microDIAGNOSIS: Microwave-based diagnosis for pneumothorax and detection of air cavities in body

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Air cavities in human and animal body, such as pneumothorax may cause serious health problems and often death if medical and surgical treatment is delayed. Pneumothorax refers to a collection of air in the pleural space between the lung and the chest wall. It is a life threatening condition since it can result in collapse of the lung on the affected side. Pneumothorax may occur following a traumatic injury to the chest wall or a known lung disease, such as lung cancer and asthma. It is conventionally primarily diagnosed with radiography methods (x-rays and CT) or ultrasound imaging. Although these methods are generally reliable, they are not always available on-site or accurate enough in order to help diagnosis of an injured patient, during an emergency. Concerning pneumothorax, the mortality rates could have been lower if the diagnosis methods included smart portable devices.

Wireless technologies for body-worn applications are in the early stages of development in the field of healthcare monitoring, facilitating the disease prediction and diagnosis. In order to detect safely and non-invasively air cavities or hematomas in the body, ultrasounds and low power microwaves can be used. Comparing to ultrasounds, microwaves can also travel through air and they can help diagnosis, when they are applied by both smaller and more accurate devices. On the other hand, microwaves are attenuated when traveling through the body. Still, for relatively small depths, microwaves are efficient for small and smart systems. Microwaves propagate through biological tissues and the amplitude of the electromagnetic wave reflected by or transmitted through the body depends strongly on the dielectric properties of the tissues. A sensitive microwave sensor (antenna) would monitor the reflected waves, which would alter in phase and amplitude, due to the presence of air or blood close to the skin surface. According to literature, the most common sensors for microwave permittivity measurements are planar antennas, open-end coaxial cables or waveguides. Regardless of the sensors being used, the radiator operates in the close proximity of the body, making the preservation of its performance characteristics an important and challenging mission. The effect of the user's body on antenna characteristics are largely due to the amount of the antenna-body coupling and will vary between different antennas, separation distances and near-field coupling with the tissue.

microDiagnosis is a novel postdoctoral research project that proposes a microwave-based portable device for non-invasive, safe and real-time detection of air cavities in a human or animal body. A diagnostic microwave-based method is employed in order to originally detect and secondarily quantitatively assess the enclosed air in the body cavities. The body-region of interest is exposed to a low power microwave radiator, e.g. conformal antenna placed at close proximity, achieving the best contact with the skin. The reflected microwave signal is detected by the microwave sensor. Diagnosis method is based on the characteristics of the reflected microwave signal and the differential post processing of the signal between healthy subjects and patients. The study describes the frequency-dependent dielectric properties of the biological tissues and it justifies the selection of the optimal frequency range used for the microwave-based sensor. The main scope of the proposed research is to introduce a novel, efficient, small and smart medical diagnostic device with wireless capabilities. A prototype will be delivered based on analytical, numerical and laboratory experiments.

The proposed research plan comprises of the following components: 1) Parametric analytical and numerical assessment of the interaction between layered tissue model exposed to plane wave, 2) Numerical description of the microwave-based sensor model, 3) Parametric numerical assessment of the microwave-based sensor diagnosis performance on layered tissue and anatomical correct models, 4) Parametric experimental assessment of the microwave-based sensor diagnosis performance on tissue phantom, 5) Integration of the microwave-based sensor and wireless communication link evaluation, 6) Parametric experimental assessment of the microwave-based sensor diagnosis performance during in vivo measurements on pigs, 7) Co-ordination of the research proposal and dissemination of scientific results.

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