Microwave Imaging Fusion for Brain Tumours Detection

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Abstract. Microwave brain imaging typically has lower resolution due to its longer wavelength. This paper will propose a microwave brain tumour imaging method by fusion conventional microwave imaging techniques and real brain slices. The simulation of microwave signals is conducted in the CST Studio Suite software at the frequency range of 0.5-2 GHz. An array of eight antennas is set up around a human head model, and a tumour is inserted into the model. The collected frequency domain data is converted into the time domain. Next, four delay-and-sum image reconstruction algorithms are used to reconstruct the image. The generated images are then fused with a 2D slice of the head model to produce high-quality brain images. The fused images can visualize the tumour location while maintaining the brain structure.

Keywords: Brain Cancer, Microwave Imaging, Image Fusion..

1 Introduction

Cancer, with the possibility of appearing in any organ and tissue in the human body, is one of the main causes of death worldwide. According to the WHO, the number of fatalities reached nearly 10 million in 2020 [1]. With timely diagnosis and effective treatment, it's possible to cure many cancer patients, and this highlights the significance of early cancer detection. Traditional imaging diagnosis technologies, including MRI and CT, produce high-resolution images, however, they have constraints such as high cost and radiation damage to the human body. While a large number of cancer patients are not able to have timely diagnosis and treatment, microwave imaging, which has many advantages over the traditional ways, has recently motivated many researchers to study and develop new approaches for applying microwave imaging to cancer detection.

Portable microwave devices with lower costs enable safe and rapid diagnostics while providing reliable brain imaging [2-4]. For example, the Microwave brain imaging system uses metamaterial fixed broadband antenna array and improved delay-multiply-and-sum (DMAS) algorithm to detect whether the brain contains tumors [3]. However, even though these devices are able to locate target locations [2], they cannot produce high-resolution images. If a reasonable image could be provided based on these microwave devices, they will be considered supplementary tools and apply to populations and environments where traditional techniques are constrained.

This paper presents a microwave image fusion method based on traditional microwave beamformers and a real head image slice. Firstly, the scatter dataset is collected from a simulation brain model using an eight antenna system. Four common microwave image methods are applied to construct the microwave images based on the scatter signals. The first is the delay-and-sum (DAS) method[5], Then, the DMAS also is applied to the image construction. The last two methods are an iterative structure of the DAS (itDAS) and DMAS (itDMAS) which have been developed and applied to reconstruct the microwave image for the breast model [6]. Finally, all four calculated images are forwarded into an image fusion model to generate a high quality image.

2 Simulation Setup

The setup of microwave imaging systems usually involves an array of antennas transmitting and receiving signals scattered back from the target. The water content in tumours is higher than in normal healthy cells, and this changes the dielectric properties of the tissues thus allowing the tumour to be distinguished from normal tissues [7]. Table 1 shows the dielectric properties of various head tissues at a frequency of 1 GHz [4]. From the table, the permittivity of tumour tissue is 62.5, which indicates an apparent difference from other tissues.

Table 1. Dielectric Properties of Brain Tissues at 1 GHz [4]

Tissue	Relative permittivity	Conductivity
Skin	*41*	0.8977
Bone	*12*	0.1557
CSF	*68*	2.4552
Grey Matter	*52*	0.9854
Tumour Tissue	*62.5*	1.2438

A 3D Duke head model is imported in the CST software and an array of eight dipole antennas is set around the head model, as shown in Fig. 1. A tumour cell with a radius of 10 mm is inserted into the model, and the permittivity of tumour tissue is set based on Table 1. Each antenna transmits in turn and receives signals scattered back from the target. Water blocks are added to reduce the impact of nearby antennas. The simulation of microwave imaging is conducted at the frequency range of 0.5-2 GHz as it is a suitable range for brain imaging [3,8].

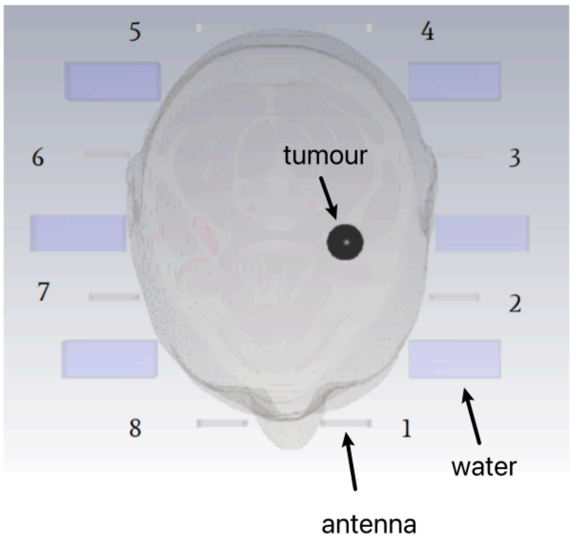

Fig. 1. A microwave brain tumour system with eight antennas, where water is used to reduce coupling between two adjacent antennas.

3 Microwave Imaging Methods

3.1 Microwave Imaging Construction

The results gained from the simulation are the S-parameters, or frequency domain data. Since the DAS algorithm focuses on reconstructing from the time domain data, the eight reflection S-parameters are transformed to time domain data using the Inverse fast Fourier transform (IFFT) algorithm by zero padding on the input data. The difference in the simulation results between a model with and without a tumour is taken, which can be used to evaluate the reconstruction method's performance. The time domain data are used to reconstruct images using the DAS, DMAS, itDAS and itDMAS algorithms [5, 6] respectively.

3.2 Image Fusion

A 2D slice of the head model is generated, as shown in Fig. 2. Both the reconstructed images and the head slice are normalized to the range of 0-1 so it can display in a fixed intensity level. The slice is fused with each of the four reconstructed images using the weighted sum method, which can be written as.

$$I_{fused} = \alpha \cdot I_{slice} + (1-\alpha) I_{rec} \tag{1}$$

while I_{slice} is the normalized pixel value of the 2D slice image and I_{rec} is the normalized reconstructed pixel value of constructed images from DAS, DMAS, itDAS and itDMAS respectively.

The optimal value of α is found to be 0.3 which provides a balance between the head slice and the reconstructed images. The location of the tumour is predicted by scanning the reconstructed image with a 5x5 kernel and calculating the average value

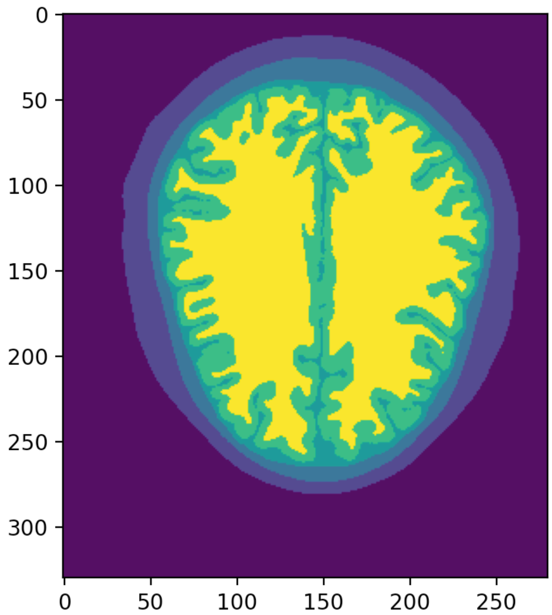

Fig. 2. An 2D slice of the head model of Fig 1. at index 140 along the z-axis

4 Results

The reconstructed images are shown in Fig. 3. The location of the tumour can be identified from all images as an area of high intensity can be observed. However, DAS contains too much clutter, while the DMAS beamformer has greatly reduced the overall intensity and also the low-intensity clutter. The iterative methods have reduced more low-intensity clutter, which corresponds to the results on the breast model [6]. However, it is difficult to identify the position in the brain.

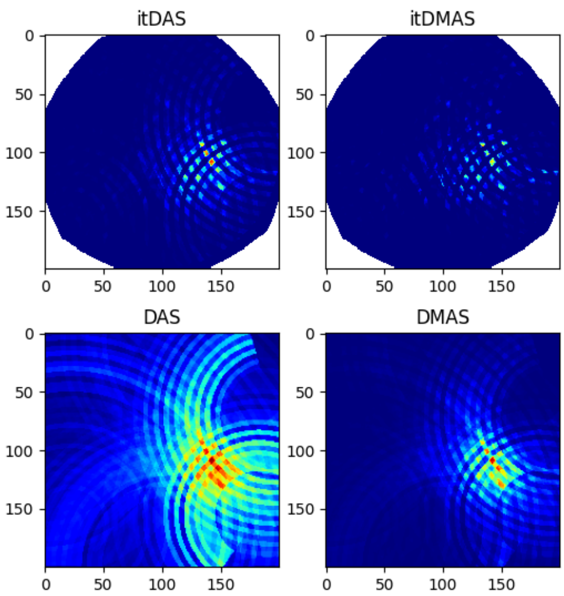

Fig. 3. Reconstructed images from itDAS, itDMAS, DAS and DMAS beamformers

To display the location of the tumour in the brain, each of the reconstructed images is fused with the 2D slice of the head model. The fused images are shown in Fig. 4. The black circles represent the location of the inserted tumour, while the red circles represent the location of the predicted tumour. The circles only indicate the location, not the size of the tumour. The distance between the centres of the black and red circles is measured to be about 4.5 mm. The intensity of the brain slice has been adjusted to display a fixed intensity level while maintaining both the brain structure and reconstructed results. While images with less clutter can produce better imaging results for tumour localization, it also has the risk of losing important information during the reduction.

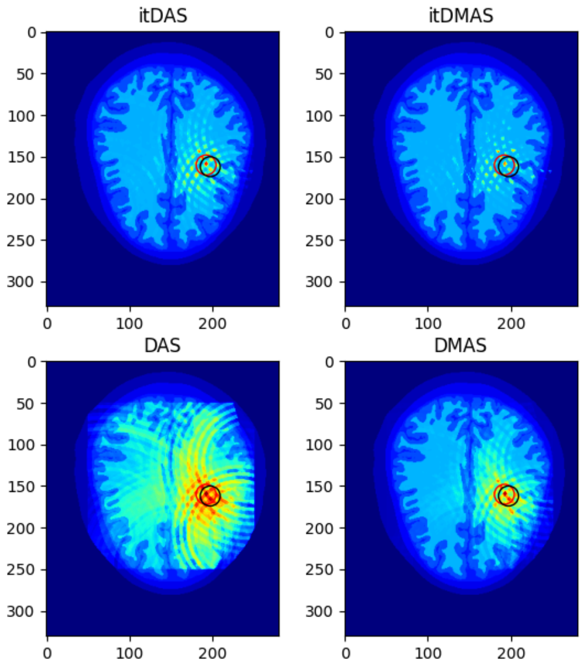

Fig. 4. fusion images with a 2D slices and four constructed images in Fig. 3

5 Results

This paper presents a microwave brain tumor image fusion method. These methods can remove more clutter than the DAS and DMAS beamformers so better images can be visualized to help localize the tumour in the brain. However, important information may be reduced and consequently produce worse imaging results. The reconstructed images are fused with a 2D slice of the head model and it can display the target position and the brain structure successfully. The tumour location can be predicted within a 5 mm distance of the inserted tumour using the 5x5 kernel for scanning and calculating the average. Although the boundary of the tumour is not clearly identified, the proposed method can be considered a supplementary visualization technique for brain tumour or stroke diagnosis and localization.

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