



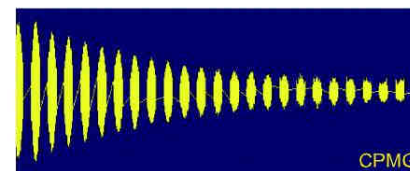
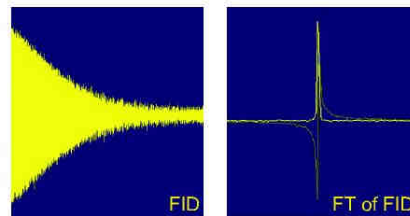
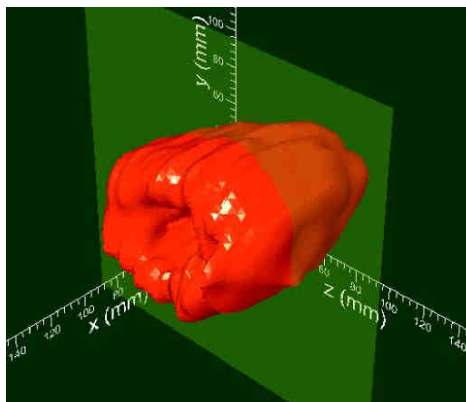
MRI & NMR for everyone, everywhere

Terranova-MRI
Presentation 2008

Teach MRI and NMR with the Terranova-MRI Earth Field System



Take students from basic NMR concepts such as Free Induction Decay, Spin Echo and CPMG, through to full 3D imaging experiments



Terranova-MRI is a Lab Course in a Box...

Includes

- Comprehensive Student Guide
- User Manual
- Phantom sample
- 3D Compass



Can be used Inside or Outside

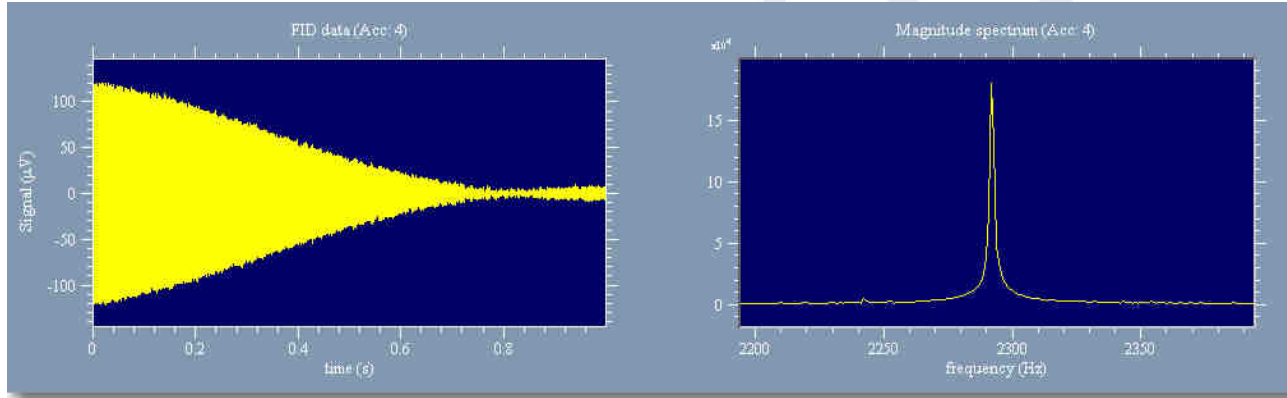


Spectrometer runs on 24V DC

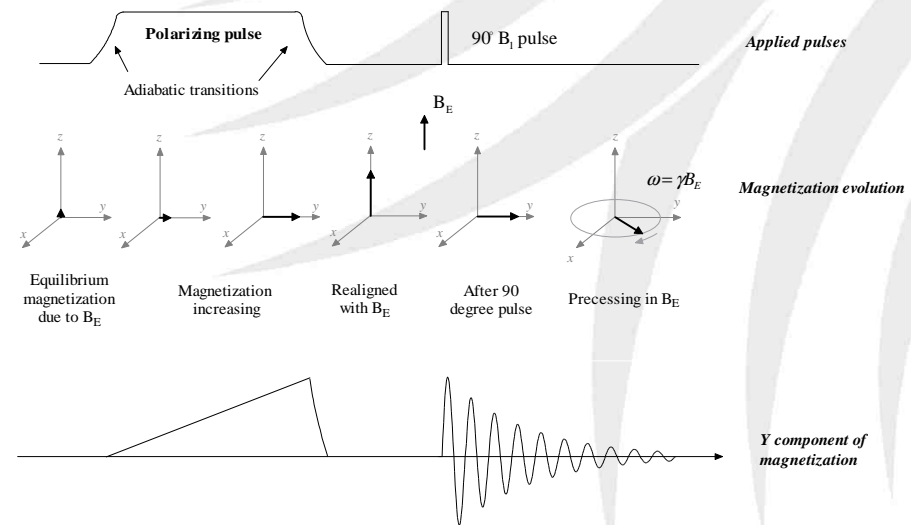
In lab environment use the DC power supply provided with the system



NMR Signal Acquisition: Pulse and Collect



- EFNMR
- MRI
- Help
- EFNMR Macro Help
- AnalyseCoil
- AutoShim
- AutoShimSE
- B1Duration
- CPMG
- MonitorNoise
- PGSE
- PulseAndCollect**
- SpinEcho
- T1Be
- T1Bp
- T2



Pulse and Collect (with Shims)

Pulse sequence parameters:

Polarizing current (A)	6	Number data points	16384
Polarizing duration (ms)	4000	Acquisition delay (ms)	25
B1 frequency (Hz)	2238	Acquisition time (s)	2
Capacitance (nF)	10.6	Repetition time (s)	6
Transmit (B1) gain	2.5	Number of scans	64
Pulse duration (ms)	1.55	Display (angle) (Hz)	200
Receive gain	2	Average	<input checked="" type="checkbox"/>
		Magnitude	<input checked="" type="checkbox"/>

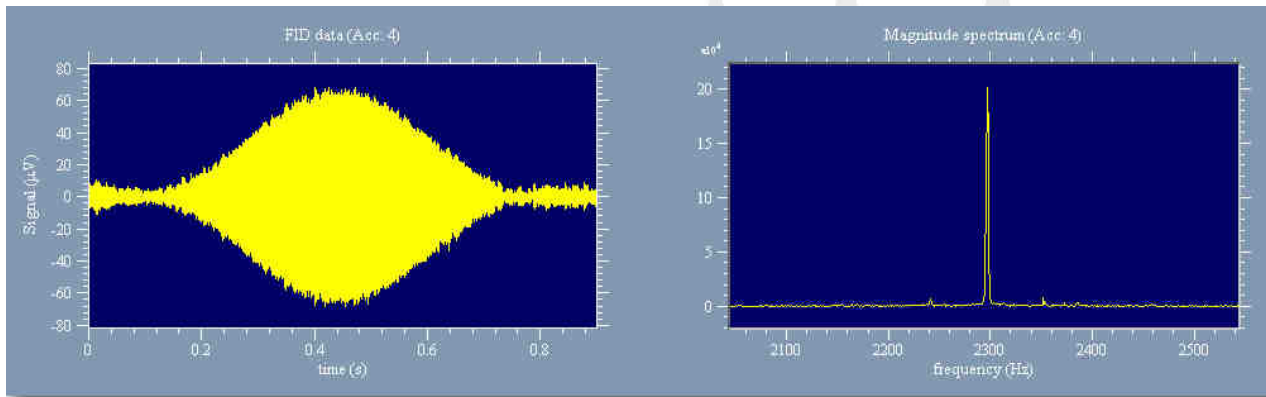
Output location:

Working directory:

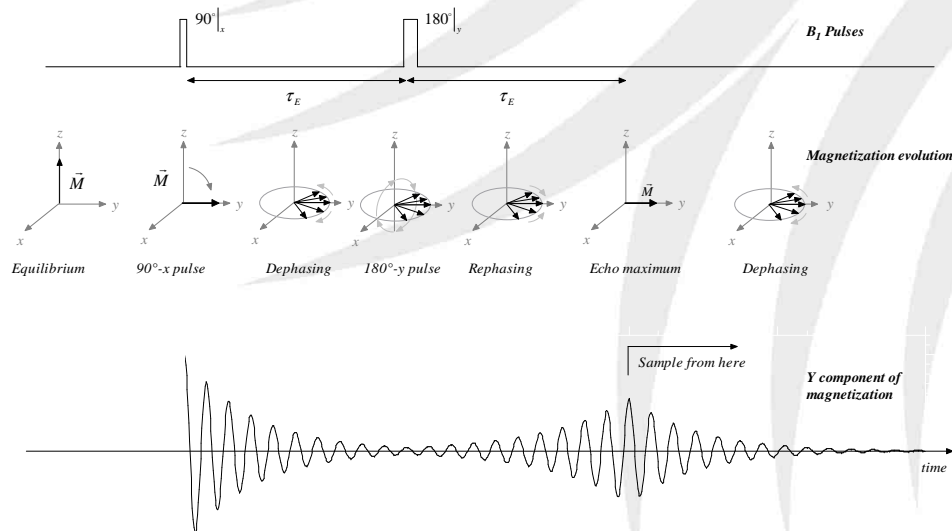
Experiment name:

Buttons: Run, Stop, Audio, Load, Shim, Help, Close

Spin-Echo



- EFNMR
- MRI
- Help
- EFNMR Macro Help
- AnalyseCoil
- AutoShim
- AutoShimSE
- B1Duration
- CPMG
- MonitorNoise
- PGSE
- PulseAndCollect
- SpinEcho**
- T1Be
- T1Bp
- T2



Spin Echo (with Shims)

Pulse sequence parameters:

Polarizing current (A)	6	Receive gain	2
Polarizing duration (ms)	4000	Number data points	16384
B1 frequency (Hz)	2130	180-acq. delay (ms)	25
Capacitance (nF)	11.7	Acquisition time (s)	1
Transmit (B1) gain	2.5	Repetition time (s)	9
90 pulse duration (ms)	1.55	Number of scans	1
180 pulse duration (ms)	2.8	Display range (Hz)	100
Echo time (ms)	200	Average <input checked="" type="checkbox"/>	Magnitude <input checked="" type="checkbox"/>

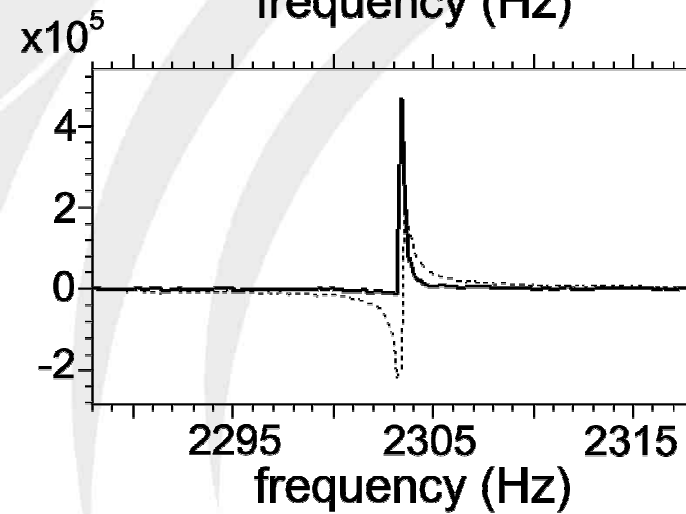
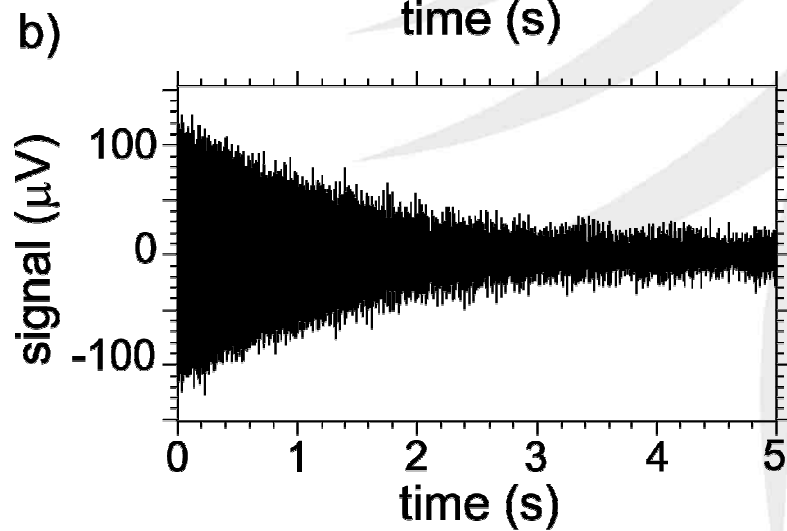
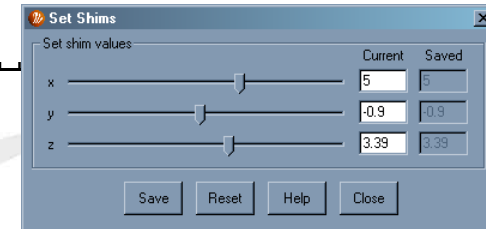
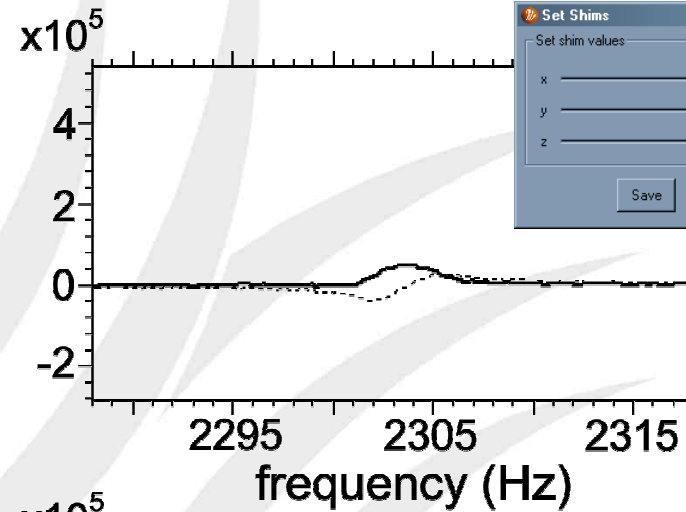
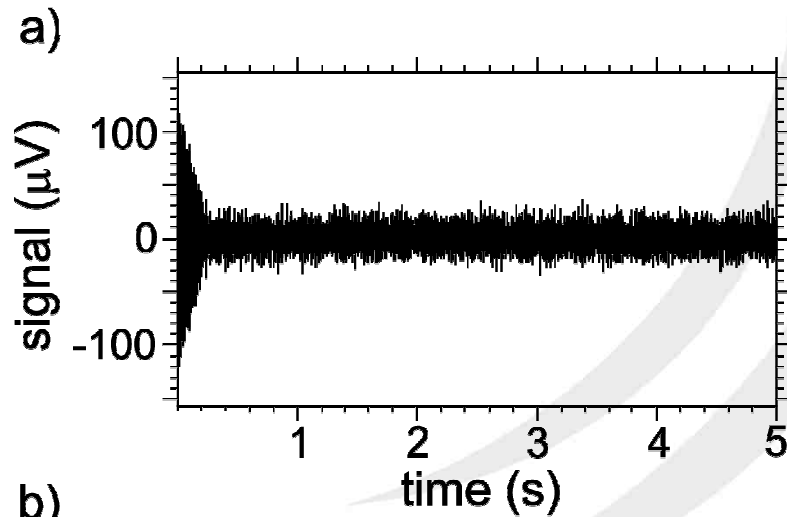
Output location:

Working directory: C:\Documents and Settings\andrew\Desktop\MRI b

Experiment name: SpinEcho

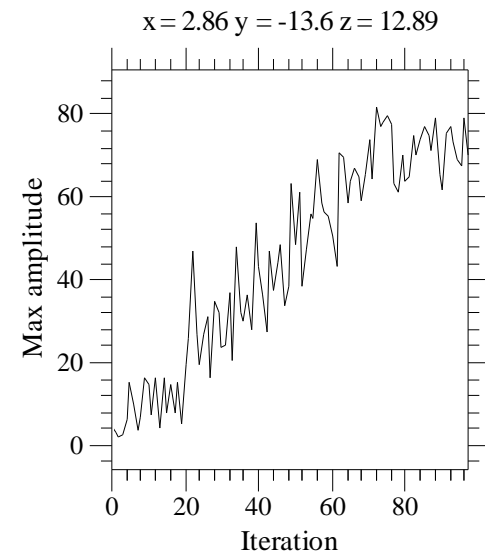
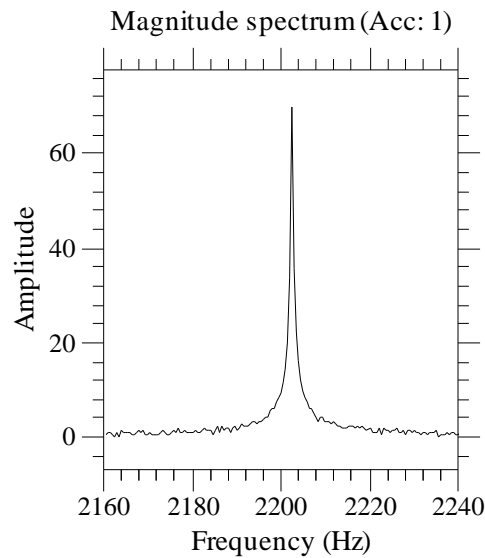
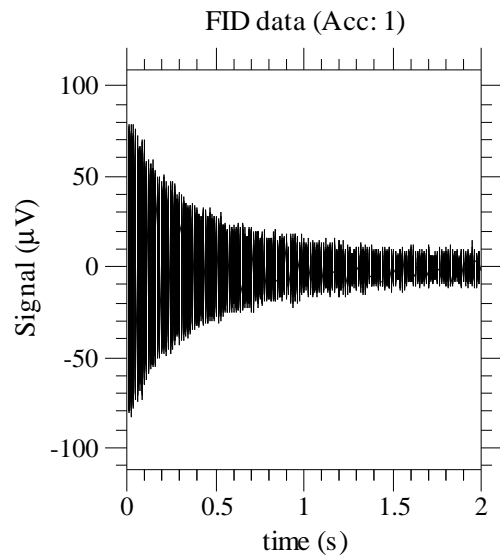
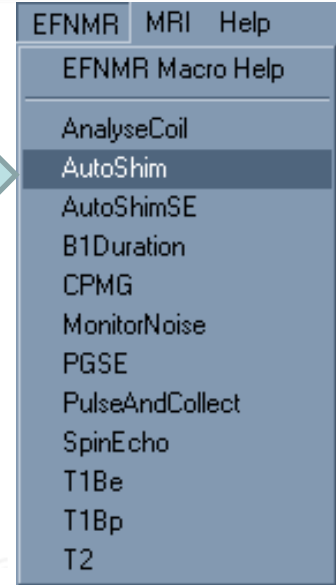
Buttons: Run, Stop, Audio, Load, Shims, Help, Close

Slider Control Shimming (4 Gradient Coils)

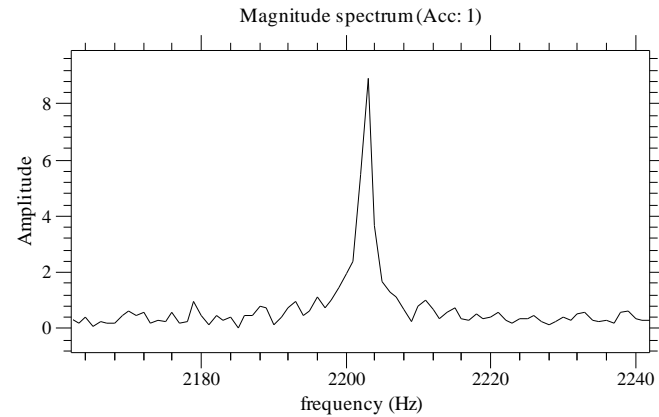
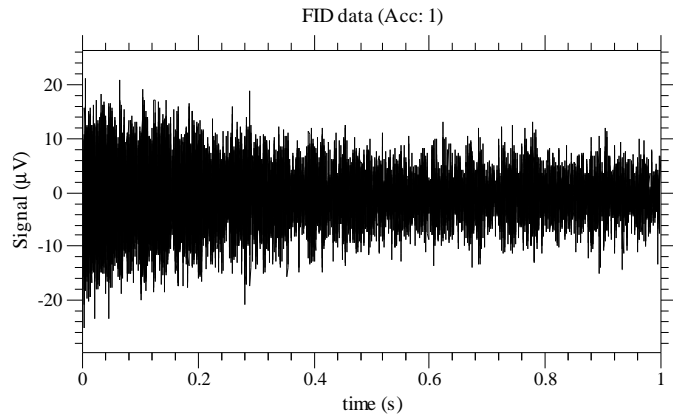


500 mL Water Sample

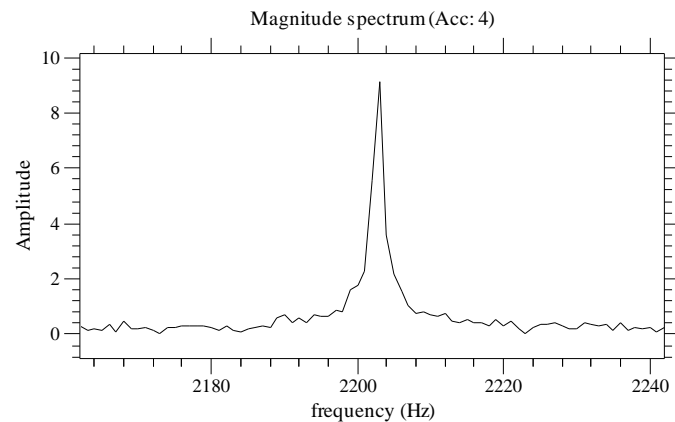
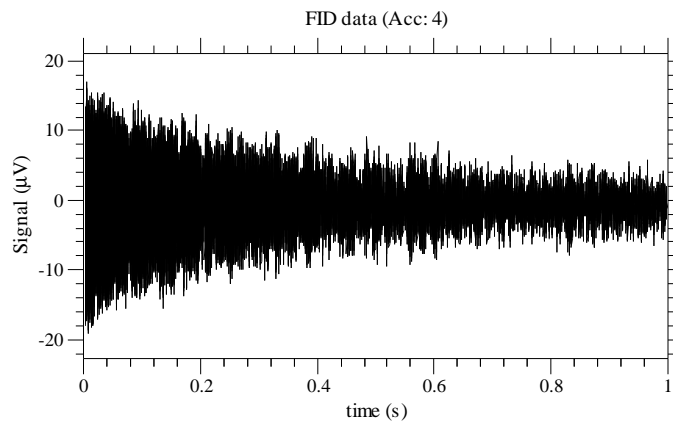
Auto-Shimming



Signal Averaging

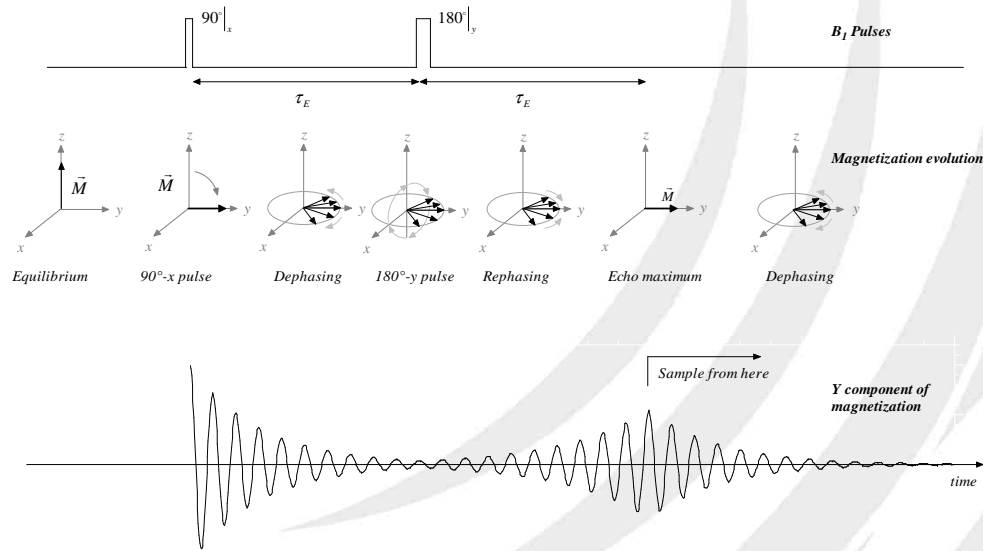


1 scan



4 scans

Spin-echo T_2 Measurement



NMR MRI Help

NMR Macro Help

- AnalyseCoil
- AutoShim
- AutoShimSE
- B1Duration
- CPMG
- MonitorNoise
- PGSE
- PulseAndCollect
- SpinEcho
- T1Be
- T1Bp
- T2**

T2 [with Shims]

Pulse sequence parameters:

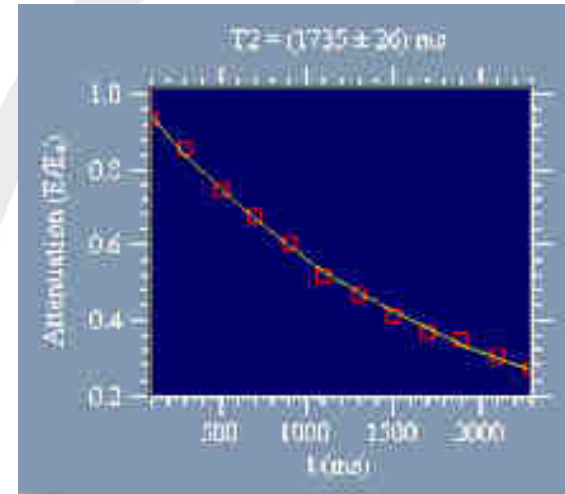
Polarizing current (A): 6	90 pulse duration (ms): 1.6	Acquisition time (s): 1	Phase: no cycle
Polarizing duration (ms): 4000	180 pulse duration (ms): 3.2	Repetition time (s): 10	Phase: cycle
B1 frequency (Hz): 2202	Minimum echo time (ms): 100	Number of scans: 2	Filter: <input checked="" type="checkbox"/>
Capacitance (nF): 10.5	Echo time step (ms): 100	Integration width (Hz): 20	Average: <input checked="" type="checkbox"/>
Transmit (B1) gain: 2.5	Number of steps: 10	Display range (Hz): 50	Magnitude: <input type="checkbox"/>
Receive gain: 2	Number of data points: 16384		

Output location:

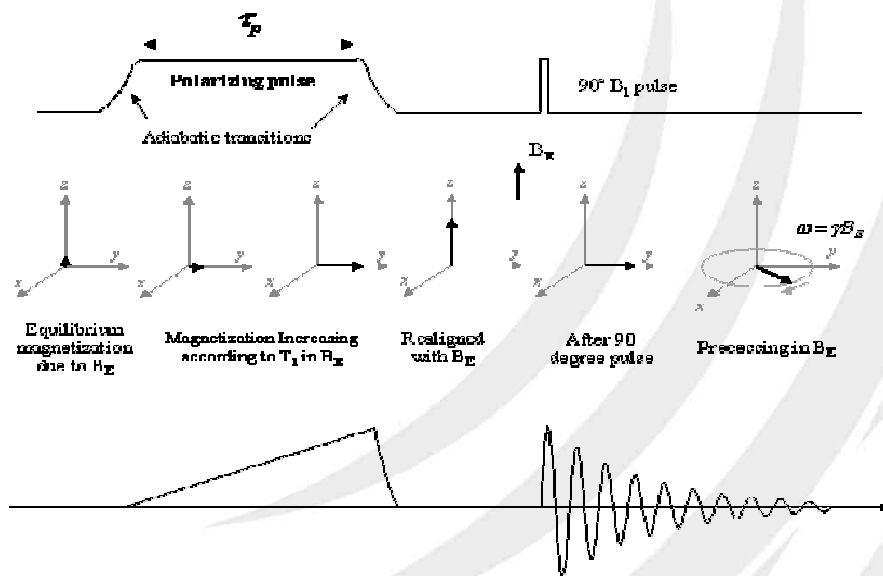
Working directory: C:\Documents and Settings\andrew\Desktop\MRI F

Experiment name: T2

Buttons: Run, Load, Help, Stop, Shims, Close



T_1 in Polarizing Field (B_p)



NMR	MRI	Help
NMR Macro Help		
AnalyseCoil		
AutoShim		
AutoShimSE		
B1Duration		
CPMG		
MonitorNoise		
PulseAndCollect		
SpinEcho		
T1Be		
T1Bp		
T2		

T1 Bp (with shims)

Pulse sequence parameters

Polarising current (A)	6	Transmit (B1) gain	2.5	Acquisition time (s)	1
Minimum polarizing time (ms)	500	90 pulse duration (ms)	1.6	Repetition time (s)	9.5
Polarizing step size (ms)	500	Receive Gain	2	Number of scans	1
Number of steps	10	90-acquisition delay (ms)	25	Integration width (Hz)	10
B1 frequency (Hz)	2202	Number of data points	16384	Display range (Hz)	200
Capacitance (nF)	10.5			Average	<input type="checkbox"/>
				Filter	<input checked="" type="checkbox"/>
				Magnitude	<input type="checkbox"/>

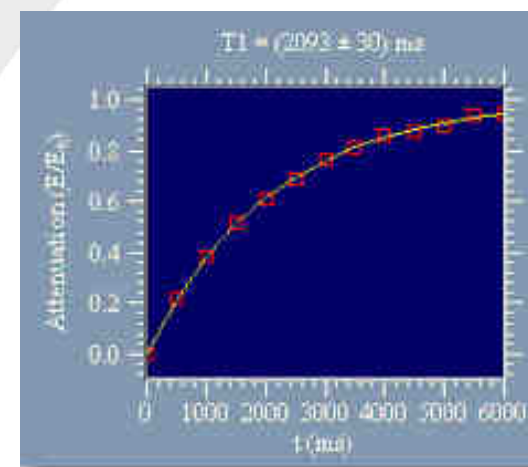
Output location

Working directory: C:\Documents and Settings\andrew\Desktop\MRI F

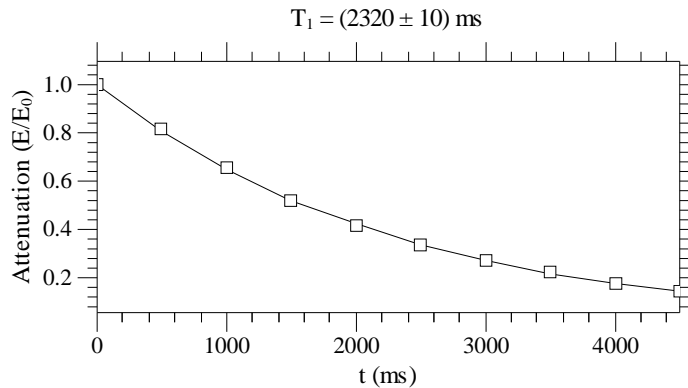
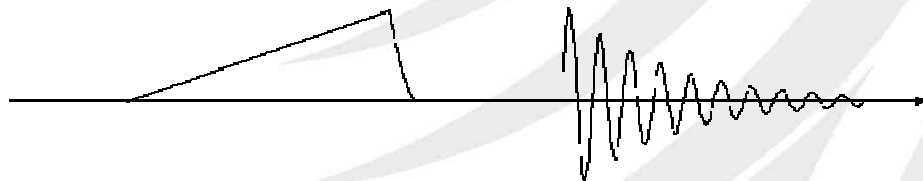
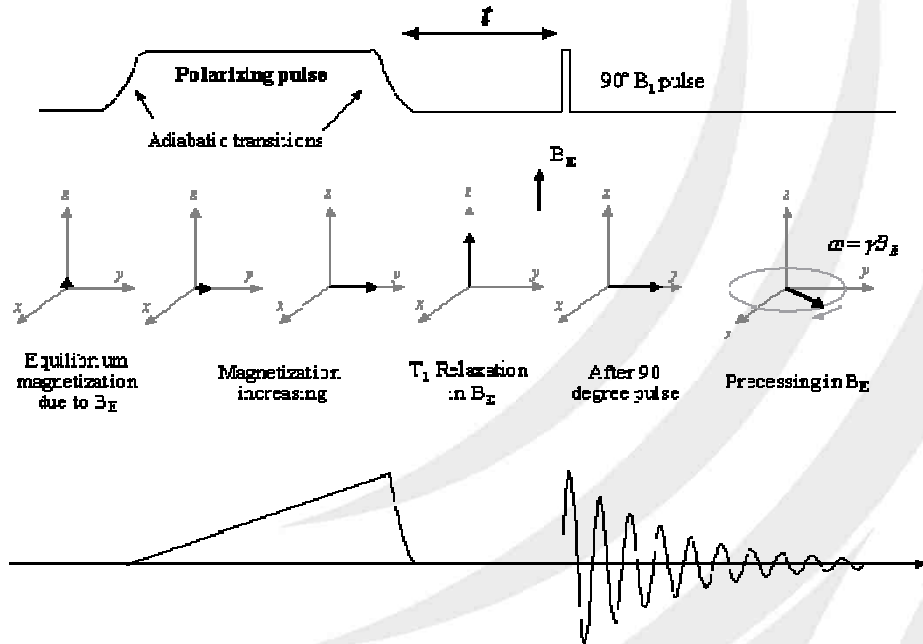
Experiment name: T1Bp

Run Load Help

Stop Shims Close



T_1 in the Earth's Field (B_E)



- NMR
- MRI
- Help
- NMR Macro Help
- AnalyseCoil
- AutoShim
- AutoShimSE
- B1Duration
- CPMG
- MonitorNoise
- PGSE
- PulseAndCollect
- SpinEcho
- T1Be**
- T1Bp
- T2

T1 Be (with shims)

Pulse sequence parameters

Polarsing current (A)	6	90 pulse duration (ms)	1.6	Acquisition time (s)	1
Polarsing duration (ms)	4000	Pre-90 minimum delay (ms)	0	Repetition time (s)	13
B1 frequency (Hz)	2202	Pre-90 delay step size (ms)	500	Number of scans	1
Capacitance (nF)	10.5	Number of steps	10	Integration width (Hz)	10
Transmit (B1) gain	2.5	90-acquisition delay (ms)	25	Display range (Hz)	50
Receive Gain	2	Number of data points	16384	Average <input checked="" type="checkbox"/>	Filter <input checked="" type="checkbox"/>
				Magnitude <input type="checkbox"/>	

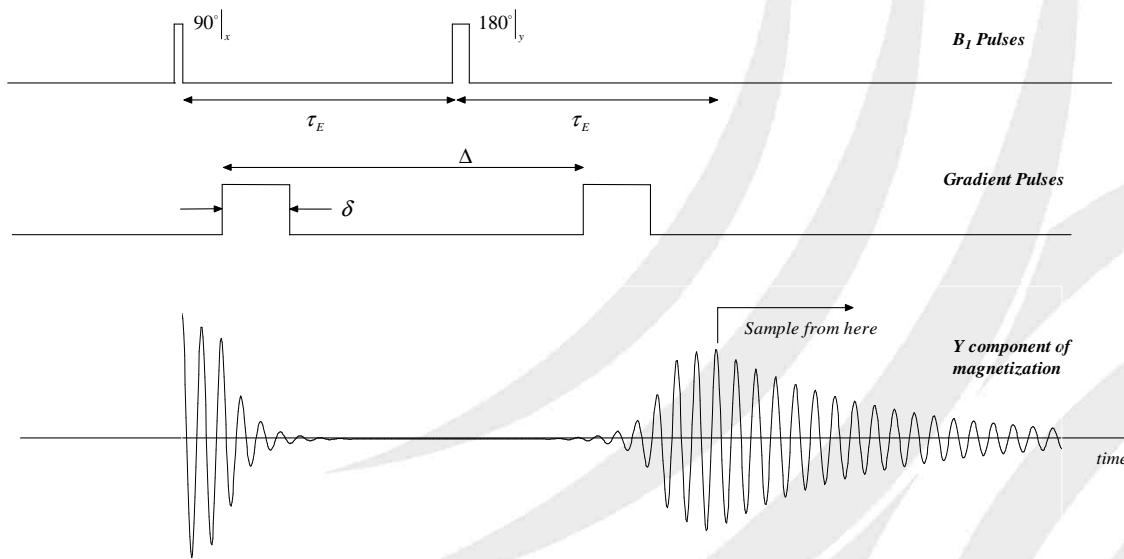
Output location

Working directory: C:\Documents and Settings\andrew\Desktop\MRI F

Experiment name: test

Buttons: Run, Load, Help, Stop, Shims, Close

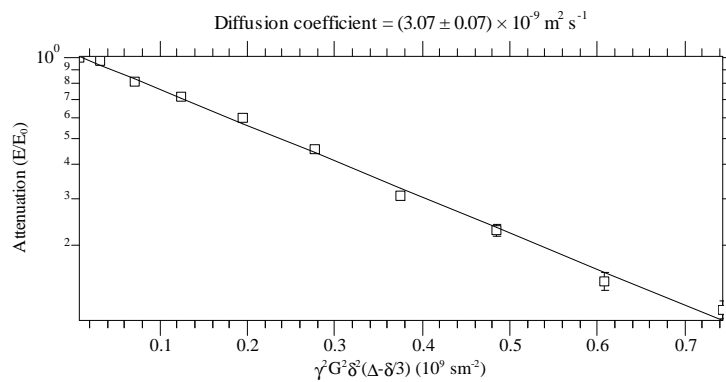
Pulsed-Gradient-Spin-Echo (PGSE)



NMR MRI Help

NMR Macro Help

- AnalyseCoil
- AutoShim
- AutoShimSE
- B1Duration
- CPMG
- MonitorNoise
- PGSE**
- PulseAndCollect
- SpinEcho
- T1Be
- T1Bp
- T2



PGSE (changing pulse width)

Pulse sequence parameters:

Polarizing current (A)	6	Pulse width step size (ms)	5	Number data points	16384
Polarizing duration (ms)	4000	Number of steps	10	Acquisition time (s)	2
B1 frequency (Hz)	2202	Gradient current (A)	2	Repetition time (s)	10.2
Capacitance (nF)	10.5	90 pulse duration (ms)	1.6	Number of scans	2
Transmit (B1) gain	2.5	180 pulse duration (ms)	3.2	Integration width (Hz)	15
Receive gain	2	Echo time (ms)	200	Display range (Hz)	50

Include first point Filter Magnitude Average

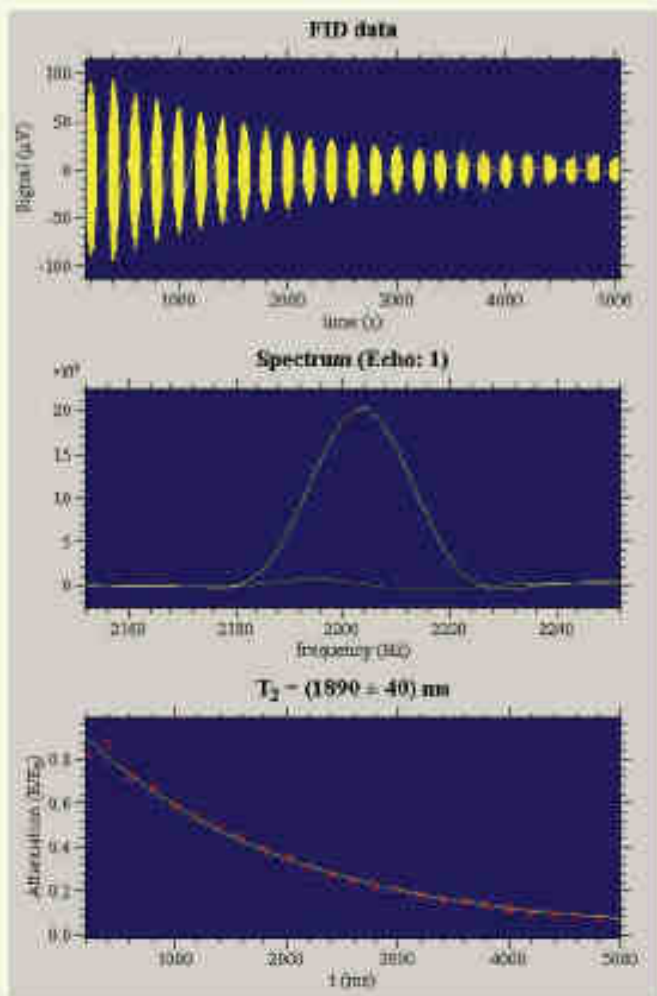
Output location:

Working directory: C:\Documents and Settings\andrew\Desktop\MRI F ...

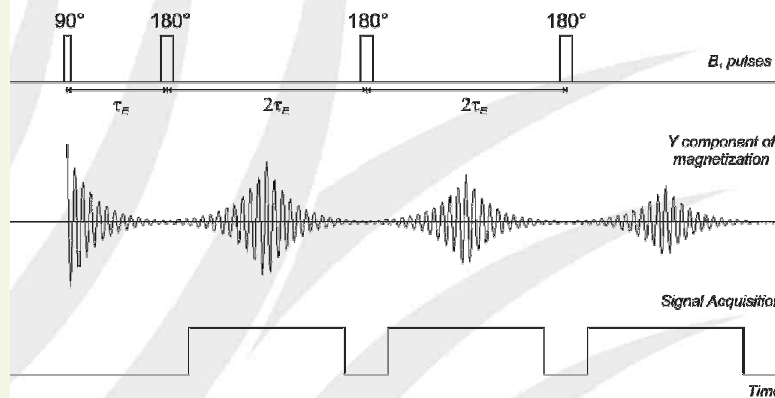
Experiment name: PGSE

Buttons: Run, Load, Help, Stop, Shims, Close

Carr-Purcell-Meiboom-Gill (CPMG)



A single shot T_2 measurement of water using the CPMG sequence.



The dialog box "CPMG (with Shims)" contains the following parameters:

Pulse sequence parameters			
Polarising current (A)	6	90 pulse duration (ms)	1.6
Polarising duration (ms)	4000	90 pulse phase (deg)	0
B1 frequency (Hz)	2202	180 pulse duration (ms)	3.2
Capacitance (nF)	10.5	180 pulse phase (deg)	90
Transmit (B1) gain	2.5	Number of Echoes	25
Receive gain	2	Echo time (ms)	100
		Zero-filling factor	4
		Number data points	1024
		Dwell time (µs)	100
		Number of scans	1
		Integration width (Hz)	40
		Display range (Hz)	100

Output location: Working directory: C:\Documents and Settings\andrew\Desktop\MRI F ... Experiment name: CPMG

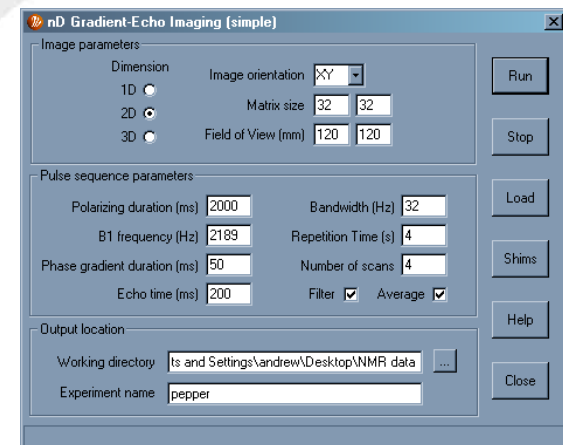
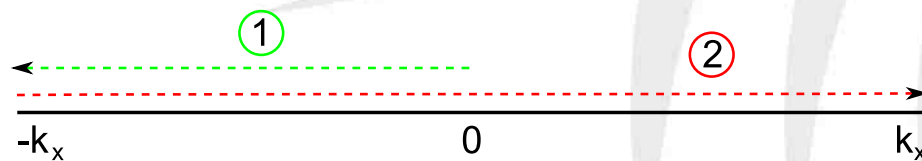
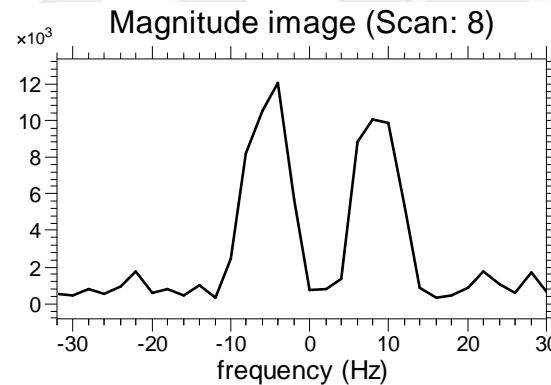
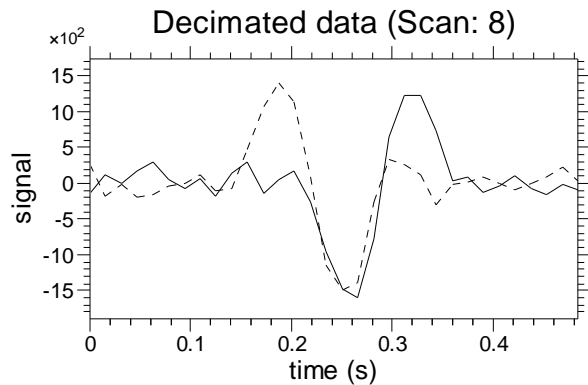
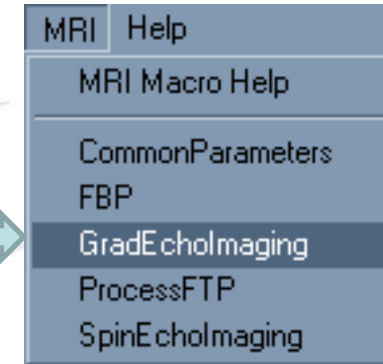
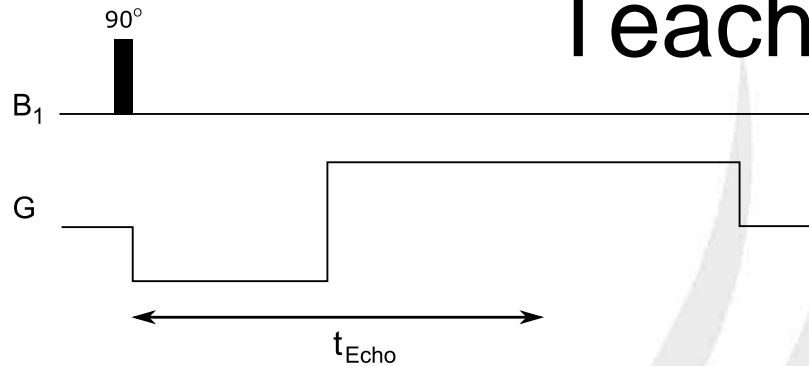
Time domain filter: Average: Constant 180 pulse phase: Alternating 180 pulse phase:

- NMR MRI Help
- NMR Macro Help
- AnalyseCoil
- AutoShim
- AutoShimSE
- B1Duration
- CPMG**
- MonitorNoise
- PGSE
- PulseAndCollect
- SpinEcho
- T1Be
- T1Bp
- T2



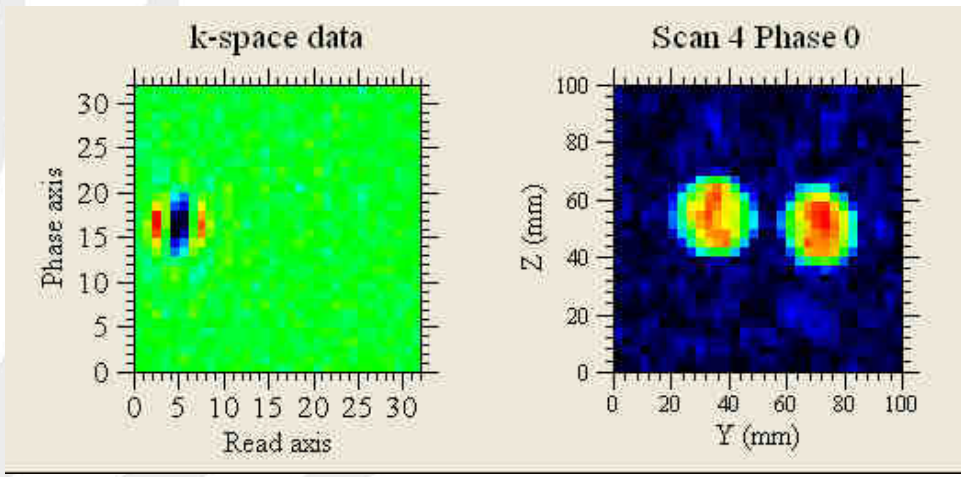
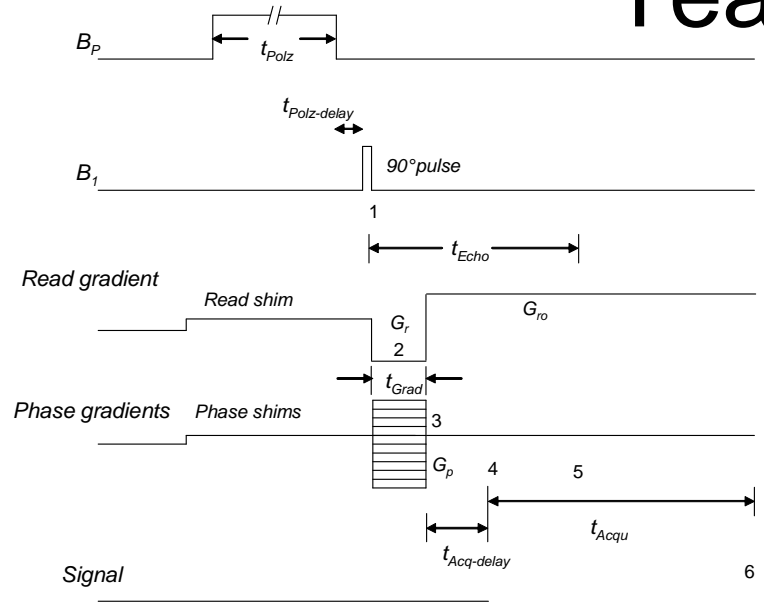
Teaching Imaging with Terranova-MRI

Teach 1D MRI

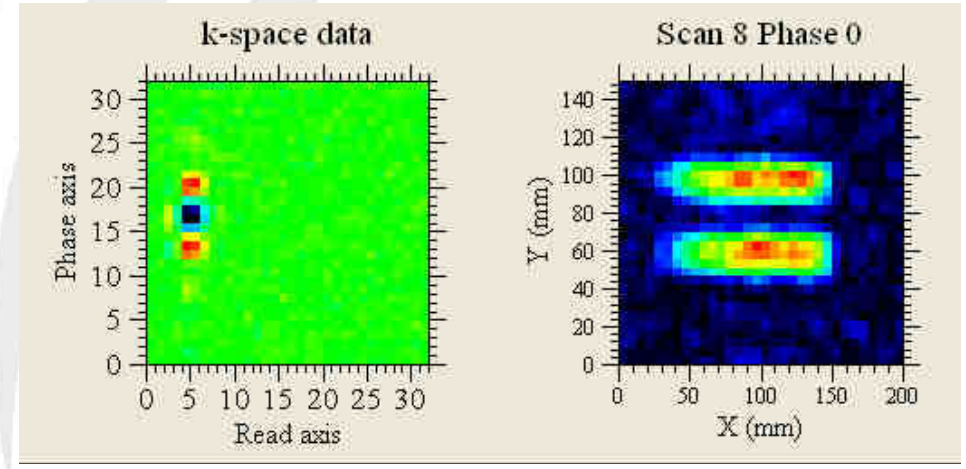
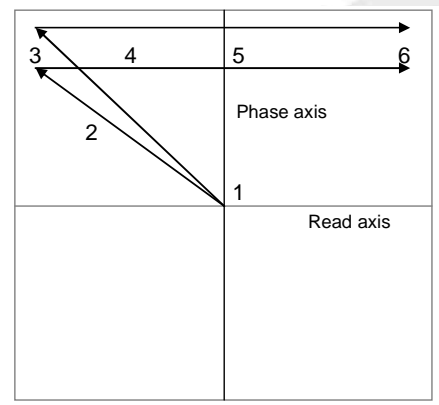


1D image along z of the two compartment phantom filled with tap water (FOV = 160 mm).

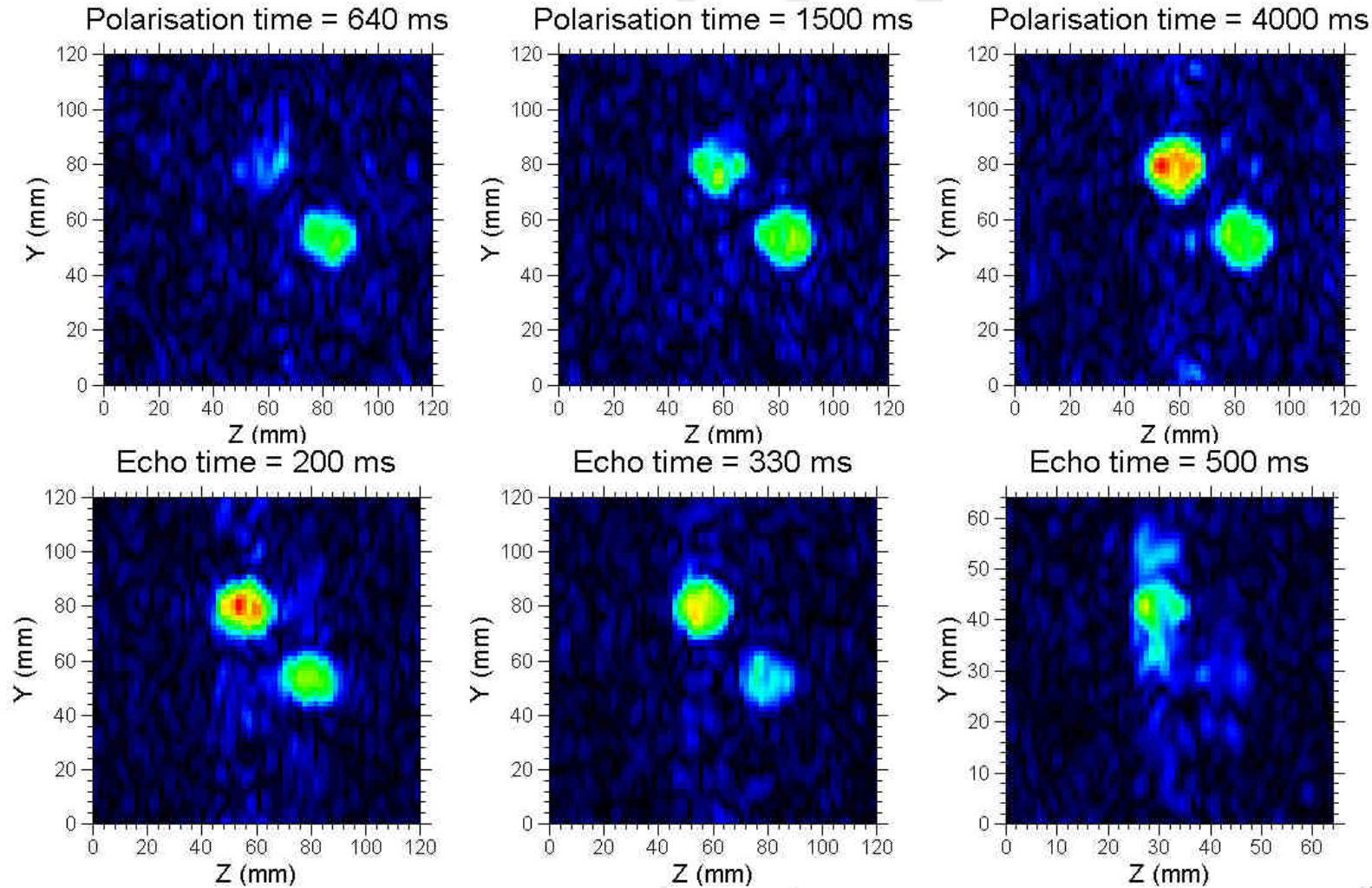
Teach 2D MRI



2D Gradient echo imaging

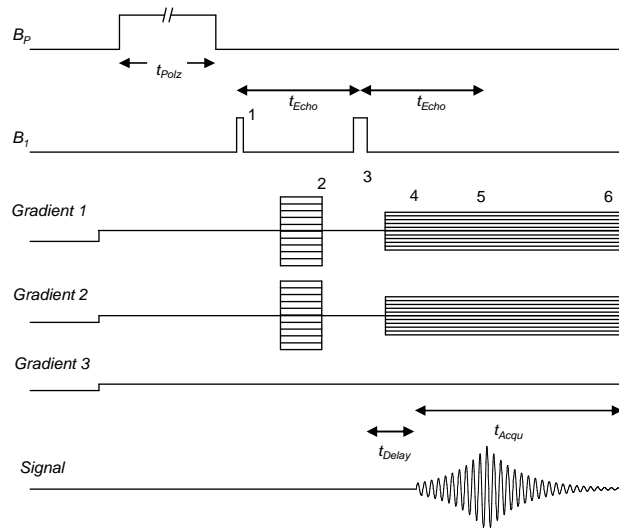


T_1 and T_2 relaxation contrast imaging

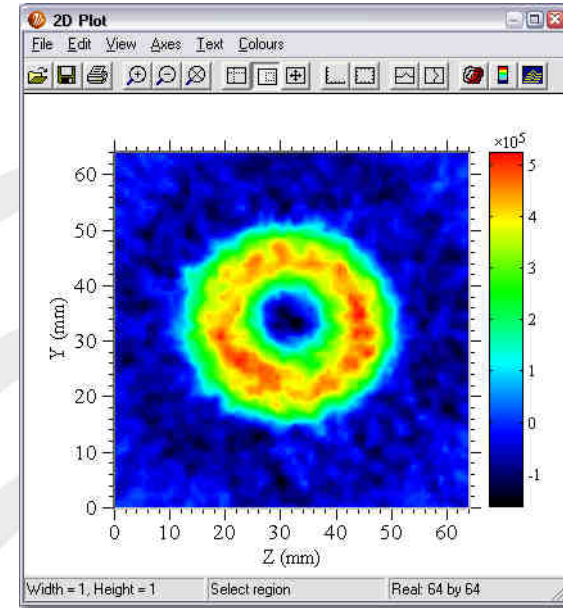


Lower tube has a shorter T_1 and T_2

2D Filtered Back Projection (FBP)

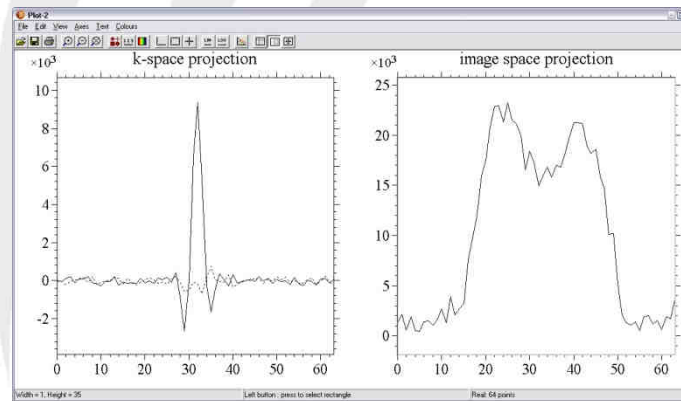


- MRI Help
- MRI Macro Help
- CommonParameters
- FBP**
- GradEcholmaging
- ProcessFTP
- SpinEcholmaging

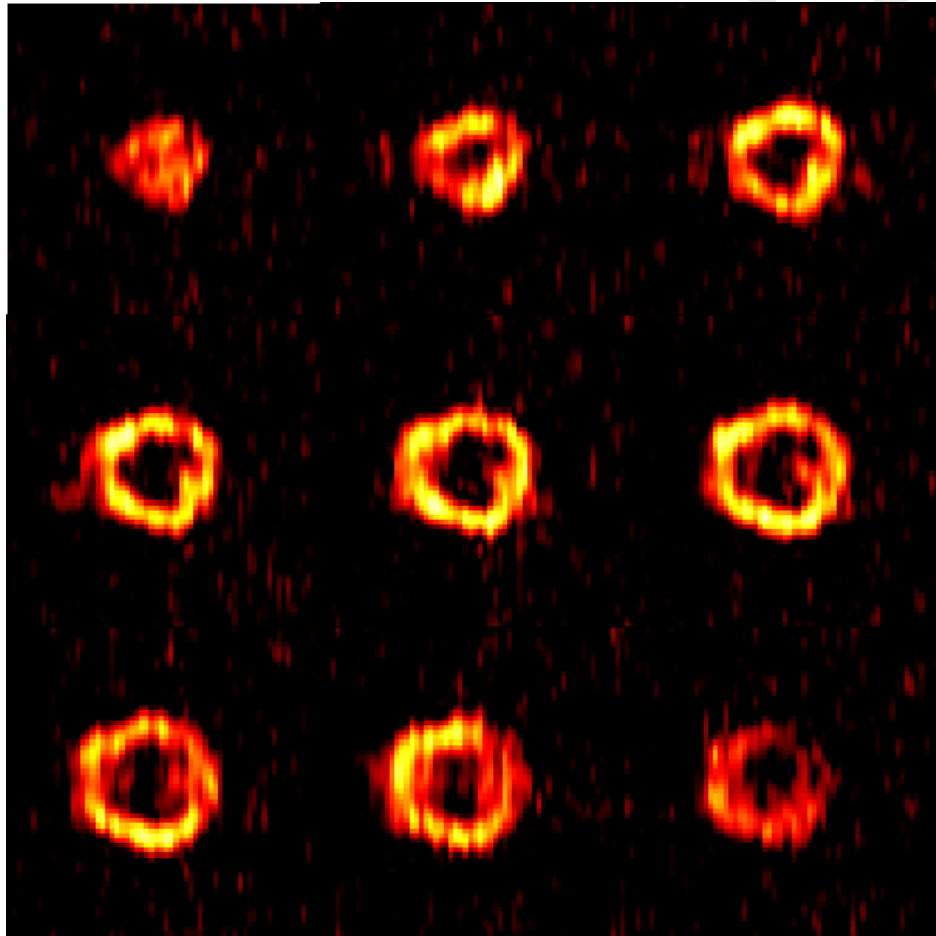


Filtered Back Projection (simple)

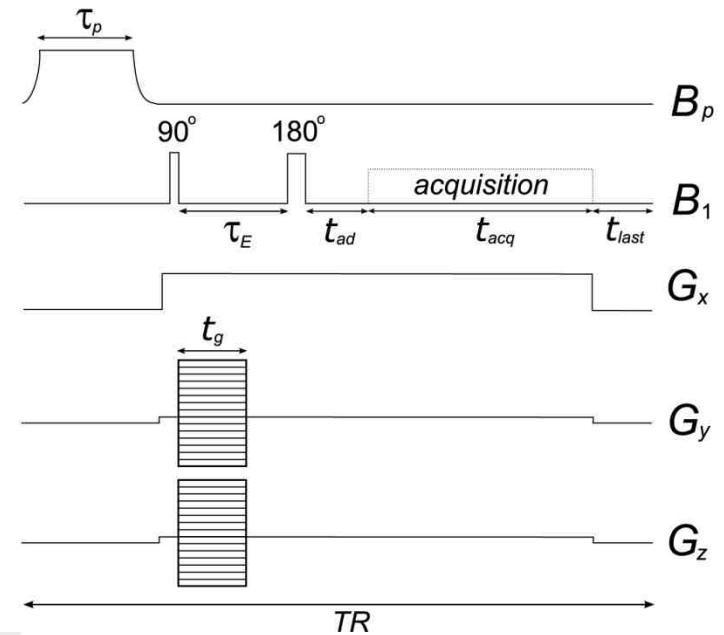
Image parameters		Phase cycle	Max angle	Run
Image orientation	YZ	None	180	Stop
Field of view (mm)	110 110	2 step	360	
Matrix size	32			Load
Pulse sequence parameters				
Polarizing duration (ms)	2000	Bandwidth (Hz)	32	Shims
B1 frequency (Hz)	2300	Repetition time (s)	3.7	
Echo time (ms)	200	Number of scans	2	Help
Number of projections	32	Average	<input checked="" type="checkbox"/>	
Output destination				
Working directory	and Settings\andrew\Desktop\MRI data			Close
Experiment name	fbp			



3D NMR Imaging in the Earth's Field



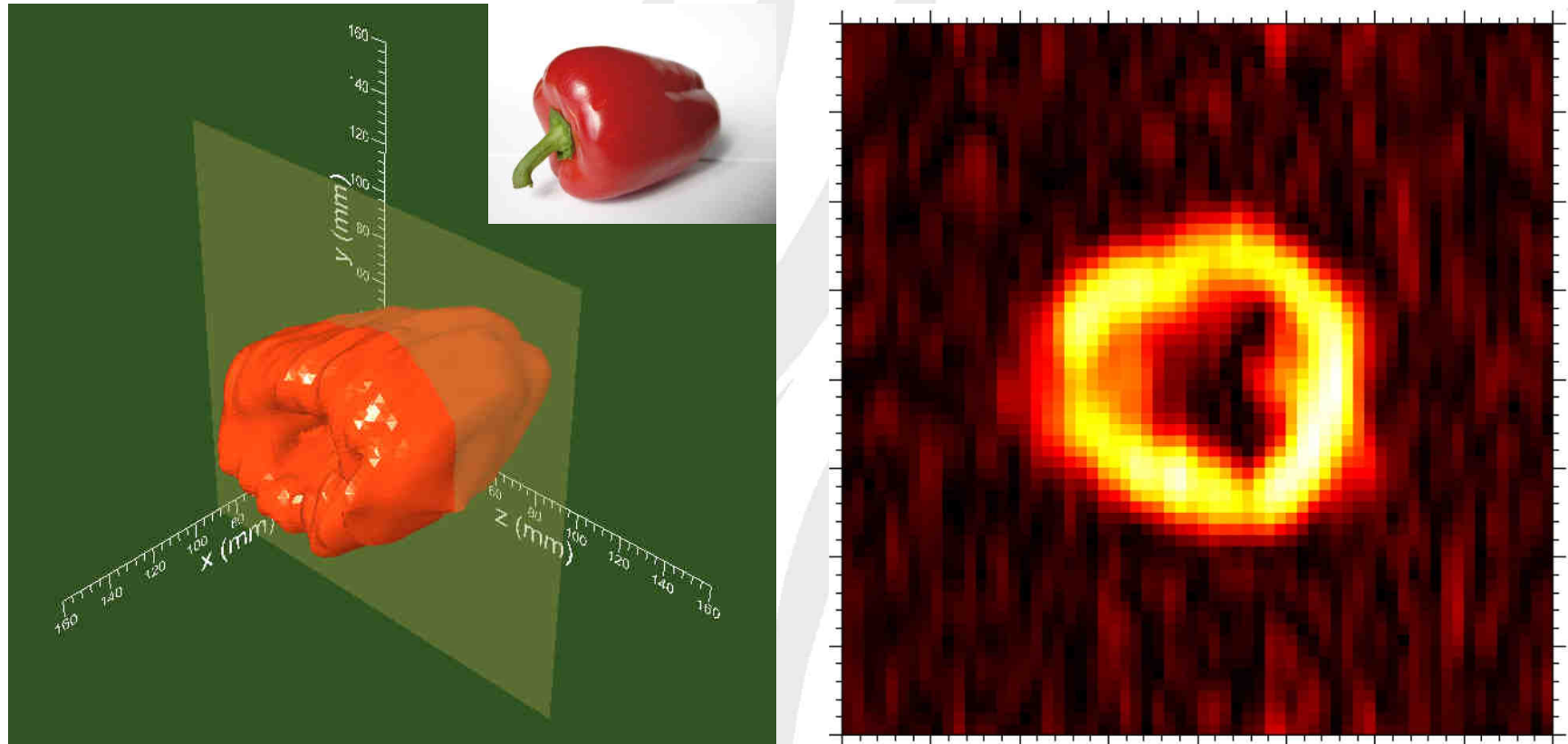
Red pepper (capsicum)



3D spin-echo imaging

3D ^1H Spin-echo MRI

Red Pepper (Capsicum)



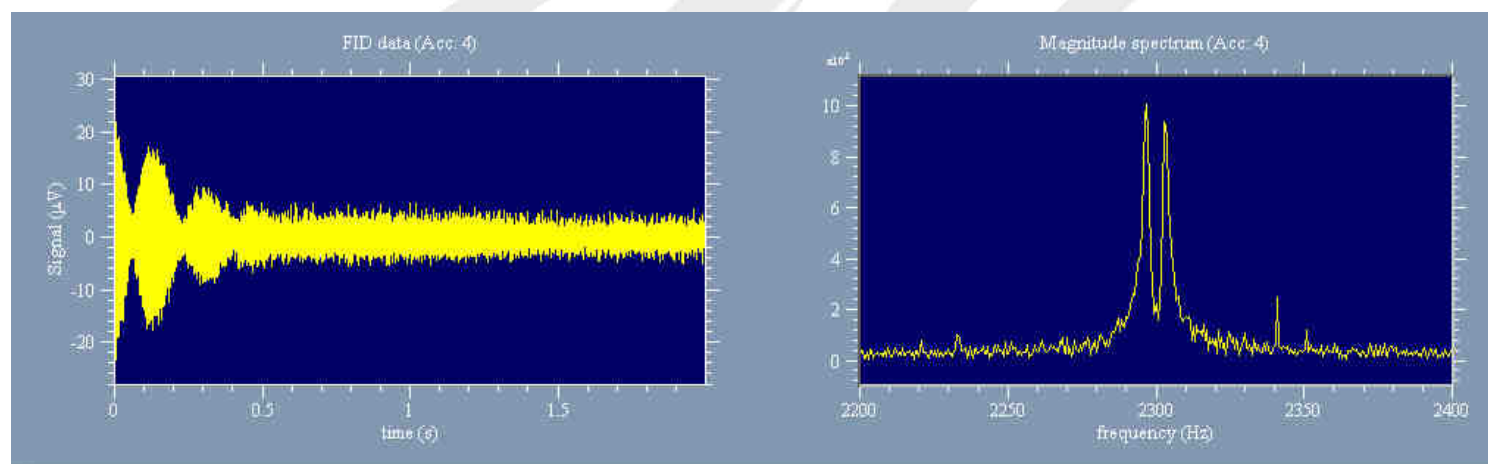
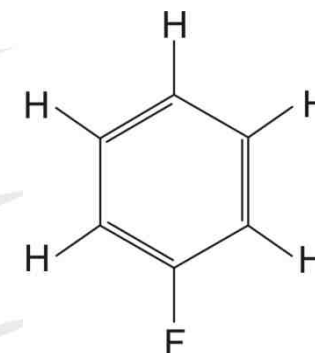
Halse *et. al.* JMR **182** (2006) 75-83



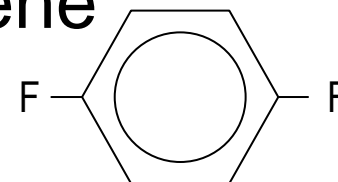
Teaching Spectroscopy with Terranova-MRI

Heteronuclear J -coupling: Fluorobenzene

Earth's field NMR is well suited to observing purely J coupled spectra. J coupling constants are independent of field and, for the case of different nuclei species, J coupling can be resolved easily in the Earth's field.



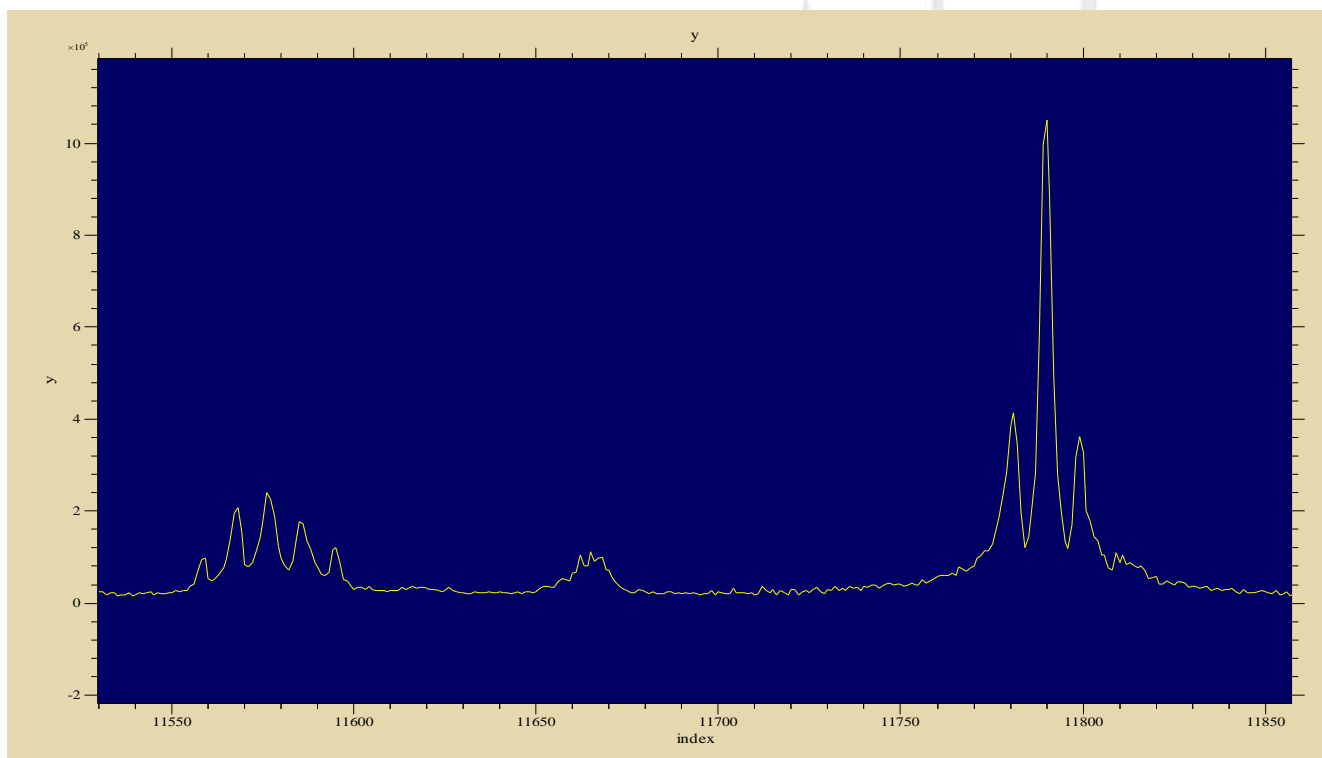
Heteronuclear J -coupling: Fluorobenzene



1,4-difluorobenzene

2 fluorine atoms
coupled to 4 protons

**Expect a proton
triplet and a fluorine
quintuplet**



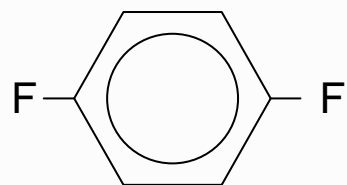
Fluorine F^{19}
~ 2275 Hz

Noise
~2350Hz
(50Hz harmonic)

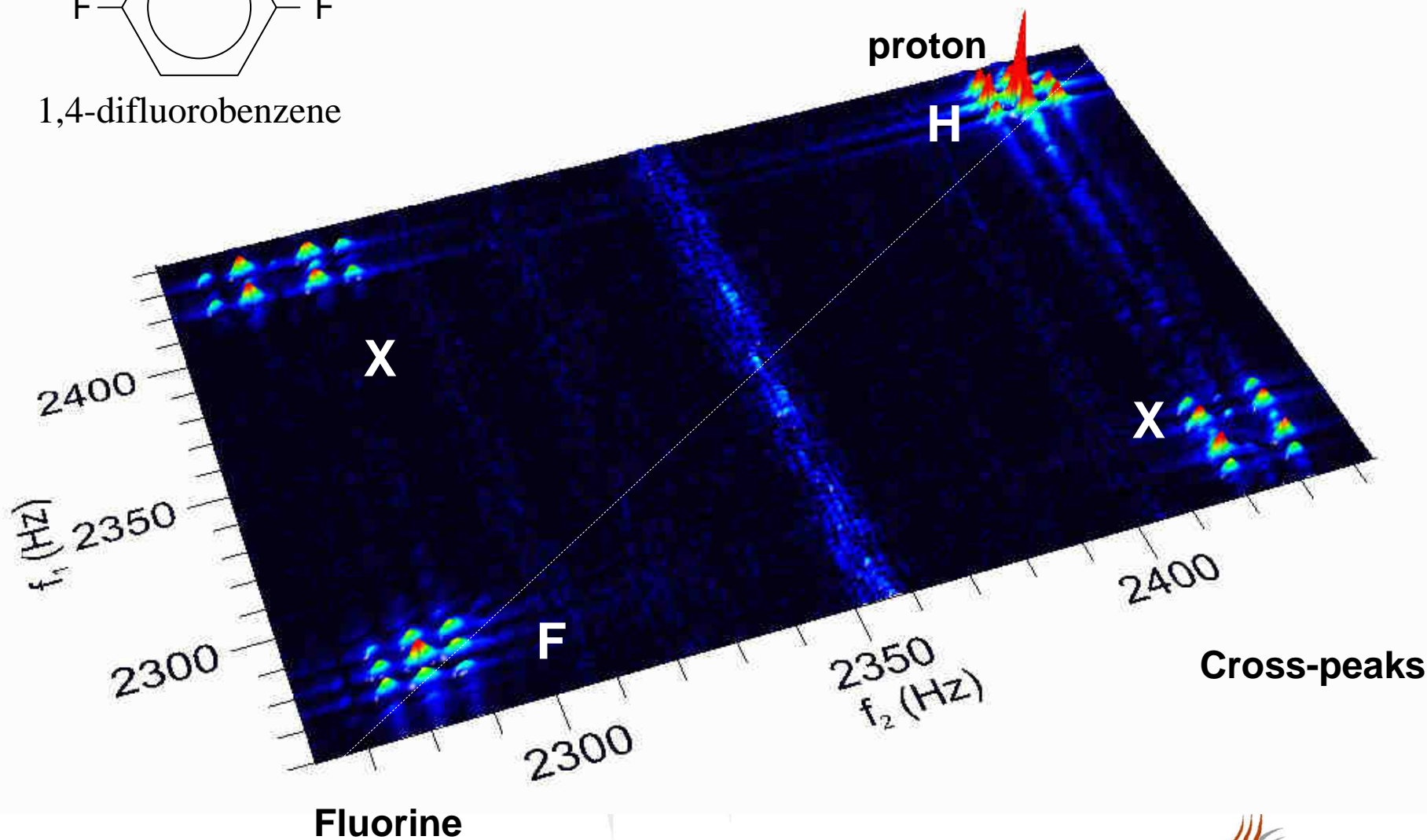
Protons H^1
~ 2425 Hz

Hetero-nuclear spin-spin J -coupling via electron (through bond).
 J -coupling is independent of frequency (measured in Hz)
Note: Simultaneous acquisition of both F and H signals.

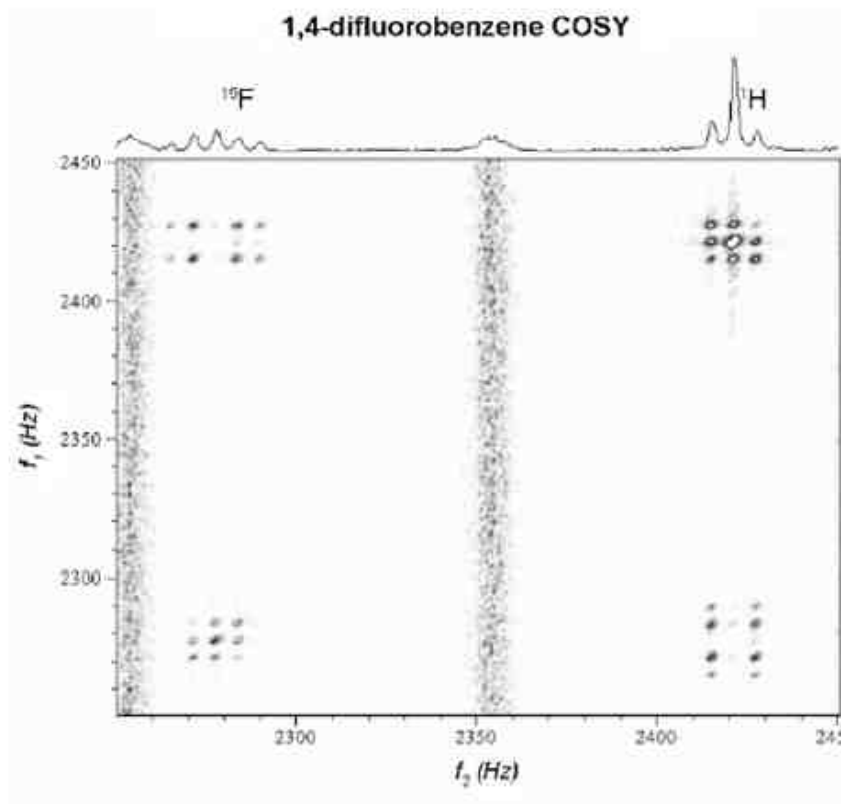
2D Spectroscopy: 2D COSY



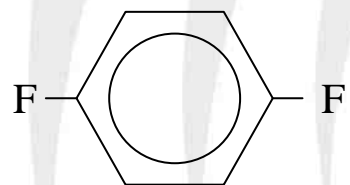
1,4-difluorobenzene



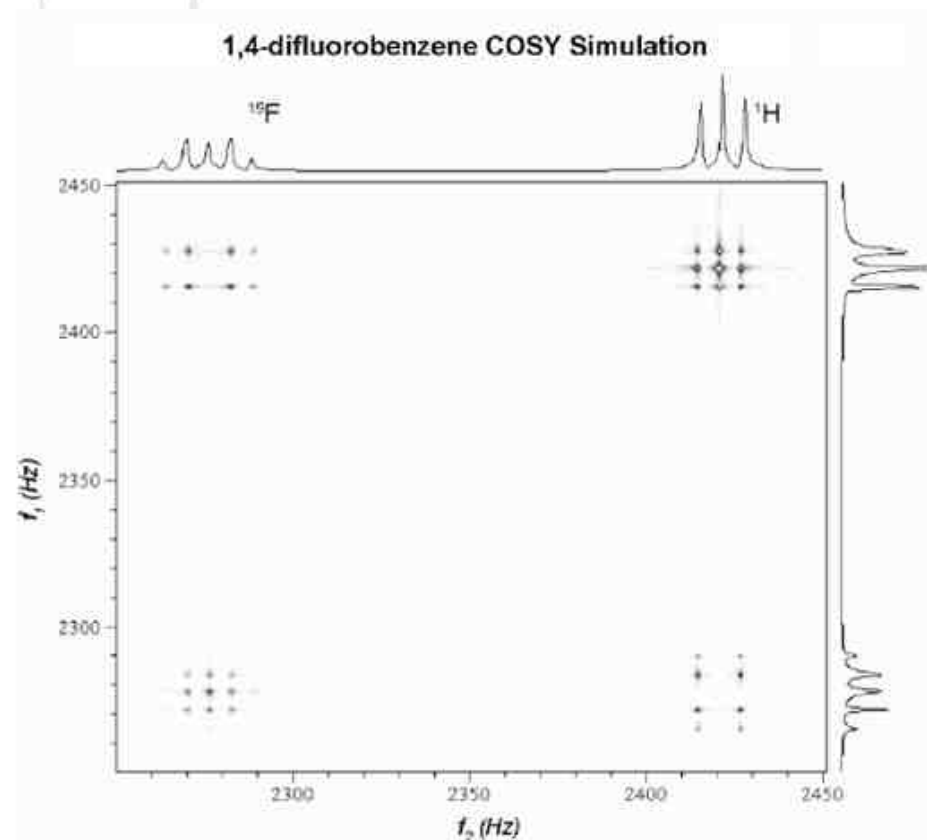
Robinson *et. al.* JMR **182** (2006)



Experiment



1,4-difluorobenzene



Theory

Thank you



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