PASTeUR : Package of Anatomical Sequences using parallel Transmission UniveRsal pulses

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Description	This current release of the PASTeUR package contains three sequences including Universal RF pulses to mitigate B1+ inhomogeneity at 7T.
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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 Ed Eberhard from German Center for Neurodegenerative Diseases (DZNE) for his help in the implementation of sequences and SAR management on the 7T MAGNETOM Terra system.

2 Overview

The PASTeUR package contains 3D anatomical sequences – a GRE3d, 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).

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.

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.

3 Installation

3.1 Summary of files

The PASTeUR package contains three 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.dll
        ├── ns_gre.lic
        ├── libns_gre.so
        ├── ns_tfl.dll
        ├── ns_tfl.lic
        ├── libns_tfl.so
        ├── ns_tse_vfl.dll
        ├── ns_tse_vfl.lic
        ├── libns_tse_vfl.so
        └── RFPulses
            ├── pTXGreHighFA.ini
            ├── pTXGreMedFA.ini
            ├── pTXGreLowFA.ini
            ├── pTXRFPulseExc.ini
            ├── pTXRFPulseInv.ini
            ├── pTXRFPulseT2p90.ini
            ├── pTXRFPulseT2p180.ini
            ├── pTXRFPulseVFA_Exc.ini
            └── pTXRFPulseVFA_Ref.ini
```

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.

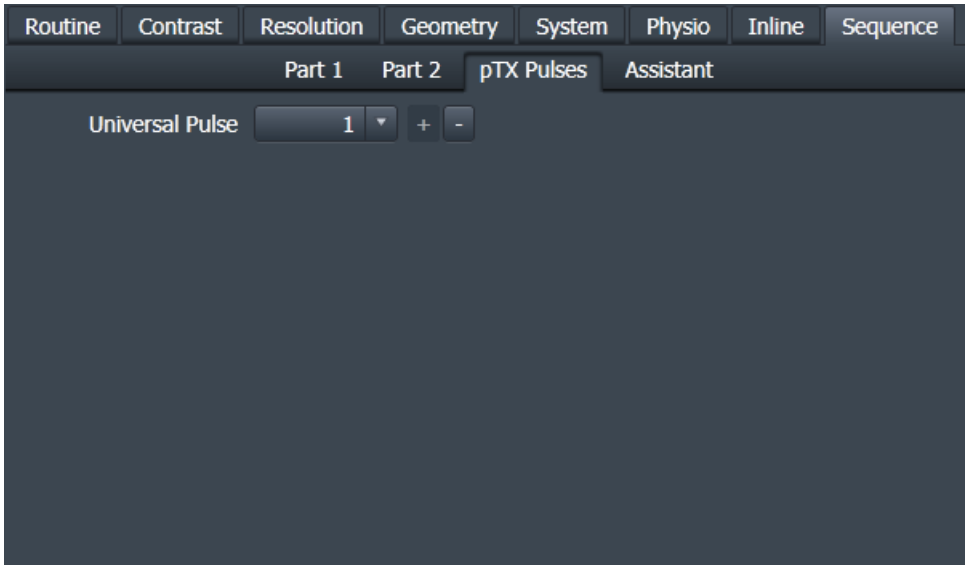

Figure 1: Activation of Universal Pulses in "Sequence > pTX Pulses" card.

4 SPACE sequence

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 1).

4.1 RF 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 2). For both excitation and refocusing pulses, the Universal Pulses are $760us$ long GRAPE pulses as described in Van Damme et al. (5).

4.2 Magnetization preparation

Three magnetization preparations are available within the "Contrast > Common" card of the SPACE sequence. When "Universal Pulse" is selected (1), all inversion pulses used in the preparation modules are Universal Pulses. The table 1 explains

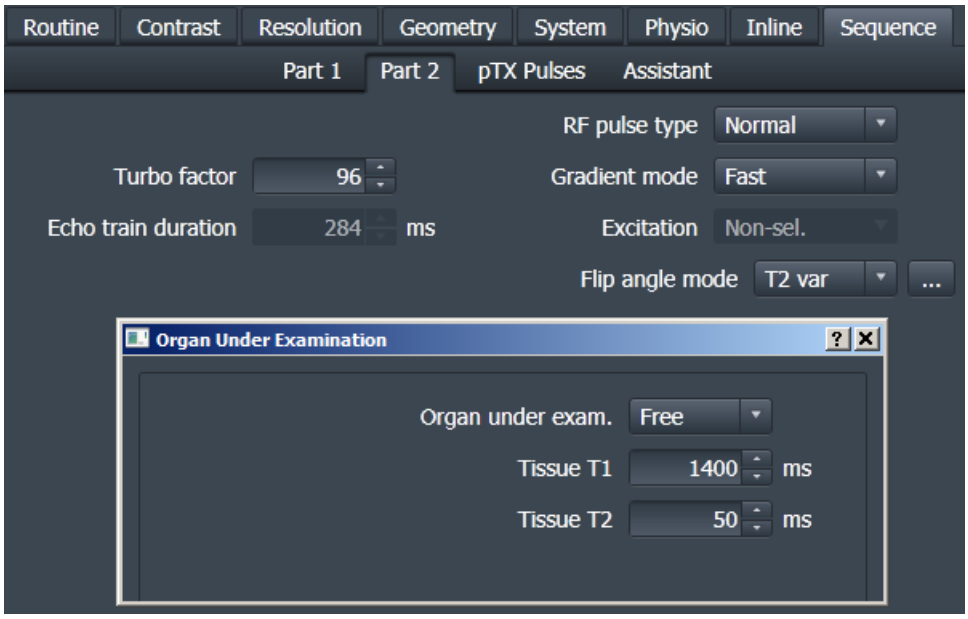

Figure 2: T_1 and T_2 values used for the flip angle calculation can be set using the "Flip angle mode" parameter in "Sequence > Part2". This parameter is a standard parameter from the Siemens sequence, but the default values have been changed in the ns_tse_vfl sequence.

the different options.

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.

The inversion Universal Pulse is a $5240us$ long GRAPE pulse. The 90° and 180° pulses of the T2 prepared inversion are kT-points of duration $1080us$ and $2120us$ respectively.

4.3 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 TreuForm. If you are trying to use these options, your feedback is welcomed.

5 GRE3D sequence

The sequence user interface is similar to the product VE12 GRE sequence. The sequence is available in a 3D acquisition mode with non-selective pulses only. To activate Universal Pulses, the user must click the "Universal Pulse" button located in "Sequence > pTX Pulses" card (figure 1). Universal pulses in GRE3D sequence are kT-point pulses.

5.1 RF pulse types

In the GRE sequence, 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 2.

Pulse Type	Duration in *us*	Maximum allowed Flip Angle
FAST	570	10°
NORMAL	800	20°
LOW SAR	1160	60°

Table 2: Pulse caracteristics in the GRE sequence depending on RF pulse type options.

6 MP(2)RAGE sequence

The sequence user interface is similar to the product VE12 tfl sequence. The sequence is available in a 3D acquisition mode with non-selective pulses only. To activate Universal Pulses, the user must click the "Universal Pulse" button located in "Sequence > pTX Pulses" card (figure 1).

6.1 Universal pulse

Both excitation and inversion Universal Pulses are GRAPE pulses as described in Van Damme et al. (5). Pulse durations are mentionned in table 3.

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.

Pulse Type	Duration in us
Excitation	240
Inversion	5240

Table 3: Universal pulse duration for MP(2)RAGE sequence.

7 Advanced features

7.1 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. The following list describes the use case of each ini file:

- pTXGreHighFA.ini → used for excitation with pulse type FAST in GRE sequence
- pTXGreMedFA.ini → used for excitation with pulse type NORMAL in GRE sequence
- pTXGreLowFA.ini → used for excitation with pulse type FAST in GRE sequence
- pTXRFPulseExc.ini → used for excitation in MP(2)RAGE sequence
- pTXRFPulseInv.ini → used for inversion in MP(2)RAGE sequence
- pTXRFPulseT2p90.ini → used for 90° excitation pulse in T2 prepared inversion module of SPACE sequence
- pTXRFPulseT2p180.ini → used for 180° refocusing pulse in T2 prepared inversion module of SPACE sequence
- pTXRFPulseVFA_Exc.ini → used for 90° excitation pulse in SPACE sequence
- pTXRFPulseVFA_Ref.ini → used for variable FA refocusing pulse in SPACE sequence

The original ini files does not contain gradient information because they are using gradient waveforms embedded in the sequences. This is controlled by the customer parameter ($InternalGradient = 1$) located in the pTXPulse section. By removing this parameter or making it equal to 0, one can use gradient waveforms as described in the ini file.

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.

8 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 improvments
- 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.

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