Introduction

Last year, (1) we introduced a type of FSE sequence which is insensitive to the original phase of the magnetization. Contrary to other solutions (2,3,4) which attenuate signal by a factor of 2, the proposed method has the advantage of maintaining the FSE signal. It relies on the use of a quadratic phase modulation of the refocusing RF pulses as in (5). We address here some difficulties encountered in the practical implementation of the basic idea.

Method

In an FSE experiment the signal at echo number $i$ can always be written in the form:

$$S_i = D q_i + C q_i^*$$

Where $q_i$ is the initial magnetization and $q_i^*$ its conjugate. Note the change of notation from (1): $D$ stands for ‘Direct’ echo, $C$ for ‘Conjugate’ echo. It is interesting to write this equation for the change of notation from (1): $D$ stands for ‘Direct’ echo, $C$ for ‘Conjugate’ echo. It is interesting to write this equation for the change of notation from (1): $D$ stands for ‘Direct’ echo, $C$ for ‘Conjugate’ echo. It is interesting to write this equation for the change of notation from (1): $D$ stands for ‘Direct’ echo, $C$ for ‘Conjugate’ echo. It is interesting to write this equation for the change of notation from (1): $D$ stands for ‘Direct’ echo, $C$ for ‘Conjugate’ echo. It is interesting to write this equation for the change of notation from (1): $D$ stands for ‘Direct’ echo, $C$ for ‘Conjugate’ echo. It is interesting to write this equation for the change of notation from (1): $D$ stands for ‘Direct’ echo, $C$ for ‘Conjugate’ echo.

$$S_{i+1} = e^{i\phi} \begin{bmatrix} D_i & C_i \\ D_{i+1} & C_{i+1} \end{bmatrix} \begin{bmatrix} q_i \\ q_0 \end{bmatrix} = e^{i\phi} \begin{bmatrix} A & B \\ B & A \end{bmatrix} \begin{bmatrix} q_i \\ q_0 \end{bmatrix}$$

where we have also introduced the ‘receive coil’ phase $\phi$.

We showed in (1) that a quadratic phase modulation, preceded by a stabilization period, permits us to obtain a sequence of coefficients $(A_j)$ which is a reasonably constant signal. We could eliminate the influence of the parasitic signal $(B_j)$ by a gradient crushing scheme. Under these conditions the signal would be alternatively proportional to $q_i^*$ and then $q_i$, as is the case when a perfect 180 degrees refocusing pulse is used (ideal case). Unfortunately this crushing scheme would render the sequence unstable in the presence of eddy currents. We thus used the standard symmetric, constant crushers of the FSE sequence. In this case the signal $(B_j)$ must be taken into account. First, it must be made constant: fortunately one can demonstrate that if $(A_j)$ is made constant, $(B_j)$ is constant too. Secondly it must not render the reconstruction process too difficult. As already noted in (1), even the ideal case requires a special reconstruction because we acquire alternatively $q_i$ and $q_i^*$, as the case when a perfect 180 degrees refocusing pulse is used (ideal case). Unfortunately this crushing scheme would render the sequence unstable in the presence of eddy currents. We thus used the standard symmetric, constant crushers of the FSE sequence. In this case the signal $(B_j)$ must be taken into account. First, it must be made constant: fortunately one can demonstrate that if $(A_j)$ is made constant, $(B_j)$ is constant too. Secondly it must not render the reconstruction process too difficult. As already noted in (1), even the ideal case requires a special reconstruction because we acquire alternatively $q_i$ and $q_i^*$, as the case when a perfect 180 degrees refocusing pulse is used (ideal case).

$$S_i + S_{i+1} = e^{i\phi}(A + B)(q_i + q_0)$$

This permits us to obtain the real and imaginary parts of the object separately using a half k-space reconstruction. Now, the coefficients $(A+B)$ and $(A-B)$ will be of same magnitude only if B is orthogonal to A, for instance pure imaginary when A is pure real. This is approximately realized if we use a quadratic phase modulation:

$$\phi_{con}(t) = \Delta t^2$$

with a value of $\Delta = \frac{10}{49}\pi$.

Results

In figure 1 we generated an artificial phase modulation by adding some gradient lobes between the flip pulse and the first refocusing pulse. This, in turn, generates a magnitude modulation on the real and imaginary part images (each one of which are very similar to what would be obtained by a standard FSE sequence). But the combination of the two images shows only a very slight residual modulation. Figure 2 was acquired with the same artificial detuning of the pre-dephasers which is without visible effect on the reconstructed magnitude image (5 slices of 3mm in 8 seconds, T2* weighting: Signa LX 1.5T).

References

5. J.B. Murdoch, SMR 2nd Meeting, 1145 (1994)

The experimental part of this work has been performed at Service Hospitalier Frederic. Joliot, CEA, Orsay France.