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Introduction

Using a technique resembling the “mag-stripe” technique used for encoding soundtracks in movies, it has previously been demonstrated that non-MR signals such as electrophysiology can be recorded by an MR scanner. The method involves modulation of the non-MR signals onto carrier frequencies in the detection range of the scanner [1]. If the frequencies are chosen appropriately (i.e., corresponding to positions outside the field of view), the MR images are left unaffected. Among other advantages, the method provides a simple way to record electrophysiological signals almost free of gradient artefacts during echo planar imaging (EPI) [2]. Residual gradient artifacts are removed relatively easily due to the perfect synchronization of the noise source and the recording equipment (the scanner in both cases). We present redesigned hardware giving much improved results compared to earlier implementations, and we demonstrate that the technique is suitable for simultaneous EEG-fMRI recorded using rapid echo-planar imaging.

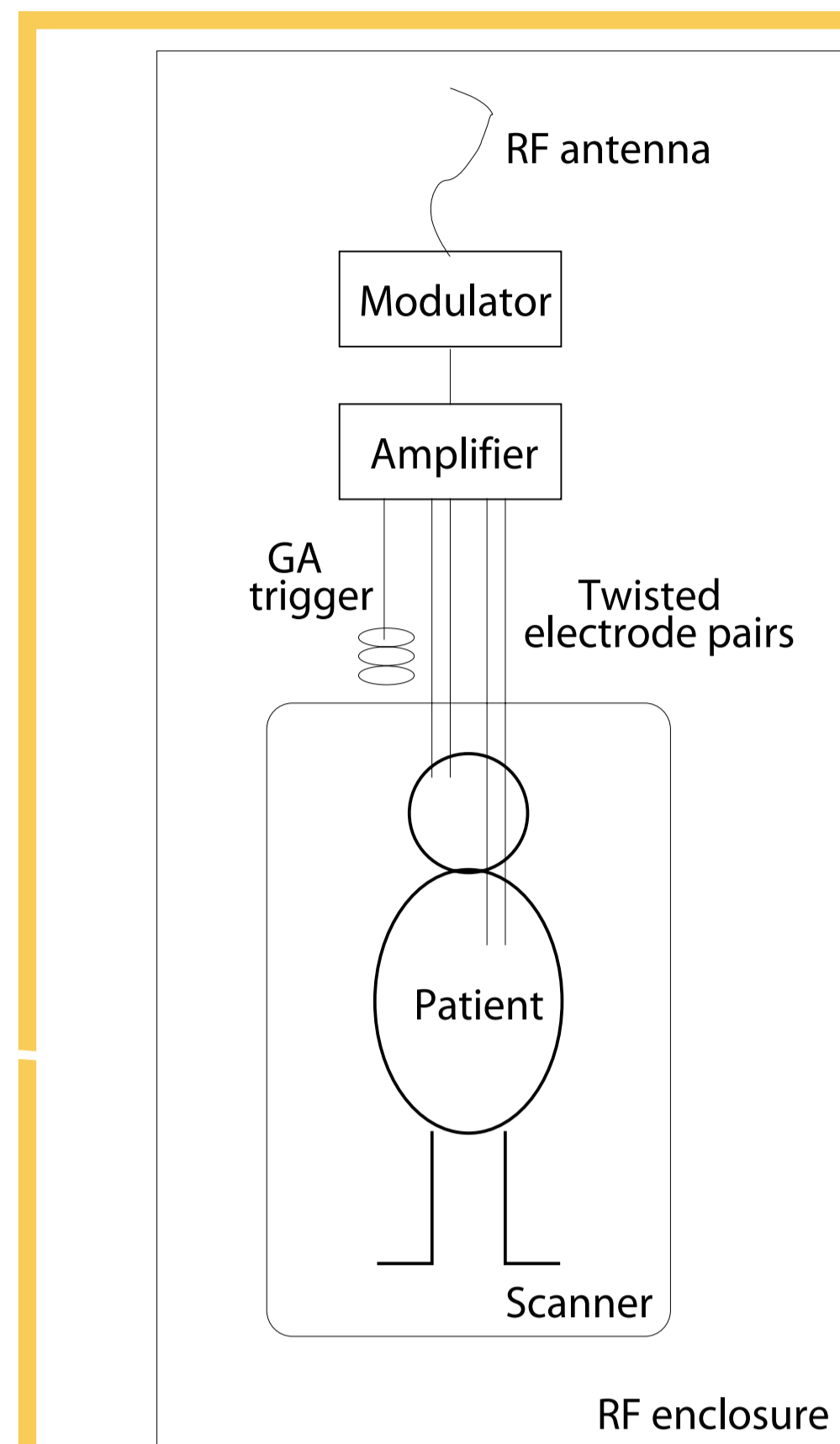


Figure 1: The setup.

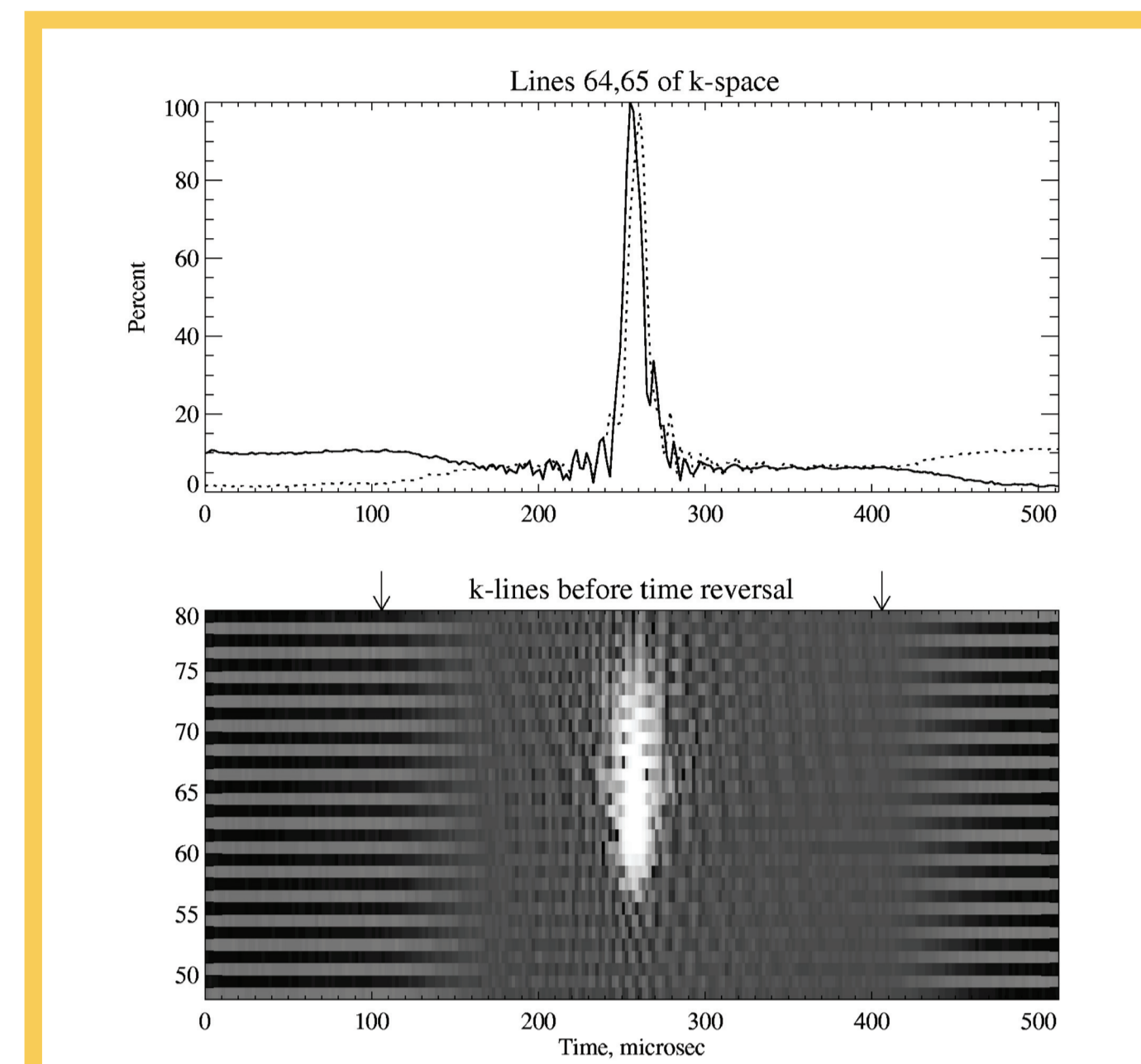


Figure 5: K-space view of an encoded signal influenced by gradient switching. Arrows indicate end and beginning of gradient switching for the used ramp-sampling EPI sequence.

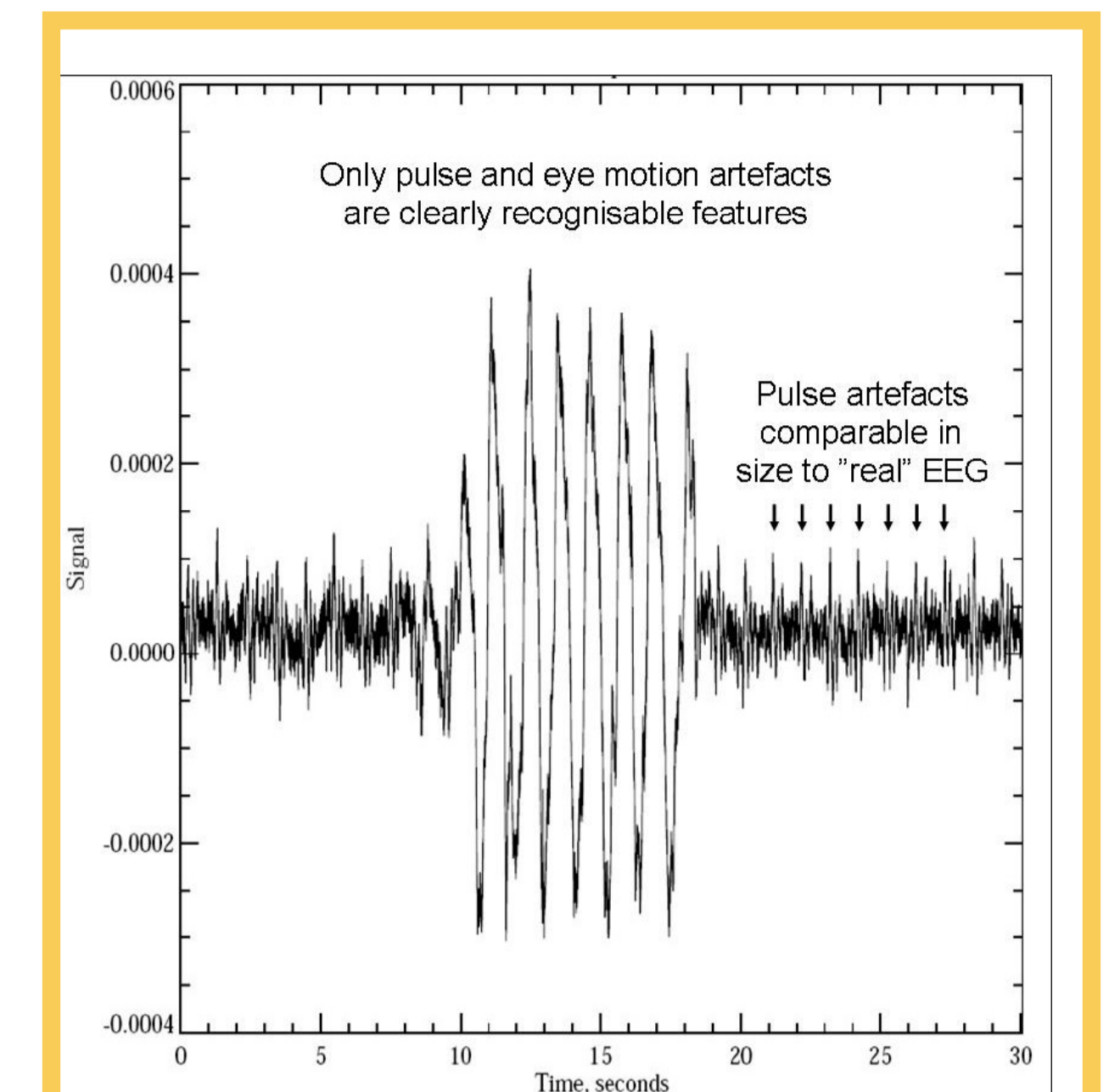


Figure 6: Example EEG recorded from positions F3-F4 during rapid EPI. Large muscular contributions are seen in the middle period where the subject was instructed to do eye movements. The 0.5 kHz bandwidth allows for further noise reduction by filtering.

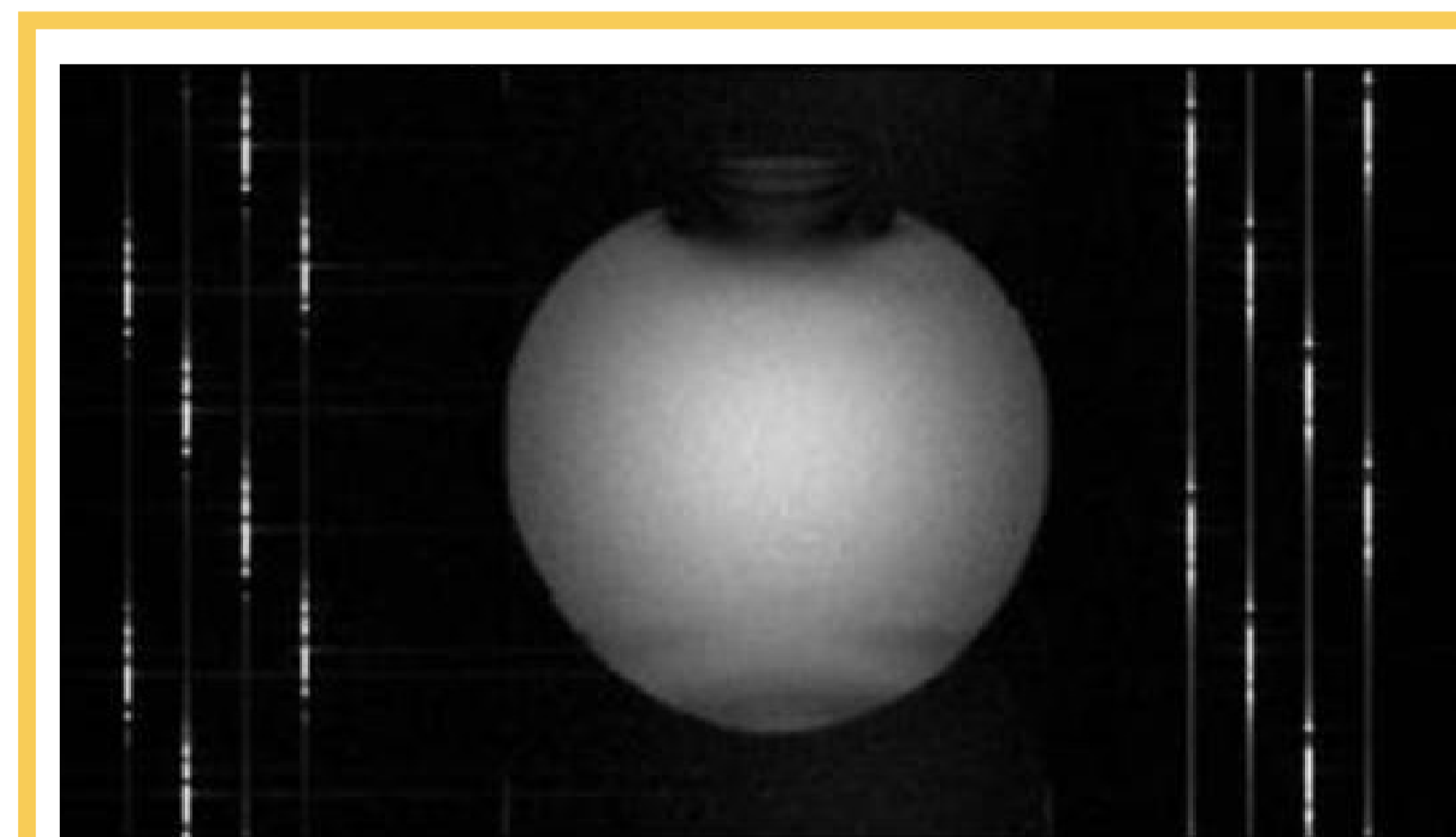


Figure 2: EPI image reconstructed offline from raw data. Eight 30 Hz signals are encoded outside the normal FOV. In contrast, images reconstructed by the scanner shows only the central 50% of the width due to default readout oversampling. The carrier frequencies are chosen so that ringing artifacts are avoided.

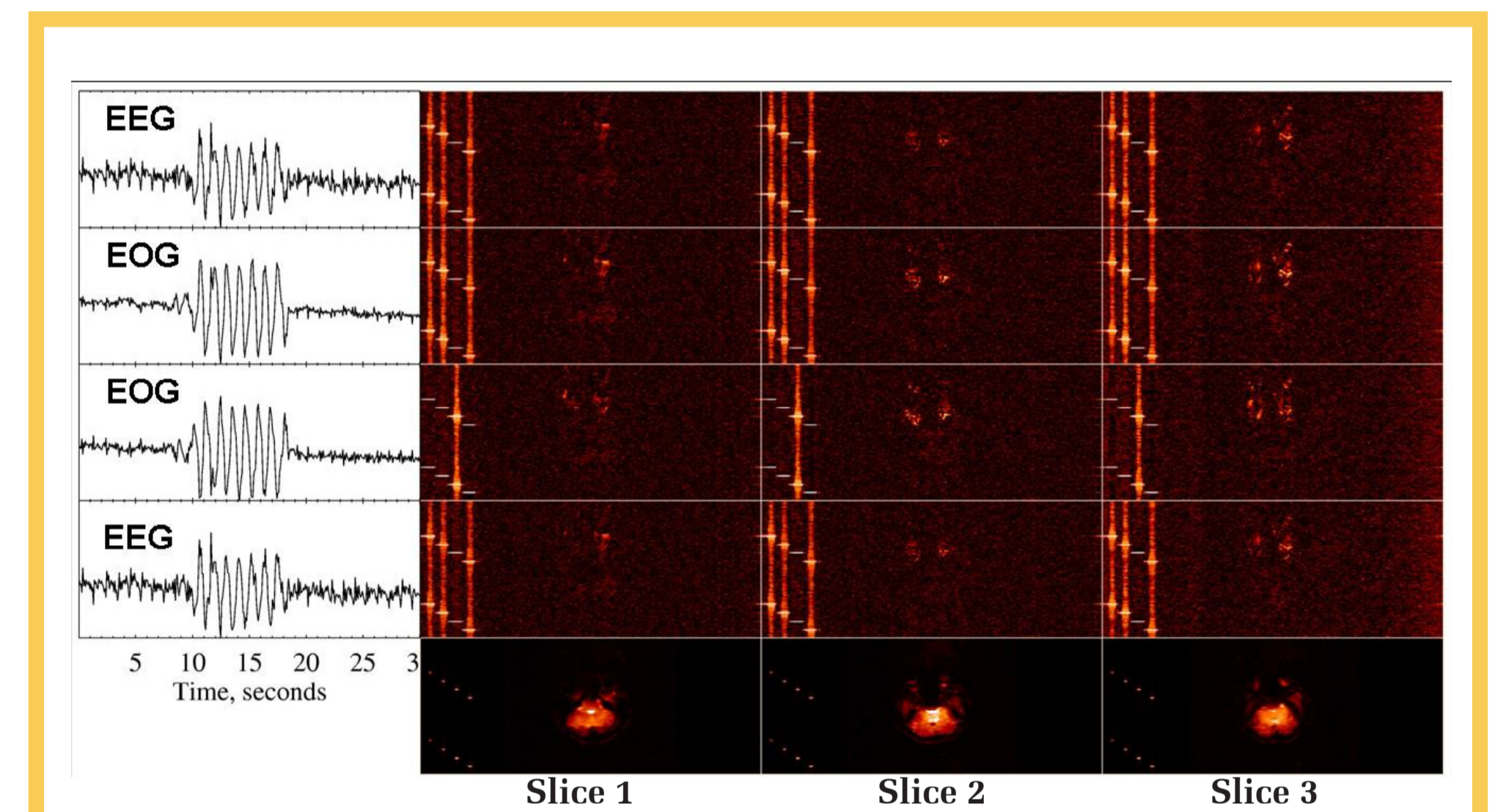


Figure 7: Spatial correlation maps for a 4 channel recording (figure 6 illustrates the corresponding F3-F4 recording). The spatial correlation is high in the eye region since the recordings are dominated by eye movement. It is also high in stripes outside the FOV (images reconstructed to full bandwidth, i.e., double FOV)

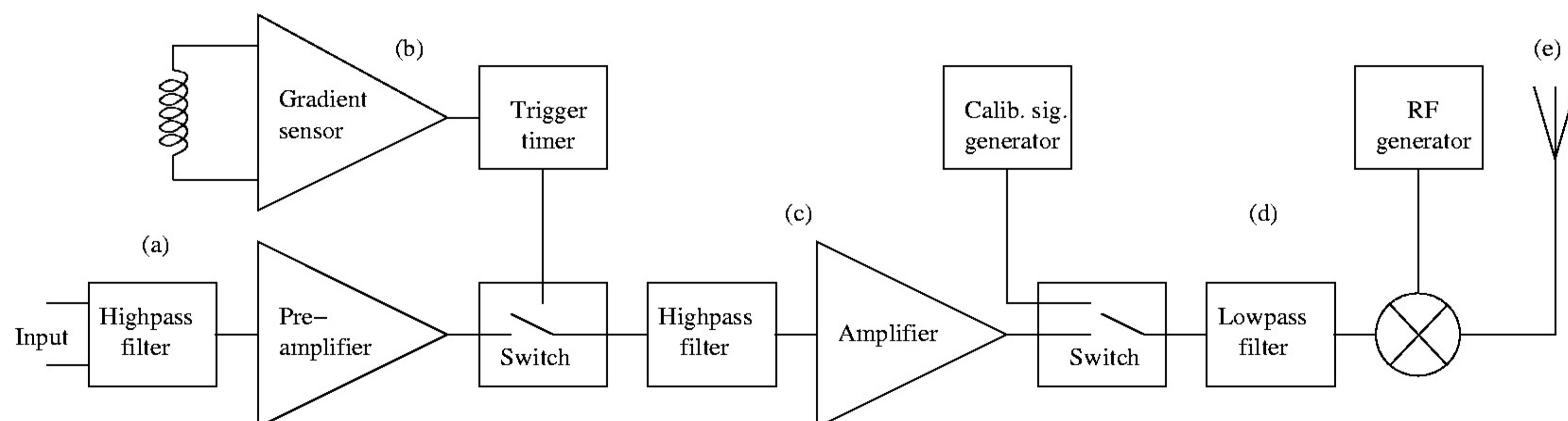


Figure 3: Diagram of one of the eight identical channels present on each circuit board. Multiple circuit boards can be controlled simultaneously via an optical interface so that many-channel recordings can be made.

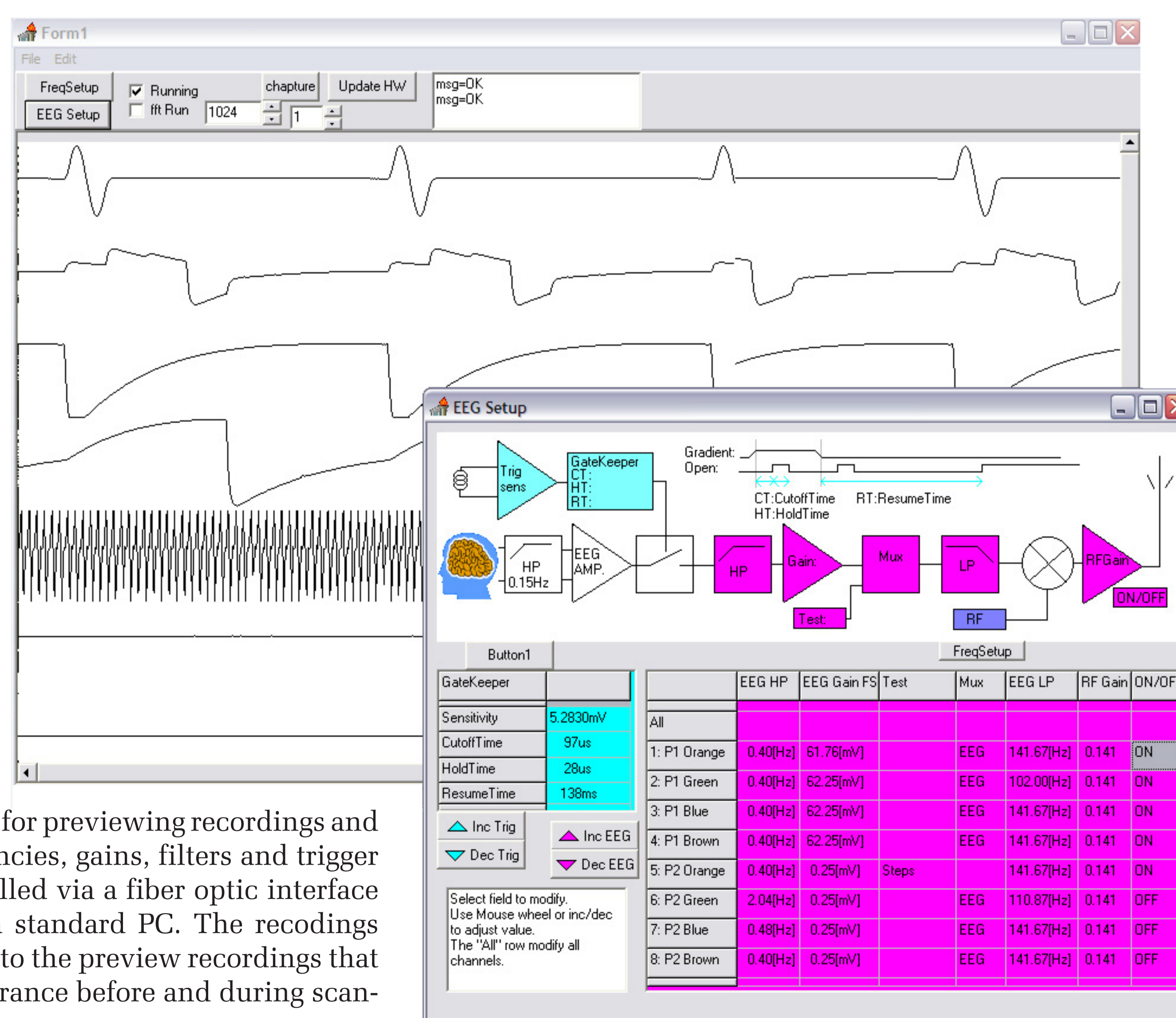


Figure 4: Graphical user interface for previewing recordings and controlling the modulator frequencies, gains, filters and trigger timings. The modulator is controlled via a fiber optic interface connected to the serial port of a standard PC. The recordings made by the scanner are superior to the preview recordings that are mostly useful for quality assurance before and during scanning.

Methods

The non-MR signals are amplified, amplitude modulated and emitted in the RF cabin. The signals are extracted from the MR raw data 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 appear in the MR images reconstructed by the scanner.

Results and Conclusion

Fig. 6 shows an example EEG recorded from positions F3-F4. Eye motion and pulse artifacts of size comparable to neural signals are clearly seen. The correlation maps in Fig. 7 show that only pixels outside the FOV are influenced by the encoded signals.

References

- [1] Hanson LG;Lund TE;Hanson CG.Proc Intl Soc Magn Reson Med 2005, 1528.
- [2] Anami K et al, Neuroimage, 19:281, 2003.

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