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SUMMING MAGNETOMETER OUTPUTS IN AN ELEKTA VECTORVIEW FOR NOVEL PURPOSES

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Introduction

We have created an extra-sensitive magnetometer by directly summing the outputs of the 102 magnetometers in our MEG helmet (Elekta VectorView). That is, we have "tied together" many small magnetometers to make one large magnetometer, with better signal/noise ratio (S/N). We have used this novel instrument for two purposes: 1. To measure the thermal magnetic noise generated by the inner permalloy layer of our magnetically-shielded room (MSR). This small noise sets the limit of magnetometer sensitivity in such MSRs; it has been calculated (1,2) for other shielding geometries, but was never calculated or measured for MSRs. 2. To measure the MEG from deep evoked auditory brainstem signals. The idea was to see if we can more rapidly measure the small suppressed signal which normally takes an uncomfortable 30 min of averaging.

1. INNER-LAYER WALL NOISE

The setup is shown in Figure 1, where the idea is to measure the magnetic noise in the x-direction due to the two vertical yz walls, right and left. We assign different weights to each magnetometer, depending on its angle to the x-axis, as seen in Fig.2.

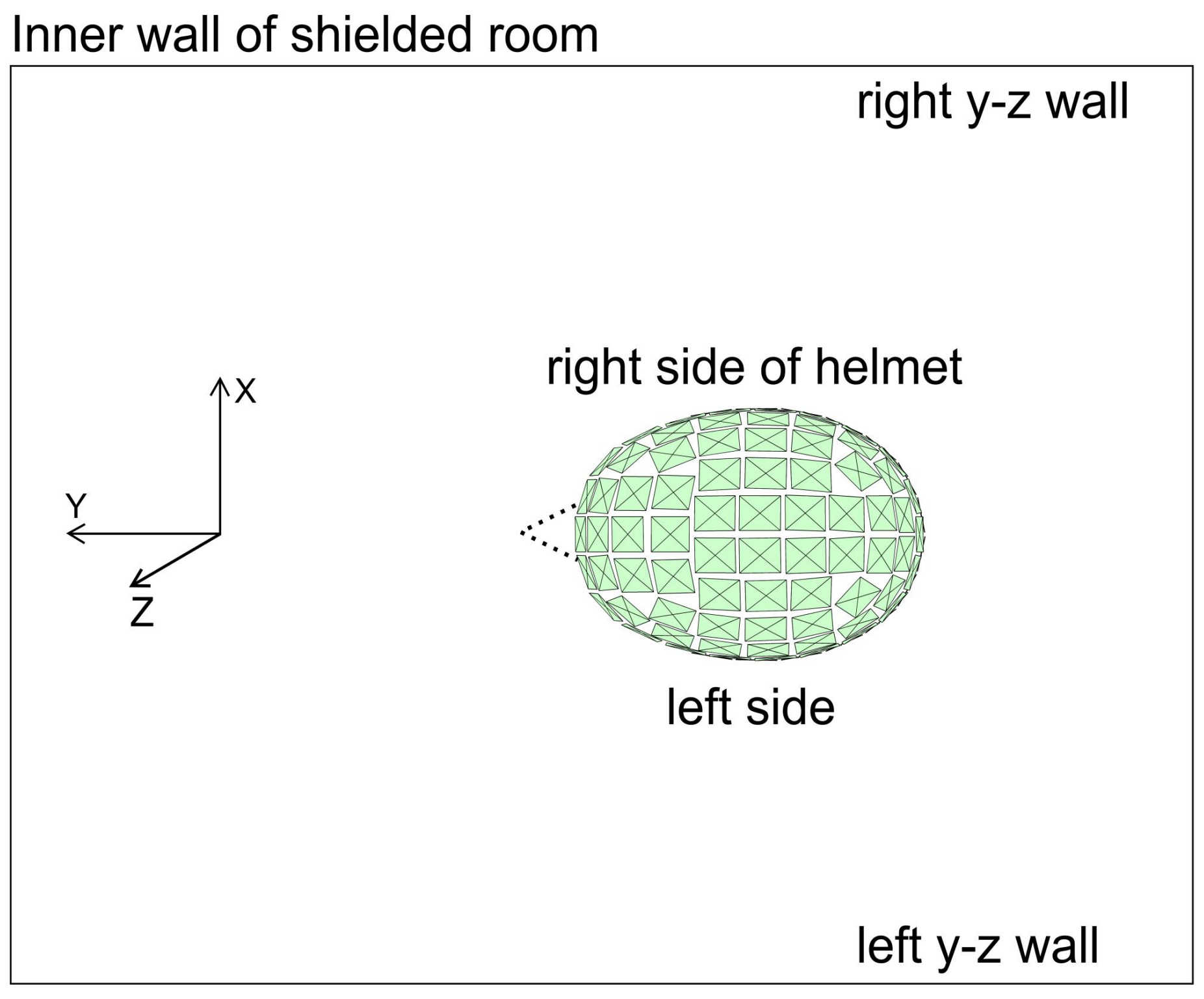

Figure 1. Looking down on our MSR, containing the MEG helmet with 102 magnetometers, here made disproportionately large. The right-hand and left hand group of magnetometers are summed separately.

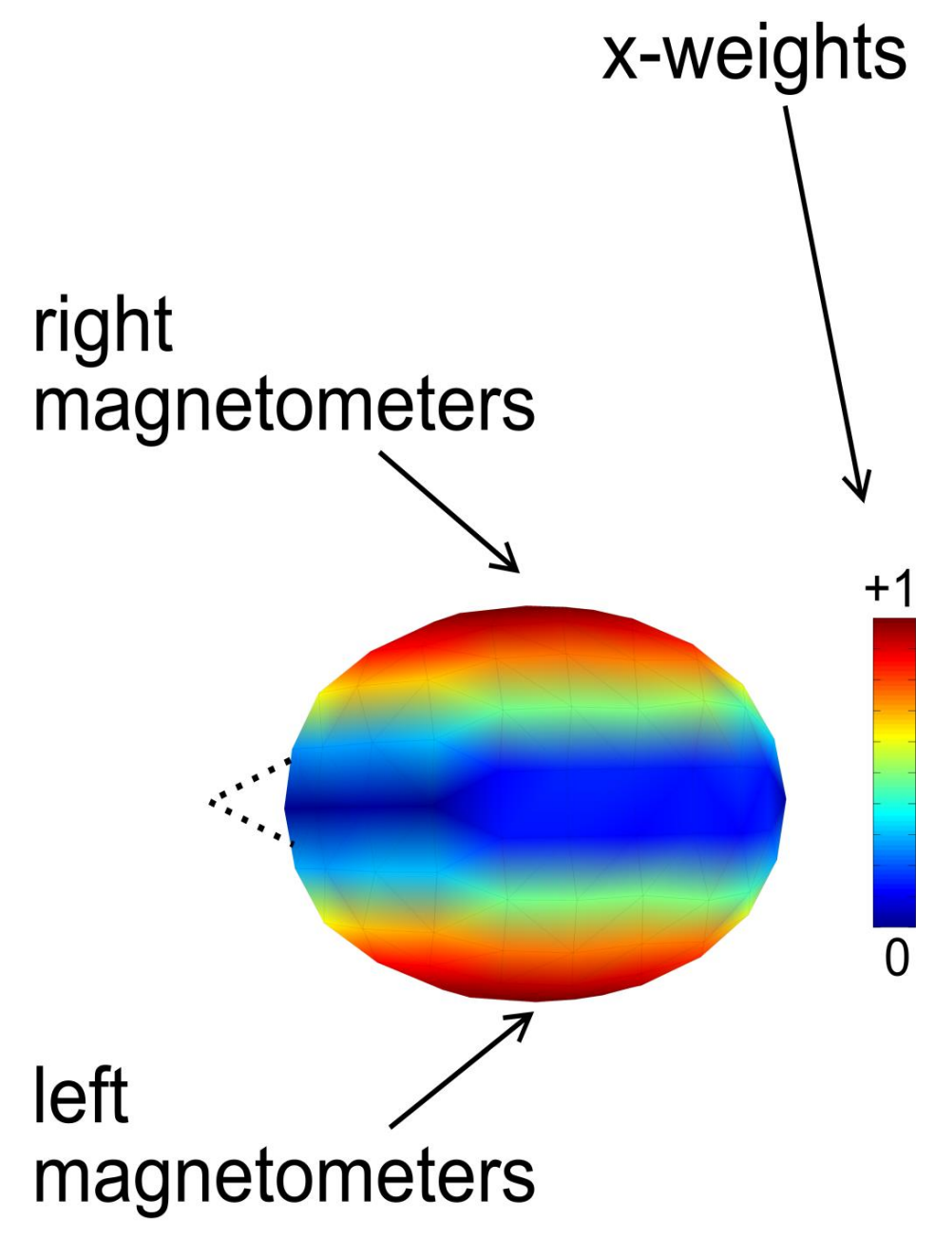

Figure.2. Each magnetometer is assigned a weight from 0 to 1, depending on its angle to the x- direction.

We sum the right and left magnetometers separately, to create two separate large magnetometers, right and left, each with an effective area of about 25 small magnetometers, hence with a S/N increase of about 5 They can be either in the l-r cancelling mode, or in the summing mode. In the cancelling mode, the grand output is roughly due only to the summed internal noise from each magnetometer (about 3 fT/$\sqrt{\mathrm{Hz}}$, including rf shield noise). In the summing mode, the grand output is due to the internal noise plus the noise of both right and left walls. This wall noise is then approximately calculated as the summed minus the cancelled output, thus approximately eliminating the internal noises, leaving only the wall noise.

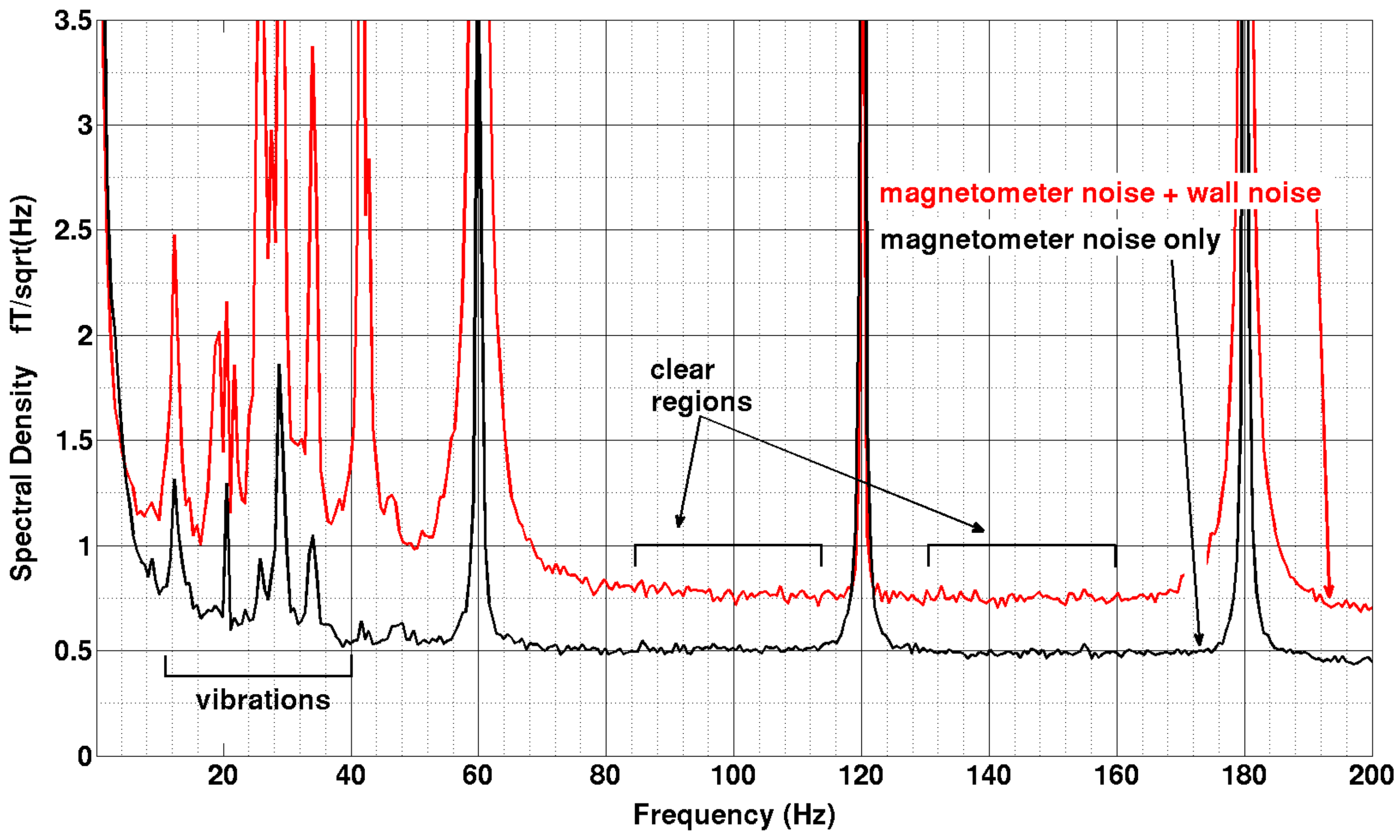

Figure 3. Raw data of wall-noise measurement, after a 20-minute recording at 4 AM, when the building is vibrationally quietest. The difference between the two curve, in the clear regions without power-line or vibration contamination, indicates the wall noise.

Frequency analysis of the data is shown in Figure. 3. Mechanical vibrations are responsible for the peaks below 40 Hz. Although the lower curve is not supposed to show external noise or signals, this is only approximate, because of the x-separation between the left and right magnetometers.

So we look at the clear regions to extract out data, which we see are the values 0.76 and 0.50 fT/$\sqrt{\mathrm{Hz}}$. Subtracting these in quadrature, we obtain: Wall noise in the x-direction, near the MSR center, due to both left and right walls, is 0.57 fT/$\sqrt{\mathrm{Hz}}$. Compare this to ~3 fT/$\sqrt{\mathrm{Hz}}$, the Elekta value of their magnetometer system noise.
We conclude that this system noise can be much reduced before MSR noise becomes a problem !

2. BRAINSTEM MEG

We use a traditional brainstem auditory stimulus, about 10 click/sec to the left ear, using only one normal male adult subject. First we looked only at the EEG, using an EEG bandpass of 180-1500 Hz, to see if his signal was normal. Then we used our standard MEG to look at magnetic brainstem signals after 30 min of averaging. Our guide was ref. #3. Our sampling rate was limited to 3KHz and the upper low-pass limit was 993 Hz. One large clear peak was seen at about 3.0 msec. About 6 magnetometers showed this latency as a large positive peak, so we simply summed these as our "large" magnetometer. From the 30-minute data we determined the best amplitude of this peak (5.5 fT) and always used that number.

Results are shown in Figures 4 and 5.

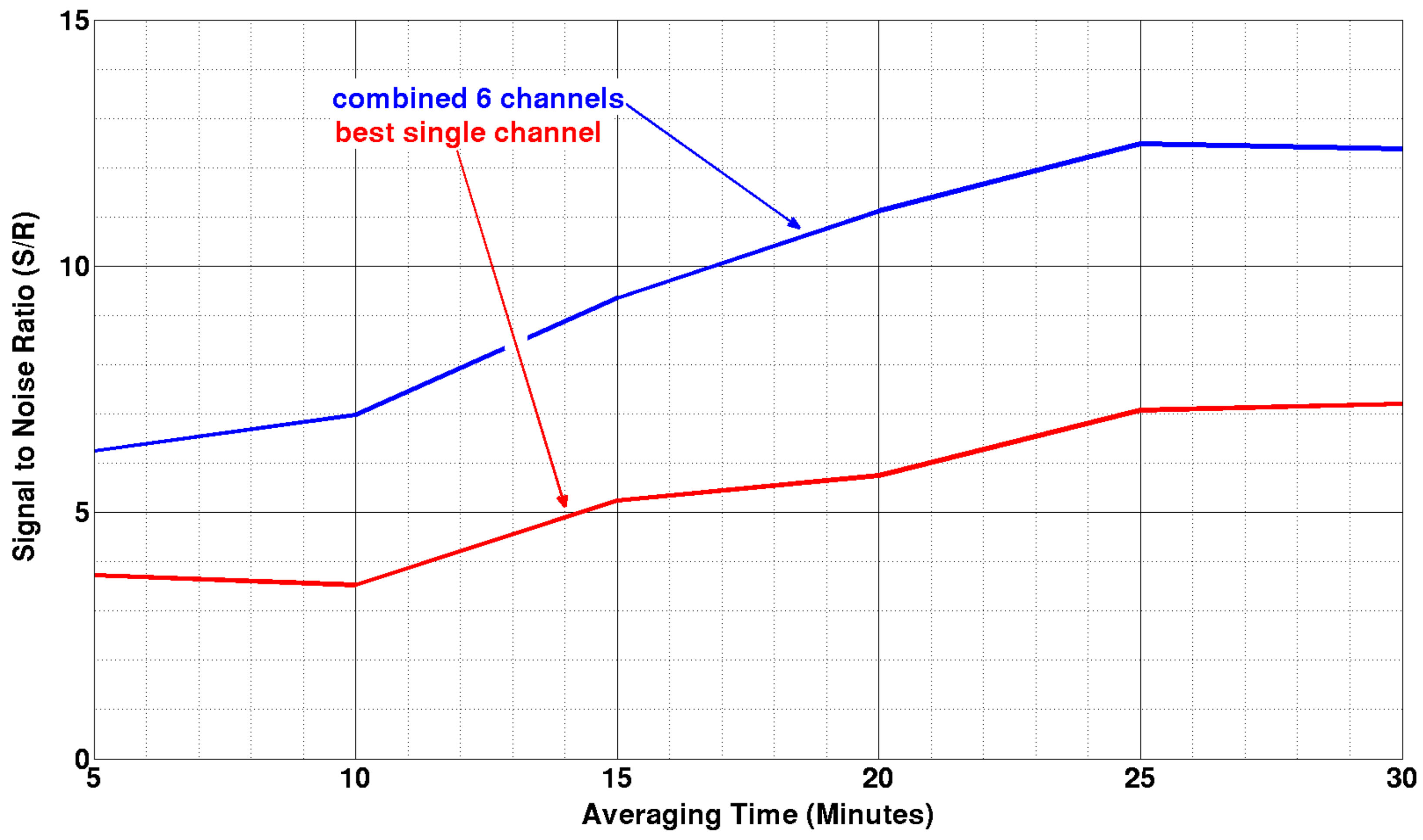

Figure 4. S/N as a function of averaging time, for the best single magnetometer, and the combined 6 channels. The combined system is seen to be about 2x better than the single channel, not far from the theoretical gain of $\sqrt{6}$= 2.4. We choose 10 minute as a useful averaging time, to clearly see the peak at 3 msec.

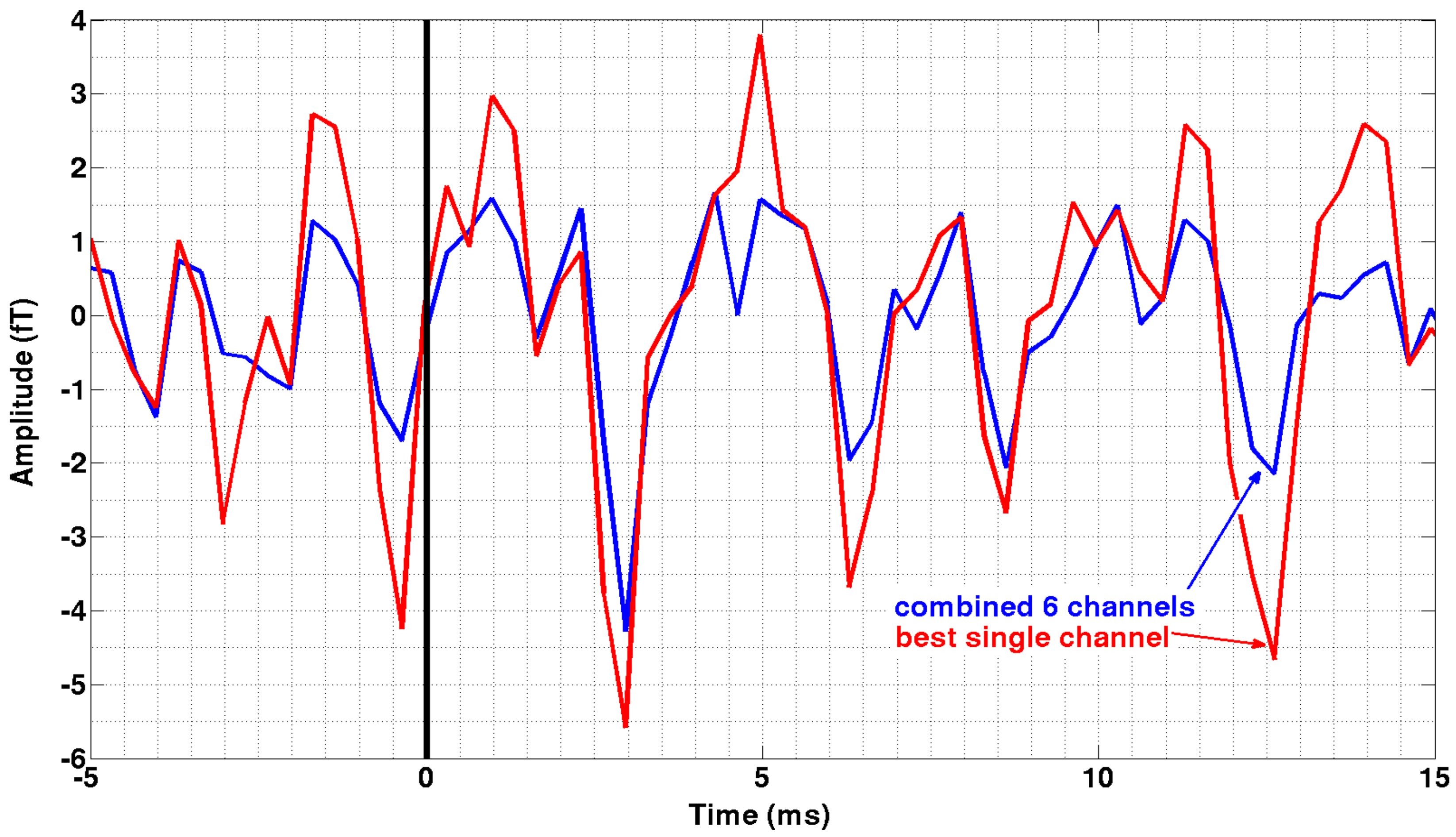

Figure 5. Raw averaged data after 10 min of averaging, showing that the 3-msec peak is reasonably seen with the combined system, compared with the single magnetometer.

We conclude that summing the magnetometers can, in certain circumstances, significantly reduce the scanning time, for deep sources.

References

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