Rapid measurement of subtle sub-one-percent changes in transmitter output and receive gain to monitor scanner stability

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Aim
1. To develop methods for rapidly characterizing subtle scanner drift
2. To correlate these with temperature changes in parts of the scanner, in order to localize the sources of drift.

Introduction

MR scanner signal instability introduces errors in the quantitative measurement of MR parameters. The transmitter output, or at least the flip angle (FA) produced in the sample, may unintentionally vary with time. Likewise, the receive sensitivity can fluctuate, and changing eddy currents may lead to signal loss by altering the effective slice select gradient [1]. Our measurements of signal from a temperature-controlled stable object showed changes of about 2%; it was unclear how much of this originated from each of these potential causes. Here we show new ways of monitoring very small FA and receive changes (<1%) that are rapid and precise. FA can be measured precisely using an EPI variant of the Double Angle Method (DAM), here using the ratio of the signal from sequences with nominal FA's of 60° and 120°. A deliberate change of <1% in the transmitter output was measured precisely using this method. Receive sensitivity changes can be measured using the noise image in the absence of any excitation. Preliminary application of these two novel methods indicates that, on our scanner, heating of the gradient coils is responsible for changes in receive sensitivity (probably through the preamplifier, which is in close contact with the gradient coils).

Methods

Signal stability was assessed for a General Electric 1.5T Signa using the birdcage head coil. Single-shot EPI images of a test object were acquired for a single 10 mm slice with flip angles of 60° and 120° (TE/TR/matrix-size 17.3ms/144ms/128x128). An EPI reference scan precedes the first of each set, and a delay of 11s before acquisition allows for full M0 recovery. A B_1 map is calculated using the DAM, from which the mean B_1 for the slice is measured.

A single sample noise measurement is the average over 81 images of sample noise, acquired with single-shot EPI (TE/TR/matrix-size 200ms/260ms/128x128). Prior to acquisition but after the necessary scanner preparatory actions, the RF pulse and gradient scaling factors are set to 0. A long echo time ensures any leaked RF is dephased before acquisition. To validate this method, B_1 maps and noise images were acquired repeatedly, while the transmitter gain (TG) was adjusted by a known amount.

The RF coil was then moved with respect to the sample to simulate a combined transmit and receive field change, and further images were acquired.

A 250ml test object containing gadolinium-doped water was encased in thermally insulating phenolic foam. Thin T-type thermocouples were used to monitor temperature changes in the test object, a saline filled loading ring, the birdcage RF coil and the gradient housing. B_1 map and noise images were followed by approximately 10 minutes of scanner activity. In this time, single shot EPI, 2D proton density weighted gradient echo (GE) and T1 weighted 3D FSPGR images were acquired to determine if the rate of signal change is equal for different sequences. For one series of 3D FSPGR images the automatic prescan (APS) was allowed to adjust transmit and receive gains and center frequency; for all other scans, these parameters were kept constant. This pattern of acquiring a stability measurement followed by standard sequences was repeated until a temperature rise of 5 was measured on the wall of the gradient housing. During the recovery period only the reference scans were acquired.

Results and Discussion

Figure 1 shows that the measured B_1 change agrees with the expected change with an RMS error of 0.1% (1 TG unit is a multiplicative factor of 10^(1/200) = 1.01). The mean sample noise is unchanged during adjustment of the transmitter, but undergoes a step change when the sample is moved relative to the coil. This is a qualitative indication that that the mean sample noise may be used as a measure of changes in the receiver sensitivity. Figure 2 shows signal drifts during a period of prolonged scanning and the subsequent recovery. The 2D GE, 3D FSPGR and EPI images show similar but not identical drift. This may be due to T_1 weighting in the 3D FSPGR, or to an eddy current effect which differs for 2D and 3D pulses. The automatic prescan adjusted center frequency by 24Hz over this period for the series labeled "APS + 3D FSPGR", however this did not reduce the signal drift compared to the same imaging sequence with gains kept constant. The noise signal followed a similar trend to the standard sequences during the period of gradient heating, but showed a relatively quick recovery. The correlation of this profile with the gradient and head coil temperatures shown in figure 3 indicate that gradient heating is causing a drift in the receiver preamplifier. The test object temperature varied over a range of 0.2° C.

Conclusions
1. A quick EPI method accurately measured B1 changes of less than 1%
2. Noise image provides a way to measure receive-chain drift of less than 1%, independent of other confounding effects
3.These two sets of measurements, interleaved with serial (dynamic) clinical data collection, could be used to correct quantitative measurements of parameters such as PD, MTR, DT, T_1 and capillary transfer constant
4. The method, when combined with temperature measurements of the scanner hardware components will assist in identifying and addressing sources of signal drift in MRI

Figure 1: Validation

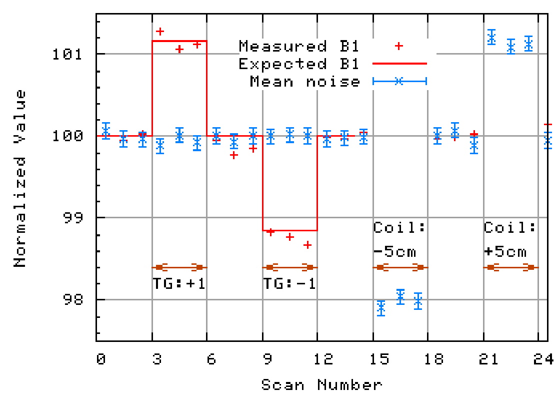


Figure 2: Signal Drift

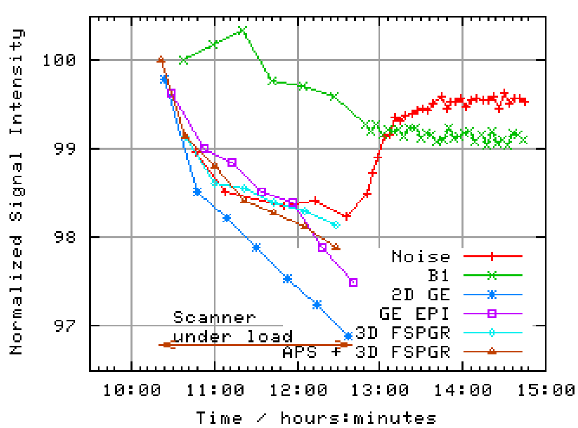
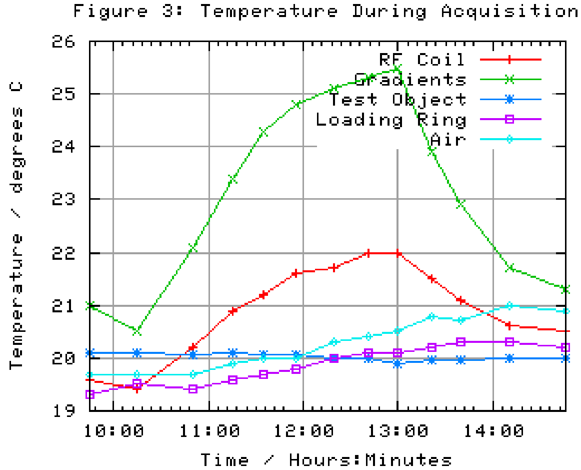


Figure 3: Temperature During Acquisition



Further Work

Adapt the method to monitor stability during in-vivo Dynamic Contrast Enhanced (DCE) MRI. Determine if center frequency changes can be accurately determined from the single shot EPI images using displacement of the center of mass in the phase encode direction.

References

[1] X. Zhou, *et al.,Proc. ISMRM* 1722 (1997)