

4T2: The Short-Time Fourier Transform (2 of 2)

Xavier Serra

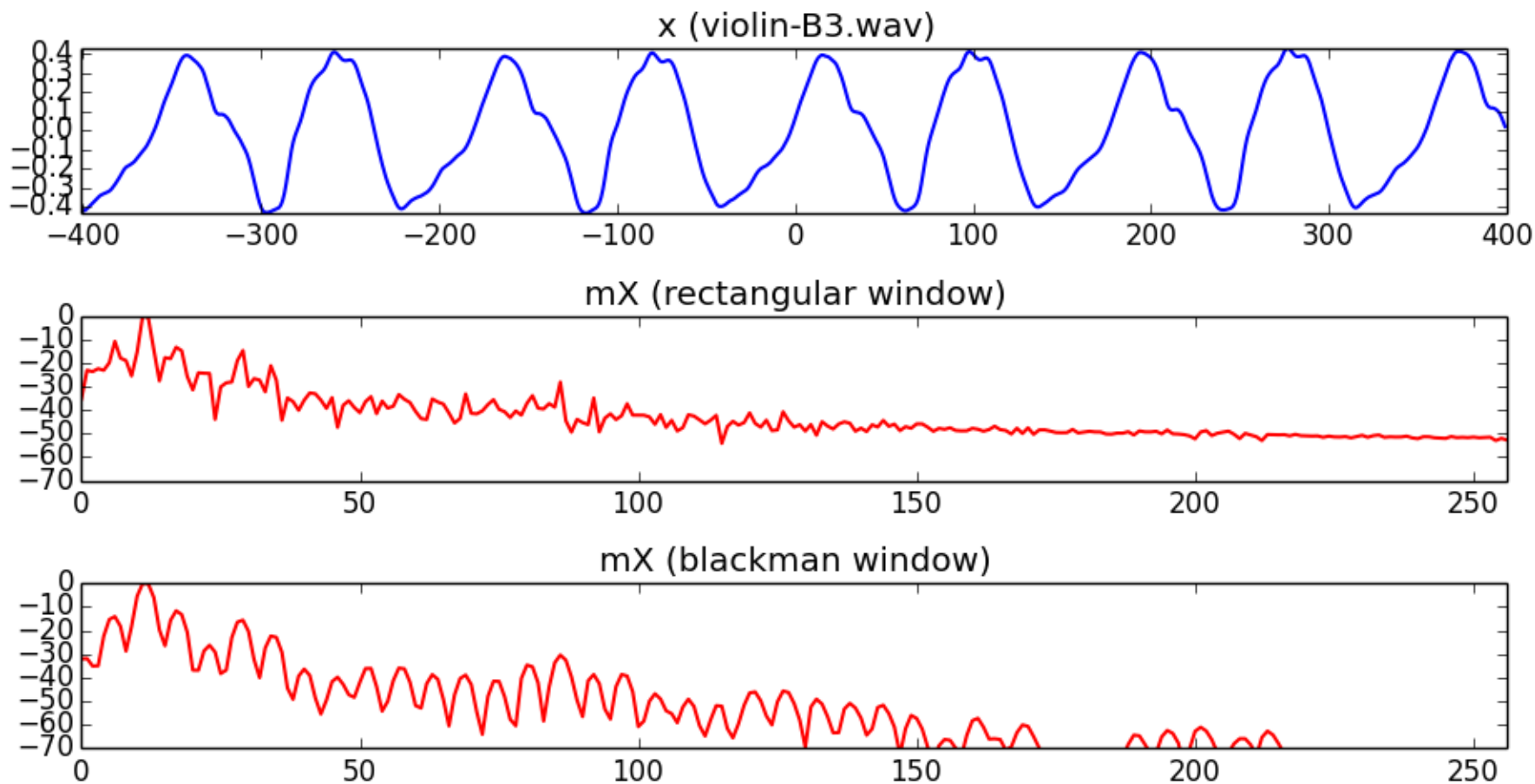
Universitat Pompeu Fabra, Barcelona

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STFT and analysis window

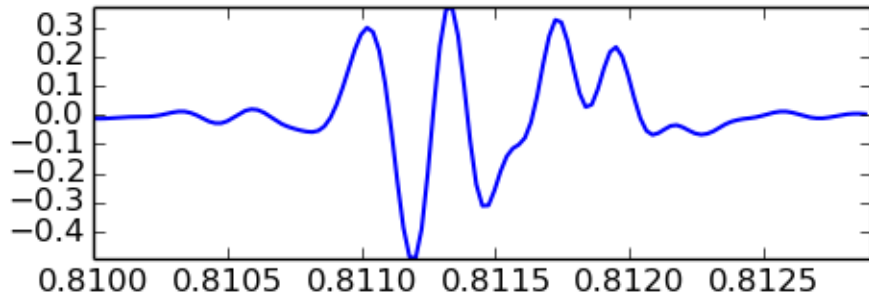
$$X_l[k] = \sum_{n=-N/2}^{N/2-1} w[n] x[n+lH] e^{-j2\pi kn/N} \quad l=0,1,\dots,$$



Window size

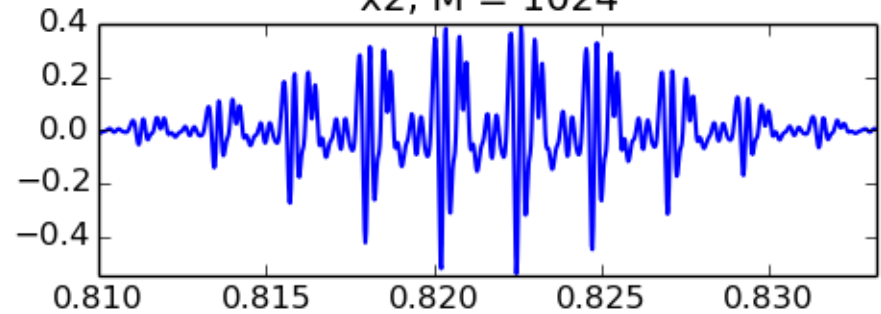
Better for onset detection
(more time resolution, as
DFT "freezes" the time in
averaging its frequency
spectrum)

x1, M = 128

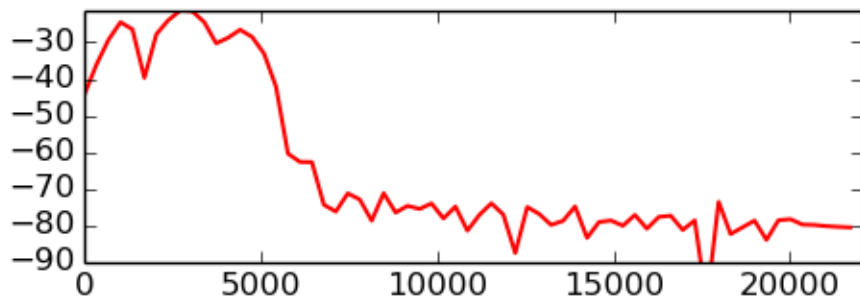


Better for pitch detection
(Better frequency
resolution)

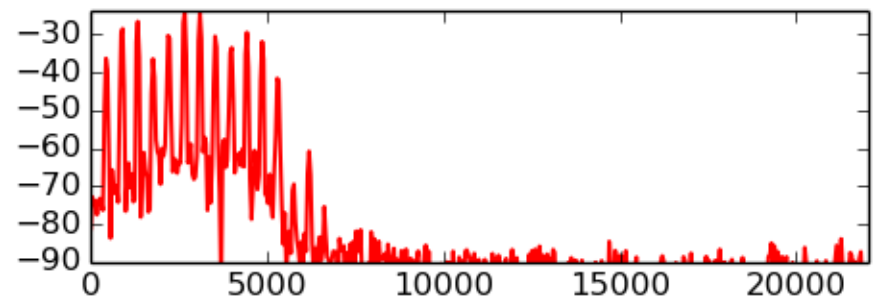
x2, M = 1024



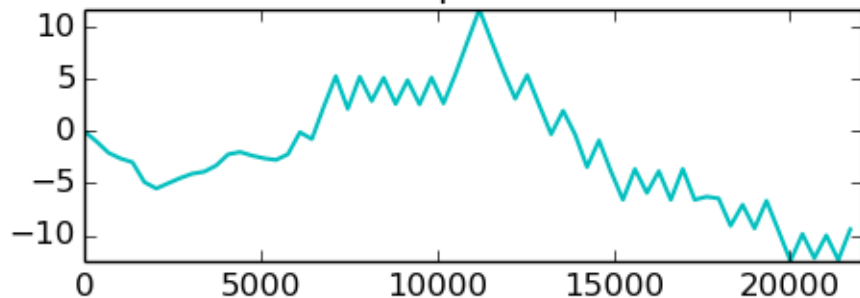
mX1



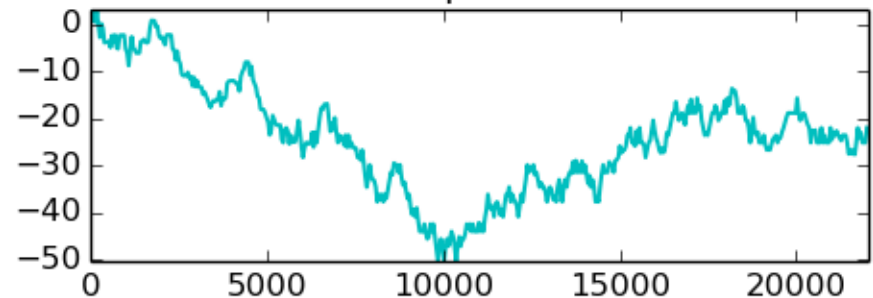
mX2



pX1

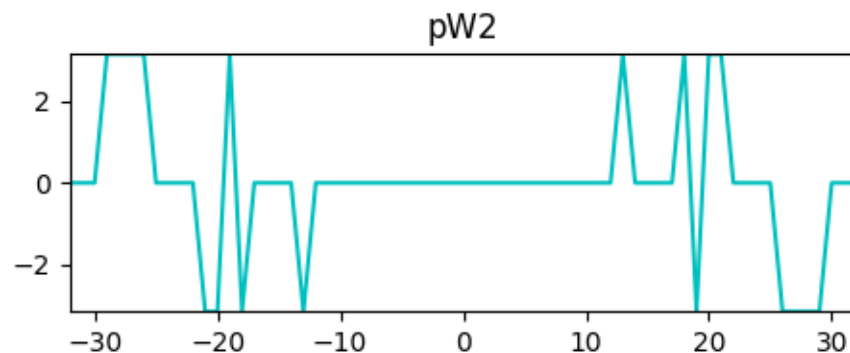
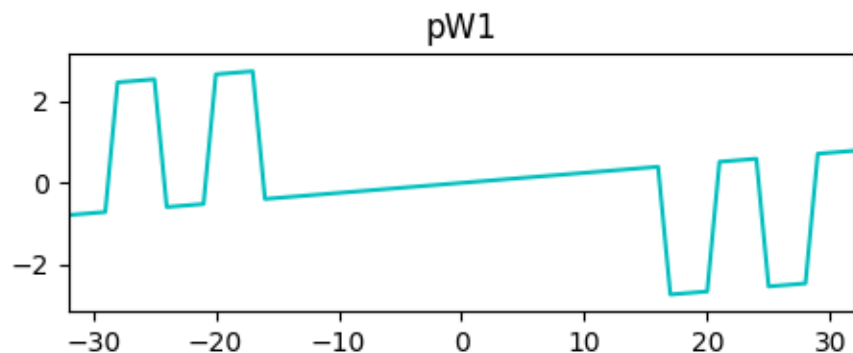
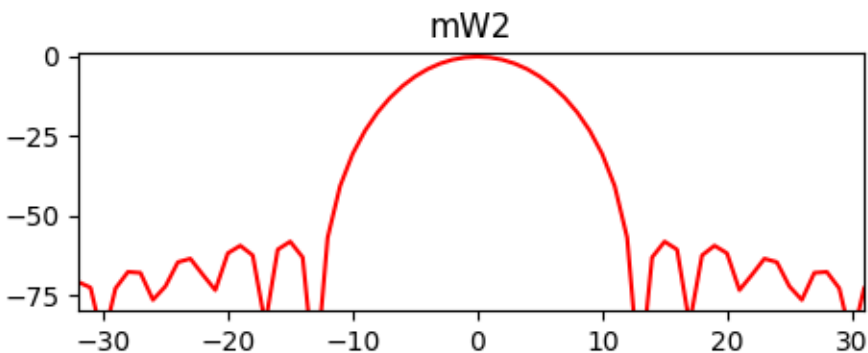
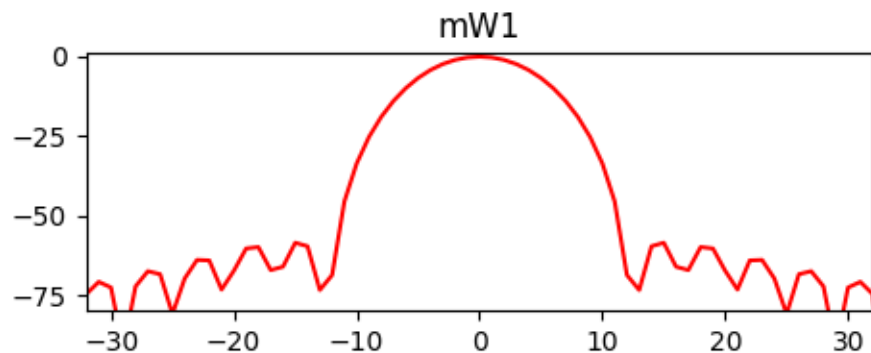
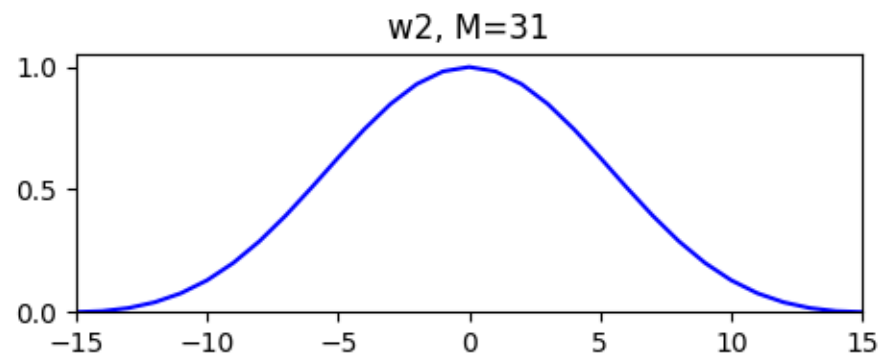
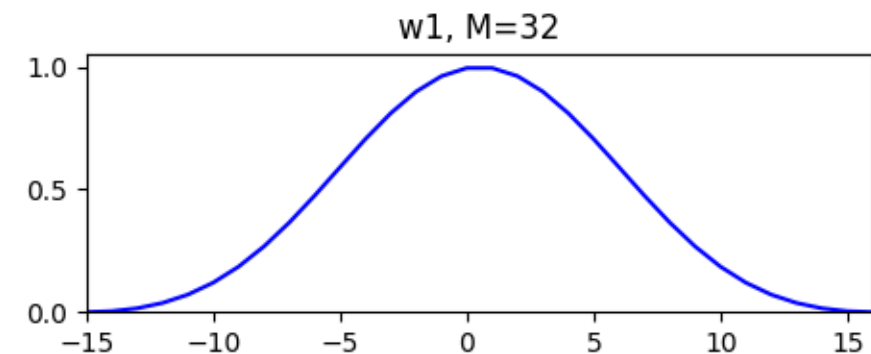


pX2

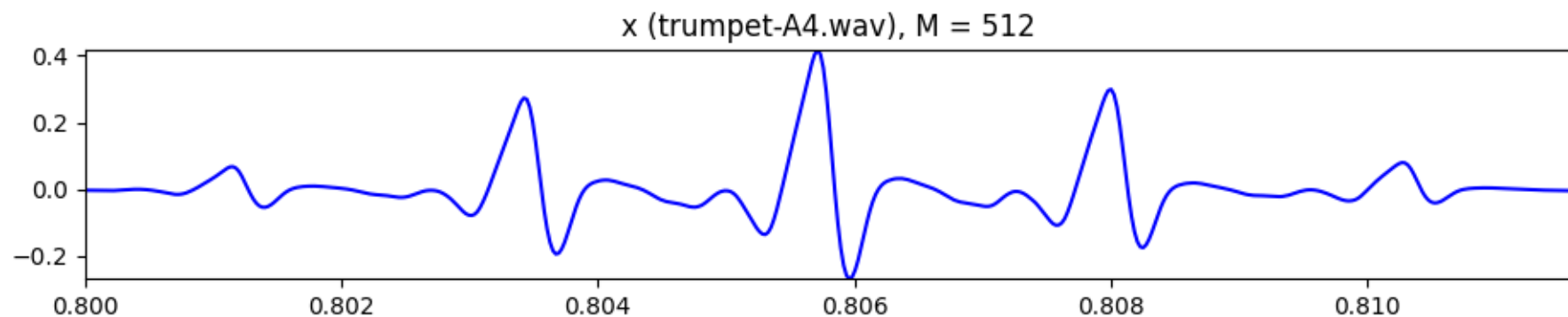


Even-odd size window

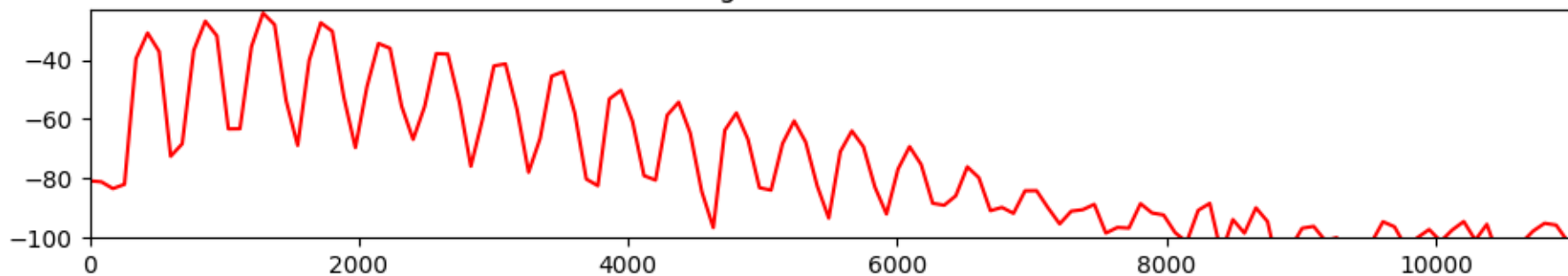
Better phase spectrum



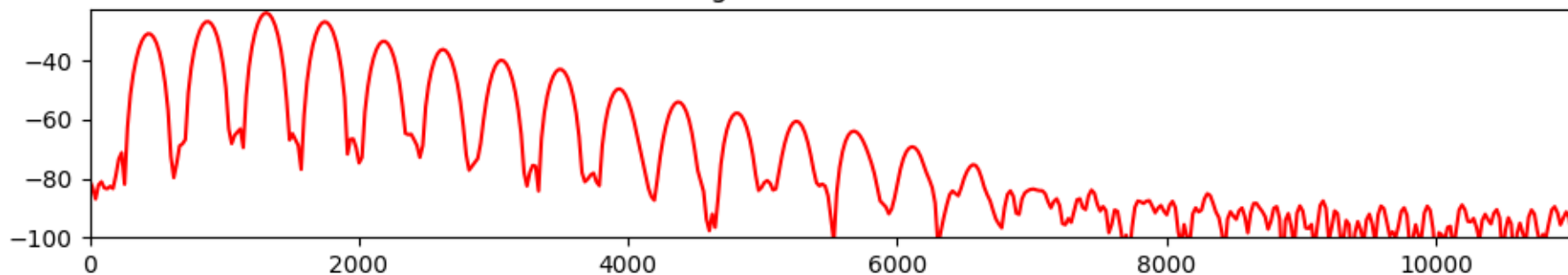
FFT size



mX, hamming window, M = 512, N = 512

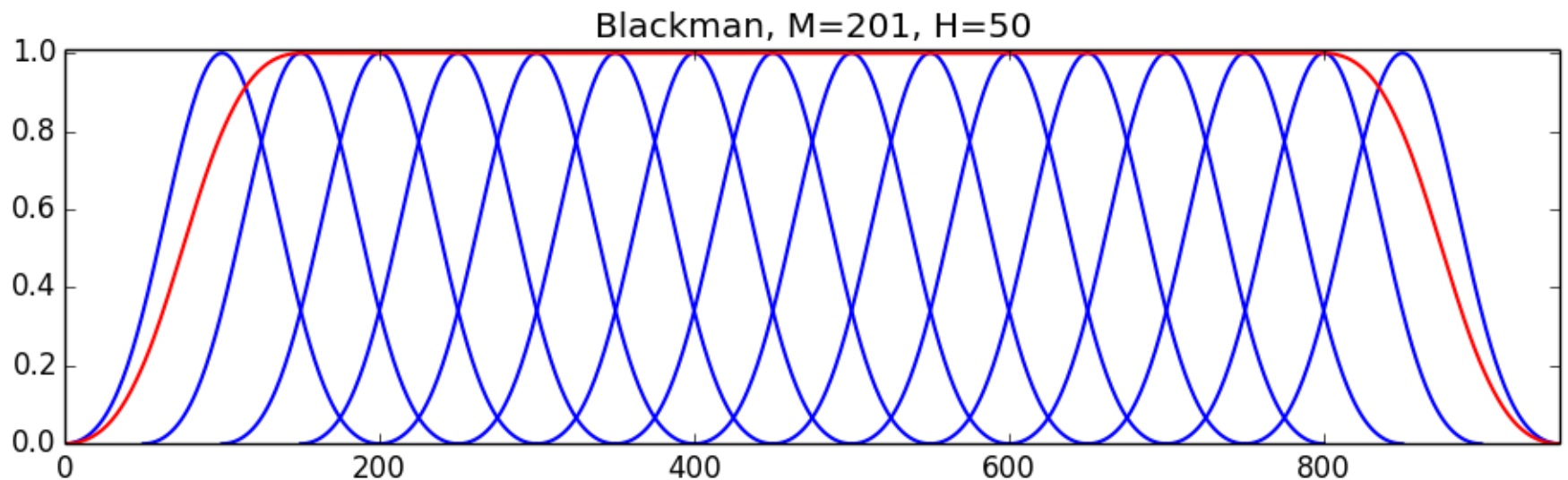
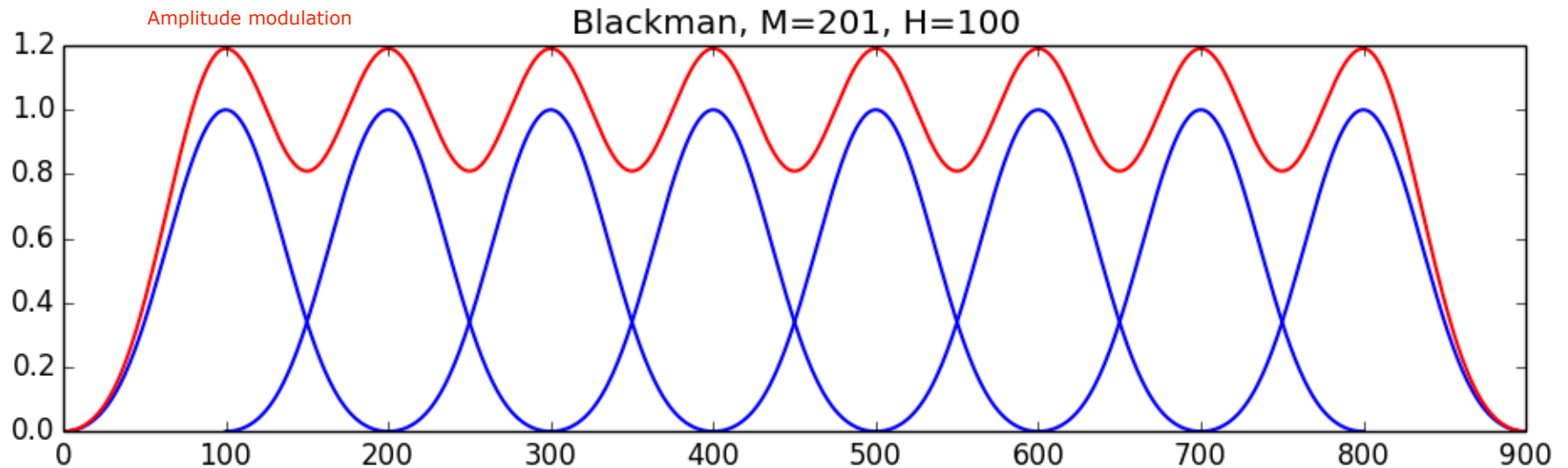


Interpolated version of the version above mX, hamming window, M = 512, N = 2048



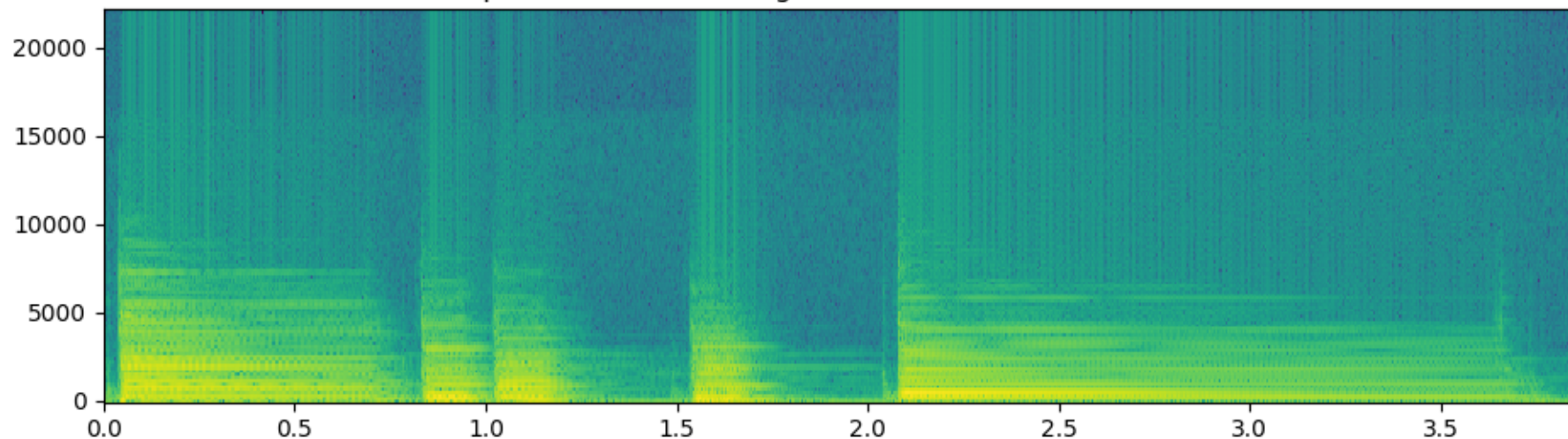
Hop size

$$A_w[n] = \sum_{l=0}^{L-1} w[n-lH] = c$$

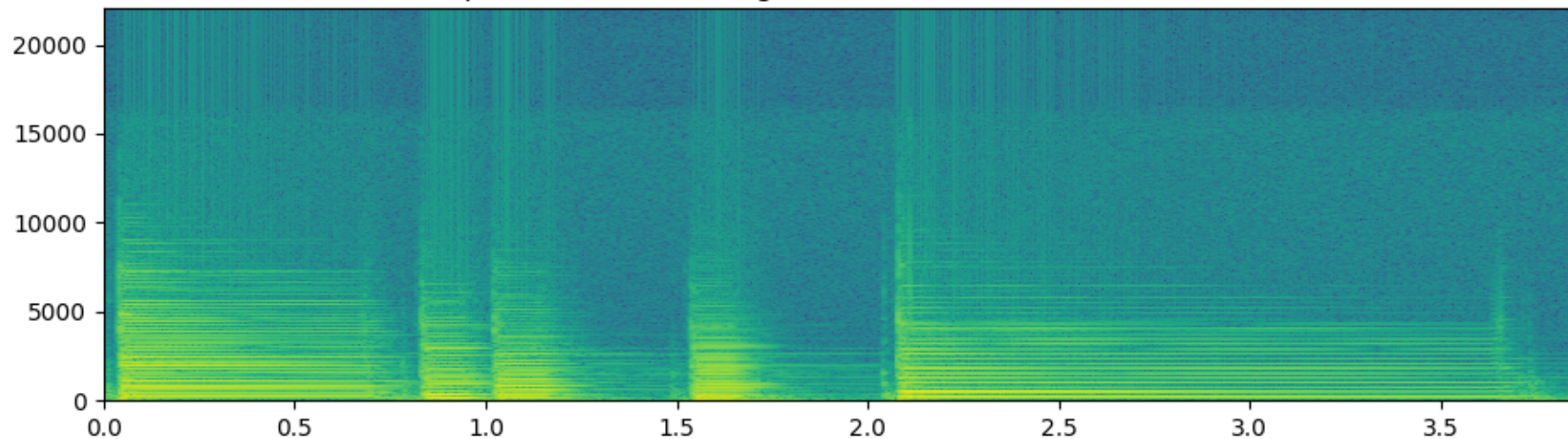


Time-frequency compromise

mX (piano.wav), Hamming window, M=256, N=256, H=128

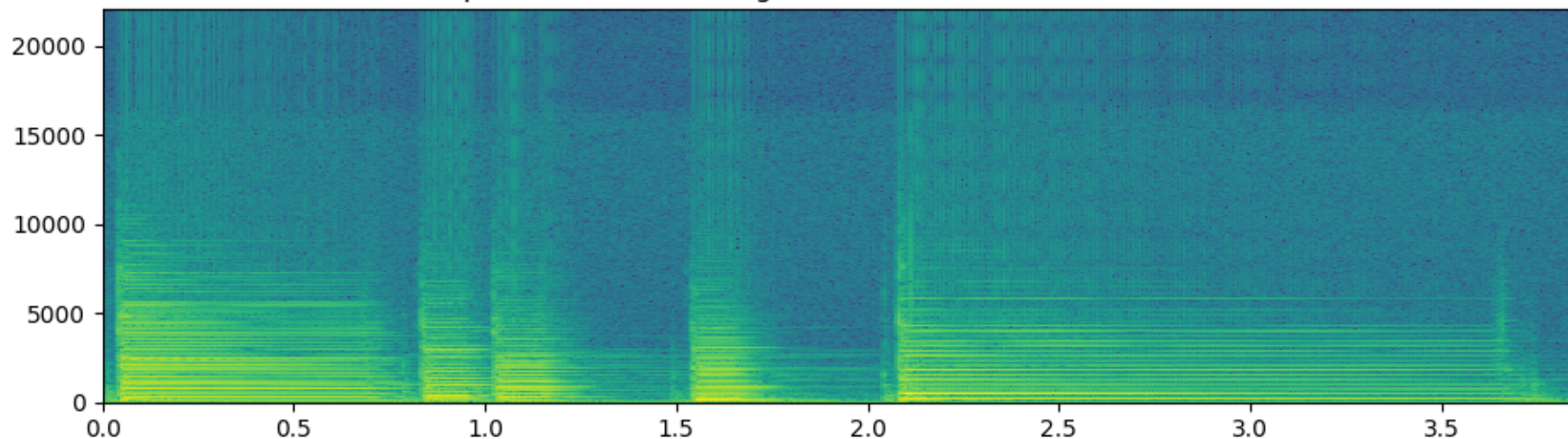


mX (piano.wav), Hamming window, M=1024, N=1024, H=128

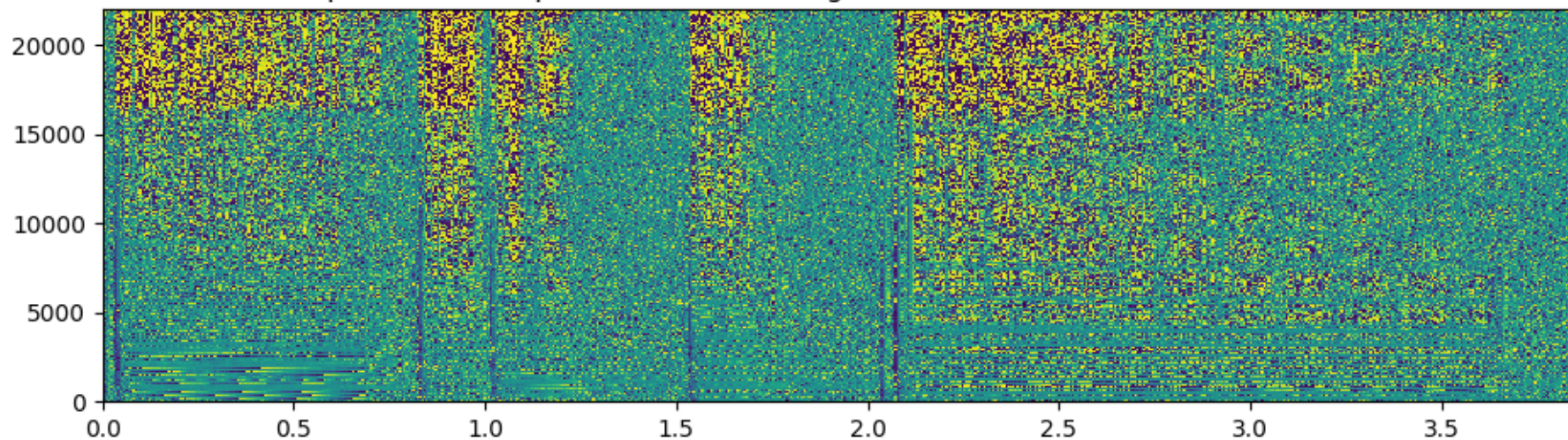


Amplitude and phase spectrogram

mX (piano.wav), Hamming window, M=1001, N=1024, H=256



pX derivative (piano.wav), Hamming window, M=1001, N=1024, H=256



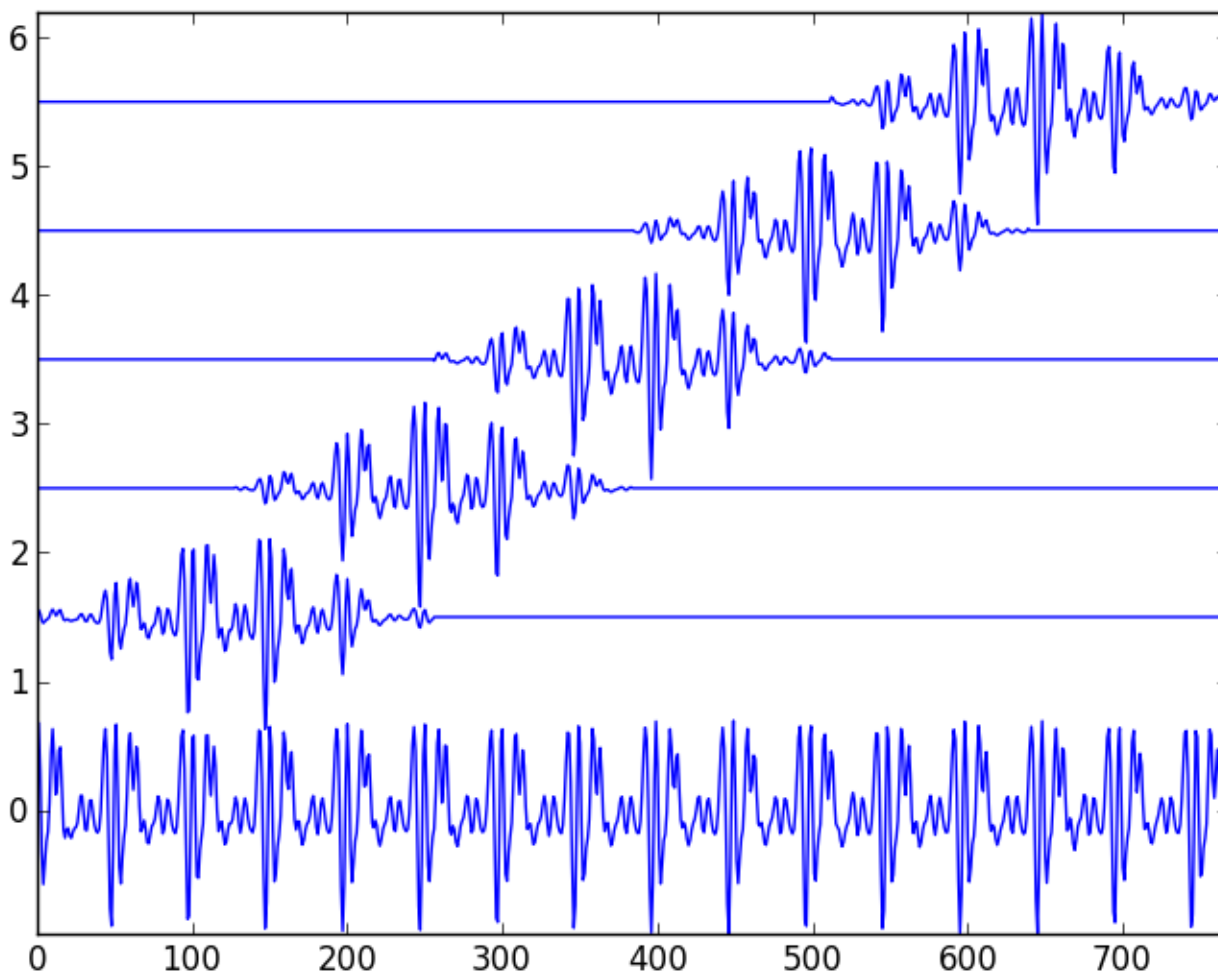
Inverse STFT

$$y[n] = \sum_{l=0}^{L-1} \text{Shift}_{lH, n} \left[\frac{1}{N} \sum_{k=-N/2}^{N/2-1} X_l[k] e^{j2\pi kn/N} \right]$$

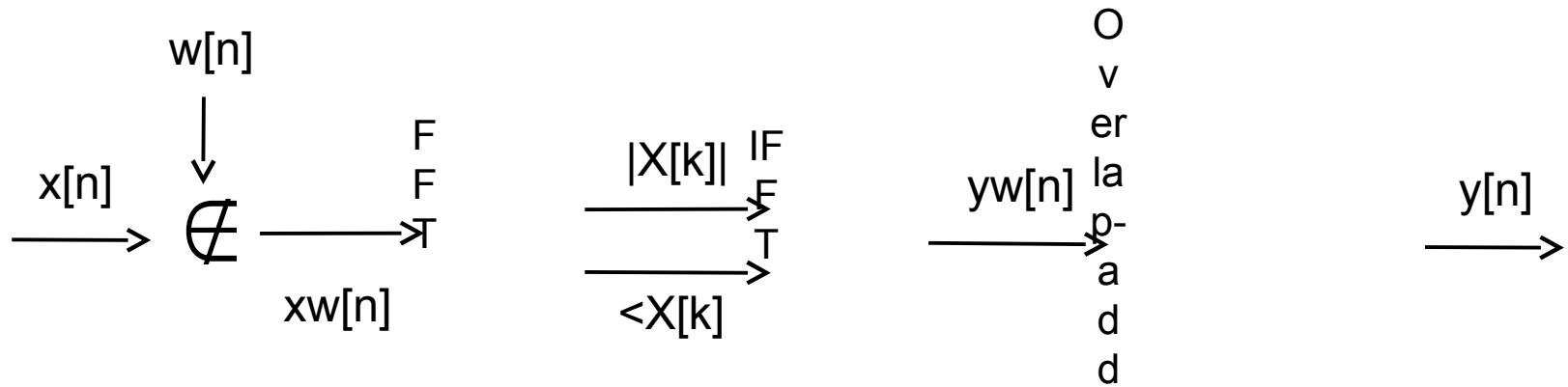
$$yw_l[n] = x(n + lH) w[n]$$

$$y[n] = \sum_{l=0}^{L-1} yw_l[n] = x[n] \sum_{l=0}^{L-1} w[n - lH]$$

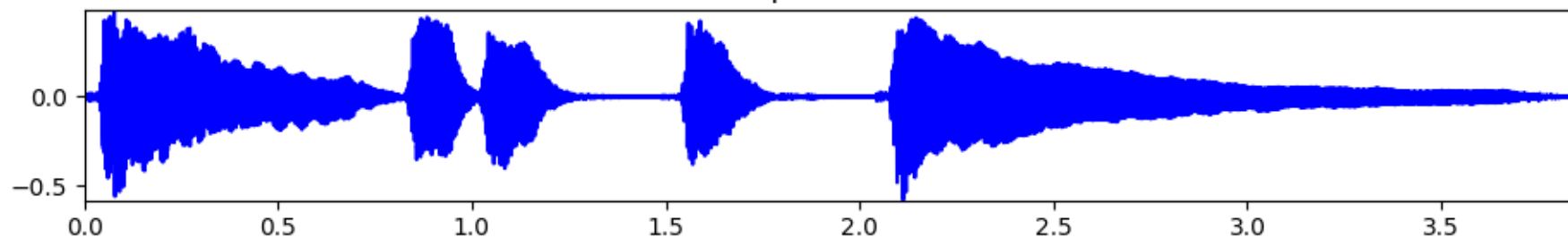
$$yw_l[n] = w[n]x[n+lH] \quad l=0,1,\dots,$$



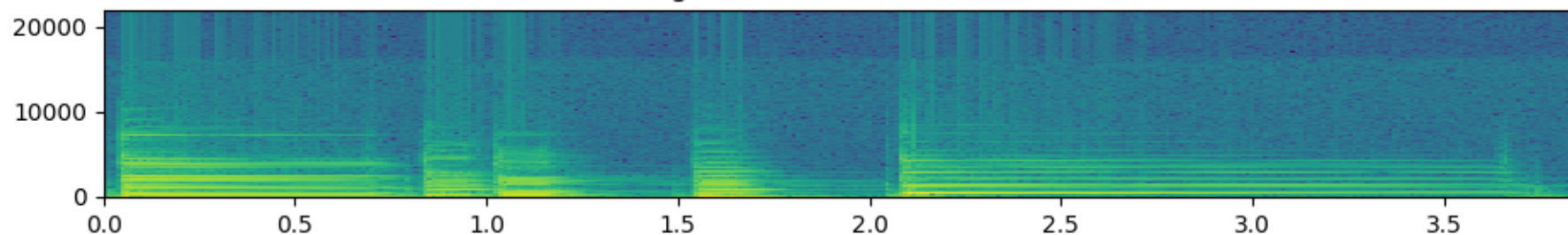
STFT system



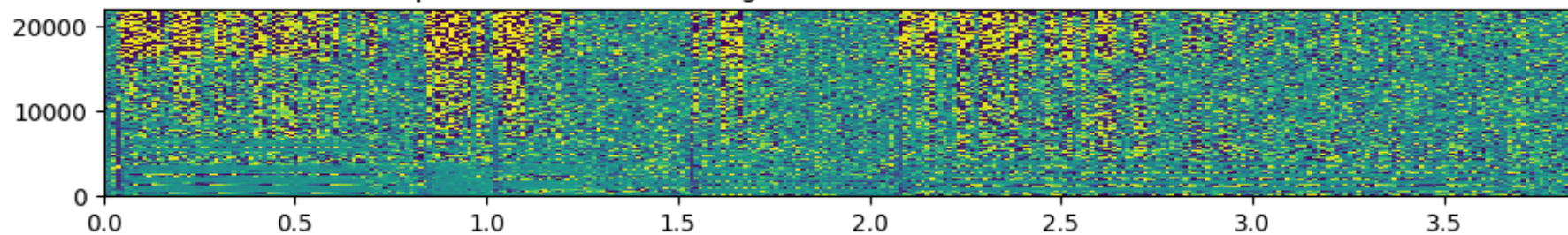
x (piano.wav)



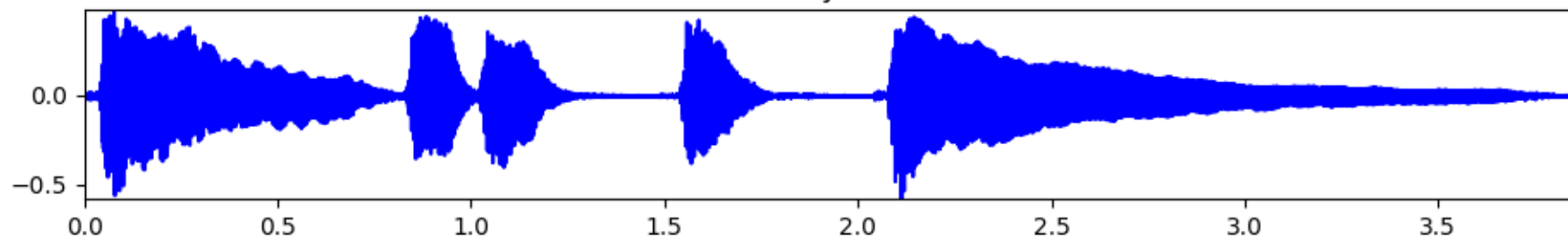
mX, Hamming window, M=1024, N=1024, H=512



pX derivative, Hamming window, M=1024, N=1024, H=512



y



References and credits

- More information in:
<https://en.wikipedia.org/wiki/STFT>
https://en.wikipedia.org/wiki/Window_function
<http://en.wikipedia.org/wiki/Spectrogram>
- Reference on the STFT by Julius O. Smith:
<https://ccrma.stanford.edu/~jos/sasp/>
- Sounds from:
<http://www.freesound.org/people/xserra/packs/13038/>
- Slides released under CC Attribution-Noncommercial-Share Alike license and code under Affero GPL license.
All available from <https://github.com/MTG/sms-tools>

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Universitat Pompeu Fabra, Barcelona