
# primeFSE TECHNOLOGY

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# HITACHI'S FAST SPIN ECHO TECHNOLOGY

## Efficacies in Improving Image Quality & Usability

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# Hitachi's Prime Fast Spin Echo Technology: Efficacies in Improving Image Quality and Usability

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We evaluated the efficacies of the "prime fast spin echo (FSE)" technique, which enables the optimization of the echo shift scheme and direct assignment of the effective echo time, as compared with those of the conventional FSE technique. We could easily obtain images with arbitrary contrast by using the prime FSE technique. In addition, in this technique, truncation artifacts were diminished, and blurring artifacts were decreased without prolongation of the acquisition time. Prime FSE is considered to be a promising technique for improving the image quality of FSE imaging.

**Key Words:** MRI, Prime FSE, k-space, Echo Shift, Truncation Artifact

## 1. Introduction

Recent modern pulse sequences on MRI including a fast spin echo (FSE) technique contribute to improving the quality of diagnostic imaging. The FSE technique is widely used for a majority of routine imaging; however, a scheme for filling echo signals in the k-space varies across MRI systems, and this issue occasionally causes considerable artifacts or leads to complications in the parameter settings. This paper reports the features and efficacies of prime FSE, a novel technique implemented in the 1.5T Echelon as an advanced FSE sequence, by focusing on the area of the central nervous system.

## 2. Description of the Echelon in our institute

The Echelon was installed as the sixth MRI unit in our institute in March 2007. Due to its compact design, after the removal of a superconductive 0.5T system of another manufacturer, the system could be installed in a small space without any expansion of the scanning room.

In the Echelon, all the sequences and capabilities commonly used at 1.5T are implemented, including rapid acquisition through a parallel imaging design (RAPID) as a parallel imaging technique, radial acquisition regime (RADAR) as a hybrid radial scan technique, balanced steady-state acquisition with rewound gradient echo (BASG) as a true fast imaging with steady-state procession (FISP) technique and MR Spectroscopy. Of these, the clinical MR spectroscopy (MRS) package is one of the unique advantages of the Echelon. Workflow of the MRS is greatly simplified in the Echelon as compared with that in systems produced by other manufacturers. Positioning, pre-scanning, data acquisition, data analysis, and filming can be performed on a console with simple procedures involving minimal clicks.

On the other hand, the conventional FSE technique in Echelon, similar to MR imagers of other manufacture, has some limitations. Optimization of the scan parameters to minimize FSE-related artifacts while maintaining image contrast and acquisition time is often a laborious task. In addition, the quality of dual-contrast FSE was not optimal; therefore, T2-weighted images (T2WIs) and proton density-weighted images (PDWIs) had to be obtained separately, consequently prolonging

the examination time. In order to overcome these limitations, Hitachi Medical Corporation recently released prime FSE, a sequence that enables automated optimization of the parameter settings and image quality by improving the scheme to fill the k-space with signals. From April 2007, we have implemented this technique in our institute.

## 3. Features of prime FSE

### 3.1 Improvement in the echo shift scheme

In the FSE technique, the effective echo time (TE) is determined by the echo that is allocated at the low-frequency area of the k-space[1,2]. In the conventional FSE technique, first, median, and last echoes can be assigned at the center of the k-space by using centric, sequential, and reverse centric orders, respectively. Other echoes also can be set as the effective TE by using an "echo shift" technique that reorders allocations of multiple echo signals in k-space. However, echo shift can cause significant truncation artifacts due to increased discreteness in the signal intensity at the boundary of the reordered neighboring echoes (Fig. 1A). On the other hand, in prime FSE, echoes are "scrolled" while maintaining relationships with the adjacent echoes of the centric order. Hence, difference in the signal intensity between the neighboring echoes is maintained at a minimum level regardless of the amount of echo shift, in order to maintain truncation artifacts at a minimum level[1,3] (Fig. 1B). Further, it is possible to arrange echo shifts independently in the PDWIs and T2WIs of dual-contrast FSE imaging.

### 3.2 Improvement in parameter settings

In the conventional FSE technique on this system, direct assignment of the effective TE is not possible. Hence, combinations of the echo number, echo interval, k-space order, and echo shift are manually adjusted to obtain the intended effective TE. This procedure can be complicated when parameters must change, sometimes causing combinations of parameters that do not optimize image quality. In prime FSE, the effective TE values are directly entered, just as in conventional spin-echo (SE). Echo shift is automatically executed to allocate the effective TE as one of the multiples of the echo interval proximate to the entered values, while maintaining values of the echo interval, echo number, and readout bandwidth. For example, with the following conditions of the echo interval of 12 ms, echo number of 10, and bandwidth of 32 kHz, effective TE can be set at 12, 24, 36, 48, 60, 72, 84, 96, 108, or 120 ms maintaining image quality, signal-to-noise ratio, and acquisition time (Fig. 2).

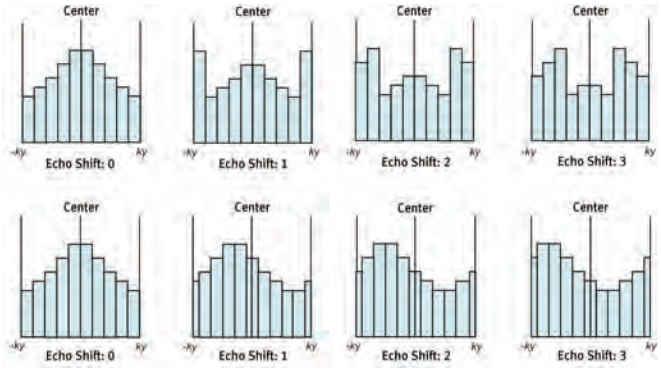


**Figure 1. Echo shift in conventional FSE and prime FSE**
A: Conventional FSE, B: Prime FSE (both sequences are in the centric order with an echo number of 5). Echo shift by conventional FSE produces large differences in signal intensity between neighboring echoes (A, arrows) that generate significant truncation artifacts. Echo shift by prime FSE maintains a minimum difference in signal intensity to suppress artifacts (B).

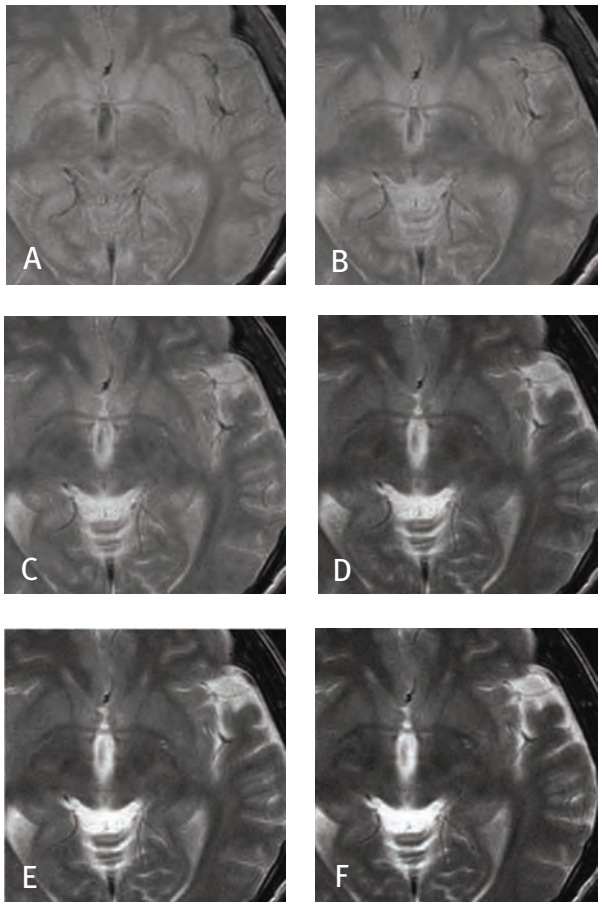


**Figure 2. Assignment of effective TEs in prime FSE**
A:Effective TE, 12ms; B:36 ms; C :60 ms ; D :84 ms ; E :96 m s ; F:108 ms (TR, 2800 ms; echo interval, 12 ms; echo number, 11; bandwidth, 32 kHz; FOV, 220 mm; matrix size, 256 × 256; and number of excitations, 2).

Prime FSE technique can assign arbitrary effective TEs as multiples of the echo interval while keeping other parameters, including the echo interval, echo number, and bandwidth, constant and maintaining FSE-related artifacts at a minimal level.

## 4. Improved image quality by prime FSE

Prime FSE enables us to obtain excellent PDWIs and T2WIs simultaneously with relatively short acquisition times by using a dual-contrast mode. (Fig. 3A, D). In the conventional FSE technique, PDWIs and T2WIs should be scanned separately because echo assignments in the first and last halves cannot be independently controlled in the conventional dual-echo mode. PDWIs equivalent to images in prime FSE can be obtained by setting the echo number to half of that in dual-echo prime FSE, but the scan time is doubled (Fig. 3B). On the other hand, images with the same echo number can avoid prolongation of the scan time, but they may worsen artifacts such as blurring and pseudo-edge enhancement (Fig. 3C). Blurring and/or truncation artifacts in T2WIs are remarkable both in the centric and sequential orders because of the use of the echo shift and/or the prolongation of the echo interval (Fig. 3E, 3F).

In addition, prime FSE enables us to obtain high-quality short inversion-time inversion recovery (STIR) images that have high contrast resolution between gray and white matters. Truncation artifacts were lower in STIR with prime FSE as compared with conventional FSE (Fig. 4).

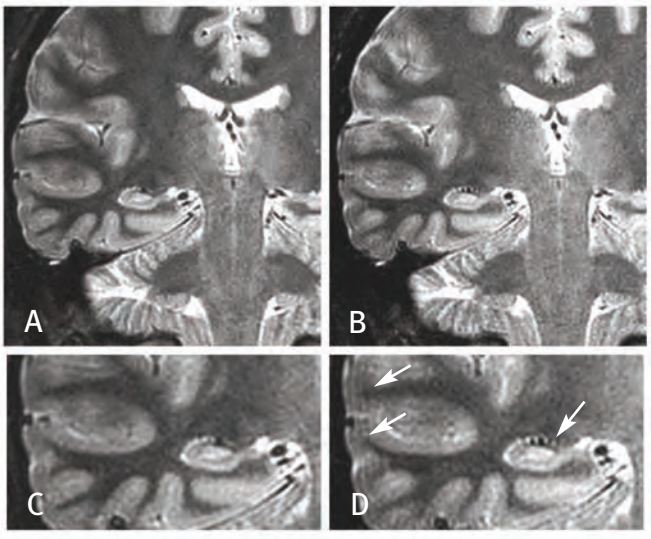


**Figure 4. Short inversion-time inversion recovery** (STIR) images in prime FSE and conventional FSE A, C: Prime FSE; B, D: conventional FSE (TR, 4000 ms; effective TE, 36 ms; inversion time (TI), 140 ms; echo interval, 12 ms; echo number, 8; bandwidth, 35 kHz; FOV, 200 mm; matrix, 256 × 256; number of excitations, 2).

Truncation artifacts that are prominent in STIR images by conventional FSE (D, arrows) are substantially reduced in those by prime FSE, and the internal structures of the hippocampus are readily visualized (C).

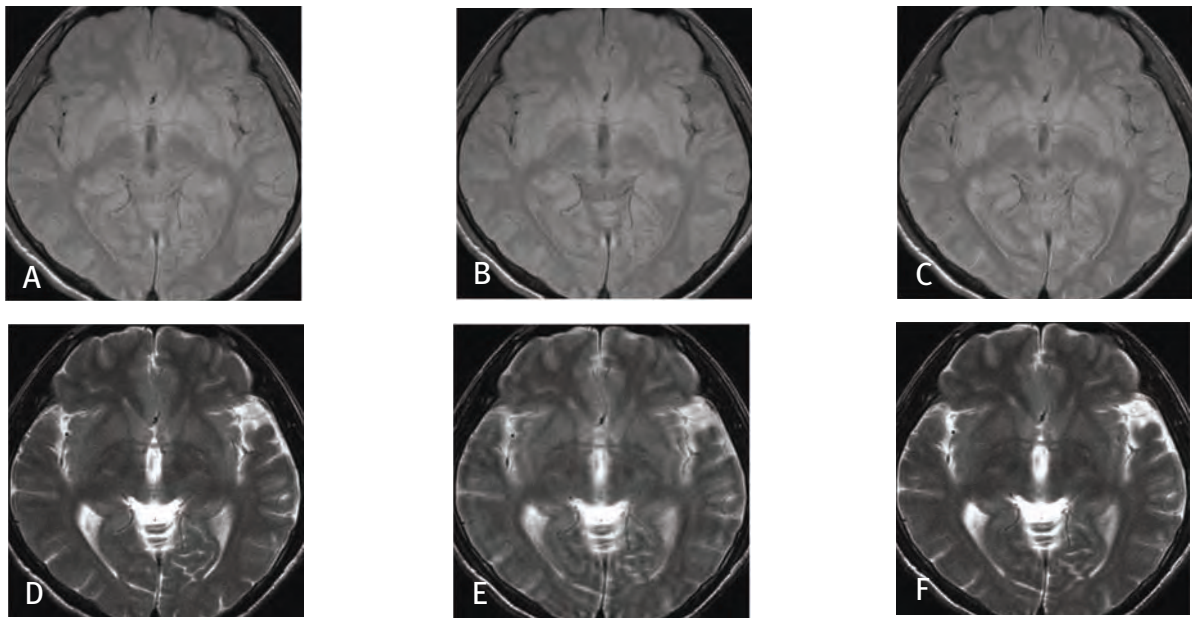


**Figure 3. Dual-contrast images by prime FSE and conventional FSE**

A-C: proton density-weighted image (PDWI); D-F: T2-weighted image (T2WI); A, D: dual-contrast prime FSE (echo number, 10 (5 + 5)); B-C and E-F: conventional FSE (B: centric order with an echo number of 5, C: centric order with an echo number of 10, E: centric order with an echo number of 9, and F: sequential order with an echo number of 10); (TR, 2800 ms; echo interval, 12 ms; FOV, 220 mm; matrix; 256× 256; number of excitation, 2).

Satisfactory PDWIs and T2WIs are obtained within 5 min by using the dual-contrast prime FSE that can assign arbitrary effective TEs with independent optimization of the reordering in 2 kinds of k-spaces (A, D). In conventional FSE images, prolongation of the acquisition time (B) and/or remarkable artifacts such as pseudo-edge enhancement (C), blurring, and truncation artifacts (E, F) are unavoidable.

## 5. Conclusion

Prime FSE is an important new scanning feature that permits easy operation, increase in latitude of selecting effective TEs, optimization of numerous sequence parameters, shortening of the acquisition time, and suppression of the blurring and truncation artifacts by a new algorithm for k-space ordering. Therefore, it is considered to be a promising technique for improving image quality in MR imaging of the central nervous system and other regions.

*Echelon is a registered trademark of Hitachi Medical Corporation in Japan.

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