ns_tfl_rfmap package

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Description	The ns_tfl_rfmap package generates B_1^+ maps for parallel transmit coils or single transmit coils on Terra systems.
Platform	VE12U, VE12U-SP01, VE12U-AP01, VE12U-AP02, VE12U-AP04
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1 Introduction

Mapping of the RF transmit distribution is usually required to deal with spatial B_1^+ field inhomogeneity at high field. Numerous B_1^+ mapping methods have been proposed with different underlying concepts, as discussed in Fautz (4).

At Ultra High Field (UHF) with transmission array, fast techniques are required in order to map B_1^+ field for each transmitting channel in a reasonable acquisition time. Very fast techniques have been developed to fulfill this requirement. The XFL sequence, a.k.a. tfl_rfmap sequence, is a very fast 2D multi-slice B_1^+-mapping sequence well suited for multi-transmit channel measurement (1; 2). Due to inherently imperfect 2D slice selection, B_1^+ measurement is biased for high flip angle. This bias can be corrected using lookup tables as shown in Amadon et al. (3).

This package contains a tfl based sequence developed on IDEA VE12U software version using a custom ICE reconstruction for B_1^+ mapping. The sequence has been developed to run on 8 channel multi-transmit Terra systems as well as on single transmit system. An ICE post-processing performs the slice profile correction for an optimized B_1^+ measurement.

2 Installation

2.1 Summary of files

The package contains a ns_tfl_rfmap sequence ('ns' stands for NeuroSpin) and an associated ICE reconstruction program.

VE12U software

```
MedCom
└─ MriCustomer
   ├─ seq
   │  ├─ ns_tfl_rfmap.dll
   │  └─ libns_tfl_rfmap.so
   └─ ice
      ├─ IceProgramXFL.ipr
      ├─ IceXFL.dll
      ├─ IceXFL.evp
      ├─ libIceXFL.so
      ├─ RECO_B0B1
      │  └─ dummy.txt
      └─ ns_tfl_rfmap
         └─ SLR
            └─ FAlookup_SliceProfileCorrection_Imaging1ms.ini
```

2.2 Installation procedure

Execute the file **install_neurospin_seq_VE12.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.

2.3 Optimized protocols

A default protocol can be found in pdf format or exar file can be imported into the system. Additionnally, pro files might be provided. This pro file can be imported by a drag and drop from a Windows explorer into the Dot Cockpit.

3 ns_tfl_rfmap sequence

3.1 Description

The ns_tfl_rfmap sequence consists of a selective preparation saturation pulse immediately followed by a 2D single shot centric-ordered FLASH readout. The sequence can be used on both combine and pTx systems.

3.2 Special card

B1 mapping type This option defines a set of images that is acquired to compute B_1^+ maps for individual channels or in a combined mode:

- Interferometric - 18 acquisitions: 1 non saturated image with default shim, 8 interferometric saturated images, 1 saturated image with default shim, 8 non saturated interferometric images. For a 16Tx system, it would consist in 34 acquisitions instead.
- Fast relative - 10 acquisitions: 1 non saturated image with default shim, 8 non saturated interferometric images and 1 saturated image with default shim. For a 16Tx system, it would consist in 18 acquisitions instead.
- Combined - 2 acquisitions: 1 non saturated image with default shim and 1 saturated image with default shim. (In combine mode, this is the only available option for "B1 mapping type" .)
- External file - The user can define its own acquisitions configuration. In this case, no B_1^+ map would be reconstructed. However, native images are available for offline reconstruction of the B_1^+ maps.

Export B1 maps If this option is enabled, the reconstruction produces a set of files into C:/MedCom/MriCustomer/ice/RECO_B0B1 that contain reconstructed images (.dat file) and a matlab script (.m file) that helps to open the .dat file in Matlab. This feature is meant to give an alternative to the usual DICOM files by providing float images instead. For more information on the content of the exported files, see: Export B1 maps option.

Mosaic recon. This option provides mosaic DICOM images for a better visualization of the reconstructed images. This mosaic option groups images from the

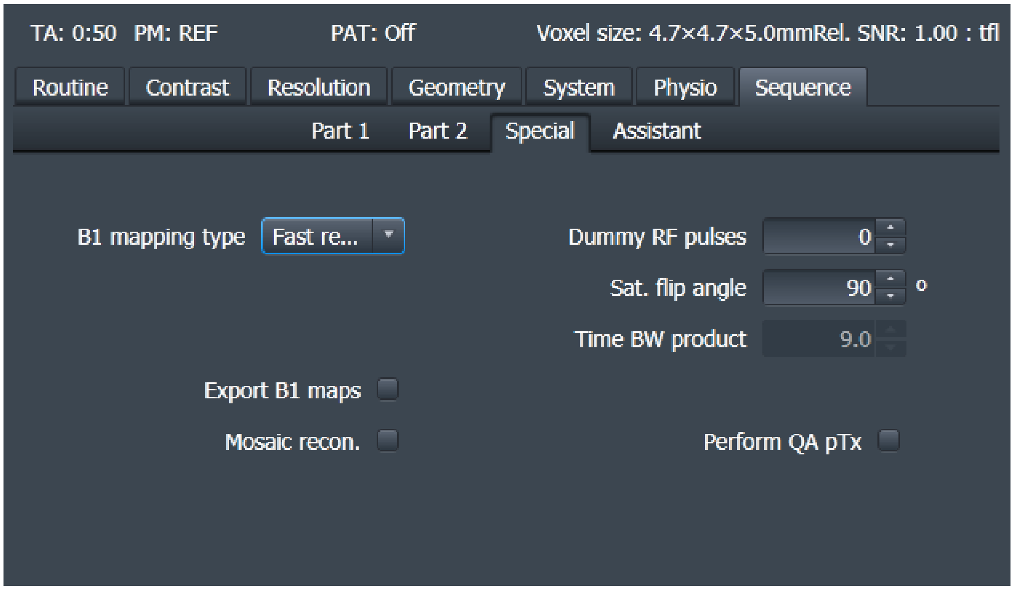

Figure 1: Custom parameters in "Sequence > Special" card.

different transmit elements (and not from the different slices as usually done in ep2d sequences).

Dummy RF pulses This is a pre-existing parameter from the Siemens tfl_rfmap sequence. (If you know more about why Siemens needs it, let me know).

Sat. flip angle Saturation flip angle used for the saturation pulse.

Time BW product Read only parameter showing the TBW of our custom stauration SLR pulse. This SLR pulse is our default saturation pulse that provides a better saturation property for better B_1^+ map accuracy.

Perform QA pTx This option is only available on pTx systems. When enabled, a 'quality assurance' is performed by comparing B_1^+ maps to a reference dataset. (Still work in progress)

4 ICE reconstruction

4.1 Available series

The ICE reconstruction will produce the following series:

- Series suffix "_Amplitude": Amplitude of all native images. Number of images per slice depends on the special card "B1 mapping type" parameter.
- Series suffix "_Phase": Phase of all native images. Same number of images as "_Amplitude".
- Series suffix "_Interf_B1_Amplitude": Amplitude of intermediate B_1^+ maps, before the interferometry is removed to produce individual transmit channel B_1^+ maps.
- Series suffix "_Interf_B1_Phase": Same as previous series for phase of interferometric B_1^+ maps.
- Series suffix "_B1_Ampli_All_Coils": Final B_1^+ map amplitude of all transmit channels.
- Series suffix "_B1_Phase_All_Coils": Final B_1^+ map phase of all transmit channels.

By default, the B_1^+ maps are expressed in tenth of degrees (1 unit equal 0.1 °). It is possible to switch to μ Tesla per Volt

4.2 Slice profile imperfections

To limit the slice profile imperfection of the saturation pulse, a SLR saturation pulse is used in the sequence (duration $5.01ms$ and time bandwidth product of 9). The saturation pulse is applied on twice the slice thickness of the excitation pulse. To prevent for slice crosstalks due to the saturation thickness, a minimum of 100% slice gap is used in the protocol. A lookup table contained in the file FAlookup_SliceProfileCorrection_Imaging1ms.ini is used to correct for the slice profile imperfection of the excitation pulse. The lookup table was computed based on the protocol pulse type used with Low SAR.

5 Additional information

5.1 Version & new features

v1.0

- Initial release

v1.2

- Sequence uses a SLR pulse for saturation instead of a sinc pulse
- Reconstruction is based on a custom ICE functor

v1.3

- Sequence and ICE reconstruction are compatible with both single transmit and pTx (8Tx/16Tx)

v1.4

- Lookup table for slice profile correction is added
- B1 maps can be exported in combined mode or uncombined mode
- Content of exported matlab file is improved

v1.5

- In combine mode, default protocol is now loading properly
- Improvements regarding QA pTx option (more information on this QA pTx package can be found on the Github page: QA pTx package.)

5.2 Export B1 maps option

When option export B1 maps is enabled, two files are created. A dat file contains float values of the reconstructed B_1^+ maps. This dat file also contains the Phoenix (or ASCCONV-BEGIN-END-Block) protocol in plain text. A Matlab script file is created to properly open the dat file and create a matlab variable containing all B1 images. The content is as follow:

```
%% MATLAB SCRIPT         : MID1005_B1MAPS_20230120_123105.m
% OPEN .dat file created at the same location and containing B1 MAPS modul
% File to open           : MID1005_B1MAPS_20230120_123105.dat
% WipMemBlock long       : 0 0 0 20 0 0 1 0 0 60 0 1 0 0 0 0 0 0 0 0 0 0 0 0
% WipMemBlock double     : 0 0 0 0 0 0 0 0 0 0 9 0 0 0 0 0
% % Data size
    dim=2;
    col=64;
    lin=40;
    set=8;
    slc=39;

% Open data as a vector
    fid=fopen('MID1005_B1MAPS_20230120_123105.dat','r');
    num_elmt=fread(fid,1,'float');
    vect_fid=fread(fid,num_elmt,'float');
    fclose(fid);

% Reshape data into a matlab matrix containing B1Map
% Unit : Magnitude in Tesla/Volt , Phase in radian
    data_resh = reshape(vect_fid,[dim col lin set slc]);
    B1MAP_ori = shiftdim(data_resh(1,:,:,:,:) +1i*data_resh(2,:,:,:,:));
    B1MAP_ori = permute(B1MAP_ori, [2 1 4 3]);
    clear data_resh vect_fid;

% Data acquired in transverse R->L
% No reorientation required
    B1MAP = B1MAP_ori;

    SliceInfo.dInPlaneRot       = 1.5708;
    SliceInfo.sNormal.dTra      = 1;
    SliceInfo.sNormal.dCor      = 0;
    SliceInfo.sNormal.dSag      = 0;
    SliceInfo.sPosition.dTra    = 0;        % Positive=Head,
Negative=Foot
    SliceInfo.sPosition.dCor    = 0;        % Positive=Posterior,
Negative=Anterior
```

```
    SliceInfo.sPosition.dSag  = 0;       % Positive=Left,
Negative=Right

% Number of transmit channels
    NumOfTXChannels = 8;

% Complex RF shim coefficients used during acquisition
    RFShim = [ ...
              0.3535+1i*0, ...
              0.25+1i*0.25, ...
              0+1i*0.3535, ...
              -0.25+1i*0.25, ...
              -0.3535+1i*0, ...
              -0.25+1i*-0.25, ...
              0+1i*-0.3535, ...
              0.25+1i*-0.25];
% Conversion to flip angle map
    TperV_2_deg = 5.41906e+08;
    FlipAngle = abs(B1MAP(:,:,:,:)) * TperV_2_deg;

% RF pulse information :
    RFPulse(1).name = 'SRFDummy';
    RFPulse(1).voltage = 0;
    RFPulse(2).name = 'SRFExcit';
    RFPulse(2).voltage = 27.2537;
    RFPulse(3).name = 'sRFPrepSLR';
    RFPulse(3).voltage = 190.272;
% EOF
```

References

1 Amadon A. et al. (2010), B1-Mapping of an 8-Channel TX-Array Over a Human-Head-Like Volume in Less Than 2 Minutes: the XEP Sequence, *in* 'Proc. Int. Soc. Mag. Res. Med.', Stockholm, Sweden, p. 2828.
URL: *https://archive.ismrm.org/2010/2828.html*

2 Amadon A. et al. (2012), Validation of a very fast B1-mapping sequence for parallel transmission on a human brain at 7T, *in* 'Proc. Int. Soc. Mag. Res. Med.', Melbourne, Australia, p. 3358.
URL: *https://archive.ismrm.org/2012/3358.html*

3 Amadon, A., Mauconduit, F., Vignaud, A. and Boulant, N. (2015), Slice profile corrections in the XFL B1-mapping sequence, *in* 'Proc. Int. Soc. Mag. Res. Med.', Toronto, ON, Canada, p. 2377.
URL: *https://archive.ismrm.org/2015/2377.html*

4 Fautz, H. P. (2010), New Angles on B1 Mapping, Introduction, *in* 'Proc. Int. Soc. Mag. Res. Med.', Stockholm, Sweden.
URL: *https://www.ismrm.org/10/session25.htm*