QA package for parallel transmission coils at ultra high field

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Description	This package consists of a set of measurements and ICE processing for an easy and automatized follow-up of the transmit path of pTx coils at 7T and higher.
Platform	VE12U, VE12U-SP01, VE12U-AP01, VE12U-AP02, VE12U-AP04
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Contents

1 Overview

The QA pTx package is based on the acquisition of B_1^+ maps and a scattering matrix to assess the transmit line of a parallel transmit (pTx) coil. The results are automatically saved in a database and are used to display follow-up graphs. This QA helps to evaluate the stability of custom coils at 7T and higher by comparing results over time.

2 Installation

2.1 Summary of files

The QA pTx package contains three different sequences and their custom ICE reconstruction pipelines.

```
MedCom
└── MriCustomer
    ├── seq
    │   ├── ns_tfl_rfmap.dll
    │   ├── libns_tfl_rfmap.so
    │   ├── ns_profile.dll
    │   ├── libns_profile.so
    │   ├── ns_smatrix.dll
    │   └── libns_smatrix.so
    └── ice
        ├── IceXFL.dll/evp
        ├── IceProgramXFL.ipr
        ├── libIceXFL.so
        ├── IceScanPosition.dll/evp
        ├── IceProgramScanPosition.ipr
        ├── libIceScanPosition.so
        ├── IcePickDico.dll/evp
        ├── IceProgramPickDico.ipr
        ├── libIcePickDico.so
        └── ns_tfl_rfmap
            └── SLR
                └── FAlookup_SliceProfileCorrection_Imaging1ms.ini
```

2.2 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.

2.3 Optimized protocols

A set of optimzed protocols can be found in the package as pdf files or can be imported into the 7T system with the exar file or pro files. Updated protocols might also be available via the following Github link: QA pTx protocols

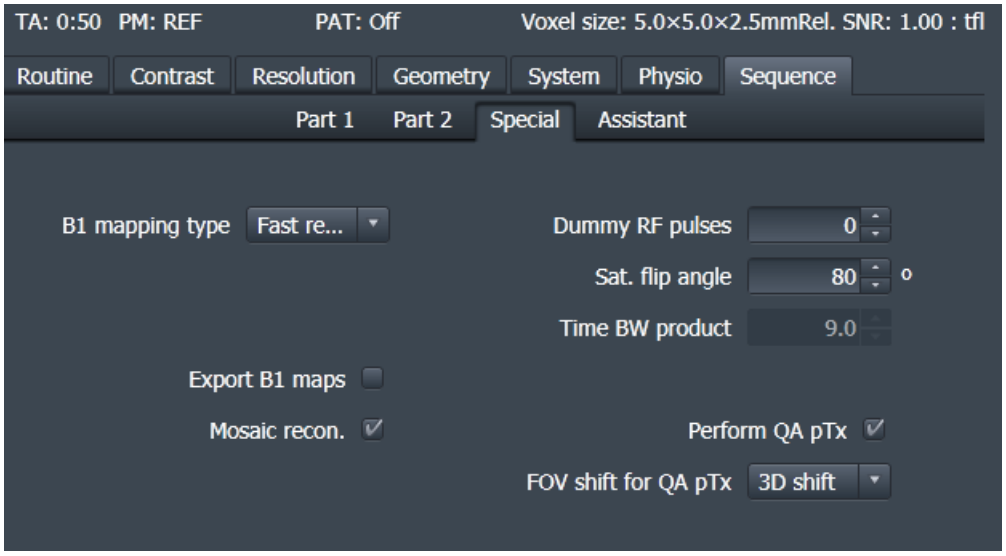

Figure 1: Special card of the ns_tfl_rfmap sequence in which the QA pTx reconstruction pipeline can be activated.

3 QA measurements

3.1 Sequences

There are two independant QA assessments in this package. They are both related to the transmit path of pTx coils:

- B_1^+ map stability assessment
- Scattering matix measurement and its stability assessment

The B_1^+ map measurement uses a custom sequence based on the Siemens tfl_rfmap sequence. The sequence used in this QA package is the same as the one in the ns_tfl_rfmap package. More information on this sequence can be found on the Github page: ns_tfl_rfmap package. In order to activate the QA assessment, the special card check box called "Perform QA pTx" must be enabled (figure 1).

The scattering matrix measurement is obtained by using the custom ns_smatrix sequence. This sequence automatically enables the Siemens option (accessible to the user via IdeaCmdTool) to save DiCo forward/reflected measurements within raw

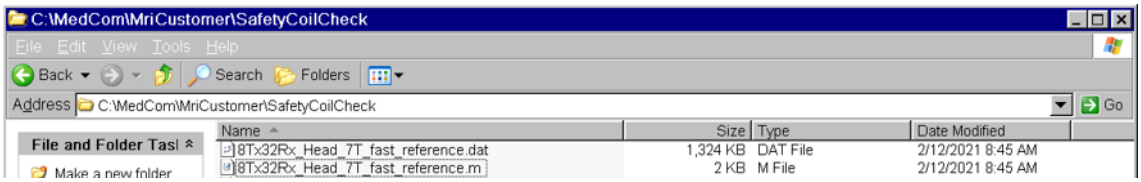

Figure 2: Folder containing the reference measurements. Each file will be named after the coil name to enable follow-ups of multiple coils.

data. At the end of the sequence, the option gets back to its original value. This step is necessary to access DiCo measurements within the ICE framework and is fully automatized.

3.2 B_1^+ map reference

During the first QA measurement, a B_1^+ reference map will be created and used for subsequent measurements. This reference is named after the coil name and is located in C:/MedCom/MriCustomer/SafetyCoilCheck/ (see figure 2). Each coil has its own reference file. Thus, it is possible to use the QA for different coils. Once the reference is created, following QA measurements will produce B_1^+ maps located in C:/MedCom/MriCustomer/ice/RECO_BOB1/ and will be compared to the reference file within the ICE processing.

3.3 Phantom installation

The stability of the QA pTx depends on the reproducibility of the phantom positioning. It is recommended to always use the same phantom and its associated holder and to define a reproducible procedure. Moreover, the phantom should be stable through time to prevent drifts due to evaporation for instance.

3.4 Automatic centering

To reduce QA variability due to phantom position, we highly recommend to use the automatic positioning of the protocol filed-of-view. It consists in a short acquisition prior the B_1^+ map measurement that will assess the phantom position using three line scans in the three main directions (figure 3). The field-of-view of the B_1^+ map acquisition can then be aligned on the phantom with a good reproducibilty and precision. This process is an option that can be activated in the special card of the

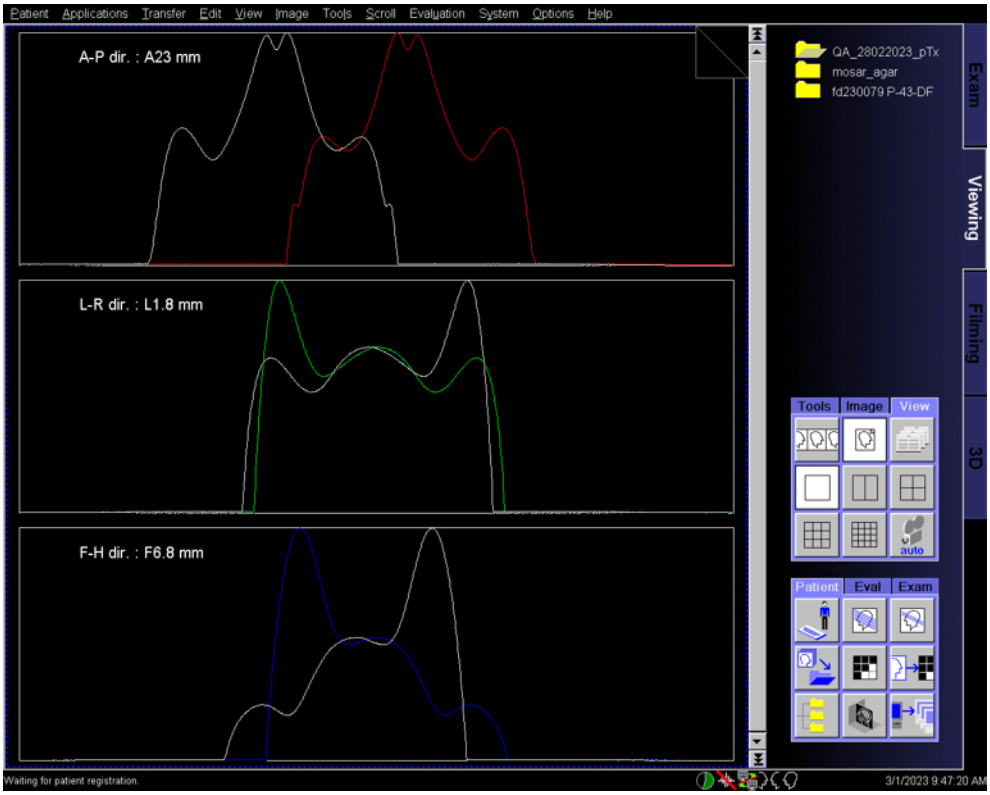

Figure 3: Results of the profile measurement durgin which the phantom position is determined. The results are used in the ns_tfl_rfmap sequence if "FOV shift for QA pTx" is not "Off". Consequently, the position of the FOV is automatically adpated the center the phantom in the FOV during B_1^+ map acquistion.

ns_tfl_rfmap sequence. There is a special card option called "FOV shift for QA pTx" with different possibilities. If the phantom is a sphere, the shift can be applied in 3D ("3D shift" option in ns_tfl_rfmap Special card) meaning that the "Position" parameter in Routine card will be adapted in all 3D dimensions. It the phantom is a cylinder, it might be enough to use the 2D shift option ("in-plane shift" option in ns_tfl_rfmap Special card) meaning that only "Position" in phase and readout directions will be adapted.

3.5 Scattering matrix

A scattering matrix can be computed using directional couplers (DiCOs) forward and reflected measurements on every transmit channels. This matrix should inform

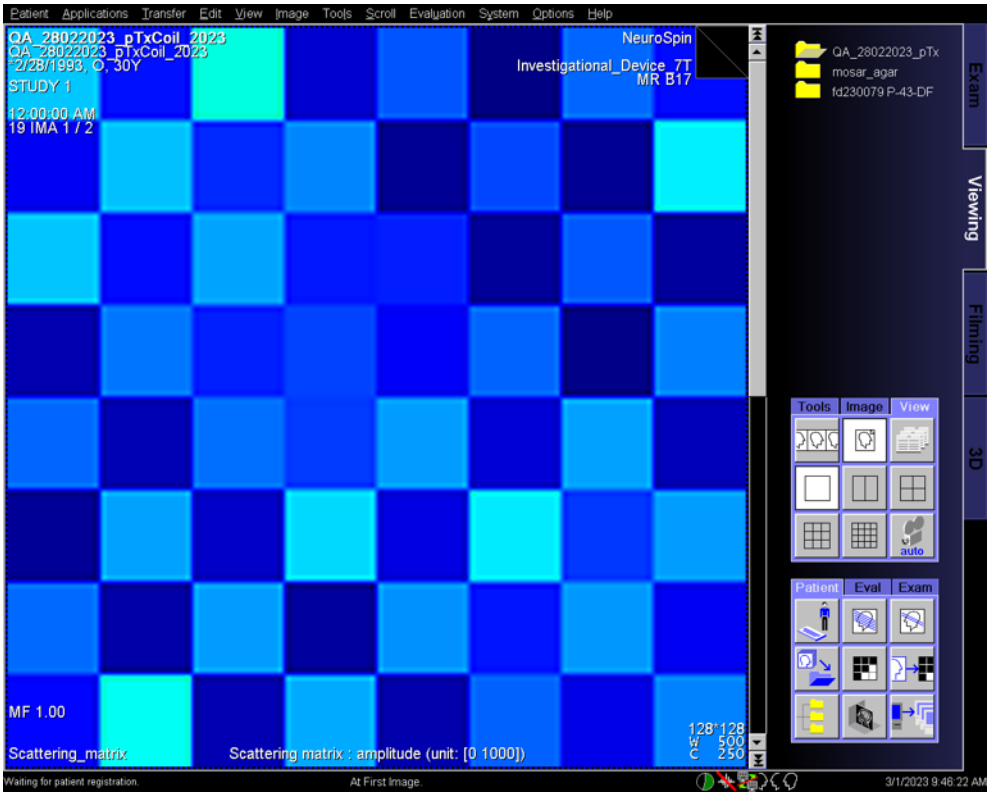

Figure 4: Scattering matrix

about transmit coil stability over time.

4 Description of post-processing

4.1 General description of follow-up procedure

The QA results are located in C:/MedCom/MriCustomer/QA/. A folder named after the coil name will be created during the first QA measurement. In this dedicated folder, files related to a given QA will be filled in during every QA measurement. A new line will be added to keep track of all values and will enable the creation of follow-up plots.

4.2 QA results of the B_1^+ maps

When QA option of the ns_tfl_rfmap is enabled, two DICOM series are generated during reconstruction:

- (PROTOCOL_NAME)_CHECK-PTX-COIL
- (PROTOCOL_NAME)_FOLOWUP-PTX-COIL

The first series named (PROTOCOL_NAME)_CHECK-PTX-COIL contains six different DICOM images (figures 5 and 7).

- B_1^+ map modulus of the reference data. "Reference magnitude" is displayed in the image comment.
- B_1^+ map modulus of the measurement data. "Measurement magnitude" is displayed in the image comment.
- B_1^+ map phase of the reference data. "Reference phase" is displayed in the image comment.
- B_1^+ map phase of the measurement data. "Measurement phase" is displayed in the image comment.
- B_1^+ map containing a visual superposition of the ROI used for the analysis (figure 6).
- A table containing QA results for each channel.

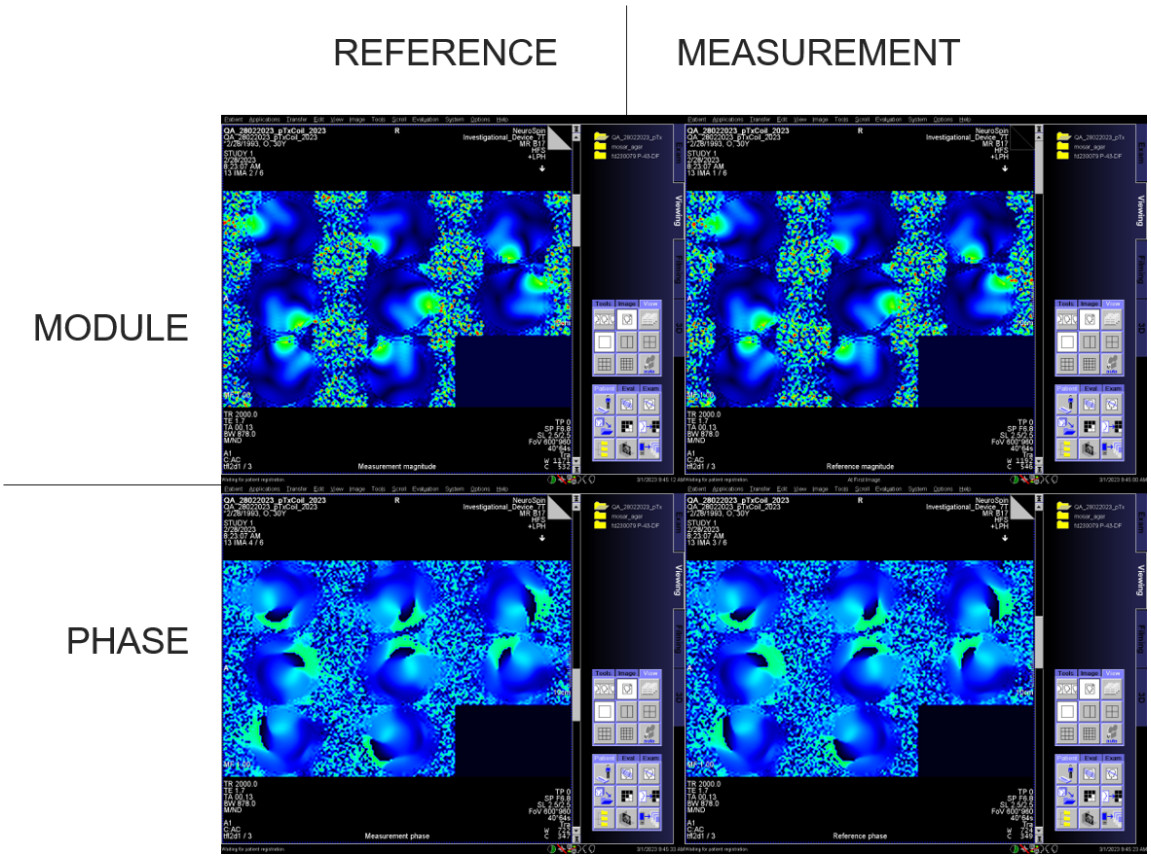

Figure 5: Central slice used during the QA processing for reference and current measurement in module and phase.

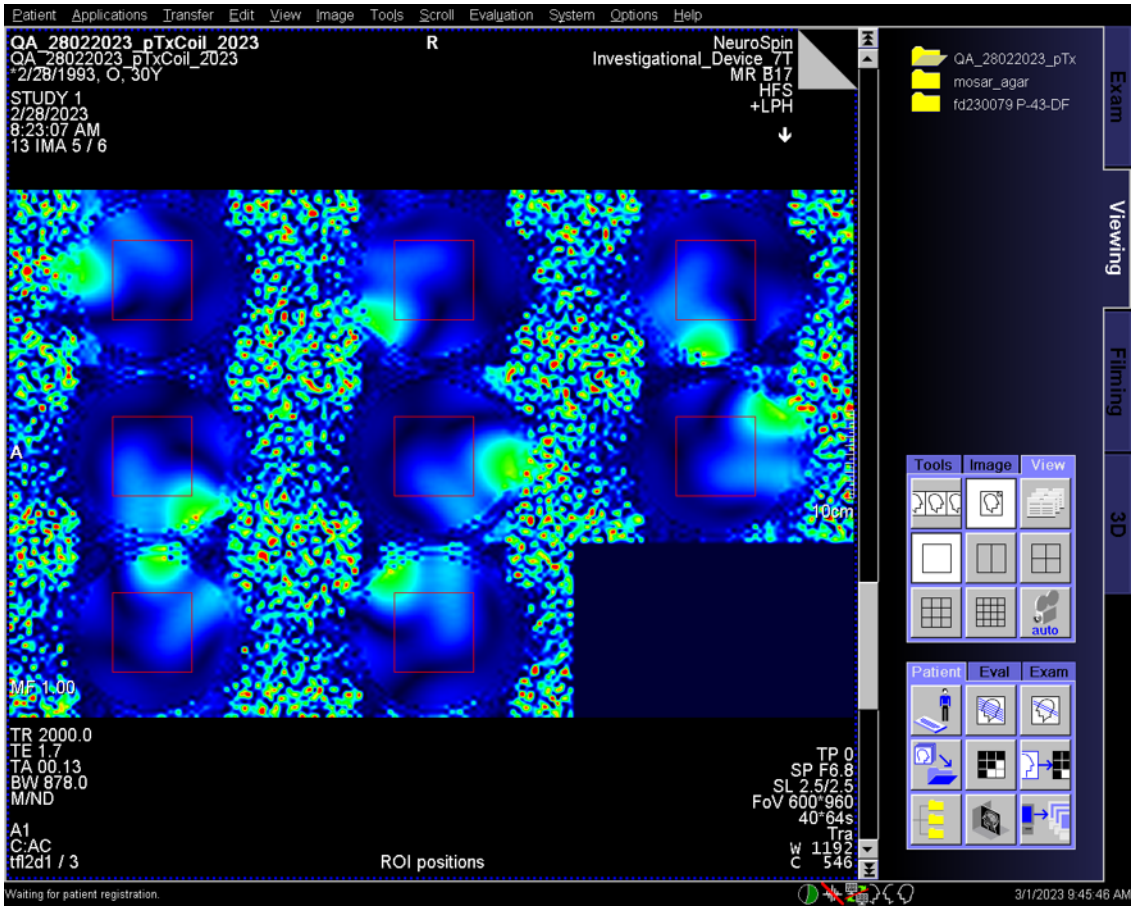

Figure 6: Depiction of the ROI used during QA processing superimposed to the B_1^+ map for each channel.

The B_1^+ map image depicts only the slice used during the analysis. It is displayed in a mosaic to show all transmit elements of the same slice. If the protocol acquires multiple slices, only the central slice of the protocol will be used during the QA analysis.

The table is constructed as follow. Values of B_1^+ maps within the aforementioned ROI are extracted from the reference and the current measurement. Three statistical measures between the two sets of data are computed: the complex coefficient of correlation, the normalized root-mean-square error and the complex linear correlation. These calculations are done for each channel independently. Channels that show abnormal values are displayed in red, otherwise they are displayed in green (figure 7). The normal range is determined by a set of default values for each type of statistical measures. The current version does not enable to change these values. A future version will let the user to set different limits for a given coil.

The second series named (PROTOCOL_NAME)_FOLLOWUP-PTX-COIL contains follow-up plots that depict the QA results across all previous QA measurements. It helps to identify the stability of the coil over time. The red lines give the limit for which the values are considered normal. The five DICOMs of this series are:

- Follow-up plot of normalized root-mean-square error (figure 8)
- Follow-up plot of magnitude of the coefficient of correlation (figure 9)
- Follow-up plot of phase of the coefficient of correlation (figure 10)
- Follow-up plot of magnitude of the linear correlation (figure 11)
- Follow-up plot of phase of the linear correlation (figure 12)

Figure 7: DICOM figure containing all resulting values and showing the good agreement between reference and current measurement.

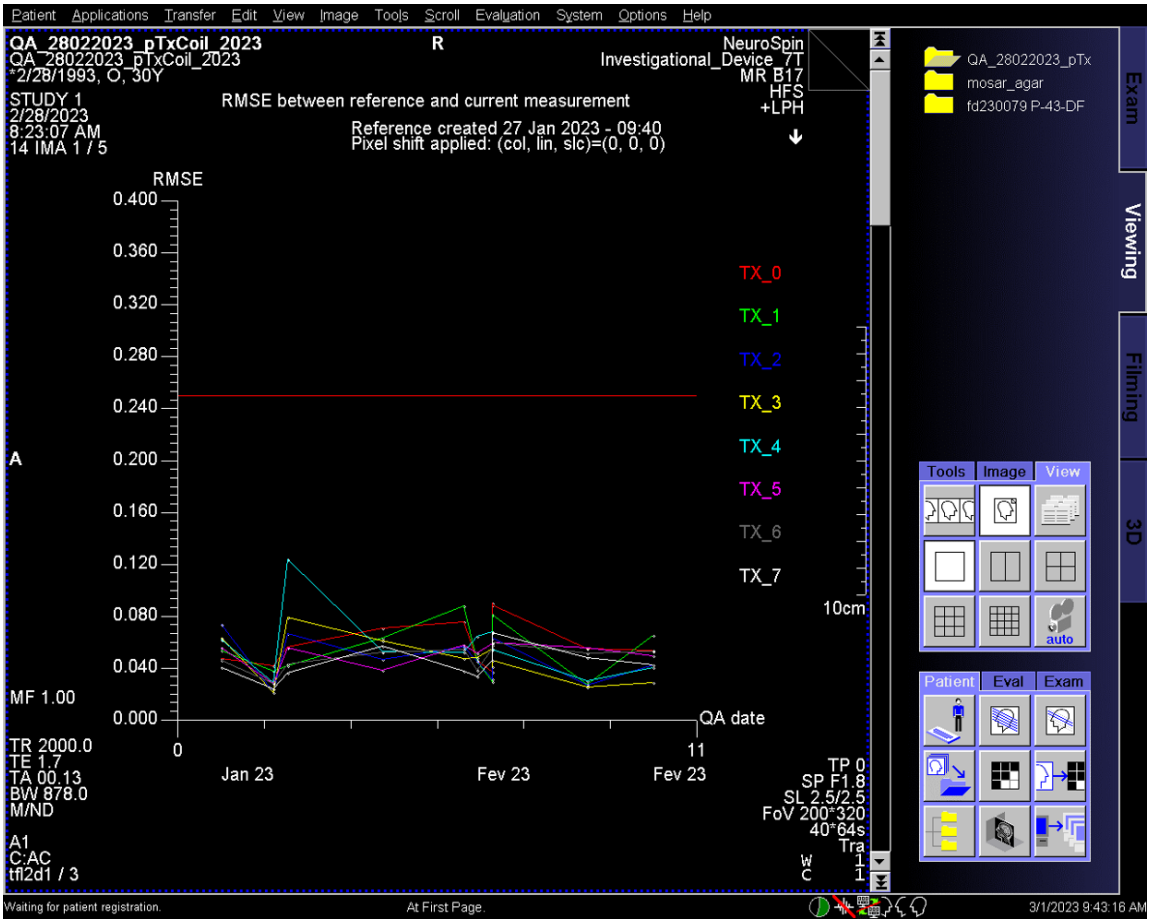

Figure 8: Follow-up plot of normalized RMSE between reference and current measurement for voxels contained in the ROI and for each channel.

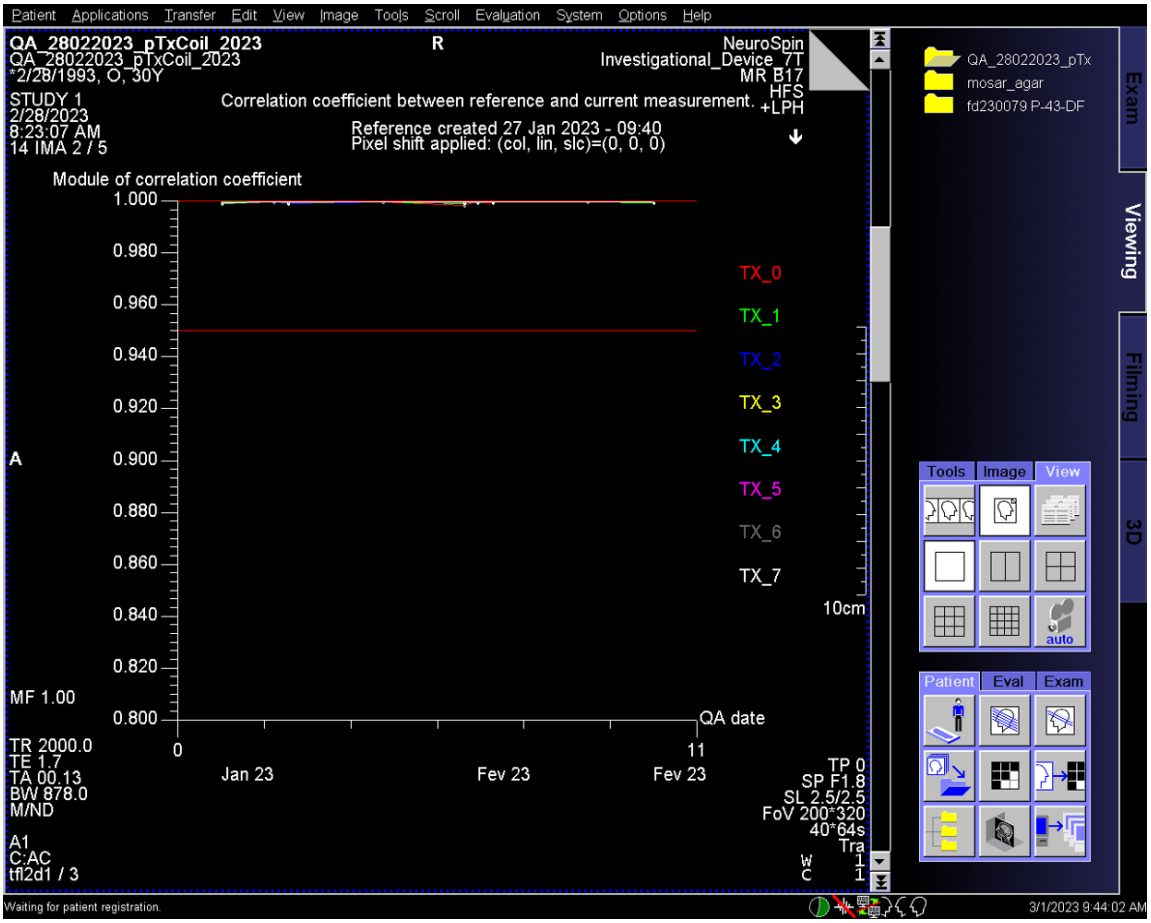

Figure 9: Follow-up plot of magnitude of the coefficient of correlation between reference and current measurement for voxels contained in the ROI and for each channel.

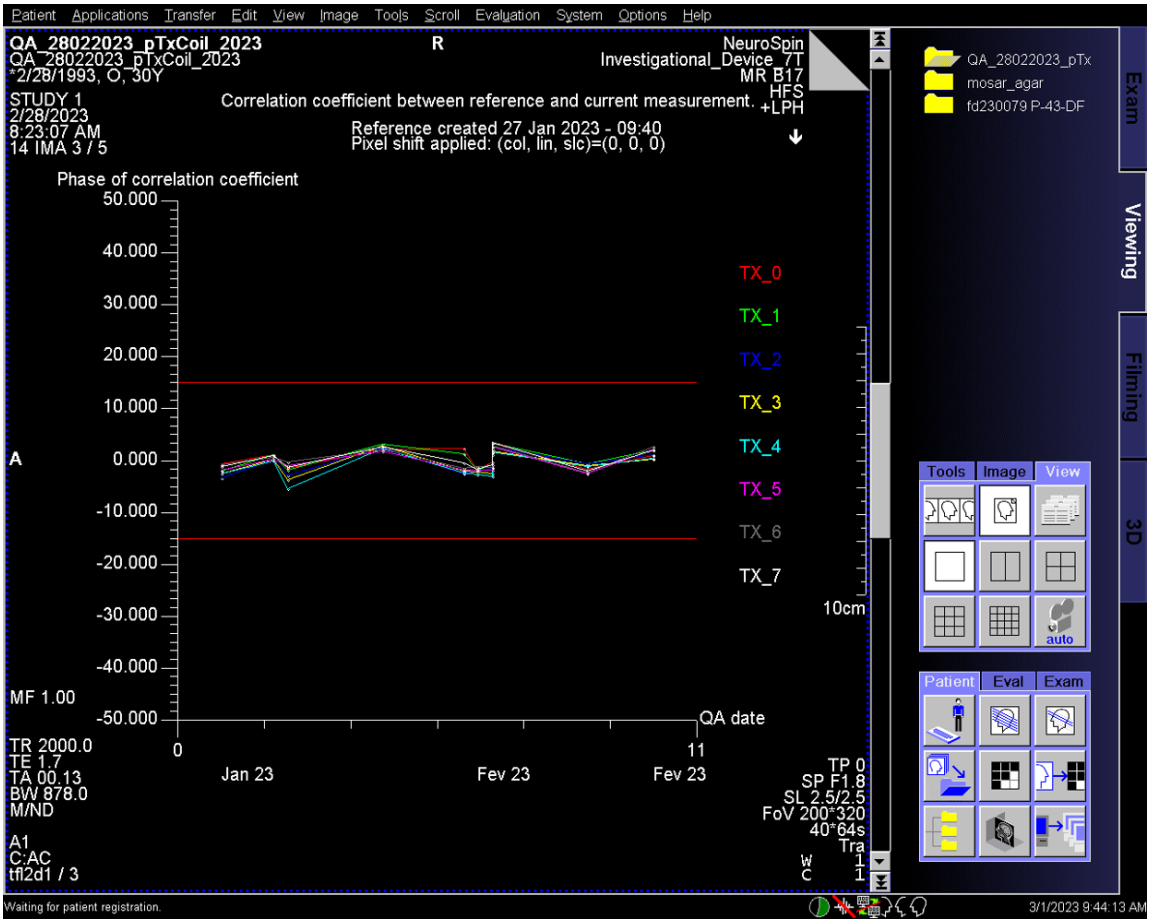

Figure 10: Follow-up plot of phase of the coefficient of correlation between reference and current measurement for voxels contained in the ROI and for each channel.

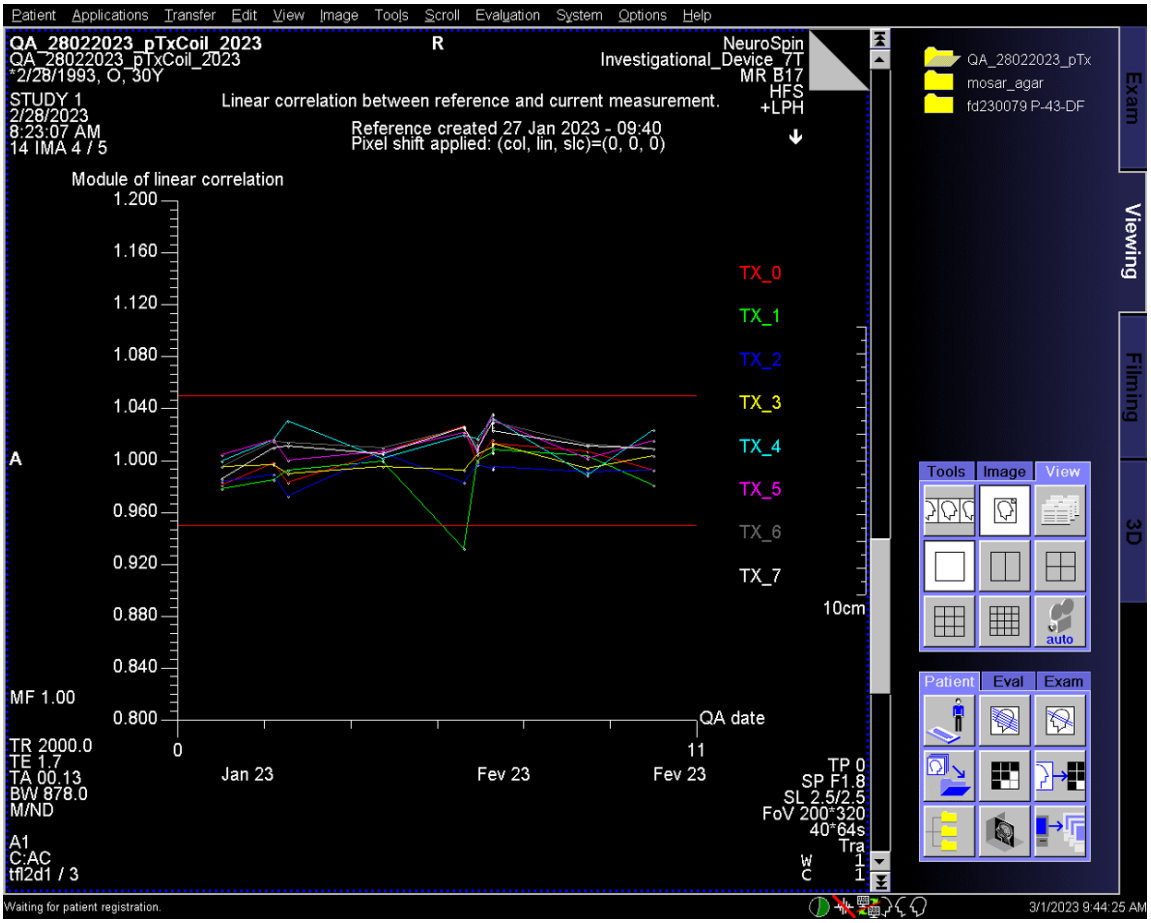

Figure 11: Follow-up plot of magnitude of the linear correlation between reference and current measurement for voxels contained in the ROI and for each channel.

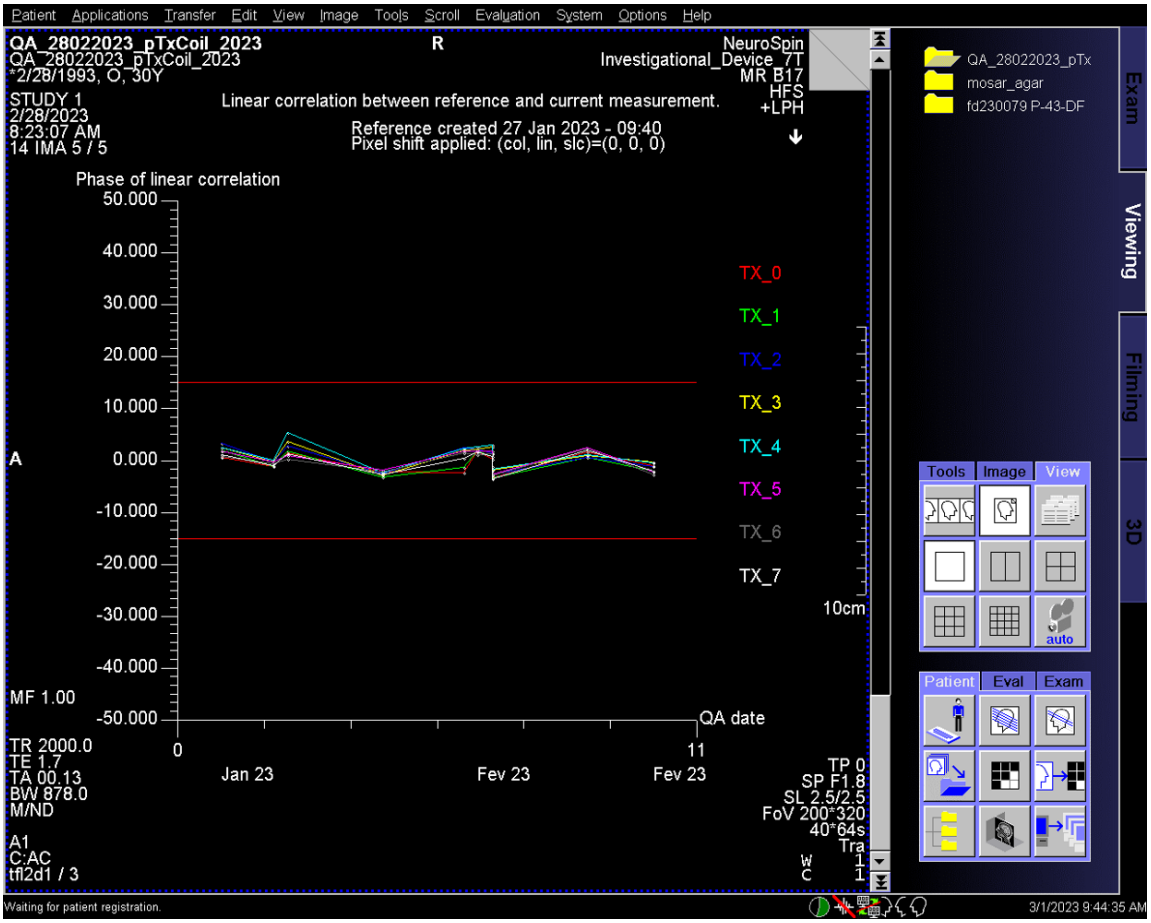

Figure 12: Follow-up plot of phase of the linear correlation between reference and current measurement for voxels contained in the ROI and for each channel.

5 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 QA improvements
- if you find out bugs
- if you think of specific features or wanted sequences
- if you have any tips to share

Please contact the authors of this package.