3D Modeling for Realistic Assessment of Vital Signs and Lung Water Content

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The Cardiopulmonary Stethoscope (CP-Stethoscope) system is a novel, low-cost, noninvasive microwave-based system for continuous assessment of vital signs such as respiration rate (RR), heart rate (HR) and also changes in lung water content (LWC). Continuous monitoring of these vital signs and in particular, changes in LWC are key to proactive prevention and management of chronic health conditions such as heart failure and lung diseases. Methods to assess LWC are invasive, costly and not suitable for continuous monitoring and to this end; the development of the CP-Stethoscope system is expected to provide unique and significant health care and patient monitoring benefits. The integrated system consists of coplanar waveguide (CPW)-based EM couplers that couples energy into the body, an RF transmission and reflection coefficient subsystem that eliminate bulky network analyzer, and microcontroller unit with DSP capabilities for real time extraction of vital signs from a single microwave measurement. A Bluetooth module has also been implemented to transmit data to a mobile device, and a mobile app has been developed to enable remote monitoring of patients.

Our previous work includes practical implementation of the system through various coupler designs to improve sensitivity, and stability of the feeding structure to minimize susceptibility to motion artifacts. Experimental results have also been benchmarked with FDA approved devices and have demonstrated the feasibility and accuracy of the system to detect LWC on phantom and animal experiments, and RR and HR of healthy human participants. However, simulation and experimental work in this area has mostly been limited to planar phantom models. To further enhance the capabilities of the system, a human 3D model structure (see Fig. 1) is needed to properly model the complexity of a human torso and help assess the accuracy of the system in more realistic simulation environment.

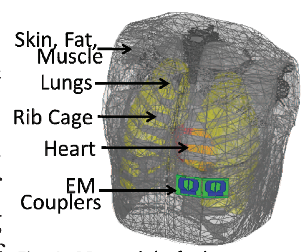

Fig. 1. 3D model of a human torso

In this paper, we describe the development of a realistic human 3D model that is based on finite element method. Preliminary results from the 3D simulation demonstrated, for the first time, the importance of accounting for specific location of the EM couplers for monitoring variety of vital signs as well as improving the accuracy of the LWC measurement. Furthermore, additional guidelines for determining the distance between transmitter and receiver for the S21 measurement were evaluated for optimum sensitivity and stability of these measurements. Efforts were also made to reduce the computational cost of simulations by utilizing symmetries in the thoracic model and this allowed carrying out extensive number of simulations leading to guidelines for optimum use in clinical trials. Results from these simulations will be presented and discussed.