Optimum Antenna Topology for Pneumothorax Detection and Quantification

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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. Indeed, in 2013 traumatic injuries caused approximately 27.3 deaths per 100,000 population per year in the USA, and 10 deaths per 100,000 population per year in the European Union. For comparison, the number of deaths due to cancer in the United States was 567.614 people in 2009, which works out to be around 0.19 deaths per 100,000 population, in that year (see [1]). If pneumothorax is left untreated can lead to a complete cardiovascular collapse and ultimately death. Therefore, it is important to diagnose pneumothorax in the first minutes after an accident. While a diagnosis can be made by a Medical Doctor in the ambulance this is based on physical examination and it is thus uncertain and possibly erroneous. Furthermore, even when X-ray and CT image is available, pneumothorax can be difficult to diagnose from medical personnel. For example, Society for Imaging Informatics in Medicine (SIIM, [2]), is running a contest for Artificial Intelligence identification of Pneumothorax [3] since September 2019. In order to detect safely and non- invasively air cavities or hematomas in the body, ultrasounds and low power microwaves can be used. Recent ultrasound transducers that need no wave-matching medium are still quite expensive and do not guarantee satisfactory Signal to Noise Ratio (SNR) levels. Also, they require high level of experience and detailed placement of ultrasound emitter in order to provide reliable results. Comparing to ultrasounds, microwaves can 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. 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 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. As has been shown [4] the detection of pneumothorax is feasible and can be based on rather very simple devices. Most common sensors for microwave measurements are planar antennas, open-end coaxial cables or waveguides. In case of imaging of an internal part of the body, usually the antenna should be in contact with the body. In that way reflections from the skin surface of the body are avoided and most of the energy emitted is directed towards the body. In order to ensure, as well, portability of the sensor along with maximum contact to the body surface, conformal antennas are proposed, printed on flexible substrates. 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. In this work we investigate some common types antennas and seek performance characteristics that will allow for a better and more accurate result. Effect of body, antennas' in-between distance and time-domain propagation are also considered.

References

[1] Samo, R., P. Saraswat, "Microwave technology for detection of traumatic pneumothorax – Development of wearable antenna array and evaluation of thoracic phantom." Gothenburg: Chalmers University of Technology, 2013. Ex - Institutionen för signaler och system, Chalmers tekniska högskola, ISSN 99-2747920-4; EX034/2013, 2013, master thesis

[2] SIIM, Society For Imaging Informatics in Medicine, [https://siim.org/]

[3] "Pneumothorax Segmentation: Identify Pneumothorax disease in chest x-rays" contest [Available in https://www.kaggle.com/c/siim-acr-pneumothorax-segmentation]

[4] Christopoulou, Maria, and Stavros Koulouridis. "Inter-Subject Variability Evaluation towards a Robust Microwave Sensor for Pneumothorax Diagnosis." *Progress In Electromagnetics Research* M 42 (2015): 61-70.