COMP6803 Seminar

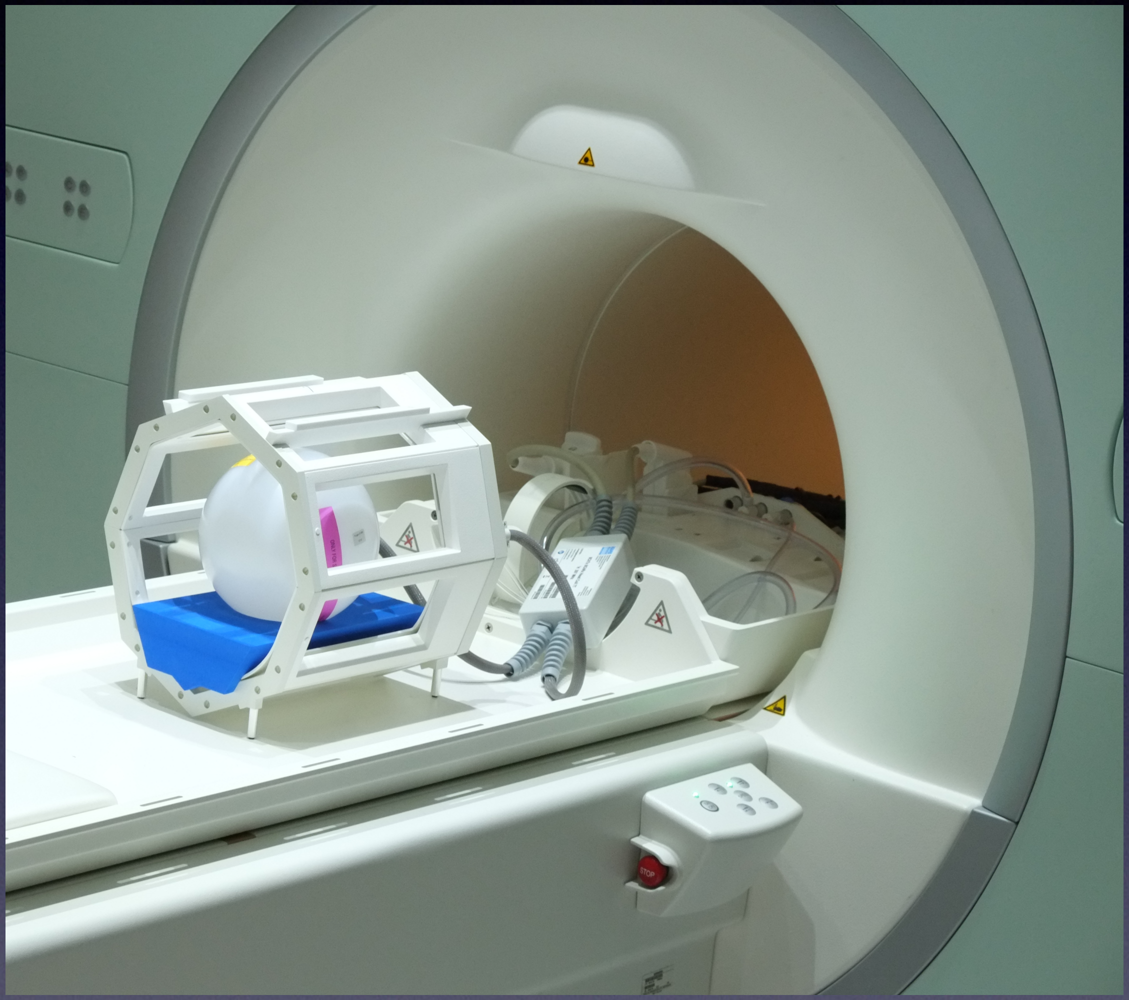
Design Parallel Transmission Radio-frequency Pulse for Siemens 7 Tesla whole-body MRI

Presenter: Xu Yangyang

Project Supervisor: Dr Jin Jin

What's next

- Why do I do this project?
- What values does it provide?
- Milestones
- What have I done?
- Demo
- Q&A Session



Why do I do this project?

What is Ultrahigh Field MRI?

main field strength $\geqq$ *7T*

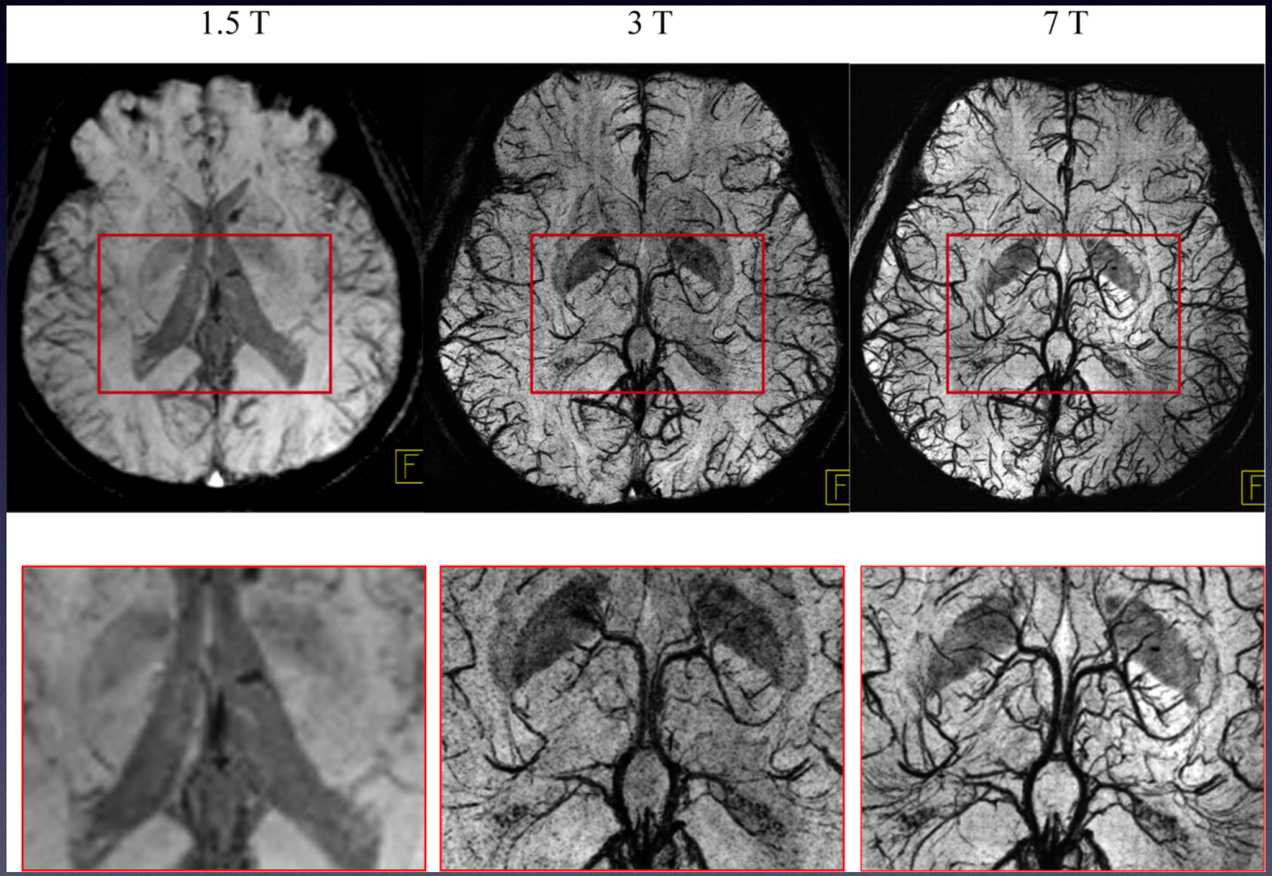
“Why Buy an Expensive ($7 Million) 7T MRI System for Biomedical Research?”

–Ravinder R. Regatte PhD

The Benefits of Ultra-High Fields MRI

Advantages of High Fields:

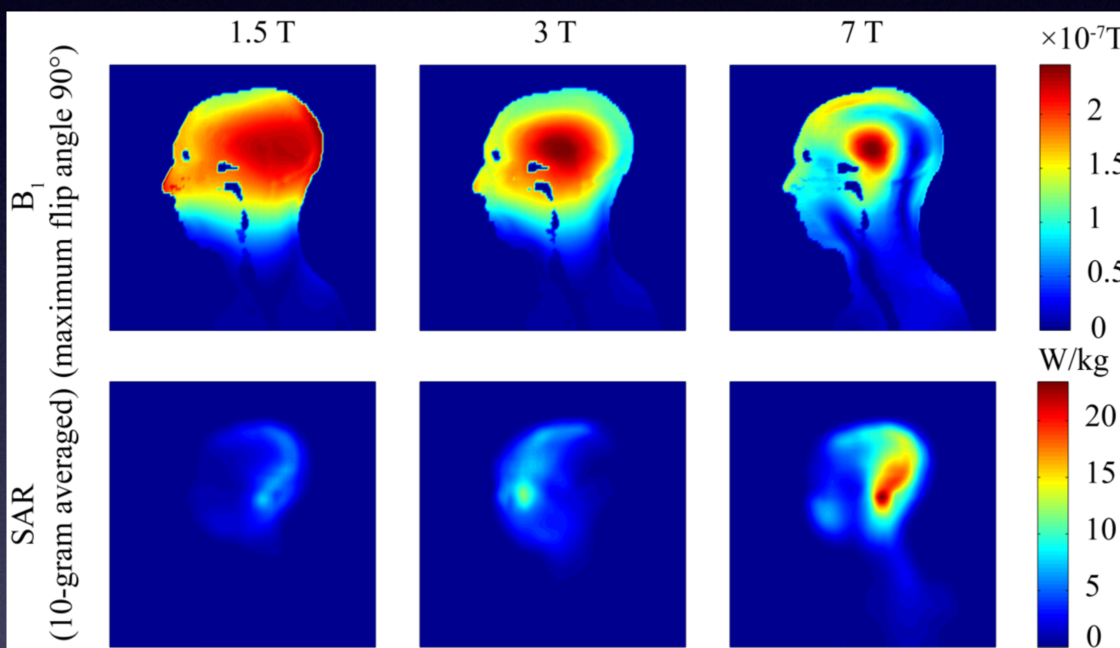
- High signal-to-noise ratio (SNR)
  - SNR scales with B_0
- High spatial/temporal resolution
- Novel contrast mechanisms
  - SWI(susceptibility weighted imaging)
  - fMRI



SWI venography of a 30-year-old female patient at 1.5 T, 3 T and 7 T
[Image courtesy of Siemens Healthcare]

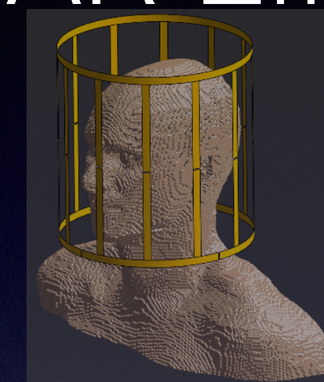
Two Challenges of Ultrahigh Field MRI?

1. Inhomogeneity of B1



Caused by shortened wavelength of electromagnetic waves at UHF

2. SAR Effect



SAR: Specific Absorption Ratio

SAR "hotspot" -> patient safety

$$\mathrm{SAR} = \frac{1}{V}\int_{\text{sample}} \frac{\sigma(\mathbf{r})|\mathbf{E}(\mathbf{r})|^2}{\rho(\mathbf{r})} d\mathbf{r}$$

where

- σ is the sample electrical conductivity
- E is the RMS electric field
- ρ is the sample density
- V is the volume of the sample

Solutions for Challenges

Parallel Transmission (pTx): B1 Shimming(the simplest form of pTx)

Multi transmit coils support the free of controlling channel

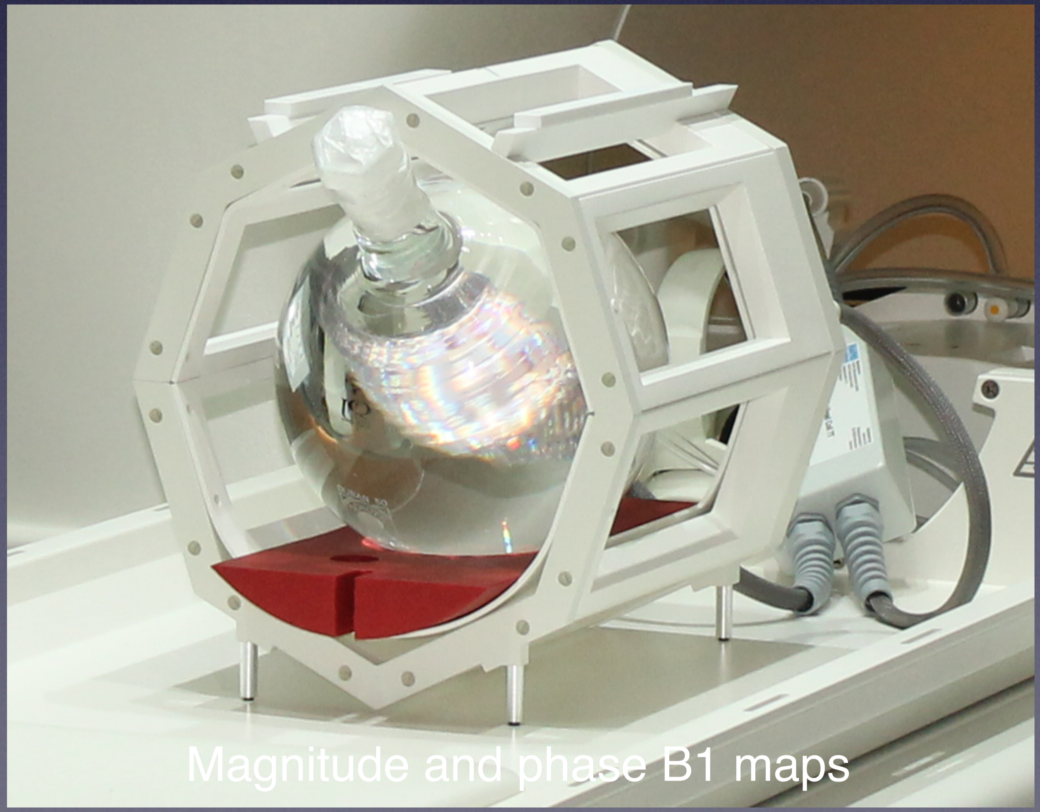
For getting a suitable combination of transmit:

How to find combination?

Control magnitudes and phases of individual channels

How suitable?

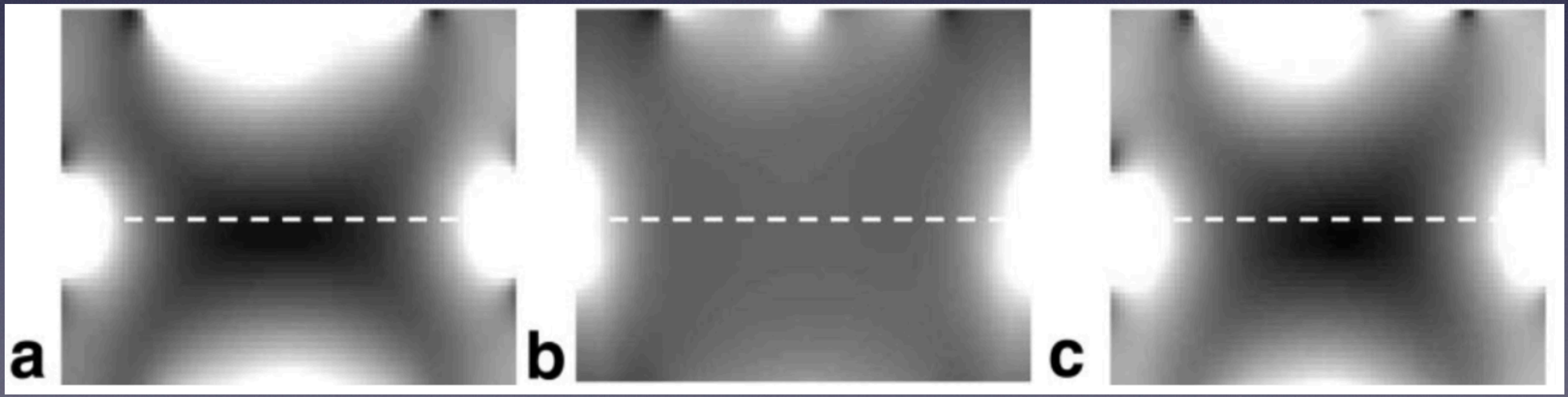
Have most favourable interference pattern for magnetic field and electric field.



Amplitude Phase

Table 1
The Amplitudes and Phases Drives for Each Coil Element in the Three Schemes

	Nonfocused (identical drive scheme)		Focused (focused drive scheme)		Circular phased (circular drive scheme)	
	Amplitude (V)	Phase	Amplitude (V)	Phase	Amplitude (V)	Phase
Coil 1	10	90°	12	45°	10	0°
Coil 2	10	90°	12	45°	10	0°
Coil 3	10	90°	11.69	90°	10	180°
Coil 4	10	90°	11.69	90°	10	180°
Coil 5	10	90°	12	180°	10	90°
Coil 6	10	90°	13.57	0°	10	90°
Coil 7	10	90°	12	180°	10	270°
Coil 8	10	90°	13.57	0°	10	270°



Focused, Eight-Element Transceive Phased Array Coil for Parallel Magnetic Resonance Imaging of the Chest—Theoretical Considerations

Solutions for Challenges

Parallel Transmission (pTx): Kt-spoke(more advanced & controllable pTx)

B1 shimming Vs. Kt-spoke

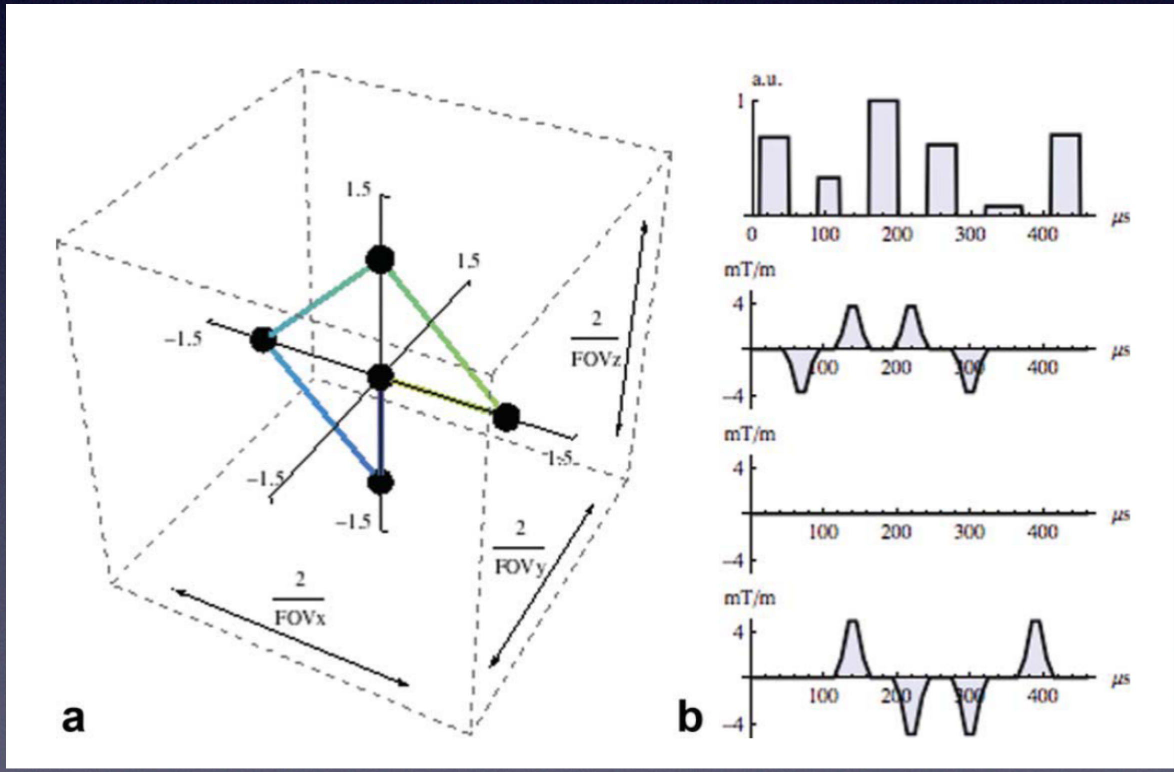
Once B_1 shimming	Multiple B_1 shimming
Single pulse	Multiple pulses

Other characters of Kt-spoke

Shimming at space points

Gradient controls:

the trajectory(k-Space transversal)



Cloos M.A., MRM, 2012

Homogeneity

Table 1
Measured FA Homogeneity and Energy-Balance Obtained with Different Excitation Pulse Strategies

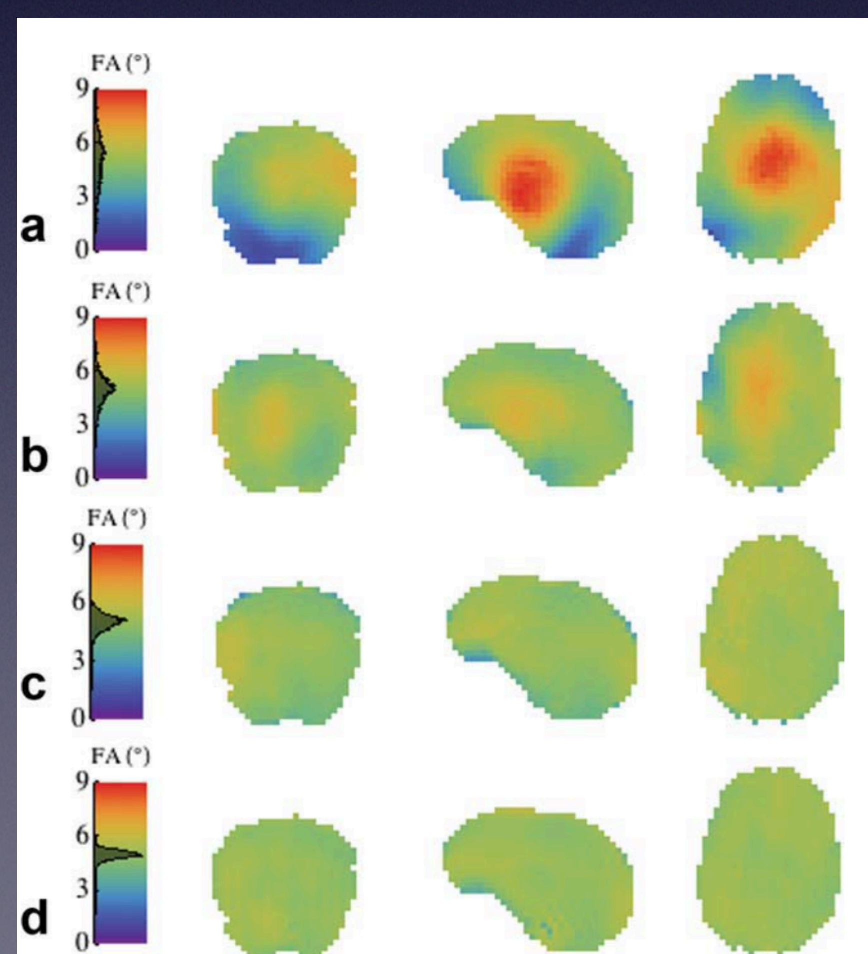
	Subject 1				Subject 2				Subject 3			
	CP-mode	Static-shim	5 k_T Points	7 k_T Points	CP-mode	Static-shim	5 k_T Points	7 k_T Points	CP-mode	Static-shim	5 k_T Points	7 k_T Points
Pulse duration (μs)	100.0	100.0	440.0	570.0	100.0	100.0	430.0	540.0	100.0	100.0	430.0	630.0
Forebrain and midbrain (%)	28.9	17.0	7.2	7.0	29.2	25.6	7.4	8.3	35.4	16.7	8.0	6.2
Cerebellum (%)	47.8	13.8	11.3	10.6	53.2	38.6	16.0	18.7	60.4	19.4	15.5	11.0
Total brain (%)	31.7	16.7	7.8	7.5	31.5	26.6	8.3	9.4	35.5	17.0	8.9	6.8
Total energy (mJ)	67.8	88.7	95.4	108.0	71.5	111.0	102.0	111.0	81.6	113.6	103.0	80.2
MTE channel (mJ)	8.5	29.8	19.0	22.6	8.9	42.0	16.4	20.6	10.2	40.2	17.6	31.4

CP-mode

Static-shim

5 Kt-Points

7 Kt-Points



Homogeneity trend

k_T-Points: Short Three-Dimensional Tailored RF Pulses for Flip-Angle Homogenization Over an Extended Volume

What values does it provide?

When do you need it?

-Need to do B1 shimming and k_T-spoke pulse

-Need to compare pTx MRI results

-Saved too many fragments of Matlab scripts for different experiment results.

-Spent too much time on coding rather than doing actual research experiment.

Who will use it?

-Students

-Professors

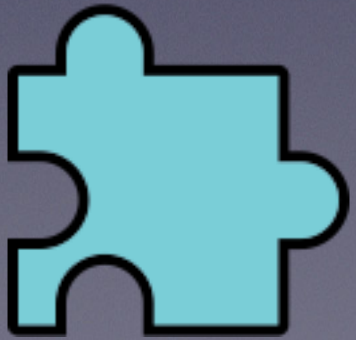
-Researchers

Why it?

-Efficient

-User Friendly

-Expandable



-Editable

Current Version

This app is tested with phantom and volunteer experiments using the state-of-the-art 7 Tesla MRI system located at the Centre for Advanced Imaging, UQ, St Lucia.

Milestones

Next Tasks

Milestone 2:	
15 May 17 -28 May 17	Make the VOI feature, which has the same shapes and shape modes as ROI.
29 May 17 - 11 Jun 17	Make Amplitude-Phase shim.
12 Jun 17 - 25 Jun 17	Verify VOI and Amplitude-Phase shim functionality.

Milestone 3:	
26Jun17-9July17	1. Implement K_T-shim on UI: • Get gradient location (manual input). • Define and calculate number of pulses.
10 July 17 - 6 Aug 17	Implement K_T-shim algorithm
7 Aug 17 - 20 Aug 17	Verify K_T-shim functionalities.

Milestone 4:	
21 Aug 17 - 15 Oct 17	Prepare poster and demonstration. Start writing thesis.
16 Oct 17 - 29 Oct 17	Do poster and demonstration on 20 Oct 17.
30 Oct 17 - 6 Nov 17	Refine thesis draft. Final thesis due on 6 Nov 17.

Completed Tasks

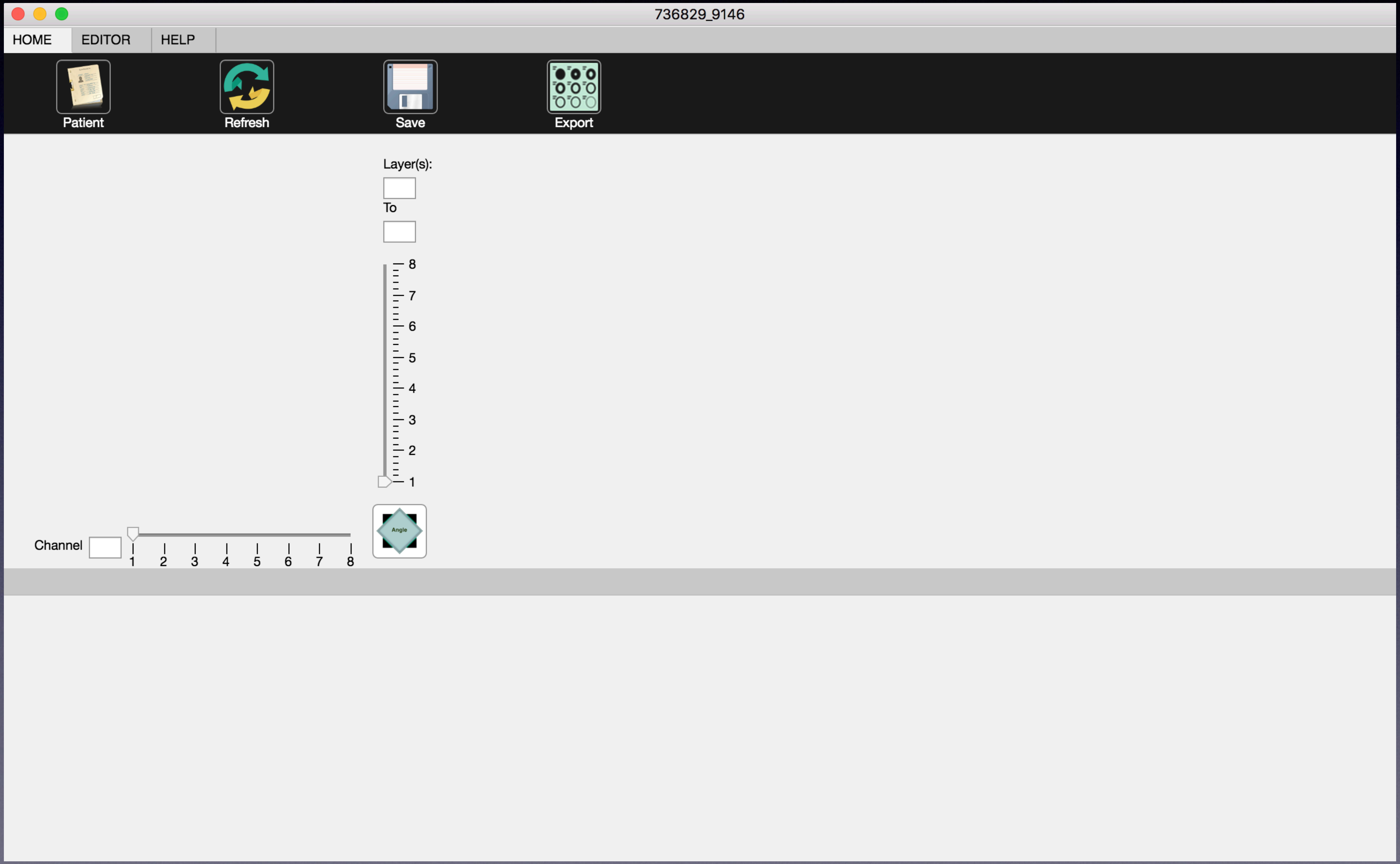
Milestone 1:	
20 Mar 17 - 2 April 17	Made a prototype. Added phase-only shim functionality for single slice.
3 April 17 - 16 April 17	Made the ROI feature, which supports three types of shape and merge/subtract functionality. Added Gaussian filter.
17 April 17 - 30 April 17	Made import functionality for both of dixim and raw data of B1+ maps which are from scans. Made export file be Siemens-format (.ini file).
1 May 17 - 14 May 17	Verified ROI and Phase-only shim functionality.

What have I done?

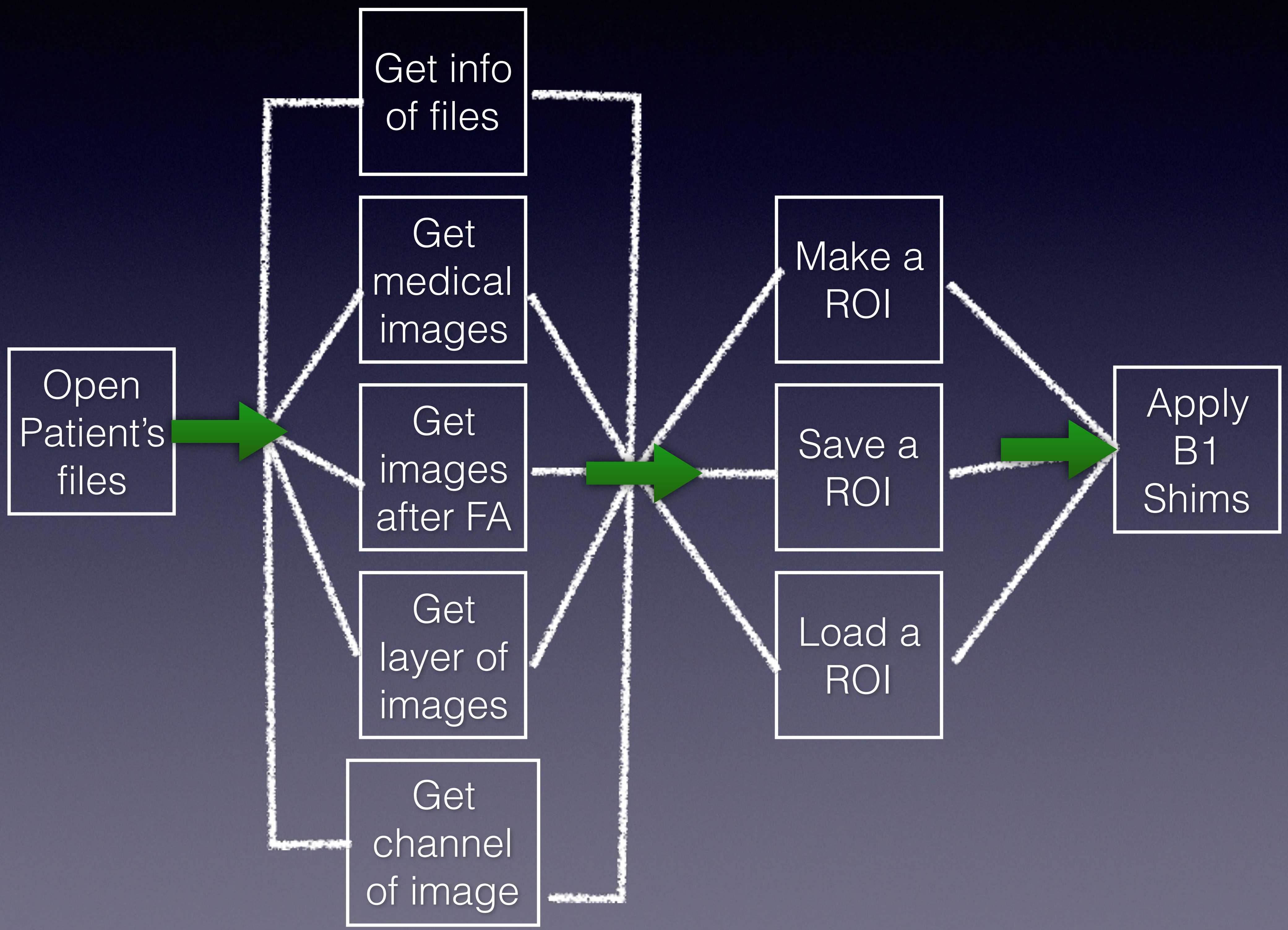
Tools used in this project

MATLAB

GUI


736829_9146
HOME
EDITOR
HELP
Patient
Refresh
Save
Export
Layer(s):
To
8
7
6
5
4
3
2
1
Channel
1
2
3
4
5
6
7
8
Angle

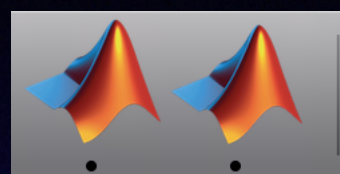
Work Flow

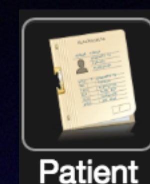


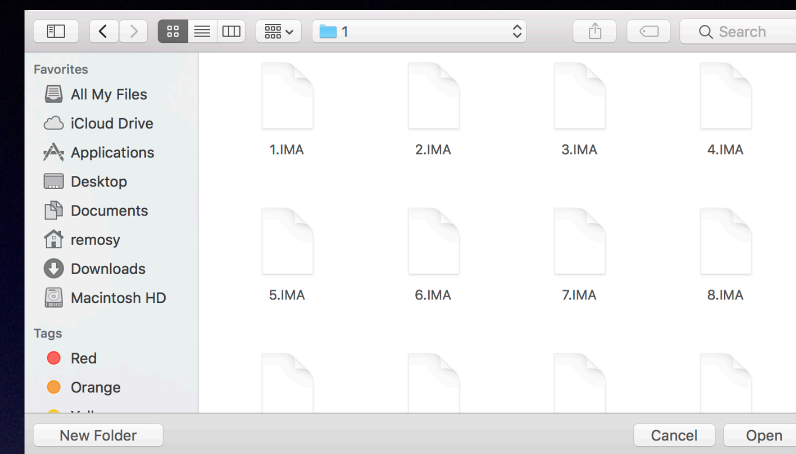
Get info of files
Get medical images
Open Patient's files
Get images after FA
Get layer of images
Get channel of image
Make a ROI
Save a ROI
Load a ROI
Apply B1 Shims

Demo

Open File





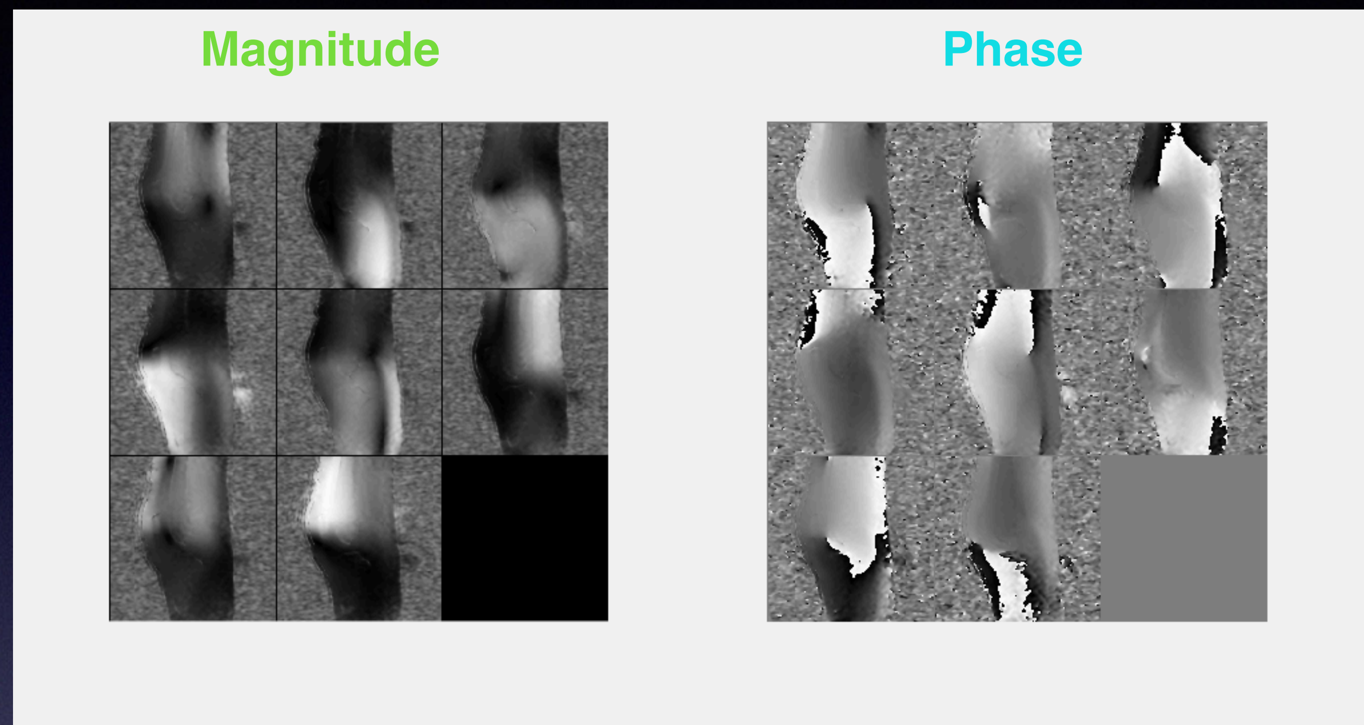


Function	**Class**	**Shared Doc**
LoadFile.m	ImageData.m	sort_nat folder
gui_Main.m		

ImageData

ID
ImageSignal
ImageAngleSignal
ImageAmplitude
ImagePhase
NumSlice
NumChannel

Solve MRI raw files



Code: ImagSig = MagSig.*exp(1i.*PhaSig)

Code: PhaSig = angle (ImagSig)

MagsigFormula $B_1^+ = \sum^n_{n=1} (B_1^+)_n \, e^{i\theta}_n$

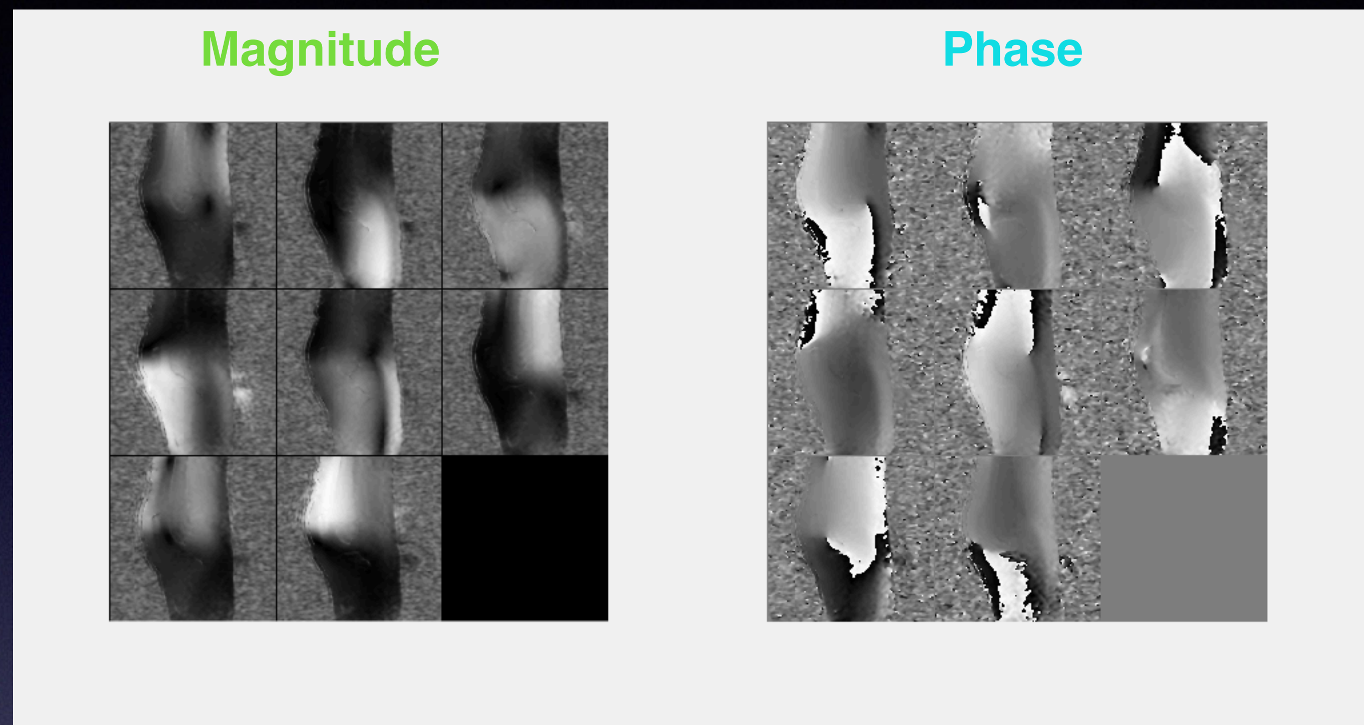
n means the n-th number of coil n= 1, 2, 3, 4, 5, 6, 7

and 8;

i is the imaginary unit;

θ_n *denotes the phase angle of the n-th channel.*

Solve MRI raw files



Code: ImagSig = MagSig.*exp(1i.*PhaSig)

Code: PhaSig = angle (ImagSig)

MagsigFormula $B_1^+ = \sum^{n}_{n=1} (B_1^+)_n \, e^{i\theta}_n$

User defined: Channel

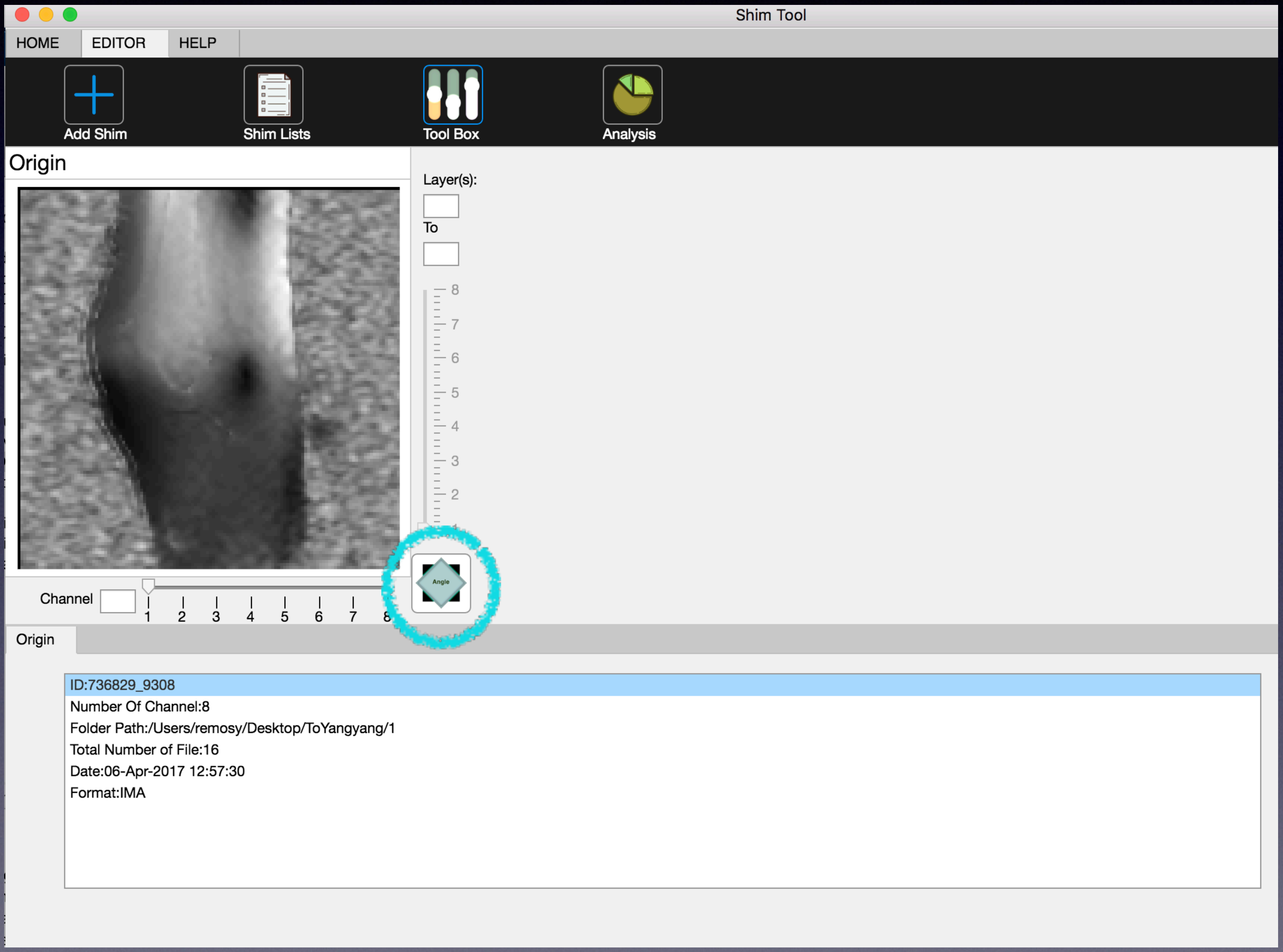
First half of files: Signal Magnitude

n means the n-th number of coil n= 1, 2, 3, 4, 5, 6, 7 and 8;

i is the imaginary unit;

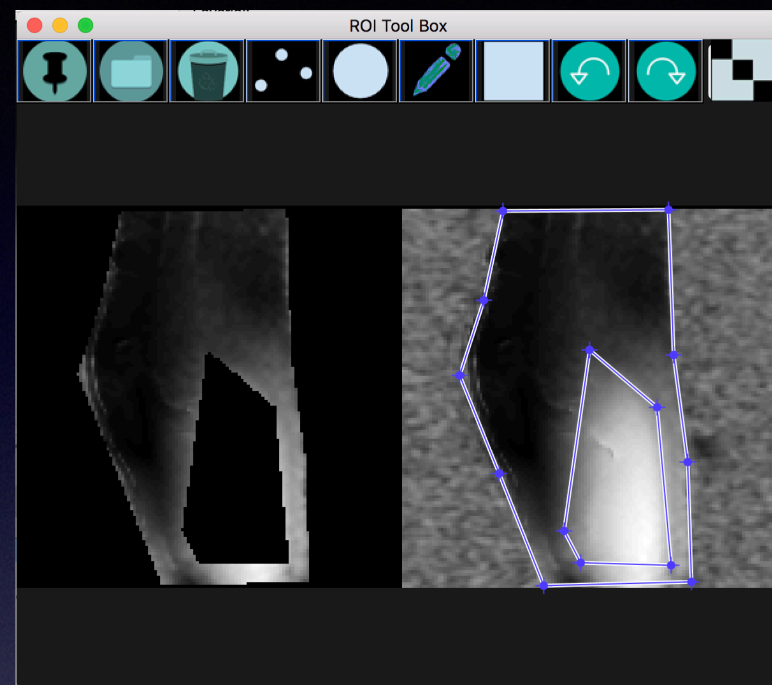
θ_n *denotes the phase angle of the n-th channel.*

What's on…



Shim Tool
HOME
EDITOR
HELP
Add Shim
Shim Lists
Tool Box
Analysis
Origin
Layer(s):
To
Channel
Origin
ID:736829_9308
Number Of Channel:8
Folder Path:/Users/remosy/Desktop/ToYangyang/1
Total Number of File:16
Date:06-Apr-2017 12:57:30
Format:IMA

Add a ROI



Addition

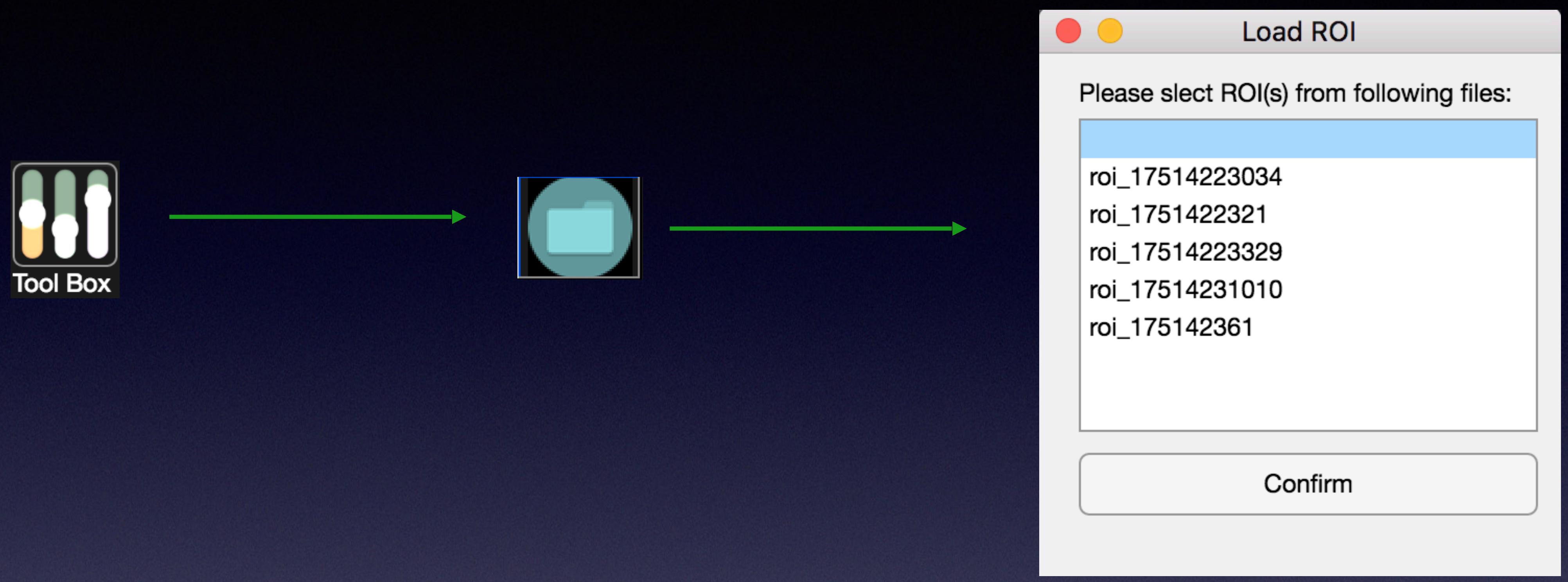
Code:this.mask = this.mask | BWadd;

Subtraction

Code:this.mask = this.mask & -BWadd;

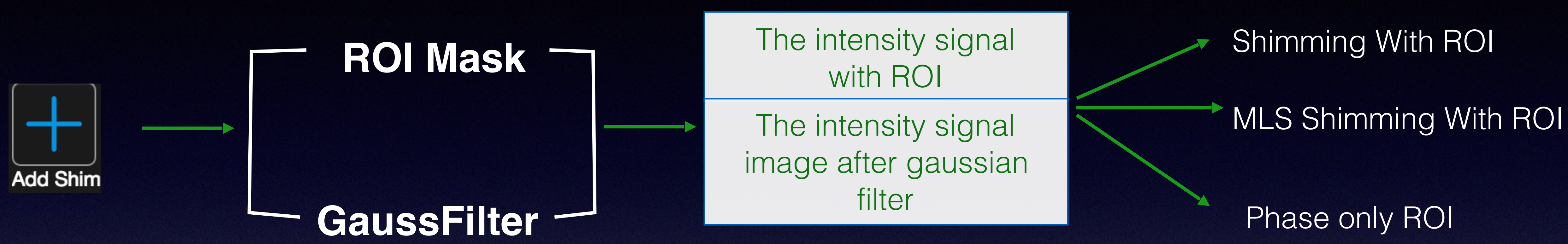
Function	Class
gui_Main.m	ImageData.m
	ROI_gui.m

Load a ROI



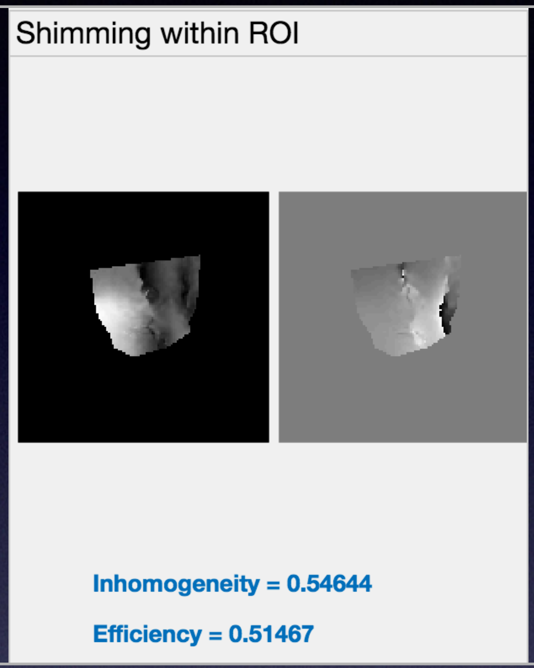
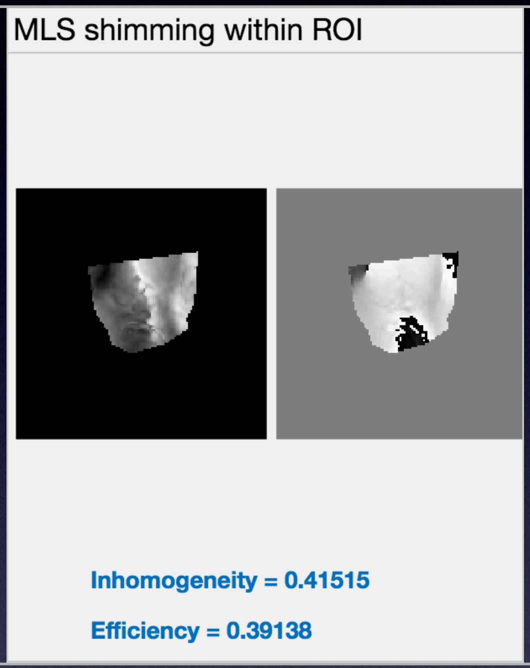
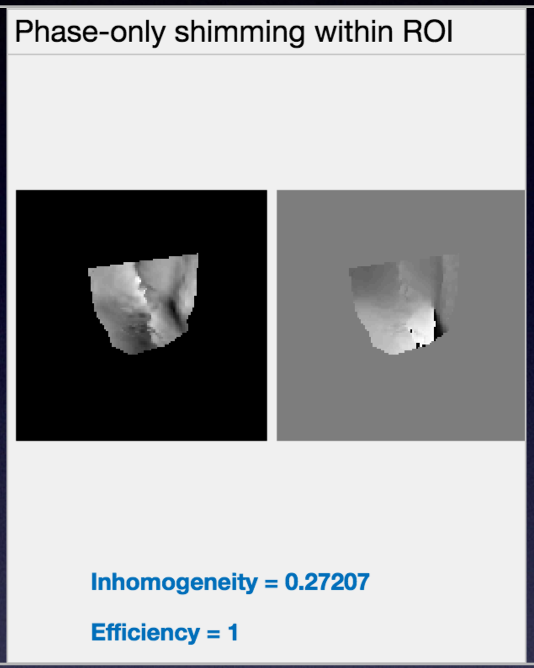
Function	Class
gui_Main.m	ImageData.m
	ROI_gui.m

Apply B1 Shims



Function	Class	Shared Doc
Shim.m	ImageData.m	myMLS.m
GuessFilter.m		
gui_Main.m		

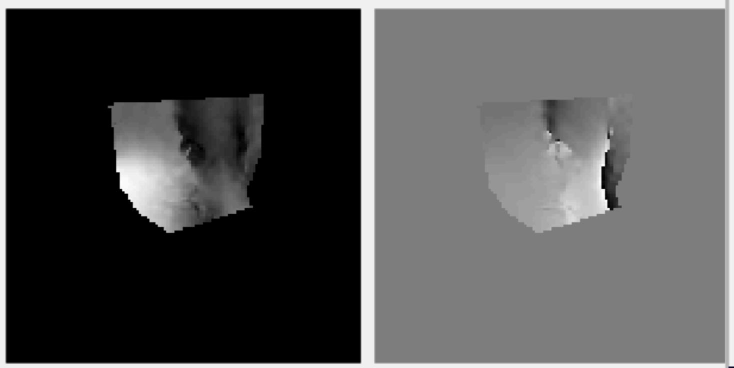
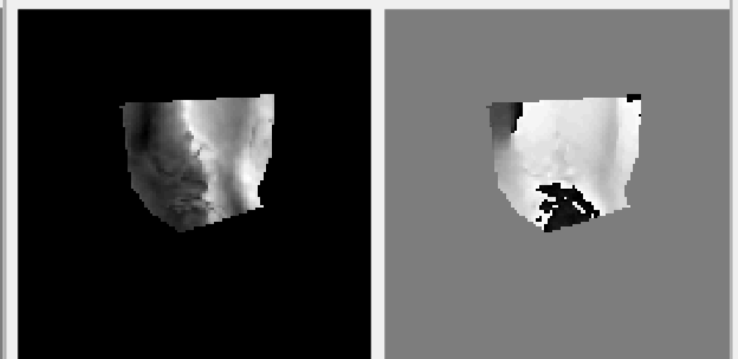
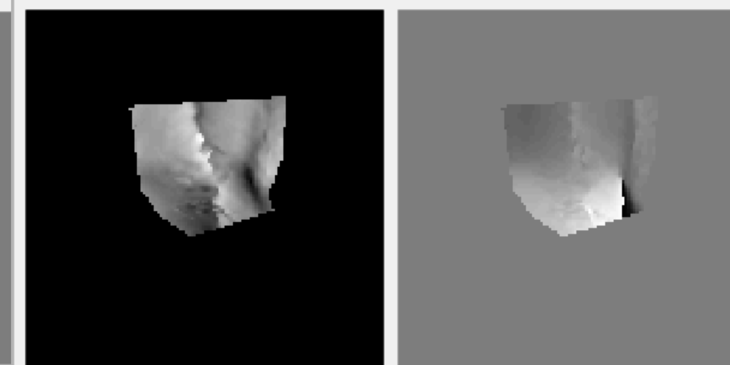
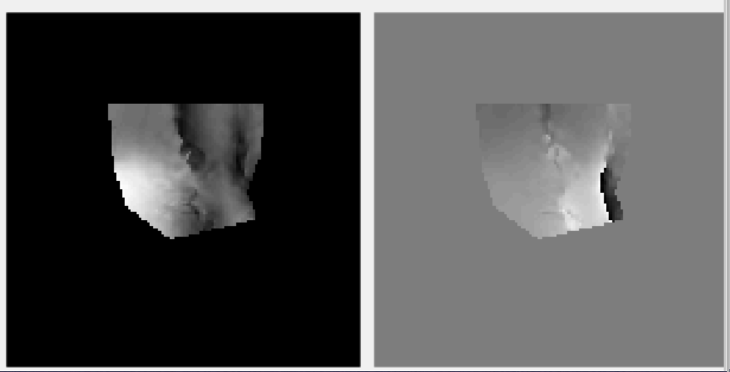
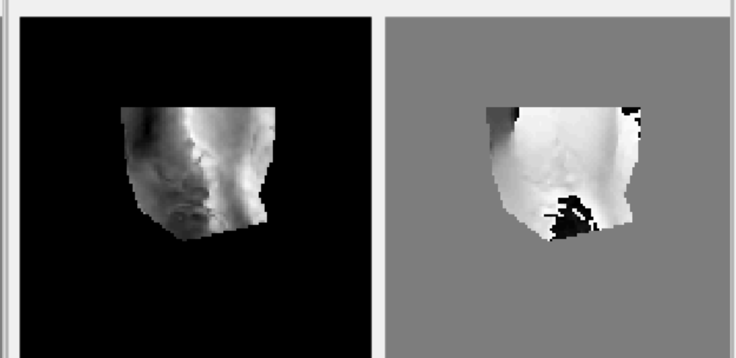
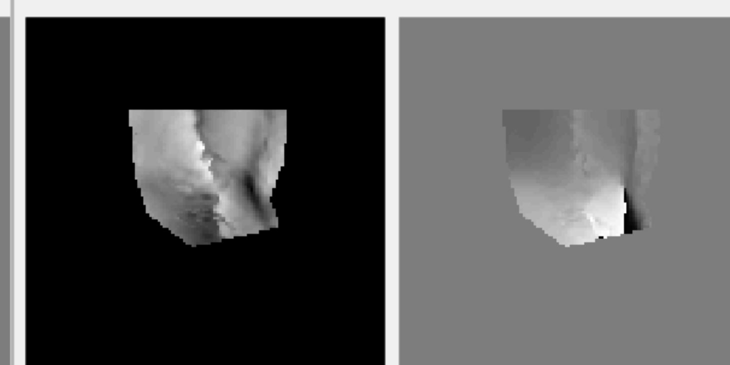
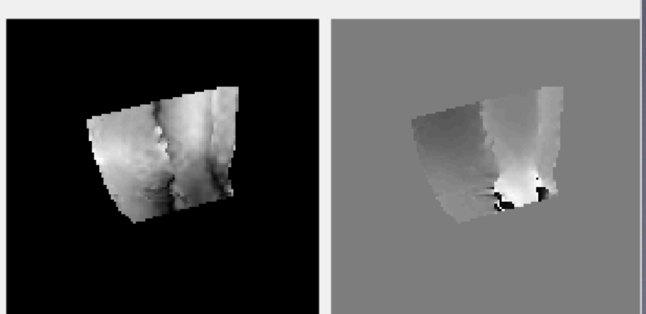
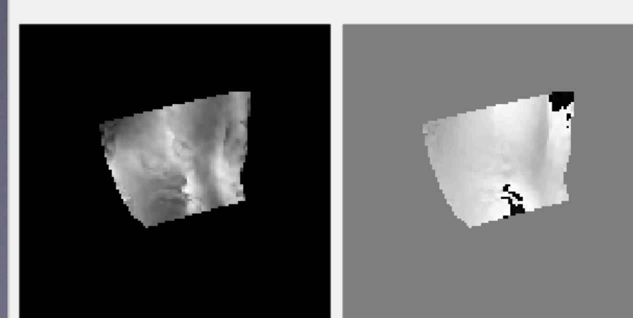
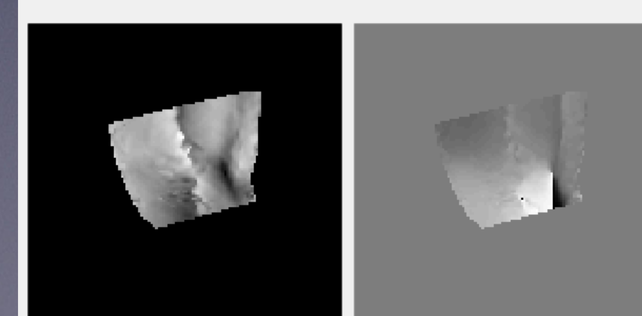
roi_17517125658

Shimming With ROI	MLS Shimming With ROI	Phase only ROI
	Focus on homogeneity	The most efficiently shim.(Set 1)
		

MSE: Mean Square Error
AvgPha: Average of Phases

Divide: ———

	Shimming With ROI	MLS Shimming With ROI	Phase only ROI
Efficiency *About B1 Magnitude.*	Mean(Shimming With ROI) / Mean(Phase only ROI)	Mean(MLS Shimming With ROI) / Mean(Phase only ROI)	1
Inhomogeneity *About B1 Magnitude.*	MSE(Shimming With ROI) / Mean(Shimming With ROI)	MSE(MLS Shimming With ROI) / Mean(MLS Shimming With ROI)	MSE(Phase only ROI) / Mean(Phase only ROI)
Relative B1 Magnitude	reshape(A_all*transpose(shim), [NX, NY, NS]) **shim: can be any the product of reshaped B1 map and phase**		
Relative Phase *B1target = 1e-6;*	pinv(B)*(B1target.*ones(numel(find(mask_shm)),1))	**myMLS**(B, B1target.*ones(numel(find(mask_shm)), 1).*exp(1i.*pi/2), 0.01, 1000);	exp(-1i.*AvgPha)

	Shimming With ROI	MLS Shimming With ROI	Phase only ROI
2nd Test	Shimming within ROI 	MLS shimming within ROI 	Phase-only shimming within ROI 
3rd Test	Shimming within ROI 	MLS shimming within ROI 	Phase-only shimming within ROI 
4th Test	Shimming within ROI 	MLS shimming within ROI 	Phase-only shimming within ROI 

Inhomogeneity

Red Line: Shimming with ROI

Blue Line: MLS Shimming with ROI

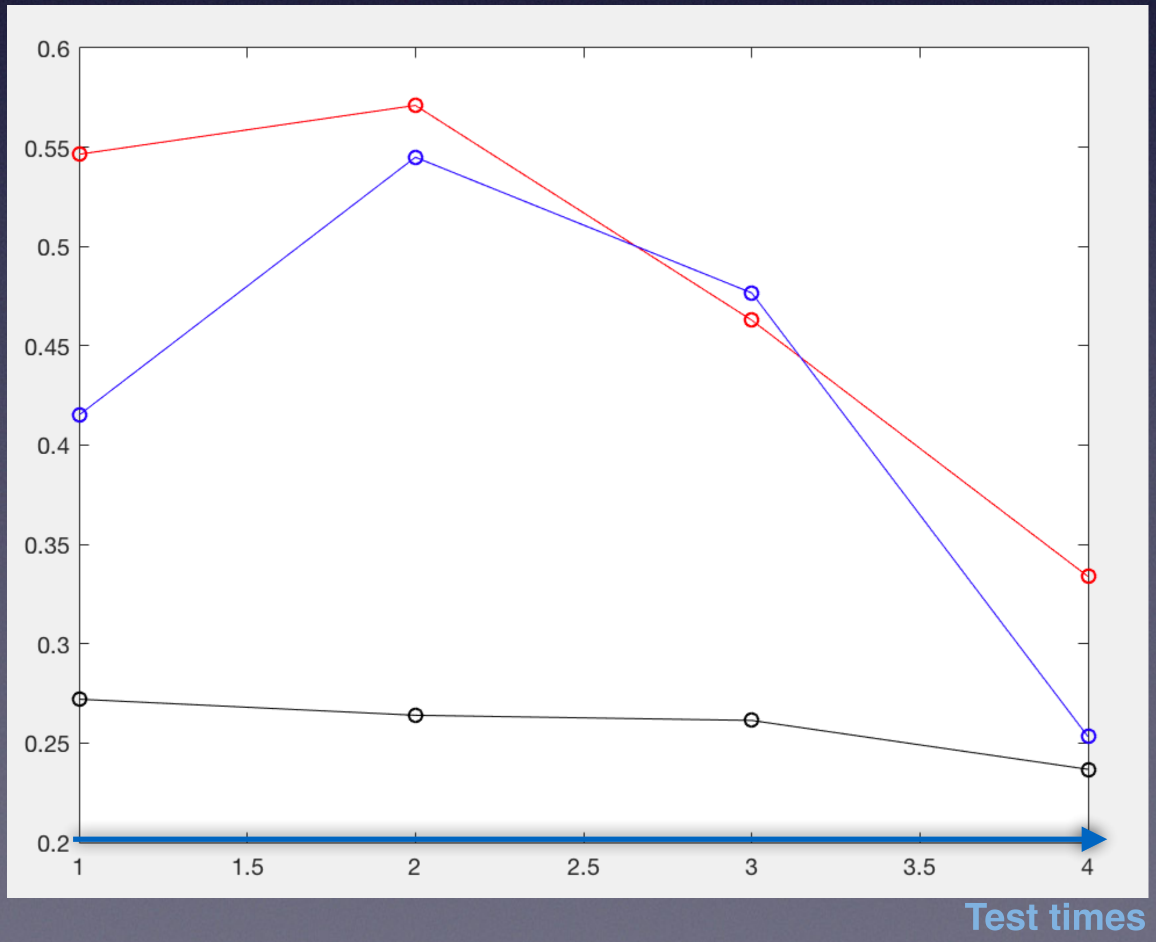
Black Line: Phase-Only Shimming with ROI

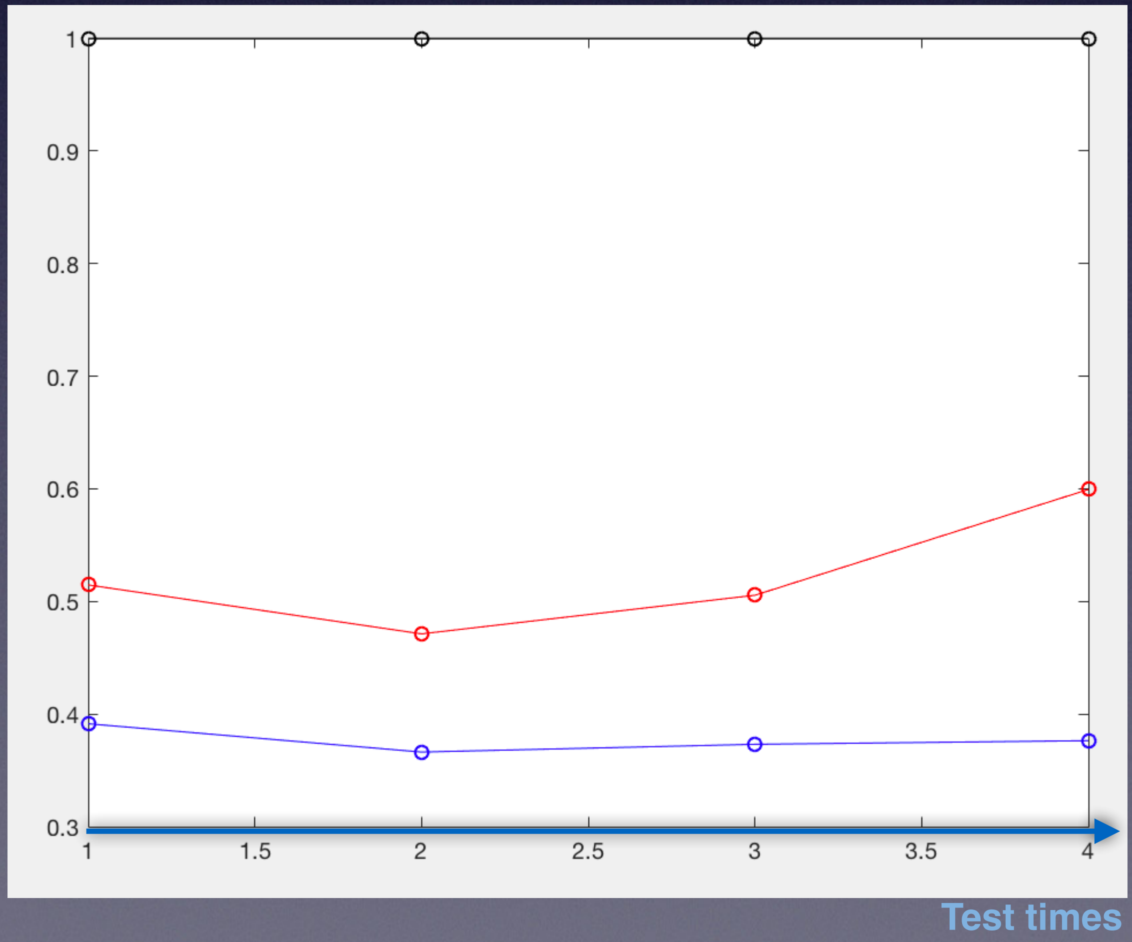
Efficiency

Black Line: Phase-Only Shimming with ROI

Red Line: Shimming with ROI

Blue Line: MLS Shimming with ROI





```
myMLS(B, B1target.*ones(numel(find(mask_shm)),1).*exp(1i.*pi/2), 0.01, 1000);
```

```
function [ x, dif, iter ] = myMLS( A, b, tol, MaxIter)
```

A: B1 Map

b: store the target amplitude and initial phase estimate of the target

tol: the target tolerence of the optimisation

MaxIter: the maximum number of iteration

Export

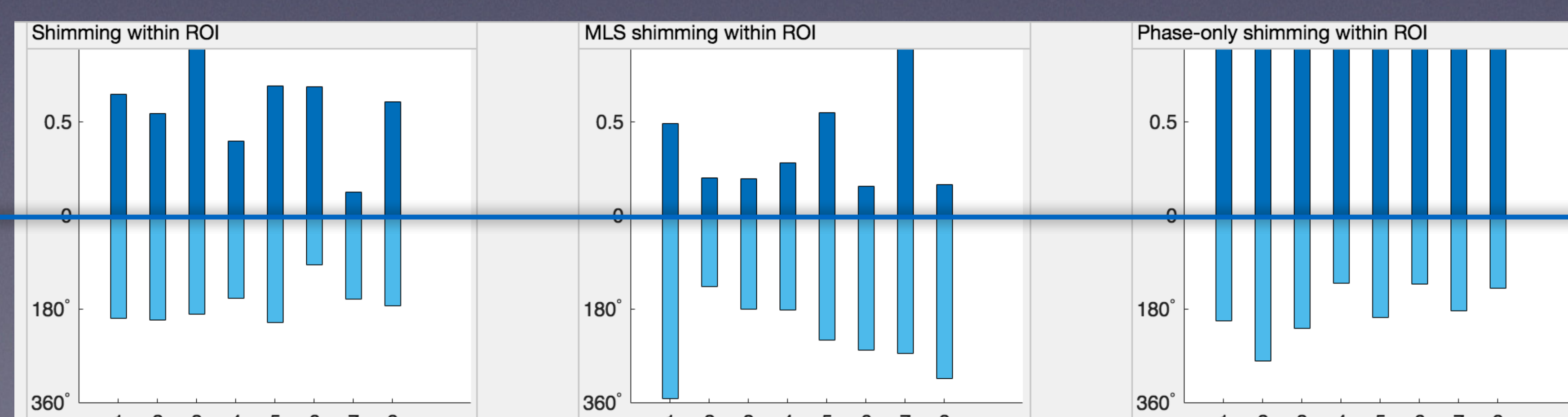
pTXComposite_KT...
pTXComposite_KT...
pTXComposite_KT...

Scheme Example: Phase-Only

```
#pTXRFPulse - created by: <create_pTXRFPulse.m><v2.0, 12-02-12>
[pTXPulse]

NUsedChannels        = 1
MaxAbsRF             = 1
Samples              = 8
PulseName            = pTX composite pulse KT 1 17-May-2017_14:01:20
Comment              = OLS spokes
SampleTime           = 5e+08
NominalFlipAngle     = 90

[pTXPulse_ch0]

RF[0]=  1    3.578
RF[1]=  1    5.154
RF[2]=  1    4
RF[3]=  1    2.237
RF[4]=  1    3.428
RF[5]=  1    2.176
RF[6]=  1    3.298
RF[7]=  1    2.325

#EOF
```

Amplitude

Phase



References

- *R. R. Regatte, "Why buy an expensive ($7 million) 7T MRI system for biomedical research?," J Magn Reson Imaging, vol. 40, no. 2, pp. 280-2, Aug, 2014.*

- *B. K. Li, F. Liu, and S. Crozier, "Focused, eight-element transceive phased array coil for parallel magnetic resonance imaging of the chest--theoretical considerations," Magn Reson Med, vol. 53, no. 6, pp. 1251-7, Jun, 2005.*

- *Cloos, M. A., Boulant, N., Luong, M., Ferrand, G., Giacomini, E., Le Bihan, D. and Amadon, A. (2012), kT-points: Short three-dimensional tailored RF pulses for flip-angle homogenization over an extended volume. Magn. Reson. Med., 67: 72–80. doi:10.1002/mrm.22978*

Thank you for listening to my presentation!

Q&A Session