MAVRIC-SL with 3x2 parallel imaging and a hexagonally sampled calibration region

Bragi Sveinsson[1], Valentina Taviani[1], Kevin Koch[2], Garry Gold[1], and Brian Hargreaves[1]
[1]*Radiology, Stanford University, Stanford, CA, United States,* [2]*Applied Sciences Laboratory, General Electric, Waukesha, WI, United States*

PURPOSE: The MAVRIC-SL sequence (1) is used in clinical practice for imaging near metallic implants. The sequence collects multiple off-resonant 3D volumes acquired under a constant slab-selection gradient (which is a 3D generalization of the view-angle-tilting (VAT) principle (2)). The ability to reduce the duration of such scans by hexagonal undersampling (3) has been developed for scans using 2×1 parallel imaging (4). In this work, we demonstrate how hexagonal sampling can be applied to 3×2 MAVRIC-SL scans.

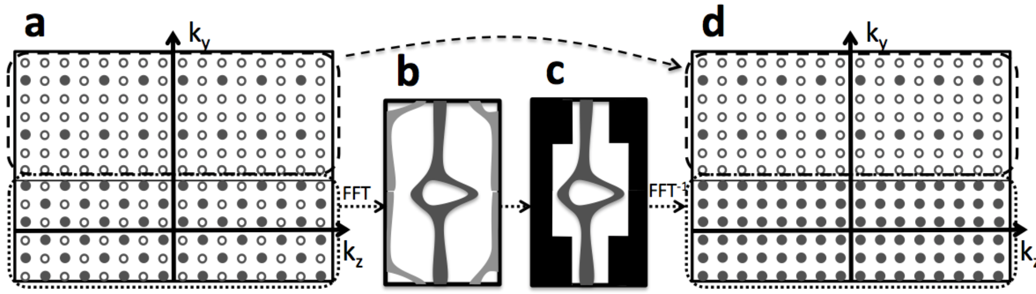

Figure 1: Reconstruction of the hexagonally sampled calibration k-space data from a 3x2 accelerated half-Fourier scan (enclosed by dots in a) results in an aliased low-resolution image (b). The aliases can be removed by masking (c) since they don't overlap with the desired object, and the resulting k-space data used as a fully sampled calibration region (d).

THEORY: MAVRIC-SL acquires multiple 3D volumes that are combined to form a final image. Each volume contains a distorted 3D slab profile. The particular shape of the distorted slab has previously been shown to allow hexagonal undersampling in ky-kz space without corrupting the image from aliasing (4). In parallel imaging scans, the calibration region can also be undersampled in a hexagonal pattern and the data then directly processed with a parallel imaging algorithm, resulting in aliasing in image space which can be resolved by a masking operation. This approach fails if applied directly to 3×2 parallel imaging (Fig. 1a) since the calibration region does not "fit" the undersampled outer k-space. However, by creating a low resolution image from the hexagonally sampled calibration region (Fig. 1b), masking out the resulting aliases (Fig. 1c) , and converting back to k-space, a fully sampled calibration region is obtained, and can be used for parallel image reconstruction (Fig. 1d).

METHODS: The method was tested on a 3.0T MRI system. First, a titanium/cobalt-chromium shoulder prosthesis immersed in agar was imaged with: 1. a normal 2×2 accelerated MAVRIC-SL scan; 2. 2x2 accelerated MAVRIC-SL with hexagonal undersampling of the calibration region; 3. 3(ky)x2(kz) accelerated MAVRIC-SL with a hexagonal undersampling of calibration region. Next, the method was tested in vivo by imaging a metal knee implant with a 3×2 MAVRIC-SL scan, with and without hexagonal undersampling of the calibration region. In both cases, 8 channel receive coils were used with 4 mm slices, 55% partial ky sampling, TR = 2.6-3.0 s, and TE = 17 ms.

RESULTS: Directly processing the k-space data from the 2×2 accelerated phantom scan with the hexagonally sampled calibration region followed by masking of the aliases in image space gave similar results (Fig. 2b) as when the calibration region was fully sampled (Fig. 2a). The same approach resulted in artifacts for the 3x2 accelerated scan (Fig. 2c), but these were resolved when the approach in Figure 1 was used (Fig. 2d). For the knee scan, directly reconstructing the k-space data from the 3x2 accelerated scan likewise resulted in poor image quality (Fig. 3b) compared to when the calibration region was fully sampled (Fig. 3a), which was resolved by using the approach in Figure 1 (Fig. 3c).

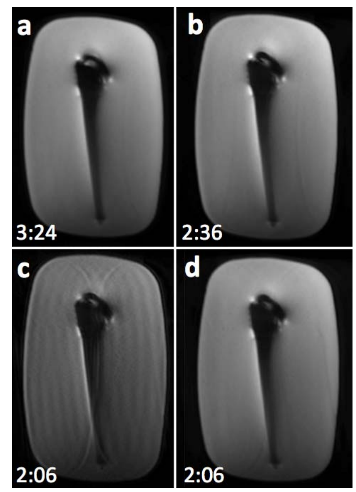

Figure 2: A 2x2 MAVRIC-SL scan with a fully sampled calibration region (a) and with a hexagonally sampled calibration region with masking done at the end (b). Similar 3x2 scan data yields poor results (c) unless the approach in Fig. 1 is used (d).

DISCUSSION: The proposed approach allows hexagonal sampling of the calibration region in MAVRIC-SL scans with arbitrary outer-k-space sampling patterns. Scan time savings are typically about 20% over parallel imaging alone, but this will increase with higher acceleration.

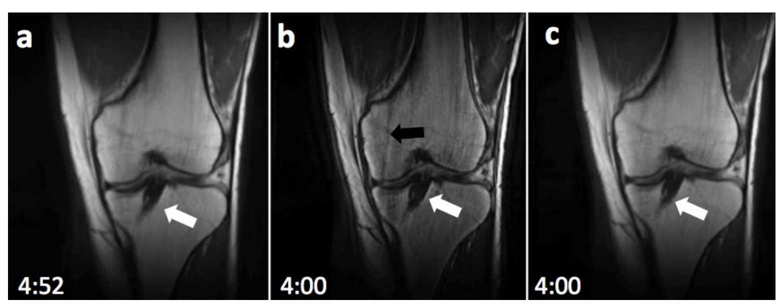

Figure 3: A 3x2 MAVRIC-SL knee scan with a metallic implant (white arrow) with a full calibration region (a). A hexagonal calibration region with aliases removed at the end of the image reconstruction (b) contains artifacts (black arrow), which are resolved with the approach in Fig. 1 (c).

CONCLUSION: Masking out aliases on a low resolution image obtained from a hexagonally undersampled calibration region allows hexagonal sampling of MAVRIC-SL scans at higher accelerations than previously demonstrated, reducing scan time by 20%.

REFERENCES: 1. Koch MRM 2011;65:71-82 2. Cho Med Phys 1988;15:7-11. 3. Kim SMRM 1990, 551. 4. Sveinsson ISMRM 2013, 557.

ACKNOWLEDGEMENTS: NIH EB002524, funding from GE Healthcare.