

## Skin Imaging at 7T

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**Introduction:** High-resolution in vivo imaging is currently SNR-limited. Recently, 7 nL resolution skin imaging was demonstrated at 3T, using a dedicated 1-inch-diameter receive-only coil [1]. At 7T, 16 nL resolution images were obtained with a 4-inch-diameter transmit-receive coil [2]. Small coils are well suited to high-field systems where they behave as mid-range coils [3]. However, frequency offsets due to chemical shift create challenges for high-resolution skin imaging because the hypodermis is a fat layer and the maximum gradient amplitudes are limited. This work investigates how to address those challenges and compares GRE and SSFP sequences for high-resolution skin imaging at 7 T.

**Methods:** A 1-inch-diameter transmit/receive coil was built. To maintain the dimensions of the conductor elements below  $\lambda/20$  ( $\lambda$ , the wavelength in free space, is 1 m at 7 T), the coil was split with four capacitors. This approach allows us to neglect radiation and dielectric losses [3]. The experiments were performed on a GE Excite 7 T whole body scanner, with a maximum gradient amplitude of 40 mT/m and a maximum slew rate of 150 mT/m/ms. When imaging at 7T, the first concern due to fat is through-slice chemical shift. In order to restrain it to one slice, the slice thickness has to be greater than 0.5 mm (the slice-selective gradient amplitude is maximized). The number of desired slices then dictates the slab thickness, hence the pulse bandwidth. We used a  $10^\circ/20^\circ$  (SSFP/GRE) sinc RF pulse with a time-bandwidth product (TBW) of 16 (duration 1.28 ms, peak amplitude  $8 \mu\text{T}/16 \mu\text{T}$ ). Alternatively, one can choose to suppress fat by using an RF pulse whose bandwidth excludes fat and by exciting a slab whose thickness exceeds the coil's sensitive area. The pulse duration is then increased to 3.84 ms to get a TBW of 2 (peak amplitude  $0.4 \mu\text{T}/0.8 \mu\text{T}$ ). Water can be suppressed similarly by shifting the center frequency of the excitation. If fat is not suppressed, resolving it is desirable: when imaging with  $117 \mu\text{m}$  resolution in the frequency direction, fat is shifted from water by at least 5 pixels (the readout gradient amplitude is maximized).

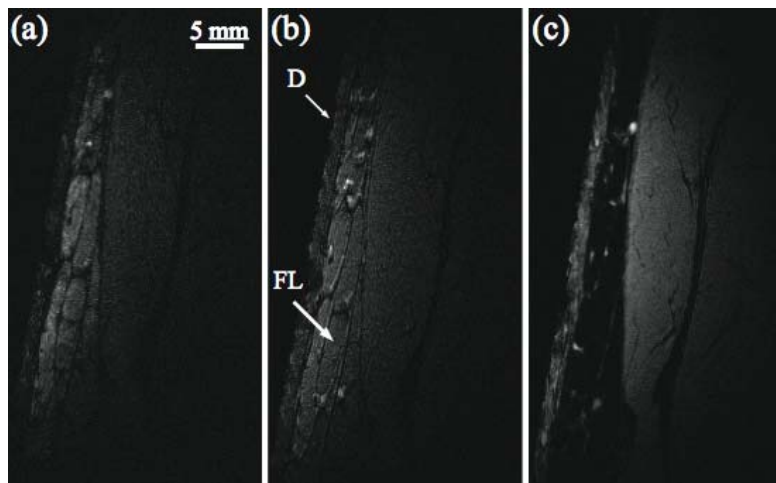
The calf of a healthy volunteer was imaged. Three pulse sequences were implemented: balanced SSFP with or without  $180^\circ$  phase alternation of the RF excitation, gradient-spoiled GRE with fractional echo to minimize the echo time, and homodyne IDEAL-GRE with three interleaved echo times corresponding to phase angles spaced by  $2\pi/3$  to resolve fat and water [4]. To reduce spurious motion, the subject's leg was immobilized using a plastic walker boot.

Sequence	TE	TR	FA	# slices	Slice thickness	Scan time
SSFP	11 ms	22 ms	$10^\circ$	16	0.5 mm	2x 1'30
GRE	5 ms	44 ms	$20^\circ$	16	0.5 mm	3'
FS-GRE	5 ms	22 ms	$10^\circ$	50	1 mm	4'42
IDEAL-GRE	5 ms	30 ms	$10^\circ$	14	0.7 mm	5'26

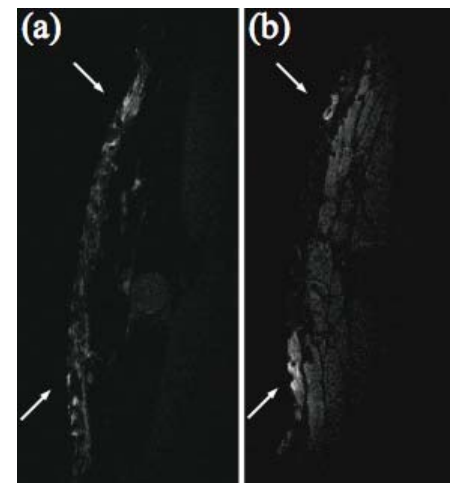
*Table 1: Imaging parameters*

**Results and Discussion:** We imaged a  $6 \times 3 \text{ cm}^2$  FOV with  $117 \mu\text{m}$  in-plane resolution and a readout bandwidth of  $\pm 32 \text{ kHz}$ . Specific parameters are summarized in Tab. 1. Figures 1a and 1b present SSFP and GRE images, each obtained in 3 min. To avoid banding artifacts, the SSFP image is taken as the point-by-point maximum of the two images (with and without  $180^\circ$  RF phase alternation). Figure 1c is a Fat-Suppressed GRE image. A longer scan time was necessary to encode the whole coil's sensitive area. The SSFP sequence does not suffer much from off-resonance effects despite the relatively long TR, and a simple approach is enough to avoid banding artifacts. However, signal from the dermis is limited since SSFP has a  $T_2/T_1$  contrast (dermis is believed to have a long  $T_1$  and a short  $T_2$  [5]). Using a GRE sequence, the dermis and fat lobules are well delineated. In all images, the epidermis is barely visible. Increasing the resolution in the direction perpendicular to the skin surface might be necessary. Figure 2 presents the water and fat IDEAL-GRE images. Appropriate fat/water separation is obtained except below the copper wire where strong inhomogeneities are present. Achieving the appropriate flip angle over the ROI is difficult with transmit/receive surface coils. A 3-mm lift-off from the coil was used to obtain the images in Fig. 1. Using this approach and adjusting the flip angle will improve the SNR of the IDEAL-GRE images.

**Conclusion:** At 7T, GRE demonstrates higher signal levels than SSFP for high-resolution imaging of the dermis. SSFP, with its SNR efficiency and spin-echo behavior, may be more useful for imaging the hypodermis. Care in sequence design is needed to avoid chemical shift artifacts. However, a variety of fat suppression or fat/water separation methods are possible.



**Figure 1:** (a) SSFP, (b) GRE, and (c) FS-GRE images. Dermis (D) and Fat lobules (FL) are distinguishable. The epidermis is barely visible



**Figure 2:** IDEAL-GRE (a) Water and (b) Fat images. The separation fails below the copper wire (arrows).

- References:** [1] Barral, ISMRM 2008, p.742 [2] Maderwald, ISMRM 2008, p. 171 [3] Doty, NMR Biomed 20:304–325, 2007  
 [4] Reeder, MRM 54:586–593, 2005 [5] Richard, J Invest Dermatol 97:120–125, 1991