Audio Measurements using JAAA

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JAAA - Overview

What is it?

FFT based spectrum analysis

Measuring noise

Internals

Demo

Things to do

Questions?
What is it?

- A signal generator and spectrum analyser.
- Checking performance of audio HW en SW.
- JAAA is a technical, not a musical tool.
  - Linear frequency scales
  - Designed for accurate measurements
  - Requires some technical knowledge
FFT based spectrum analysis

• **FT** : Fourier Transform. Transforms function of time $f(t)$ (a signal) into a function of frequency $F(\omega)$ (a spectrum).
  – Operates on continuous (not sampled) functions.
  – Can be reversed: no information is lost in the transform.

• **DFT** : Discrete Fourier Transform. Same as FT, but operating on discrete (sampled) signals, and producing a discrete (sampled) spectrum.

• **FFT** : Fast Fourier Transform. Optimized version of the DFT.

• **FFTW3** : A very nice open source FFT library, used in many Linux applications.
FFT based spectrum analysis

- An \( N \)-point FFT replaces \( N/2 \) bandpass filters.
- Frequency step \( \Delta F = F_{samp}/N \).
- \( F_{samp} = 44.1 \) kHz, 1024 point FFT → filters at 0, 43, 86, 129 . . . 22007 Hz.

Could it be so simple? . . .
FFT based spectrum analysis

A simple analyser
FFT based spectrum analysis

What's going wrong?

Filter shape is the FT of the input window.
FFT based spectrum analysis

Rectangular window
FFT based spectrum analysis

Raised cosine window
FFT based spectrum analysis

- Raised cosine
- JAAA window
FFT based spectrum analysis

Analyser with windowing

Multiplication before FFT is equivalent to convolution after FFT.
A short convolution can be done by an FIR filter, so...
FFTBased spectrum analysis

JAAA analyser

Polyphase FIR replaces windowing, and interpolates the spectrum.
Feedback path added for averaging power over time.
FFT based spectrum analysis

Filter responses spaced $\Delta/2 \rightarrow$ maximum error = 0.25 dB.
More accurate measurements are possible by interpolation.
Measuring noise

How can we measure noise? Let's try…
Measuring noise

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Apparent noise level depends on FFT length, or bandwidth.
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A spectrum analyser can be used to measure noise density, $N_0$.

$N_0$ is noise power per 1 Hz of bandwidth.

Total noise power = $N_0 \times B$.

The unit of $N_0$ is 1 / Hz, or dB / Hz.

Noise level = -10 dB, $F_{\text{sample}} = 44.1$ kHz $\rightarrow B = 22.05$ kHz = 43.43 dBHz $\rightarrow N_0 = -53.43$ dB/Hz

Noise level = -10 dB, $F_{\text{sample}} = 48.0$ kHz $\rightarrow B = 24.00$ kHz = 43.80 dBHz $\rightarrow N_0 = -53.80$ dB/Hz
JAAA program architecture
More pixels than spectrum points, the easy case.

More spectrum points than pixels.

Correct signal level display requires peak value
Correct noise level display requires average value

JAAA displays two traces in this case.
Peak markers are calculated using 2nd order interpolation.
Demo signal routing.
Things to do

- Clean up the code
- Documentation
- More signal generators
- Integrated noise calculation
- Trace memories
- JACK transport
Audio Measurements using JAAA

Question time!