**Strategies for avoiding image artefacts when scanner is used for recording of non-MR signals**

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**Introduction:** It has been demonstrated earlier that non-MR signals such as electrophysiology can be recorded by an MR scanner using a method involving (1) modulation of the non-MR signals onto carrier frequencies in the detection range of the scanner, (2) emission of the signals as radio waves in the RF cabin and (3) detection by the scanner [1, 2]. Among other advantages, the method provides a simple way to record electrophysiological signals free of gradient artefacts during echo planar imaging (EPI). It is crucial that the MR images are not affected by the technique and consequently the preferred carrier frequencies correspond to positions outside the field of view (FOV). Even when this is fulfilled, there may still be ringing artefacts appearing in the MR images. We present two strategies for avoiding these.

**Methods:** The non-MR signals are amplified, amplitude modulated, and emitted in the RF cabin. The signals are extracted from the frequency distribution calculated for each EPI line sampling period, e.g., from 512 microsecond periods recorded every 560 microseconds. Since the non-MR signals are encoded at frequencies corresponding to positions outside the field of view, peaks corresponding to the encoded signals do not directly appear in the reconstructed MR images. However, the invocation of the Fourier transform in image reconstruction implicitly relies on periodic boundary conditions, i.e. signal continuity across the boundaries of each line sampling period. This condition is typically violated in MR imaging. Hence "voxel bleeding" appears which is normally a minor issue as signal contributions at the edges of k-space are small. The broadcasted non-MR signals, however, have significant amplitude at all times and hence at all points in k-space. Furthermore, the non-MR recordings benefit noise-wise from being transmitted with high amplitude. Significant ringing artefacts may therefore extend into the FOV even though the signals are encoded at frequencies corresponding to positions outside.

We present two strategies for eliminating these image artefacts: 1) suppression of signals at the edges of k-space by filtering, and 2) selecting frequencies so that all carriers go through an integer number of cycles during each readout period, which is the case if the scanner and modulator frequencies differ in frequency by an integer times the bandwidth per pixel (bpp). The first approach is readily available on most scanners as raw data filtering. It reduces sidebands in the spatial point spread function at a cost of central lobe broadening. Such filtering is often needed in fMRI analysis to fulfil statistical requirements, and the resulting spatial smoothing following from the artefact reduction is therefore normally acceptable. The second approach only requires from the scanner that the carrier frequency is constant during signal reception or that it changes by multiples of the bpp. This is normally easy to fulfil. This approach removes phase-discontinuities only, and for rapidly varying signals such as electrophysiological signals with imaging artefacts, gradient activity triggered sample-hold is therefore needed for this approach to be perfect. The two approaches were tested and compared using a Siemens Trio 3 Tesla whole-body scanner and a home-built 8 channel modulator with optional, unused triggering. A programmable signal generator provided well-characterized signals. These non-MR signals were emitted in the RF cabin during echo planar imaging with the parameters quoted above.

**Results and conclusions:** Fig. 1 shows MR images reconstructed from raw data, i.e. without discarding oversampled frequencies. Eight strong 30 Hz signals (each with 100 Hz bandwidth) are encoded outside the normal FOV. (Left) worst case timing without any artefact suppression, (middle) worst case with spatial broadening (Gaussian filter with full width at half maximum equal to half the acquired k-space width), and (c) modulator frequencies adjusted to the bpp. The encoded signals appear as broad patterns affecting image quality when the modulator frequencies are not adjusted optimally. Spatial filtering and frequency adjustment both suppress long range ringing. The methods do not require image reconstruction beyond what is already provided with most clinical scanners.

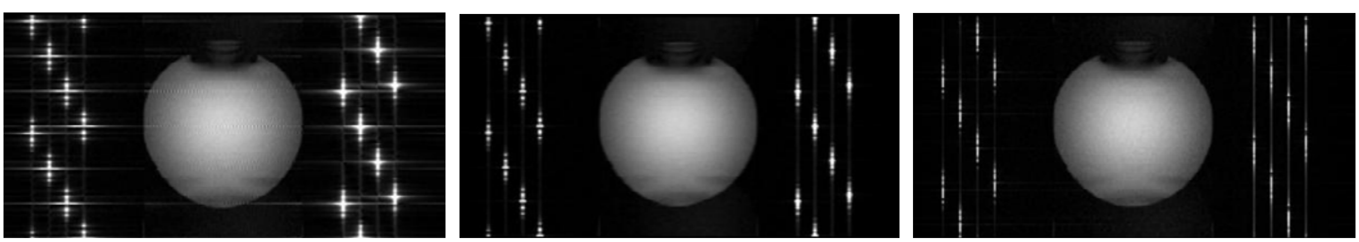

Figure 1: EPI images reconstructed offline from raw data. Eight 30 Hz signals are encoded outside the normal FOV. In contrast, images reconstructed by the scanner shows only the central 50% of the width due to default readout oversampling. Left: No artifact suppression. Middle: Raw data filtering. Right: Carrier frequency optimization.

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