A Lightweight Deep Learning Based Microwave Brain Image Network Model for Brain Tumor Classification Using Reconstructed Microwave Brain (RMB) Images

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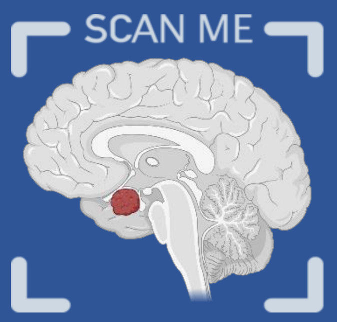

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INTRODUCTION

Brain tumors, which are abnormal cells growing inside the brain, are a serious cause of death globally, with brain cancer being the tenth leading cause of death. There are two types of brain tumors: benign and malignant. The former is made up of non-cancerous cells and does not expand to other areas, while the latter is cancerous and grows uncontrollably, posing a threat to human life. The development of brain tumor classification using microwave imaging (MWI) technology has recently been gaining attention due to its non-ionizing radioactivity, non-invasiveness, and cost-effectiveness. Researchers have been applying deep learning techniques to microwave imaging systems to overcome the limitations of MBI modalities, which include noisy, blurry, and low-resolution images and difficulty in classifying

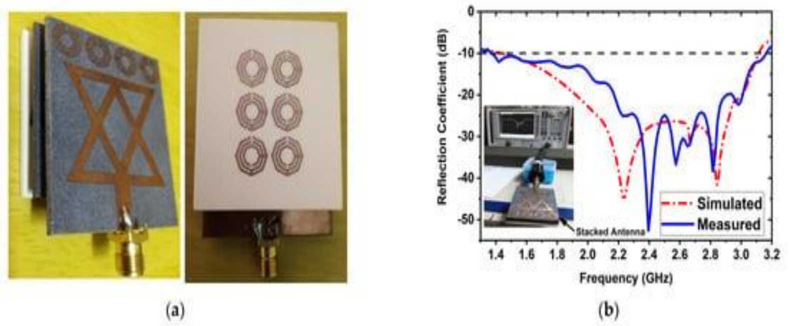

Figure 1. (**a**) Fabricatted 3D stacked antenna, (**b**) Measured and simulated reflection coefficient.

METHODOLOGY

The research developed a new metamaterial-inspired 3D wideband stacked antenna sensor for a microwave brain imaging (MBI) system, which has a fractional bandwidth of 79.20 percent, 93 percent radiation efficiency, a 98 percent maximum fidelity factor, and 6.67 dBi gain. The antenna was tested in both free space and near a head model and was found to be suitable for producing the desired microwave brain images in the implemented SMBI system. The developed antenna sensor showed appropriate field penetration in the head, high fractional bandwidth, high radiation efficiency, and good gain. These results suggest that the antenna sensor can be used to produce desired RMB images in the implemented

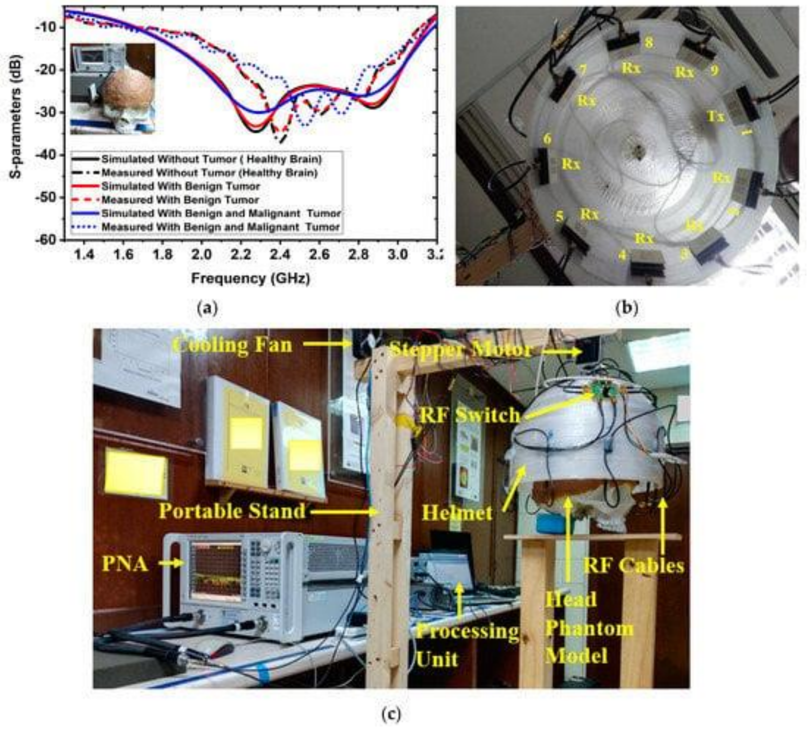

Figure 2. Antenna sensor measurements and experimental setup for the SMBI system: (**a**) Measured and simulated results of the antenna sesnor with a fabricated head phantom model, (**b**) MTM loaded 3D stacked antenna sensor inside the helmet, (**c**) Overall SMBI system model.

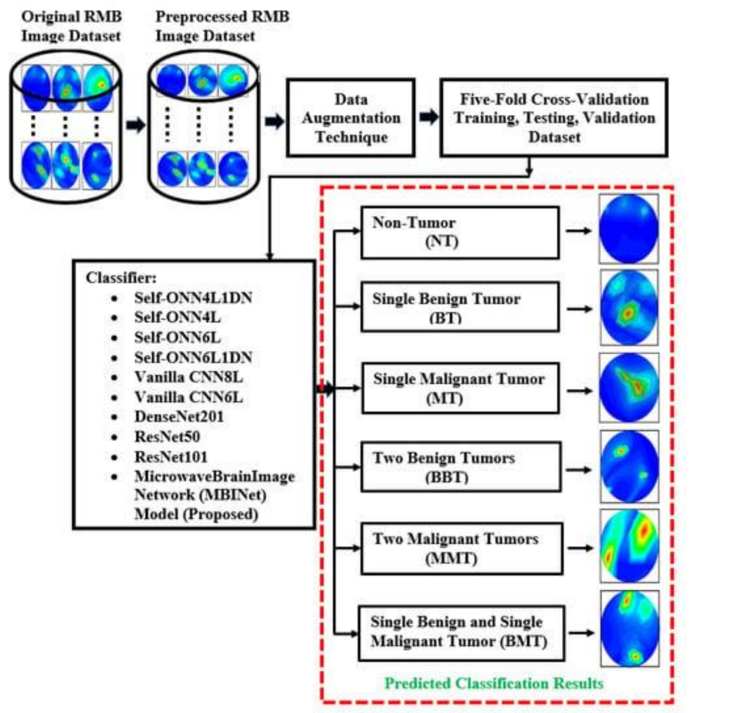

Figure 3. The flowchart for the complete research process.

CONCLUSION

- This study proposes a deep learning-based microwave brain image network (MBINet) to classify brain tumors from reconstructed microwave brain (RMB) images.
- The MBINet model outperforms other state-of-the-art models in terms of accuracy, precision, recall, specificity, and F1 score, making it a promising tool for classifying brain tumors from RMB images and potentially applicable to the SMBI system.
- The study identifies limitations of the proposed classification model and suggests future directions, including the development of a new image reconstruction algorithm, optimization of learning parameters, and reduction of computational complexity.

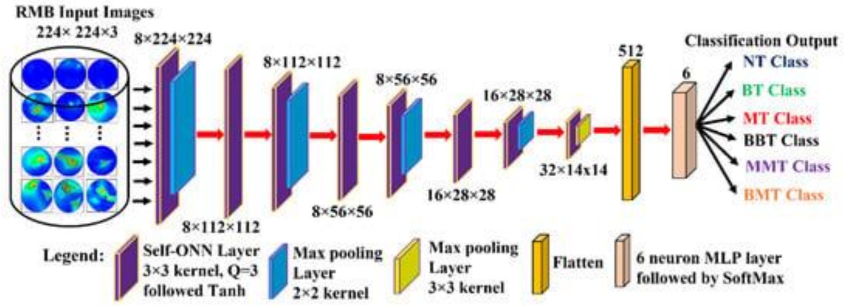

Figure 4. Proposed Microwave Brain Image Network (MBINet) model using Self-ONN.

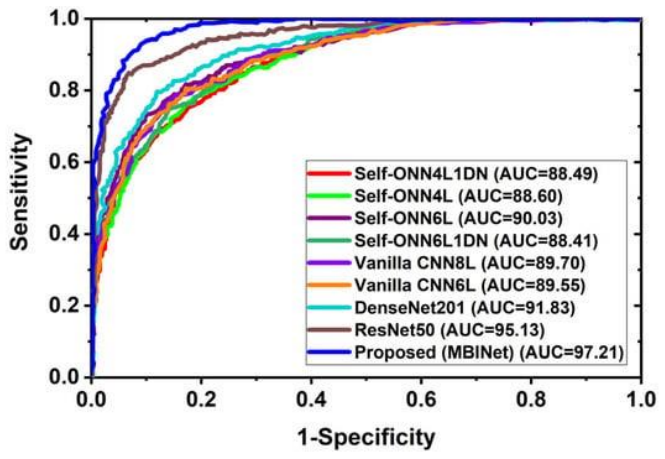

Figure 5. Receiver Operating Characteristics (ROC) curve with AUC.

DISCUSSION

The proposed MBINet model demonstrated superior classification performance compared to conventional deeper CNN networks and achieved an accuracy, precision, recall, specificity, and F1 score of 96.97%, 96.93%, 96.85%, 97.95%, and 96.83%, respectively, for the raw RMB brain images, with lower standard deviation values. The model's main advantages include a lightweight architecture that uses non-linear operations, optimized learning weights, and reduced computational complexity.

Hossain A, Islam MT, Abdul Rahim SK, Rahman MA, Rahman T, Arshad H, Khandakar A, Ayari MA, Chowdhury MEH. A Lightweight Deep Learning Based Microwave Brain Image Network Model for Brain Tumor Classification Using Reconstructed Microwave Brain (RMB) Images. Biosensors. 2023; 13(2):238. https://doi.org/10.3390/bios13020238