PASTeUR v2 : Package of Anatomical (and functional) Sequences using parallel Transmission UniveRsal pulses

Contributors	Alexis Amadon[1], Nicolas Boulant[1], Vincent Gras[1], Redouane Jamil[1], Daniel Löwen[2], Aurelien Massire[3], Franck Mauconduit[1], Eberhard Daniel Pracht[2], Rüdiger Stirnberg[2], Tony Stöcker[2], Alexandre Vignaud[1] [1] *Université Paris-Saclay, CEA, CNRS, BAOBAB, NeuroSpin, Gif-sur-Yvette, France* [2] *German Center for Neurodegenerative Diseases (DZNE), Bonn, Germany* [3] *Siemens Healthcare SAS, Saint Denis, France*
Last update	December 5, 2024
Description	This current release of the PASTeUR package (version 2) contains four sequences including Universal RF pulses to mitigate B1+ inhomogeneity at 7T. Updates of the documentation can be found at: link to PASTEUR package.)
Platform	VE12U-SP01, VE12U-AP01, VE12U-AP04
Contacts	Franck.Mauconduit@cea.fr Nicolas.Boulant@cea.fr

Contents

1 Acknowledgement

The authors are very thankful to Prof. Guillevin and colleagues in Poitiers who hosted our team to test the package and acquire the first in vivo images on their 7T MAGNETOM Terra system. We also thank Eberhard 'Ed' Pracht from German Center for Neurodegenerative Diseases (DZNE) for his help in the implementation of sequences and SAR management on the 7T MAGNETOM Terra system. We finally thank Rüdiger Stirnberg from the same team for providing the 3D-EPI sequence.

2 Overview

The PASTeUR package contains 3D sequences – a GRE3d, a 3D-GE-EPI, a SPACE (with FLAIR and DIR preparations) and a MP(2)RAGE sequence – that use Universal RF pulses to mitigate B1+ inhomogeneity. These Universal Pulses are based on an offline pulse design performed on a database of different subject field maps to be robust with respect to inter-subject variability. The PASTeUR package provides a plug and play solution for pTx systems that suppress the ubiquitous B1+ artefacts observed with the CP excitation mode. This current release is based on Classic MAGNETOM 7T Universal Pulse solutions that have been adapted to fit MAGNETOM Terra specifications (channel ordering, phase shifts, table position and scaling). Non-selective and slab-selective Universal Pulses now are available.

Restrictions / optimal usage conditions:

- The sequences are meant to be used on the NOVA 8Tx 32Rx coil for which the pulses have been optimized. Tests on phantoms can be attempted to verify that the sequences run properly. However, good image quality should not be expected as the pulses and flip angle trains are designed for adult human heads.
- The NOVA coil center (cross) should be positioned at scanner iso-center during acquisition to achieve the best performance.
- In slab-selective mode, the pulses are designed for a minimal slab thickness that depends on the orientation of the slab. Thus, there is a lower limit of the slab thickness.

Comments and remarks:

- Small artefacts might remain in the images due to B0/B1 inhomogeneity variability across subjects. They can be seen particularly at the bottom of temporal lobes and at the periphery of the cerebellum.
- B0 shimming and frequency adjustment must be performed before any PASTeUR sequence to prevent artifacts. Off-resonance acquisition would result in non-homogeneous RF excitation.
- Adjusting the reference voltage has no effect on the pulses. The pulses were designed to work at specific voltages by taking into account field maps variability across subjects.

- The sequences of PASTeUR can be played in TrueForm (CP) mode. Comparing the Universal Pulse result with the one of TrueForm can be a sanity check that the pulses are played as expected.
- Because of system limitations, slab-selective Universal Pulses are segmented into multiple .ini files. All of them are necessary, the number of sub-pulses is specified inside the .ini file by the field `NbSpokes`.

3 Installation

3.1 Summary of files

The PASTeUR package contains four different sequences. Reconstruction used are the standard reconstruction from Siemens environment. The following sequence (.dll, .so, .lic) and pulse files (.ini) will be copied to the %CustomerSeq% directory on the scanner by the installation procedure. The .lic files are mandatory license files that require yearly renewal. Pulse and sequence improvements, bug-fixes that way will be provided.

```
MedCom
└─ MriCustomer
   ├─ seq
   │  ├─ ns_gre_v2.dll, ns_gre_v2.lic, libns_gre_v2.so
   │  ├─ ns_ep3d_v2.dll, ns_ep3d_v2.lic, ns_ep3d_v2.so
   │  ├─ ns_tfl_v2.dll, ns_tfl_v2.lic, libns_tfl_v2.so
   │  ├─ ns_tse_vfl_v2.dll, ns_tse_vfl_v2.lic, libns_tse_vfl_v2.so
   │  └─ RFPulses
   │     └─ Pasteur
   │        └─ bunch of folders containing ini files
   └─ ice
      ├─ IceMP2RAGE_ns.dll/evp, libIceMP2RAGE_ns.so
      ├─ IceB0Reco.dll/evp, libIceB0Reco.so
      ├─ IceRedirectRefScans.dll/evp, libIceRedirectRefScans.so
      ├─ IceVirtualCoilCombination_ns.dll/evp, libIceVirtualCoilCombination_ns.so
      ├─ dzne_IceParamConfig2.dll/evp, libdzne_IceParamConfig2.so
      ├─ FixIcePatPipeline.dll/evp, FixIcePatPipeline.so
      ├─ IceMosaic2D3D.dll/evp, libIceMosaic2D3D.so
      ├─ IceSortPS.dll/evp
      ├─ IceProgramB0Reco.ipr, IceProgramMP2RAGE.ipr
      ├─ IcePatRedirectRefScans.ipr, IcePatMP2RAGE.ipr
      ├─ IcePAT_SortPS.ipr, IceDecoratorMosaic2D3D.ipr
      └─ dzne_IceParamDecorator.ipr, FixIcePatPipelineDecorator.ipr
```

3.2 Installation procedure

Execute the script **install_neurospin_seq_VE12.bat** on the host which copies the installation files to C:/MedCom according to the corresponding tree. For VE platform or higher, do not forget to switch to update mode by using the MrEmbeddedControlGui tool before executing the install script.

3.3 Optimized protocols

A set of protocols for each sequence can be found in a pdf or can be imported into the 7T system with the exar file. These protocols have been optimized and tested in vivo on volunteers with Siemens current SAR supervision limits.

4 Additional Features compared to product sequences

Besides the possibility to use Universal Pulses, the PASTeUR sequences have been modified to include additional features. These features are described in the following sections.

4.1 CAIPIRINHA

All sequences now have the possibility to use a CAIPIRINHA acceleration mode. In this case, the Siemens product IcePAT algorithm is used during the reconstruction process. When choosing CAIPIRINHA, and setting the reordering shift to 0 the acquisition pattern will still be standard GRAPPA. Furthermore, it is possible to choose external reference scans. This options is in general faster and less motion sensitive compared to the integrated reference scans.

4.2 Slab-selective Universal Pulses

In addition to the non-selective Universal Pulses, all sequences can now be set to use 3D slab-selective Universal Pulses. This option is triggered by changing the excitation mode as usualy done in any siemens product sequence (in "Sequence > Part 2 > Excitation").

4.3 Sequence specific features

The new features specific to each sequence are detailed in the following sections. A summary is given here:

- GRE → an option to reconstruct B_0 maps while acquiring 3 echoes.
- MP(2)RAGE → an optimized Linear Reordering Scheme (FREE 0) to enable elliptical scanning; a custom ICE reconstruction is available for UNI, UNI-denoised and synthetic contrast reconstructions.
- SPACE → an EPG-based variable flip angle train can be activated to reduce SAR; a possibility to choose magnetization preparation RF pulses between Universal pulses and adiabatic pulses.

5 3D-SPACE sequence

5.1 "pTx Pulses" card

The sequence user interface is similar to that of the product VE12 tse_vfl sequence. To activate Universal Pulses, the user must click the "Universal Pulse" button located in "Sequence > pTX Pulses" card (figure 2). For both excitation and refocusing pulses, the Universal Pulses are GRAPE pulses as described in Van Damme et al. (12).

5.2 Excitation mode

The SPACE sequence can perform both non-selective and slab-selective Universal pulses. This option can be switched by using the Siemens standard parameter "Excitation mode" in "Sequence > Part 2 > Excitation". For detailed information about slab-selective SPACE sequence using Universal pulses, please refer to Lowen et al. (7).

5.3 RF refocusing train

5.3.1 Siemens standard refocusing train

The flip angle of the refocusing train is generated by using T_1/T_2 relaxation times of a given tissue. Depending on these T_1/T_2 values, the energy of the train could change drastically. For this reason, it is recommended to use the default values set as $T_1 = 1400ms$ and $T_2 = 50ms$ (figure 1).

5.3.2 EPG based refocusing train

Alternatively, the user can choose to use an EPG based refocusing train. This option is available in the "Sequence > Special" card. The refocusing flip angles are calculated for the signal shape of the Siemens standard refocusing train. Hence, the contrast of the resulting images should be close to the ones obtained with the Siemens standard refocusing train. If SAR is a concern, the user can choose to reduce the flip angles of the refocusing train by setting the "Refocusing FA reduction" parameter to a value between 0 and 1 Pracht et al. (8). In most cases a value between 0.9 and 1.0 should be a good compromise between SAR reduction and image (SNR and contrast). Reducing the flip angles introduces slightly more T1 weighting in the

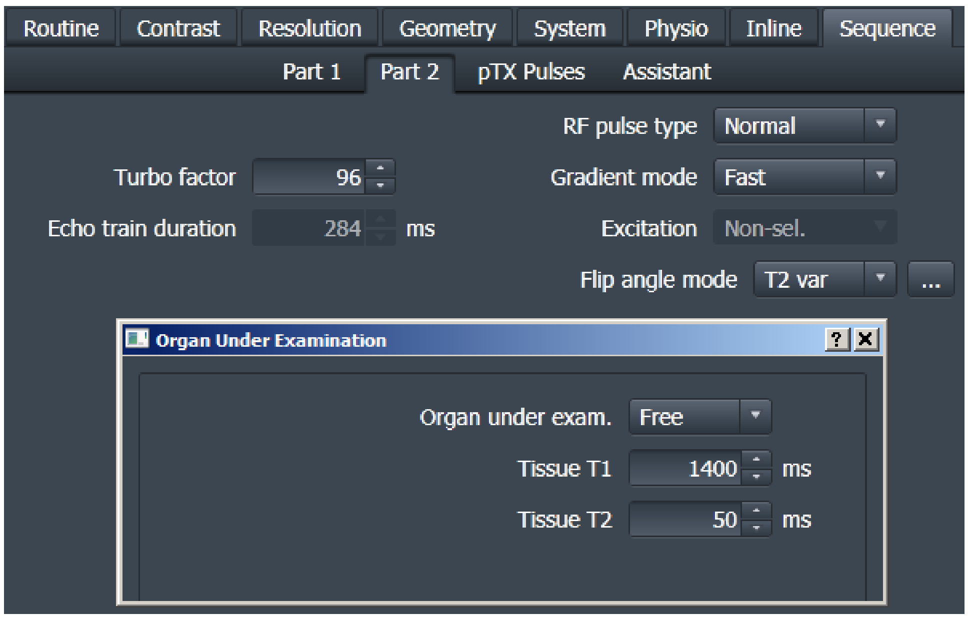

Figure 1: T_1 and T_2 values used for the flip angle calculation can be set using the "Flip angle mode" parameter in "Sequence > Part2". This parameter is a standard parameter from the Siemens sequence, but the default values have been changed in the ns_tse_vfl sequence.

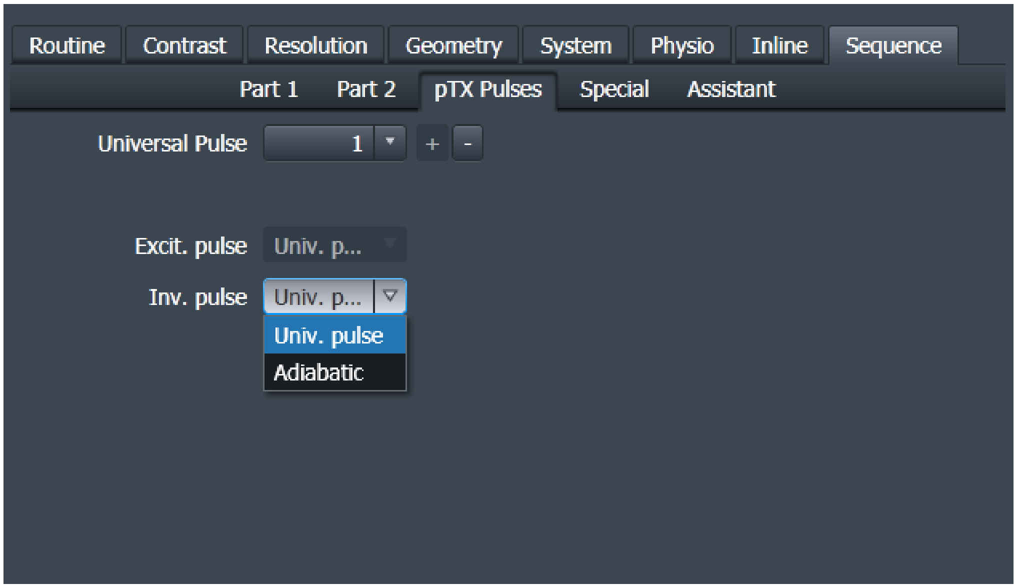

Figure 2: Activation of Universal Pulses in "Sequence > pTX Pulses" card for the excitation and refocusing pulses. When a magnetization preparation module is activated, the user can choose between a UP and an adiabatic pulse for this module.

resulting images. A tooltip is available to display information about the refocusing train (figure 3).

5.4 Magnetization preparation

Three magnetization preparations are available within the "Contrast > Common" card of the SPACE sequence. The table 1 explains the different options. For FLAIR protocols, the "Non-sel. T2-IR" option is recommended to improve the white-grey matter contrast. The "Non-sel. DIR" option can be choosen to perform a Double Inversion Recovery preparation.

Adiabatic preparation The type of RF pulses used during the preparation modules can be changed using the parameter "Inv. pulse" in "Sequence > pTX Pulses" card. The user can switch between a "Universal Pulse" and the Siemens standard adiabatic pulse (figure 2).

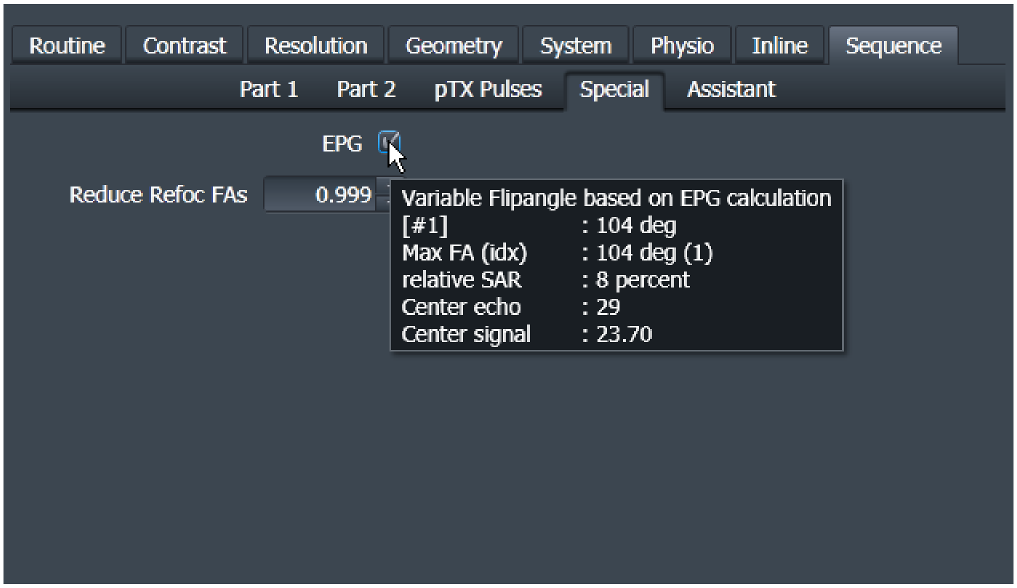

Figure 3: View of the "Sequence > Special" card containing an option to switch between Siemens standard refocusing train and EPG based refocusing train. The tooptip display information about the refocusing train.

5.5 Fat saturation & other preparations

At the moment, fat saturation, restore and dark blood preparations do not use any optimized pTx pulses. In other words, they are played in TrueForm. If you are trying to use these options, your feedback is welcomed.

Magn. preparation	Option name	Description	Specific parameters
Non selective inversion	"Non-sel. IR"	A single inversion pulse followed by an inversion time	Inversion Time : "TI 1"
T2-weigthed inversion	"Non-sel. T2-IR"	A T2 prepared inversion module followed by an inversion time	Inversion Time : "TI 1"
Double inversion recovery	"Non-sel. DIR"	A double inversion recovery module using two inversion times	Inversion Times : "TI 1 & TI 2"

Table 1: Magnetization preparation options in the SPACE sequence using UP pulses.

6 3D-GRE sequence

6.1 "pTx Pulses" card

The sequence user interface is similar to the product VE12 GRE sequence. To activate Universal Pulses, the user must click the "Universal Pulse" button located in "Sequence > pTX Pulses" card.

6.2 Excitation mode

The GRE sequence can perform both non-selective and slab-selective Universal pulses. This option can be switched by using the Siemens standard parameter "Excitation mode" in "Sequence > Part 2 > Excitation".

6.3 RF pulse types

In the GRE sequence, RF pulse type can be used to select excitation Universal Pulses with different properties. Pulse duration, maximal reachable flip angle as well as power deposition are modified when switching between the different options as shown in table 2.

Pulse Type	Duration in us	Maximum allowed Flip Angle
non-sel. FAST	160	10°
non-sel. NORMAL	240	20°
non-sel. LOW SAR	480	60°
slab-sel. FAST	5-spokes of 240 us	10°
slab-sel. NORMAL	3-spokes of 480 us	20°
slab-sel. LOW SAR	3-spokes of 920 us	60°

Table 2: Pulse characteristics in the GRE sequence depending on "RF pulse" type parameter and on "Excitation mode" parameter.

6.4 B_0 map reconstruction

In the "Sequence > Special" card, a B_0 map reconstruction can be activated. In this case, the number of echoes is automatically switch to 3-echoes and the reconstruction mode to "Mag./Phase". An additional series is then available and contains B_0 map expressed in unit of $0.1Hz$.

7 3D-MP(2)RAGE sequence

7.1 "pTx Pulses" card

The sequence user interface is similar to the product VE12 tfl sequence. To activate Universal Pulses, the user must click the "Universal Pulse" button located in "Sequence > pTX Pulses" card (figure 4). For detailed information about GRAPE excitation and GRAPE inversion Universal Pulses, please refer to Van Damme et al. (12).

Water excitation Universal pulse The excitation pulse can be switched between a Universal pulse and two different water-excit. Universal pulses to apply a fat saturation to the image.

Flip angles The flip angle of the excitation Universal Pulse can be set between 0° and 8° in the protocol via the standard "Flip angle" parameter in "Contrast > Common" card. In the case of MP2RAGE acquisition, each train can have a different flip angle value determined by the two "flip angle" parameters.

7.2 Excitation mode

The MP(2)RAGE sequence can perform both non-selective and slab-selective Universal pulses. This option can be switched by using the Siemens standard parameter "Excitation mode" in "Sequence > Part 2 > Excitation".

7.3 Reordering & Elliptical scanning

The MP(2)RAGE sequence has been modified to include an optimized Linear Reordering Scheme (option named "FREE 0" for parameter Reordering in "Sequence > Part 1" card). If this option is selected, elliptical scanning can be enabled. Furthermore, the turbo factor is no longer fixed to the number of acquired partitions. Thus, giving the user more flexibility during protocol optimization. The other options of the reordering parameter are based on the default siemens product sequence behaviour:

- "Linear": During one TR, the k-space is stepped through the partition encoding direction. The turbo factor equals the number of partition encoding lines.

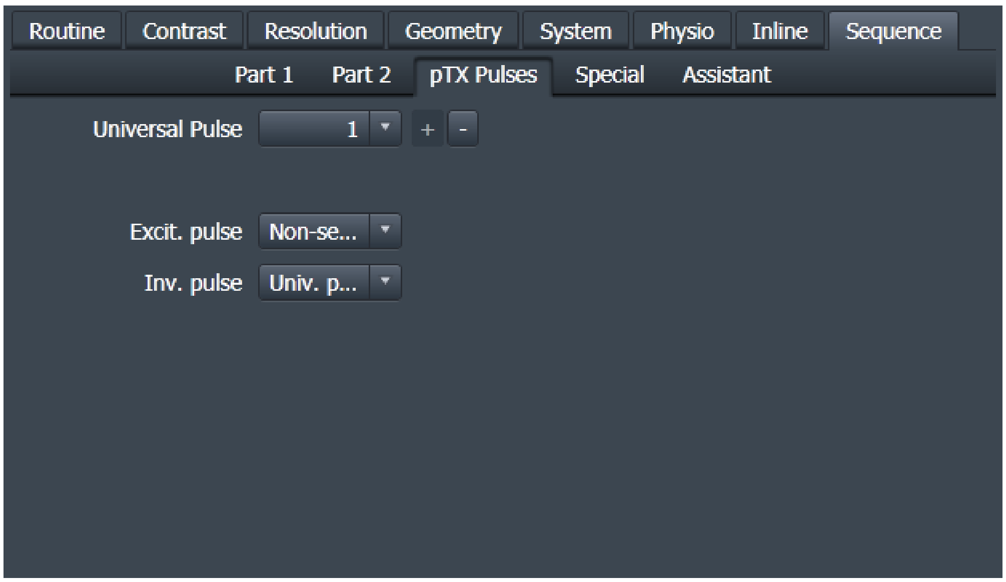

Figure 4: Activation of Universal Pulses in "Sequence > pTX Pulses" card for the excitation and refocusing pulses. When a magnetization preparation module is activated, the user can choose between a UP and an adiabatic pulse for this module. Excitation Universal pulse can be switched between a Universal pulse, a water-excit. UP and a fast water-excit. UP.

- "Linear rot.": During one TR, the k-space is stepped through the phase encoding direction. The turbo factor equals the number of phase encoding lines.
- "Radial": During one TR, the k-space ordering is optimized in a radial centric-out fashion and the number of encoding steps per TR is adjusted with the "turbo factor" parameter available in "Sequence > Part 2" card. Elliptical scanning is available with this option.
- "Free 0": During one TR, the k-space ordering is optimized in a radial centric-out fashion and the number of encoding steps per TR is adjusted with the "turbo factor" parameter available in "Sequence > Part 2" card. Elliptical scanning is available with this option.

7.4 Reconstruction for MP2RAGE acquisition

The sequence has a reconstruction switch in the special card to use either standard Siemens MP2RAGE reconstruction or a custom MP2RAGE reconstruction (figure 5).

Background suppression When using custom reconstruction, a background suppression can be activated for UNI images in order to obtain a UNI denoised series in addition.

Synthetic image reconstruction If T_1 mapping is activated (available in "Inline > MapIt" card), synthetic images can be reconstructed by switching the on/off options in the special card. For more information about synthetic images, please refer to Bapst et al. (1).

CAIPIRHNIA mode If CAIPIRHNIA is used, the MP2RAGE reconstruction is using the custom reconstruction pipeline due to incompatbility between Siemens MP2RAGE recosntruction and CAIPIRHNIA reconstruction.

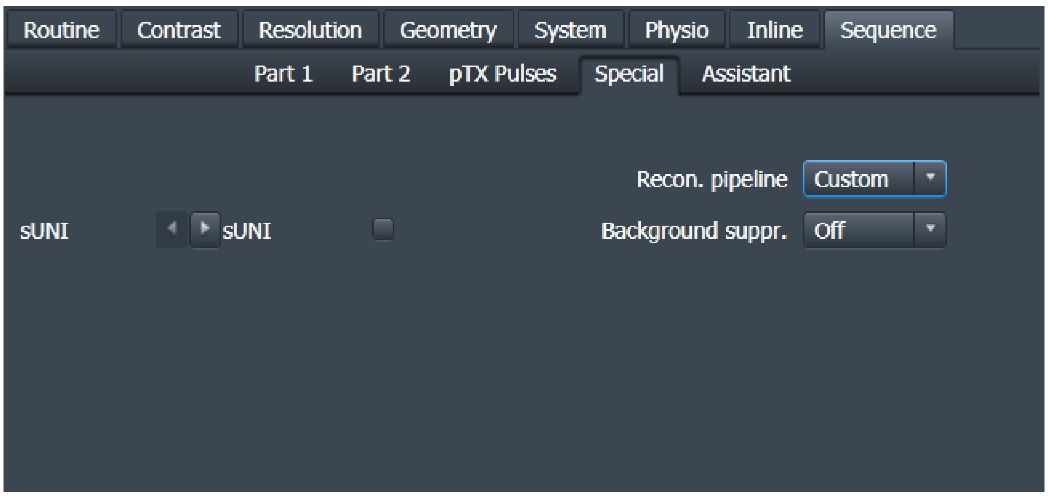

Figure 5: View of the "Sequence > Special" card containing an option to switch between Siemens standard MP2RAGE reconstruction and a custom MP2RAGE reconstruction. If T_1 mapping is activated ("Inline > MapIt" card), synthetic contrast reconstruction can be switched on.

8 3D-EPI sequence

This 3D gradient echo EPI has been provided by Rüdiger Stirnberg from DZNE Bonn.

8.1 "pTx Pulses" card

To activate Universal Pulses, the user must click the "Universal Pulse" button located in "Sequence > pTX Pulses" card (figure **??**). Universal pulses in 3D-EPI sequence are kT-point pulses. Excitation mode can be changed between non-selective and slab-selective excitation in "Sequence > Part 2 > Excitation".

8.2 RF pulse types

In non-selective mode, RF pulse type can be used to select excitation Universal Pulses with different properties. Pulse duration as well as power deposition are modified when switching between the different options as show in table 3. In slab-selective mode, only one pulse is used.

Pulse Type	Excitation mode	Duration in us	Maximum allowed Flip Angle
FAST	non-selective	600	10°
NORMAL	non-selective	800	20°
LOW SAR	non-selective	1200	60°
NA	slab-selective	3-spokes of 920 us	15°

Table 3: Pulse characteristics in the 3D-EPI sequence depending on RF pulse type options and excitation mode.

8.3 Gradient delay calibration

Slab selective pulses uses bipolar gradient shapes that can be sensitive to gradient delays. The delays can result in shading and local loss of signal. If these artifacts are present, a solution based on the trim blips method described in Jamil et al. (6) can be employed to alleviate them. The calibration has to be performed once for all on phantom.

The tool implemented consists simply in a slab selective double spoke RF pulse dephased by 180° in combine mode on which the user can apply an additional phase on the second pulse via the sequence protocol GUI. Once in PTX and slab-selective mode, the user can choose to set the sequence into gradient delay calibration mode by setting "Enable gradient delay calibration mode" from 0 to 1 (see Fig. 6). The FOV must be shifted by 45 mm from isocenter in the gradient direction that is calibrated. Next, the goal is to have the dark band on the central slice by choosing the right phase offset as illustrated in Fig. 6 - A. The phase offset is applied when "apply Grad del correction" is set to 1. Once the dark band is centered for one gradient axis, the user can switch to the next gradient axis. Finally, once the tool is calibrated on the three directions, "Enable gradient delay calibration mode" can be set back to 0 to return to imaging mode. The sequence will then use the phase offsets to correct for the gradient delays.

8.4 Features

The sequence comes with features that are partly experimental. This list is non-exclusive.

- 2D-CAIPIRINHA sampling with (Stirnberg and Stöcker (11)) or without (Stirnberg et al. (10)) additional segmentation along primary phase encode direction.
- variable echo train lengths (a.k.a. "(semi-)elliptical" sampling) (Stirnberg et al. (10))
- multi-echo acquisition ("true" multi-echo and "segmented" multi-echo)
- several spatially selective and non-selective fat suppression options (**?** Stirnberg et al. (10))
- several special card parameters to tweak the excitation RF pulse (duration, BWT product but not available in ptx)
- integrated or external (5 deg excitation) phase correction scans (adjustable rate: once per series/ per volume/ per "blade" / per shot / "in dummies")
- adjustable rate of regional or other saturation pulses (once per volume/ per "blade" / per shot)
- approach to steady state from "equilibrium" or following inversion or saturation recovery for high contrast "dummy" images (Stirnberg et al. (10))
- optional dummy shots per volume (e.g. for external PC)

- optional dummy measurements (number of initial non-steady-state volumes without ext. trigger, fully reconstructed though!)
- extensive tooltips, amongst others for:
  - imaging (and PATRef) Ernst angle: mouse-hover over Special card > Ernst T1
  - Skipped-CAIPI trajectory type, y-blip, z-blips and z-blip cycle: mouse-hover over Sequence > Part 2 card > Segmentation
  - EPI-specific information (phase encode bandwidth, fat pixel shift, actual TR/shot for imaging and PATRef): mouse-hover over Sequence > Part 2 card > Segmentation
- automatic image intensity scaling depending on the (first) TE (may change in the future; can be corrected using System > Tx/Rx > Img. scale cor.)
- Manual EPI gradient rise time factor on Special card to fine-tweak protocols (obtainable echo spacings, TE, etc.) in conjunction with the readout bandwidth

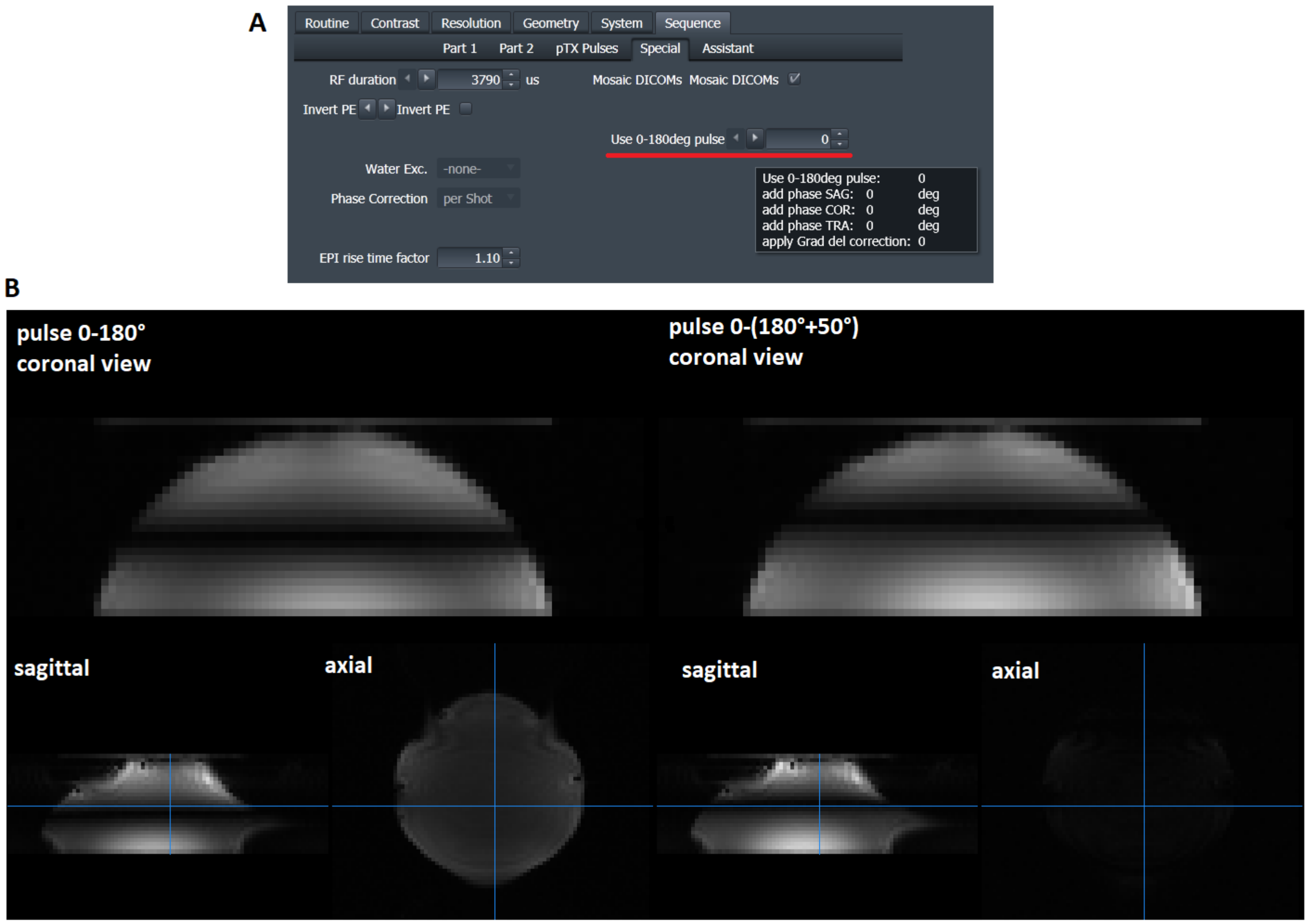

Figure 6: A - Underlined in red, is the section dedicated to the gradient delay calibration. B - Image on phantom with in gradient delay calibration mode with no additional phase en left, and with a +50° phase offset on right. The slab is oriented in the axial direction. The axial view shows the central slice of the FOV.

9 Additional information

9.1 Version & new features

v1.0 Initial release of the Pasteur package containing ns_gre, ns_tfl and ns_tse_vfl sequences.

v1.1 Embedded pTx gradients can be inhibited from ini file so that external ini files can be changed easily for custom purposes.

v1.2 UI improvements.

v1.3 License file contains a version number.

v1.4 Correct a bug that prevents to acquire some FOV orientations.

v2.0 Major release change compared to v1.x versions

- Adding ns_ep3d sequence.
- Adding slab-selective UP in all sequences.
- Adding CAIPIRINHA option in all sequences.
- Sequence specific improvements and new features.

9.2 RF Pulse ini files

To integrate new pTx RF pulses into the available sequences in the PASTeUR package, one can replace the ini files located in C:/MedCom/MriCustomer/seq/RFPulses/Pasteur/. The following list describes the use case of each ini file.

For ns_gre sequence , in GRE subfolder:

- pTXGreHighFA.ini → used for non-sel. LOW_SAR mode
- pTXGreMedFA.ini → used for non-sel. NORMAL mode
- pTXGreLowFA.ini → used for non-sel. FAST mode

- pTXGreMedFASlabSel(_,2,...).ini → used for slab-sel. NORMAL mode
- pTXGreLowFASlabSel(_,2,...).ini → used for slab-sel. FAST mode

For ns_tse_vfl sequence , in TSE_VFL subfolder:

- pTXRFPulseVFA_Exc.ini → used for 90° pulse in non-sel. mode
- pTXRFPulseVFA_Ref.ini → used for variable FA refocusing in non-sel. mode
- pTXRFPulseVFA_ExcSlabSel(_,2,...).ini → used for 90° pulse in slab-sel. mode
- pTXRFPulseVFA_Ref180.ini → used for 180° refocusing in slab-sel. mode
- pTXRFPulseVFA_RefSlabSel.ini → used for variable FA refocusing in slab-sel. mode

For ns_tfl sequence , in TFL subfolder:

- pTXRFPulseExc.ini → used for non-sel. excit.
- pTXRFPulseExcWE.ini → used for non-sel. water-selective excit.
- pTXRFPulseExcWEfast.ini → used for non-sel. water-selective fast excit.
- pTXRFPulseExcSlabSel(_,2,...).ini → used for slab-sel. excit.

For magn. preparation used in ns_tse_vfl and ns_tfl, in SBB_IR subfolder:

- pTXRFPulseInv.ini → used for inversion, double inversion recovery modules
- pTXRFPulseT2p90.ini → used for 90° excitation pulse in T2 prepared inversion module
- pTXRFPulseT2p180.ini → used for 180° refocusing pulse in T2 prepared inversion module

For ns_ep3d sequence , in EP3D subfolder:

- pTXEPIHighFA.ini → used for non-sel. LOW_SAR mode
- pTXEPIMedFA.ini → used for non-sel. NORMAL mode
- pTXEPILowFA.ini → used non-sel. FAST mode
- pTXEPIPulseSlabSel(_,2,3).ini → used for slab-selective excit. in EPI
- DelayMeasExp.ini and EP3D/DelayMeasExp2.ini → used for excitation in EPI sequence in gradient delay calibration mode

The rotation matrix used in the PASTeUR sequences is the unitary matrix, meaning that in the ini file, gradients must be defined as follow: considering the standard head first supine position, first column is played in antero-posterior direction, 2nd column is played in left-right direction, 3rd column is played in feet-head direction. Once properly set, the FOV can be tilted or protocol orientation can be changed without requiring modifications of the ini file.

10 Your feedback

Your feedback is welcome regarding the use of this package. In particular, we are interested in having feedbacks on the following topics:

- if you encounter unexpected artifacts
- if you have suggestions for protocol improvements
- if you find out bugs while scanning
- if you think of specific features or wanted sequences
- if you have any tips to share

Please contact the authors of this package.

References

1 Bapst, B., Massire, A., Mauconduit, F., Gras, V., Boulant, N., Dufour, J., Bodini, B., Stankoff, B., Luciani, A. and Vignaud, A. (2023), 'Pushing MP2RAGE boundaries: Ultimate time-efficient parameterization combined with exhaustive T $_1$ synthetic contrasts', *Magnetic Resonance in Medicine* p. mrm.29948.
URL: *https://onlinelibrary.wiley.com/doi/10.1002/mrm.29948*

2 Gras, V., Boland, M., Vignaud, A., Ferrand, G., Amadon, A., Mauconduit, F., Le Bihan, D., Stöcker, T. and Boulant, N. (2017), 'Homogeneous non-selective and slice-selective parallel-transmit excitations at 7 Tesla with universal pulses: A validation study on two commercial RF coils', *PLOS ONE* **12**(8), e0183562.
URL: *https://dx.plos.org/10.1371/journal.pone.0183562*

3 Gras, V., Mauconduit, F., Vignaud, A., Amadon, A., Le Bihan, D., Stöcker, T. and Boulant, N. (2018), 'Design of universal parallel-transmit refocusing k $_t$ -point pulses and application to 3D T $_2$ -weighted imaging at 7T: Universal Pulse Design of 3D Refocusing Pulses', *Magnetic Resonance in Medicine* **80**(1), 53–65.
URL: *http://doi.wiley.com/10.1002/mrm.27001*

4 Gras, V., Pracht, E. D., Mauconduit, F., Le Bihan, D., Stöcker, T. and Boulant, N. (2019), 'Robust nonadiabatic T $_2$ preparation using universal parallel-transmit k $_t$ -point pulses for 3D FLAIR imaging at 7 T', *Magnetic Resonance in Medicine* **81**(5), 3202–3208.
URL: *http://doi.wiley.com/10.1002/mrm.27645*

5 Gras, V., Vignaud, A., Amadon, A., Bihan, D. and Boulant, N. (2017), 'Universal pulses: A new concept for calibration free parallel transmission', *Magnetic Resonance in Medicine* **77**(2), 635–643.
URL: *https://onlinelibrary.wiley.com/doi/10.1002/mrm.26148*

6 Jamil, R., Mauconduit, F., Gras, V. and Boulant, N. (2021), 'General gradient delay correction method in bipolar multispoke RF pulses using trim blips', *Magnetic Resonance in Medicine* **85**(2), 1004–1012.
URL: *https://onlinelibrary.wiley.com/doi/10.1002/mrm.28478*

7 Lowen, D., Pracht, E. D., Gras, V., Massire, A., Mauconduit, F., Stoecker, T. and Boulant, N. (2024), 'Design of calibration-free RF pulses for T 2$$ {}_2 $$-

weighted single-slab 3D turbo-spin-echo sequences at 7T utilizing parallel transmission', *Magnetic Resonance in Medicine* p. mrm.30212.
URL: *https://onlinelibrary.wiley.com/doi/10.1002/mrm.30212*

8 Pracht, E. D., Feiweier, T., Ehses, P., Brenner, D., Roebroeck, A., Weber, B. and Stöcker, T. (2018), 'SAR and scan-time optimized 3D whole-brain double inversion recovery imaging at 7T', *Magnetic Resonance in Medicine* **79**(5), 2620–2628.
URL: *https://onlinelibrary.wiley.com/doi/10.1002/mrm.26913*

9 Stirnberg, R., Brenner, D., Stöcker, T. and Shah, N. J. (2016), 'Rapid fat suppression for three-dimensional echo planar imaging with minimized specific absorption rate', *Magnetic Resonance in Medicine* **76**(5), 1517–1523.
URL: *https://onlinelibrary.wiley.com/doi/10.1002/mrm.26063*

10 Stirnberg, R., Huijbers, W., Brenner, D., Poser, B. A., Breteler, M. and Stöcker, T. (2017), 'Rapid whole-brain resting-state fMRI at 3 T: Efficiency-optimized three-dimensional EPI versus repetition time-matched simultaneous-multi-slice EPI', *NeuroImage* **163**, 81–92.
URL: *https://linkinghub.elsevier.com/retrieve/pii/S105381191730678X*

11 Stirnberg, R. and Stöcker, T. (2021), 'Segmented K-space blipped-controlled aliasing in parallel imaging for high spatiotemporal resolution EPI', *Magnetic Resonance in Medicine* **85**(3), 1540–1551.
URL: *https://onlinelibrary.wiley.com/doi/10.1002/mrm.28486*

12 Van Damme, L., Mauconduit, F., Chambrion, T., Boulant, N. and Gras, V. (2021), 'Universal nonselective excitation and refocusing pulses with improved robustness to off-resonance for Magnetic Resonance Imaging at 7 Tesla with parallel transmission', *Magnetic Resonance in Medicine* **85**(2), 678–693.
URL: *https://onlinelibrary.wiley.com/doi/10.1002/mrm.28441*

13 Wu, X., Gras, V., Vignaud, A., Mauconduit, F., Boland, M., Stoecker, T., Ugurbil, K. and Boulant, N. (2018), The travelling pulses: multicenter evaluation of universal pulses at 7T., *in* 'Proceedings of the International Society for Magnetic Resonance in Medicine', Paris, France.