Application Guide & Release Notes

Spectroscopy C2P

Release 2017-07.2 “Tokyo”
1 April 2021

Center for Magnetic Resonance Research
University of Minnesota
Driven to Discover℠

Conditions of Use

This package is provided to support collaborative research projects between the University of Minnesota and users of Siemens MRI equipment, in accordance with a current C2P agreement.

In your publications and abstracts, please acknowledge the use of this package as follows: “We would like to acknowledge Edward J. Auerbach, Ph.D. and Małgorzata Marjańska, Ph.D. (Center for Magnetic Resonance Research and Department of Radiology, University of Minnesota, USA) for the development of the pulse sequences for the Siemens platform which were provided by the University of Minnesota under a C2P agreement.”

Authors

Małgorzata Marjańska, Ph.D.
Center for Magnetic Resonance Research
University of Minnesota

and

Edward J. Auerbach, Ph.D.
Center for Magnetic Resonance Research
University of Minnesota

Table of Contents

Overview

The following pulse sequences are included in this package:

eja_csi_laser	LASER CSI w/ VAPOR water suppression
eja_csi_mslaser	MEGA-SEMI-LASER CSI w/ VAPOR & OVS
eja_csi_press	PRESS CSI w/ VAPOR & OVS
eja_csi_slaser	SEMI-LASER CSI w/ VAPOR & OVS
eja_svs_laser	LASER SVS w/ VAPOR
eja_svs_mpress	MEGA-PRESS or MEGA-PRESS+4 SVS w/ VAPOR & OVS
eja_svs_mslaser	MEGA-SEMI-LASER SVS w/ VAPOR & OVS
eja_svs_press	PRESS SVS w/ VAPOR & OVS
eja_svs_slaser	SEMI-LASER SVS w/ VAPOR & OVS
eja_svs_steam	Short-TE or conventional STEAM w/ VAPOR & OVS

The pulse sequences in this package are based in part on the product svs_se and csi_se sequences from Siemens.

These descriptions and instructions provided herein assume that the user is familiar with running and evaluating spectroscopy examinations.

For further information about the sequences included in this archive and access to the latest versions, please refer to http://www.cmrr.umn.edu/spectro/.

Sequence Description

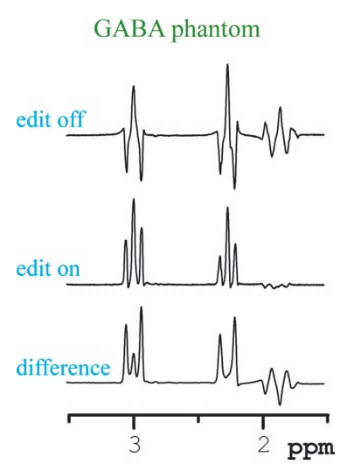
VAPOR

All of the sequences in this package have the option of using water suppression with variable power optimized relaxation delays (VAPOR), with optional embedded outer volume suppression (OVS) pulses (1) to suppress water and to improve the localization of the volume of interest (VOI). Default timings and RF pulse parameters have been optimized for 3 T and 7 T and are loaded automatically when installing the sequences.

1) Tkac I, Starcuk Z, Choi IY, Gruetter R. *In vivo* ^{1}H NMR spectroscopy of rat brain at 1 ms echo time. Magn Reson Med 1999;41(4):649-656.

MEGA-PRESS / PRESS

MEGA-PRESS is a spin-echo variant of the *J*-difference editing method described by Mescher et al. (1, 2), with spatial localization performed with PRESS and editing performed with MEGA. In the provided implementation, selective 180° Shinnar-Le Roux (used at 3 T and lower) or Gaussian (used at 7 T and higher) pulses can be applied at various (up to 4) frequencies depending on which metabolite is being edited (e.g., 1.9 ppm for GABA, 4.56 ppm for GSH, 4.11 ppm for Lac). VAPOR with 3D OVS is applied prior to each acquisition for water suppression. The frequency-selective editing pulses can also be executed as double-banded pulses, with the second band automatically applied at the water frequency for additional water suppression.



A standalone PRESS sequence is also provided.

More detailed information about the pulse sequence and parameters can be found in the following references (3-5):

1) Mescher M, Merkle H, Kirsch J, Garwood M, Gruetter R. Simultaneous in vivo spectral editing and water suppression. NMR Biomed 1998;11(6):266-272.
2) Mescher M, Tannus A, Johnson MO, Garwood M. Solvent suppression using selective echo dephasing. Journal of Magnetic Resonance Series A. Volume 123; 1996. p 226-229.
3) Marjanska M, Lehericy S, Valabregue R, Popa T, Worbe Y, Russo M, Auerbach EJ, Grabli D, Bonnet C, Gallea C, Coudert M, Yahia-Cherif L, Vidailhet M,

Meunier S. Brain dynamic neurochemical changes in dystonic patients: a magnetic resonance spectroscopy study. Mov Disord 2013;28(2):201-209.
4) Tremblay S, Beaule V, Proulx S, Lafleur LP, Doyon J, Marjanska M, Theoret H. The use of magnetic resonance spectroscopy as a tool for the measurement of bi-hemispheric transcranial electric stimulation effects on primary motor cortex metabolism. J Vis Exp 2014(93):e51631.
5) Cheong I, Marjanska M, Deelchand DK, Eberly LE, Walk D, Oz G. Ultra-high field proton MR spectroscopy in early-stage amyotrophic lateral sclerosis. Neurochem Res 2017;42:1833-1844

LASER

LASER is a fully adiabatic pulse sequence in which excitation is performed using a nonselective numerically optimized adiabatic half-passage (AHP) pulse and 3D localization is performed with three pairs of adiabatic full passage (AFP) pulses in each dimension (1). In this implementation, hyperbolic secant (HS) pulses are used. The user can specify the stretch factor (N) and bandwidth*time (R) value (Sequence/Special card: "LASER HS pulse N" and "LASER HS pulse R"). The default values are 1 and 20 (HS1_R20), respectively. A higher N value results in lower B_1 peak power which can allow for a shorter pulse length, and a higher R value results in larger bandwidth but higher B_1 needed. For the same length of the pulse, going from a HS1 to HS4 pulse of the same R value reduces the B_1 peak power requirement by ~23%. The bandwidth can be calculated by dividing R/length of the pulse (e.g., 8.2 ms HS1_R20 pulse – 2440 Hz bandwidth).

More detailed information about the pulse sequence and parameters can be found in the following references (2, 3):

1) Garwood M, DelaBarre L. The return of frequency sweep: designing adiabatic pulses for contemporary NMR. J Magn Reson 2001;153:155-177.
2) Muetzel RL, Marjanska M, Collins PF, Becker MP, Valabregue R, Auerbach EJ, Lim KO, Luciana M. In vivo ^{1}H magnetic resonance spectroscopy in young-adult daily marijuana users. Neuroimage: Clinical 2013;2;581-589.
3) Allaili N, Valabregue R, Auerbach EJ, Guillemot V, Yahia-Cherif L, Bardinet E, Jabourian M, Fossati P, Lehericy S, Marjanska M. Single-voxel ^{1}H spectroscopy in the human hippocampus at 3 T using the LASER sequence: characterization of neurochemical profile and reproducibility. NMR Biomed 2015;28(10):1209-1217.

MEGA-SEMI-LASER / SEMI-LASER

In the semi-LASER sequence, the AHP pulse and one pair of AFP pulses are replaced with a slice-selective 90° Hamming-filtered sinc pulse (1,2). 1D OVS is applied in the same dimension. The other two dimensions are selected with a pair of AFP pulses. As in the LASER sequence, the user can specify N and R factors for the HS AFP pulses. The implementation of MEGA-SEMI-LASER in this package is based on (3):

1) Klomp DW, Bitz AK, Heerschap A, Scheenen TW. Proton spectroscopy imaging for the human prostate at 7 T. NMR Biomed 2009;22:495-501.
2) Marjanska M, Auerbach EJ, Valabregue R, Van de Moortele P-F, Adriany G, Garwood M. Localized ^{1}H NMR spectroscopy in different regions of human brain in vivo at 7 T: T_2 relaxation times and concentrations of cerebral metabolites. NMR Biomed 2012;25:332-339.
3) Andreychenko A, Boer VO, Arteaga de Castro CS, Luijten PR, Klomp DW. Efficient spectral editing at 7 T: GABA detection with MEGA-sLASER. Magn Reson Med. 2012 Oct;68(4):1018-25.

STEAM

Stimulated echo acquisition mode (STEAM) sequences are provided with the option of using asymmetric RF pulses for ultra-short echo time (1).

More detailed information about the pulse sequence and parameters used can be found in the following reference (2):

1) Tkac I, Starcuk Z, Choi IY, Gruetter R. *In vivo* ^{1}H NMR spectroscopy of rat brain at 1 ms echo time. Magn Reson Med 1999;41(4):649-656.
2) Marjanska M, McCarten JR, Hodges J, Hemmy LS, Grant A, Deelchand DK, Terpstra M. Region-specific aging of the human brain as evidenced by neurochemical profiles measured noninvasively in the posterior cingulate cortex and the occipital lobe using ^{1}H magnetic resonance spectroscopy at 7 T. Neurosci 2017;354:168-177.

Hardware and Software Requirements

Versions of the included sequences are currently provided for multiple Siemens software versions, supporting various system types. It may additionally be possible to use the sequences with other systems not listed (e.g. 1.5 T systems), but compatibility and coil performance has not been tested.

VB17A:	MAGNETOM Trio, a Tim System 3 T, MAGNETOM Verio 3 T MAGNETOM 7 T/9.4 T/10.5 T/11.7 T
VB19A:	MAGNETOM Trio, a Tim System 3 T
VB20P:	Biograph mMR
VD11D:	MAGNETOM ConnectomA/S 3 T
VD13A-SP4:	MAGNETOM Skyra 3 T
VD13B:	MAGNETOM Skyra^{fit} 3 T
VD13D:	MAGNETOM Prisma/Prisma^{fit} 3 T
VE11A:	MAGNETOM Skyra 3 T
VE11B:	MAGNETOM Prisma 3 T
VE11C:	MAGNETOM Skyra/Prisma 3 T
VE11E:	MAGNETOM Skyra/Prisma 3 T
VE11P:	Biograph mMR
VE11K:	MAGNETOM Terra 7 T (1ch Tx)
VE11R:	MAGNETOM Terra 7 T (1ch Tx)
VE11U:	MAGNETOM Terra 7 T (pTx)
VE12U:	MAGNETOM Terra 7 T (1Tx & pTx)

For 3 T systems, the **32-channel Head,** 12-channel **Head Matrix,** and **Head/Neck 20** coils have been tested and are recommended. The **Head/Neck 64** coil has not been extensively evaluated.

For 7 T systems, the **Nova Medical 32-channel** head coil is recommended, with the caveat that transmit B_1 may be very limited. This may result in excessive chemical shift displacement for some applications. Alternative coils may be desirable.

Installation Procedure

Important note: Starting with versions **VE11C**, **VB19A**, and **VB20P**, the host uses McAfee Embedded Control (Solidifier) security software. It is necessary to switch Embedded Control into UPDATE mode before installing any custom sequences. Please see the Embedded_Control_Mode.pdf document included in this archive for instructions on how to switch the Embedded Control mode.

1. Login as “Advanced User”. If the Advanced User account is not enabled or you do not know the password, contact Local Service.

2. If the system has Embedded Control installed, start the MrEmbeddedControlGui and switch the Embedded Control system into UPDATE mode. *If you do not know the Administrator account name or password, contact Local Service.*

3. Extract the .zip file to a temporary directory.

4. Run the installer program. The installer will automatically restart various processes and reboot the imager if necessary to unlock shared objects.

5. If the installer reports any error, please power cycle the system and try again.

6. If a sample protocol is available for your system, it will appear at the end of the USER tree in the Exam Explorer. If a sample protocol is not available, create a default protocol in Exam Explorer by selecting Insert Sequence, USER, then cmrr_mbep2d_* for the desired sequence variant.

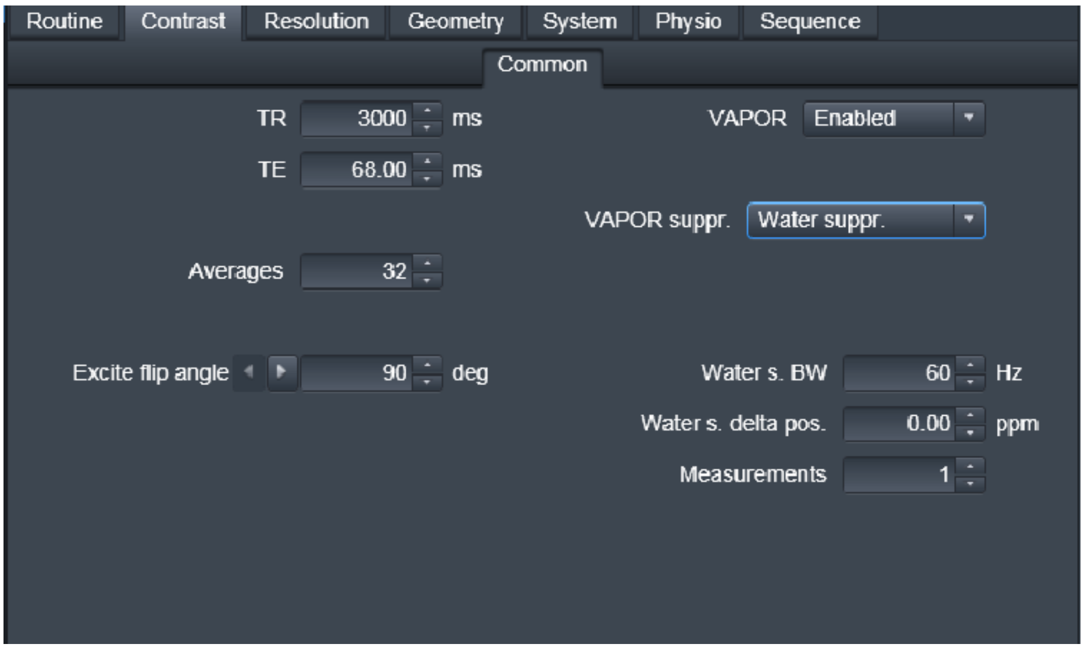
7. If the system has Embedded Control installed, re-enable host security and switch the Embedded Control system into the ENABLED mode.

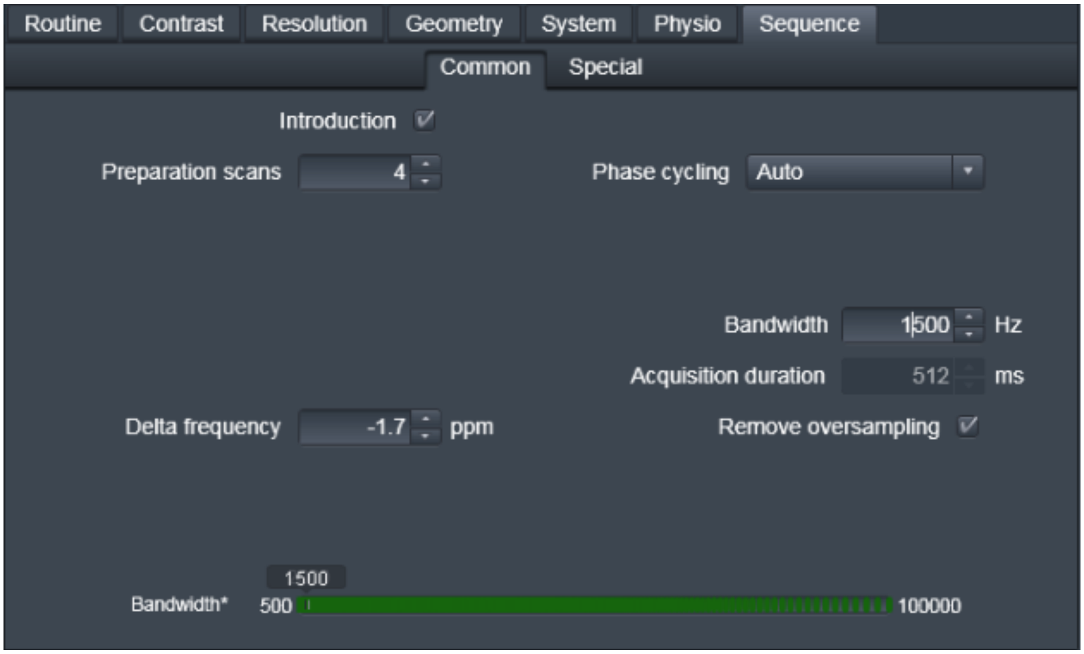
Usage

Sample Protocol: MEGA-PRESS

The most important parameters appear on the following measurement cards (parameters used on 3 T Trio and Prisma systems for GABA detection):

Water suppressed scan:



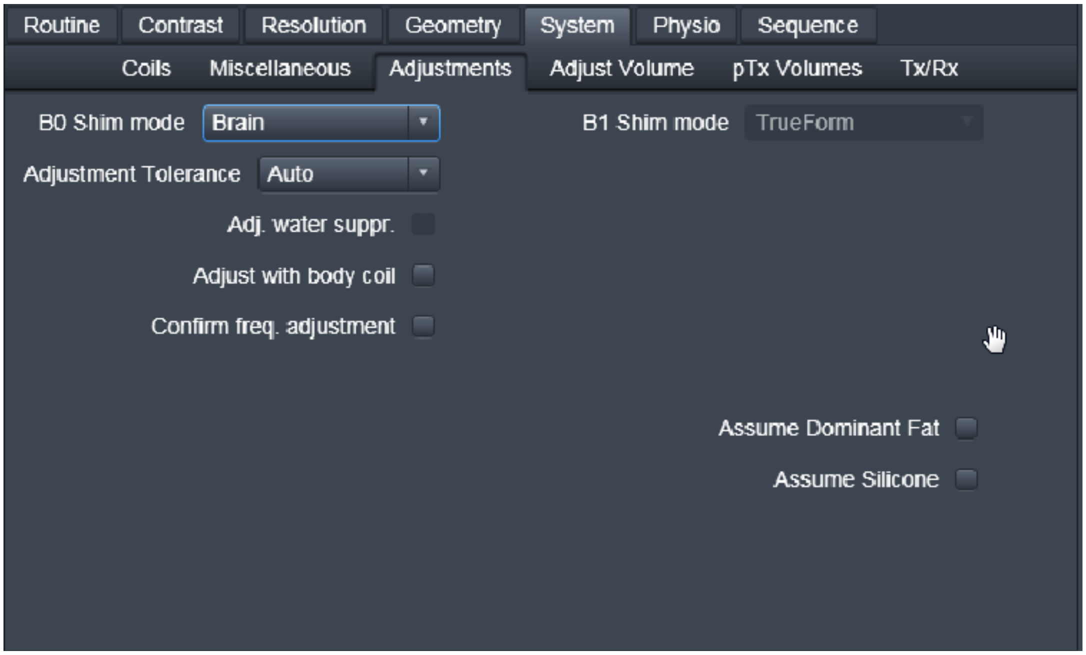


The delta frequency of -1.7 ppm shifts the localization pulses to be on resonance at 3 ppm.

In this protocol, ‘OVS’, ‘Resolve averages’, and ‘MEGA water suppr’ are enabled.

Number of label freqs. is set to 2 with ‘Editing pulse freq [1]’ = 7.5 ppm and ‘Editing pulse freq [2]’ = 1.9 ppm for GABA.

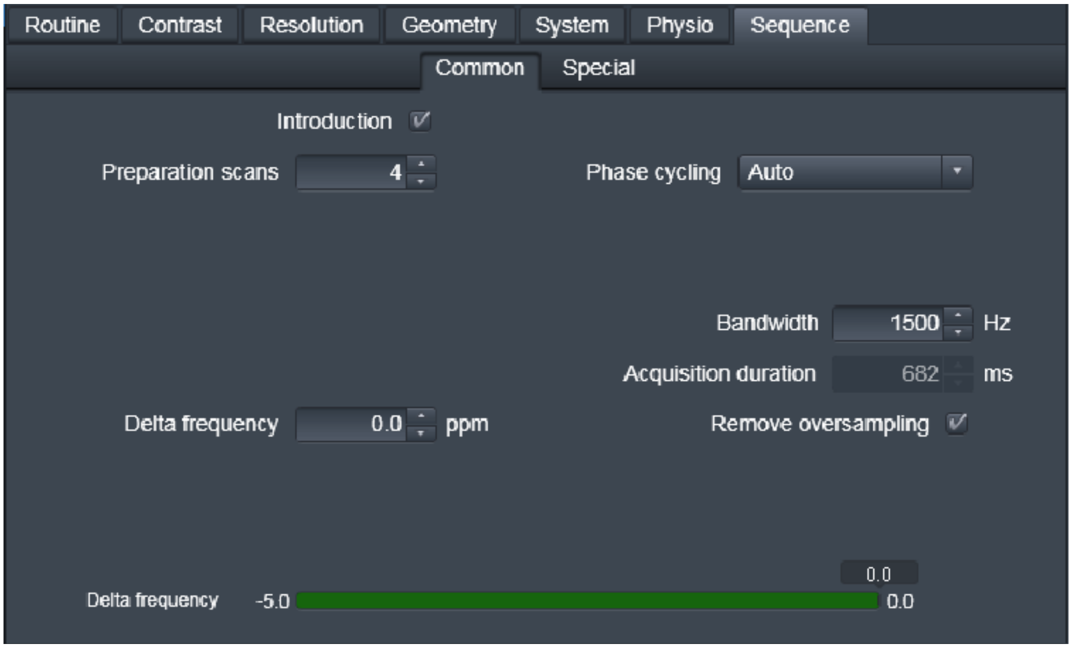
Choose the smallest ‘Editing pulse BW’ for the editing pulses to achieve a TE of 68 ms.



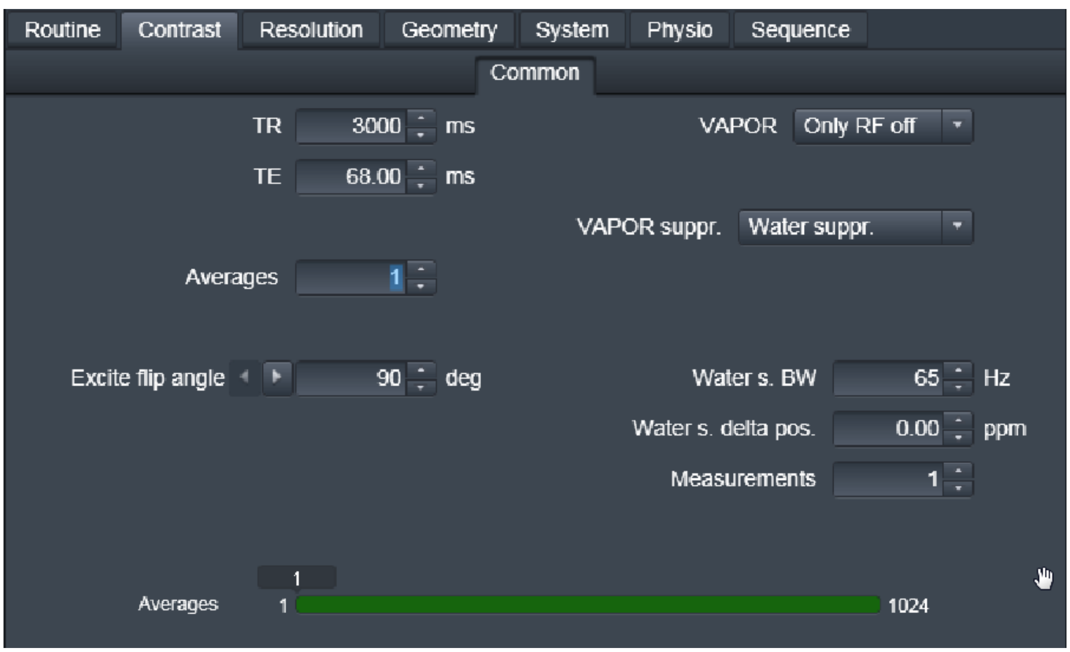
If available on your system, use “Brain” (GRE) shim for VOIs in the brain. If not available, consider using FAST(EST)MAP to get the narrowest linewidth within the VOI.

In our standard protocols as described in the JoVE 2014 publication, the acquisition of water suppressed spectra is repeated 4 times to obtain 128 edit off and 128 edit on scans with the update of frequency between each acquisition.

Water reference scan:



Delta frequency changed to 0 ppm so localization is on resonance for water.



Water suppression RF pulses are turned off, but gradients are still on for accurate information about eddy currents.

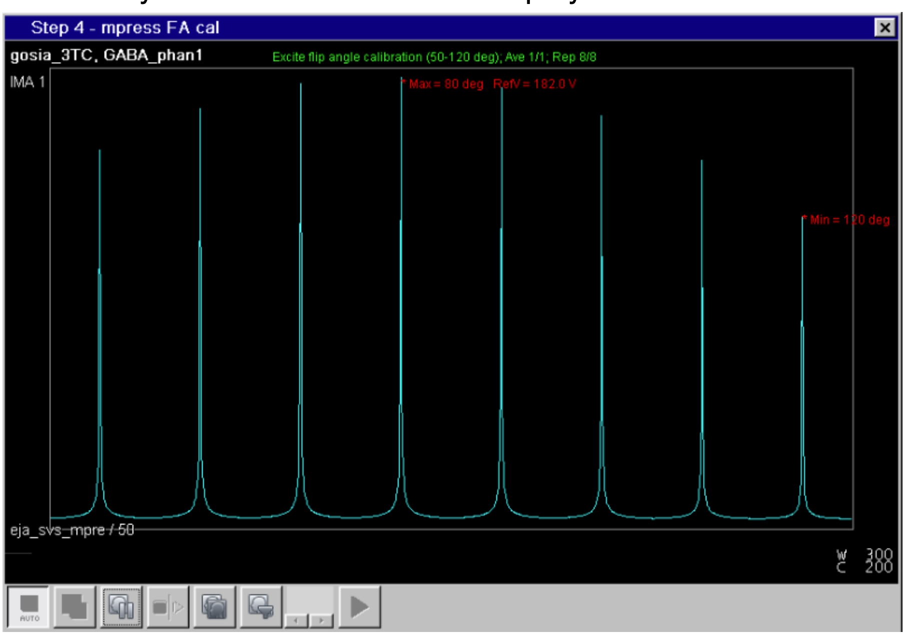
Adjust frequency or double check that the frequency is adjusted correctly by going to Options/Adjustment/Frequency.

Semi-Automatic Calibrations

Flip angle adjustment within the VOI (needs to be done on every subject):

After the lengths of RF pulses and other parameters are set, the following parameters need to be set to calibrate the power in the VOI (example below uses the PRESS sequence):

- Contrast card: Excite flip angle: 50 deg
- Sequence common: delta freq: 0
- Sequence/Special card:
  Debug loop type: Excit. FA
  Excit. FA inc: 10
  Measurements: 8
  This setup will create an array of excitation flip angles from 50 to 120 deg every 10 deg.
- Turn on the 'inline display'.
- Here is what you will see in the inline display:

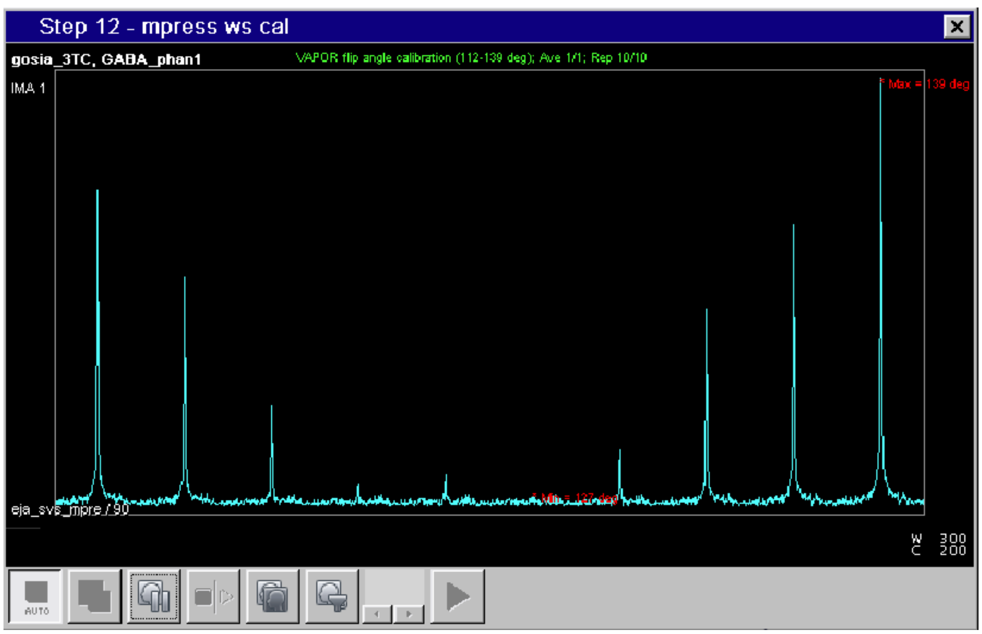


- In this example, the maximum signal is obtained at 182 V rather than 220 V.
- Go to Adjustment/Transmitter and change the value for Amplitude (temp) to 182 V and Apply
- You can also consider creating a protocol for calibrating the power using the STEAM sequence, which typically has a smaller chemical shift error associated with it than the PRESS sequence.

Water suppression adjustment:

Once optimized, water suppression seems to perform well from subject to subject without re-optimization, but optimization seems to be always needed when scanning a different brain region.

- Sequence/Special card:
  set VAPOR delay 8 to shortest possible value within your setup
  debug loop: WS FA
  WS FA inc: 2
  Measurements: 10
  VAPOR flip angle: starting point for example 70
  This setup will create an array of water suppression flip angle pulses from 70 to 88 deg every 2 deg.
- Turn on the 'inline display'.
- Here is what you will see in the inline display:



- In this example, the minimum water signal is observed at 127 deg.
- VAPOR flip angle = 127
- Similarly, VAPOR delay 7 can be adjusted using debug loop: VAPOR delay 7.
- In addition, when using MEGA-PRESS for GABA editing, additional water suppression can be obtained by turning MEGA water suppression on. When this option is turned on, the editing pulses become double-banded.

Output of Data

All sequences are capable of outputting data as individual averages and summed spectra in DICOM format. To save individual averages, the “resolve averages” checkbox needs to be checked on the Sequence/Special card.

For editing sequences (MEGA-PRESS/MEGA-SEMI-LASER), the edit off and edit on scans are acquired interleaved, but they are reshuffled in ICE so at the end with the example protocol, there will be 32 edit off and 32 edit on scans produced. This implementation does not produce difference spectra, but other software, such as Matlab, can be used to produce difference spectra.

Troubleshooting

Log output for the scan process on VB17/VB19/VB20 systems can be read using the Siemens *mrtraceviewer* tool. On newer systems (VD11/VD13/VE11), all log output can be read using the Siemens *logviewer* tool.

Log output for the ICE process can be read on all versions using the Siemens *logviewer* tool.

In the case of a severe error, please generate a savelog according to the procedure described in the included Savelog_Instructions.pdf.

Version Changes

Release 2017-07.2, 1 April 2021

- Enabled Patient Specific & Volume Selective B1 shim modes on VE11/VE12 pTx systems
- Fixed UI crashes when moving VoI on VE11/VE12 pTx systems

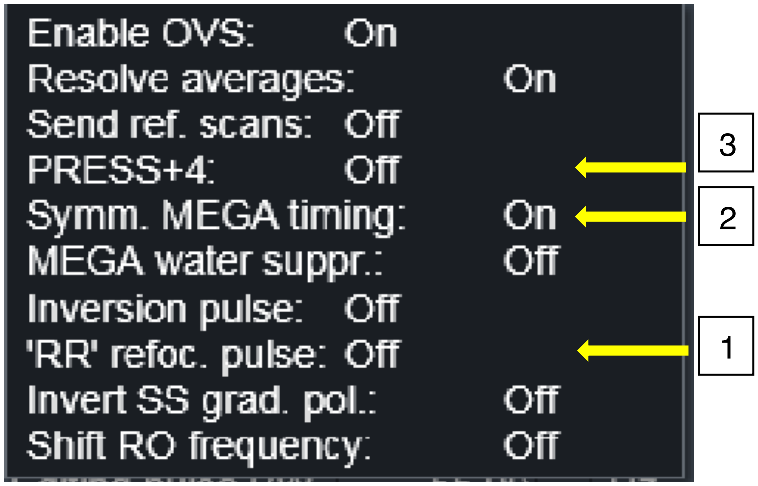
Release 2017-07.1, 26 February 2020

- Fixed spoiling gradient scheme for MEGA-SEMI-LASER
- STEAM TM maximum increased
- Delta frequency range increased
- Added option for symmetric MEGA timing
- Added option for alternative high bandwidth PRESS refocusing pulses
- Fixed reconstruction issue with “remove oversampling” option deselected

Release 2017-07 (“Tokyo”), 14 July 2017

This release has a number of modifications which were developed in collaboration with Lana Kaiser, Ph.D., from Siemens Japan, first presented at the workshop in Tokyo, Japan, in February 2017. These new features can be found on the Sequence/Special Card as checkboxes:

1. *RF shapes with higher bandwidth (MEGA-PRESS/PRESS seqs.)*
   Two new pulses, root reflected, with higher bandwidth are available for refocusing. First RR pulse uses very similar power to the default mao pulses, but provides 40% higher bandwidth. Second RR pulse requires more power than mao pulse, and provides two times higher bandwidth.
2. *T_E editing symmetry (MEGA-PRESS seq.)*
   A new option is introduced which places the editing pulses symmetrically in the delay between refocusing pulses. This new feature is especially important for editing with long T_E (such as for lactate) where the editing pulses do not completely fill the time available between refocusing pulses.
3. PRESS+4 (MEGA-PRESS seq.) (Kaiser LG, Young K, Matson GB. Elimination of spatial interference in PRESS-localized editing spectroscopy. Magn Reson Med 2007;58:813-818) has been fully debugged and is now working well.



Other changes and bug fixes:

- Enabled all available advanced shim modes for VB19A/VB20P.
- Fixed display of excitation RF pulse amplitude in UI for VD11/VD13/VE11.

Release 2016-06, 15 June 2016

- “Weighted averaging” mode added, which allows for specifying a different number of averages for each measurement.
- Enabled “Performance” gradient mode for Prisma systems.
- Optional 3D OVS may now be specified for SEMI-LASER sequences (default is still 1D).
- MEGA-SEMI-LASER scheme updated to match MRM 2012;68(4):1018-25.
- “Invert SS grad. pol.” now inverts adjacent spoilers to avoid gradient slew rate problems.
- Increased maximum allowed TM for STEAM to 200 ms.
- Minor SAR calculation fix for VAPOR.

Release 2014-09, 24 September 2014

Initial “named” release.