Sound Level Comparison between Insert, Whole Body, Composite Gradients

K Craig Goodrich[1], Seong-Eun Kim[1], Robb Merrill[1], Yong Wang[2], Richard Wiggins[1], J Rock Hadley[1], and Dennis L Parker[1]
[1]*UCAIR, University of Utah, Salt Lake City, Ut, United States,* [2]*Otolaryngology, University of Utah, Salt Lake City, Ut, United States*

Introduction: Composite gradient systems (insert + body gradients operating simultaneously) can provide a 3 fold increase in gradient performance but also result in an increase in acoustic noise power. We have measured sound pressures levels (SPL) comparing operation of the MR gradient system in 1) insert only mode, 2) whole body gradient mode and 3) composite mode operation. Details of the head/neck gradient were published at last year's meeting[2]. We have previously shown gradient composite mode imaging can be done with triple the gradient field strength and one third the rise times of our standard whole body gradients without significantly increasing peripheral nerve stimulation[3].

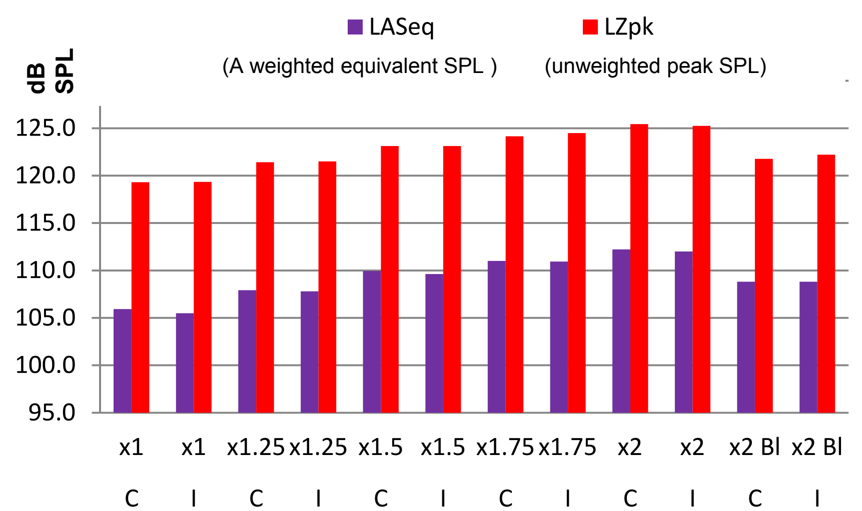
Methods: SPL was measured in a Siemens 3T TIM Trio scanner (Siemens Medical, Erlangen Germany). The microphone of a Larson Davis LxT2 SPL meter was placed in a RF head coil next to a spherical 17 cm NiSO4 H2O phantom. **Exp1:** Using the 3 gradient modes described above during a standard 3 plane GRE localizing scan, a CISS sequence and single shot EPI. Each pulse sequence was run to acquire images at 250mm FOV,128x128 matrix, isotropic in-plane resolution. **Exp2**: Using the loudest composite sequence from Exp1, we varied receive bandwidth (BW), rise time and field of view (FOV). **Exp3**: Using the loudest protocol from Exp2, we measured pressure levels while increasing the insert's amplitude and slew rate from equivalent to body gradients to double the body gradients yielding a total composite gradient strength triple that of body mode alone. **Exp4**: Using the loudest protocol from Exp3 we attempted to reduce SPL with placement of insulation within the bore[5].

Results: **Exp1**: Insert only gradient operation produced the highest SPL for the pulse sequence tested at identical resolution. Standard 3 plane GRE localizer during axial image acquisition had the highest SPL of the 3 sequences. GRE: 118.1dB/106.3dB, CISS: 115.5dB/107.6dB, EPI: 118.0dB/93.3dB (unweighted peak SPL/A weighted equivalent SPL, all in insert only mode). We noticed a SPL increase at 125Hz for operation of the body gradients with the insert mounted in the bore even when the insert was not used for imaging. **Exp2**: Faster rise times, higher BW and smaller FOV increases SPL. The loudest sequence tested was the axial scan of the 3Plane GRE 125 mm FOV, 3.5mm slice thickness, 1780Hz/px BW, fast gradient mode. **Exp3**: As expected, increasing the gradient field increases SPL, see Fig 1. **Exp4**: Sound levels were reduced by at least 3dB with a sound insulation (R5 vinyl backed 1.5" fiberglass) between the insert and the imagers bore (last 2 columns of Fig 1).

Figure 1: SPL values from 3 plane GRE sequence in Exp3 where current to the insert was increased from equal to body gradients (x1) to double the body gradients (x2) in 25% increments while keeping the body gradient contribution fixed at its maximum. Values plotted are for composite (C) and insert only (I). SPL plotted in last 2 columns are for operation with an insulating blanket (Bl) at maximum insert gradient strength (x2). Body gradients alone for this protocol would have produced a 250mm FOV in all cases.

Table 1: FOV(mm) vs Insert/Body gradient ratio

Insert / body	x1	x1.25	x1.5	x1.75	x2
C (comp)	125	111	100	91	83
I (insert)	250	200	167	143	125



Discussion: Although FDA standards[4] limit peak unweighted sound pressure levels in an MR scanner to less than 140dB, we chose to also report A weighted equivalent sound pressures since that is a better indicator of potential hearing damage. Nevertheless, the loudest sequence tested at the maximum gradient strength and slew rate of our system was much less than the FDA 140dB peak limit. We expect to attenuate the sound pressure by 25 dB using earplugs or earphones, and at least another 10dB reduction optimizing insulation within the magnet bore. Fig.1 shows that insert operation is responsible for most of the SPL in composite mode. Advantages of composite gradients include higher gradient strength, faster rise times, reduced echo times, decreased gradient lobe spacing, and decreased PNS relative to body gradients alone. We have now shown composite mode gradients have lower SPL than insert only mode at the same spatial resolution allowing inclusion of the body gradients with negligible increase in SPL levels over insert alone.
Future work will include characterizing SPL resonances of the insert and composite systems to avoid pulse sequence parameters that induce high SPL. Sound pressures will be measured for all protocols prior to human imaging to insure safe sound pressure operating levels. Optimal Gradient design needs to avoid geometry, material, and dimensions that resonate at imaging frequencies. Ideal construction might include suspension of gradient conductors in a vacuum.

References:

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