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Microwave Brain Imaging System Validation via Realistic Experiments

D. O. Rodriguez-Duarte*, J. A. Tobon Vasquez, and F. Vipiana
 Dept. Electronics and Telecommunications, Politecnico di Torino, Torino, Italy,
 {david.rodriguez, jorge.tobon, francesca.vipiana}@polito.it

A brain stroke is a widespread disorder and a top-ranking worldwide cause of death, disability, and dementia in otherwise healthy adults. Stroke care widely relies on brain and vessel imaging technologies, identifying the specific pathophysiologic conditions for tailored treatment and enhancing effectiveness. The most well-established solutions are computerized tomography (CT) and magnetic resonance imaging (MRI). Both technologies provide reliable, accurate, and high-resolution images. However, CT could be harmful due to ionizing radiation, and MRI systems are costly and time-consuming, possibly causing a further delay in supplying proper therapies. Moreover, these technologies are not always available in the first care points, limiting emergency imaging ability, and are not feasible at the patient bedside. Thus, to overcome the limitations of the currently available technologies, microwave imaging (MWI) has been emerging as a complementary tool for brain stroke diagnosis and monitoring at the cost of a lower resolution.

In this paper a microwave imaging (MWI) device, recently proposed by the authors [1], is experimentally validated, showing its capability to follow-up the progression of ischemic and intracranial hemorrhagic strokes evolving from a healthy condition to an early-stage ill one. The work involves realistic scenarios, considering a 3-D human-like head phantom and clinical-sized comparable strokes localized in different positions. The modeled head includes a human-shaped brain made of ex vivo calf brains and liquids mimicking the strokes' dielectric properties. The MWI system works at 1 GHz and uses a low-complexity architecture that consists of an antenna array of twenty-two monopoles [2]. Each monopole is embedded into a "brick" made of a semi-flexible dielectric matching medium and properly positioned conformally to the upper part of the head [3]. The imaging algorithm exploits a differential approach considering measurements at two different instants, i.e., distinct pathological conditions, such as healthy and ill-affected ones. It provides 3-D images of the dielectric contrast in the brain region, employing the singular value decomposition of the discretized scattering operator, obtained via accurate numerical models [4]. Moreover, we propose and validate a novel calibration technique based on measured data that involves an auxiliary reference channel to mitigate the possible change in time effects, combined with a tuning of the measured data with the system numerical model [5]. The reconstructed dielectric contrast images achieve good performance, localizing the stroke area in all the considered 3-D scenarios for both hemorrhage and ischemia cases. For future work, we plan to investigate a multi-frequency approach and realize a wearable version of the designed MWI device.

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