Characterization of the Acoustic Noise Response of a 4T MRI Scanner

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Introduction

The rapid pulsed gradient magnetic field used to achieve fast imaging causes significant vibrations of the gradient coils and surrounding structures leading to unacceptably high levels of acoustic noise emission. The high level (~130 dB) that is directly proportional to the gradient amplitude and magnetic field [1] can result in problems ranging from simple annoyance and communication difficulty to more crucial concerns such as anxieties and permanent hearing loss [2,3]. Furthermore, the acoustic noise can degrade image quality due to the oscillations resulting from the coupling between the gradient coils and magnet [4]. To be able to control the high noise level produced by the Lorentz forces as the result of the rapid current switching, a more thorough understanding of the frequency characteristics of the MRI sound field is needed, which forms the basis for this study.

Method and Results

A Varian UnityINOVA 4T whole-body MRI scanner was utilized in this experimental study. The sound pressure data was acquired using a pair of special purpose, nonferrous microphones (B&K 4189 with Nexus conditioning amplifier type 2690) placed at various locations of interest including the patient ear positions. The sound pressure signals were recorded with a TASCAM digital audio tape recorder, and subsequently processed using a computer workstation. The digitized data was then analyzed in both time and frequency domain applying an advanced sound quality and signal processing tool that is also equipped with various types of digital filters.

The acoustic noise spectrum shown in Figure 1 illustrates the existence of not only harmonics (1,2,3,…) but non-harmonic tones (0) as well. In addition, the response also possesses a fairly significant level of broadband energy as shown in Figure 2 that compares the residual spectrum after the tones were filtered out to the room background level. A comparison of the relative contributions of these 3 forms of response measured can be seen in Table 1. Furthermore, an example of the effect of scan parameters such as TE on the noise levels at the patient ear positions is shown in Figure 3.

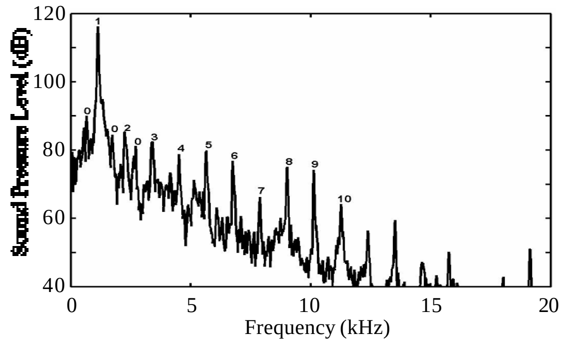

Fig.1 – Presence of harmonics (1,2,…) and non-harmonics (0) in the MRI noise

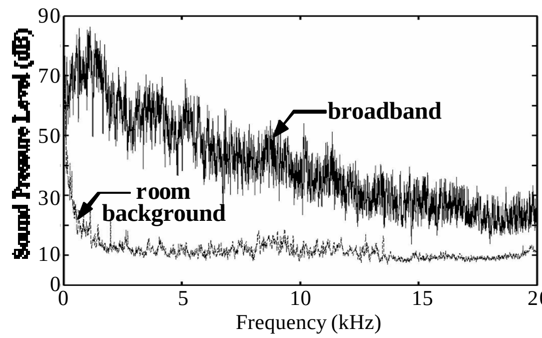

Fig.2 – Comparison of room background and broadband MRI noise

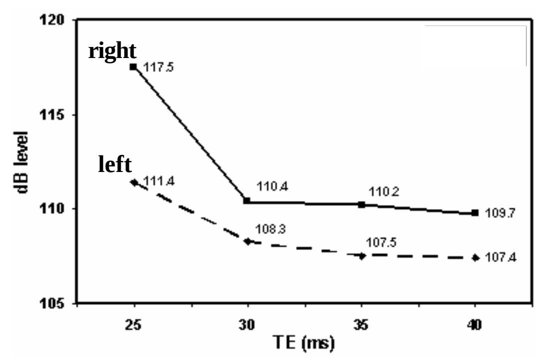

Fig.3 – Noise levels at right/left ear positions

Table 1 – Original and filtered noise levels

Case	dBA	Loudness (phon)
Original	117.7	127.6
Harmonics Filtered	104.7	113.5
All Peaks Filtered	99.0	111.0

Conclusion

Our analysis of measured sound pressure level produced by a 4T MRI scanner using EPI sequences reveal 3 types of excitations. The imaging condition, echo time and gradient amplitude are also found to affect the levels and the spatial distribution of the sound emitted. Gradient excitations produced both harmonic and non-harmonic tones as well as broad band noise in this unique environment. Further experiments will be conducted to identify the precise noise source and obtain a quantifiable relationship between the sound field and the imaging parameters. In addition, numerous noise control measures will be examined to determine the effectiveness and practicality.

References

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