Microwave based diagnostics and treatment

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Microwave Based Diagnostics and Treatment

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***Abstract*— Microwave based diagnostics and treatment will be discussed with application to stroke diagnostics, 3-D microwave tomography with application to breast cancer diagnostics and microwave hyperthermia with application to cancer treatment.**

I. Stroke

In Sweden roughly 30 000 people suffer a stroke each year and the corresponding number in United States is approximately 700 000 persons per year. About 15-30% becomes permanently disabled, and 20% require institutionalization during the first three months after the stroke. Approximately 85% of all strokes are ischemic (blood cloth induced) and 15% hemorrhagic (bleeding) strokes. Stroke comes third among reasons for acute death and first among reasons for neurological dysfunction in Swedish health care. Among stroke survivors, 20% have serious remaining dysfunctions. Thrombolysis (blood cloth resolving medication), has been shown to improve the outcome from ischaemic stroke, **if given in time.** This requires the ability to quickly distinguish between ischaemic and hemorrhagic stroke. For successful thrombolytic treatment, new cerebral ischemic events need to be identified within 15-30 min. At least partly due to these limited time windows, less than 5% of those patients that could benefit from this treatment are presently receiving it. The total cost for the society in Sweden is estimated to SEK 12 billion per year.

This quick diagnosis of stroke type has been highly demanded for a decade as thrombolytic therapy in acute stroke treatment became internationally approved. Thrombolytic therapy can be used very successfully for ischemic stroke but have disastrous effect if given to patients suffering from haemorrhagic stroke, thus making it extremely important prior treatment to rule out haemorrhagic stroke. The effect of the therapy is better the sooner the treatment is initiated since more brain tissue is rescued the sooner the blood flow is restored. Thrombolytic treatment can not be started if more than 3h have passed since the first symptoms as the risk for causing a bleeding in the damaged area has become too high.

Advances in neuro diagnostics based on microwave antenna system in terms of a helmet including a set of broad band patch antennas is presented. It is shown that classification algorithms can be used to detect internal bleeding in stroke patients. The diagnostic of stroke patients suffer from a number of serious limitations. The most severe problem is that the diagnosis often takes too long time to establish. In 80% of the patients the stroke are caused by a clot, which can be treated with clot-resolving medication if given in time. Unfortunately most patients will not receive their diagnosis in time to save the brain from damage due to delays in the chain of care. This is because it needs to be established that the stroke is not caused by hemorrhage. It has been suggested that microwave based systems can solve some of these outstanding problems. For this purpose we have developed a microwave helmet and performed an initial clinical study on 20 stroke patients. Using classification algorithms we have obtained encouraging results, but more patients have to be measured before any definitive conclusions can. The stroke detection helmet is built by 10 patch antennas that have been mounted in a helmet and the multistatic scattering matrix is measures at a large number of frequencies. The measured scattering coefficients are then used as input for the classifier algorithm. This measurement strategy is similar to what is commonly used in microwave tomography experiments. The multistatic matrix is measured using each antenna both as transmitter as well as receiver. A two port network analyzer is used as the transmitting and receiving unit. To fully control the experiment a multiplexer module is used to automatically connect and disconnect the different combinations of antenna pairs to the network analyzer. A particular problem with the helmet is that it is rigid whereas the size and shape of different patients varies. To fit the antenna to individual patients the solution is to mount flexible plastic bags inside the helmet that can be filled with water. The purpose of the water bags is to fill up the space between the antennas and the skull but also to provide impedance matching between the antenna and the skull. If the antennas were just left with an air gap between the antenna and the skull the differences in intrinsic impedances between skin and air would cause a strong reflection at the surface of the skin, thereby preventing a large portion of the signal to penetrate into the skull. Only the signal penetrating will be useful in stroke detection and a weak signal into the skull means a weak signal out and consequently also a low signal to noise ratio. We are currently investing data driven approaches to develop detection and classification algorithms where the scattering measurements are treated as multidimensional signal samples. Based on labeled data we construct the classifier by extracting features from the high dimensional data and then project them to lower dimensions suitable for discrimination between the classes. Subspace based techniques both in classical euclidean spaces as well as in higher dimensional linear spaces has been successful in medical applications detecting bleeding stroke. Also, In Western Sweden, roughly 650 people/year suffer a cerebral transient ischemic attack (TIA). Common symptoms of TIA are transient hemiparesis, dysfasia, sensory disturbances and/or blindness. TIA constitutes a clear warning of impending stroke, occurring after approx. 15-20% of TIAs. As many as 2/3 of manifested strokes can be prevented if the patients receive early treatment with vascular surgery and/or trombolytic treatment. However, trombolytic treatment can only be performed during a critical and narrow time window. Thus, successful active treatment of TIA/impending stroke depends on sensitive continuous monitoring of brain function before and after treatment. The hypothesis, to be tested in the project, is that this role can be played by a portable microwave based monitoring system.

II. Microwave measurement techniques

Breast cancer is a serious health problem for women. According to national statistics of Sweden from year 2007 it is the most common cause of death from cancer among women, with about 30 yearly deaths per 100,000 inhabitants. The situation is similar in the rest of Europe, Northern America and Australia. Worldwide breast cancer is the second most common form of cancer after lung cancer. In year 2002 1.15 million new cases of breast cancer were diagnosed world wide. A relatively favorable prognosis, compared to other cancer forms, resulted in about 410,000 deaths the same year.

The standard method for breast cancer diagnosis today is X-ray mammography. Despite its recognized ability to detect tumors it suffers from some limitations. Neither the false positive nor the false negative detection rates are negligible. This leads to a number of unnecessary additional investigations and, more seriously, a fraction of the tumors are not detected at an early stage which is a prerequisite for efficient treatment. An important reason for the limitations using the X-ray technique is that the contrast between the tumor and the surrounding tissue. An interesting alternative being researched extensively today is microwave tomography. From measurements on excised tissue a dielectric contrast has been observed between the healthy and malignant tissue. Depending on the mixture between fatty and glandular tissue in the breast the contrast varies largely between individual patients, from about 10% for a breast with a large portion of glandular tissue and up to >100% for breasts consisting of mostly fatty tissue. In some recent clinical studies the ability to detect breast cancer tumors with microwaves have been shown.

In microwave tomography the object under investigation is surrounded by a number of transmitting and receiving antennas. In the measurements each antenna is operated as a transmitter as well as a receiver for every possible combination of antennas. In our work we use wide band measurements which leads to a square multistatic data matrix for each frequency component. In most of our previous work we have used a flat antenna array, where the antennas have been placed on a circle, and a two-dimensional (2D) reconstruction algorithm. This setup is also most suitable for imaging 2D objects with dielectric properties that are constant in the z-direction perpendicular to the antenna plane. When it comes to imaging three-dimensional (3D)

In our current strive to develop a clinical prototype we have therefore found that the most suitable design for a clinical prototype consists of an antenna array where antennas are placed also outside the plane in a 3D pattern. Our aim is therefore to construct a cylindrical antenna array. Together with a 3D reconstruction software the potential for improved accuracy is optimized. However the price that has to be paid for this approach is a significantly increased computational burden in the reconstruction algorithm.

III. Microwave hyperthermia

During the last decade clinical studies have demonstrated the ability of microwave hyperthermia to dramatically enhance cancer patient survival. However, the clinical results are limited with respect to cancer forms a tumor positions. We believe that this is partly du to limitations in technology and algorithms. The fundamental challenge is to adequately heat deep-seated tumors while preventing surrounding healthy tissue from undesired heating and damage. This challenge needs to be resolved for hyperthermia to develop into standard treatment for a larger number of tumours. Specifically, the challenge to deliver power levels with spatial control, the challenge of patient treatment planning, and the challenge of temperature measurements need to be resolved. While treatment planning can somewhat limit the need for temperature measurements, quality assurance and effectiveness of the treatment can still benefit from high quality temperature monitoring. It is useful both for feedback control and for evaluation of the clinical efficiency. Invasive measurements are still regarded by many as the gold standard but it suffers from incomplete information about highly inhomogeneous temperature distributions. The most clinically advanced approach of non-invasive thermometry is MRI techniques which, while clinically feasible, are likely to be too expensive to be long term clinical solutions. We are therefore instead developing a method to measure temperature with microwaves. Knowledge of the temperature characteristics of biological tissues together with the geometrical constraint obtained from the segmented patient specific models are coupled to an existing optimization based microwave tomography method. The method is tested using the Chalmers microwave tomography system.