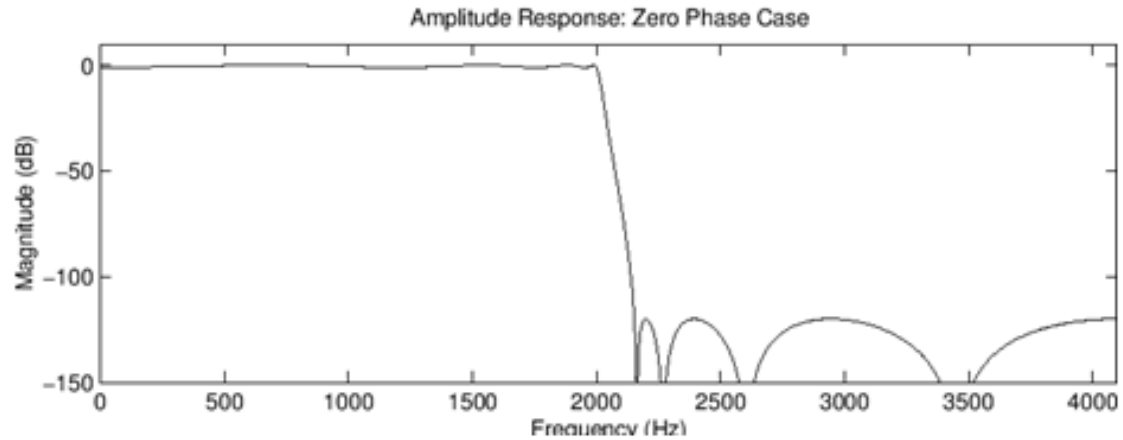
Pre-ringing demonstration

Stanford University has conducted an experiment, which demonstrates audibility of pre-ringing, introduced by certain linear phase filters. The choice of filter was deliberate, and clearly aimed at showing the students how pre-ringing manifests itself. This educational exercise should not be extended as a blanket case for all linear phase filters.

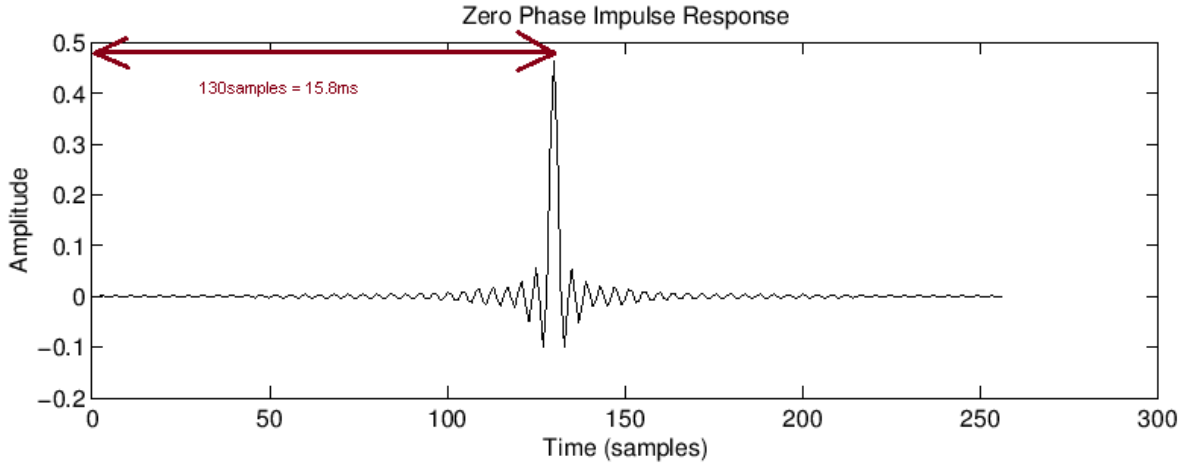
Here is why.

Low-pass used in the experiment was, 8-th order elliptical filter with the following parameters:

```
N = 8;      % filter order
Rp = 0.5;   % passband ripple (dB)
Rs = 60;    % stopband ripple (-dB)
Fs = 8192; % default sampling rate (Windows Matlab)
Fp = 2000; % passband end
Fc = 2200; % stopband begins [gives order 8]
Ns = 4096; % number of samples in impulse responses
```

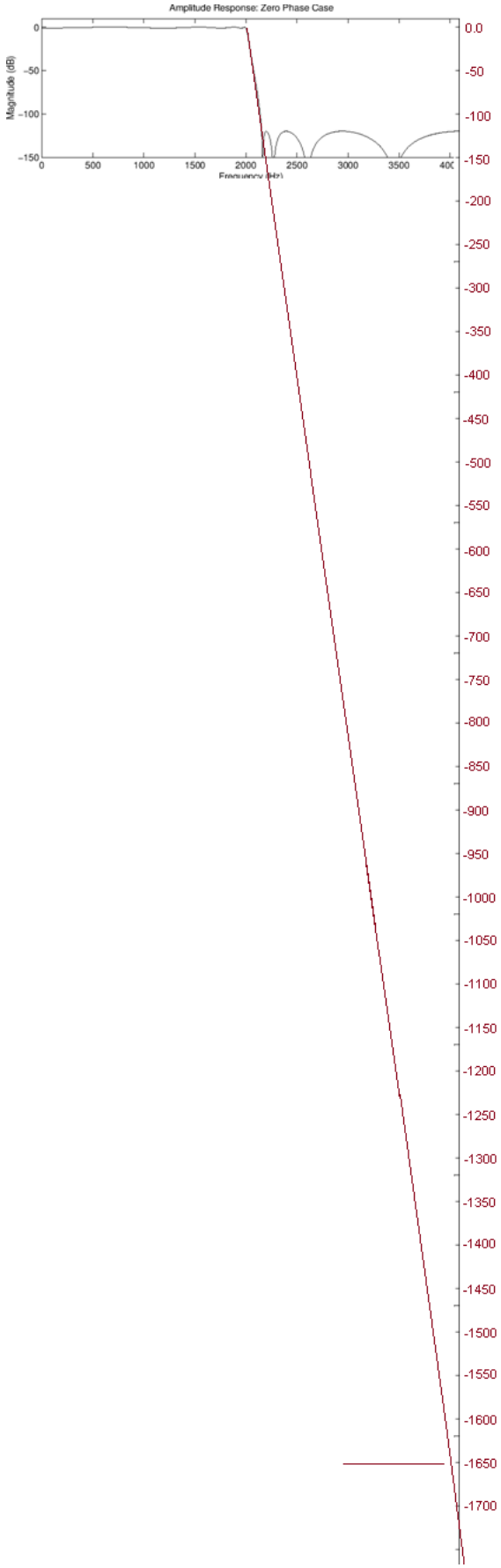


Frequency response is shown above. Sampling rate **was Fs = 8192, so one sample is 0.122ms.**



The peak of the impulse response is located at **130samples, so figures, that pre-ringing extend over 15.8ms.**

We can find approximation of the low-pass slope of the 8-th order elliptical filter by extending the asymptotic slope of the LP filter – see picture below.

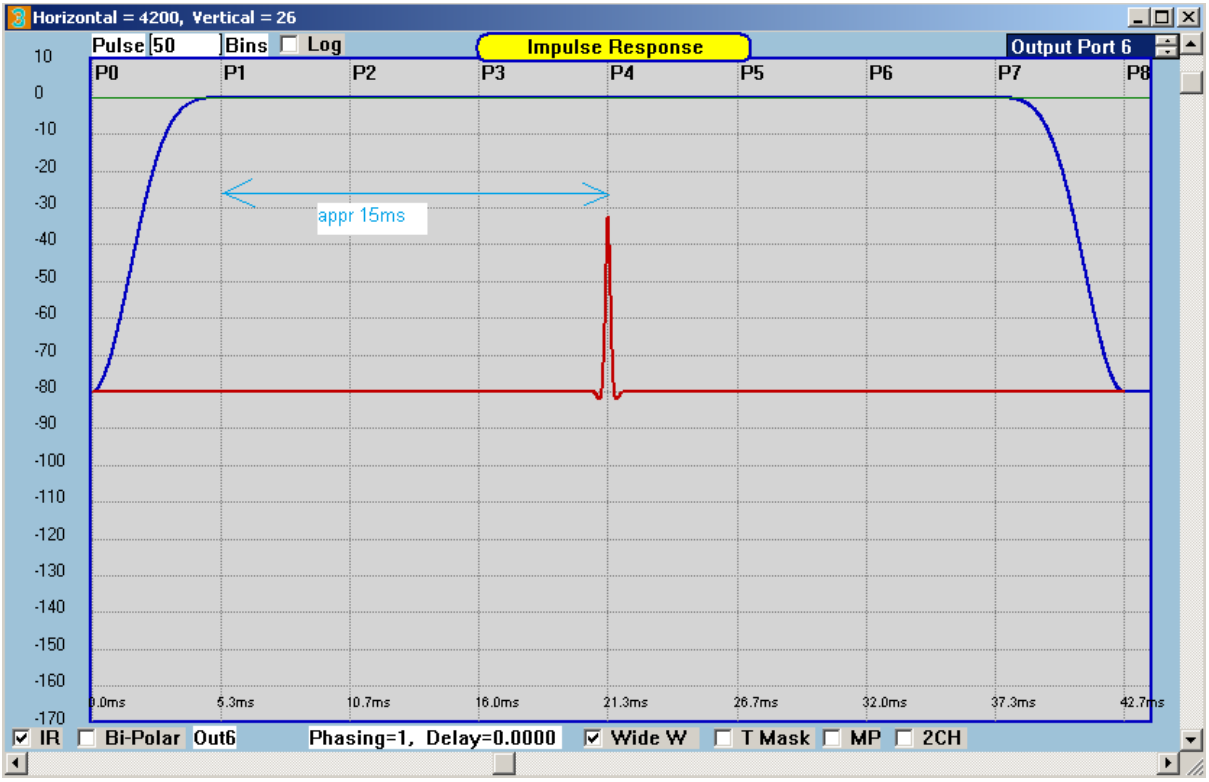


It turns out, that the slope is about -1650dB/oct. This is comparable with “brick-wall” filters. The pre-ringing was clearly audible of such a sharp filter.

It is beneficial to compare the somewhat extreme level of pre-ringing elliptical filter of 8th order to the pre-ringing of a typical loudspeaker filter.

In the following two examples, the amplitude of the peak of the impulse response was scaled to be around 5 divisions, to match the elliptic filter, and the time scale is also similar.

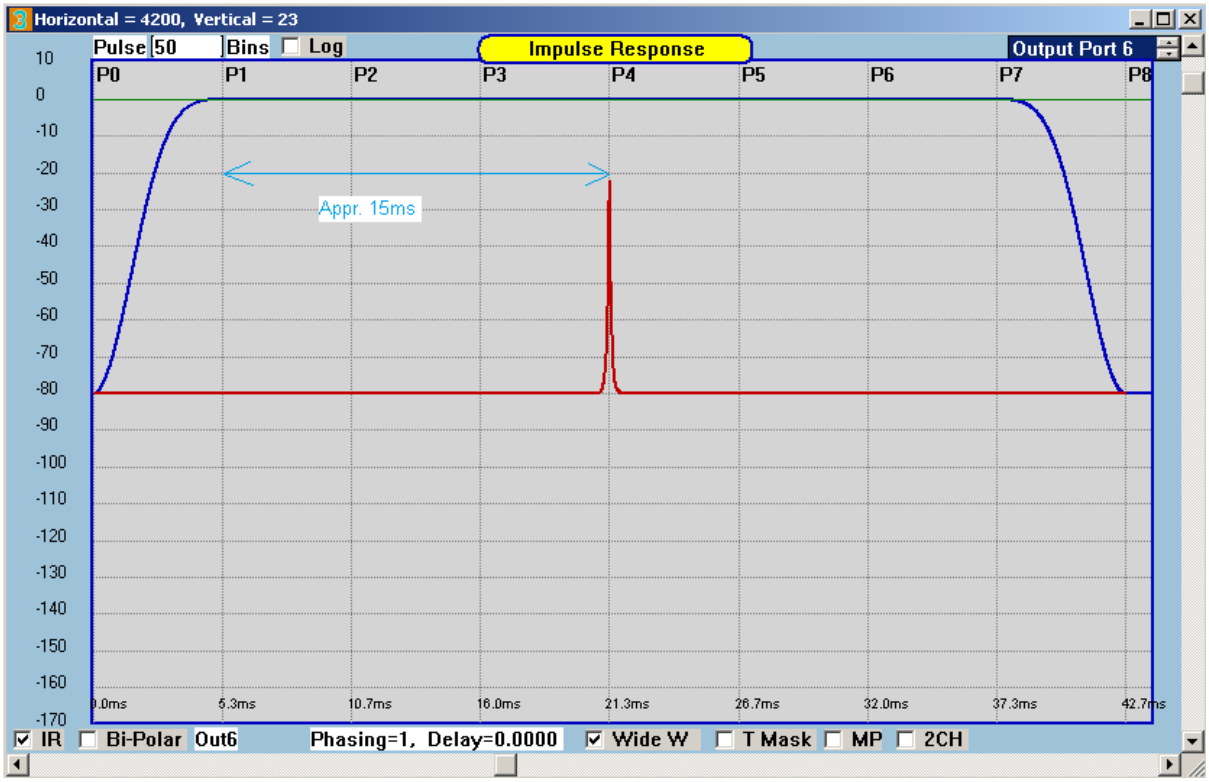
1. **-24dB/oct 2000Hz, Low-Pass, Linkwitz-Riley**



It is observable, that there is only one small ripple, extending to less than 1ms on both side of the peak.

This ripple would be easily covered by pre-masking.

2. **-12dB/oct 2000Hz, Low-Pass, Linkwitz-Riley**

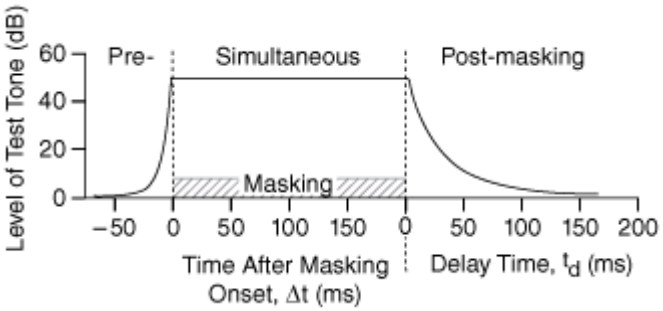


It is observable, that there is no visible ripples on this picture. It does not mean, that there is no pre-ringing – it only means, that pre-ringing is extremely small.

This would be easily covered by pre-masking.

Conclusions

Pre-masking is when the test tone occurs before the masking sound. Post-masking is when the test tone occurs after the masking sound. The following figure shows the time regions of pre-masking, simultaneous masking, and post-masking in relation to the masking signal.



It is evident, that both filters: -12dB/oct and -24dB/oct LR filters would fit very comfortably under the masking curves – thus rendering the pre-ringing inaudible.

Furthermore,

Henri Korhola. “Perceptual Study of Loudspeaker Crossover Filters” Master’s Thesis submitted in partial fulfilment of the requirements for the degree of Master of Science in Technology. Espoo, 25th February 2008

http://lib.tkk.fi/Dipl/2008/urn011933.pdf

offers the following conclusions regarding the “safe orders” of FIR filters:

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“….Hence, pursuiting of the ”ideal” reproduction of a signal seems to be good on the paper, but perceptual tests, with headphone simulation and a real loudspeaker, show that hearing clearly perceives ringing degradations in the audio quality with both analytical and real life signals. Rough safety limits according to both test methods would be to keep the order of a linear phase FIR crossover filter under 600 at higher frequencies (1 and 3 kHz) to prevent from the ringing phenomenon producing audible errors. At low frequencies, such as 100 Hz and 300 Hz, the order may be up to thousands, and still no audible errors will occur…..

Thank you for reading

Bohdan