

Externally Calibrated Parallel Imaging in the Presence of Metallic Implants

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Target audience: Researchers and clinicians interested in imaging near metallic implants.

Introduction: 3D multi-spectral imaging (3D-MSI) acquisitions such as a SR-FPE¹, MAVRIC², and SEMAC³ address the extremely large off-resonance signal near metallic implants by acquiring multiple acquisitions at different frequency offsets (Fig 1a). Acquiring multiple 3D images is time consuming and requires self-calibrated parallel imaging to obtain clinical feasible scan times. Unfortunately, a substantial amount of time is spent acquiring the fully sampled calibration region, particularly for fully phase-encoded methods like SR-FPE (Fig 1b). **The purpose of this work** was to develop an external calibrated parallel imaging technique that is feasible in the presence of metallic implants.

Theory: Externally calibrated parallel imaging techniques remove the need to acquire calibration data by acquiring a separate calibration scan (Fig 1c). In this work we propose to use an ultra-short echo time (UTE) acquisition with broadband excitation of the *entire* off-resonance spectrum, by using low flip angles and non-selective pulses. Further, we propose to avoid frequency encoding by using a single point imaging sequence, thereby preventing in-plane distortions in the coil sensitivities.

Methods: External calibration, self-calibrated SR-FPE, and self-calibrated MAVRIC acquisitions were acquired of a hip prosthesis phantom and a volunteer with a cobalt/chromium/molybdenum alloy hip head placed posterior to the knee (with IRB approval). Imaging was performed using a 16 channel wrap coil (NeoCoil, Pewaukee, WI) at 3T (MR 750, GE Healthcare, Waukesha, WI). For comparison, the fully-sampled calibration regions of SR-FPE and MAVRIC acquisitions were retrospectively decimated for all RF offsets and reconstructions were performed using external calibration.

External Calibration: In phantom and in-vivo experiments, external calibration was performed using a purely phase encoded UTE single point sequence using the following parameters: 8us hard pulse (150kHz bandwidth), TE=60us, TR=1.1ms, matrix size=31x31x31 with elliptical k-space sampling, flip angle=2°.

SR-FPE Acquisitions: Phantom and in-vivo 3D undersampled SR-FPE acquisitions ($R=3 \times 2 \times 2$, ACS=18x18x18, ETL=24, ADC samples = 34, 2.3kHz multiband Gaussian pulses centered at [-4, 0, 4]kHz, 24kHz spectral coverage) were acquired. Phantom scan parameters were: matrix=150x100x38, FOV=22.5x14.8x15.2cm, acquisition time=37/28min (self/external). In-vivo scan parameters were: FOV=24x14x13cm, matrix=150x86x32, acquisition time=36min/26min.

MAVRIC Acquisitions: Phantom and in-vivo MAVRIC acquisitions were also acquired ($R=2 \times 2$, ACS=32x16 elliptical, ETL=24, 2.3kHz Gaussian pulse, 24kHz spectral coverage). Phantom and in-vivo imaging parameters were kept identical except the following: phantom matrix=256x168x38, phantom acquisition time = 8:23/6:47min (self/external), in-vivo matrix=256x146x32, in-vivo acquisition time=6:24min/4:48min (self/external).

Results and Discussion: Figure 2 shows phantom and in-vivo comparisons of externally calibrated and self-calibrated parallel imaging SR-FPE and MAVRIC acquisitions. By using the same outer acceleration factors and removing calibration regions, scan times can be significantly reduced (~25%). This effect is particularly impactful for SR-FPE, although additional acceleration is needed to acquire SR-FPE acquisitions in clinically feasible acquisition times.

Conclusion: A wide bandwidth UTE single point acquisition allowed externally calibrated parallel imaging for 3D-MSI, eliminating the need for calibration regions at each frequency offset. Significant reductions in acquisition time can be achieved, particularly for fully phase-encoded methods like SR-FPE.

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References: 1.Artz et al. MRM 2013;681-690. 2.Koch et al. MRM 2009;381-390. 3. Lu et al. MRM 2009;66-76. 4.Koch et al. MRM 2014;2024-34.

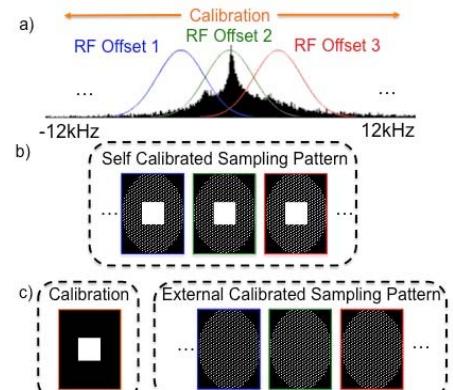


Figure 1: An external, wide bandwidth UTE single point calibration acquisition spanning the entire off-resonance spectrum induced by metallic implant (a) can be used to calibrate parallel imaging reconstruction for each RF frequency offset of 3D-MSI acquisitions. This calibration scan removes the self calibrated sampling pattern restrictions (b) and allows externally calibrated sampling patterns (c).

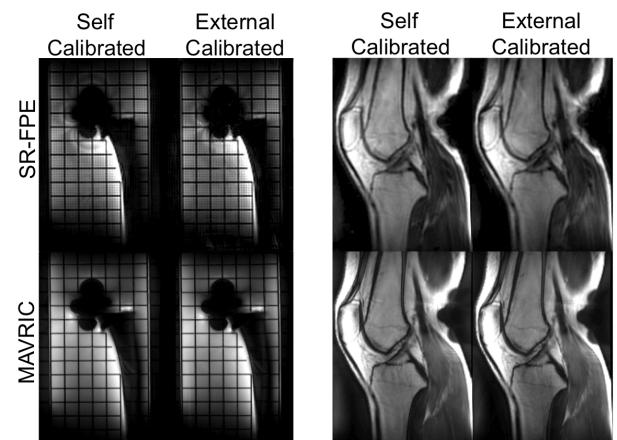


Figure 2: Externally calibrated SR-FPE ($R=3 \times 2 \times 2$) and MAVRIC ($R=2 \times 2$) acceleration show equivalent image quality as self-calibrated but with substantial time savings (~25%). SR-FPE and MAVRIC acquisitions using self and external calibration are shown of a hip prosthesis phantom and volunteer with a cobalt/chromium/molybdenum alloy hip head placed posterior to the knee.