>
<td>52.70</td>
<td>52.00</td>
</tr>
<tr>
<td>Relative Conductivity [S/m] (*1)</td>
<td>1.30</td>
<td>1.40</td>
<td>1.52</td>
<td>1.52</td>
<td>1.95</td>
<td>2.73</td>
</tr>
</tbody>
</table>

(*1) Standard values of relative permittivity and conductivity comply with FCC OET BULLETIN 65.

![Graph](image2)

**Figure 2** Coupling between transmit (front torso) and receive (back torso) antennas
Figure 3 Several receive nodes placed on the body

Figure 4 Coupling between transmit and receiving nodes
3. References


