Acoustic Noise on 1.5 T MRI Systems: Worst Case and Comparative Measurements

David L. Price[1], Janet P. De Wilde[1], Annie M. Papadaki[1], Jane S. Curran[1], Richard I. Kitney[1]
[1]MagNET, Department of Electrical Engineering, Imperial College, Exhibition Rd, London, UK;

Introduction

Acoustic noise has become a serious safety concern for both patients and workers present in the scan room. MRI scanners produce noise levels that can cause temporary shifts in hearing threshold. This can lead to irreversible damage if repeated over time. Acoustic noise can also contribute to patient stress. IEC-601-2-33 (1) recommends hearing protection be used if the scanner can exceed an Leq of 99 dB(A),. where the Leq is the A-weighted sound pressure level (SPL) averaged over at least one minute of the pulse sequence. In this study we present acoustic noise measurements on the latest 1.5 T systems. This work is part of an on-going survey of acoustic noise levels on systems from 0.2 T to 3 T (2). Here we focus on 1.5 T systems because they are the loudest in widespread use. We have measured acoustic noise for system-specific 'worse case' fast imaging sequences and for a set of comparative sequences.

Manufacturer	Model	Gradient System	Maximum gradient amplitude mT/m	Maximum gradient slew rate mT/m/ms	Sequence Type/TR/TE/SW -/ms/ms/mm
GE	iMR	Echospeed 120	23	120	FSPGR/2.5/635/2.0
Marconi	Eclipse	PD-250	27	72	FAST/2.2/315/4.0
Philips	Intera	Master	23	105	FFE/2.0, 3.7/262/4.0
Philips	ACS-NT	Powertrack 6000	23	105	FE/2.2, 5.0/348/4.0
Siemens	Symphony	Ultra	20	80	TrueFISP/3.0/6.0/4.0
Siemens	Symphony	Quantum	20	80	TrueFISP/2.1/4.5/4.0
Toshiba	Excelart		23	46	FE /3.5/312/5.0

Table 1: 1.5 T MRI Systems: Gradient Specification and 'Worse Case' Sequences

Methods

Acoustic noise measurement methods were performed using a sound measurement kit (Casella CEL, Bedford, UK). This consisted of an integrating sound level meter (CEL–275) and omni-directional air condenser microphone (CEL-192). The microphone has been extensively tested and shown to be insensitive to the magnetic environment. A 10 m extension cable was used to connect the microphone placed inside the head coil to the sound level meter in the console room via a wave-guide. A flood-field phantom was placed at the iso-centre with the microphone offset by 8 cm in the z-direction. During the survey, maximum and minimum and median measurements were made of the instantaneous SPL dB(A). The Leq over 1 minute was also recorded on most systems and was found to be close to the median SPL. The systems surveyed together with their gradient specifications are shown in table 1. Four pulse sequences were selected. The first was a 'worse case' specific to each system (also shown in table 1). This was designed to give users an indication of the maximum hazard during clinical imaging. The sequence is the same as that used for the MagNET fast imaging test. In this test the manufacturer is asked to devise a 2D imaging sequence that images a fixed volume with the maximum number of slices in the minimum time. Certain parameters are specified by MagNET; the FOV must be 250 mm and the imaging matrix must be 256 x 256, the slice width (SW) must be less than 5.0 mm and a range of 200 mm must be covered with contiguous slices. All the manufacturers chose sequences of the fast gradient echo type. As far as possible identical spin echo (SE), fast spin echo (FSE) and 3D gradient echo (3D GE) pulse sequences were run on each system (table 2). These are not the noisiest but enable a direct comparison to be made.

	TE (ms)	TR (ms)	Matrix	FOV (mm)	Flip	SW (mm)	Slices
SE	15	450	256 x 256	320	n/a	4	10
FSE (ETL=4)[1]	15	4000	256 x 256	320	n/a	4	10
3D GE [2,3]	9	23	160 x 256	170	30^0	1	10

1- For Siemens Symphony TE = 12, ETL = 3

2- For Siemens Symphony Ultra TE = 10.3, TR = 25 and for both Symphony Ultra and Quantum Slices = 16

3- Marconi Eclipse TE = 5, FOV = 160 x 220

NB: No comparative sequences were evaluated on the Philips ACS-NT

Table 2: Comparative Sequences

Results and Discussion

The results shown in figure 1 demonstrate that acoustic noise levels for 'worse case' sequences are above or just below the IEC limit of 99 dB(A). The exception to this is the noise level of 83.5 dB(A) on the Toshiba Excelart which features the Pianissimo noise reduction system. The results also illustrate the efforts of other manufacturers to reduce acoustic noise. The noise for the worst case pulse sequence on the Philips Intera (tested in 2000) is approximately 3 dB(A) less than measured on the ACS-NT (1997) whilst the noise level on the Siemens Symphony with Quantum gradients (2000) was 9.4 dB(A) lower than on the Symphony with Ultra gradients (1998). This was despite the fact that in both cases the 'worse case' sequences run on the newer systems featured shorter TE and TR times. These are expected to increase noise (2). The 3D GE sequence was the noisiest of the comparative sequences for all but one of the tested systems. However there was much more variation in noise levels measured on the SE and FSE sequences. The noise levels for 3D GE varied from 94.1 to 76.4 dB(A) whereas for the FSE they varied from 99.5 to 67.3 dB(A). Overall the results demonstrate that acoustic noise levels for fast sequences at 1.5 T require the use of hearing protection on most systems although efforts at noise reduction by manufacturers are having some effect. Noise values can also vary quite dramatically from manufacturer to manufactuer even with an identical sequence.

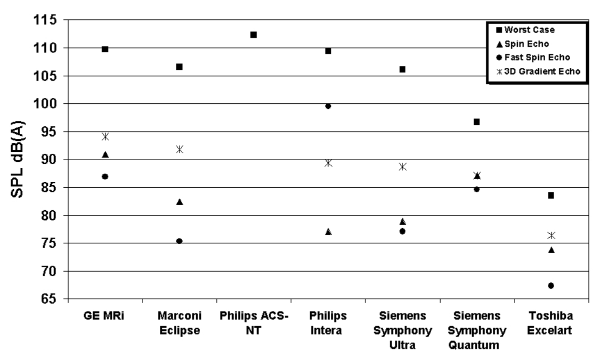

Figure 1: Median SPL dB(A) for 1.5 T MRI Systems

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References

(1) IEC 601-2-33:1995 (Medical Electrical Equipment. Part 2. Particular Requirements for Safety. Section 2.33 Specifications for Magnetic Resonance Equipment for Medical Diagnosis)

(2) D.L. Price, J.P. De Wilde, A.M. Papadaki, J.S. Curran, R.I. Kitney: An Investigation of Acoustic Noise on 15 MRI Scanners from 0.2 T to 3 T. J. Magn. Reson. Imag. (In the Press)