An RF pulse with reduced MT saturation for FSE

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INTRODUCTION: Inherent Magnetization Transfer (MT) saturation effects in pulse sequences with high flip angle rf pulses (e.g. FSE) can significantly reduce SNR; its differential effect on tissues can also change image contrast. At higher fields (e.g. 3T), longer T1's can make MT saturation even more pronounced. This MT effect scales with rf power as does SAR, but also depends on slice select gradient strength G_s. Lengthening the rf pulse, or using variable rate gradient (VERSE) rf pulses[(1)] to nonuniformly stretch the pulse, lowers SAR, but also lowers G_s. This lower gradient 'spreads' the MT effect from each slice's rf pulses to a greater number of neighboring slices. For example, increasing an rf pulse duration by N reduces its power by N, reduces G_s by N, and therefore affects N times more slices, so that each slice receives roughly the same amount of MT saturation. We have developed a new, Low-MT rf refocusing pulse which plays out the mainlobe (and only the mainlobe) several times using an alternating G_s at the maximum slew rate; this greatly increases the gradient amplitude during rf application (limiting the spread of MT saturation) and keeps SAR low.

METHODS: The rf pulse was designed by fitting a sinc pulse (TBW 10) to a 15-parameter model and iteratively optimizing its shape based on its passband (180 degrees) and stopband (calculated numerically from the Bloch equations) using the k-space trajectory in Fig. 1(c) (play out left sidelobes once, mainlobe 5 times, then right sidelobes once). The final rf pulse is shown in Fig. 1(d). For this pulse and the two others in Fig. 1(a,b), the MT saturation in Fig. 1(e) was calculated using a SuperLorentzian[(2)] with a T2 for bound protons of 10usec. The rf pulses in Fig. 1(a) and (d) were then used in an FSE sequence on a GE 3T scanner, 8-channel head coil, slice thickness 4mm, refocusing flip angle 125˚, TR/TE = 800/20, ETL 2 (2nd echo at k-space center), 24cm FOV, 384x384 mtx.

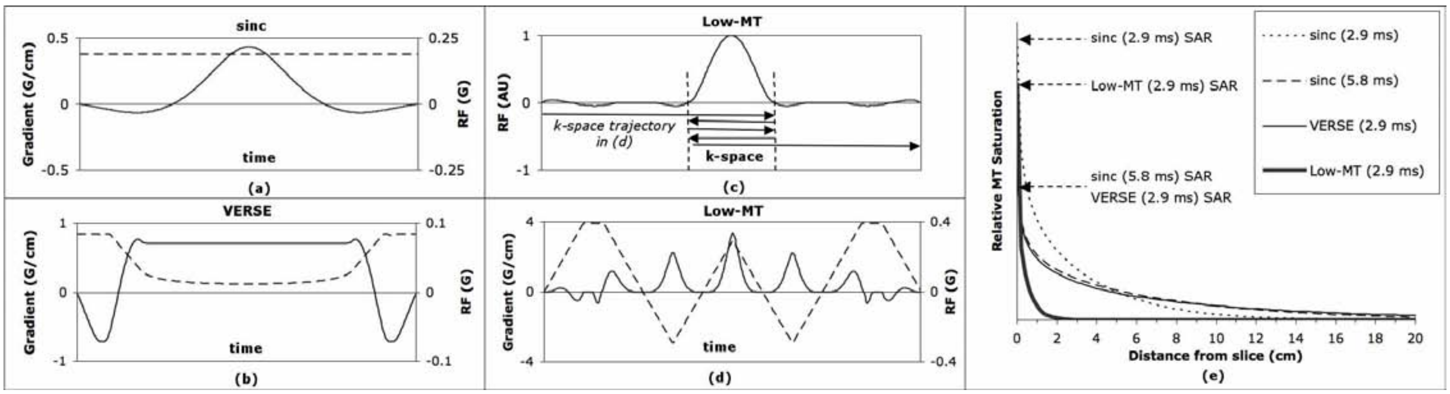
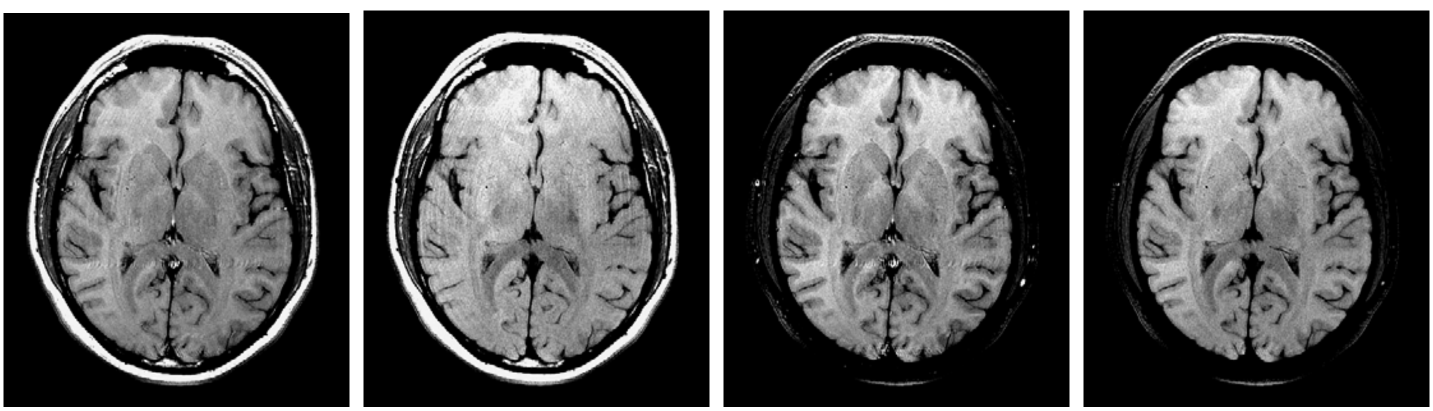


Fig. 1. Gradient (dotted line) and rf (solid line) for (a) sinc, (b) VERSE implementation of (a), and (d) proposed rf pulse, all designed for a passband of 4mm, and a pulse duration of 2.9 msec. The graph in (c) shows the new rf pulse in k-space, along with the k-space trajectory used to generate the gradient and rf waveforms in (d). The mainlobe was played out 5 times, with relative heights of 1, 2, 3, 2, 1, for an improved spectral response. The calculated relative MT saturation as a function of distance from the slice is shown in (e) for the three rf pulses (a,b,d) as well as the sinc pulse played out with twice the duration (5.8 ms) and half the gradient amplitude. Note how compact the MT profile of the proposed pulse is compared to the others. The relative SAR for each pulse, equal to the intersection of the curves at the actual slice location (distance = 0), is shown by the arrows.



(a) (b) (c) (d)

Fig. 2. Slice collected by itself (a,c) and with 17 interleaved slices (b,d) for standard (a,b) and proposed (c,d) rf pulse. Note that T1 contrast is preserved for multiple slices using the proposed rf pulse. The loss of fat signal in (c,d) is due to the spectral band of the proposed rf pulse.

RESULTS & DISCUSSION: Figure 2 shows how with a regular rf pulse, multiple slices (Fig. 2b) effect image SNR and contrast compared to a single slice (Fig. 2a) due to MT saturation; the proposed Low-MT rf pulse results in less MT saturation (Fig. 2c vs. 2d).

REFERENCES: 1. Conolly et. al., "A reduced power selective adiabatic spin-echo pulse sequence" Mag Res Med 18: 28. 2. Morrison, Henkelman, "A Model for Magnetization Transfer in Tissues", Mag Res Med 33: 475.