ns_gre_arb : gre sequence using arbitrary k-space trajectories

Contributors

Franck Mauconduit[1], Carole Lazarus[2], Philippe Ciuciu[2], Alexandre Vignaud[1]

[1] *Université Paris-Saclay, CEA, CNRS, BAOBAB, NeuroSpin, Gif-sur-Yvette, France*

[2] *CEA/DRF/JOLIOT/NeuroSpin/PARIETAL, Gif-sur-Yvette, France*

Last update February 28, 2023

Description The sequence can play an arbitrary gradient readout defined in an external file for 2D or 3D acquisitions.

Contacts Franck Mauconduit, CEA NeuroSpin

Contents

1 Introdution

The ns_gre_arb sequence provide a tool to play out a readout gradient using an arbitrary waveform that would be feasible by the scanner. In 2D acquisitions, the sequence runs the same n shots to fill in the 2D k-space of each slice. In 3D acquisitions, the sequence runs n shots to fill in a complete 3D k-space.

2 Installation

2.1 Summary of files

```
MriCustomer
└─seq
  ├─ns_gre_arb.dll
  ├─libns_gre_arb.so
  └─ArbitraryReadoutGradientFiles
    ├─trajectory1.bin
    ├─trajectory2.bin
    └─etc.
```

2.2 Installation procedure

Execute the file **install_neurospin_seq_VE11.bat** 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 Sequence description

3.1 Standard parameters

Amoung standard MR parameters, we tried to keep as much as possible the basic functionnality of the parameters such as TE, TR, number of slices in 2D acquisitions, Excitation type (non-selective or slab-selective) in 3D, etc. For some parameters, the behaviour is not standard anymore. In this case, they are either grayed out to keep information visible to the user or absent in the UI because they not are considered useful anymore. Details are given below:

FOV read parameter depends on the gradient file and is not changeable.

FOV phase same as FOV read.

Slice thickness : in 2D trajectories, it behaves as a standard parameter. In 3D sequences, it is imposed by the gradient file.

Base resolution is removed from the UI. For technical reasons, this parameter is not used anymore by the ns_gre_arb sequence.

Dimension is automatically selected to 2D or 3D depending on the gradient file information.

Orientation can be defined as in a standard sequence. The slice/slab will be tilted accrodingly by rotating the gradient waveforms within the gradient frame of reference.

Offcenter acquisitions are enabled. However, NCO phase shifts are not applied during acquisition, meaning that data is acquired as if FOV is located at isocenter. The shifts must be applied during reconstruction. For this reason, readout, phase and slice shifts are saved in WipMemBlock.adFree parameters for later availability (readout → adFree[6], phase → adFree[7] and slice → adFree[8]).

3.2 Special card parameters

Gradient File Selection parameter is a list box to select one of the available trajectories. A given trajectory file defines the in-plane FOV, the matrix size and the number of shots. Thus, these parameters are not changeable in the protocol. This list will display up to 16 different trajectories. In the case, the folder contains more than 16 trajectory files, only the 16 first will be selectable in the protocol. In addition, the tooltip shows the list of available trajectories and the selected one is surrounded with $**$.

Gradient spoiler parameter is a switch box to enable/disable the gradient spoiler applied at the end of every TR shot.

Spoiler momentum is a value that defines the gradient momentum to be applied in $ms * mT/m$. The gradient duration and gradient strength can be seen in the corresponding tooltip.

Readout OS factor : the ADC dwell time is synchronized with the gradient raster time ($10us$). By changing the readout OS factor, ADC dwell time is shorten accordingly ($Dwell\_time = Raster\_time/OSfactor$). Additional ADC information can be found in the tooltip of the readout os factor parameter : total ADC duration, number of data points per shot, ADC dwell time, total number of shots in the trajectory.

Nb of dummy scans can be defined to acquired dummy spokes prior to the first acquired spoke.

Gadgetron reco. enables to send data in real time to an external PC using gadgetron framework. ICE Gadgetron must be installed on the system for this feature.

Send trajectory enables the recording of the gradient trajectories (as specified in the gradient file) within the Siemens raw data file. Available options are :

- Option "OFF" : No trajectory data is saved.
- Option "Prior meas." : The trajectory is saved prior any measurement data. In this case, depending on the number of spokes in the trjectory, acquisition may start with a delay.
- Option "During meas." : The trajectory is saved during acquisition time. In this case, the sequence may abort suddently if the TR is too short. Trajectory data and measurement data will be interleaved in the raw data file.

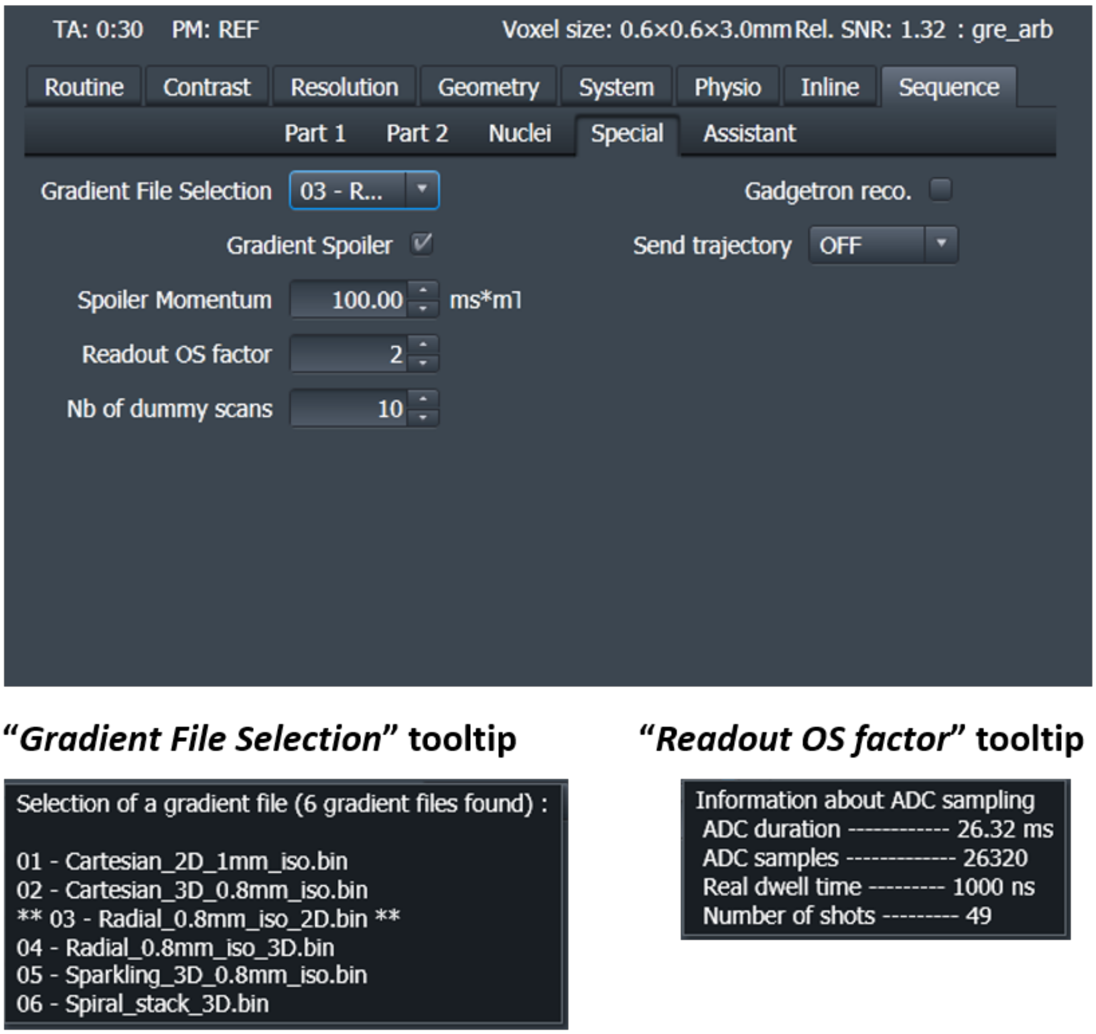

Figure 1: Special card of the ns_gre_arb sequence.

4 External trajectories

4.1 Gradient file description

Gradient files are located in "C:/MedCom/MriCustomer/seq/ArbitraryReadoutGradientFiles/" The sequence is searching for files with "bin" extension. If they are considered valid, they will be displayed in the corresponding list box in the sequence special card. The file content should be a collection of float values in a binary format and is explained in the table 1.

Name	Type	Size	Unit	Description
Version	float	1	n.a.	file version this new version would be "4.0"
Dimension	float	1	n.a.	2 -> 2D , 3 -> 3D
FOV	float	Dim	m	FOV size (x,y,z) : z absent if 2D dimension
Matrix	float	Dim	n.a.	Reconstruction matrix size (x,y,z) : z absent if 2D dimension
Minimum OSF	float	1	n.a.	Minimum OS for the trajectory
Gamma	float	1	Hz/T	Useful for X-nuclei imaging
Spokes	float	1	n.a.	Number of spokes
Samples	float	1	n.a.	Number of samples per spoke
K-space center	float	1	n.a.	Relative value in the range [0-1] to define center of spokes
MaxGrad	float	1	mT/m	Maximum absolute gradient in all 3 (or 2) directions
recon_tag	float	1	n.a.	Reconstruction tag
Empty places	float	10	n.a.	Yet unused : Default initialized with 0
kStarts	float	Dim*Spokes	1/m	K-space location start for all dimensions and spokes If dimension is 3D, only x and y kStarts are present
Gradient array	float	Dim*Samples *Spokes	n.a.	Gradient trajectory expressed in the range [-1; 1] relative to MaxGrad

Table 1: Description of the expected content of an arbitrary gradient file. The list is given in the order in which it should appear in the file.

Remarks : "FOV" and "Matrix" parameters should have 2 values if the trajectory dimension is 2D (3 values with if dimension is 3D). For "kStarts", the inner loop is dimension (2 or 3 values according to dimension) and the outer loop corresponds to the spokes. For "Gradient array", inner to outer dimension are : dimension (2 or 3 values according to dimension), all samples in one spoke, and all spokes.

4.2 Matlab example

Matlab example to create your own gradient file:

```
% Matlab example to create a gradient file
fid = fopen('MyGradientFile.bin', 'w');
fwrite(fid, 4.0, 'float');                % Gradient file version
fwrite(fid, 2.0, 'float');                % Trajectory dimension
fwrite(fid, [.220 .220], 'float');        % FOV in m
fwrite(fid, [256 256], 'float');          % k-space matrix size
fwrite(fid, 2.0, 'float');                % Minimum OS factor
fwrite(fid, 42576000, 'float');           % Gamma in Hz/T
fwrite(fid, NoOfSpokes, 'float');         % Number of spokes
fwrite(fid, NoOfSamples, 'float');        % Number of samples in a spoke
fwrite(fid, 0.5, 'float');                % Definition of echo time
fwrite(fid, MaxGrad, 'float');            % Maximum gradient all spokes
fwrite(fid, 0, 'float');                  % Recon_tag : unused by the seq
fwrite(fid, zeros(1,10), 'float');        % Dummy : unused by the seq
fwrite(fid, kstarts, 'float');            % k-space start positions
fwrite(fid, gradient, 'float');           % gradient trajectories
fclose(fid);
```

References

1 Lazarus, C., Weiss, P., Chauffert, N., Mauconduit, F., El Gueddari, L., Destrieux, C., Zemmoura, I., Vignaud, A. and Ciuciu, P. (2019), 'SPARKLING: variable-density k-space filling curves for accelerated T $_2$ * -weighted MRI', *Magnetic Resonance in Medicine* **81**(6), 3643–3661.
URL: *https://onlinelibrary.wiley.com/doi/10.1002/mrm.27678*

2 Lazarus, C., Weiss, P., El Gueddari, L., Mauconduit, F., Massire, A., Ripart, M., Vignaud, A. and Ciuciu, P. (2020), '3D variable-density SPARKLING trajectories for high-resolution T2*-weighted magnetic resonance imaging', *NMR in Biomedicine* **33**(9).
URL: *https://onlinelibrary.wiley.com/doi/10.1002/nbm.4349*