

# **User Guide:**

# **Single-Voxel Spectroscopy semiLASER**

Siemens syngo VD and VE platforms

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Version 1.0



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## 1. Sequence description

The `svs_sLASER` sequence presented here is designed for  $^1\text{H}$  localized MR spectroscopy in the brain at high and ultra high magnetic fields such as 3T and 7T. `sLASER` package offers a relatively short  $T_E$  sequence that provides full intensity signal similar to PRESS, but optimized to minimize/eliminate unwanted coherences and to generate high quality spectra that enable the reliable quantification of a profile of 10-20 neurochemicals from selected brain regions. Additionally, the sequence is designed to reduce chemical shift displacement errors, which are more severe at higher field strength due to increased chemical shift dispersion.

The current `svs_sLASER` sequence [1] (Figure 1) is based on the modified semi-adiabatic localization by adiabatic selective refocusing [2], and combines critical features for optimized *in vivo* MRS at high field scanners including:

- 1- A short  $T_E$  (26-30 ms) and slice-selection with pairs of adiabatic  $180^\circ$  pulses in two dimensions for reduced  $T_2$  relaxation effects and reduced J-modulation of coupled spins.
- 2- High bandwidth slice selective RF pulses for minimal chemical shift displacement.
- 3- Outer volume saturation (OVS), for more accurate localization and reduced signal contamination from outside the VOI.
- 4- The VAPOR (**V**ariable **P**ower and **O**ptimized **R**elaxation **D**elays) technique [3] for excellent water suppression.
- 5- A loop routine for parameter optimization to maximize spectral quality and minimize signal loss from misadjusted parameters.
- 6- Single-shot acquisition, i.e. saving of individual FIDs, to enable frequency and phase correction of individual scans and elimination of shots corrupted by subject motion.

A detailed description of the sequence `svs_sLASER` is found in reference 1. The timing diagram in Figure 1 depicts positioning of the VAPOR and OVS modules with respect to the semi-LASER localization scheme.

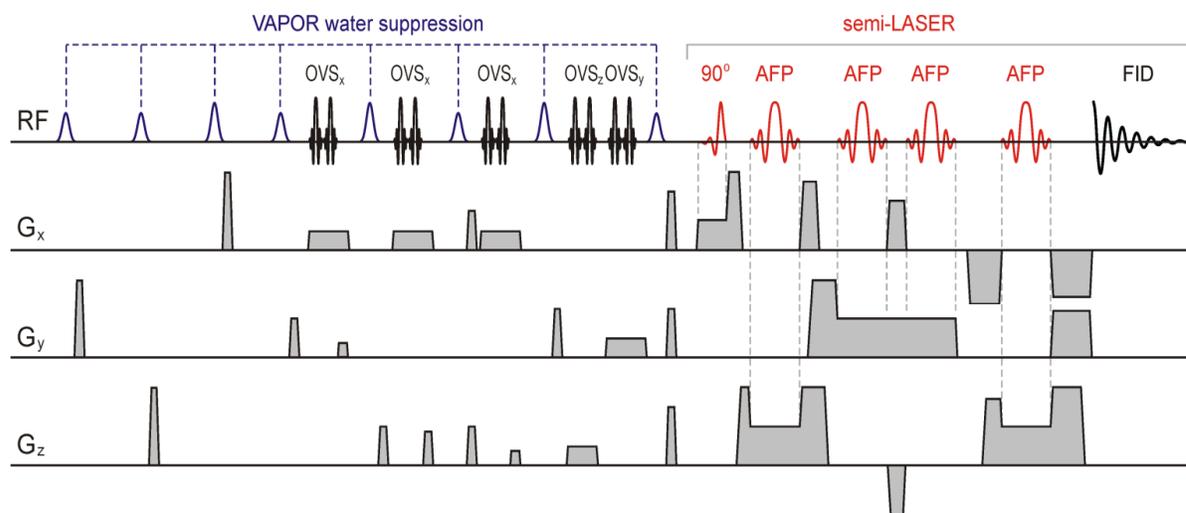


Fig. 1. The scheme of the modified semi-LASER sequence. Three pairs of OVS pulses are applied in the X-dimension selected by the slice selective excitation pulse while single pairs of OVS pulses are applied in the Y- and Z-dimensions. [From Öz G & Tkáč, I. Magn Reson Med 2011; 65(4):901-10]

## REFERENCES

1. Öz G, Tkáč I. Short-echo, single-shot, full-intensity  $^1\text{H}$  MRS for neurochemical profiling at 4T: Validation in the cerebellum and brainstem, Magn Reson Med 2011; **65**:901-10.
2. Scheenen TW, Klomp DWJ, Wijnen JP, Heerschap A. Short Echo Time  $^1\text{H}$ -MRSI of the Human Brain at 3T With Minimal Chemical Shift Displacement Errors Using Adiabatic Refocusing Pulses, Magn Reson Med. 2008;**59**:1-6.
3. Tkáč I, Starčuk Z, Choi IY, Gruetter R. In vivo  $^1\text{H}$  NMR Spectroscopy of Rat Brain at 1 ms Echo Time, Magn Reson Med 1999; **41**: 649-656.

## 2. Sequence Features

### 2.1 The Sequence/Special card

Special features of the svs\_sLASER are found in the “Sequence/Special” card of the user interface and described below.

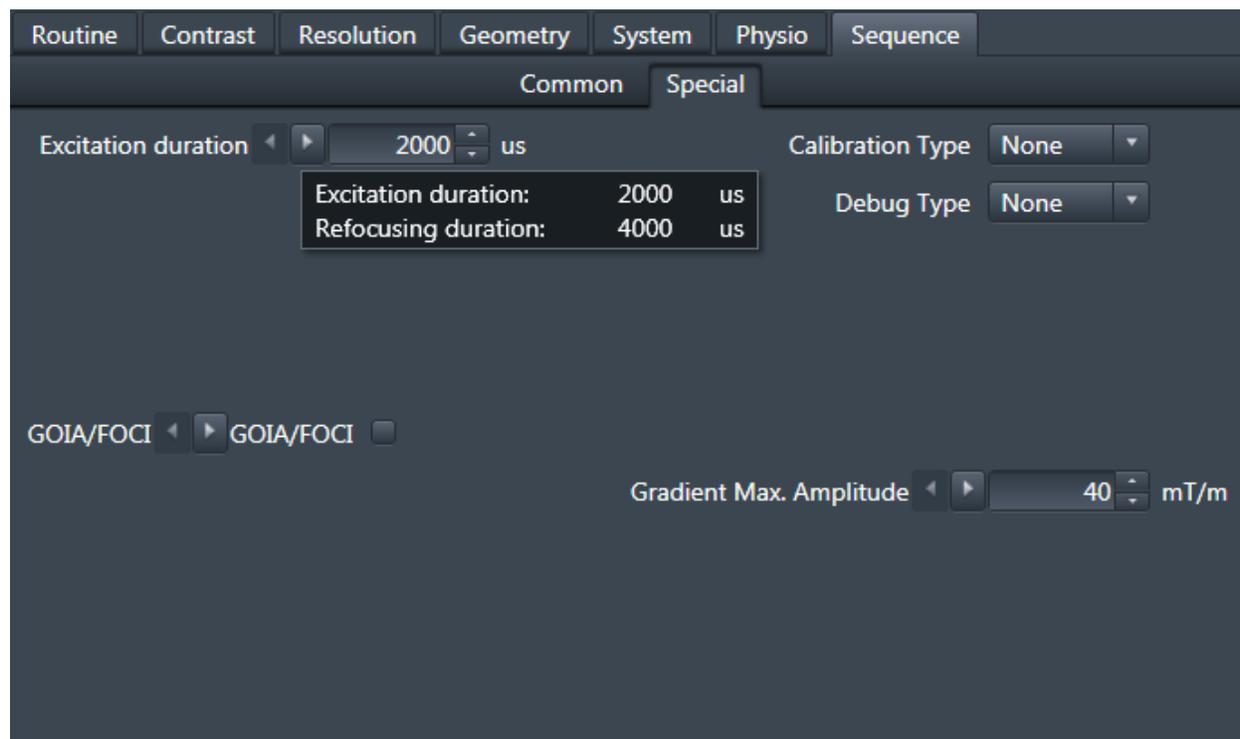


Figure 2: New features included in the Sequence/Special card

The Special features include:

- 1- Settings for the duration of the excitation and refocusing pulses.
- 2- Options for using gradient offset independent adiabatic, e.g. GOIA-HS, GOIA-WURST, FOCI and BASSI pulses.
- 3- An option for including an inversion pulse with user selectable inversion time to acquire macromolecule spectra.
- 4- An option for enabling automatic calibration of excitation and VAPOR water suppression flip angle in the MRS VOI (FA AutoCalib). NOTE that this option only works when multiple protocols are setup; refer to the distributed sLASER.exar1 protocols (on VE11B) for more details.
- 5- A calibration loop, which is a very useful tool for optimization of parameters that may degrade spectral quality and cause signal loss is also provided. Those parameters

include the 90° and 180° flip angles, the water suppression (VAPOR) flip angle, VAPOR delays (i.e. 7 and 8) and the inversion time. Selection of the parameter to be optimized is done from the drop-down menu of the 'Calibration Type' (Figure 3). When optimization is completed, the "none" option is selected for acquisition of the final spectral data (Figure 3). Starting values of the 90°, 180° for the calibration procedure are set in the contrast card (Figure 4) while the number of measurements and incremental step size are in the Special Card (Figure 5).

- 6- A debug loop to acquire VOI and OVS profiles of the selected MRS voxel. The spectra width and number of points are automatically adjusted when this option is enabled.

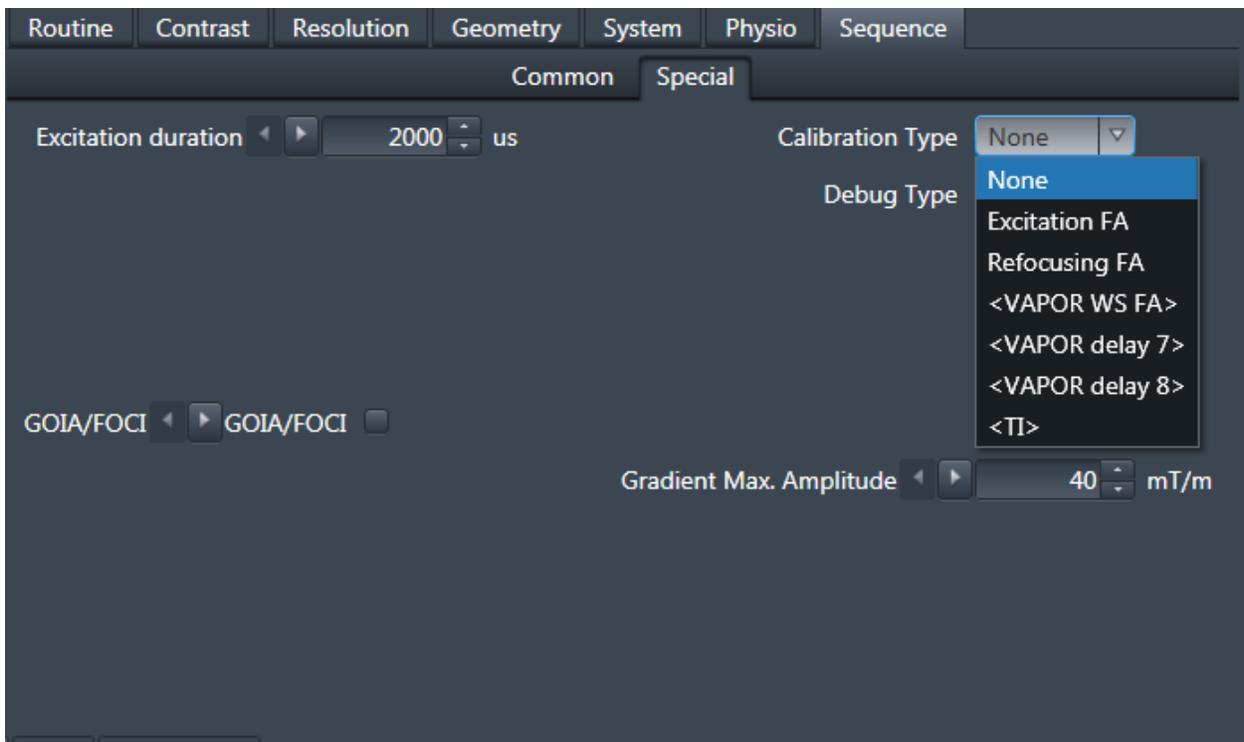


Figure 3: Calibration options in the Sequence/Special card

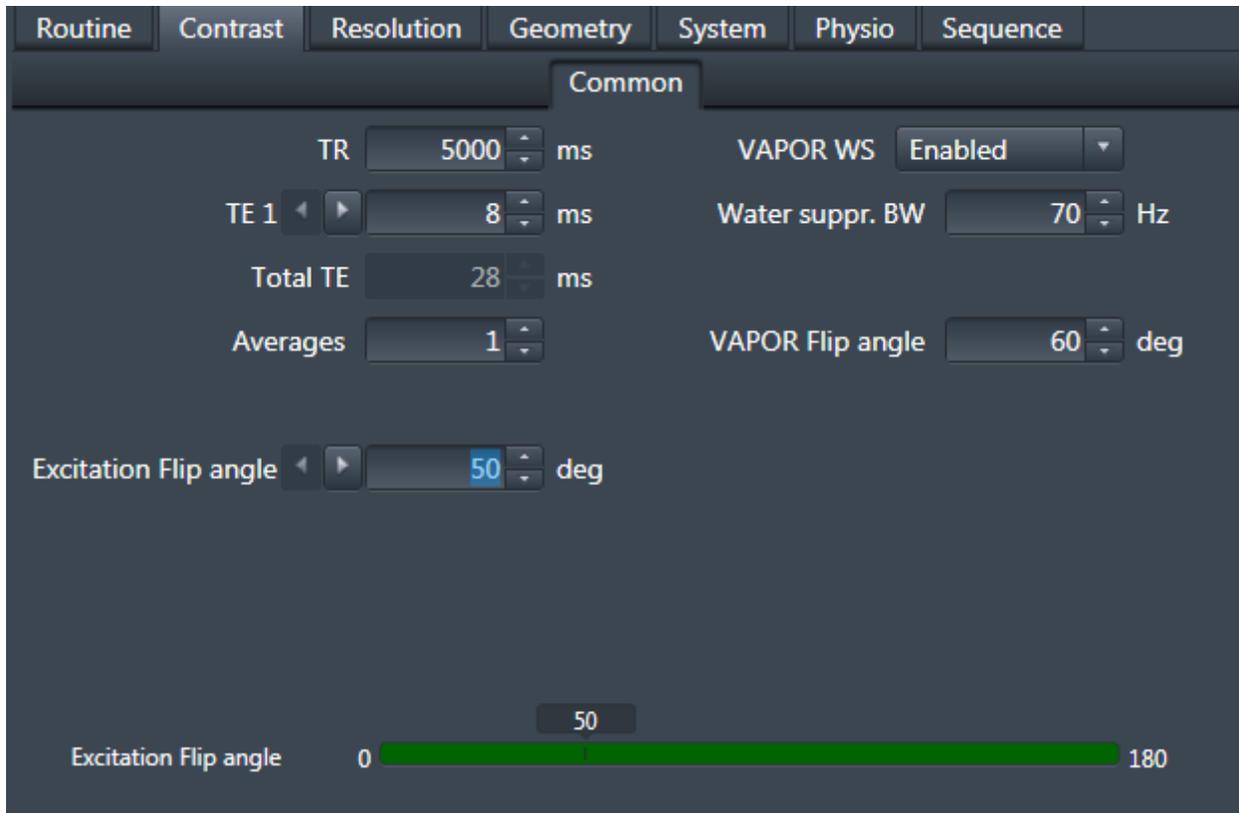


Figure 4: Starting values for the FA calibration option in the Contrast/Common card.

## 2.2 FA calibration

When the “90° Calibration” is selected in the Sequence/Special card, a new field appears for entering incremental steps and number of measurements of the calibration loop. Since the calibration is performed on the water signal, VAPOR water suppression is automatically set to “None” in the Contrast/Common card. This option is only available on VE platform for now.

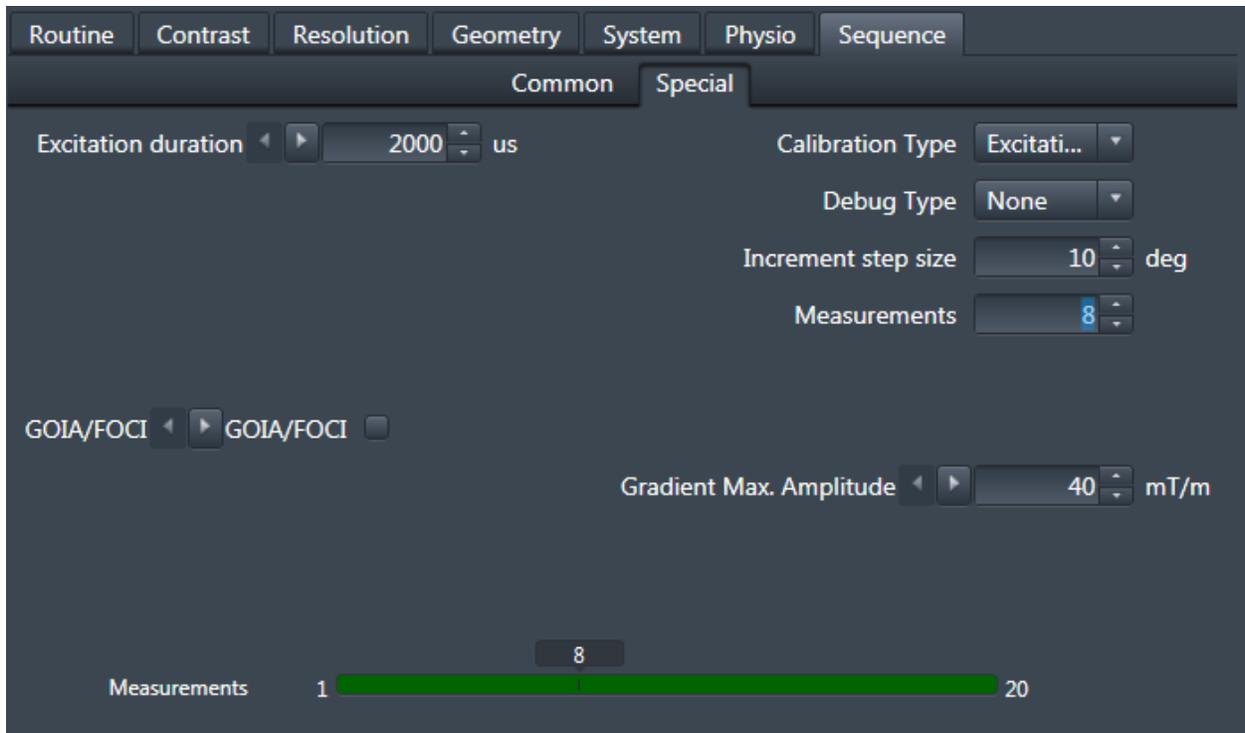


Figure 5: Setting of the incremental steps and number of measurements in the Sequence/Special card during 90 Calibration.

Real time monitoring of the calibration loop measurement is done with the “Inline display” feature in the exam card. Examples of the inline display are shown in figures 6 and 8 from in vivo measurements.

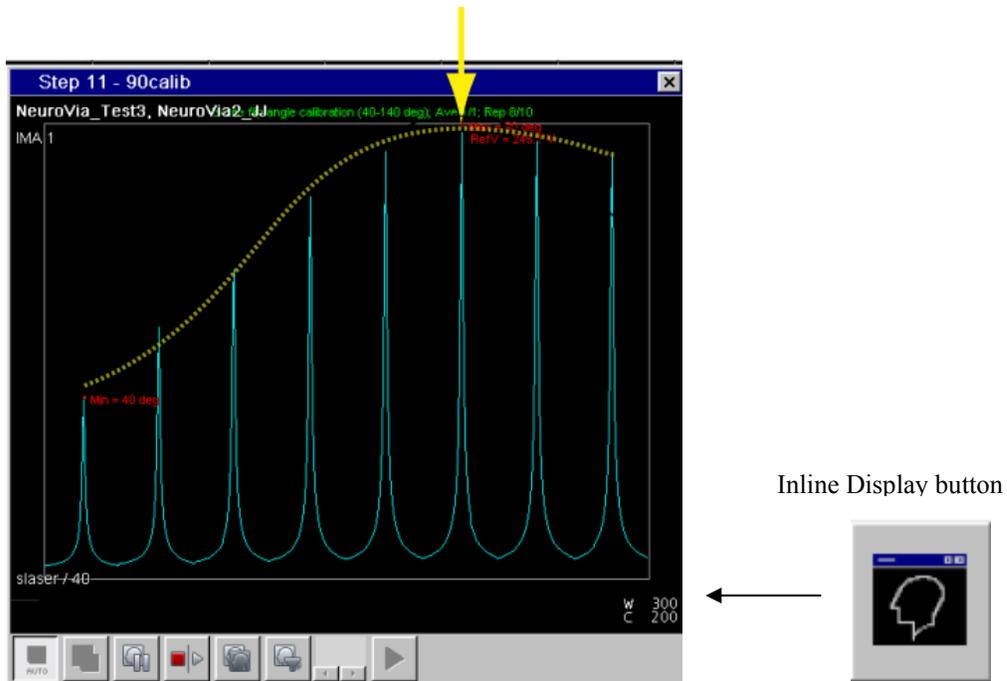


Figure 6: Inline display during 90deg calibration of the flip angle in vivo. The minimum and maximum signals are labeled in red with the corresponding flip angle and transmitter reference amplitude. When FA AutoCalib is enabled, the maximum intensity spectrum (denoted here with yellow arrow) will be automatically selected by the system. Yellow dotted line was added for display purpose only in this figure.

When the “VAPOR FA Calibration” is selected in the Sequence/Special card, “VAPOR WS” is automatically enabled. Starting value of the VAPOR FA calibration is entered in the VAPOR flip angle field, and incremental steps in the “Increment step size” field (Figure 7).

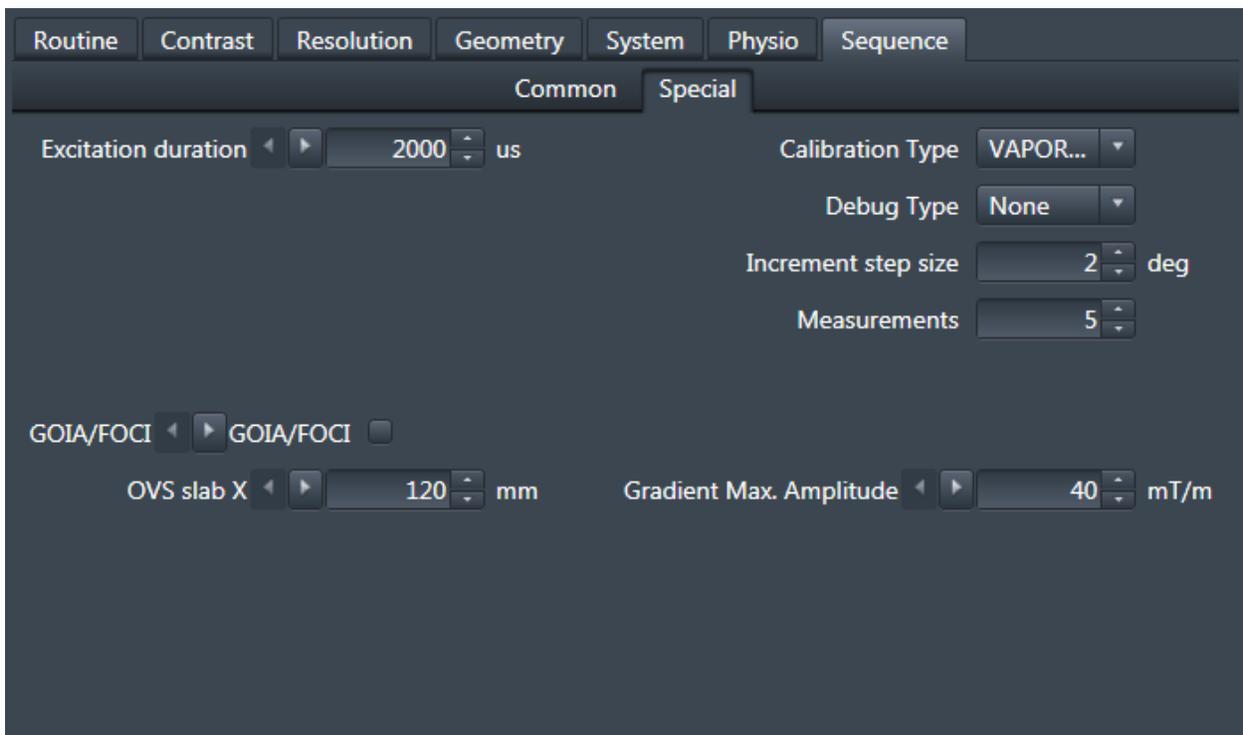
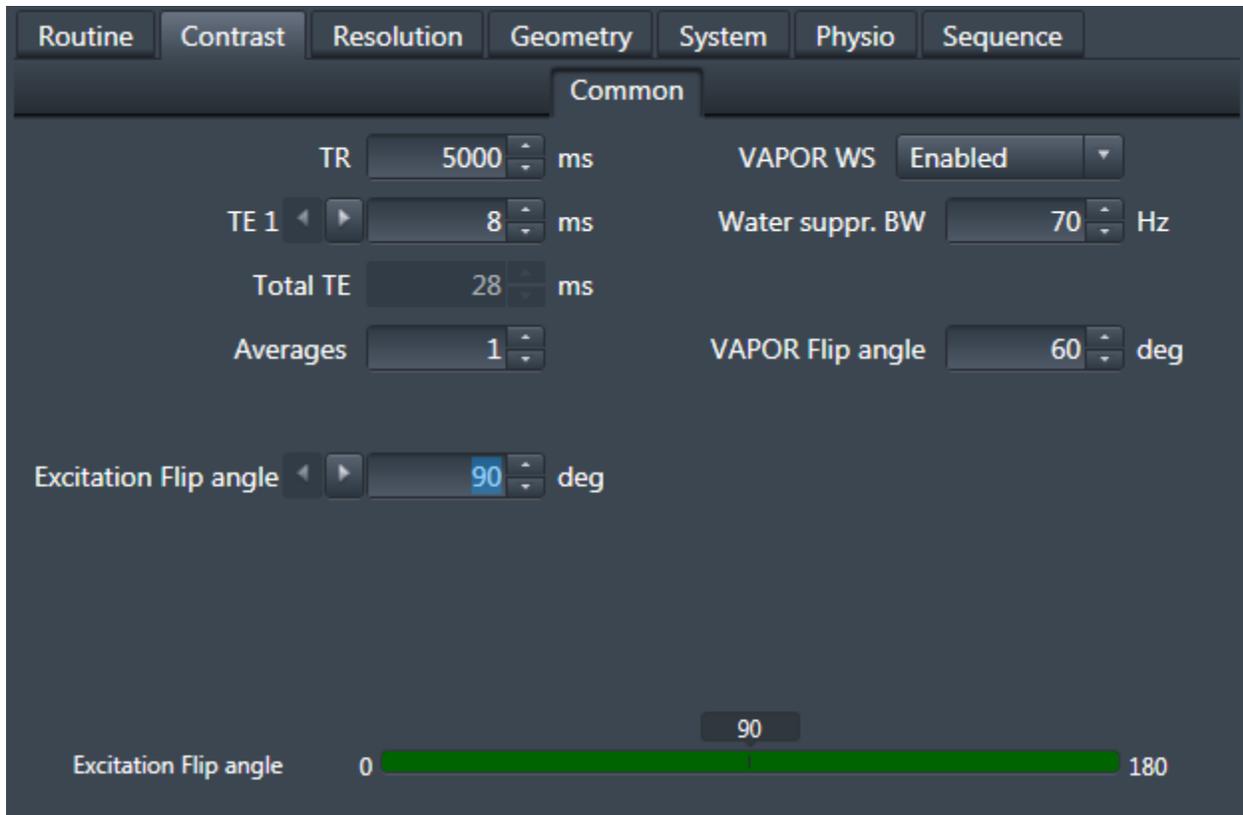


Figure 7: Setting the VAPOR flip angle Calibration and VAPOR bandwidth in the Contrast/Common card and incremental steps and number of measurements in the Sequence/Special card.

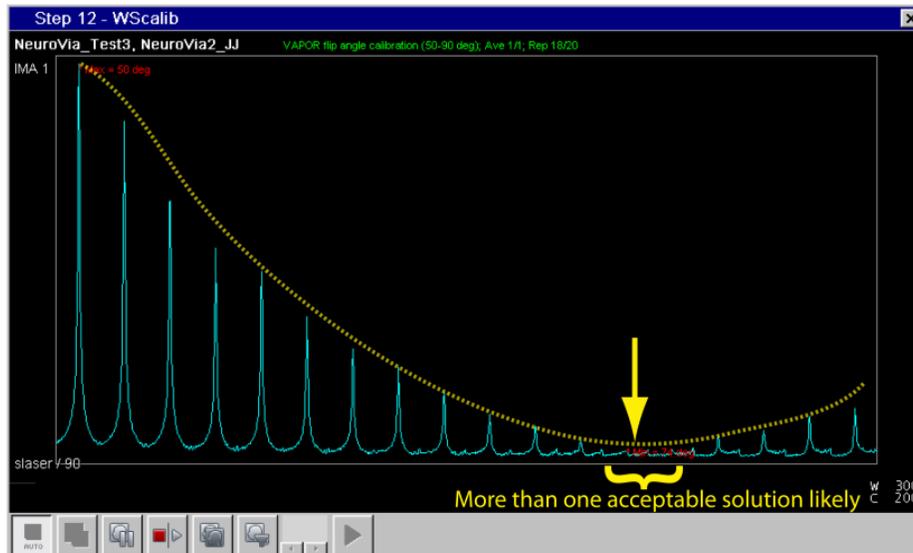


Figure 8: Inline display during calibration of the VAPOR flip angle in vivo. The flip angles producing the smallest and largest water signals are labeled in red. When FA AutoCalib is enabled, the minimum water signal spectrum (denoted here with yellow arrow) will be automatically selected by the system.

### 2.3 Saving single-shot FIDs

The capability of saving individual averages and the summed spectrum (Figure 9) is also available. With the VAPOR option selected, "Save single averages" saves both the individual averages as well as the summed spectrum.

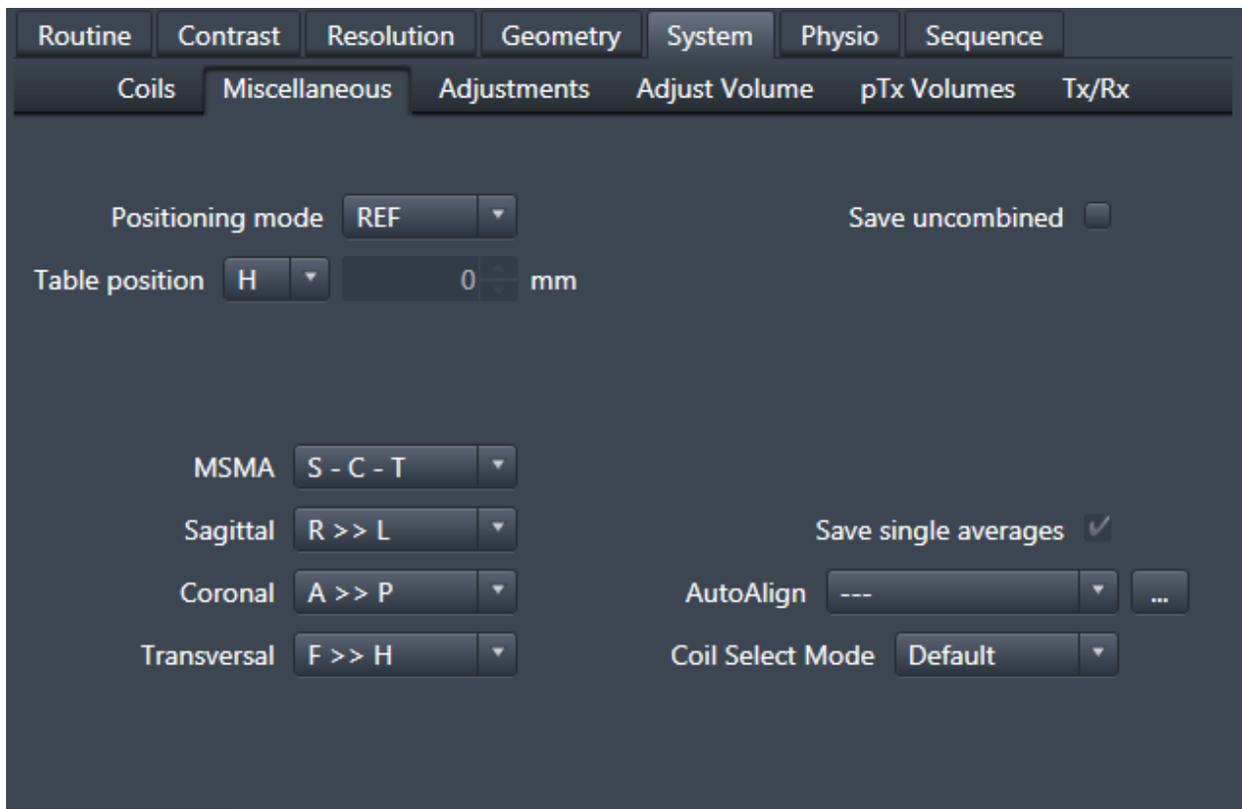


Figure 9: Save single averages option is located in the System/Miscellaneous card.

## 2.4 Gradient-modulated RF pulses

The default refocusing pulses in sLASER are an HS4-R25 adiabatic full passage pulse which requires a  $B_1$  of  $\sim 25 \mu\text{T}$  (when GOIA/FOCI option in the Sequence/Special card is disabled). If the  $B_1$  is limited or if one wants to further reduce the echo-time of sLASER, gradient-modulated RF pulses can be used. Four types of refocusing RF pulse are available (Figure 10) and these are GOIA-HS, GOIA-WURST, FOCI and BASSI RF pulses.

For GOIA RF pulses, the bandwidth at 1ms, modulation of the HS pulse and gradient factor can be entered in the Sequence/Special card (Figure 11). For FOCI, only the bandwidth can be changed. The bandwidth of BASSI pulse (and other RF parameters) is hard-coded to be 45 kHz at 1 ms duration. This pulse was optimized for 4.5 ms duration at a required  $B_1$  of  $15 \mu\text{T}$ .

**NOTE:** Before using these type of refocussing RF pulses, please run Bloch simulator based on the available  $B_1$  field of your RF coil to determine the required duration/bandwidth/gradient factor.

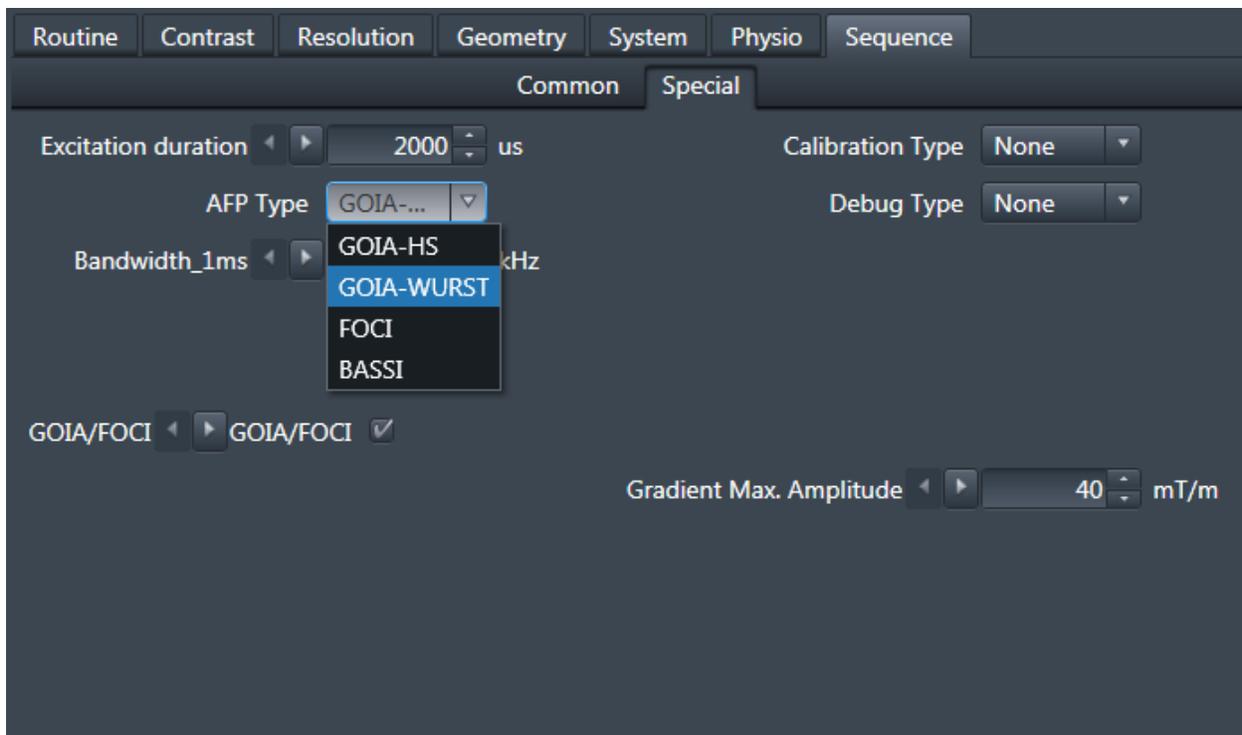


Figure 10: Gradient-modulated refocusing RF pulse options in the Sequence/Special card

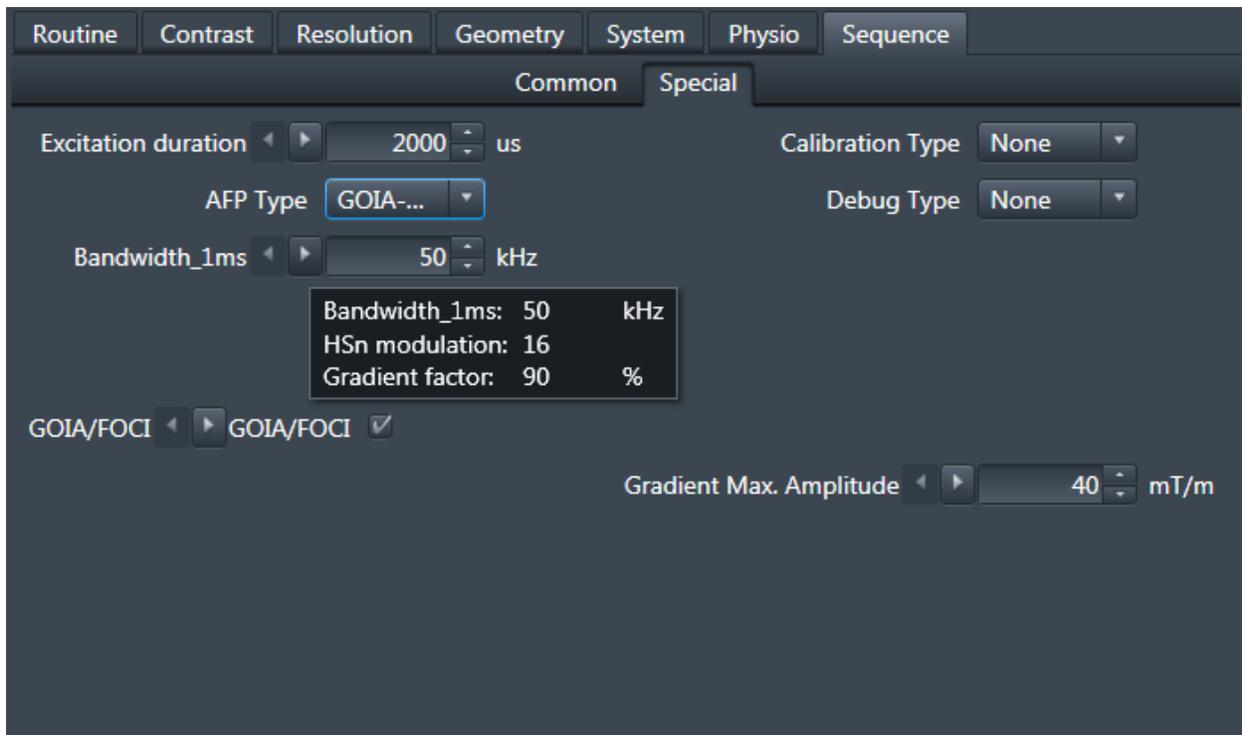


Figure 11: Bandwidth, HS modulation or gradient factor to define the gradient-modulated RF pulse in the Sequence/Special card

## 2.5 Water references scans

A new feature available on sLASER is the possibility to save the water reference scans and metabolites data together as individual FIDs within one protocol. The water scans includes the water reference scans for eddy-current correction (set VAPOR WS to “Only RF off” in Contrast/Common card) and for quantification (set VAPOR WS to “None” in Contrast/Common card).

This “Water Ref. Scan” option is only visible when VAPOR is enabled (Figure 12) and the “No. of ref. scans” field defines the number of scans to acquire before and after the metabolite spectrum is acquired, as shown in the data structure (Figure 13).

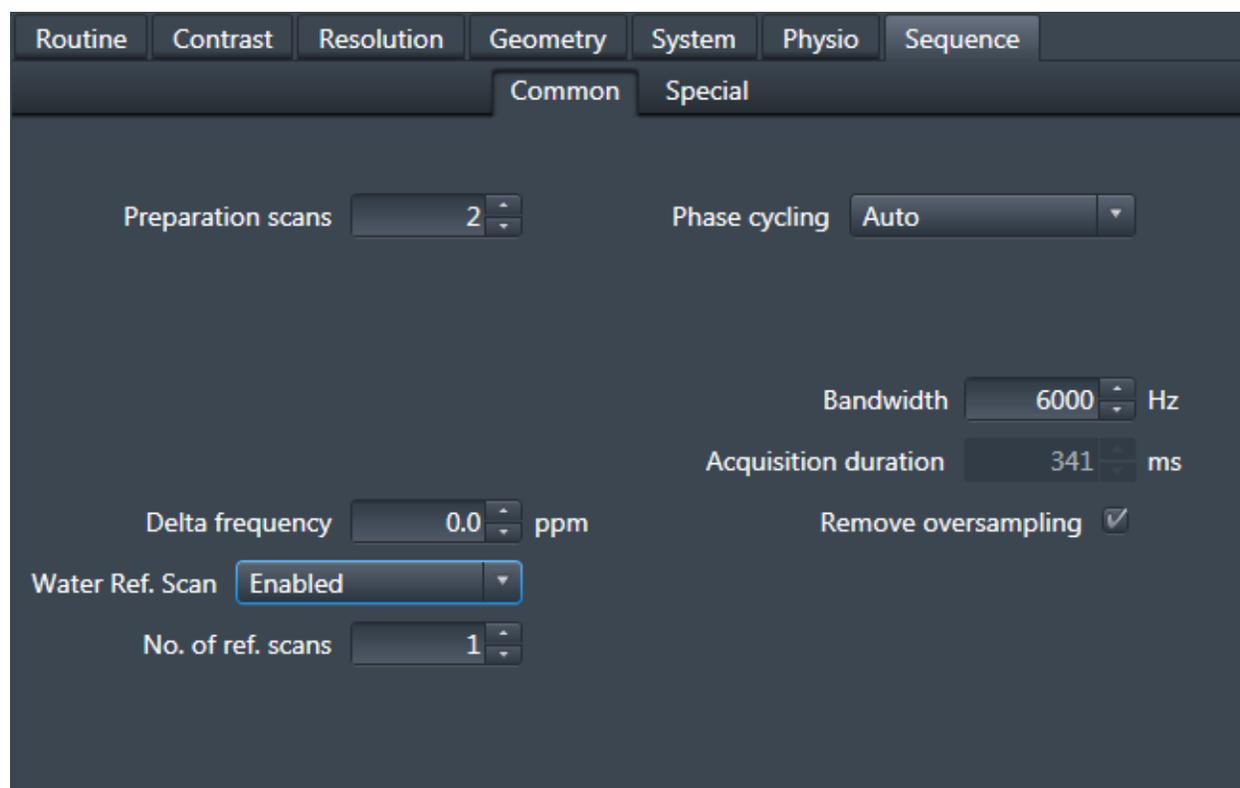


Figure 12: Bandwidth, HS modulation or gradient factor to define the gradient-modulated RF pulse in the Sequence/Special card

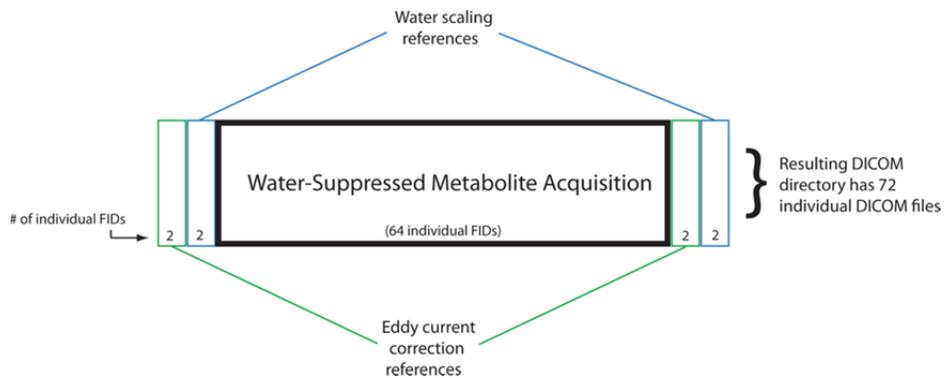


Figure 13: The structure of the water suppressed protocol when Water Ref. Scan is enabled.

## 2.6 Automatic RF calibration

Another new feature implemented in sLASER is the option to automatically perform the excitation and VAPOR flip angle calibrations. This option only works if four separate protocols are setup as described below (Figure 14). Note that on VE11B, sLASER.exar1 file are provided for these protocols:

### 1) sLASER\_LW

Contrast/Common card: Excitation Flip angle = 90 deg, Measurements = 1, Averages = 1, VAPOR WS = None; FA AutoCalib = off

Sequence/Common card: Preparation scans = 1, Delta frequency = 0 ppm

Sequence/Special card: Calibration type = None

### 2) sLASER\_90Calib

Sequence /Special card: Calibration type = Excitation FA, Increment step size = 10 deg, Measurements = 8; FA AutoCalib = On

Contrast/Common card: Excitation Flip angle = 50 deg, Averages = 1, VAPOR WS = None.

Sequence/Common card: Preparation scans = 1, Delta frequency = 0 ppm

### 3) sLASER\_WSCalib

Sequence/Special card: Calibration type = VAPOR WS FA (this automatically sets VAPOR WS = enabled), increment = 2 deg, Measurements = 8, FA AutoCalib = on

Sequence/Common card: Preparation scans = 1, Delta frequency = -2 ppm

Contrast/Common card: Excitation Flip angle = 90 deg, Averages = 1, VAPOR WS = Enabled, VAPOR flip angle = 52

### 4) sLASER\_WS64

Sequence/Special card: Calibration type = None, FA AutoCalib = On

Sequence/Common card: Preparation scans = 1, Delta frequency = -2 ppm

Contrast/Common card: Excitation Flip angle = 90 deg, Measurements = 1, Averages = 64 (or 32)

**IMPORTANT**: Set up steps #2-4 such that the “Measurement Parameters” is copied from step 1 (Figure 14).



The screenshot shows a software interface with a dark background and white text. At the top, it reads "New Tree » Dinesh » MRS » sLASER". Below this is a list of four protocols, each with a small icon of a person running and a button with the number "1". The protocols and their durations are:

Protocol Name	Duration
sLASER_LW	00:15
sLASER_90Calib	00:50
sLASER_WSCalib	01:10
sLASER_WS64	06:10

Figure 14: Protocols required for successfully running the automatic RF calibration

### 3. Measurement Protocols

This `svs_sLASER` sequence acquires single shots that can be exported and corrected for frequency and phase shifts prior to summing. The following common parameters are set as default in the protocol.

- In Contrast card
  - TR = 5000 ms
  - TE1 = 8 ms, TE2 = 11 ms and TE3 = 9 ms, i.e. total TE = 28 ms
  - Water s. BW = 70 Hz
- In Sequence/Special card:
  - Excitation duration = 2000  $\mu$ s
  - Refocussing duration = 4000  $\mu$ s
  - FOCI/GOIA = Off
- In Sequence/Common card:
  - Bandwidth = 6000 Hz

Two  $B_0$  shimming technique can be used with `sLASER`: FAST(EST)MAP or system 3D-GRE shimming routines as described below.

#### 3.1 Using FAST(EST)MAP shim

The following workflow includes use of the FASTESTMAP shimming procedure based on the original work by Rolf Gruetter and Ivan Tkáč (Gruetter and Tkáč, *Magn. Reson. Med.* 43:319-324, 2000). The FASTESTMAP sequence is available from Edward J. Auerbach, Center for Magnetic Resonance Research (CMRR), Minneapolis, MN, USA. Create the protocols, as described below, and use them as suggested in the workflow (next section).

- **Fastestmap-Linear\_3**
  - Contrast/Common card: Tau = 5 ms
  - System/Adjustments card: B0 Shim mode = Tune Up
  - Sequence/Special card: Type of fit = Linear 3-proj, Bar FoV = 300 mm, Bar thickness = 5 mm, multi-echo acquisition = On, Number of echoes = 8, Inversion pulse = Off
- **Fastestmap-Full\_6**
  - Contrast/Common card: Tau = 5 ms

- System/Adjustments card: B0 Shim mode = Advanced
- Sequence/Special card: Type of fit = Full 6-proj, Bar FoV = 300 mm, Bar thickness = 5 mm, multi-echo acquisition = On, Number of echoes = 8, Inversion pulse = Off
- **Fastestmap-Linear\_6**
  - Contrast/Common card: Tau = 10 ms
  - System/Adjustments card: B0 Shim mode = Advanced
  - Sequence/Special card: Type of fit = Linear 6-proj, Bar FoV = 300 mm, Bar thickness = 5 mm, multi-echo acquisition = Off, Inversion pulse = Off

### 3.2 Using system 3D-GRE shim

To use the system 3D-GRE B<sub>0</sub> shim option, the “B0 Shim mode” in the System/Adjustments card must be set to “Brain” (Figure 15) in the sLASER LW protocol (section 2.6). After positioning the VOI in the LW protocol, the system will automatically adjust the first- and second-order shims in one or two iterations before acquiring the sLASER data.

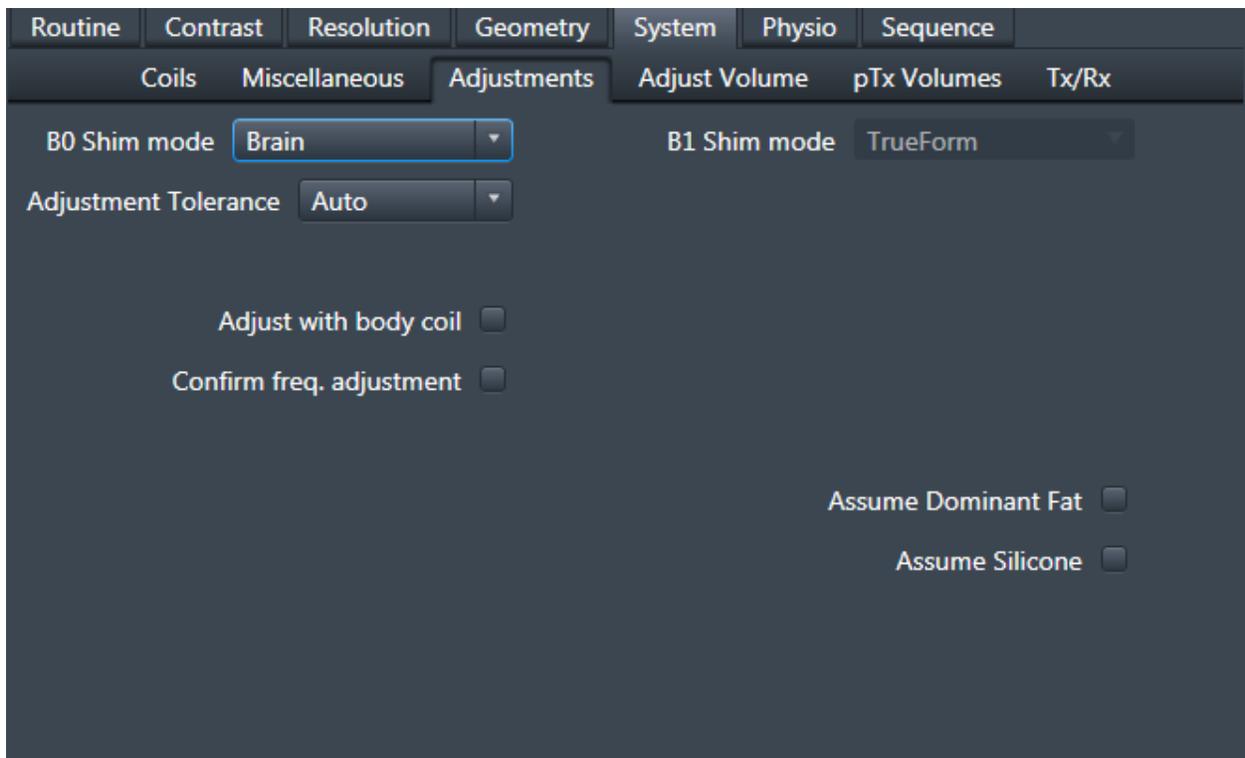


Figure 15: Set system B0 shim mode to Brain with sLASER

## 4. Measurement Workflow

The suggested MRS measurement workflow when using either FAST(TEST)MAP or 3D-GRE shim are described below.

1. Run **Localizer** (3 Plane Scout)
2. Run **MPRAGE**
  - a. Extract/Recon images into two other orientations, i.e. transverse and sagittal
  - b. Load all 3 images in the Exam card
  - c. Start “Inline display” and keep it open!

*If FAST(EST)MAP shim is used:*

3. Open **Fastestmap-Linear\_3**
  - a. Position voxel in region-of-interest
  - b. Click “Apply”.
4. **Fastestmap-Full\_6**
  - a. Copy Measurement Parameters from previous step.
  - b. Wait until the scan has ended.
    - i. Press “Ctrl + Esc” buttons
    - ii. Select “Set FASTMAP Shims”
    - iii. Type “a”, then Press “Enter”
      1. Wait for the blue screen to automatically close
  - c. Click “Apply”
5. **Fastestmap-Full\_6** (repeating the second order shimming step improves linewidth)
  - a. Copy Measurement Parameters from previous step.
  - b. Wait until the scan has ended.
    - i. Press “Ctrl + Esc” buttons
    - ii. Select “Set FASTMAP Shims”
    - iii. Type “a”, then Press “Enter”
      1. Wait for the blue screen to automatically close
  - c. Click “Apply”
6. **Fastestmap-Linear\_6**
  - a. Copy Measurement Parameters from previous step.
  - b. Wait until the scan has ended.
    - i. Press “Ctrl + Esc” buttons

- ii. Select “Set FASTMAP Shims”
- iii. Type “a”, then Press “Enter”
  - 1. Wait for the blue screen to automatically close

c. Click “Apply”

## 7. **sLASER\_LW**

a. Copy Measurement parameters from **Fastestmap-Linear\_6**.

b. Wait until the scan has ended.

- i. Press “Ctrl + Esc” buttons
- ii. Select “Set FASTMAP Shims”
- iii. Type “a”, then Press “Enter”

1. Wait for the blue screen to automatically close

c. Click “Apply”

Is the gray vertical line centered on the water peak (green line)? If not, adjust the frequency in Options/Adjustment/Frequency Tab and rerun **sLASER\_LW**

d. Goto Step #9 below

### If 3D-GRE shim is used:

## 8. **sLASER\_LW**

a. Position voxel in region-of-interest in 3D MPRAGE images

3D  $B_0$  maps will be acquired in one or two iterations and the shims will be automatically set

b. Click “Apply”.

Is the gray vertical line centered on the water peak (green line)? If not, adjust the frequency in Options/Adjustment/Frequency Tab and rerun **sLASER\_LW**

c. Goto Step #9 below

9. These protocols should start automatically: **sLASER\_90Calib**, **sLASER\_WSCalib** and **sLASER\_WS64**

10. Run **Localizer** again (to ensure subject has not moved)

11. Done!

## 5. Water linewidth estimation

The linewidth of the water peak after shimming can be estimated as follows:

- Start Spectroscopy Task Tab by selecting Applications / Spectroscopy from top of the screen
- Go to Spectroscopy Tab
- Load filename containing "sLASER\_LW" from the Patient Browser
- Go to Protocol Open, then Select "SLASER\_waterLW"
- The value next to the W (in yellow) will be the estimated linewidth in Hz (Figure 16).



Figure 16: Estimating water linewidth on the scanner

## 6. Installation

Installation of this package should be performed by an experienced user. For installation you need to access the file-system of the scanner (“Advanced User” functionality), which requires a password. Please contact the local application support for this information.

Please follow the installation steps below:

- Login as “Advanced User”.
- Insert your medium in the appropriate drive on the host computer.
- Open “Windows explorer” and find the file “install\_slaser.bat” on the inserted medium.
- Double click on the file name to start the installation (note: there is no need to copy the file to the system).
- The window below displays progress of the installation.
- Monitor the installation and follow the displayed messages.
- When the message “Done!” is displayed, close the window by pressing any key on the keyboard (Figure 17).

The installation automatically copies the following files to the appropriate folders on the system:

- o **Sequence:**

svs_slaser_dkd.dll	to	C:\medcom\MriCustomer\Seq\
libsvs_slaser_dkd.so	to	C:\medcom\MriCustomer\Seq\

- o **Ice programs:**

dkdIceSpecSEAD2.dll	to	C:\medcom\bin\
dkdIceSpecSEAD2.evp	to	C:\medcom\bin\
dkdIcePrgSpectro2.ipr	to	C:\medcom\bin\
libdkdIceSpecSEAD2.so	to	C:\medcom\MCIR\Med\lib\

- o **RF pulse:**

extrf_sead.dat	to	C:\medcom\MriCustomer\Seq\
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- o **Processing file:**

\$\$SLASER_waterLW.pro	to	C:\medcom\MriCustomer\MrSpec\EvaProtocols\
------------------------	----	--

```
Administrator: C:\Windows\system32\cmd.exe - install_slaser.bat
G:\sLASER_Oct2016>install_slaser.bat

Installer for sLASER on UE platform
Dinesh Deelchand, Oct 2016

*** Installing sequence files:
svs_slaser_dkd.dll          ... success!
libsvs_slaser_dkd.so       ... success!
extrf_sead.dat             ... success!

Some system components and the MARS must be restarted in order to properly
install the ICE binaries. Before continuing, please make sure no scans are
running and note that the system will be unusable for at least 10 minutes
while the MARS reboots.

If you continue, the MARS will be rebooted NOW.

Are you sure you want to continue [y/n]?
Are you sure you want to continue [y/n]? y

Rebooting MARS...
ssh root@mars reboot
rem attempt to unload the PAS and restart Cocos to hopefully unlock dlls
Waiting 10 seconds for MARS shutdown...

*** Installing ICE program files:
dkdIcePrgSpectro2.ipr      ... success!
dkdIceSpecSEAD2.evp       ... success!
dkdIceSpecSEAD2.dll       ... success!
libdkdIceSpecSEAD2.so     ... success!

*** Installing linewidth protocol
$$SLASER_waterLW.pro      ... success!

Please import the sLASER protocols (i.e. sLASER.exar1 located in the protocol fo
lder) using the Dot Cockpit.

Done!

Press any key to continue . . .
```

Figure 17: Installation screen when using install\_slaser.bat file