Improved Phase to Noise Ratio for Short T2* Spins in MRE

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Introduction: The application of the motion sensitizing gradients in MR Elastography (MRE)[1] extends the minimum achievable TE and makes imaging short T2* spins challenging. We introduce a novel pulse sequence, MRE–echo train (MRE-et), that uses the motion sensitizing gradients as read gradients. Imaging along the echo train allows acquisition of the signal earlier in the signal decay process. This paper will examine the phase to noise ratio (PNR) of this new sequence compared to a standard grass MRE pulse sequence (MRE-gre).

Materials and Methods: The PNR can be calculated as:

$$PNR = SNR\phi \qquad [2,3]$$

where SNR is the signal to noise of the magnitude image and ϕ is the sampled phase difference. Using this definition of PNR, we can calculate the PNR for the MRE-gre sequence as:

$$PNR_{et} \propto \left[\frac{\Delta x \sqrt{N_{acq}}}{\sqrt{BW}} e^{-\frac{TE}{T2^*}} \right] G_n A$$

where Δx is the pixel size, N_{acq} is the number of data samples, G_n is the number of sensitizing gradients pairs, and A is the amplitude of the sensitizing gradients. Each image of the MRE-et sequence along the echo train experiences T2* decay and has an increasing sensitivity to motion. Summing up the PNR of each echo gives:

$$PNR_{et} \propto \frac{1}{\sqrt{2G_n}} \sum_{i=1}^{2G_n} \left[\frac{\Delta x \sqrt{N_{acq}}}{\sqrt{BW}} e^{-\frac{TE_i}{T2^*}} \right] \frac{1}{2} iA \, .$$

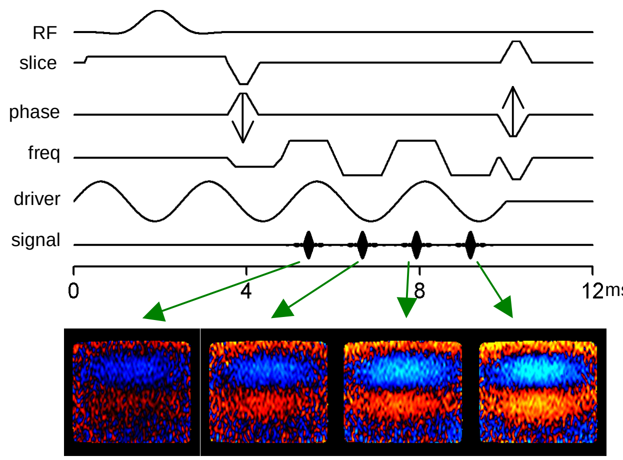

Figure 1 MRE-et pulse sequence. An image echo is generated at each gradient lobe used for motion sensitization.

Scans were performed using the MRE-et pulse sequence, shown in **Figure 1**, on a 1.5T scanner (GE Medical Systems, Milwaukee WI). A copolymer of dimethylsiloxane was imaged as a model for short T2* spins. The sample has a T2* of 2.4ms with 20% the proton density of water. The sample was mechanically excited at 400Hz. The MRE-et sequence used a 64KHz receiver BW which allowed 132 frequency points after ramp interpolation. Due to the short T2*, the maximum PNR for the MRE-gre acquisition is obtained with one motion sensitizing gradient and a 32KHz receiver BW.

Results: Calculated PNR values for a 16cm FOV acquisition are compared in **Figure 2**. The percent increase is shown for the sequence which provides the higher PNR. The PNR-gre values use 256 sample points and a BW of 16KHz. The PNR-et values use 256 sample points (132 points at 400Hz) with a BW of 64KHz. The slot times represent the amount of time needed for the MRE-gre sequence to play out between 1 and 6 pairs of motion sensitization gradients. In the same slot time, the MRE-et sequence can utilize more gradient lobes: 1 at 100Hz, 2 at 200Hz, and 6 at 400Hz. The MRE-et sequence produces higher PNR for all cases shown at 400Hz. Though normalized for the increase in pixel size, this gain at 400Hz comes at the cost of decreased resolution. For the experiment shown in **Figure 3**, the phase difference signal was Fourier transformed through the 8 acquired phase progressions. The amplitude of the fundamental was used as the phase difference in the PNR calculations. Using the MRE-et sequence gave a PNR of 12.6 compared to 8.6 for the MRE-gre sequence. The PNR-et value was reduced to normalize for different pixel dimensions.

Discussion: T2* signal decay competes with increasing motion sensitivity along the echo train to determine the PNR for the MRE-et sequence. In general the MRE-et sequence will have superior PNR for scans of short T2* spins or scans with a large number of motion sensitizing gradients. The dual use of the motion gradients creates a mutual dependency between motion sensitivity, FOV, BW, and the number of sample points. Contrary to conventional imaging, a higher receiver BW increases PNR. While doubling the BW decreases SNR by a factor of root 2, the corresponding doubling of the sensitivity to motion results in a net root 2 increase in PNR. This need for a high BW leads to the relatively low PNR for some parameter combinations.

References: [1] Muthupilai R., et al, Science, 1854-1857, 1995.; [2] Pelc NJ, et al, JMRI, 1:405-413, 1991.; [3] Bernstein MA, et al, JMRI, 1:725-729, 1991.

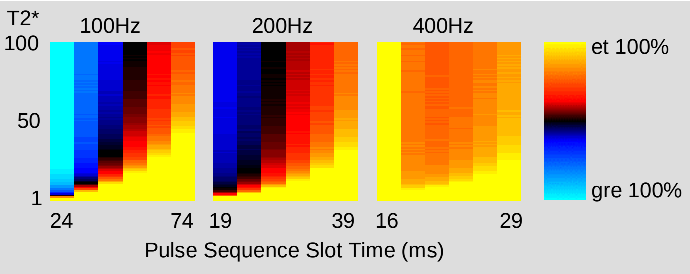

Figure 2 PNR comparisons of 3 mechanical excitation frequencies for various T2* values and slot times.

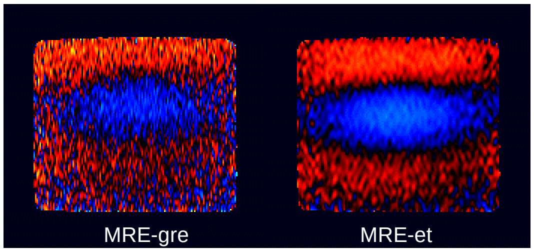

Figure 3 Four echoes of the MRE-et sequence are obtained and combined in the same slot time as the MRE-gre sequence.