Figure 1 is a simple test to demonstrate that our oscilloscope works. It shows the addition of two single cycles of 100 Hz.

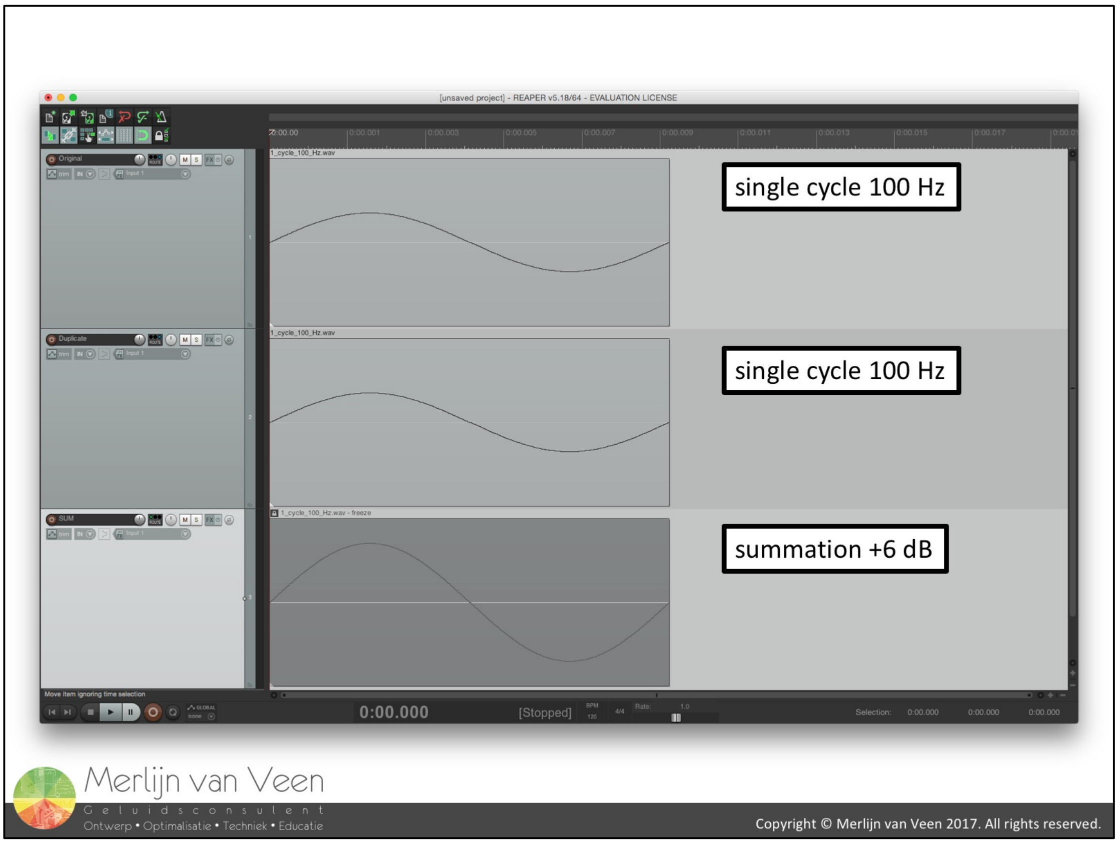

figure 1

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Figure 2 shows the addition of the same signals where one instance has been delayed by +5 ms of pure delay (180° @ 100 Hz).

figure 2

The delayed duplicate shows a 5 ms "vacation" in front of the waveform and the combined result corresponds with our expectations.

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Figure 3 repeats the previous experiment but instead of pure delay, I resorted to a 2nd order all-pass filter introducing the same phase shift of 180° at 100 Hz as 5 ms of pure delay.

figure 3

Contrary to the previous example, the duplicate doesn't start with a 5 ms "vacation"…

This is where e.g. Wikipedia's definition of Group Delay (among others);

"group delay is the time delay of the amplitude envelope"

starts to make increasingly more sense to me.

However, of more immediate concern to me is the outcome which is near identical, namely cancellation. As far as I'm concerned that implies there's some sort of offset.

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A side by side comparison of both outcomes in figure 4 shows the subtle differences which isn't zero (null test).

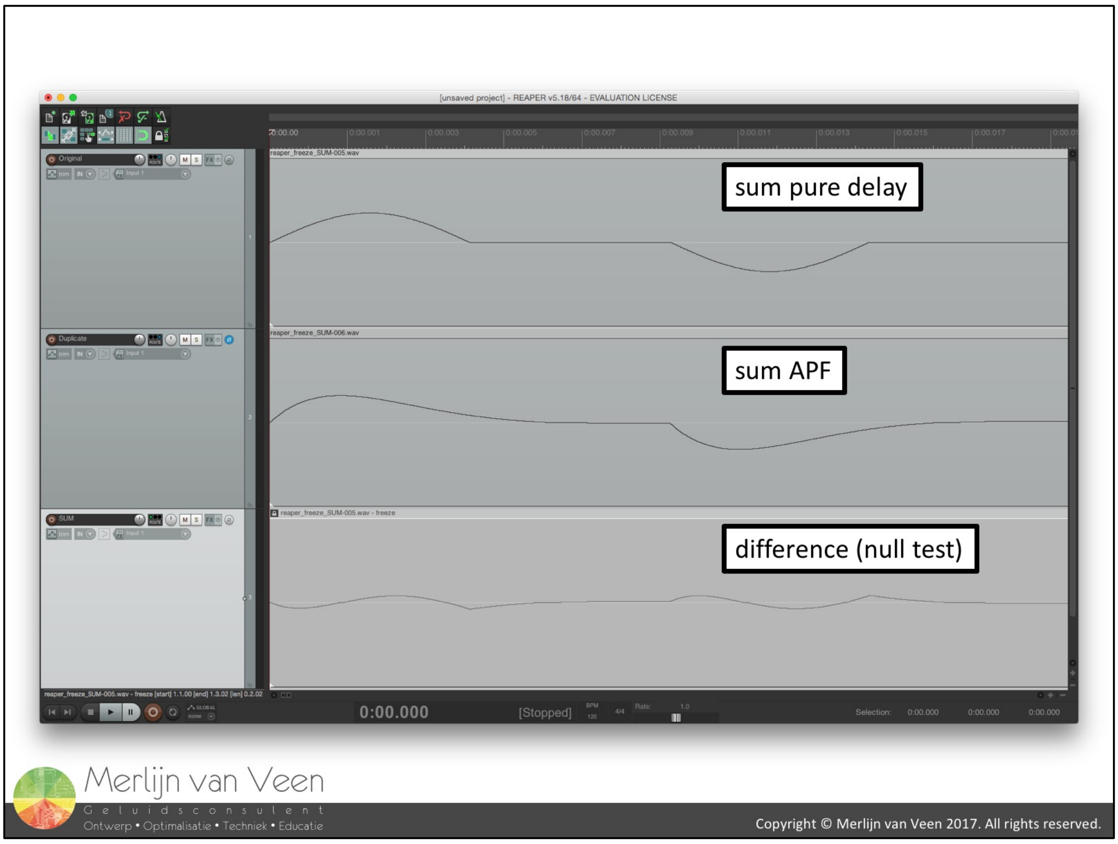

figure 4

I have to conduct further testing to determine what the difference "sounds" like…

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Figure 5 shows a broadband TF of a 5 ms comb filter.

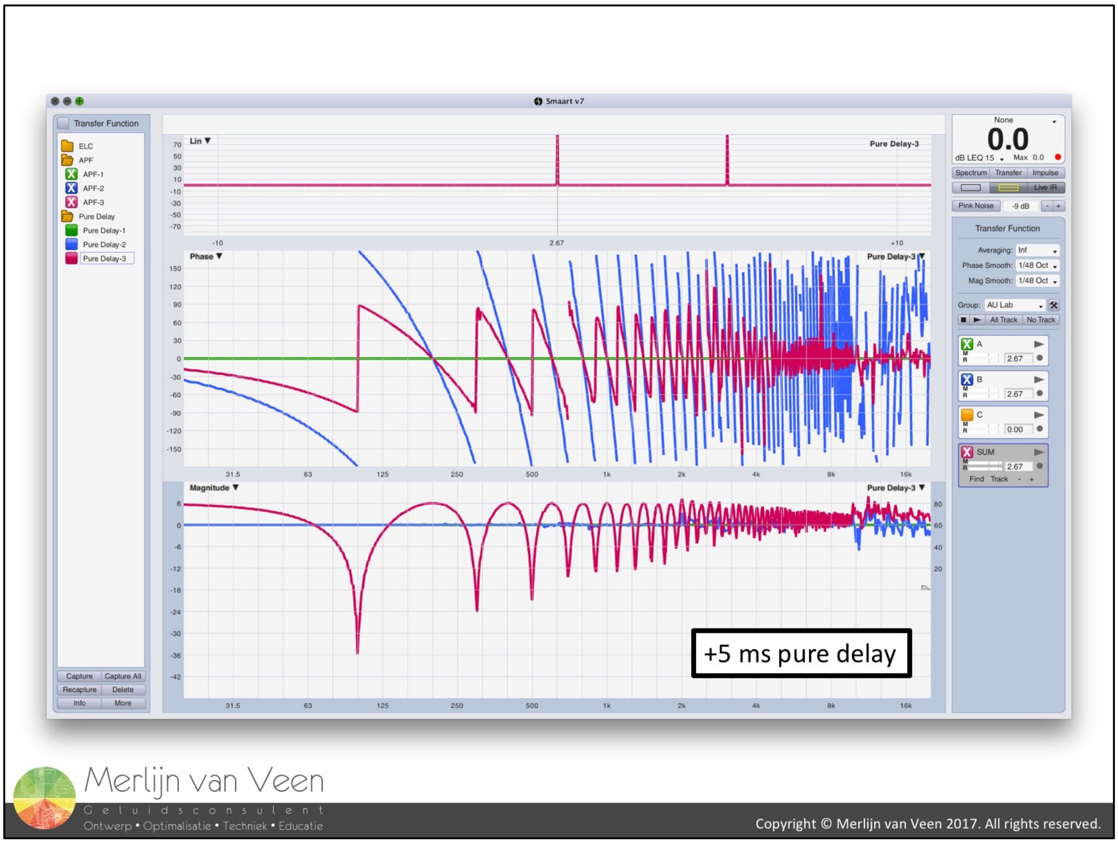

figure 5

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Figure 6 shows a broadband TF of a 2nd APF at 100 Hz.

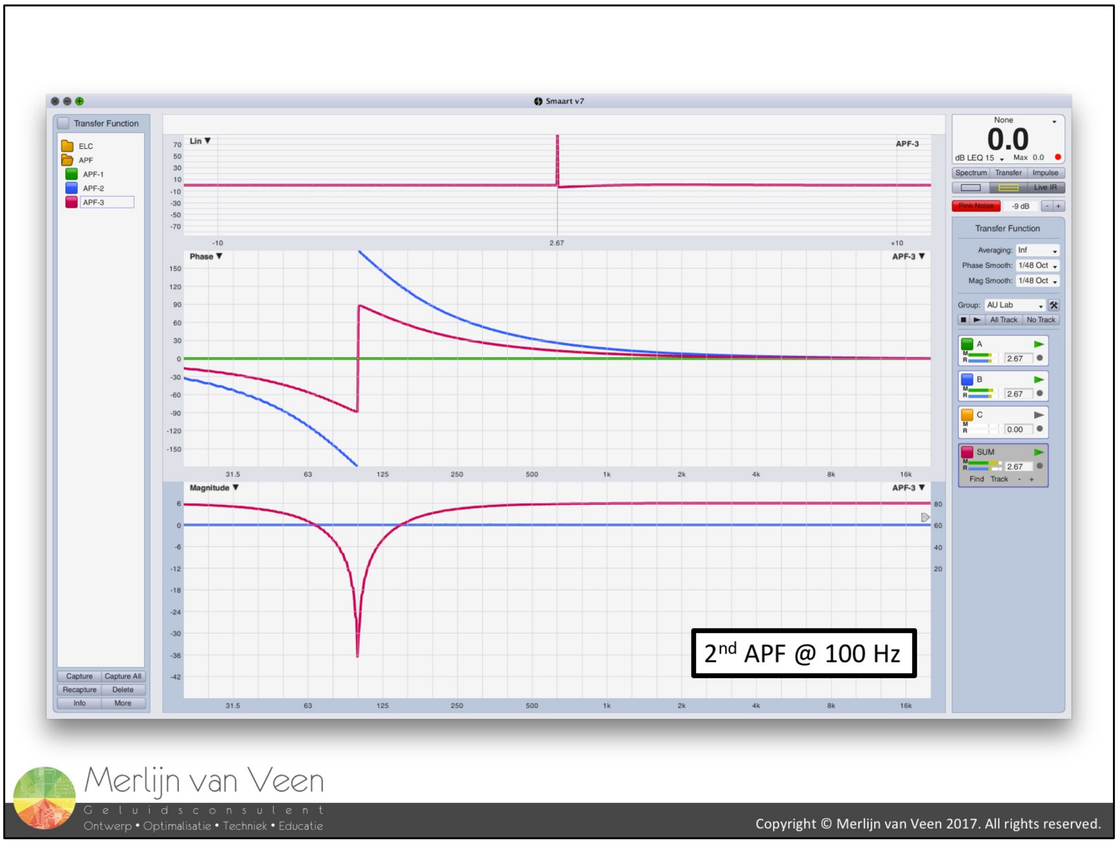

figure 6

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Figure 7 shows both outcomes next to each other and again the cancellation at 100 Hz is near identical because there's an apparent offset in, most likely, time.

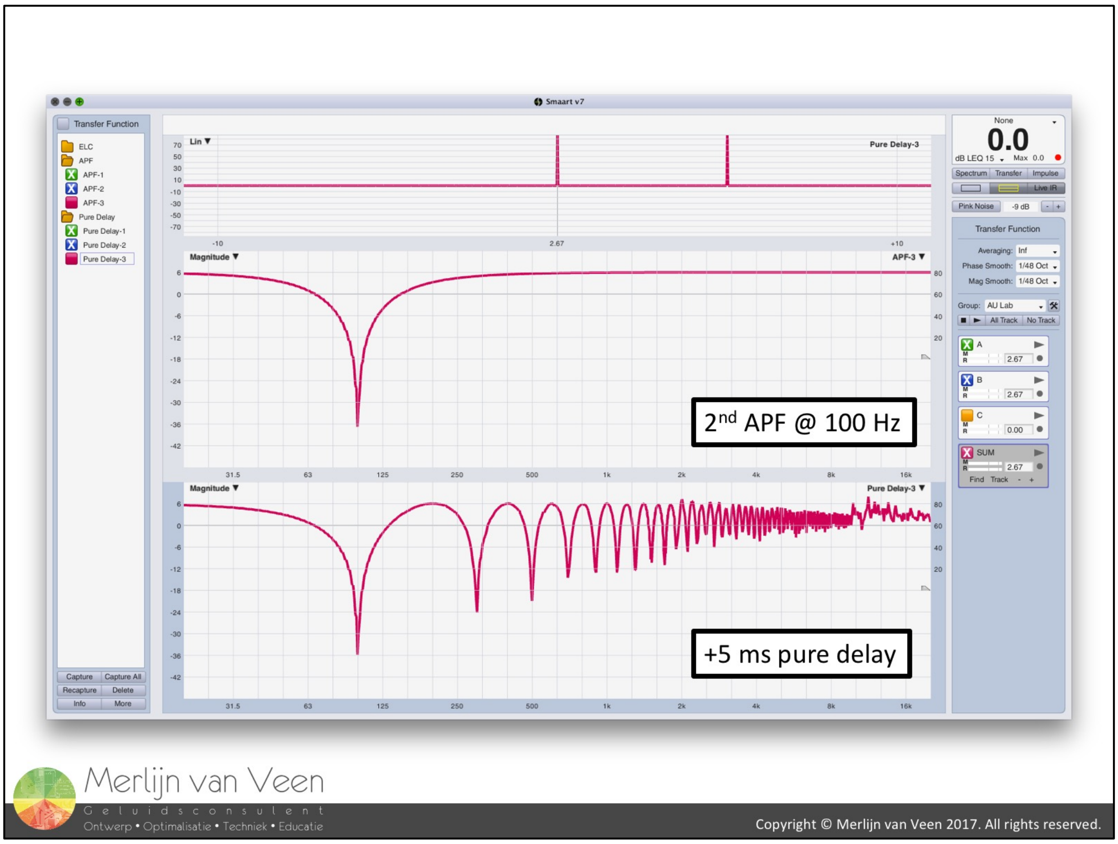

figure 7

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The “group delay” for a 4th order LR LPF is 5 ms in the pass band. Figure 8 shows the peak arriving 5 ms late (2.67 ms is the latency of AU Lab). The reduced amplitude is caused by the loss of data inherent to band limiting.

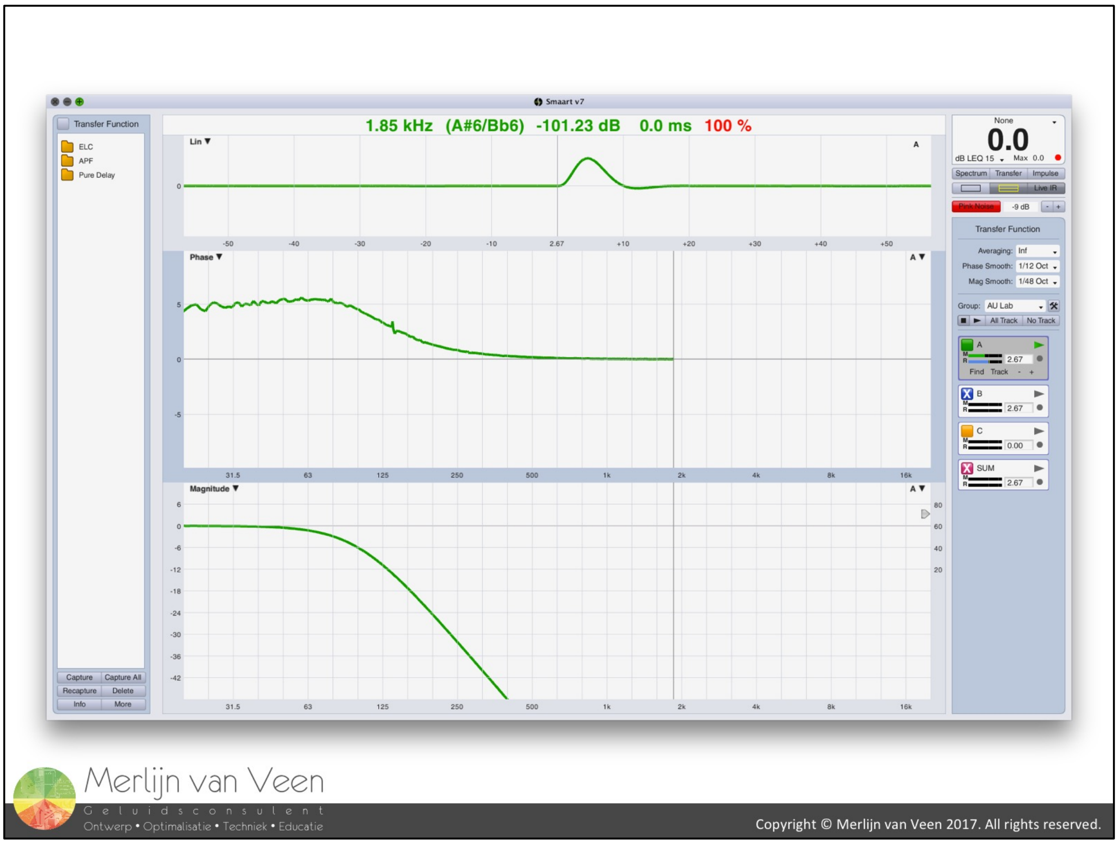

figure 8

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Adding 5 milliseconds to the delay locator flattens the phase response at 100 Hz (figure 9), showing that the all frequencies in the stop band are leading (positive slope). This puts us close to the peak of the IR which is late by 5 ms.

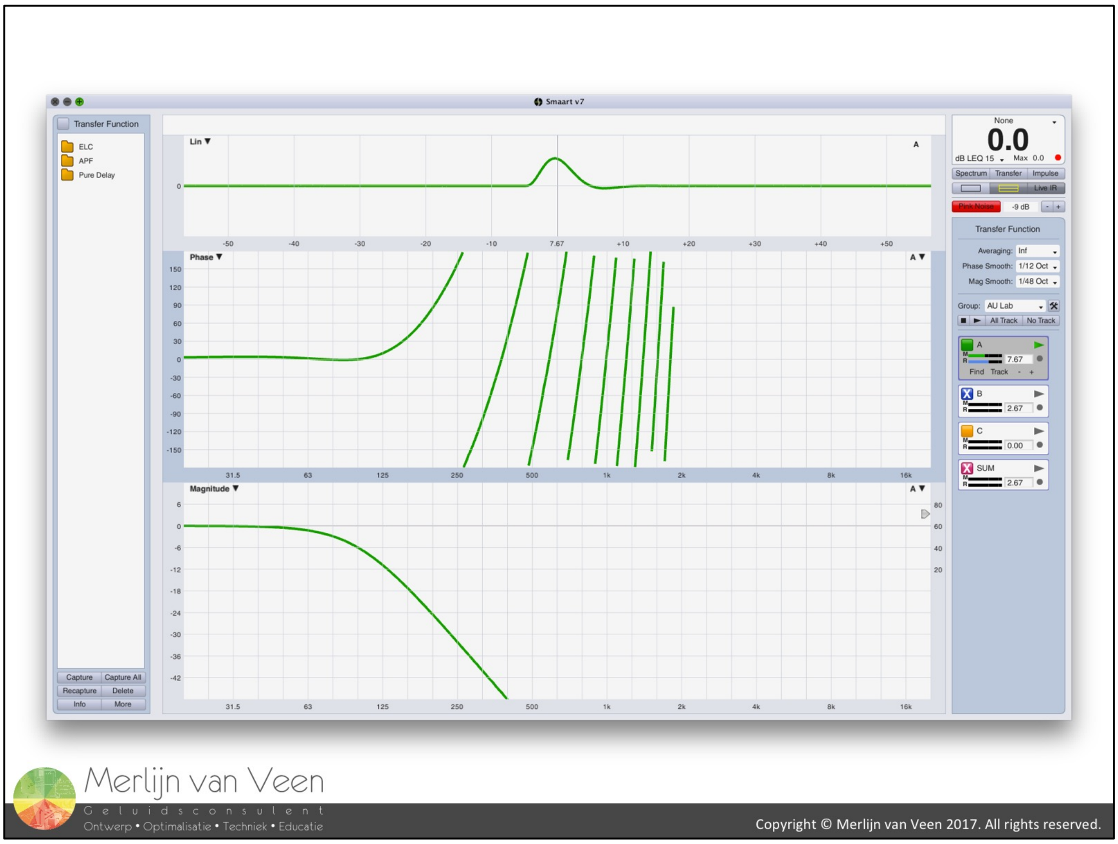

figure 9

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A tone burst is a 6.5 cycle sine wave with a Hann amplitude envelope which turns it into a pulse with a frequency bandwidth of exactly 1/3 octave and a crest factor of 2.3 (7.3 dB).

If I send two tone bursts side by side through an imaginary "microphone cable" with a flat phase response, both pulses are centered (figure 10).

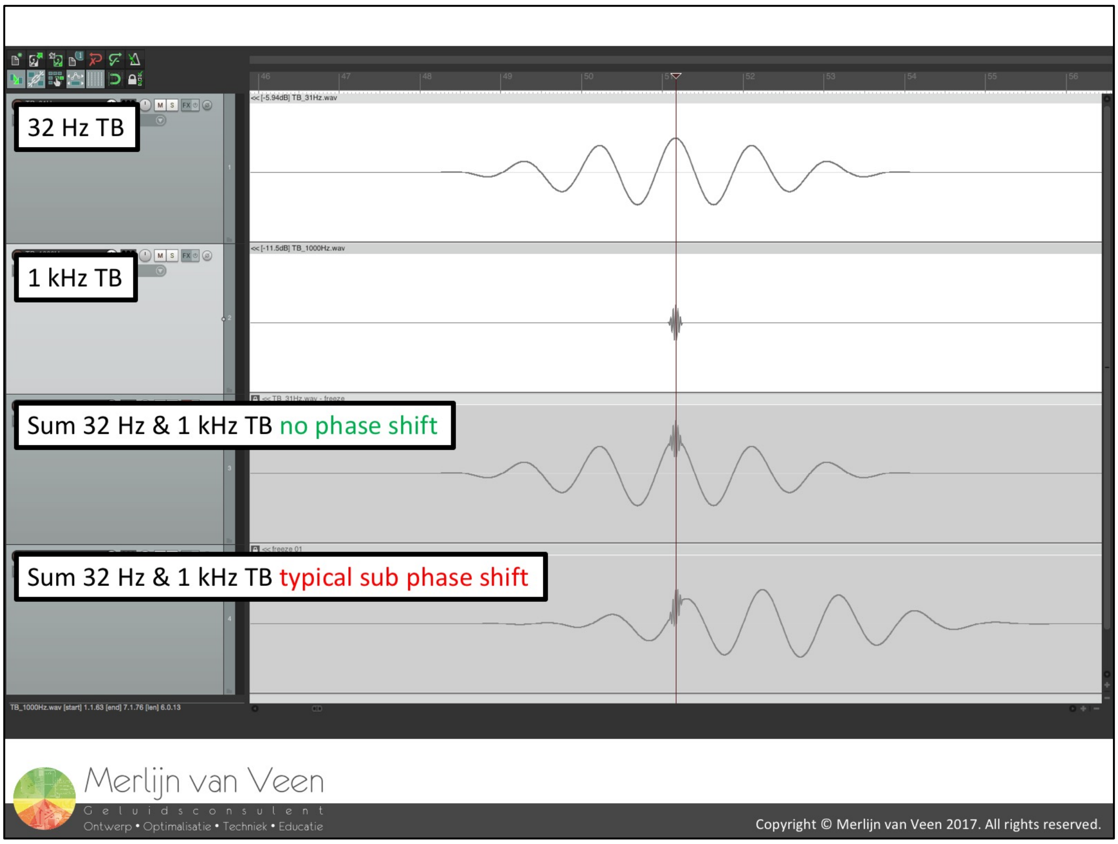

figure 10

The same pulses send side by side through a "microphone cable", exhibiting the phase response of a typical subwoofer (figure 11 next page), are clearly offset.

Even though phase shift appears to stretch the envelope in contrast to introducing a "vacation" like pure delay (page 3).

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Typical phase shift of a subwoofer (figure 11).

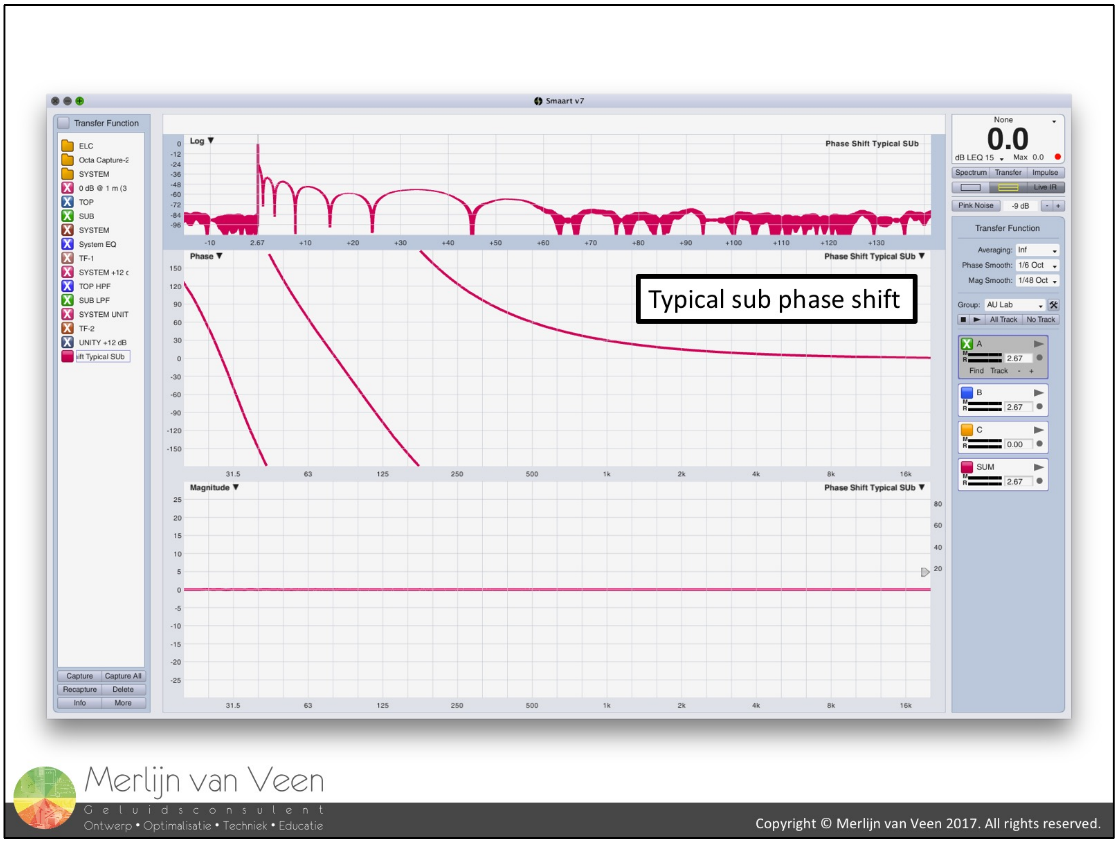

figure 11

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Typical “group delay” of a subwoofer (figure 12).

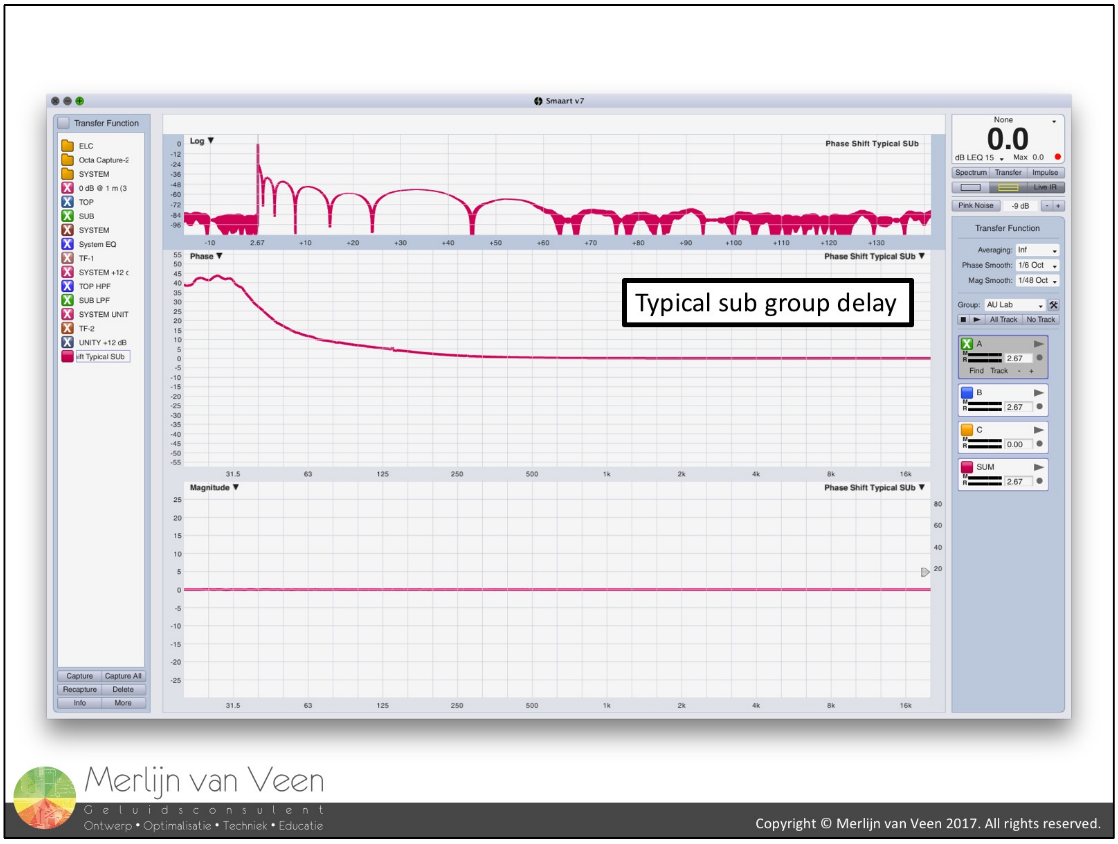

figure 12

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I can relate very well with Markus' sentiment;

"…denn je länger ich darüber nachdenke, desto weniger sicher bin ich, dass ich es überhaupt verstanden habe."

I feel that group delay stinks!

Due to the PP article about the KS28 and Anselm's statement (which makes me doubt myself), I ended up spending hours on the MATLAB forum (among others) reading a thread featuring over 400 posts about the physical meaning of group delay and whether it can be regarded as frequency dependent delay or not?

People much smarter then me didn't agree about the implications and unfortunately only achieved consensus regarding the mathematical equations that define phase delay and group delay.

Maybe "Ockham's Razor" is called for;

"Of two equivalent theories or explanations, all other things being equal, the simpler one is to be preferred."

In more simple words;

"When you hear hoofbeats, think horses, not zebras"

I agree that group delay and pure delay aren't the same. But in my daily activities, group delay "acts and behaves" like frequency dependent delay.

Until someone comes up with a better explanation or metaphor, I'm inclined to keep considering it and explaining it as such.

Sincerely,

Merlijn

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