The MFAMOUS technique: Electrophysiological signal recording by MR image acquisition

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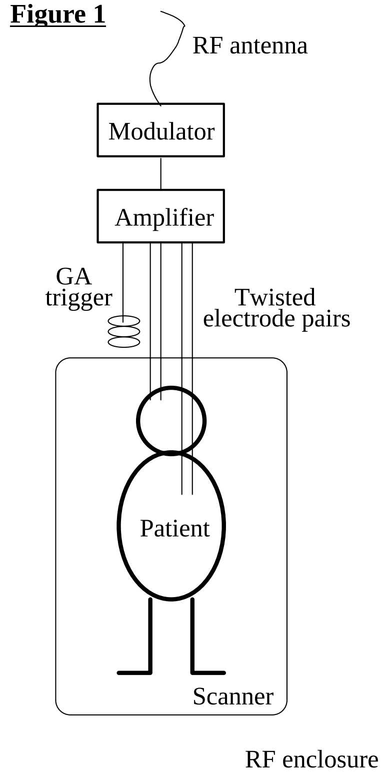
Introduction: Recording of electrophysiological (*eph*) data during MRI, *eph*MRI (e.g., encephalography, EEG), is problematic for several reasons. Gradient switching and RF cause severe signal distortion, a problem that is significantly reduced by sampling only in periods where gradients are constant [1]. This method requires microsecond synchronization between the scanner and sampling apparatus and it sets high demands for the sampling device. Here, we demonstrate that the scanner can be used for recording multi-channel *eph*-data whilst performing fast echo-planar imaging. The method is compatible with most existing MRI systems and sequences and relies on a new and conceptually simple technique, Multi Frequency Amplitude MOdUlation for Scanning (MFAMOUS), to transform the *eph*-signals into the RF-range detectable by the scanner. Low-power, battery driven hardware connected only to the *eph*-electrodes is used together with special processing of the MRI raw data.

Figure 1



Methods: Figure 1 shows the required hardware and arrangement. An MR-compatible 8-channel *eph*-amplifier with gradient-activity (GA) triggered sample-hold was constructed. The GA was detected using a simple coil positioned at the opening of the scanner. The amplified *eph*-signal was fed to a modulator that offsets, and amplitude modulates, the signals to distinct programmable frequencies near the Larmor frequency of a 3T Siemens Trio, whole-body MR-scanner. The signals were mixed and transmitted wirelessly to the standard head coil using a simple antenna in the scanner-room. The *eph*-signals were detected together with the proton RF signals emitted from the brain of the patient during fast echo planar imaging, TR=111 ms, echo spacing 0.56 ms, matrix 128x128, FOV 280 mm. Readout oversampling was performed to provide extra bandwidth for the *eph*-signals. As the MRI signal was sampled in the sub-millisecond EPI line-readout periods without gradient switching, the same was true for the *eph*-signals. For this reason, and because of the sample-hold circuit, *eph*-signals were largely undistorted by gradient activity. In order to reconstruct *eph*-signals and MR-images, the measured raw data was Fourier line-transformed once to form a spectrogram of signals with millisecond resolution, or twice to form normal MR images. The *eph*-signals are simply individual columns of the spectrogram.

To demonstrate the approach, an example is presented where a volunteer in the scanner was instructed to periodically alternate looking left and right without moving the head. Electrophysiological data was recorded simultaneously from two pairs of skin-electrodes located near the heart and eye musculature.

Results: Figure 2 shows the reconstructed *eph*-signals. The electrical activity of eye (top) and heart musculature (bottom) is clearly recognizable even though a hundred EPI brain images were acquired in the same period. The noise and signal distortions due to the magnetic field and cross-talk between channels can be removed by filtering. Even at kHz bandwidth, high signal-to-noise ratio is obtained when measuring known test signals. When the MFAMOUS frequencies were chosen appropriately the MR-images exhibit artifacts from the *eph*-recordings outside of the head region only.

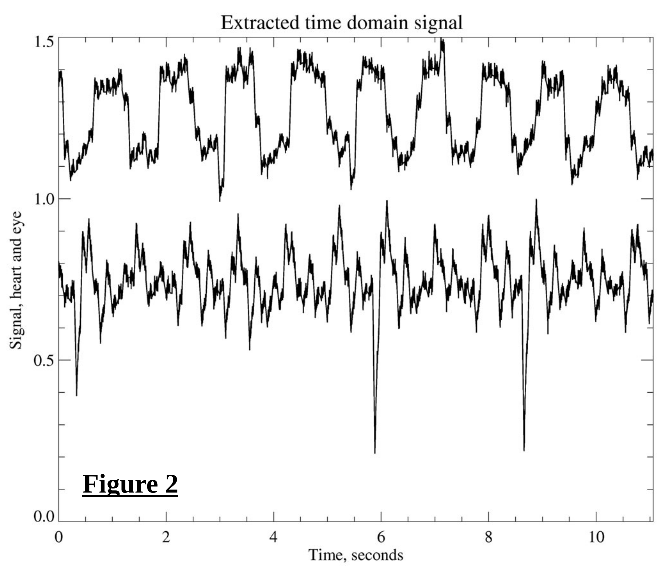


Figure 2

Conclusion: The surplus bandwidth of most MR scanners can be used for high-quality recording of any electrical signal originating in the scanner room, e.g. response recordings or EEG. Since the scanner provides the crucial high-bandwidth sampling, the additional hardware is relatively simple and low cost. Neither new signal paths, nor changes to existing hardware are required.

[1] Anami et al, Neuroimage. 2003 Jun;19(2 Pt 1):281-95