Outline of the reconstruction method for MR-NT

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Introduction

Many applications of conductivity distribution in diagnostic imaging have been documented, for example, gastrointestinal and esophageal function, hyper- or hypothermic treatment of malignant tumors, imaging of the head, pulmonary function, cancer detection, measurements of cardiac output and investigation to locate the focus of epileptic seizures. Noise Tomography (NT), which aims to determine the distribution of the conductivity in the sample, is a new non-invasive medical imaging technique. The NT technique is designed to use the correlations in the detected electronic thermal noise in an RF probe array and the relationship between conductivity and the noise power coupled between the sample and probe to measure the electrical conductivity distribution within the sample.To generate a more acurate result, corresponding MR images can be used as guiding image to provide anatomical information. This work focuses on the reconstruction method for MR image guided Noise Tomography (MR-NT). The details of the physics can be found in [1]. Experimental results from a 2D phantom are given.

Method

Noise tomography aims to determine the distribution of conductivity in a given sample. The NT technique uses the non-resonant electronic thermal noise of the tissue sample, detected by an array of RF probes, and the known, or calculated overlap of the electromagnetic fields of those probes. Electronic thermal noise is a basic property of all matter and has been well characterized in both one-dimensional (Johnson/Nyqusit) and three-dimensional (Black Body Radiation) cases. This NT technique is based on a combination of the fluctuation dissipation theorem and the principle of reciprocity. The objective of the NT technique is to use the noise correlation between the different channels in an array of RF probes to plot the conductivity distribution within the sample. The approach to noise tomography is based on equation (1). Constrained by acquisition time, the available number of measured noise correlation measurements is limited. Hence it would be difficult to generate a high resolution conductivity distribution map. However, if we assume the conductivity of each tissue is a constant, then the number of unknowns can be dramatically reduced with the geometry information provided by an MR guiding image. Equation (1) can then be simplified to equation (2). To increase the number of equations, the coil can be rotated to produce more noise correlation measurements at different locations. With the definition of *R* by equation (3), the relative conductivity can be produced by solving equation (4). In this equation, *M*s are measured, *R*s are simulated, the unknowns are only σ_t. Figure 1 shows the flowchart of the reconstruction scheme of MR-NT. The intensity correction and segmentation can be any appropriate scheme. In our implementation, a partial differential equation based method is used [2]. The simulation of electronic fields is only based on the geometry of the coil . To calculate the measured noise correlation, noise images are acquired by disconnecting the transmitter during acquisition. The correlation among images of each channel is used as noise correlation. The correlation may need calibration because of system noise. The calibration information can be generated by using a uniform phantom during acquisition.

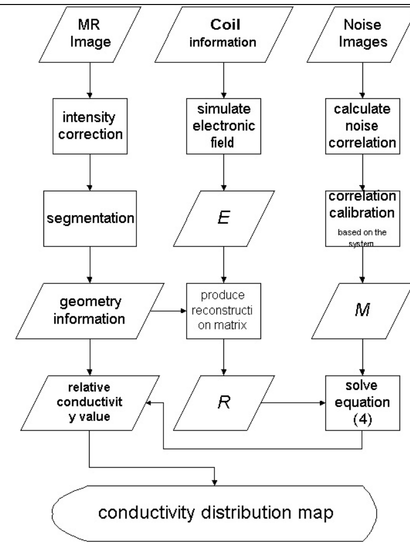

Figure 1. MRI guided Noise Tomography reconstruction Flowchart →

$$M_{jk} = \int_\Omega \sigma(\vec{r})\vec{E}_j(\vec{r})\cdot\vec{E}_k(\vec{r})dV \quad (1)$$

$$M_{jk} = \sum_{t=1}^{T}\sigma_t \int_{\Omega_t} \vec{E}_j(\vec{r})\cdot\vec{E}_k(\vec{r})dV \quad (2)$$

$$R^t_{jk} = \int_{\Omega_t} \vec{E}_j(\vec{r})\cdot\vec{E}_k(\vec{r})dV \quad (3)$$

M_{jk} is the measured noise correlation between coil *j* and *k*. $\vec{E}_j$ is the simulated electronic field of coil *j*. *j*,*k* = 1,2,…,*N*. *N* is the number of channels or the product of the number of channels and the number of rotations. σ is the conductivity distribution in region Ω. σ_t is the constant conductivity at region Ω_t. *T* is number of tissues in Ω.

$$\begin{pmatrix} M_{11} \\ M_{12} \\ \dots \\ M_{NN} \end{pmatrix} = \begin{pmatrix} R^1_{11} & R^2_{11} & \dots & R^T_{11} \\ R^1_{12} & R^2_{12} & \dots & R^T_{12} \\ \dots & \dots & \dots & \dots \\ R^1_{NN} & R^2_{NN} & \dots & R^T_{NN} \end{pmatrix} \begin{pmatrix} \sigma_1 \\ \sigma_2 \\ \dots \\ \sigma_T \end{pmatrix} \quad (4)$$

Results

The proposed method was applied to 2d phantom data. The phantom was constructed from a 180mm long (197mm diameter) acrylic tube that was filled with a solution of Cu_2SO_4 (2.0 grams/Liter) and *NaCl* (4.5 grams/Liter). Data was then collected by a 1.5T GE Excite II system (field of view (FOV) 240 mm, matrix 256×256, TE 14 ms) with an 8-channel tuned loop array of coils (MRI Devices Corporation, Waukesha, WI, USA). Figure 2 A shows the picture of the phantom. 2 B is the MR image for geometry information. 2 C is the segmentation result with an automated method [2]. Each color is one object. There are 3 objects in this case. To acquire the noise correlation information, the transmitter was disconnected during data collection. For this 8-channel system, there were 28 noise correlations for each position of the coil. In this experiment, only the data collected at the position corresponding to the guiding image was used for reconstruction. The E-field was simulated based on the coil geometry by using Matlab. Equation (4) was formed by using the geometry information from the guiding MR image. Equation (4) was then solved using total lease square method. Figure 2 D shows the reconstructed conductivity map. The true relative conductivities of Cu_2SO_4 and *NaCl* are 0.283:1. The result is not ideal because of the short averaging time and narrow bandwidth used, however it gives the right direction and fairly reasonable result.

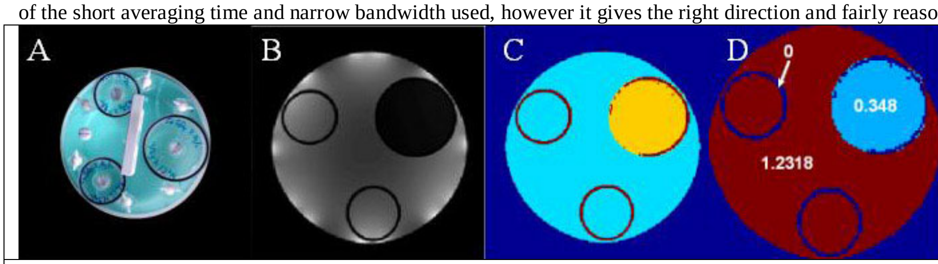

Figure 2. A) The picture of the MR-NT phantom B) The MR image for guiding of geometry information C) The segmentation result D) The reconstructed conductivity map.

Reference:

[1] Reza S, *et al.* ISMRM 2005 submitted

[2] Huang F, *et al.* ISMRM 2005 submitted

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