FFT-Based Dynamic Range Compression

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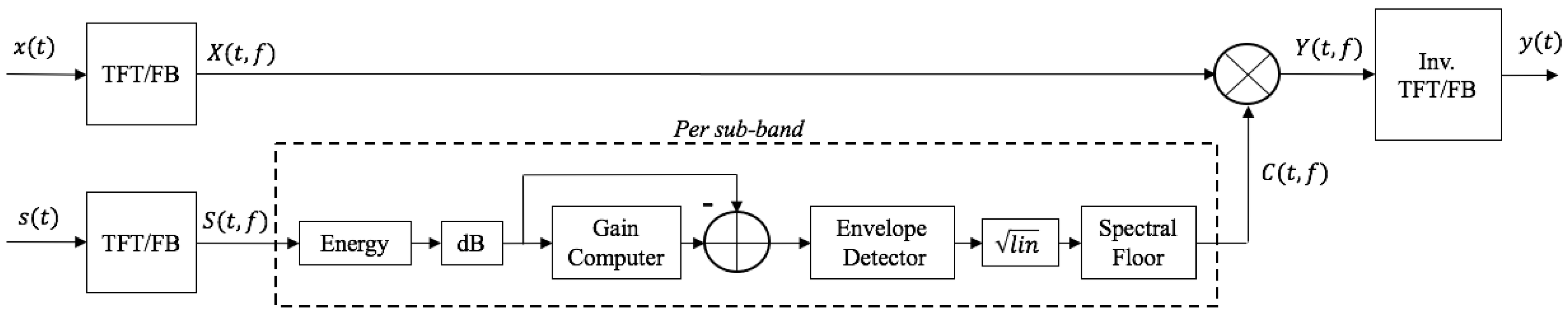
Introduction

- Many of the dynamic range compressor (DRC) designs that are deployed in the marketplace today are constrained to operate in the time-domain; therefore, they offer only temporally dependent control of the amplitude envelope of a signal. Designs that offer an element of frequency dependency, are often restricted to perform specific tasks intended by the developer. Therefore, in order to realise a more flexible DRC implementation, the paper proposes a generalised time-frequency domain design that accommodates both temporally-dependent and frequency-dependent dynamic range control; for which an FFT-based implementation is also presented. Examples given in the paper reveal how the design can be tailored to perform a variety of tasks, using simple parameter manipulation; such as frequency-depended ducking for automatic-mixing purposes and high-resolution multi-band compression.

The Proposed Design



- Time-domain signals transformed into the time-frequency domain, via a short-time Fourier Transform or a perfect-reconstruction filterbank.
- Side-chain signal is converted to instantaneous energy and analysed per frequency band

$$X_G(t,f) = 10\log_{10}|S(t,f)|^2,$$

- A second-order gain computer utilises Threshold (T), Ratio (R), and Knee-width (K) parameters, which can be independent from other frequency bands

$$Y_G = \begin{cases} X_G & 2(X_G - T) \leq -W \\ X_G + \frac{(\frac{1}{R}-1)(X_G - T + \frac{W}{2})^2}{2W} & 2|(X_G - T)| \leq W \\ T + \frac{(X_G - T)}{R} & 2(X_G - T) > W, \end{cases}$$

- An envelope detector is then applied that utilises Attack (A) and Release (R) parameters.

$$V_G = \begin{cases} \alpha_A V_G z^{-1} + (1-\alpha_A) B_G & B_G > V_G z^{-1} \\ \alpha_R V_G z^{-1} + (1-\alpha_R) B_G & B_G \leq V_G z^{-1}, \end{cases}$$

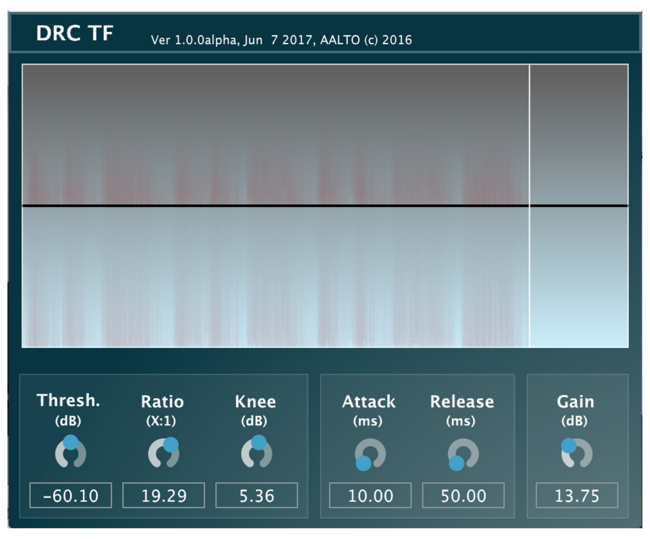
- The side-chain processing result is then converted back to a linear value, and subjected to a spectral floor parameter, which mitigates certain artefacts that occur when a frequency band is attenuated too harshly.

$$C(t,f) = \max\left(\lambda, \sqrt{10^{\frac{V_G(t,f)}{20}}}\right),$$

- The frequency-dependent and temporally-dependent gain factor is then multiplied element wise with the input signal. An appropriate inverse time-frequency transform is then performed to complete the method.

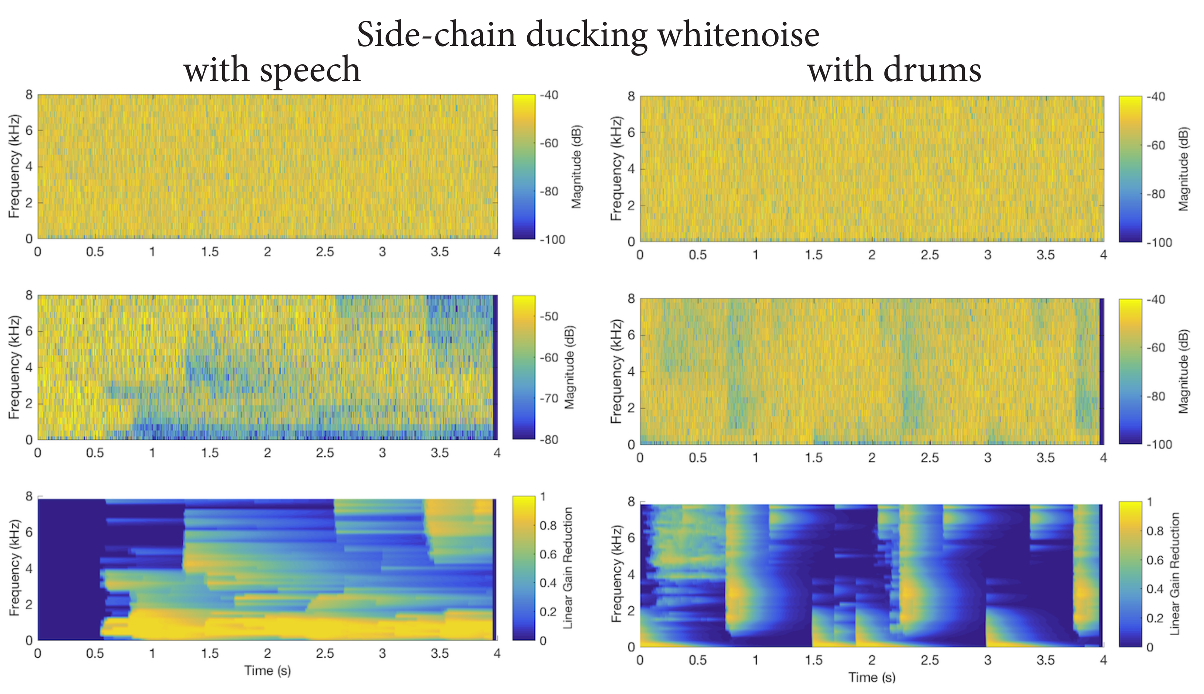
VST Implementation

- In order to investigate the behaviour and performance of the proposed design, the algorithms presented were implemented using MatLab and then realised as a Virtual Studio Technology (VST) audio plug-in. The graphical user interface (GUI) was designed using the open source JUCE Framework.
- The alias-free STFT filterbank, which uses analysis and synthesis windows that are optimised to reduce temporal aliasing, was selected as the time-frequency transform for the implementation. A hop size of 128 samples and an FFT length of 1024 samples were selected.
- A total of 8 seconds of historic frequency-dependent gain factors, utilised in the processing section of the VST, are stored and displayed on the GUI to provide the user with visual feed-back of the extent of gain reduction.

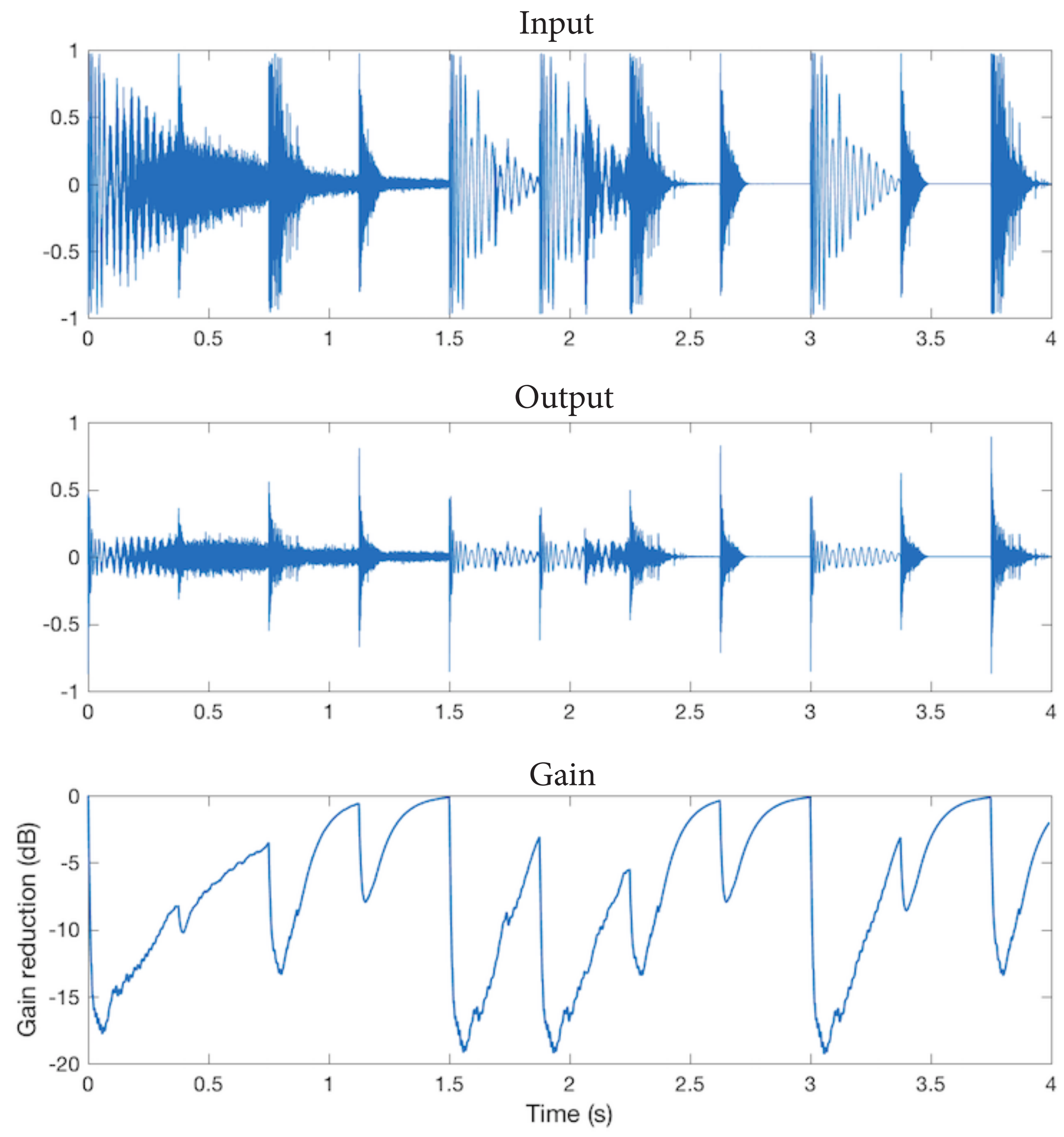


Applications

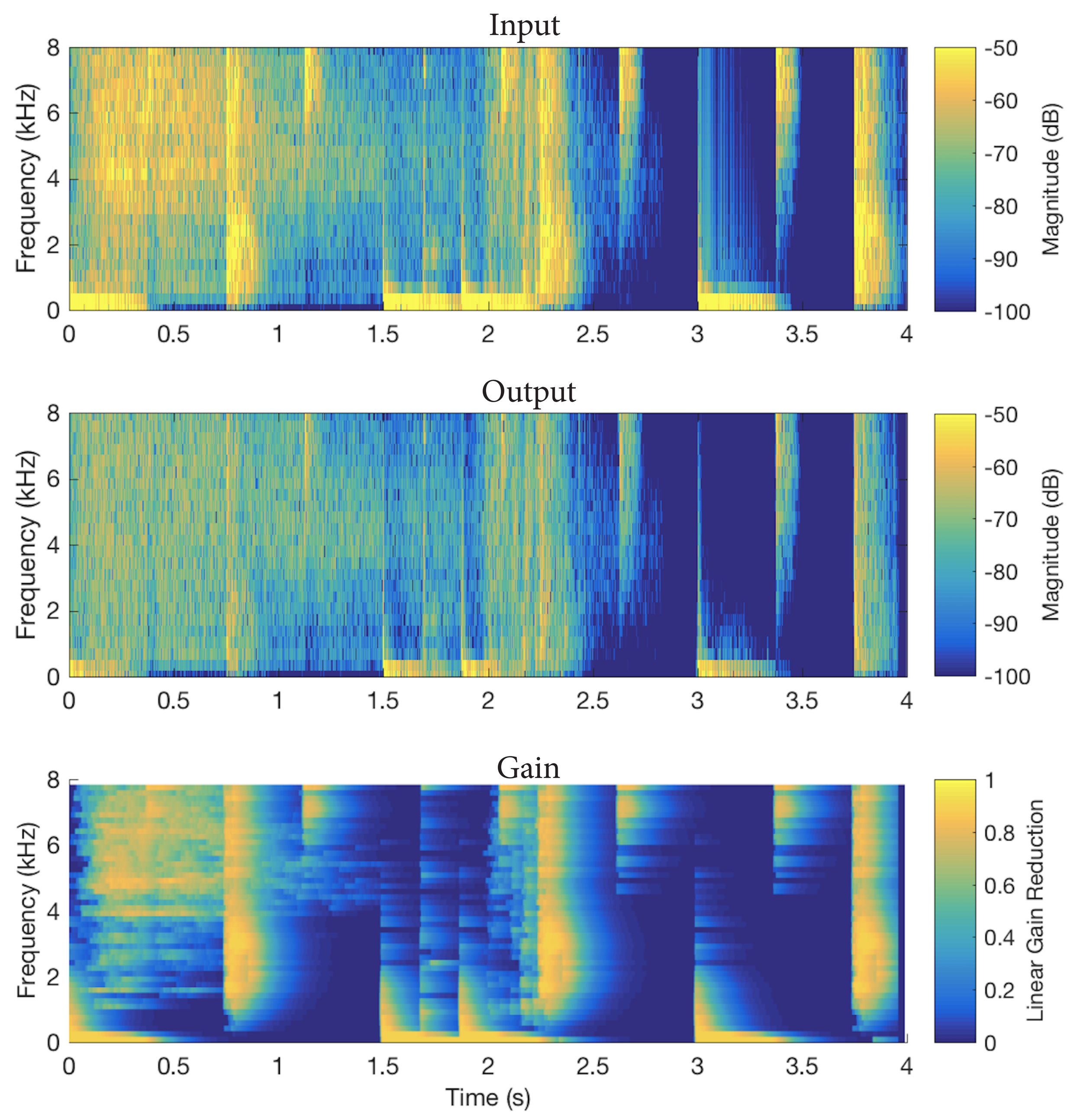
- A high-resolution multi-band dynamic range compressor
- Frequency-dependent side-chain compression for automatic-mixing and side-chain ducking for broadcasting.
- Gain factor estimates are independent, but can be grouped together to mimic traditional designs, such as De-essers etc.



Time Domain



Time-Frequency Domain



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