# T2-Weighted 3D Spin-Echo Train Imaging of the Brain at 3 Tesla: Reduced Power Deposition Using Low Flip-Angle Refocusing RF Pulses

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### Introduction

MR imaging systems that operate at field strengths of 3 T and above are becoming increasingly common. Power deposition at these field strengths is a very important consideration in pulse-sequence design, especially for human applications. Spin-echo-based techniques, which are the workhouse of clinical MRI, are particularly affected due to their use of high flip angles (> 100°) for the refocusing RF pulses. Therefore, the development of SE-based pulse sequences with reduced power deposition is of significant interest for high-field applications.

Recently, T2-weighted single-slab 3D imaging of the brain, based on a fast-SE pulse sequence, was demonstrated at 1.5 T [1]. This technique uses a very long spin-echo train (160 echoes) with variable-flip-angle refocusing RF pulses to achieve prescribed signal evolutions for the tissues of interest. Of relevance to high-field imaging, the average of the variable-flip-angle series used in this pulse sequence is only 60°, and consequently the power deposition is substantially lower than that corresponding to 180° RF pulses. The purpose of this investigation was to evaluate the usefulness of this long-echo-train method for human brain imaging at 3 T.

### Methods

The variable-flip-angle, 3D single-slab T2-weighted fast-SE-based pulse sequence described in reference 1 was implemented on 1.5-T and 3-T whole-body imagers (Symphony and Allegra, Siemens Medical Systems, Iselin, NJ). The 1.5-T system was equipped with a transmit body coil and a receive head RF coil, whereas the 3-T system used a transmit/receive head RF coil. Identical sequence parameter values were used on the two systems, and included: TR/effective TE, 2750/328 ms; matrix, 256 (readout) x 160 (in-plane phase encoding) x 216 (3D phase encoding); field of view, 25.6 x 16.0 x 21.6 cm; echo spacing, 4.1 ms; echo train length, 160; refocusing RF pulse duration, 500 µs; acquisition time, 10 min. The prescribed signal evolution, designed to achieve T2 weighting for brain tissues, had the following shape: exponential decay for the first 20 echoes (decay constant 114 ms), constant for 66 echoes, and exponential decay for the remaining echoes (decay constant 189 ms) [1]. The total duration of the echo train was 656 ms. The variable-flip-angle series corresponding to this prescribed signal evolution is shown in Fig. 1. All flip angles are less than 100°, introducing a strong T1 dependence to the signal evolution which thereby lengthens the usable echo-train duration substantially beyond the T2 value (~100 ms). This approach provides usable echo-train durations considerably longer than those that can be obtained with 180° RF pulses or with other low-flip-angle strategies [2,3].

Images of the human head were acquired after obtaining informed consent. The general image quality and contrast, and the specific absorption rate (SAR), were compared for image sets obtained on the 1.5-T and 3-T systems. The SAR values were calculated using the standard software supplied by the manufacturer.

### Results and Discussion

The very long SE-train images displayed T2-weighted contrast that appears very similar to that for conventional T2-weighed SE imaging. No significant image artifacts were observed at either 1.5 T or 3 T. Figure 2 shows representative T2-weighted 3D-brain images, with isotropic 1-mm spatial resolution, from the 3-T system. For this 70-kg volunteer, the partial-body and local SAR values were 0.53 W/kg and 0.97 W/kg at 1.5 T, respectively, compared to 1.29 W/kg and 3.16 W/kg at 3 T. The FDA limits for partial-body and local SAR are 3.0 and 8.0 W/kg, respectively. The ratios of the partial-body and local SAR values at 3 T to their corresponding values at 1.5 T were both less than the square of the ratio of the field strengths. However, the transmit RF-coil configurations were substantially different for the two systems. The SAR values at 3 T were much less than the FDA limits, indicating that there remains substantial latitude in the pulse-sequence design from the perspective of power deposition, including the possibility for even more refocusing RF pulses per excitation.

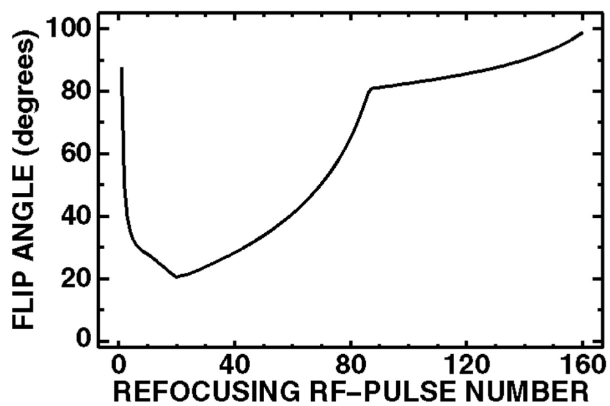


**Figure 1. Variable flip-angle series used in the pulse sequences at 1.5 T and 3 T.**

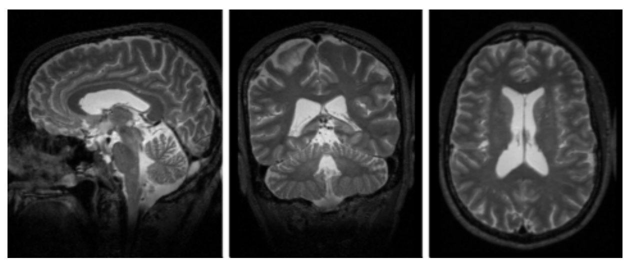

**Figure 2. T2-weighted sagittal, coronal and axial 3-T brain images from a healthy volunteer. The three 1-mm thick images were all reconstructed from the same 3D acquisition.**

### Conclusions

Very long SE trains based on prescribed signal evolutions permit high-quality T2-weighted 3D brain images to be acquired at 3 T with power deposition well below the FDA limits. Investigation of this variable-flip-angle approach for obtaining other image contrasts, and for imaging at fields above 3 T, appears warranted.

### References

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