

Sound Level Measurements in MR Scanners: A Comparative Study.

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Introduction

Exposure to acoustic noise inside MR scanners is a patient comfort, and potential safety, concern. The noise inside the scanner can increase with newly introduced pulse sequences, field strength, and magnet or gradient design. The FDA non-significant risk guidelines for noise in MR scanners are exceeded when the un-weighted (Z-weighted) sound pressure level exceeds the threshold of 140dB, or the A-weighted sound pressure level (with ear protection in place) exceeds 100dB. The A-frequency weighting replicates human ear response at low sound pressure levels. With the advent of new imaging techniques, which require high gradient fields and fast activation and deactivation of gradient coils, appropriate testing of the sound levels corresponding to pulse sequences becomes increasingly important. We report and compare results of the sound level measurements carried out at our site in clinical 1.5T and 3T, short and long bore MR scanners. The measurements were performed for typical “quiet” (i.e., conventional spin echo), and the “loud” FIESTA (i.e., True FISP) pulse sequences.

Methods

The sound level measurements were performed using calibrated free-field microphone connected via 10m extension cable to a hand-held analyzer (4189 microphone, type 2250 analyzer, Brüel&Kjær, Nærum, Denmark). The microphone was suspended in the isocenter of the magnet bore from the frame of the head coil. To avoid damaging the microphone the RF signal was turned off during the measurements. In each of the MR scanners sound levels were measured for two pulse sequences: spin echo (TR msec/TE msec, 350/20; matrix, 512×192; FOV, 24cm; slice thickness 6mm) and FIESTA (MinFull/12; 256×256; 12cm; 1mm). The measurements were repeated in the following General Electric MR scanners: 1.5T: a compact CXX4 magnet with TwinSpeed gradients and a long bore S3 magnet with BRM gradients; 3T: G3 short bore magnet with TwinSpeed gradients, and Magnex 3T94 with CRM gradients. On the 1.5T and 3T TwinSpeed systems, the measurements were performed in both zoom and whole body modes. The A- and Z- equivalent continuous sound levels were recorded by averaging over ~30sec time duration, 10sec after the start of the pulse sequence. Each measurement consisted of ten repeat recordings, and the corresponding mean and standard deviations were computed. The A-weighted sound levels were reduced by 25dB to account for a typical sound attenuation by ear plugs.

Results

Results of our measurements are shown in Figure 1. The average measurement precision among all A- and Z-weighted sound levels was $\pm 0.2\text{dB}$ (0.2%). The “loud” pulse sequence is on the average $7\pm 3\text{dB}$ louder than the “quiet” sequence. The sequences are on the average $16\pm 4\text{dB}$ louder on the 3T short bore scanners than the same ones on the 1.5T, with equivalent TwinSpeed gradients. The difference between 3T and 1.5T long bore scanners is significantly less, $-1.7\pm 1.2\text{dB}$.

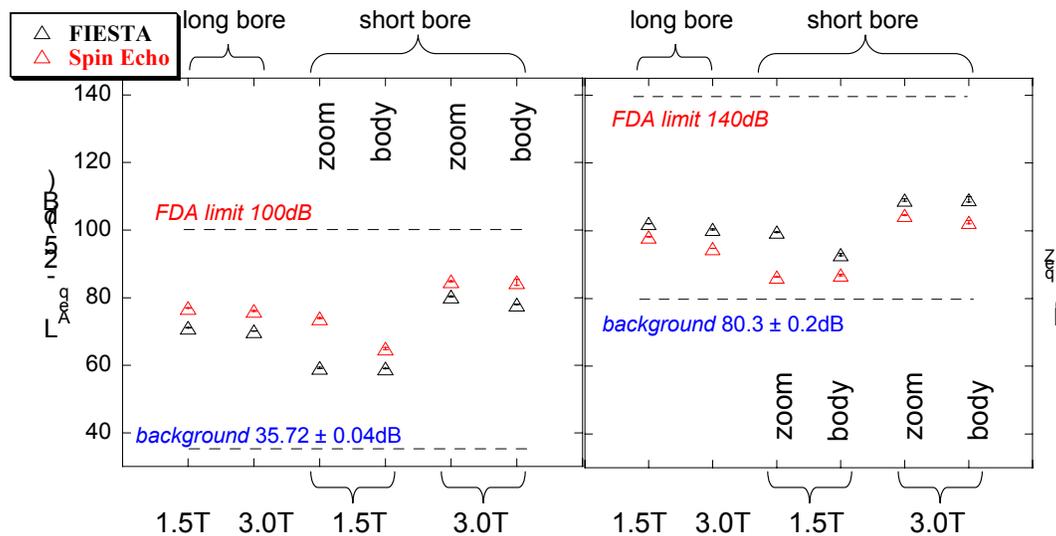


Figure 1: Measured continuous equivalent sound levels. The left panel displays A-weighted levels, LAeq. The right panel displays Z-weighted levels, LZeq. To account for ear plugs A-weighted levels shown are reduced by 25dB. Terms “zoom” and “body” correspond to acquisitions in the zoom and the whole body mode, respectively. Background indicated is a sound level measured inside a bore of a CXX4 magnet with no pulse sequence running.

Conclusions

The measured sound levels, even in case of the “loud” sequence, are well below the FDA recommended thresholds. On short bore systems with TwinSpeed gradients, going from 1.5 to 3T resulted in increases in acoustic noise well above the expected 6dB value. In contrast, on the long bore scanners, the noise decreased somewhat when going from 1.5 to 3T. We speculate that the significant noise increase on 3T short bore scanners may be caused by less efficient vacuum isolation on that system. On the other hand, the slight decrease in noise in 3T long bore may be due to the much higher mass of the Magnex 3T94 magnet, which may have a damping acoustic effect.