# Spatially Localized Tissue Fingerprinting (STiF)

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**Target audience:** For those researchers who are interested in EM modeling and tissue properties.

**Introduction:** Brain is mainly composed of three different tissue types with each tissue having different physical, thermal and electrical characteristic properties. Brain MR parametric maps such as $T_1$, $T_2$ and $T_2^*$ provide significant information about such properties and functions and aid in understanding and analyzing their response to an external magnetic field. Spatially localized Tissue Fingerprinting (STiF) provides Non-MR parametric maps based on tissue properties like electrical conductivity, thermal conductivity, tissue density, heat capacity, elasticity and heat generation rate. These maps reflect structural, functional and pathological conditions of the tissues and they can be used for SAR modeling and analysis which are based on tissue types [1].

**Methods:** $T_1$, $T_2$ and Apparent diffusion coefficient (ADC) maps were used to localize brain tissues namely Cerebrospinal fluid (CSF), White matter (WM) and Grey matter (GM) using Magnetic Resonance Fingerprinting (MRF) as described in Ma et. Al [2]. A non-MR property for these tissues like electrical conductivity, thermal conductivity, tissue density, heat capacity, elasticity and heat generation rate were obtained from [3], and contains about sixty eight references for different non-MR properties of tissue, these properties were used for the generation of parametric maps. These properties are very useful in Specific Absorption Rate (SAR) modeling. The equation for SAR is given by, $SAR = \frac{1}{V}\frac{\sigma}{\rho}\int E^2$ [4] where $\sigma$ is electric conductivity, $E$ is electric field strength inside tissue and $\rho$ is mass density of tissue and $V$ is volume of tissue. A dictionary for MRF based matching was built using a range of $T_1$ and $T_2$ values for GM, WM and CSF. The ranges of $T_1$ and $T_2$ values were obtained from acquired MR parametric maps which are in close agreement with previously reported value (range) [2]. $T_1$ map was obtained using spin echo based random repetition time (TR) acquisition and $T_2$ map was obtained using spin echo based variable echo time (TE) acquisition and ADC map was obtained using spin echo sequence with TR=3000 ms and TE=104 ms using Siemens Avanto 1.5T scanner. The $T_1$, $T_2$ and ADC values (range) were then used to localize the brain tissues and to obtain optimal match in the dictionary. MRF was implemented using PSIF sequence and a set of forty eight images were obtained using PSIF (Mirrored FISP ) sequence with pseudorandom TR and FA combinations. Magnetic Resonance Fingerprinting (MRF) [2] was used to perform the match between acquired images and the dictionary entry. Each matched dictionary entry contains multiple tissue characteristic properties which are used to generate parametric maps for electrical conductivity, thermal conductivity, tissue density, heat capacity, elasticity and heat generation rate. Based on the matching result database for other parametric maps were obtained from the dictionary.

**Results:** Figure 1 a, b and c shows the obtained ADC, $T_1$ and $T_2$ map for brain tissues. Range of $T_1$ and $T_2$ values were obtained using ImageJ and are in close match with the previously reported value [2], as can be seen from Table-1. Table-2 gives the corresponding coefficients of tissue properties [3]. Non-MR parametric maps were generated by using MRF to localize tissues and identify different brain tissues and hence retrieve Non-MR Parameters from matched database, the block diagram for STiF work flow can be seen in Figure-2. Figure-3 shows Non-MR parametric maps were generated using STiF for electrical conductivity, thermal conductivity, tissue density, heat capacity, elasticity and heat generation rate.

**Discussion and Conclusion:** STiF is a fast and efficient computational method which relies on Lookup Table (LUT) approach rather than a tedious procedure of segmentation to determine electrical conductivity and mass density of tissues. Mapping of MR data to Non-MR parametric maps help to understand the tissue behavior and hence can be used to build tissue specific models, Non-MR parametric maps generated using tissue properties will help in better understanding the function of brain matters and their properties. Electrical field inside the tissue generates heat which can be determined using heat generation maps, the electrical conductivity of particular tissue type and density of the tissue determines the SAR factor. Ventricles in the Figure-3 have partial volume artifact so partial area of the ventricles are filled with default values. MR Elastography maps such as Figure-3c would also prove to be useful for simulation of data related to MR Elastography.

**Future works:** To relate MR data with non-MR parametric maps through analytical solutions so as to map a range of MR parameters to a range of non-MR parameters via tissue characteristics similar to MRF which maps signal evolution to MR parametric maps.

**References:** [1] Pabitra N. Sen, et al., Biophysical Journal 2005. [2] Ma D et al. *Nature*. 2013;495(7440):187–92. [3] (www.itis.ethz.ch_assets_Downloads_TissueDb_Files20140801_References_20140801). [4] Graesslin I et al. *Magn. Resn. Med.* 2012.

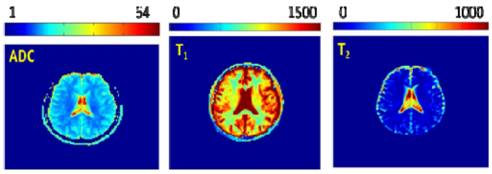


*Figure-1: a)ADC b)$T_1$ map and b) $T_2$ map of brain*

| Brain Matters | T1 (ms) | T2 (ms) |
|---|---|---|
| Cerebrospinal Fluid | 4135.2 | 2081.9 |
| Previously Reported | 4103-5400 | 1800-2460 |
| White Matter | 710 | 99.64 |
| Previously Reported | 608-756 | 54-81 |
| Grey Matter | 1220 | 87.06 |
| Previously Reported | 998-1304 | 78-98 |

*Table-1: $T_1$ and $T_2$ range of brain matters*

| Property | Cerebrospinal Fluid | Grey Matter | White Matter |
|---|---|---|---|
| Electrical Conductivity (S/m) | 1.96 | $2.55*10^{-6}$ | $7.97*10^{-1}$ |
| Elasticity (kPa) | - | 5.22 | 13.6 |
| Thermal Conductivity (W/m/°C) | 0.57 | 0.55 | 0.48 |
| Density (kg/m³) | 1007 | 1045 | 1041 |
| Heat Capacity (J/kg/°C) | 4096 | 3696 | 3583 |
| Heat Generation Rate(W/kg) | 0 | 15.53 | 4.34 |

*Table-2: Properties of brain matters and their corresponding values*

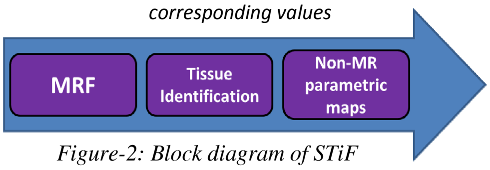


*Figure-2: Block diagram of STiF*

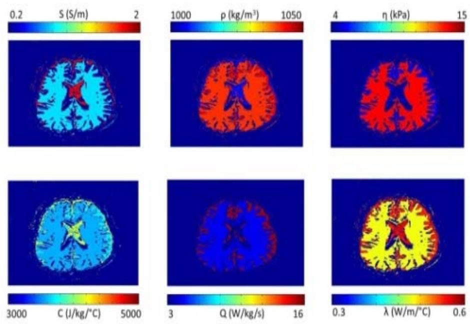


*Figure-3: Generated (top row L-R) a) Electrical conductivity b) Density c) Elasticity (bottom row L-R)d) Heat capacity e) Heat generation rate and*