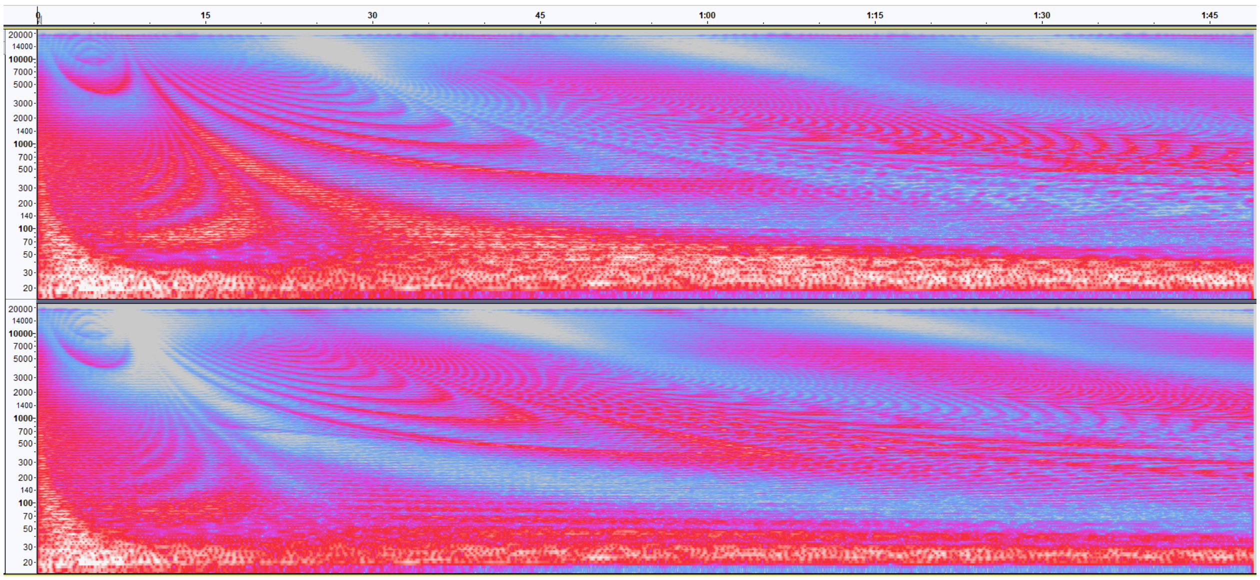

Generating Interference Patterns with a Resonant Filter Bank

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Introduction

The author did a study project about a kind of reverb method and came across the present subject in the process. The original idea was to reverberate a (musical) audio input stream so that frequency bands would each have a different delay time at the audio output stream. Which means in practice that, for example, the impulse response of the system contains as many decaying reverberation sounds as there are frequency sub-bands, each starting to sound at slightly different time according to their delay parameters. The result was promising. Then a question came up: But what would happen if feeding the system with white noise [1] instead?

Overview

The built system consists of a filter bank with 100 resonant bandpass filters [2] for the sub-bands. A resonant filter has a high Q factor to provide some resonance, which was a desired feature in the project. Also the bandwidth is narrow to reduce excess overlap with neighbouring sub-bands. The bank's sub-bands are logarithmically spaced from 20 Hz until 20 kHz. The input audio signal is generated with a standard pseudo-random number generator [3]. Same signal is fed to all sub-bands, but each have a different dynamic delay parameter for the input. The first result was that there are some kind of "phasing" or "flanging" patterns heard at the output of the system. The seed of the noise generator did not change the effect, but changing the delay parameters control setting change the resulting audio patterns. With a one-stage filter bank the effect was not prominent but recognizable. Repeating the process four times, using output file of the previous run as input to next run, enhanced the patterns to become clearly audible and visible in a spectrogram. Though the frequency ranges of the passbands of the sub-bands do not overlap (however there is overlap of transition bands), there is still enough signal leakage to produce interference patterns caused by the differing

Fig. 1. (on top) The spectrogram generated with 100 sub-bands.

delays of the sub-bands. (Cf. Flanging audio effect [4].) The appearance of the interference patterns is in a way similar to so-called *Emergence* and *Pattern formation* phenomena [5; 6] usually seen in nature but also in physics, math and computational models.
The method of creating interference patterns proposed in this paper may be called Resonant-Filter Interference-Pattern Synthesis (RFIPS). The method is a form of subtractive synthesis as it starts from white noise on which filtering is then applied. Compared to flanging, the RFIPS method has more parameters to control, and thus provides more variability in use. The next section describes its implementation.

Architecture and Operation

A block diagram of the principal parts and functions of a single filter bank is shown in Fig. 2.

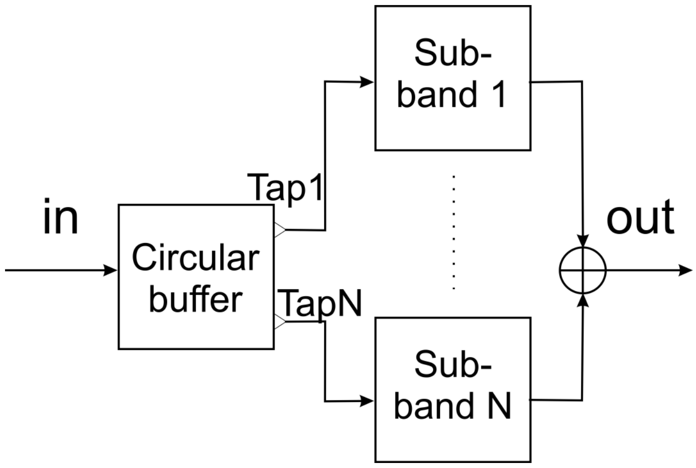

Fig. 2. A block diagram of the principal parts and functions of a single filter bank.

The whole system's architecture is presented in Fig. 3.

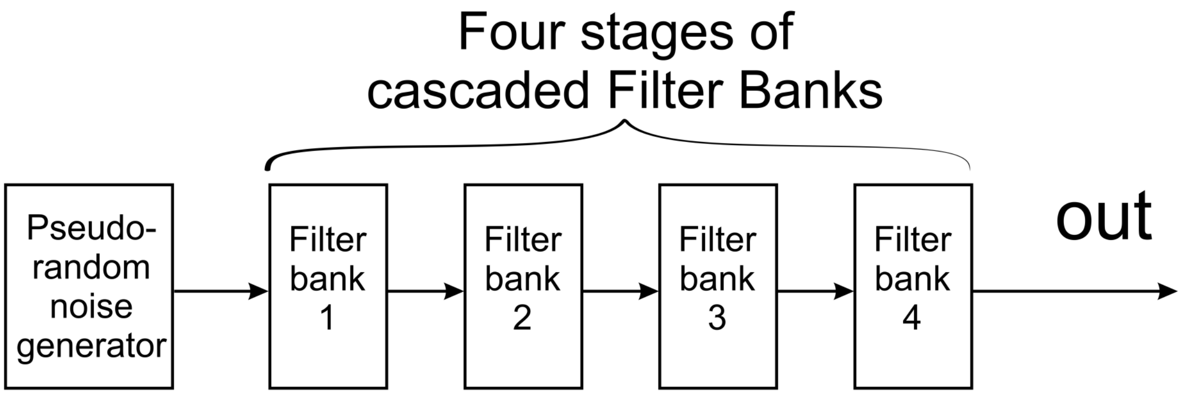

Fig. 3. The whole system's architecture.

The RFIPS method is efficiently and practically implemented by cascading four stages of filter banks to reduce manual work. The banks consist of 100 sub-bands of resonant bandpass filters. A combined output signal of a bank is connected to a general input of the next stage bank. The input of a stage goes first in a circular buffer that forms the delay line. Each sub-band has a dedicated delay tap with a (dynamic) delay control parameter. The delay parameters are in the range 0...50 ms, and typically change gradually in a slow pace, each with a slightly differing rate. For a simplified example of the control, the n-th delay time d value is

d[n] = (sin(c[n]*t*Time_scale)*.5 + .5)*Delay_range;

where c is a dedicated fixed coefficient, t is the current time (in seconds), Time_scale is a common fixed scaling factor. The factor Delay_range has a fixed value according to the common delay buffer size. (Symbol n is the index of the sub-band.) The cyclic function sine is used just to easily provide a continuously-changing value that keeps in the range 0...1 with the help of the twin ".5" terms in the formula (therefore to keep each tap pointing inside the delay buffer at all times). For accuracy, note that the delay values should not be limited to integral sample numbers, so therefore a so-called fractional delay line is used as a buffer implementation model. An example value range for the constant c is 0.001...0.2 (evenly distributed accorning to increasing sub-band number), the constant Time_scale value is 1.0, and the Delay_range is 50 ms, as a starting point. (The implementation software should convert the delay time from seconds to a pointer/index to the (fractional) location in the circular buffer, which is however beyond the scope of this brief paper.) So, in essence, each delay changes as a function of time t.

Results

1 sub-band
When there is only one sub-band in use, no interference patterns appear - which is natural because different delay paths of a same signal do not interfere with each other in that case. The output contains filtered narrow-band signal with (nearly) steady amplitude.

100 sub-bands
With one hundred sub-bands in use, the forming of interference patterns is prominent in the output signal after the four-stage banks. Also much of the noise-generator's "noisiness" has changed to pitched sounds - because of the resonant filters -, that undulate, forming patterns. The spectrogram is shown in Fig. 1 (on the front page). (Note that the output was made stereophonic by using the delay parameter of each sub-band for L/R localization. The pitch-spacing is approximately in a 10-edo scale.) At moments, the patterns become denser thus closely resembling melodic and rhythmic patterns or polyphonic texture, when carefully listened to.

50 sub-bands
With 50 sub-bands, i.e. skipping every second band, the sense of discordance decreases because there are less pitches per octave (5-edo scale). However, the amount of patterns also diminishes (or, at least, the vertical resolution of the interference patterns). The spectrogram is shown in Fig. 4.

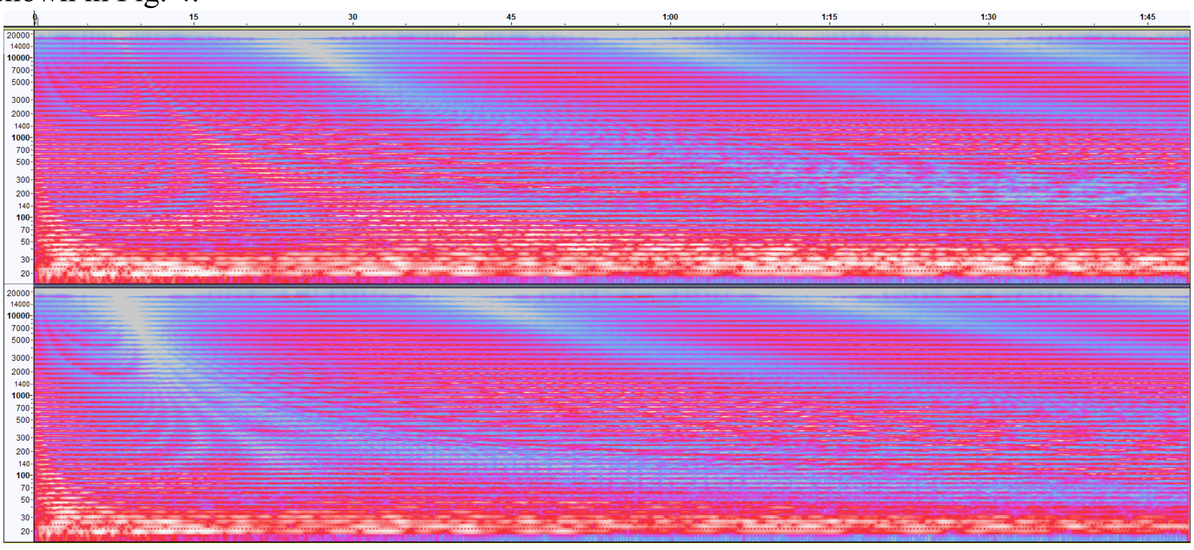

Fig. 4. The spectrogram generated with 50 sub-bands.

20 sub-bands
By reducing further, when there are twenty sub-bands left, the result is losing information in the way that the patterns are kind of fading away. The spectrogram is shown in Fig. 5.

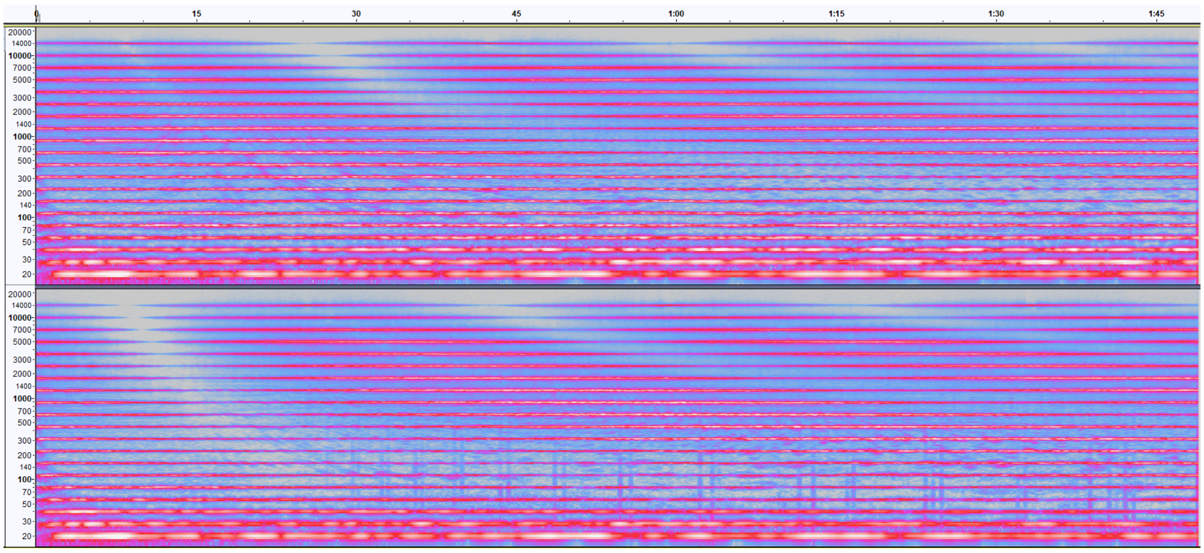

Fig. 5. The spectrogram generated with 20 sub-bands.

Impact of time-scale
The effect of changing the time-scale is shown in the *Appendix*.

Examples and Applications

The RFIPS method's audio output has potential for further study in musical context.

However, in completely different context, the spectrogram pictures could be used in visual arts or illustrations. (Note that the spectrogram pictures look not so dissimilar from old-fashioned b/w CRT-images with good horisontal but limited vertical resolution because of the beam line quantization in the tube.)

Links to audio samples:
- https://www.vakeva.org/samples/pattern100sb.mp3
- https://www.vakeva.org/samples/pattern50sb.mp3

References

[1] https://en.wikipedia.org/wiki/Pseudorandom_noise

[2] https://en.wikipedia.org/wiki/Band-pass_filter

[3] http://www.cplusplus.com/reference/cstdlib/rand/

[4] https://en.wikipedia.org/wiki/Flanging

[5] https://en.wikipedia.org/wiki/Emergence#Emergent_properties_and_processes

[6] https://en.wikipedia.org/wiki/Moir%C3%A9_pattern

APPENDIX: Effect of changing the Time_scale parameter (ie. "zooming")

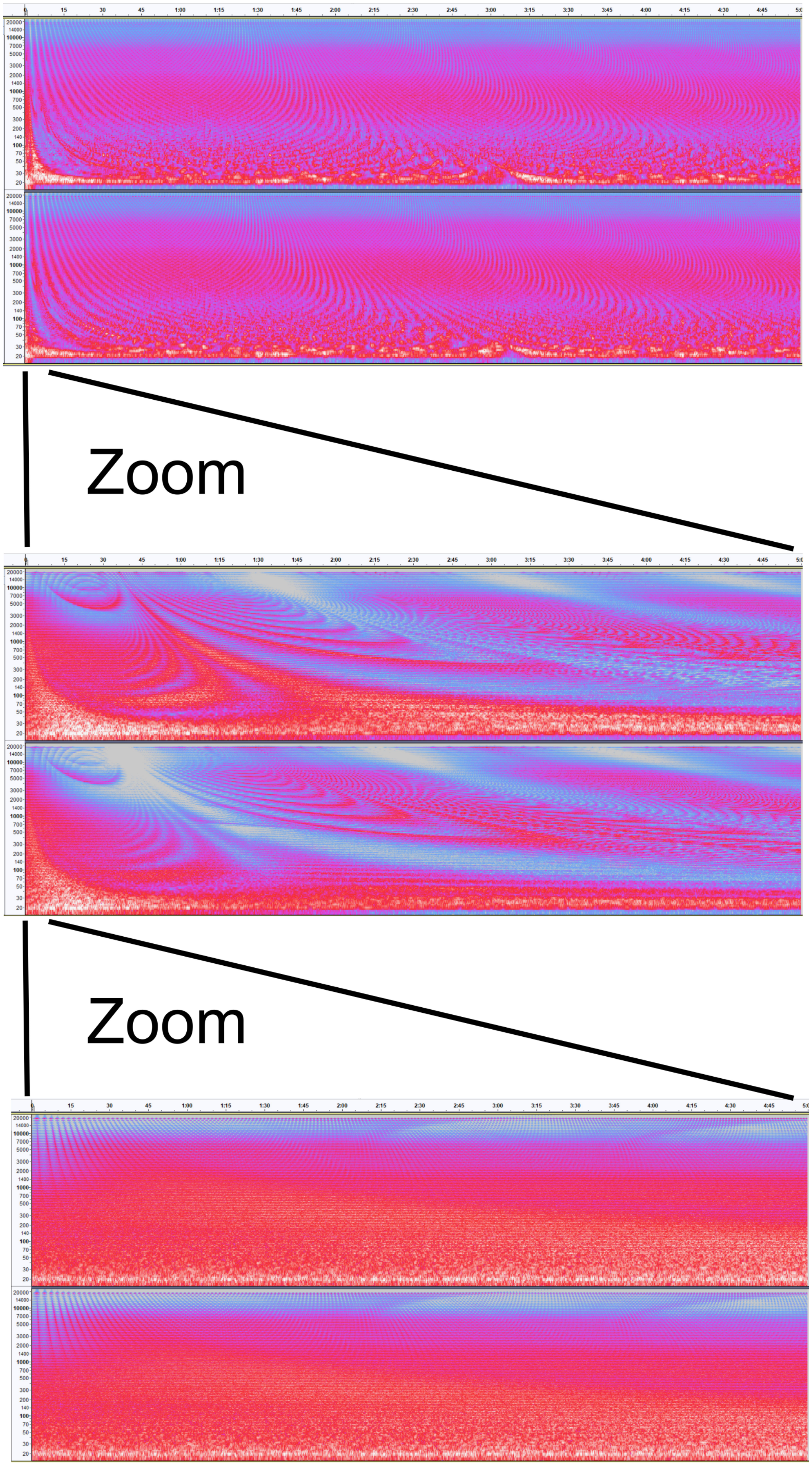

Fig. A1. The effect of changing the Time_scale parameter.