### CMRRpack2

a collection of pulse sequences from the

University of Minnesota, Center for Magnetic Resonance Research (CMRR)

Version: 2.63\_package

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# CMRRpack2 pulse sequence and reconstruction collection.

CMRRpack2 pulse sequence implementations and recons.

### 1.1 Obtaining the CMRRpack2

- Please contact Dr. Michael Garwood [gar@cmrr.umn.edu]

## Installation

### 2.1 Installation prodecure (using installer)

Obtain the self-installing archive from CMRR. In this example it is a file called "INSTALL\_CMRRpack2\_2.5\_master-128-gd745578.run".

```
tesch 134>chmod u+x ./INSTALL_CMRRpack2_2.5_master-128-gd745578.run
tesch 135>./INSTALL_CMRRpack2_2.5_master-128-gd745578.run
Verifying archive integrity... All good.
Uncompressing CMRRpack2 2.5_master-128-gd745578.....
**** THIS IS THE CMRRpack2 PULSE SEQUENCE & RECON PACKAGE INSTALLER ****
The install directory for running a sequence should be the
user's ~/vnmrsys/ directory. You may select any arbitrary
directory if you are only using the reconstruction software.
The install directory will get several subdirectories, including:
 {cmrr2/ maclib/ parlib/ psglib/ psgpatch/ shapelib/ tablib/ templates/}
Any existing CMRRpack2 installation will be over-written!
(Backup files should be created of any collision files;
 nonetheless: USER BEWARE!)
Select install directory: [/lhd/home/tesch/vnmrsys]
About to extract CMRRpack2 into /lhd/home/tesch/vnmrsys ... Proceed ? [y/N]
```

Hit return here to accept the default installation location, or type in another directory. Installing in a location other than your local vnmrsys/ directory will work for recon, but obviously you wont be able to use the sequences from VnmrJ.

Extracting ...
Installing into /lhd/home/tesch/vnmrsys ...
Backing up /lhd/home/tesch/vnmrsys/./CMRRPACK2.version to /lhd/home/tesch/vnmrsys/./CMRRPACK2.version.cmrrpack2back
A list of installed files is in /lhd/home/tesch/vnmrsys/CMRRPACK2.contents.

A fist of instatied files is in / ind/ nome/ testin/ vimitsys/ cmilt Rok2. content

Extracting documentation into /lhd/home/tesch/vnmrsys ... Packagte documentation is available in a browser at file:///lhd/home/tesch/vnmrsys/cmrr2/doc/html/index.html

The install has modified and made backups of these files: /lhd/home/tesch/vnmrsys/CMRRPACK2.version.cmrrpack2back

The installer has completed, the next time VnmrJ start, there should be a new tab called 'CMRRPack2' in the experiment selector.

### 2.2 Installation prodecure (using sequence source)

If you're running >= VnmrJ 4, then you'll need to build both the sequence and a psglib locally for yourself.

The patches and sequence are currently tested only for 3.2, but they should work for VnmrJ 4 as well.

The following commands should be run from a shell in the account with SWIFT installed already as per the previous section. The pacth command should be repeated for each of the other patch files in  $\sim$ /vnmrsys/psgpatch/.

```
psggen
cd ~/vnmrsys/
rm psg/psgmain.cpp
cp /vnmr/psg/psgmain.cpp psg/
patch -p0 < ~/vnmrsys/psgpatch/psgmain.cpp.patch.VnmrJ_VERSION_3.2_REVISION_A</pre>
```

rm psg/....other patch files.... cp /vnmr/psg/...other patch files... psg/ patch -p0 < ~/...other patches....</pre>

psggen seqgen rcswift

Intro

## SWIFT

### 4.1 Getting Started with SWIFT

#### 4.1.1 SWIFT Scan Panel

Scan Parameters	FOV
TR Min 5.00 ms	FOV Offset
Averages 1 Repeats 1	X 320.0 mm 0.0 mm
Dummy Scans 0 0	Y 320.0 mm 0.0 mm
np # views # spirals Total Views: 170 1 1 1	Z 320.0 mm 0.0 mm
HS pulse n-Factor 2	Show Clear
RF TX Fraction 0.50	
Approx. Res. (pix): 255 x 255 x 255	
Approx. Res. (mm): 1.25 x 1.25 x 1.25	
Comment	RF Coil BCQ1swiftQuad Scan Time 0.0s
Protocol rcswift	Gradient 205_120_HD

Figure 4.1: SWIFT Scan Panel

- TR Min (checkbox) when set, the sequence always uses the smallest possible TR
- TR (value) when TR\_min is not checked, force this to be the TR. If this is too small, the sequence may not run.
- Dummy Scans (1) Number of non-acquisition steady-state setup TRs before acquisition.
- Dummy Scans (2) Number of non-acquisition steady-state setup TRs between spirals.
- np Approximate image pixel count
- # views Number of spokes per sphere / frame / spiral
- # spirals Number of spirals per image
- · Repeats [untested]
- · HS pulse n-factor "N-factor" in hyperbolic secant excitation pulse
- RF TX fraction Fraction of the readout during which RF is interleaved
- · FOV Field of view.

#### 4.1.2 SWIFT Advanced Panel

Nucleus     Proton     RF     Duty Cycle     25.0     %     Gain       Obs Frequency     169.257     MHz     T/R to Tx Delay     3.00     us     Set gain to 30 % of max       Obs Offset     66.6     Hz     Tx to T/R Delay     3.00     us     Set gain to 30 % of max       Spectral Width     62500     Hz     T/R to Rx Delay     3.00     us     Profile       Acquisition Time     2.7200     ms     Acquisition Gap     3.000     us     Raw Profile       presig     low     18.8     %     swifthz:     323       Glim     90     %     Data rate/chan     1.0     MiB	Acquisition —			Gapping			Prescan
Obs Frequency     169.257     MHz     T/R to Tx Delay     3.00     us     Set gain to 30 % of max       Obs Offset     66.6     Hz     Tx to T/R Delay     3.00     us     Set gain to 30 % of max       Spectral Width     62500     Hz     T/R to Rx Delay     3.00     us     Profile       Acquisition Time     2.7200     ms     Acquisition Gap     3.000     us     Raw Profile       presig     low     ■     18.8     %     swifthz:     323       Glim     90     %     Data rate/chan     1.0     MiB     Program	Vucleus	Proton	-	RF Duty Cycle	25.0	%	Gain
Obs Offset     66.6     Hz     Tx to T/R Delay     3.00     us     Set gain to 30     % of max       Spectral Width     62500     Hz     T/R to Rx Delay     3.00     us     Profile       Acquisition Time     2.7200     ms     Acquisition Gap     3.000     us     Profile       Receiver Gain     16     dB     0.333     MHz     MW Profile     swifthz:     323       Ilim     90     %     Data rate/chan     1.0     MiB     Spectral/Pice     38.50	Obs Frequency	169.257	MHz	T/R to Tx Delay	3.00	us	
Spectral Width         62500         Hz         T/R to Rx Delay         3.00         us         Profile           Acquisition Time         2.7200         ms         Acquisition Gap         3.000         us         Raw Profile           Receiver Gain         16         dB         0.333         MHz         Raw Profile           gresig         10w<	Obs Offset	66.6	Hz	Tx to T/R Delay	3.00	us	Set gain to 30 % of max
Acquisition Time         2.7200         ms         Acquisition Gap         3.000         us         Raw Profile           Receiver Gain         16         dB         0.333         MHz         Raw Profile           presig         low          18.8         %         swifthz:         323           Glim         90         %         Data rate/chan         1.0         MiB         Roward(R):         38.50	Spectral Width	62500	Hz	T/R to Rx Delay	3.00	us	Profile
Receiver Gain         16         dB         0.333         MHz         Raw Profile           presig         low         ▼         18.8         %         swifthz:         323           Glim         90         %         Data rate/chan         1.0         MiB         Power(dB):         38.50	Acquisition Time	2.7200	ms	Acquisition Gap	3.000	us	
presig low ▼ 18.8 % swifthz: 323 Glim 90 % Data rate/chan 1.0 MiB Power(dp): 38.50	Receiver Gain	16	dB		0.333	MHz	Raw Profile
Glim 90 % Data rate/chan 1.0 MiB Power(dP) 38.50	oresig	low 🗨	•		18.8	%	swifthz 323
EDWEITUDI 20.20	Slim	90	%	Data rate/chan	1.0	MiB	Power(dB) 38.50
Base Sampling 0.250 MHz				Base Sampling	0.250	MHz	
seqcon cccsn Oversampling 4 🗸 Version	seqcon	cccsn		Oversampling	4	-	Version
[MRR_VERSION=UNKNOW							[MRR_VERSION=UNKNOWNX

Figure 4.2: SWIFT Advanced Panel

- · Spectral Width bandwidth across FOV
- Receiver Gain Receiver gain. Might be useful in case of low signal.
- RF Duty Cycle % of gap used for RF excitation.
- T/R to TX delay homorof1
- Tx to T/R delay homorof2
- T/R to Rx delay homorof3
- Oversampling the receive readout is performed at (Spectral Width \* Oversampling). Actual parameter is os.

#### 4.1.3 SWIFT RF Panel

RF pulses										
Excitation	Flip angle 2.5	Width	Pattern	Power (db) 38.50	Power (hz) 322.65					
T1 estimate (s): 1.3 Ernst Angle (est) : 5.02										
Close										

Figure 4.3: SWIFT RF Panel

- Flip Angle the flip angle in degrees each HS pulse should achieve. This value is converted to a power in Hz, and then finally into a dB value for the RF amplifier. The conversion requires a correct entry in pulsecal for the current *rfcoil*.
- T1 estimate this is just a utility for the user to estimate the Ernst angle. It does not affect the pulse sequence at all.

#### 4.1.4 SWIFT Timing Parameter Setup

SWIFT is difficult to initially setup. This is an attempt at simplifying the setup procedure. The rapid switching between transmit and receive usually needs some timing setup for any given setup. Some steps to find the correct gap timing:

- Start with a normal sample with a lot of signal.
- Tune your coil and get some normal images using a non-SWIFT scout sequence.
- First optimize a single SWIFT pulse-acquire using the "Raw profile" button in the SWIFT Advanced Panel .
- Start with a high level of oversampling (os = 64 or 128) and slow sw (=32 kHz).
- Start with a low tip angle  $\sim$ 1-2 degrees so as to limit the RF power in case homorof2 isnt set well.
- Increase FA to 5-6 deg when you are comfortable with your homorof2 setting. SWIFT RF Panel.
- Set ssc and ssc2 values to 0 (they need to be set back when making an image). SWIFT Scan Panel.
- Start with conservative safe values of homorof1,2,3 maybe (3us,3us,0.1us) YMMV.
- Set homorof1 to a reasonable value for your system.
- Calculate a safe small value of homorof2, or reduce homorof2 slowly to find the start of the ring-down signal.
- Use the "Raw profile" button to inspect a single readout, zoom in to see 2-5 gaps at a time.
- Increase homorof3 until raw signal contains no ring-down.
- For imaging, reduce os to maybe 12 (or 4 or 8) maybe try increasing sw, etc...
- Data errors from VnmrJ can sometimes be mitigated by forcing a longer TR. SWIFT Scan Panel

The SWIFT timing for a single gap looks like this:



Figure 4.4: SWIFT Gap Timing

Spikes at the beginning of the sampling period indicate that the homorof3 (and possibly homorof2) is too short. Spikes at the end of the sampling period indicate a mis-set *alfa*, if that happens, try setting different values of alfa roughly between 2 and 15. *alfa* is an internal timing parameter (us) for VnmrJ, the correct value may vary depending on your system.

High levels of oversampling aren't necessary for imaging, but can be very helpful for debugging what is going on with the receive data in regards to the ring-down signal. Oversampling significantly increases the amount of data that is sent back to the console. For actual imaging, an oversampling of 8-12 is probably sufficient.

The raw recorded data from a full SWIFT acquisition looks like this:

Exp:1 Seq:	rcswift	Index: 1				۲				
0.0001 0.0003 0.0005 0.0007 0.0009 0.0011 0.0013 0.0015 0.0017 0.0019 sec										
vpfi <mark>0</mark>			crf <mark>0.00081</mark>	√f 104.6	deltaf 0.000356					
Start Acquire	Process Press	an Gain			Start scan	р Ф Х				
Scan Advanced RF Pulses Gradients Contrast Preps	Acquisition Nucleus Obs Frequency Obs Offset Spectral Width Acquisition Time Receiver Gain presig Glim	Proton   I 69.257 MHz  66.6 Hz  78125 Hz  2.1760 ms  16 dB  low   90 %	Gapping RF Duty Cycle T/R to Tx Delay Tx to T/R Delay T/R to Rx Delay Acquisition Gap Data rate/chan Base Sampling	25.0 % 0.02 us 0.50 us 2.80 us 6.275 us 0.159 MHz 49.0 % 8.3 MIB 2.500 MHz	Prescan Gain Set gain to 30 % of max Profile Raw Profile swifthz: 807 Power(dB): 46.44					
	seqcon	cccsn	Oversampling	32 🔻	IMRR VERSION=UNKNOWNX					

Figure 4.5: Raw Gapped data, rffraction=0.5

In VnmrJ, looking at the same data zoomed in - this pulse shows a pretty good signal, there is a small amount of ring-down at the beginning of the IEN window, evident from the little high-blips at the beginning of some sampled periods.



Figure 4.6: Gapped data

#### 4.1.5 homorof1

When the receive has finished, there is a delay homorof1 between when the RF unblank signal changes and when the RF transmit starts. This is to allow slow unblank circuits to open up. Usually this parameter can be very small, around or less than 0.1 us.

#### 4.1.6 homorof2

The RF pulse is ON when xout is high. After RF goes off, there is a delay of homorof2 until the T/R switch switches (UNBLANK and TR happen at the same time). homorof2 is critical to protecting your pre-amp from the transmit energy in the coil, *do not make it too small*. But make it as small as possible. In reality, we have never blown a pre-amp, and are not terribly careful about it, BUT in theory it IS possible.

#### 4.1.7 homorof3

homorof3 controls when the receiver ADC is given a 'data valid' signal. homorof3 does not control any circuitry, so it is safe to use a very small value and increase it until the ring-down from the coil is no longer visible. After homorof3, the IEN signal goes high to indicate to the DDR that the data coming from the ADC is valid.

## **Problem Resolution**

### 5.1 Information to collect

The following information is pretty helpful when trying to debug these sequences:

- magnet strength & bore size
- · phantom type
- · scout image of your phantom, if available
- image showing the problem (either fid or image)
- sw, fov, tr, #views, #spirals
- · type of coil & size
- · screen show of the overall "Raw profile" zoomed all the way out
- screen shot of the "Raw profile" of the signal, zoomed in to see 3-10 pulse gaps, oversampled at least 32x

**Parameter Index** 

**Credit and Thanks** 

# References

8.1 Version ChangeLog.

Release changelog

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# **CMRR-VERSION**

this is package version CMRR\_VERSIONX git ident:

ld:

c797996b9601dcd5ec6d887202fc49f2c1db53db

footer