A multi-frequency amplitude modulator for encoding electrical signals in MR images

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Introduction: It was shown in [1,2] that electrophysiology and other non-MR signals can be measured by MR equipment after modulation to frequencies close to those of the MR-signals. After wireless transmission to the scanner, these signals were recorded in perfect synchrony with the image acquisition. Surplus sampling and storage capacity of the scanner were thus exploited for recording of electrophysiology while imaging-induced distortions were largely avoided. Here, a flexible modular 8-channel modulator constructed for the purpose is presented. Filters, gains, trigger timings and frequencies are controlled via an optical PC-link.

Methods: The non-MR signal recordings are high-pass filtered and pre-amplified (Fig. 1a). A gradient-activity sensor consisting of a simple coil near the opening of the scanner can optionally be used to trigger a sample-hold circuit with variable shutter timings, thus providing a means of avoiding large, rapidly varying signals induced by gradient activity (Fig. 1b). Subsequently the signals are highpass-filtered and amplified (Fig. 1c). The non-MR signals or a calibration signal generated internally in the modulator are selectively low pass filtered and are mixed with an RF carrier near the Larmor frequency generated by Direct Digital Synthesis (DDS) (Fig. 1d). The high-frequency output is amplified and emitted into the scanner room by a simple aerial (Fig. 1e). It is detected by the RF coil of the scanner and is extracted from the MR raw data. The eight carriers are generated from individual DDS based on a common reference oscillator. The filter settings, timings and gains are controlled via an optical PC-link. The system provides encoding of a wide range of signals in the 0-130 MHz range with 0.1 Hz resolution. The system was tested on Siemens Trio 3 Tesla scanner with known test signals generated from a tailored programmable signal generator.

Results and conclusion: Example ramp-sampling echo planar EPI measurements are presented in Fig. 2. The complete system is easy to use and it fits in a lunchbox (< 2 liter). Excluding computer and cables, it weighs 2 kg including batteries. Results acquired with the new hardware supports the claims [1,2] that image and signal qualities are not sacrificed by the method.

Fig. 1:

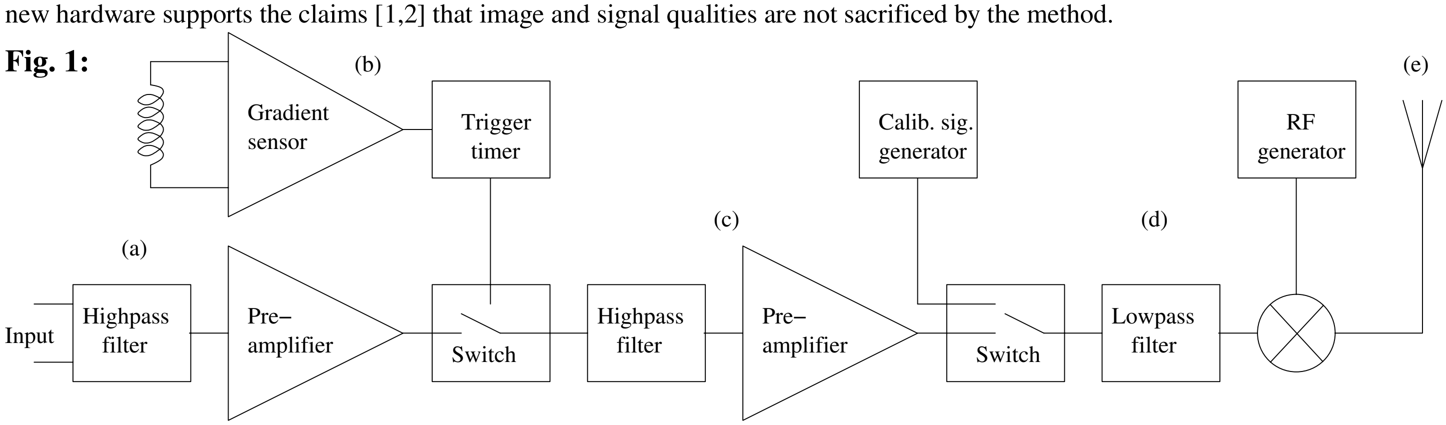
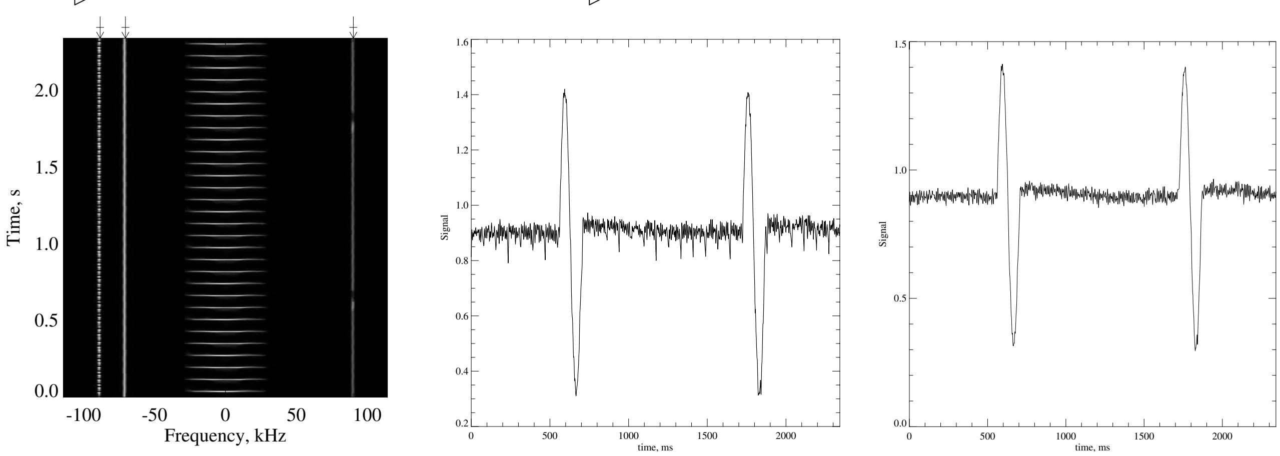


Fig 2:



Left: Spectrogram derived from EPI raw data (30 images) showing 3 encoded signals. Middle: One of these, an extracted, artificially generated ECG-like signal would have been dominated by readout gradient artifacts by a factor of two, if the gradient trigger had not been used as was done here. Right: Simple gradient artifact filtering removes the residuals. Time resolution: 0.5 ms, Filter: 100 Hz.

[1] Hanson LG;Lund TE;Hanson CG.Proc Intl Soc Magn Reson Med 2005, 1528.
[2] Hanson LG;Lund TE;Hanson CG. Neuroimage 2005, 26(1), 810.