Various TR Linear Combination FIESTA on Open MR systems

A. Yamazaki[1], M. Miyoshi[1], S. Kosugi[1]
[1]GE Yokogawa Medical Systems, Hino, Tokyo, Japan

Abstract

Steady State Free Precession provides strong signal, high contrast images in a short scanning time. However, strong fat signal contaminates image. This paper is to separate fat signal on Open MR system by applying linear combination method.

Introduction

Steady State Free Precession (SSFP, FIESTA, True FISP, balanced FFE) provides high SNR image rapidly. But it suffers from a bright fat signal. Current techniques to reduce the fat signal are Fat Saturation RF pulse [1], Fluctuation Equilibrium MR (FEMR)[2], Linear Combination SSFP (LCSSFP)[3]. In ISMRM 11th meeting, some post-processing fat separation methods are presented; that is out-of-phase TE [4], multi point Dixon [5] and Phase cycling single quadrature Dixon [6].

LCSSFP method separates fat signal from water with out-of-phase TR as Fig. 1. SSFP is scanned with Signa Open Speed 0.35T scanner (GE Yokogawa Medical Systems) with 2D FIESTA pulse sequence. The protocol in Fig.1 is TE 5ms, TR 10ms, flip angle 40, slice thick 7.0 mm, 192*192 matrix, 2NEX with RF phase cycles: 0-90-180-270, and 0-270-180-90.

Fig. 1 Knee; Fat signal(center) is separated from water(left). Right is a combined image.

Because out-of-phase TR is long on Open MR systems and low magnetic field MR systems, there is banding artifact by B0 in-homogeneity as Fig.1. This method gives proper RF phase cycles to separate fat signal from water with various TR.

Theory

This method is to separate fat and water signals by using proper RF phase cycles for TR. Fig.2 shows conceptual RF phase cycles with non out-of-phase TR and combine data-sets method. P(center) means RF phase cycle for giving lowest fat signal, and +/-P(step) means RF phase cycle for canceling out fat signal. For example, P(center) is π, P(step) is π/2, in the case of out-of-phase TR. Denoting data-sets from SSFP with phase cycle of P(center)-P(step) as D(-), P(center)+P(step) as D(+). Conventional LCSSFP water and fat images are reconstructed by D(-)+i*D(+) and D(-)-i*D(+) respectively.

If TR is not same as out-of phase, RF phase cycles must be modified by TR to get good fat water separation.

RF phase cycles modification is added by spectrum simulation as Fig.3. For example, 8ms on 0.35T, proper P(center) is 12/10 π, P(step) is 4/10 π to make fat chemical shift at the bottom of Fig. 3.

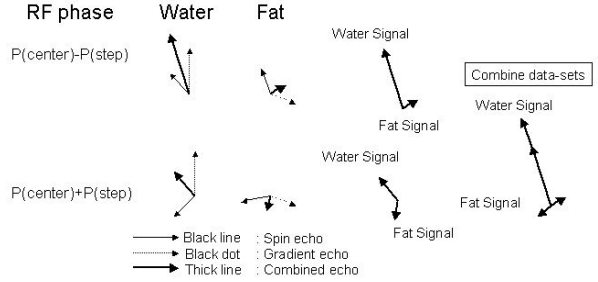

Fig.2 RF phase cycles with non out-of-phase TR and combine method.

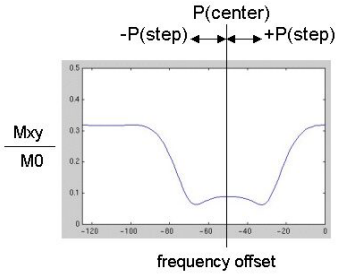

Fig.3 spectrum simulation (TR8ms, 0.35T)

Method

SSFP is scanned with Signa Open Speed 0.35T scanner with 2D FIESTA pulse sequence. The TE/TR is 4 ms/ 8 ms. RF phase cycles are 12/10 π +/- 4/10 π. Fat and water images given by D(-)+/-exp(I*6/10 π)*D(+).

Fat signal is separated from water very clearly as shown in Fig. 4.

Fig.4 Knee; Fat signal(center) is separated from water(left). Right is a combined image.

Result and Discussion

As this method gives proper RF phase cycles for TR, fat and water signal are separated with various TR. Band artifact can be reduced by shorter TR even if on Open MR systems and low magnetic field MR systems.

Additionally, this method can be used in several applications including Myerography.

Reference

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