Documentation
QUALITY ASSURANCE PACKAGE

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Equipment	Magnetom 7T, Prisma 3T and other systems
Software version	VB17, VE11C, VE11E, VE12U-SP01
Description	The sequence generates follow-up graphs for different quality assurance protocols based on an ep2d acquisition
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Contents

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1. Overview

The *ns_qa_ep2d_fid* package contains 3 different quality assurance tests based on an ep2d_fid acquisition:

- Evaluation of the transmit coil linearity (mainly for local transmit coils as used at 7T)
- Evaluation of the Noise, SNR and matrix correlation of a receive coil
- Evaluation of epi stability using fBIRN[1] protocol

For each QA, results are saved in a file and a graph showing time-evolution is displayed in dedicated image series.

2. New features

NEUROSPIN_QA_EPI_STABILITY: v2.4

- Radius of decorrelation obtained from the weisskoff analysis is plotted on a follow-up graph

NEUROSPIN_QA_EPI_STABILITY: v2.3

- Custom threshold lines can be drawn on follow-up graphs for central tSNR and peak-to-peak results. A parameter file named “ICE_Parameter.txt” must be placed in the folder dedicated to a given coil. A file example can be found in the package.

NEUROSPIN_QA_EPI_STABILITY: v1

- A NCM (noise correlation matrix) evaluation has been added to the “Noise evaluation” scan

3. Installation

3.1. Summary of files

The ns_qa_ep2d_fid package contains one measurement sequence and associated ICE programs for results and follow-up graphs. The following files will be copied to the directory %MEDHOME%\MriCustomer on the scanner by the installation procedure.

VB17

```
├──bin
│       IceQA_EPI.dll
│       IceQA_EPI.evp
│
├──MCIR
│   └──med
│       └──lib
│               libIceQA_EPI.so
│
└──MriCustomer
    ├──IceConfigurators
    │           IceProgramQA_EPI.evp
    │
    └──seq
            qa_ep2d_fid.dll
            qa_ep2d_fid.i86
```

VE11/VE12

```
└──MriCustomer
    ├──ice
    │       IceQA_EPI.dll
    │       IceQA_EPI.evp
    │       libIceQA_EPI.so
    │       IceProgramQA_EPI.evp
    │
    └──seq
            qa_ep2d_fid.dll
            qa_ep2d_fid.i86
            ns_qa_ep2d_fid.lic
```

3.2. Installation procedure

Execute the file **install_neurospin_seq_VXXX.bat** which copies the installation files to C:\MedCom according to the tree.

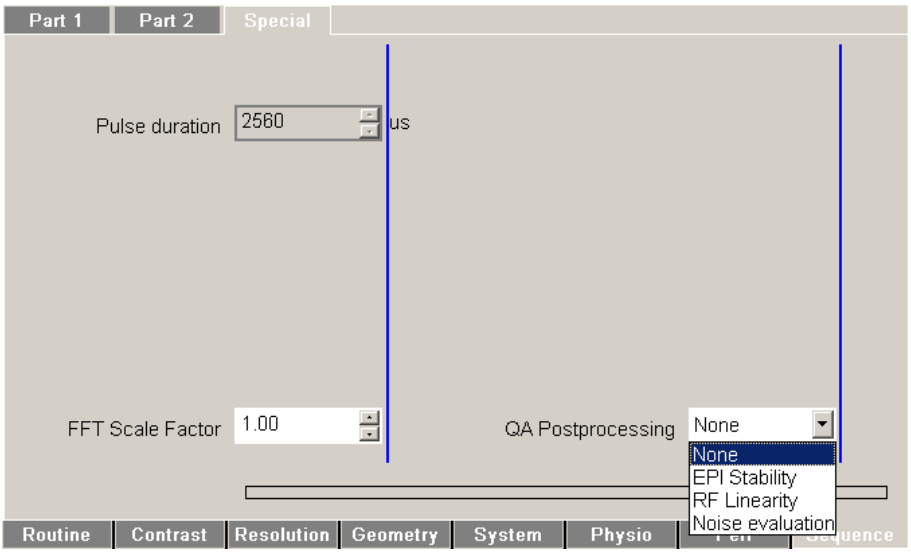
3.3. Optimized protocols

A set of protocols for each of three QA can be found in pdf and imported into the system with the edx/exar file.

4. Sequence User Interface

The sequence user interface is similar to that of the product sequence ep2d_fid. Specific options for the QAs are available in the Sequence/Special card.

4.1. Sequence/Special card



The desired QA post-processing can be selected in the corresponding UI element. Selecting "none" option corresponds to the product ep2d_fid sequence without modification. Other options are described below:

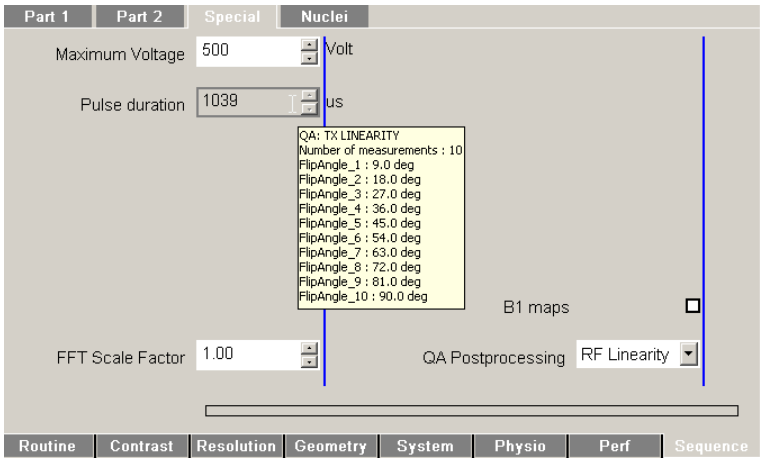
- "EPI Stability" option

On a sequence side, acquisition is the same as the product ep2d_fid sequence. Only if the number of repetitions is greater than 2, the EPI stability post-processing will be switch on in the ICE chain.

Comment: Save uncombined option (in System/Miscellaneous card) is forced to be switch off.

- "RF Linearity" option (only VB17 version)

With this option, the value of "Maximum Voltage" parameter will be set for the RF pulse of the last repetition. Consequently, the reference amplitude does not affect the applied voltage. In order to match the prescribed flip angle at the last repetition, the RF pulse duration is adapted to a proper value and shown in the UI. For all repetitions, RF pulses will have the same duration and a linearly increasing voltage value over repetitions.



Dummy preparation scans in the ep2d_fid sequence are disabled with this option. Only if the number of repetitions is greater than 2, RF Linearity post-processing will be switch on in the ICE chain. The maximum number of repetitions is 32.

Comment: Save uncombined option (in System/Miscellaneous card) is forced to be switch off.

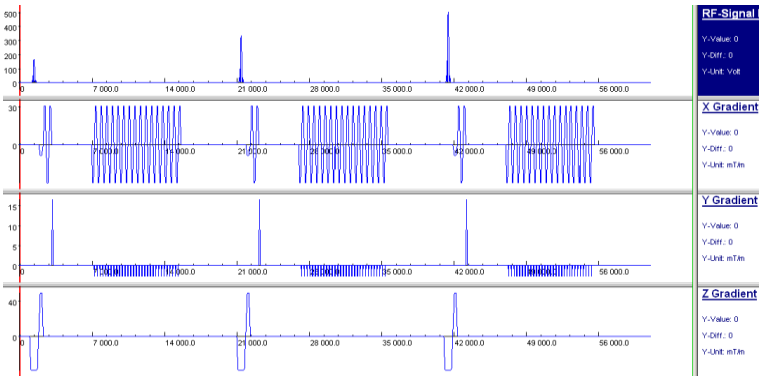


Figure 1: Sequence diagram with RF linearity option and 3 repeti tions. The RF voltage is increased for each repetition. The last RF pulse is deisgned to reach the flip angle parameter in the protocol and a voltage given by the special card value.

- "Noise evaluation" option

With this option, the number of repetitions is forced to 2. Prior to the repetitions, a long train of noise scans are acquired for matrix correlation estimation. Then, during the first repetition, no RF pulse is applied for noise measurement used for SNR evaluation. During the second repetition, a standard RF pulse is applied for signal measurement in the image.

Save uncombined option (in System/Miscellaneous card) is forced to be switch on to enable evaluation of every channel as well as the combined image.

Moreover, a set of noise scans are acquired at the beginning of the sequence which lengthen the acquisition time accordingly.

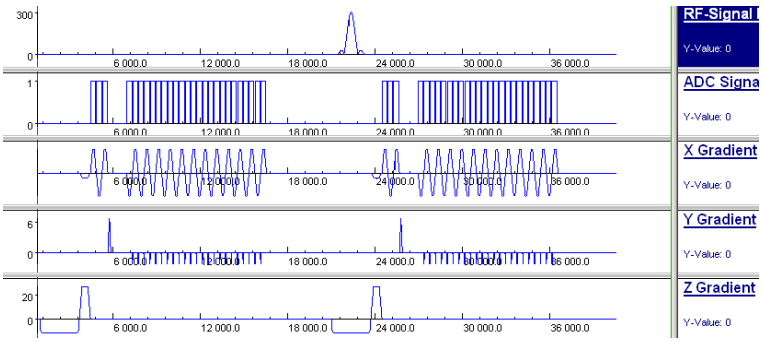
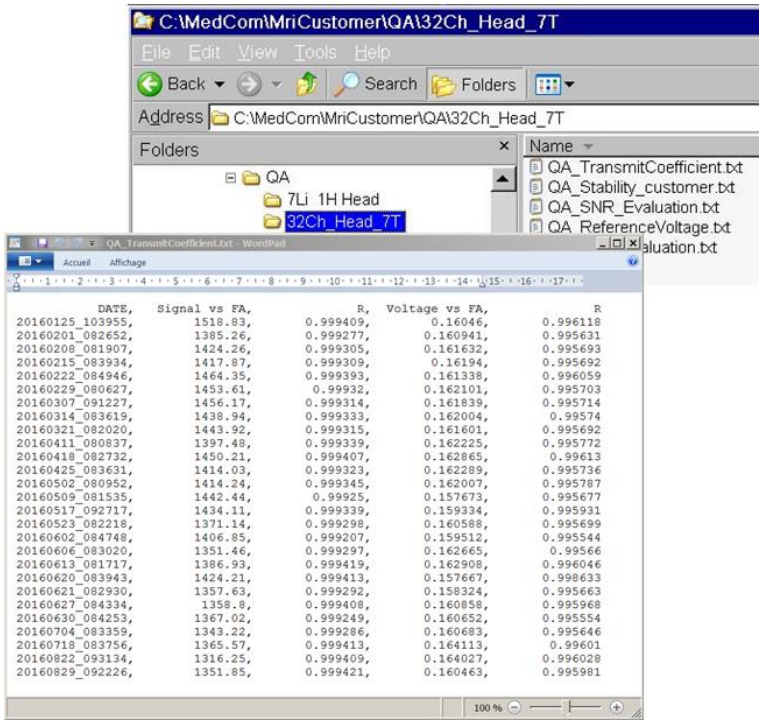


Figure 2: Sequence diagram with Noise evaluation option. The first repetition is play without RF.

5. Description of Post-Processing

5.1. General description of follow-up procedure

The first time a QA protocol runs at the scanner, the folder 'C:\MedCom\MriCustomer\QA' will be created.
For a given coil, a folder will be created with the name of the coil. Files related to a given QA measurement will be filled in every time the QA is done. A new line will be added to keep track of all values and be able to create follow-up plots.



For all QAs, the numerical results are computed on the central slice of the acquired multi-slice volume.

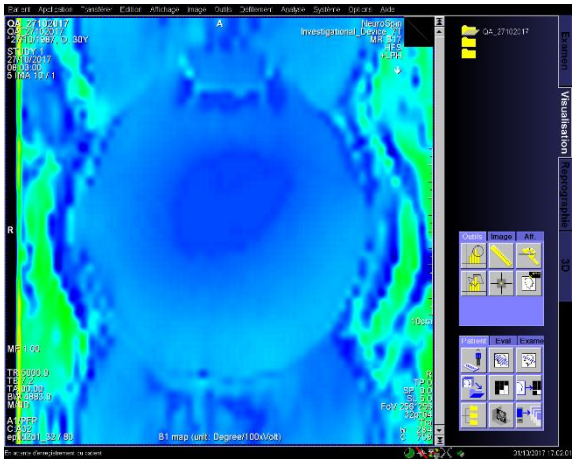
5.2. RF linearity post-processing (VB17 only)

- Reconstructed series

By default, 3 different series are generated in the Dicom database by the transmit linearity QA:

Series 1: Native module series containing all slices, all repetitions.

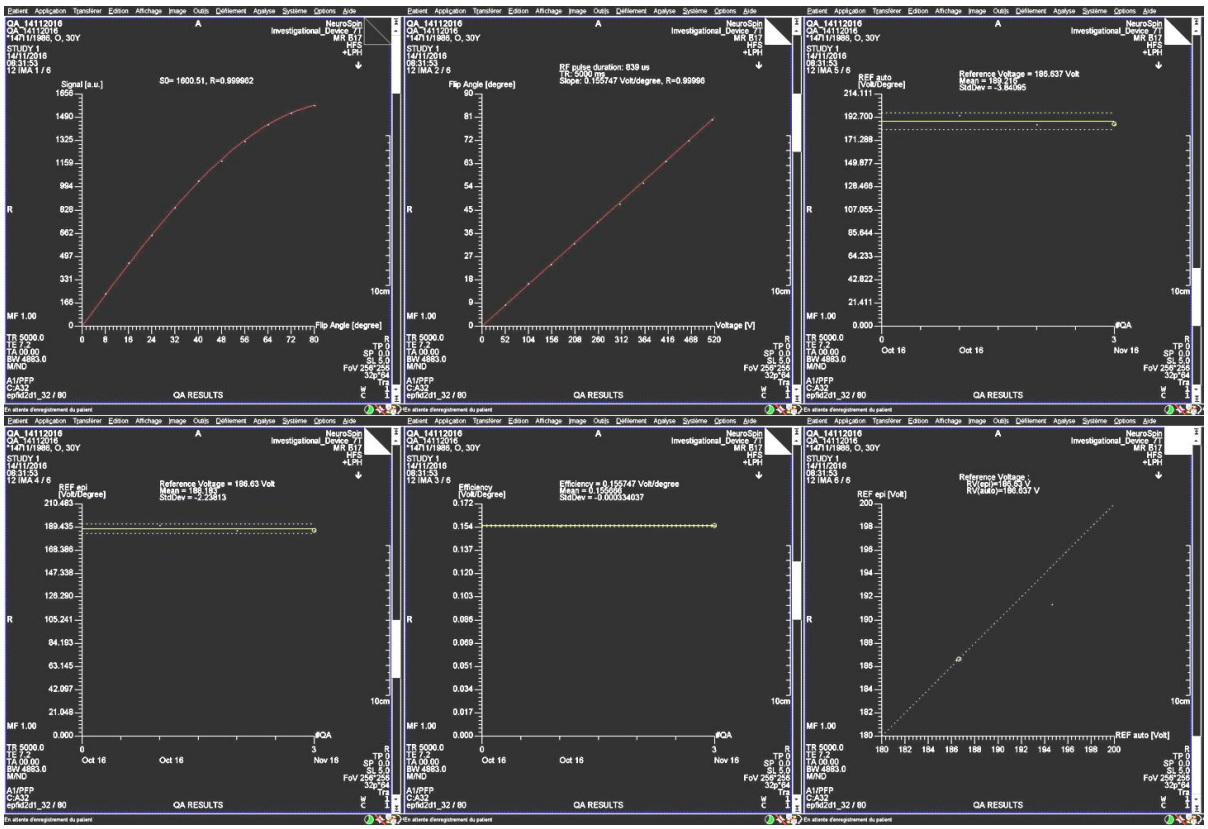
Series 2: Ending with the suffix "B1_MAP", this series contains reconstructed B1 maps. The unit is expressed in Volt/Degree.



Series 3: Ending with the suffix “Graph”, this series contains 6 graphic plots:

1- The average signal taken from an 8x8 centered ROI in the image is plotted against the prescribed flip angle in the protocol. Measured flip angle is determined using the fitted curve.
2- Measured flip angle is plotted against applied voltage. From this curve, the coil transmit coefficient (Volt/Degree) is determined by a linear regression.
3- Transmit coefficient is plotted over time (all QA measurements with this coil)
4- Scanner reference voltage is plotted over time (all QA measurements with this coil)
5- EPI reference voltage (evaluated from coil efficiency) is plotted over time (all QA measurements with this coil)
6- EPI reference voltage is plotted against Scanner reference voltage for all QA measurements with this coil

Example: Nova 1Tx/32Rx @7T



- Saved information in files

Two files are saved during the RF linearity post-processing:

- QA_TransmitCoefficient.psv
- QA_ReferenceVoltage.psv

- Comments

- During the first transmit linearity QA of a given coil, follow-up graphs will not be created (Series “Graph”, images 3 to 6).

5.3. Reception Evaluation post-processing

- Reconstructed series

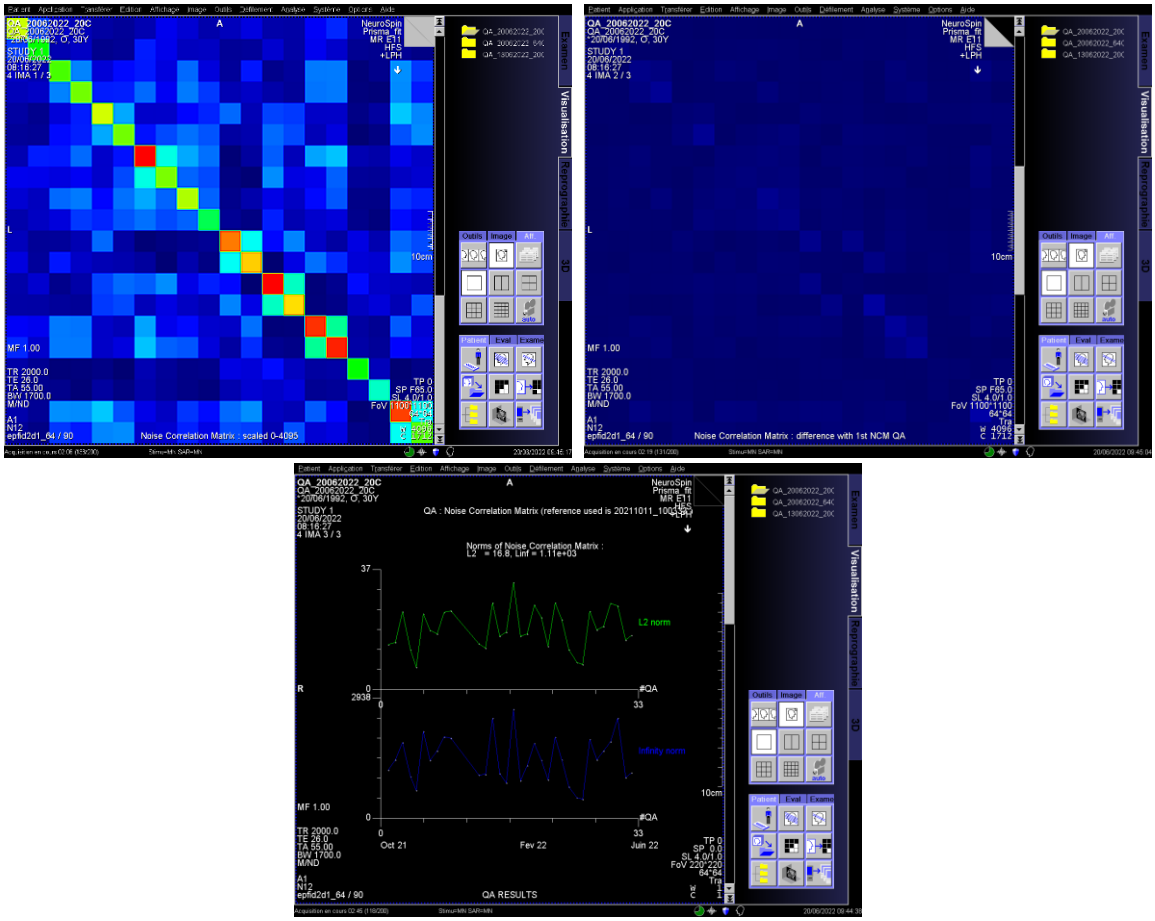
By default, four different series are generated in the Dicom database by the noise QA:

Series 1: Native uncombined series containing uncombined images for repetition 1 (noisy images) and repetition 2 (phantom images), i.e. Total number of images is 2 x Nchannels x Nslices

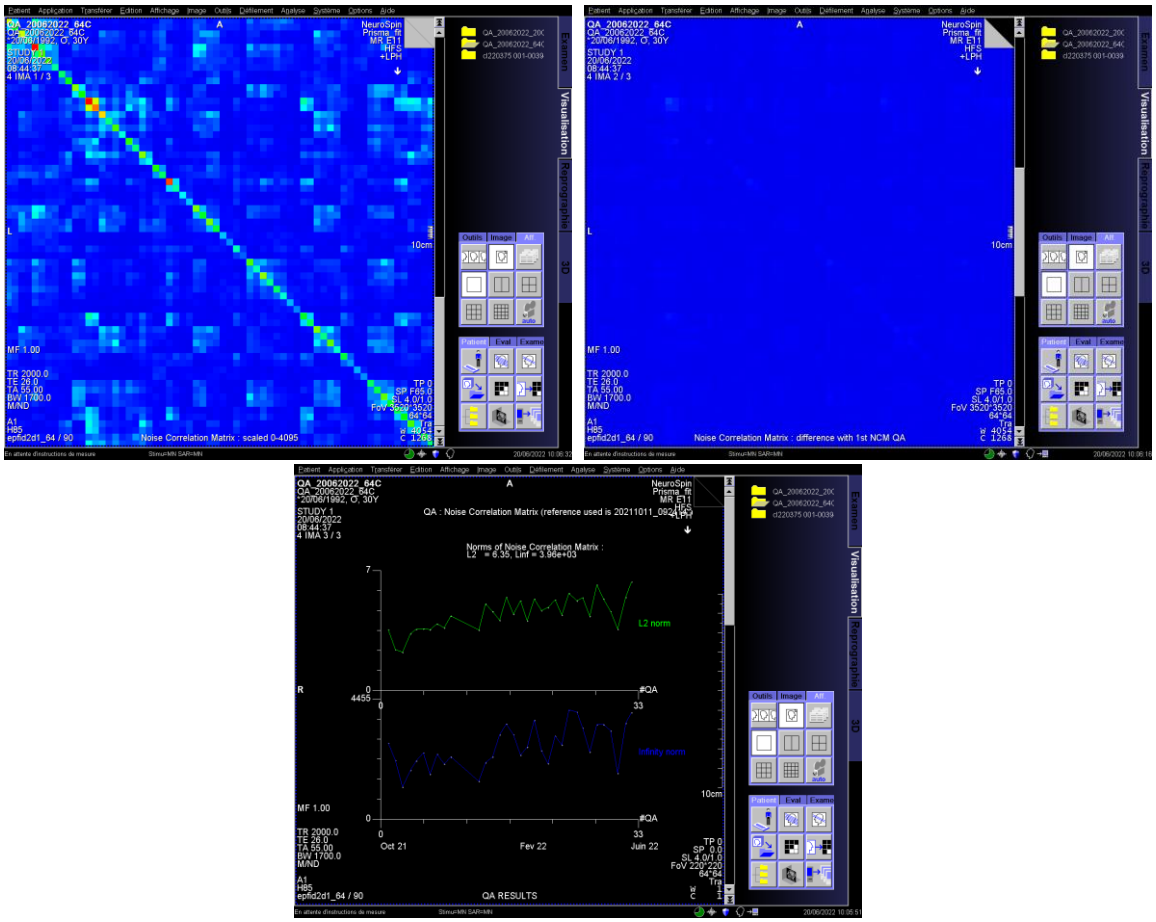
Series 2: Ending with the suffix “Graph_NCM”, this series contains 3 graphic plots:

1- A correlation matrix of the receive channels selected during acquisition. Diagonal values are usually much larger than other values. Default windowing is not necessarily the best display to use. For display purpose, the correlation matrix is scaled so that the highest diagonal value is set to 4095.
2- A matrix difference between the first correlation matrix in database (defined automatically as a reference) and the currently measured correlation matrix.
3- L2-norm and infinity-norm of the difference matrix (between reference and current measurement) are plotted over time.

Example: HeadNeck 20 channels



Example: HeadNeck 64 channels



- Comment

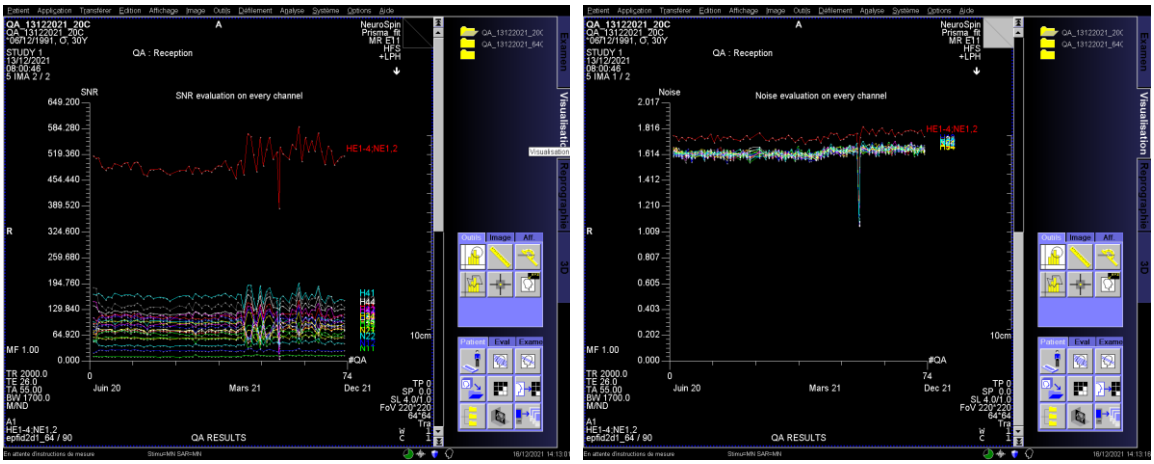
- The first line (first measurement done) of the “QA_NCMEvaluation.psv“ file correspond to the first measurement realized. This first measurement is used as a reference for any new measurement. Replacing this line is possible to change the reference to be used.

Series 3: Native combined series containing combined images for both repetitions, i.e. Total number of images is 2 x Nslices.

Series 4: Ending with the suffix “Graph_Noise”, this series contains 2 graphic plots:

1- A noise plot over time (standard deviation on the noisy image) of each individual channel and the combined noise image value are plotted.
2- A SNR plot over time (mean on the phantom image (no ROI) over the std dev. On the noisy image) of each individual channel and the combined SNR image value are plotted.

Example: HeadNeck 20 channels



- Saved information

Three files are saved during the Noise evaluation post-processing:

- QA_NoiseEvaluation.psv
- QA_SNR_Evaluation.psv
- QA_NCMEvaluation.psv

- Comments

- The SNR evaluation does not tell about the performance of each channel relatively to the others. Indeed, channels do not receive an equivalent signal from the phantom due to their own position in the coil. The plot needs to be seen as an assessment of channel stability over time.

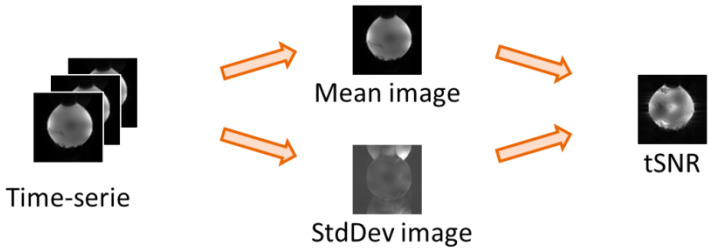
5.4. EPI Stability post-processing

- Reconstructed series

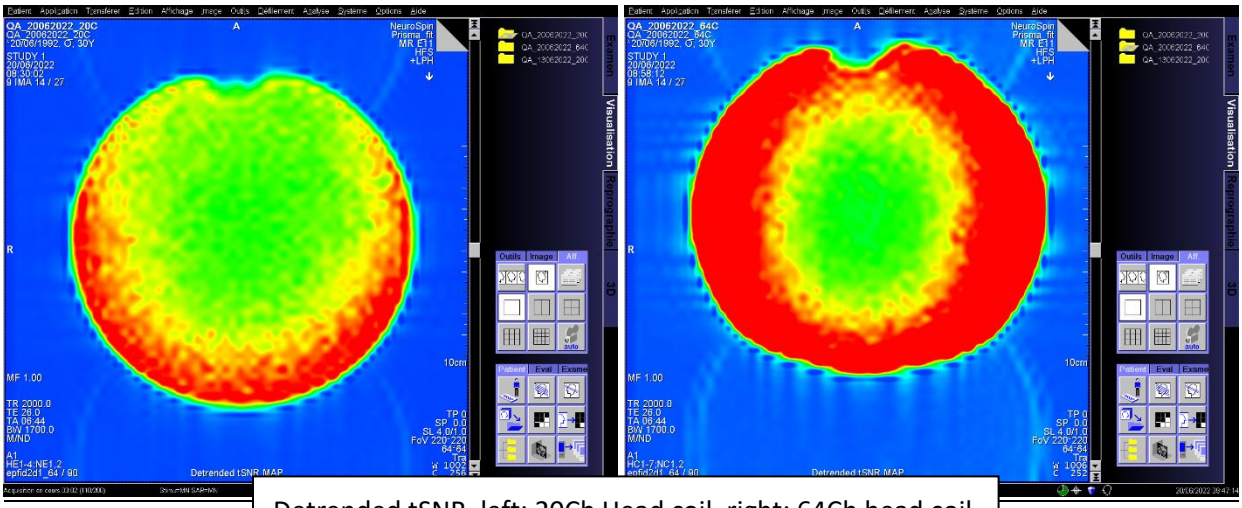
By default, 5 different series are generated in the Dicom database by the noise QA:

Series 1: Native module series containing all slices, all repetitions in a mosaic configuration

Series 2: This series, ending with the suffix “tSNR”, contains voxel wise tSNR maps for every slices.



Series 3: This series, ending with the suffix “tSNR_det”, contains voxel wise detrended tSNR maps for every slices. Detrending process uses a second order polynomial fit.



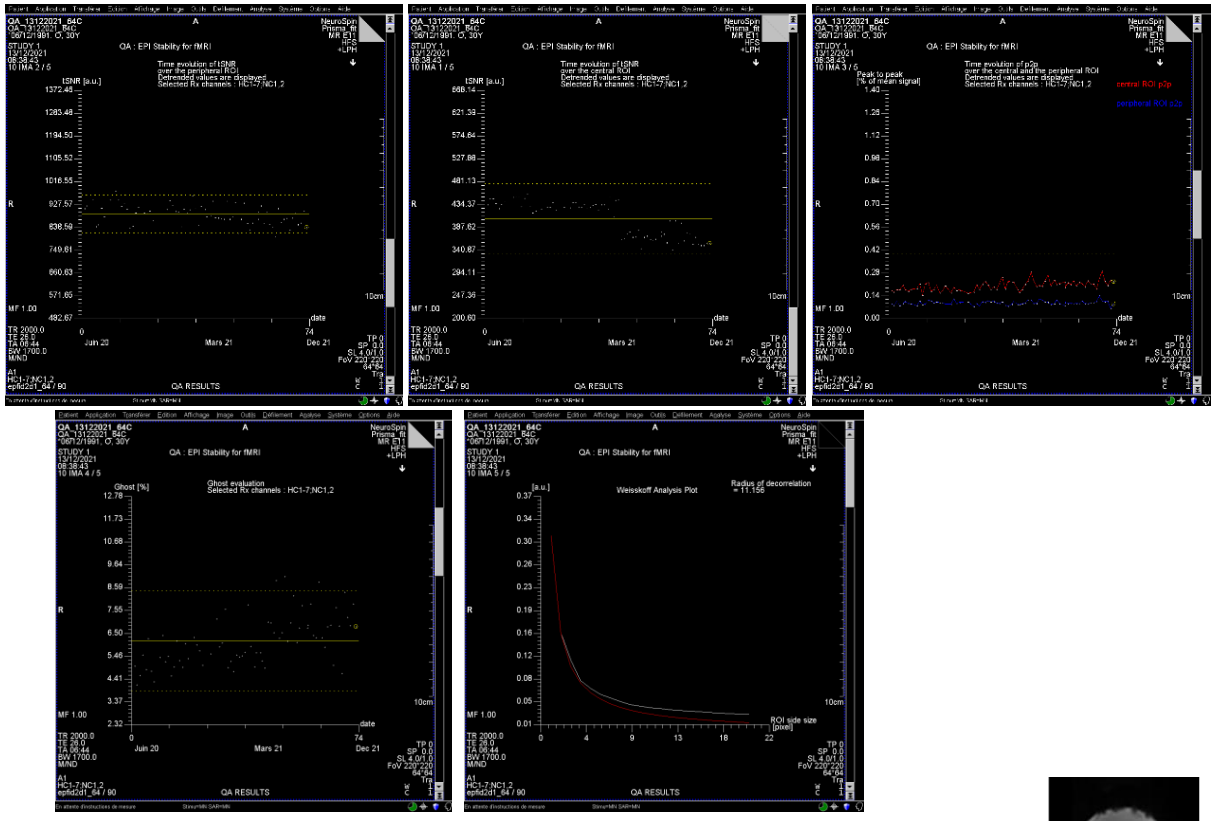
Detrended tSNR, left: 20Ch Head coil, right: 64Ch head coil

Series 4: Ending with the suffix “Graph”, this series contains 4 graphic plots:

All statistic values in the plots are obtained from either a centered 10x10 pixels ROI in the phantom (central ROI) or a peripheral 3 pixel width circular ROI (peripheral ROI). ROIs can be seen within Mask series. The ghosting evaluation is obtained by using a FOV/2 shifted 10x10 ROI and compared to the centered ROI.

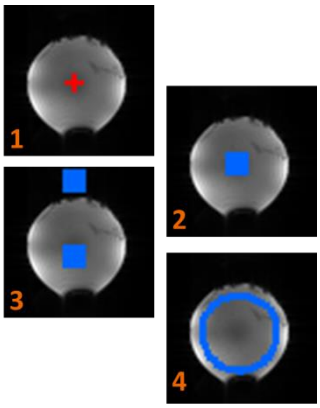
1- Detrended tSNR in central ROI is plotted over time (all QA measurements with this coil).
2- Detrended tSNR in peripheral ROI is plotted over time (all QA measurements with this coil).
3- Detrended Peak-to-peak in central and peripheral ROIs are plotted over time (all QA measurements with this coil).
4- Ghosting artifact evaluation is plotted over time (all QA measurements with this coil).
5- Weisskoff analysis and radius of decorrelation of the current QA are plotted and displayed in this graph.

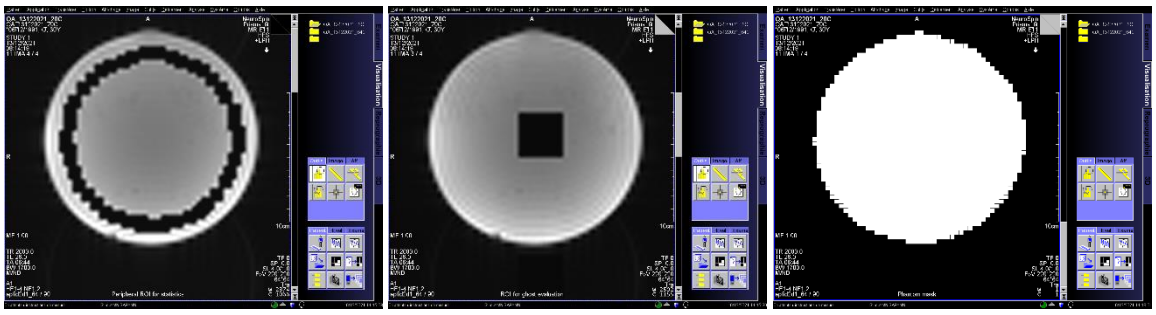
Example: HeadNeck 64 channels



Series 5: Ending with the suffix “Mask”, this series contains 4 images:

1- The phantom mask can be seen as a bright region. From this mask central and peripheral ROIs are computed.
2- The central ROI can be seen as a dark region into the phantom image.
3- The ROI for ghost evaluation can be seen as a dark region into the phantom image.
4- The peripheral ROI can be seen as a dark ring into the phantom image.





- Saved information in files

Two files are saved during the RF linearity post-processing:

- QA_Stability_customer_Detrended.psv
- QA_Stability_customer_NonDetrended.psv

- Comments

- The stability QA could be significantly impacted by a system warm-up effect. For this reason, it is advisable to do a first protocol without stability post-processing during a few minutes. After this warm-up, QA Stability can be done.
- Non-detrended statistics are computed but not displayed in QA graphs. However they can be found in the corresponding QA file.

6. Recommendations & Known bugs

- When using “RF linearity” option (VB17 only), the sequence does not run properly if the reference voltage is not yet calibrated. To avoid this situation, always insert any other protocol in the queue prior to the RF linearity measurement.
  Moreover, a RF linearity protocol standing in the queue should not be opened while the reference voltage is not yet calibrated.

- Due to a low reference voltage value, a protocol error might occur when using transmit linearity QA (VB17 version only). As a work around, the Maximum Voltage in the special card should be decreased or the slice thickness should be increased to solve the issue.

- PhaseFOV should always be kept to 100% to avoid evaluation problems during reconstruction.

- FOV should be large enough compared to phantom size to enable a correct ghosting artifact evaluation.

- Positioning of the phantom in the receive coil should be as accurate as possible to obtain a good reproducibility of the measurements over time.

- For a given coil, the same set of receive channels must be always selected to avoid any problem during reconstruction.

7. Future implementations

A number of new features could be implemented in order to fulfill requirements. Please address your comments or remarks if any.

8. References

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Fully automated fBIRN-like stability assessment: follow-up and case report at 7T. Proc. Intl. Soc. Mag. Reson. Med. 28 (2020) 4005.
http://mauconduit.fr/?conf=Mauconduit_ISMRM2020_p4005.pdf