# General method for acoustic noise reduction by avoiding resonance peaks

**J. Smink[1], G-J. Plattel[1], P. R. Harvey[1], and P. Limpens[1]**
[1]Philips Medical Systems, Best, Netherlands

## Introduction

Magnetic Resonance Imaging has several side effects that can reduce patient comfort, for example SAR, Peripheral Nerve Stimulation (PNS) and acoustic noise. The first two can be mitigated by simply slowing down the sequence. SAR can be reduced by using a lower b1 amplitude or by increasing the repetition time (TR). Similarly, PNS can be reduced by reducing the gradient amplitude and/or slew rate. For acoustic noise it is often assumed that by reducing the gradient strength or slew rate, the noise will be lower. However, it may occur that by reducing the gradient performance, the timing of the sequence will be affected such that its frequency content coincides with one or more of the mechanical or acoustical resonance frequencies of the scanner and the acoustic noise actually increases [1],[2].

## Methods

Experiments are performed on several types of cylindrical and open scanners on field strengths 1.0, 1.5 and 3.0 T. The goal was to achieve acoustic noise reduction by changing the timing of the sequence such that the acoustic resonance peaks of the scanner are avoided. In our approach we first predict the sound pressure level (SPL) of a sequence by calculating the product of the gradient waveform spectrum and the frequency transfer function of the scanner [3]. By using longer echo spacing in EPI or TSE, or increasing the TR in other scans, the spectrum condenses towards lower frequencies. In a first order estimate, the number of peaks and their amplitude will remain the same, they only move to lower frequencies. With this assumption it is straightforward to predict the gradient spectrum for a range of different timings, for which the SPL can be calculated. Changing the timing is generally undesirable. In EPI scans the sensitivity to off-resonance mechanisms increases while for other scans the scan time becomes longer and the contrast may change. To avoid too drastic changes the predicted SPL is multiplied with a weighting function, favoring small noise improvements at limited cost over bigger improvements at high cost.

## Results

A gradient echo scan with a TR of 2.4 ms has a gradient spectrum with a first peak around 420 Hz, see figure 1. By increasing the repetition time, predicting the gradient spectrum and calculating the SPL, the graph in figure 2 is obtained. The algorithm searches for a minimum value in the weighted SPL curve. At a TR of 2.7 ms, the reduction in SPL is predicted as 11.0 dB. It is interesting to note that for longer repetition times, the acoustic noise will become higher again. The actual gradient spectrum for the TR of 2.7 ms is shown in figure 3. The first peak has moved to 370 Hz. Even lower predicted values of the SPL, around a TR of 3.6 ms and 4.5 ms are considered as less desirable due to the weighting factor. With the proposed increase in TR by just 14% applied, the actual SPL reduction is 8.7 dB.

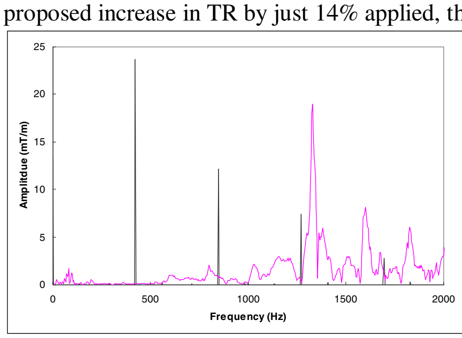


Figure 1. Gradient spectrum (readout direction) of a gradient echo scan with a TR of 2.4 ms, the frequency response function is shown in the background.

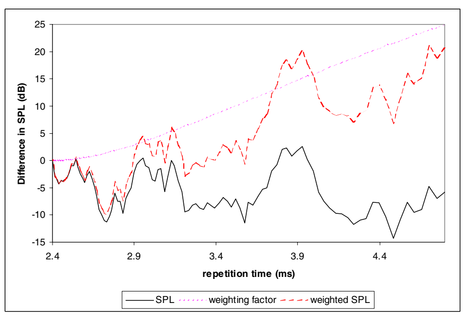


Figure 2. Prediction of the SPL reduction for a range of repetition times.

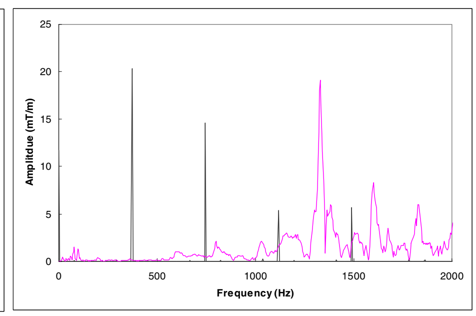


Figure 3. Gradient spectrum (readout direction) of a gradient echo scan with a TR of 2.7 ms, the frequency response function is shown in the background.

Our algorithm has been applied to the standard database of protocols as used on a standard 3.0T scanner. In about one third of the protocols, the protocol parameters allowed to change the timing. A histogram of the reduction in SPL after avoiding the resonance frequency is shown in figure 4. The average decrease in SPL was 3.9 dB.

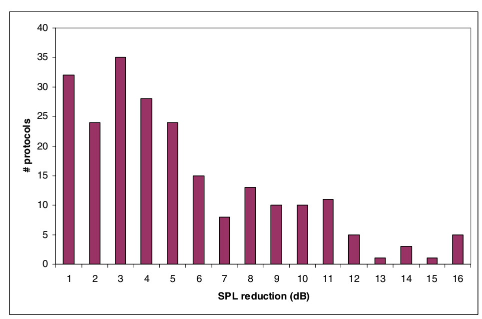


Figure 4. Histogram of the reduction in SPL after avoiding resonance peaks on a database of 225 protocols.

## Conclusion

This algorithm is flexible and automatic. It can be applied to any scan as long as the protocol definition allows some freedom in the timing. Protocols with a single dominant frequency in the excited spectrum are efficiently optimized with respect to acoustic noise, without significant penalties. Other scans with a rich spectrum like GraSE or multi-shot EPI contain a large number of peaks and are thus difficult to optimize.

## References

[1] L.S. Petropoulos et al., ISMRM fourteenth scientific meeting, Seattle, 2006: 2048
[2] S. Schmitter et al., ISMRM fourteenth scientific meeting, Seattle, 2006: 2814
[3] R.A. Hedeen, W.A. Edelstein, Magnetic Resonance in Medicine, 37 (1997) 7-10