Special Session Title:

MICROWAVES IN BIOMEDICAL APPLICATIONS - PART I:

Breast cancer detection and monitoring

Special Session Organizer Name & Affiliation:
Milica Popović, McGill University

Special Session Speaker Name & Affiliation 1:

Stephen Pistorius, University of Manitoba, Canada

Special Session Speaker Name & Affiliation 2:

Takamaro Kikkawa, Hiroshima University, Japan

Special Session Speaker Name & Affiliation 3:

Milica Popović, McGill University, Canada

Special Session Speaker Name & Affiliation 4:

Raquel Conceição, University of Lisbon, Portugal

Special Session Speaker Name & Affiliation 5:

Robin Augustine, Uppsala University, Sweden

Theme:

- ○ 01. Biomedical Signal Processing
- ○ 02. Biomedical Imaging and Image Processing
- ○ 03. Micro/ Nano-bioengineering; Cellular/ Tissue Engineering &
- ○ 04. Computational Systems & Synthetic Biology; Multiscale modeling
- ○ 05. Cardiovascular and Respiratory Systems Engineering
- ○ 06. Neural and Rehabilitation Engineering
- ● 07. Biomedical Sensors and Wearable Systems
- ○ 08. Biorobotics and Biomechanics
- ○ 09. Therapeutic & Diagnostic Systems and Technologies
- ○ 10. Biomedical & Health Informatics
- ○ 11. Biomedical Engineering Education and Society
- ○ 12. Translational Engineering for Healthcare Innovation and Commercialization

Special Session Synopsis— Max 2000 Characters

Microwave imaging has gained considerable interest, due to demonstrated existing dielectric contrast between tissues at microwave frequencies. Such contrast may allow for modalities that complement currently used systems based on different underlying physics. Many microwave-based systems are low-cost, making them accessible to small clinics and societies disadvantaged by challenging economic standards.

Research efforts in this field persist as they promise development of devices which could complement currently used modalities. Groups investigating this topic worldwide vary in their approach, but all rely on the reported inherent dielectric contrast between healthy and malignant tissues in the microwave frequency range. Different tissues have different water content and hence different microwave frequency properties. These properties are also anticipated to change with the health of the tissues.

The first part of the session will focus on application of microwave imaging to breast health, ranging from early detection to post-surgery tracking. A number of teams strive to address different challenges, such as sensor design, effective measurement techniques and hardware, noise level reduction, optimal signal processing and algorithm development and the overall system design. In this session, papers explore the development of phantoms used in testing and evaluation of systems and approaches to imaging. Several different approaches to imaging are also tested on both phantoms and human subjects. This testing is aimed at studying tumor detection in different challenging scenarios, as well as post-treatment changes.

The co-chairs for the session: Milica Popović (McGill University) and Elise Fear (University of Calgary).

The Viability of Carbon Fiber-doped 3D-printed Material as a Skin Surrogate in Breast Microwave Imaging

Stephen Pistorius, University of Manitoba

Abstract - Microwave imaging has emerged as a potential modality for breast cancer detection. As breast microwave imaging (BMI) systems move toward clinical use, rigorous preclinical evaluation using breast phantoms is required. MRI-derived 3D-printed phantoms are morphologically anthropomorphic but require the use of a 3D-printing material, resulting in plastic layers in the phantoms. These plastic layers may have undesirable features due to their low-permittivity, relative to the permittivity of breast tissues. In addition, the long-term reliability of skin-mimicking materials requires improvement.

This work used reflectivity and transmission measurements of 1-8 GHz microwave signals to explore the viability of using carbon fiber (CF)-doped plastic as both the outer layer of a 3D-printed phantom that contains the adipose tissue surrogate, and as a skin surrogate. The effects of material thickness and the polarization of the individual carbon fibers on the reflectivity of 3D-printed CF-doped plastic structures were examined. Comparisons to common low-permittivity 3D-printing plastics, including polycarbonate and polylactic acid (PLA), and other skin-surrogate material will be made. Preliminary results have demonstrated that the 3D print design will play an important role in optimising the magnitude of the skin-layer reflectivity and that the higher reflectivity of CF-doped plastics, 3D-printed shells produced with these materials may be suitable as a skin surrogate in BMI.

Detectability of Breast Tumors in Excised Breast Tissues by A Portable Breast Tumor Screening Device

Hang Song[1], Shinsuke Sasada[2,3] , Norio Masumoto[2,3] , Takayuki Kadoya[2,3], Koji Arihiro[3], Morihito Okada[2,3], and Takamaro Kikkawa[1]

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2. Research Institute for Radiation Biology and Medicine, Hiroshima University, Japan

3. Hiroshima University Hospital, Hiroshima, Japan

Abstract - This paper is to investigate the detectability of breast tumors having various histolopathological types in excised breast tissues of total mastectomy by the use of a portable, impulse-radar-based breast cancer screening device.

Microwave Radar Breast Tissue Screening: Verification of Prototype Function for Post-Biopsy Conditions with Titanium Clip Marker

Lena Kranold and Milica Popović, McGill University

***Abstract* –** Within the research efforts on feasibility of microwave breast cancer detection, our group's work focuses on the time-domain radar approach. Here, the low-power microwave pulses emitted into the breast from the skin surface propagate and scatter within the complex breast tissue and the resulting detected signals are processed to reveal the location of the main scatterers within the breast volume. Our approach is aimed for tracking breast health frequently, over extended periods of time, so that the development of an anomaly can be detected through algorithmic comparisons of prior scans.

In this paper, we report experimental setup and measurements with breast tissue phantoms, ranging from the ones mimicking a healthy breast to those with a titanium clip embedded in a gland, in order to simulate the scenario of a patient who has undergone a biopsy and is left with the location-marking clip within the tissue. Our experiments indicate that the presence of this clip will still allow detection of a malign tumor which may develop after the biopsy.

Axillary Region Numerical Models for a Microwave Imaging System

D.M. Godinho[1], J.M. Felício[2], T. Castela[4], N.A. Silva[3], M.L. Orvalho[4], C.A. Fernandes[2], R.C. Conceição[1]

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***Abstract* -** Breast cancer accounted approximately 2.09 million new cancer cases in 2018, being the second most common cancer worldwide and the most common among women. The tumour can drain cancer cells to surrounding lymph nodes, such as axillary lymph nodes (ALN), in most breast cancer cases in stages II to IV.

We aim to design and build a full Microwave Imaging (MWI) system to detect and diagnose ALNs. MWI has been used for early detection of breast cancer, but the evaluation of ALNs has only been addressed in a few publications. Our system will be based on Ultra-Wideband (UWB) radar microwave imaging, which consists in illuminating the axilla with a UWB pulse and recording the backscattered signals by one or more antennas. Those signals will be used to create an energy profile of the axilla. The focus of this paper lies on the creation of an axillary region model which is required to test and validate this MWI system.

In this paper, we analyse two different sequences of MRI images of the upper torso, 3D T1-weighted and DIXON, both with a voxel-size of 1mm x 1mm x 1mm acquired with a dedicated coil for the breast to build an anatomically-realistic model of the axillary region. The images were pre-processed and segmented in four main steps. Firstly, pre-processing filters were applied to the images in order to remove artifacts, while preserving the edges and increasing the signal-to-noise ratio. Then, we segmented the images into two tissues, the background and the torso, using manual thresholding and some manual corrections. The torso itself was then segmented using the K-means clustering algorithm which is an unsupervised method that, when applied to images, divides the data into K groups based on their voxel intensity values and location. The images were segmented into an optimal number of tissues which can be labelled as lymph nodes, different categories of fibroglandular tissue and fat, and other anatomical structures. In the last step of segmentation, we applied a skin detection algorithm and merged the segmented skin with the previous segmented data. Finally, we assigned dielectric properties to each tissue by mapping the voxel intensities to several dielectric properties curves defined by. The permittivity and conductivity values of ALNs were interpolated from the dielectric properties curves of fibroglandular tissue considering the voxel intensities values of each type of tissue.

Non-Invasive 2-Port Transmission Probe Based Tumor Detection Using Anthropomorphic Breast Phantom at 2.45GHz

Laya Joseph[1], Paul Meaney[2,3], Noor Badariah Asan[1] , Bappaditya Mandal[1], Robin Augustine[1]

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Abstract - In this paper, we propose the development of semi-solid and stable breast phantom with skin, fat, muscle and spherical tumor models and a transmission-based sensing method for tumor detection. The proposed breast phantom emulates the anatomical, physical and electrical properties as human breast tissues. The dielectric properties of the breast phantom tissues are measured using open ended coaxial slim probe from Keysight Technologies in the frequency range of 500 MHz-20GHz. The S21 scattering parameters are measured and studied for a normal breast phantom and breast phantom with tumor models representing its different growth stages using Topology Optimized Planar Antenna (TOPA) based probe. The study shows a detection an S21 amplitude variation of 2 - 12 dB for tumor inclusion models of size from 4mm - 16mm diameter with respect to normal breast model. This study indicates that with further development transmission-based methods can be used for preliminary screening of breast tumor.