Simulation of Dynamic Lower-Body Electromagnetic Wave Propagation with Experimental Verification

George Lee*, Brian Garner, and Yang Li
School of Engineering and Computer Science, Baylor University, Waco, TX 76706, USA

Wireless body area network (WBAN) technology has great potential to improve human quality of life. Wearable, on-body sensors must be power efficient and miniaturized in order to operate for long periods of time without obstructing daily activities. Designing antennas optimized for such sensors will require a thorough understanding of how electromagnetic (EM) waves propagate along and around the human body as the body segments move. Recent studies have used experimental and computational methods to investigate on-body wave propagation for a variety of motions including walking (Swaisaenyakorn *et. al*., *IEEE Transactions on Antennas and Propagation*, 62, 2231-2237, 2014). In our own previous work, we have developed a simulation framework of the human body that was applied for upper body motions (Lee *et. al*., *IEEE MTT 2016 Texas Symposium on Microwave and Wireless Circuits and Systems*, 2016). The purpose of this work is to utilize this full-wave simulation platform to compute EM propagation paths between on-body transmitters and receivers during various human activities that involve lower body motions and antenna placements.

This study utilizes both experimental and simulation techniques to study on-body wave propagation. For the experiments, two adult volunteers, one male and one female, were recruited to perform various activities such as leg raises and sit to stand motions. Three-dimensional motion capture data and EM transmission data were collected simultaneously during the experimental trials. The EM transmission data was measured for three frequencies (433MHz, 915MHz, 2.45GHz) using a vector network analyzer (VNA) with antennas placed in various configurations including placements on the waist, knees, and ankles. CST Microwave Studio simulation software was used to generate a full-size human body model, composed of simple geometric cylinders and homogeneous human muscle tissue properties, capable of reproducing the recorded body positions over the duration of each activity. The human body model segments were positioned and oriented to match the human body position at each frame of the recorded motion data. For each frame, the EM propagation from transmitter to receiver was computed, and the computational results were compared to the experimentally collected transmission data.

Comparison of the simulation and experimental results for the various motion tasks and antenna placements have generally shown good agreement. Combining results from this study, which focuses on the lower body, with results from previous work, which focused on the upper body, will allow for validation of the human body model for whole body EM simulation.