Computational Design and Analysis of Microwave Tomography in Intracerebral Hemorrhage

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Introduction: Intracerebral hemorrhage is a condition in which a blood vessel in the brain ruptures and causes bleeding preventing the blood flow to particular parts of the brain leading to hemorrhagic stroke. 800 in every 100,000 people suffer from stroke each year making it one of the leading causes of mortality worldwide[1]. Diagnosis involves a series of Neurological examination with MRI/CT scans and remains as a costly and time consuming process. To overcome this drawback Microwave Tomography (MWT) is proposed as a feasible, cost effective and portable system to diagnose the occurrence of hemorrhage based on tissue dielectric properties[2].

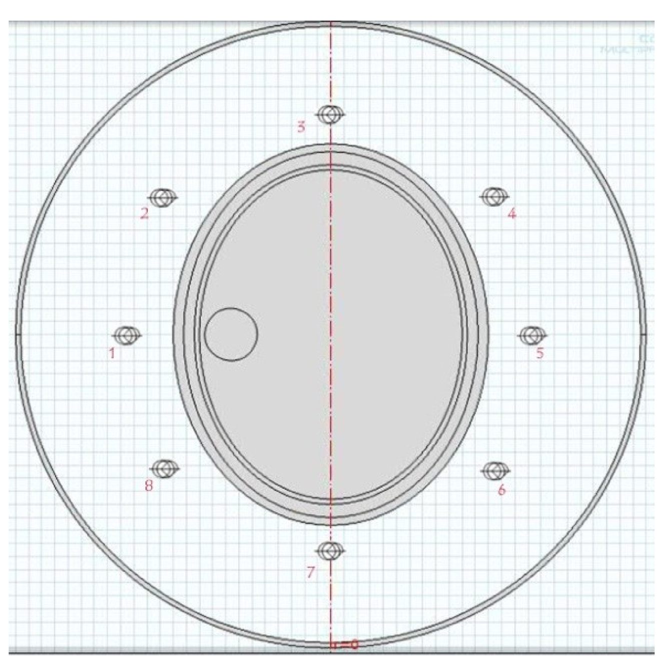


Figure 1. MWT setup of an elliptical head phantom with domains of hemorrhage, grey matter, cerebrospinal fluid, skull and skin from inside to outside surrounded by an array of eight dipole antennas.

Tissue	e_r	s [S/m]
Skin	41	0.89977
Skull	12	0.15566
CSF	68	2.4552
Grey Matter	52	0.98541
Ischemic Stroke	36	0.15
Intracerebral Hemorrhage	61	1.5829

Table 1. Tissue dielectric properties at 1GHz, used in the head phantom

Computational Methods: MWT is a technique that involves addressing the forward problem that gives the scattered electric field data from the different dielectric medium and the inverse problem that reconstructs the head phantom from the scattered field. The MWT setup is shown in Figure 1 and the corresponding dielectric properties for each of the domains at 1GHz is given in Table 1.

- The forward problem is given by the electromagnetic wave equation (1) where ω, ε and σ are the angular frequency, permittivity, permeability and electrical conductivity respectively and E and H are the electric and magnetic field vectors respectively.

$$\nabla \times \mu^{-1} (\nabla \times E) - \omega^2 \varepsilon_0 (\varepsilon_r - j\sigma/(\omega\varepsilon_0)) E = 0 \qquad (1)$$

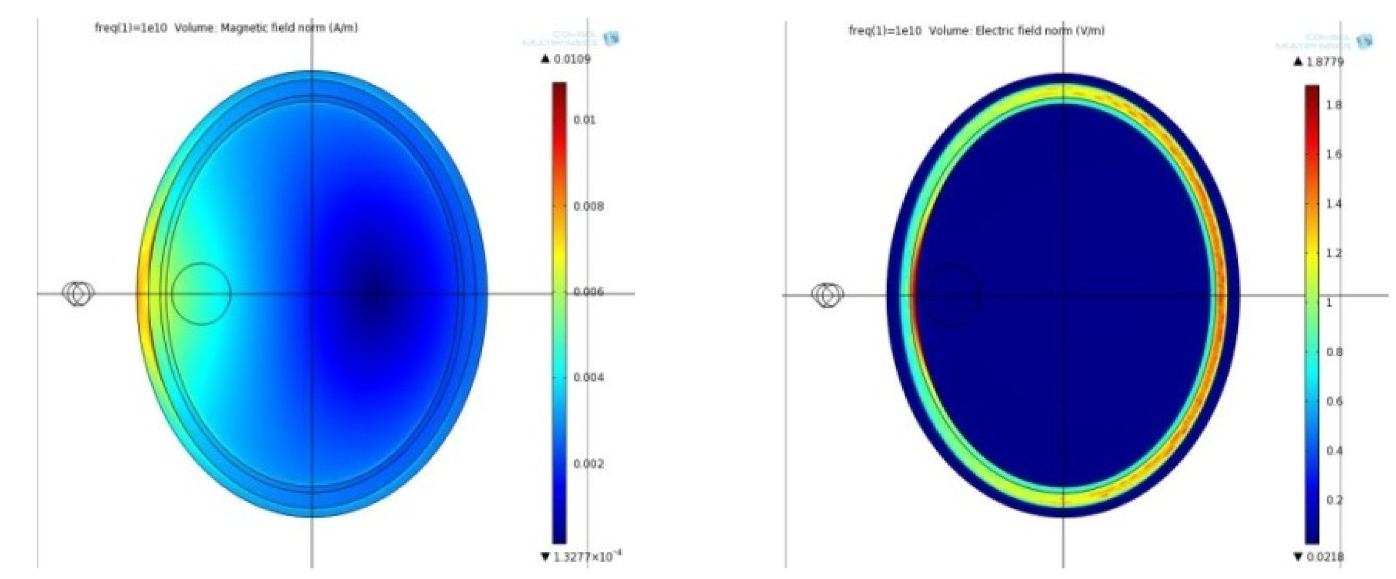
- The inverse problem to reconstruct the head phantom is addressed by Contrast Source Inversion (CSI) algorithm[3] given by equations (2-4). Here G is the Green's function of the background medium, (q,q') forms the position vectors in the imaging domain D upon which the integration is performed. k is the squared complex wave number.

$$E_j(q) = E_j^{inc}(q) + k^2_{bg} \int_D G(q,q')\, E_j(q')\, \chi(q')\, dq' \qquad (2)$$

$$k^2_{bg}(q) = \omega^2\mu_0\varepsilon_{bg} + j\omega_0\mu_0\sigma_{bg} \qquad (3)$$

$$\chi(q) = k^2(q) / (k^2_{bg} - 1) \qquad (4)$$

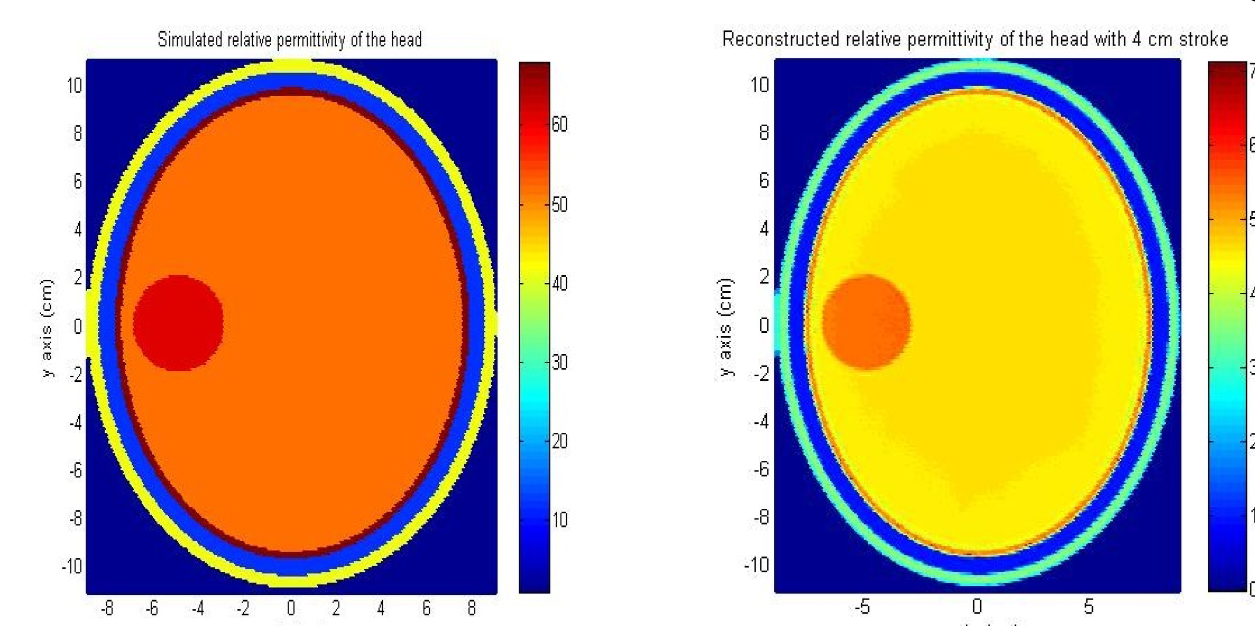
Results: The MWT brain imaging was performed at 1GHz using a phantom head model simulated with hemorrhage. The simulations are run for each of the eight transmitters placed equidistant in an elliptical array around the head and excited sequentially. The normalized electric field and the normalized magnetic field when the transmitter is in location 1 is shown in Figure 2.



a) b)

Figure 2. Spatial distributions of a) the normalized Magnetic field and b) the normalized Electric field in the head phantom with a 3 cm hemorrhage when the dipole antenna is in location 1 and radiating at 1 GHz.

The scattered data vary as a function of the dielectric properties of the tissues and are exported from COMSOL into MATLAB to solve for the inverse problem using CSI algorithm from which the dielectric profiles of the simulated phantom head could be reconstructed as shown in Figure 3.



a) b)

Figure 3. Validation of the MWT imaging method: a) Simulated Relative Permittivity and b) Reconstructed Relative Permittivity, of the head phantom with 4 cm hemorrhage using the CSI method under ideal conditions.

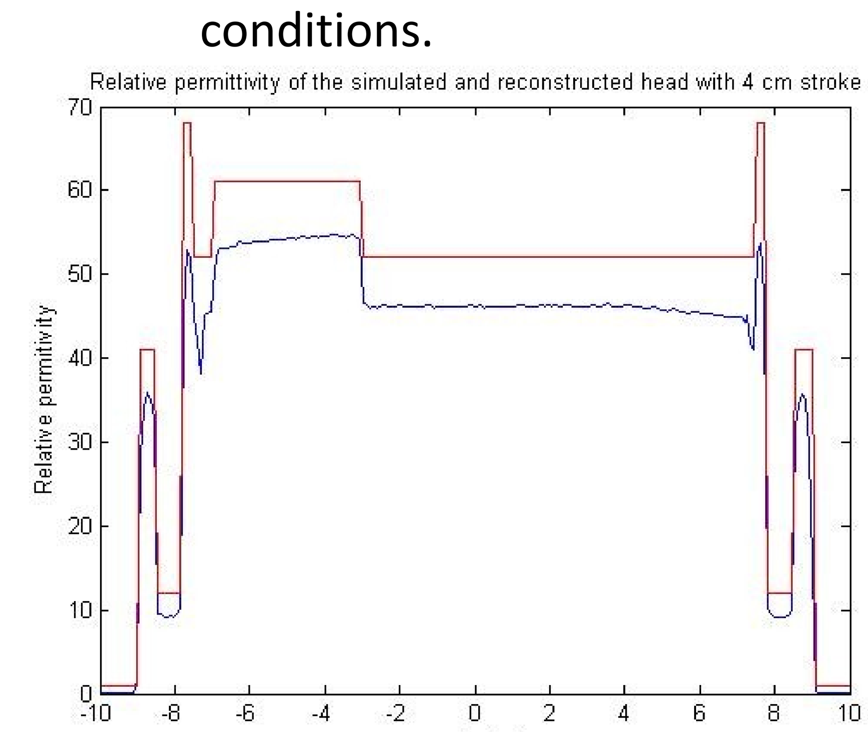


Figure 4. Difference in the relative permittivity of the simulated and reconstructed head across x=0 axis

No priori information except the dielectric properties of the background medium was taken into consideration. The relative permittivity of the hemorrhage after reconstruction was ε_r = 55.64712 under ideal conditions.

Conclusions: The notable contrast in the tissue dielectric properties offered a significant advantage for the purpose of diagnosing between different tissues. The FEA results give evidence that the microwaves could be used in analyzing the hemorrhage formations from which progressive growth or recurrence could be monitored.

References:

1. R. Scapaticci, L. Di Donato, I. Catapano and L. Crocco L, "A Feasibility study on Microwave Imaging for Brain Stroke Monitoring", Progress In Electromagnetics Research, 2012, Vol. 40, pp: 305-324.
2. Mishra NK, Khadilkar SV. "Stroke program for India" Annals of Indian Academy of Neurology, 2010; pp: 28-32.
3. Amer Zakaria, Colin Gilmore and Joe LoVetri, "Finite-element contrast source inversion method for microwave imaging", IOP Publishing, Inverse Problems 26 (2010) 115010 (21pp).

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