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Mary had a little Lamb: Scanner-recorded speech during MRI without gradient-induced sound

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Synopsis

During MRI, fast switching of imaging gradients generate loud noise of high intensity due to vibration of the gradient coils. The in-bore intercom used for patient communication is therefore typically turned off during scanning. This has implications for safety and image quality since patient speech and yells are not heard by the scanner operator. Using standard sequences, we demonstrate that sound can be recorded by MRI scanners and extracted from the scanners raw data, thereby enabling communication with patients for safety or experimental reasons.

Introduction

For most MRI sequences, acquisition is performed without ramp-sampling and therefore in silent periods. Using the scanner itself for acquisition of a sound signal alleviates timing challenges arising when using external equipment. This is however not directly feasible, as the filters of the scanner attenuates signal outside a narrow range around the Larmor frequency. However, by performing an amplitude modulation of the sound signal to a frequency close to the Larmor frequency allows the signal to pass the filters of the scanner, and the demodulation performed by the scanner restores the original sound signal except for a small frequency offset. The sound can then be extracted from the raw data of the scan. The constant timing between sampling and gradient waveforms allow for easy filtration of residual gradient induced noise in the sound signal. Using a dedicated receive channel of the scanner allow for sampling of the sound signal with high SNR and without interference from MR signals.

Method

Two 2" loudspeakers were sacrificed to make a simple MR-compatible microphone: A loudspeaker coil mounted on a membrane was placed in a tube inside the static field (B0) of the scanner. Membrane vibration thus generated a coil voltage, i.e. a sound signal. An identical coil with no membrane was mounted in series with similar orientation and close to the microphone coil to cancel out gradient-induced voltages. The coils were connected to a modulator circuitry developed previously[1] for amplitude modulation of non-MR signals for wireless recording by scanners. Due to a maximum carrier frequency of 130MHz producible by the modulator, the signal was send through a 200MHz mixer to reach the frequency range of the scanner (hydrogen at 7T, Siemens Magnetom). To remove any DC component, the modulated signal was sent via two inductively coupled coils, before reaching a receive channel of the scanner. A 50ohm resistor in parallel with the transmission line of the modulator made the setup recognizable by the scanner as a coil element. The sound signal was send by the modulator continuously, but only sampled by the scanner during acquisition periods. During a GRE sequence (256x128 receive matrix, 5 volumes) a subject was asked to repeatedly say out loud "Mary Had a Little Lamb" (chosen for melodramatic effect, as the verse was famously used by Edison for the first sound recording ever). Non-linearities from the modulator were compensated before the DC component was removed. The phase-locked noise from the read-out gradient and noise from the phase-encoding gradient were relatively easily estimated and subtracted. The non-equidistant sampling in time of the GRE sequence left periods without sound data. Autoregressive modeling across short subsets of the data, where the noise was assumed to be unchanged, was used to fill these gaps.

Results

A sound recording with easily recognizable repetition of "Mary Had a Little Lamb", acquired by an MRI scanner was obtained after removal of residual scanner noise. In contrast to direct audio recording, gradient noise is barely audible.

Discussion & Conclusion

Through the use of a homebuilt MR compatible microphone and amplitude modulation, we have shown it possible to record sound signals using a receive channel of an MRI scanner. The limited signal processing needed to obtain recognizable vocalization allow for fast signal processing, and thereby real-time oral communication with a patient during scanning. Here a separate channel of the scanner was used for receiving the sound signal. As previously shown[1], it is possible to transmit a signal wirelessly at a frequency in the oversampled range of the scan (sampled by the scanner, but not in FOV), and thereby receive the sound MRI signal on common receive channels.

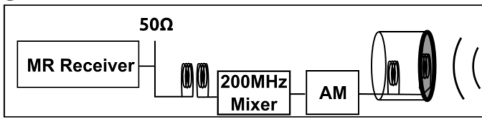
Acknowledgements

No acknowledgement found.

References

[1] Hanson LG;Lund TE;Hanson CG. Encoding of electrophysiology and other signals in MR images. J Magn Reson Imaging 2007, 25(5), 1059-1066

Figures



A loudspeaker coil mounted on a membrane, and an identical coil with no membrane was mounted in series with similar orientation and close to each other. The signal from here was passed to an amplitude modulator. To reach the frequency range of the scanner, the signal was then passed through a 200MHz mixer. To remove any DC component the signal was passed through two inductively coupled coils before reaching the MR receive channel. A 50ohm receiver in parallel allowed for the setup to be recognized as a coil element by the scanner.