Acoustic Noise Model Development and Verification for a Gradient Coil Insert in a 4T MRI

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Introduction

Ongoing development of magnetic resonance imaging (MRI) technology is resulting in ever more powerful scanners, with high static magnetic field strength (7-8T) and high gradient coil current switching speeds. It is generally acknowledged that a serious limiting factor in the development of these machines is the acoustic noise that they generate during scanning [1]. Considerable efforts have gone into the design of "quiet" gradient coils [2]. Finite element analysis (FEA) as well as vibro-acoustic computational methods have also been used to estimate the acoustic noise distribution of the gradient coil during scanning [2, 3]. However, not all the models were verified through experimental testing. Based on a validated FE model, an acoustic noise analysis model was developed to predict the acoustic noise behavior of the gradient coil. The acoustic model was verified through acoustic noise measurement in a 4T MRI under swept sinusoidal excitation. For further verification, comparisons were performed using results from the acoustic noise model and experimental noise measurements under two different types of trapezoidal excitement input sequences.

Materials & Methods

An acoustic noise analysis model was developed using LMS SYSNOISE. In this analysis, we assumed that the gradient coil insert was installed in a 4T Varian/Siemens MRI. A relatively fine modeling mesh was created to meet the requirement of at least 6 acoustic elements per wavelength of the highest frequency being modeled, thereby ensuring the accuracy of the solution in the frequency range of interest. There were a total of 2240 elements used in the model. The velocity response computed by the FE model with boundary constraints (mimicing the true operating conditions) was imported and then added onto the corresponding node in the acoustic model. To verify the acoustic model, experimental acoustic noise measurements were conducted when the gradient coil was in operation condition. Measurements were performed with a GRAS free-field ½ inch condenser microphone with integrated preamplifier. Acoustic signal was recorded using a data acquisition and analysis system and processed with MATLAB®. The excitation signal was programmed in the control console and then output to be amplified prior to driving the coil. To match these conditions in the acoustic model, current was only applied to one coil (X coil) without any current to the Y and Z coils.

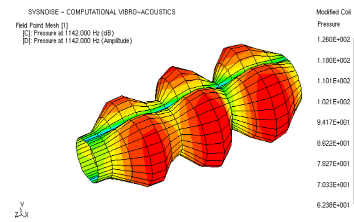

Figure 1: The computed sound field distribution at 1142Hz

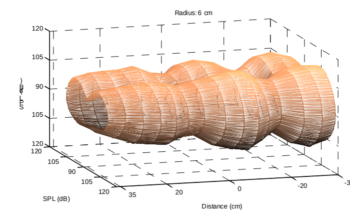

Figure 2: The measured sound field distribution at 1100-1200 Hz

Results & Discussions

For ease of comparison, model measurement points were defined to match the experimental measurement point locations (on the surface of imaginary cylinders with radii of 6cm and 10cm). The overall sound pressure level (SPL) distribution within the gradient coil insert shows that there are three dominant frequency bands where the SPL is much higher than at other locations. In general, the SPLs at radius 10cm are much higher than those at radius 6cm. This demonstrated that the acoustic noise is radiated from the inner surface of the gradient coil insert. Another phenomenon is that the SPL in the horizontal direction on the same surface is higher than that in the vertical direction, which is caused by the applied Lorentz force on the X coil. Figures 1 and 2 show the SPL distribution in the frequency range from 1100 to 1200 Hz both from model prediction and acoustic measurement. It is clearly shown that the acoustic noise distribution profile and the amplitude are in close agreement. The similarities of the acoustic noise distribution profile both from the model prediction and measurement at other frequency bands also show that the acoustic model developed can predict the noise distribution accurately. More predictions were conducted with two types of trapezoidal pulses with base frequencies of 500 and 1000Hz. Figure 3 shows the predicted SPL over the frequency range of interest compared with measurement results as well as estimated results using frequency response functions (FRF). It is noted that the predicted SPLs at the three dominant harmonics are very close to those from measurement and estimation. Again, the model predicts accurate results.

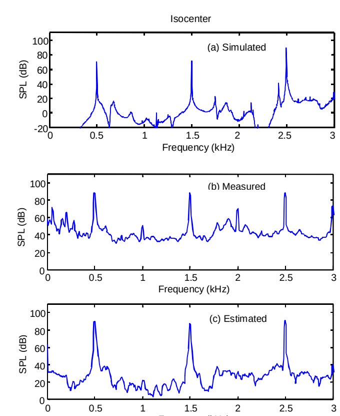

Figure 3: The comparison of responses for type A pulse (500 Hz)

Conclusions

A comparison of the SPL distribution from the acoustic model and noise measurement showed that the predicted acoustic distribution profile using swept sinusoidal excitation input was very close to that from acoustic measurement. The accuracy of the acoustic model was validated. The validation of the acoustic model was verified further through the comparison of prediction and measurement results under two different types of trapezoidal pulse input sequences.

References

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