# Recovering bSSFP Signal Loss near Metals with Shimming

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**Target Audience** Researchers and clinicians who desire the ability to visualize tissue structure close to metals using balanced steady state free precession (bSSFP) MRI will benefit from this study.

**Purpose** When MRI $B_0$ field inhomogeneity causes spin frequencies to stray beyond ±1/(2TR) off-resonance, spins refocused by bSSFP sequences can experience a relative phase shift of ±π. This biphasic nature yields signal-cancellation banding artifacts when opposed phase spins exist in voxels. Strong variations in field inhomogeneity yield closer band spacing, converging on complete signal loss near metals.

Moderate banding may be corrected using exact solutions such as the geometric solution (GS) [1], but biphasic signal loss is unaffected. Here gradient shimming compensates for the field inhomogeneity gradient to minimize the range of off-resonant spin frequencies near metals. Signal is recovered as the bands spread out; these are mitigated through combination of images acquired with varied shim orientations and phase cycling. Combined with these shimmed images, a regular GS-bSSFP image can have reduced signal loss near metals.

**Fig. 1: CrCoMo hip prosthesis within a Lego structure is stabilized by a polyethylene mesh cage.**

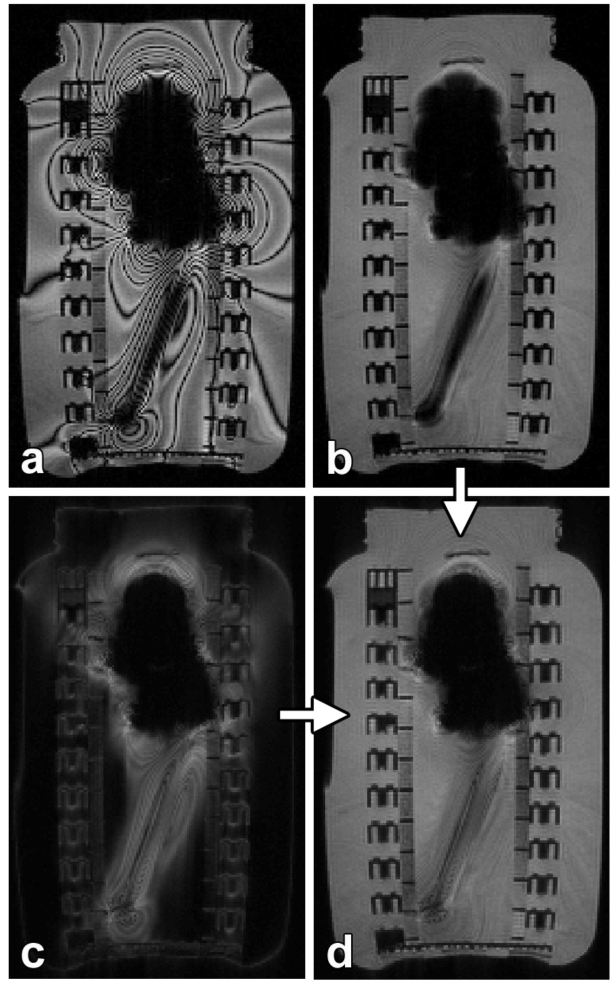


**Fig.2: a) Δθ = 0° TrueFISP magnitude image. b) Geometric debanding solution. c) Sum of Squares of 12 shimmed images: ±x, ±y, and ±z shims each with 0° and 180° phase cycles. d) Maximum intensity of b) and c) shows reduced signal loss.**

**Methods** A 1.5T Siemens Avanto scanner was used to image a water phantom consisting of a Lego™ building encasing a Zimmer™ (Warsaw, IN) Cobalt Chromium Molybdenum hip prosthesis stabilized by a polyethylene mesh cage (Fig.1). 3D TrueFISP (bSSFP) images were acquired with α = 40°, TE/TR = 2.3/4.6ms, receiver bandwidth BW = 558 Hz/pixel, and 256/168/160 matrix size and 1.2/1.2/1.2 mm voxel size along frequency/phase/slice directions. The GS was computed as described in [1] on four unshimmed datasets acquired with Δθ = 0°, 90°, 180°, and 270° respective phase cycling. Shim gradients were applied in six directions ±x, ±y, and ±z; for each, Δθ = 0° and 180° phase cycled images were acquired to yield 12 shimmed images total. A sum of squares [2] of these images was computed and the pixelwise maximum intensity of this composite image and the unshimmed GS formed a debanded bSSFP image with reduced signal loss.

**Results** Figure 2a) shows a Δθ = 0° bSSFP magnitude image, and the b) GS magnitude is computed from all four relatively phase-cycled datasets. Bands have been removed, but there is signal loss near the metal implant. Figure 2c) shows the sum of squares of Δθ = 0° and 180° phase cycled ±x, ±y, and ±z shimmed images; some signal close to the implant is recovered, but formerly on-resonant regions are now outside the imaging bandwidth. Fig. 2d) features the pixelwise maximum intensity of the unshimmed image in b) and the shimmed image sum in c). While there is still residual signal loss, significant signal is recovered near the implant when compared with b).

**Discussion** The potential for imaging near metals with bSSFP is bolstered by the recovery of signal close to a metal implant. Image combination artifacts are a concern when employing sum of squares and maximum intensity methods, and gradient strength should be chosen carefully to recover more signal. Future work will implement the shim orientations in a manner that will circumvent the necessity of phase cycling for band mitigation. Since each shimmed image displays image domain sparsity, the possibility for subsampling with compressed sensing [4] to minimize the shimmed data scan time is assured.

## Conclusion

When combined with bSSFP debanding via the GS, this shimming method introduces an important step towards comprehensive metal artifact correction near metals with bSSFP imaging.

**References**

[1] Xiang & Hoff, Proc. ISMRM, 18:74, 2010. [2] Bangerter *et al.*, MRM, 51:1038-1047, 2004. [3] Lustig *et al*., MRM, 58:1182–1195, 2007.