

# Complex Histogram Based Analysis for Visualization of MRI Data

P. A. Wassenaar<sup>1</sup>, M. V. Knopp<sup>1</sup>, and P. Schmalbrock<sup>1</sup>  
<sup>1</sup>Radiology, The Ohio State University, Columbus, OH, United States

## Introduction

Over the last decade, there has been an increased awareness of the value of the information contained in the phase component of MRI data [1-4]. Especially at high field strengths, the phase contains useful information stemming from the presence of paramagnetic material inside tissue. This work introduces a new approach to represent and visualize complex MRI data, and demonstrates its potential in tissue classification through a complex mapping scheme.

## Methods

Data were acquired at 7 Tesla (Philips Achieva) using 3D FFE sequences with TE=10-12ms, with complex information preserved. Phase unwrapping was achieved through the removal of low frequency phase variations through k-space filtering [1-2]. All data analysis was performed using IDL (ITT). For localized data analysis, ROIs were selected in brain data acquired on healthy volunteers and formalin fixed multiple sclerosis tissue specimens. The statistical characteristics of both the real and the imaginary components of the data in different brain tissues were represented as histograms in a complex plane. Furthermore, from the complex histograms, images were displayed using a complex color map to visualize both magnitude and phase simultaneously.

## Results

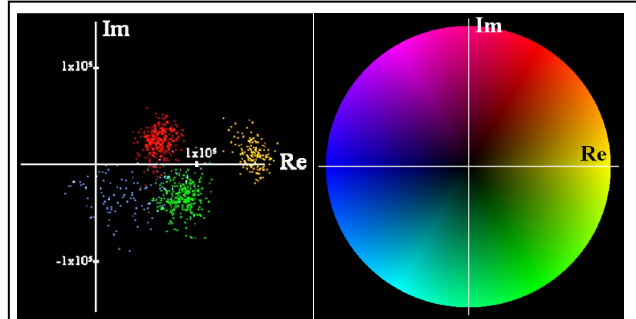
Figure 1 shows a complex plane with data from different brain tissues presented as distributions in different colors. The corresponding ROIs are indicated in both the magnitude and unwrapped phase images of the gradient echo sequence shown in Figures 3a and b. One can see that the selected brain tissues occupy specific regions in the complex plane, with their locations being representative of their means and spreads in magnitude and phase. Using the complex plane as a starting point, complex color maps were generated to visualize both the magnitude and phase images simultaneously. Each point in the complex plane is assigned a unique color according to the color wheel shown in Figure 2. A resulting image, shown in Figure 3c, clearly displays both phase and magnitude characteristics contained in one image. Unlike the approach where magnitude and phase images are multiplied, this method retains all information. Furthermore, the human eye can distinguish color changes more easily. Clearly visible are transitions in color in the regions surrounding the putamen and the caudate nucleus. In this scheme, blue colors represent bulk susceptibilities, as seen near airspaces and large vessels. Red-green variations correspond to mesoscopic effects, due to iron loaded cells and small vessels. Figure 4 shows the results as applied to a MS brain specimen. While phase variations appear minimal, good color contrast can be noted, depicting substructure in the lesions.

## Discussion

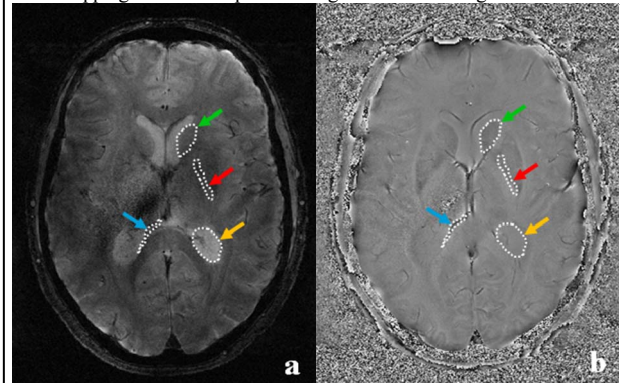
Complex histogram based analysis provides a new approach to visualizing complex MRI data, and gives insight into different tissue types at high fields. Complex histograms can show the separation of data in terms of both magnitude and phase. This approach allows for a new way of displaying both characteristics simultaneously, while retaining phase and magnitude information. Furthermore, it may provide a starting point for tissue segmentation through constraints defined in the complex plane.

## References

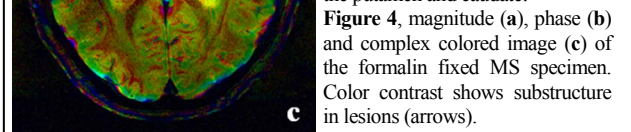
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**Figure 1**, complex histogram showing brain tissues as clouds in a plane: red: posterior limb of internal capsule, green: caudate nucleus, blue: sinus sagittalis inferior, yellow: lateral ventricle. **Figure 2**, an example complex color mapping scheme to represent images as shown in Figure 2c.



**Figure 3**, a magnitude (a) and phase image (b) of a healthy brain (0.3x0.3x1.0mm<sup>3</sup>). Indicated are the ROIs used for Figure 1. The colored image (c) was acquired using the complex color map of Figure 2. All magnitude and phase characteristics are preserved. Note the red-green contrast surrounding the putamen and caudate.



**Figure 4**, magnitude (a), phase (b) and complex colored image (c) of the formalin fixed MS specimen. Color contrast shows substructure in lesions (arrows).

