Physical Simulation Study of Active Noise Control Up To 5 KHz

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Introduction

The noise generated during MRI scanning, which has long been recognized as a problem, is becoming a more critical issue as the sound pressure levels increase along with static magnetic field strength and faster scans. Various methods have been proposed to deal with the sound, including active noise control (ANC), which has attracted increasing attention as SPLs increase. It is well perceived that ANC technique is limited in treating high frequency noises. Nevertheless, some prior studies have demonstrated noise reduction both for simulated and *in situ* studies can be achieved at frequencies up to 2 kHz [1-2]. Here, we report significant noise reduction achieved using an ANC system tuned to control sound up to 5 kHz in stimulation studies.

Methods and Results

Several MR pulse sequences and the resulting sound near the patient's ear were simultaneously recorded during operation of a 4T Varian UnityINOVA whole-body MRI scanner. These signals were replayed in a sound quality chamber to simulate the MRI environment. A dummy was equipped with MRI compatible headphones. A microphone installed inside the headphones measured the sound pressure level (SPL) at the "patient's" ear, while another outside the headphones measured the SPL near the patient. A laptop with a dSPACE system was used to run the control system. Anti-aliasing and reconstruction filters were included in the experimental setup as well. The SPL at the "patient's" ear was measured during MRI scanning with and without the ANC system activated, and then compared.

The ANC system utilizes the FxLMS algorithm [3]. In order to preserve stability of the feedforward system, the effective frequency range is limited by the spectral characteristics of the reference signals. In this experiment, multiple copies of the algorithm were implemented in parallel and tuned to maximize reduction of a different portion of the frequency spectrum by adding high pass frequency filters to the reference signals. The resulting individual algorithm control signals are combined for the total control signal. The error signal, measured by the microphone located inside the earpiece near the "patient's" ear, is the sum of the original MRI acoustic noise and the control sound signal. This signal is to be minimized by the control algorithm. The sampling rate for the digital model was 10 kHz. Figure 1 shows the control system used to obtain these results. It utilizes four different reference signals; the Z (i.e. read-out) gradient, the unfiltered microphone, and two different high pass filtered microphone signals.

Figure 2 shows the experimental results comparing the SPL measured at the patient ear location with and without the ANC system operating. A total reduction of 31.8 dB is achieved up to 5 kHz by the ANC system alone. Other sequences showed similar reductions (data not shown). A patient's perceived reduction would be further enhanced by the passive reduction capacity of the headphones. Please note that the simulated SPL indicated in the figure, which was much lower than the actual measures, was scaled during the actual experimentation due to safety reasons.

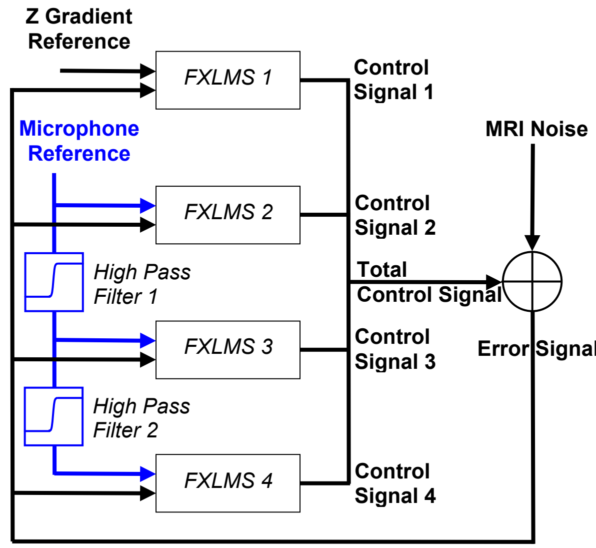

Figure 1 – Active Noise Control System with Filtered Reference Feedforward FxLMS Algorithms

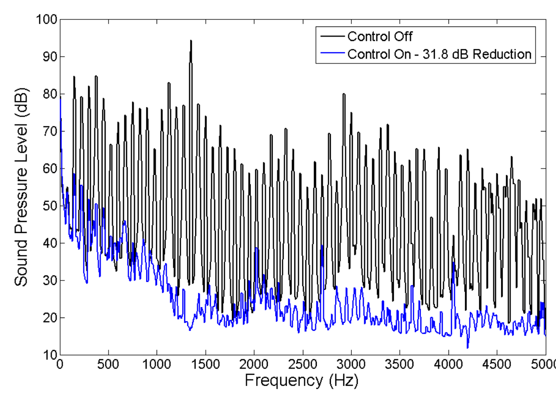

Figure 2 – ANC results for Simulated GEMS scan

Conclusion

A feed-forward ANC system has been tuned specifically to address MRI scanner noise at frequencies up to 5 kHz for MRI scans. While earlier studies have demonstrated the feasibility of ANC for MRI noise, this study demonstrates reduction to higher frequencies is feasible. The experimental results presented here were measured during simulated MRI scans with the ANC system operating in real time. Further research is being planned to demonstrate this ANC system during an *in situ* MRI scanning as well as evaluating at even higher frequencies.

References

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