

Spectral Delay Filters*

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This paper discusses the implementation of spectral delay using filters comprising a cascade of many low-order allpass filters and an equalizing filter. The spectral delay filters have chirp-like impulse responses causing a large, frequency-dependent delay that is useful in audio effects processing. An equalizing filter design and a multirate technique, which stretches the allpass filters, impulse response, are introduced.

0 INTRODUCTION

Filtering an audio signal with an allpass filter does not usually have a major effect on the signal's timbre. The allpass filter does not change the frequency content of the signal, but only introduces a phase shift or delay. Audibility of the phase distortion caused by an allpass filter in a sound reproduction system has been a topic of many studies, see, e.g., [1], [2]. In this paper, we investigate audio effects processing using high-order allpass filters that consist of many cascaded low-order allpass filters. These filters have long chirp-like impulse responses. When audio and music signals are processed with such a filter, remarkable changes are obtained that are similar to the spectral delay effect [3], [4].

1 CHIRP-LIKE IMPULSE RESPONSES AND GROUP DELAY

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$$A(z) = \frac{a_1 + z^{-1}}{1 + a_1 z^{-1}}, \quad (1)$$

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$$\tau_{g,\max} = \begin{cases} \tau_g(0) = \frac{1-a_1}{1+a_1}, & \text{when } a_1 \leq 0 \\ \tau_g(\pi) = \frac{1+a_1}{1-a_1}, & \text{when } a_1 > 0. \end{cases} \quad (2)$$

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- 1) Green-function determined experimentally and published.
- 2) Black-function determined using similarity searches and published.
- 3) Red-function determined using similarity searches and determined in this study.
- 4) Blue-O-antigen structure unknown. Function determined using similarity searches and proposed in this study.

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Table 1. Active sites and allosteric sites of the GNE MNK enzyme

Excerpt No.	Genre	Spatial Mode	Correlation
1	Pop	FB	94%
2	Classical	FB	33%
3	Jazz	FF	76%
4	Arabian	FF	41%
5	GNE	H220	45%
6	GNE	H45	93%
7	MNK	G416	74%
8	MNK	D413	72%
9	MNK	R420	94%
10	MNK	N516	91%

Note. This table does not include sentence enhancement statuses. This table does not include sentence enhancement statuses.

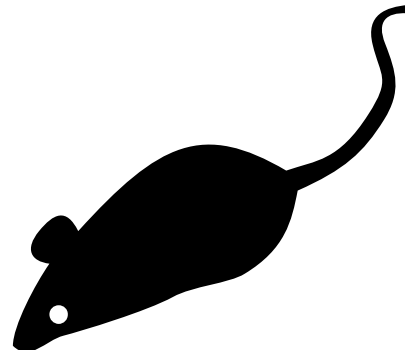


Fig. 1. The spectral delay filter consists of M allpass filters and an equalization filter.

¹This point is emphasized by Loewer, see esp. p. (610).

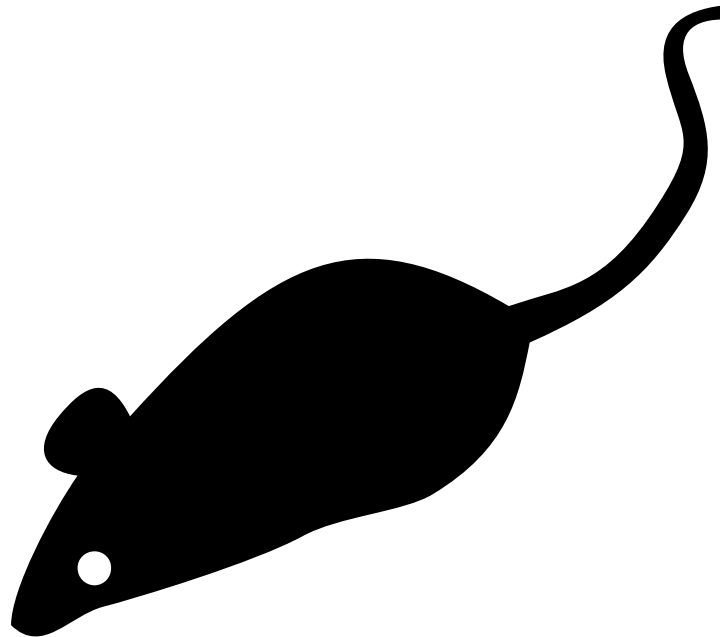


Fig. 2. This paper is organized as follows. In Section 1, we discuss the group delay of a cascade of first-order allpass filters and its relation to the chirp-like impulse response of the spectral delay filter. Furthermore, a multirate method to stretch the impulse response of the spectral delay filter is proposed. Section 2 discusses the amplitude envelope of the impulse response and suggests a design method for the equalizing filter. Section 3 presents application examples using the spectral delay filter. Section 4 concludes this paper.

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$$\tau_g(\omega) = -\frac{d\phi(\omega)}{d\omega}.$$

Audibility of the phase distortion caused by an allpass filter in a sound reproduction system has been a topic of many studies, see, e.g., [1], [2]. In this paper, we investigate audio effects processing using high-order allpass filters that consist of many cascaded low-order allpass filters. These filters have long chirp-like impulse responses. When audio and music signals are processed with such a filter, remarkable changes are obtained that are similar to the spectral delay effect.

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2 SUMMARY

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3 CONCLUSION

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4 ACKNOWLEDGMENT

This research was conducted in fall 2008 when Vesa Välimäki was a visiting scholar at CCRMA, Stanford University. His visit was financed by the Academy of Finland (project no. 126310). The authors would like to Dr. Henri Penttinen for his comments and for the snare drum sample used in this work.

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- [4] Roads C., *The Computer Music Tutorial*. MIT Press, Cambridge, MA, 1996.

APPENDIX

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$$\phi(\omega) = -\omega + 2 \arctan \left(\frac{a_1 \sin \omega}{1 + a_1 \cos \omega} \right) \quad (1)$$

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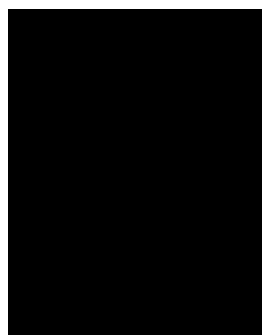
NOMENCLATURE

a_c = condensation coefficient condensation coefficient

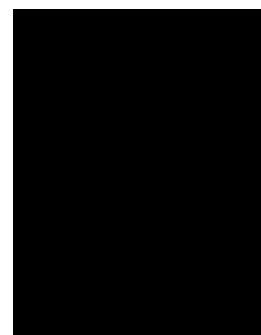
TLR = Toll-like receptor

PAMPs = pathogen-associated molecular patterns condensation coefficient condensation

THE AUTHORS



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