# IMAGING ELECTRICAL CURRENT DENSITY USING 0.15T MAGNETIC RESONANCE IMAGING SYSTEM

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**Abstract -** In this study, electrical current density in conducting objects, which contain nuclear magnetic resonance (NMR) active nuclei is imaged using a 0.15T Magnetic Resonance Imaging (MRI) system. Current to be imaged is externally applied to the object in synchrony with a standard spin-echo pulse sequence. Applied current pulse creates a measurable magnetic flux density. Measurement of all three components of magnetic flux density makes the reconstruction of current density possible with a spatial resolution equal to the half of the MR resolution.

**Keywords -** Magnetic Resonance Imaging, Current Density, MR-CDI

## INTRODUCTION

Knowledge of spatial distribution of externally applied electrical current to the body provides vital information in many biomedical engineering applications. For example, current density distribution on the myocardium during cardiac defibrillation is very important to optimize the defibrillation efficacy [1, 2, 3]. Determination of electrical current density applied between a pair of electrodes can be used to determine lead-sensitivity maps of biopotential recording set-ups (i.e. ECG, EEG, etc.) [4]. Finally, accurate measurement of current density distribution may lead to high fidelity conductivity imaging [5]. Which could be utilized to improve the accuracy of ECG and EEG volume conductor models.

Joy et al. [6] and Scott et al. [7, 8] have demonstrated the possibility of imaging current density inside a volume conductor, which contains Nuclear Magnetic Resonance (NMR) active nuclei, by using MRI. Referred studies have been carried on a 2T MRI System. In this work, a 0.15T Imaging System, at Middle East Technical University, is used.

## THEORY

Nuclear Magnetic Resonance imaging techniques can be utilized to image spatial distribution of electric current density. For this purpose, two magnetization density measurements with and without the applied current are required.

Magnetization density when no current is applied:

$$M_c(x,y) = M(x,y)\exp[j\ \ Bt + j\ \ _c]$$

Magnetization density when current is applied:

$$M_{cj}(x,y) = M(x,y)\exp\{j\ \ [Bt + B_j(x,y)T_c] + j\ \ _c\}$$

Taking the ratio,

$$\frac{M_{cj}(x,y)}{M_c(x,y)} = e^{j\ \ B_j(x,y)T_c} \longrightarrow \text{normalized phase term}$$

$$B_j(x,y) = \frac{\quad}{\ \ T_c}$$

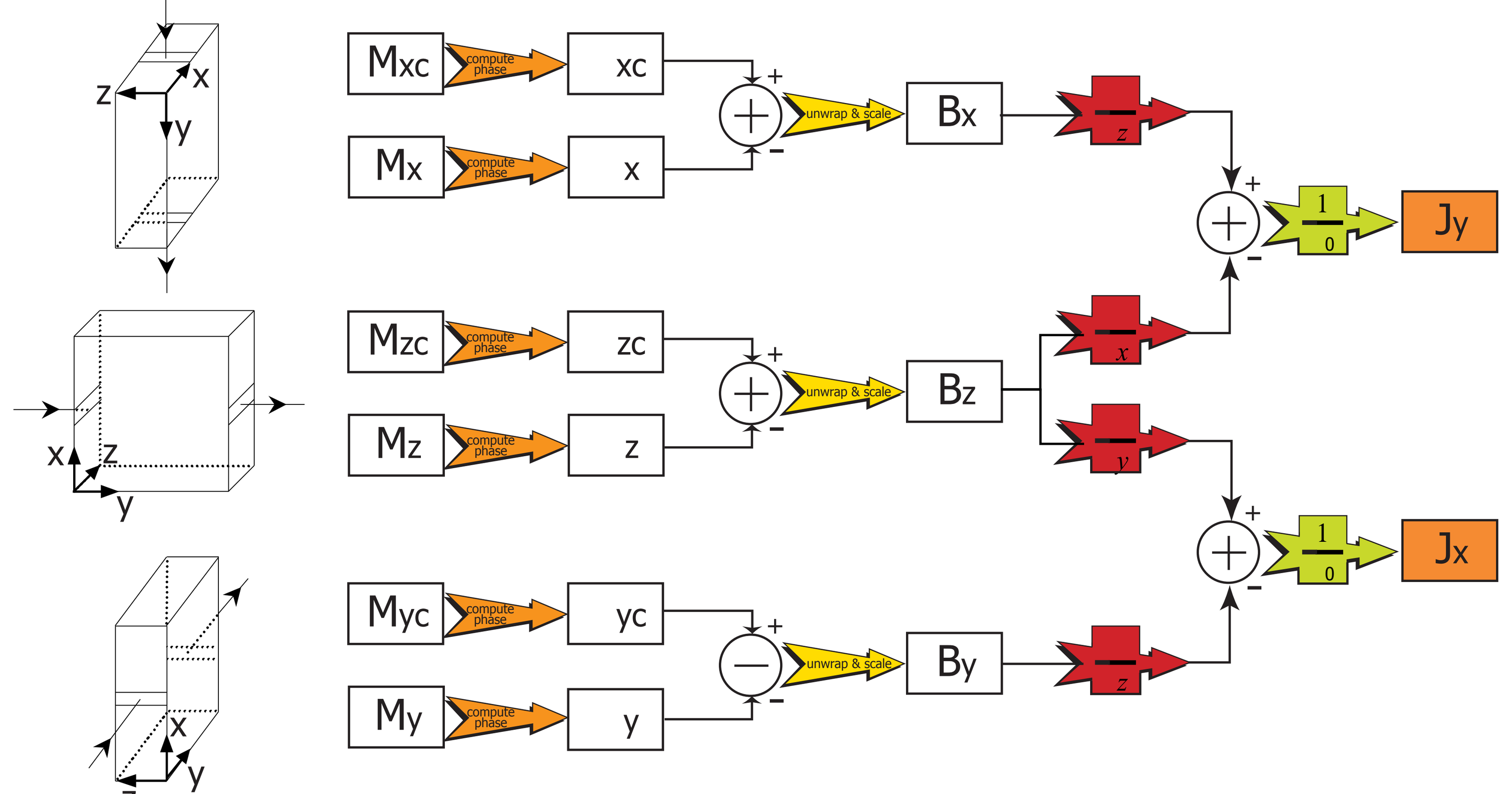
□where $B_j$ : magnetic flux density
$T_c$ : total duration of applied current
: gyromagnetic constant

## METHODOLOGY

Current density can be obtained by the magnetic flux density.

$$\vec{J} = (\quad \vec{B})/\ \ _0$$

To obtain current density in all three directions, $B$ field must be known in three orthogonal directions. Since only the parallel component of $B$ with the main magnetic field is measurable in one configuration, three sets of measurements are done. A diagram showing the steps required to obtain the current density from magnetization distribution is given below. The orientation of the object for each configuration is sketched on the left side of the diagram.



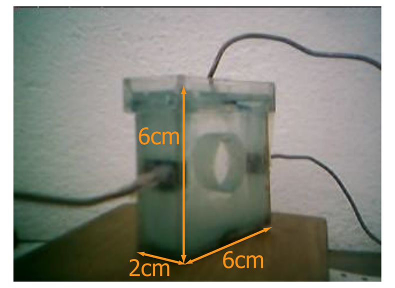

**Mxc** is the **M**agnetization in **x** direction with **c**urrent pulse applied.
**Mx** is the **M**agnetization in **x** direction with no current pulse .
$B_0$ shows the main magnetic field.

## EXPERIMENTAL SETUP

**Main Magnet**

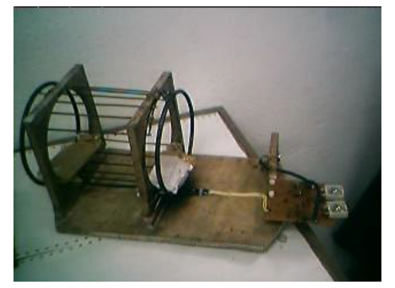
Oxford 0.15 Tesla. Resistive air core. 80 cm bore.

**Phantom**




Filled with 12.5g/l NaCl, 2g/l $CuSO_4 \cdot H_2O$ solution. 2x1cm copper electrodes. 1mm electrode thickness.

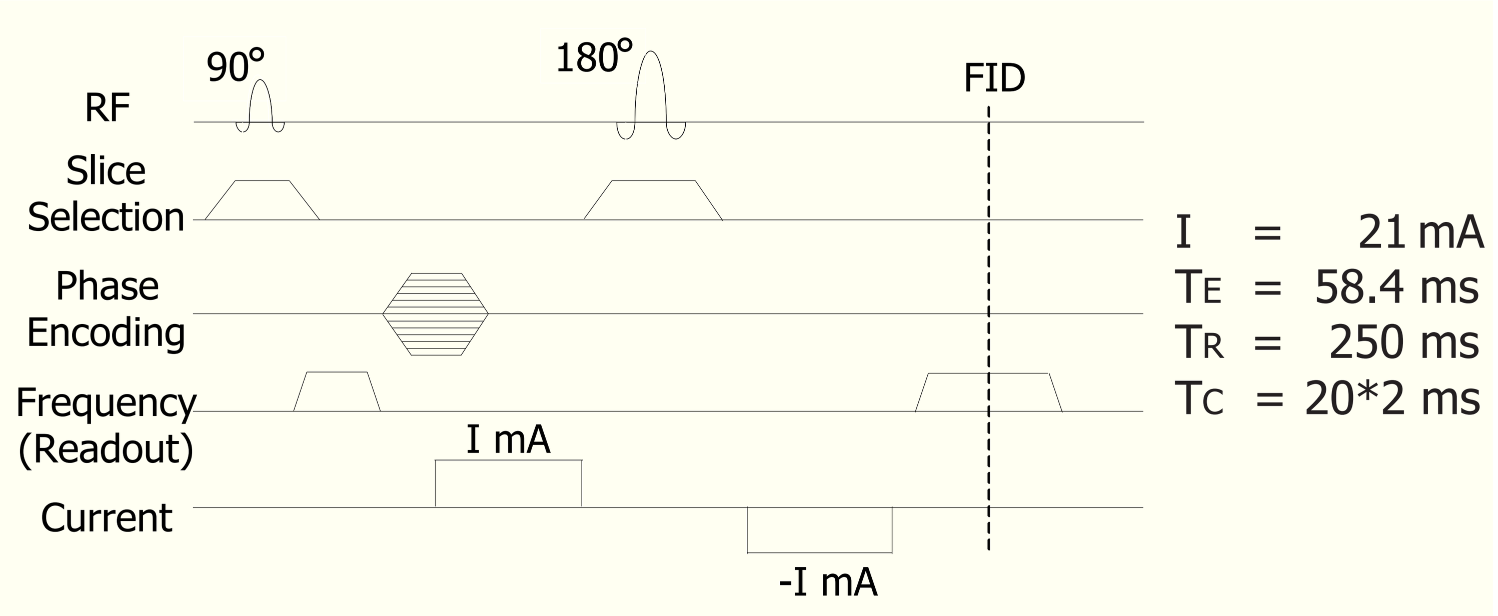
**Coil**



Saddle type. 30 cm diameter. 3 turns each side. Tuned to 6.4 MHz.

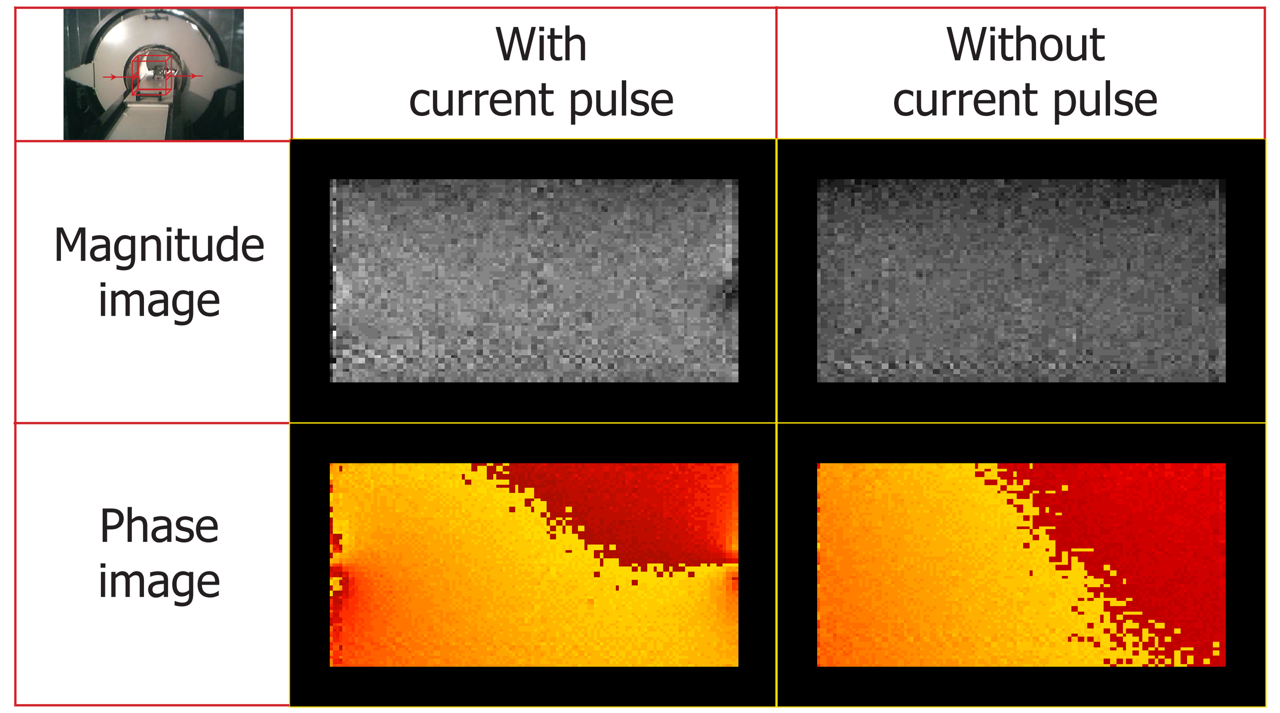
### MRCDI Pulse Sequence

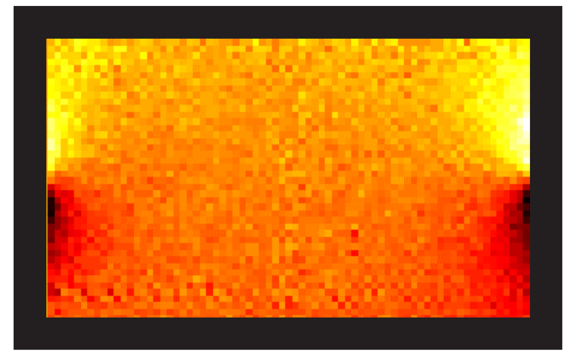
External current is applied to the conductor in synchrony with a standard spin echo pulse sequence.




## RESULTS

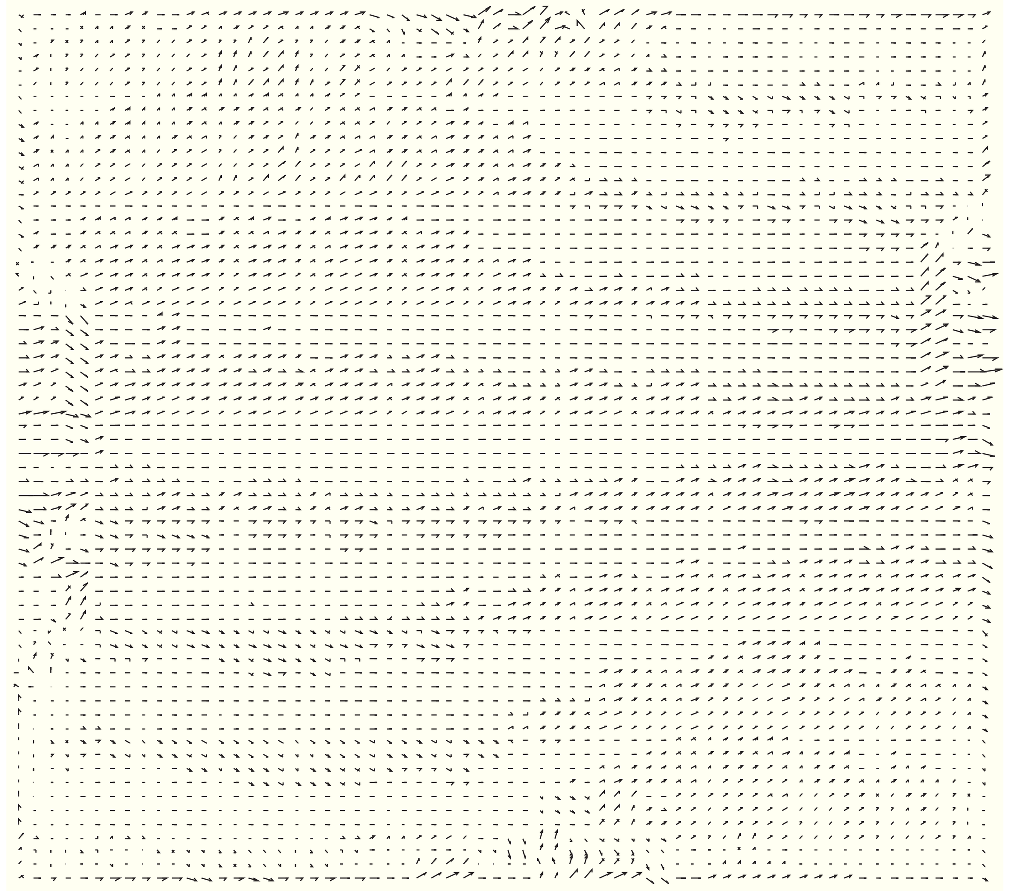
Magnitude and phase images with and without current pulses are shown below. The images are axial and object orientation is shown in the upper left part.



Phase unwrapped normalized phase image obtained by using the two phase images above. This image is in fact a scaled version of magnetic flux density. Red regions represent the magnetic flux density pointing into the page, while yellow ones represent that out of the page.

Repeating the same scenario to obtain the other two components of magnetic flux density, current density can be calculated as described above. The result is plotted below. The direction and length of the arrows in the plot shows the direction and magnitude of the current density.



## CONCLUSION

In this study, current density images are practically realized in a low field (0.15 T) MR system satisfactorily. Accurate measurement of current density distribution may lead to high fidelity conductivity imaging. A study aiming at reconstructing conductivity images using the current density measurement will also be presented at this conference [9].

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