

## Audio Measurements using JAAA

Fons Adriaensen

2nd Linux Audio Developers Conference  
ZKM Karlsruhe 28 April - 2 May 2004

What is it ?

FFT based spectrum analysis

Measuring noise

Internals

Demo

Things to do

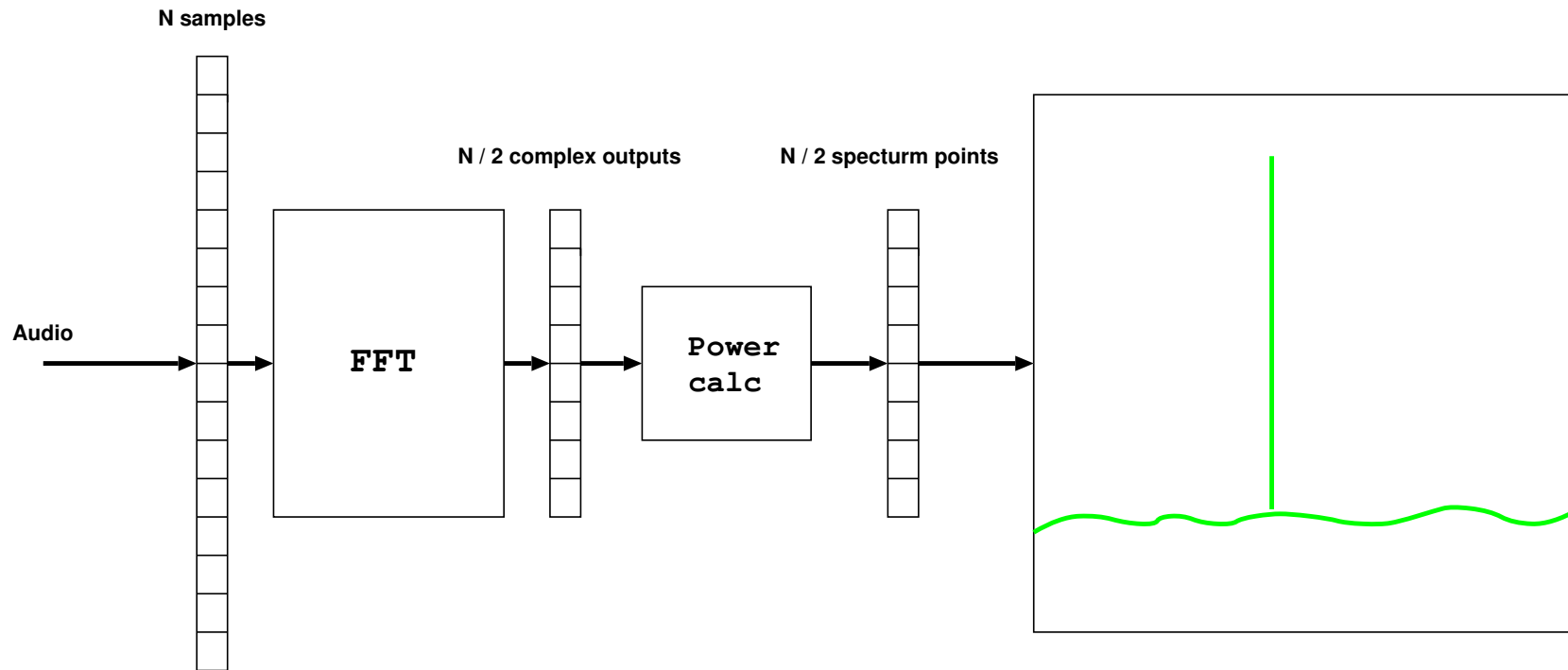
Questions ?

- 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

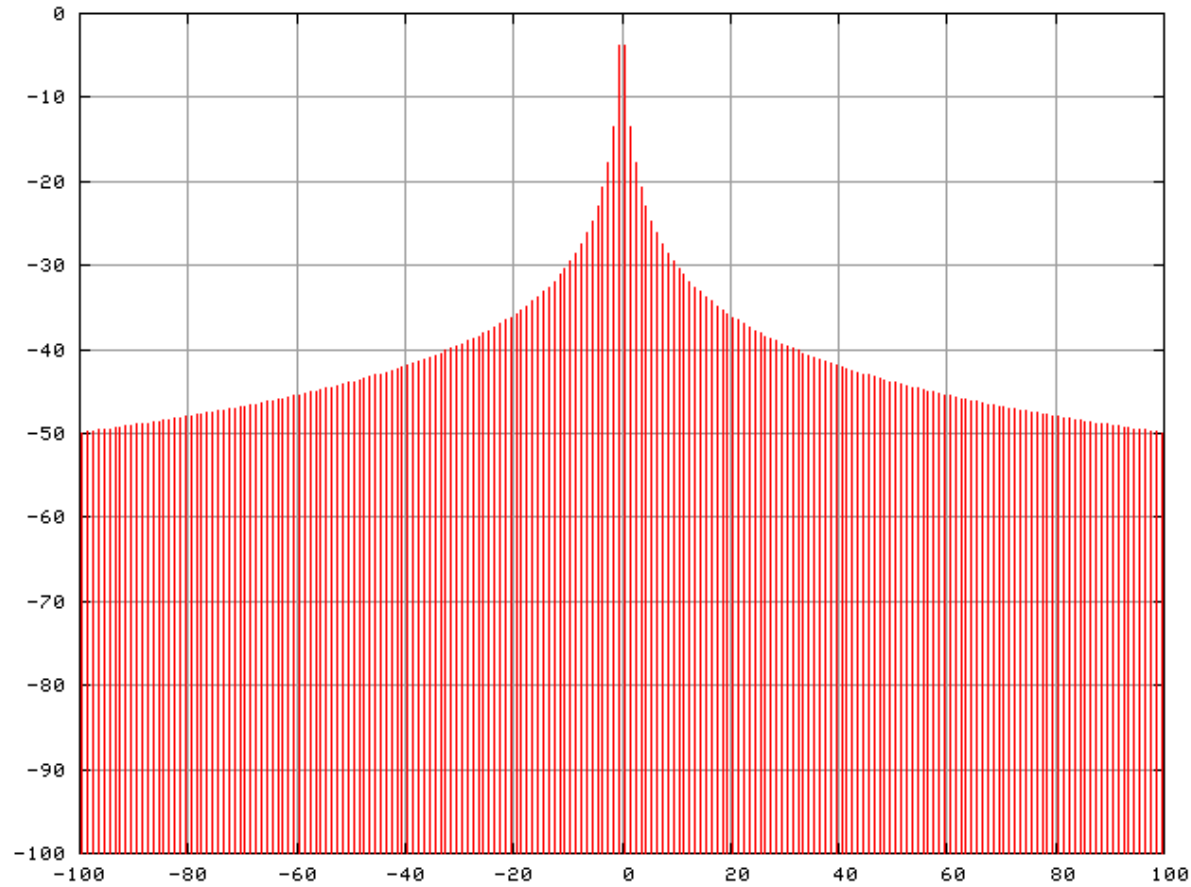
- **FT** : Fourier Transform. Transforms function of time  $f(t)$  (a signal) into a function of frequency  $F(\omega)$  (a spectrum).
  - Operates on continuous (not sampled) functions.
  - Can be reversed : no information is lost in the transform.
- **DFT** : Discrete Fourier Transform. Same as FT,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

- An  $N$ -point FFT replaces  $N/2$  bandpass filters.
- Frequency step  $\Delta_F = F_{samp}/N$ .
- $F_{samp} = 44.1$  kHz, 1024 point FFT  $\rightarrow$  filters at 0, 43, 86, 129 ... 22007 Hz.

Could it be so simple ? ...



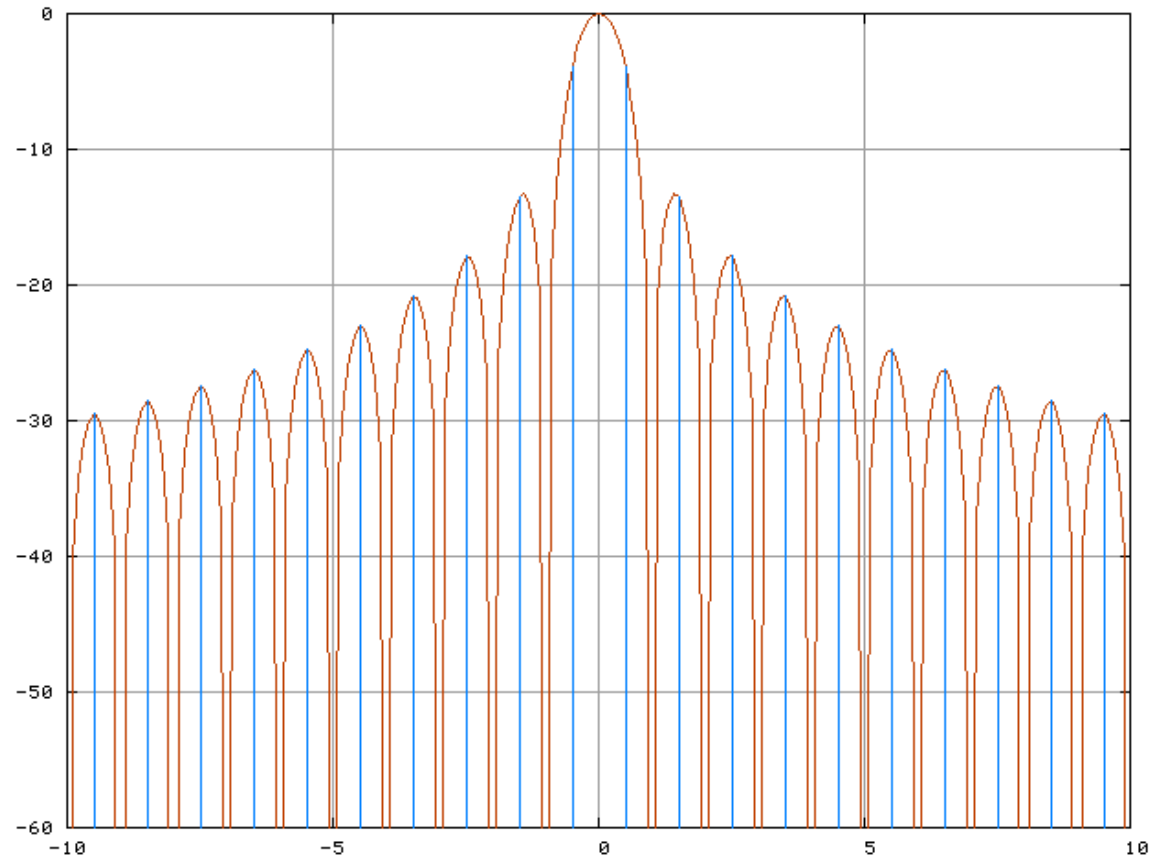
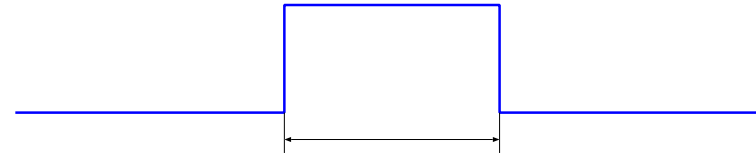
A simple analyser



What's going wrong ?

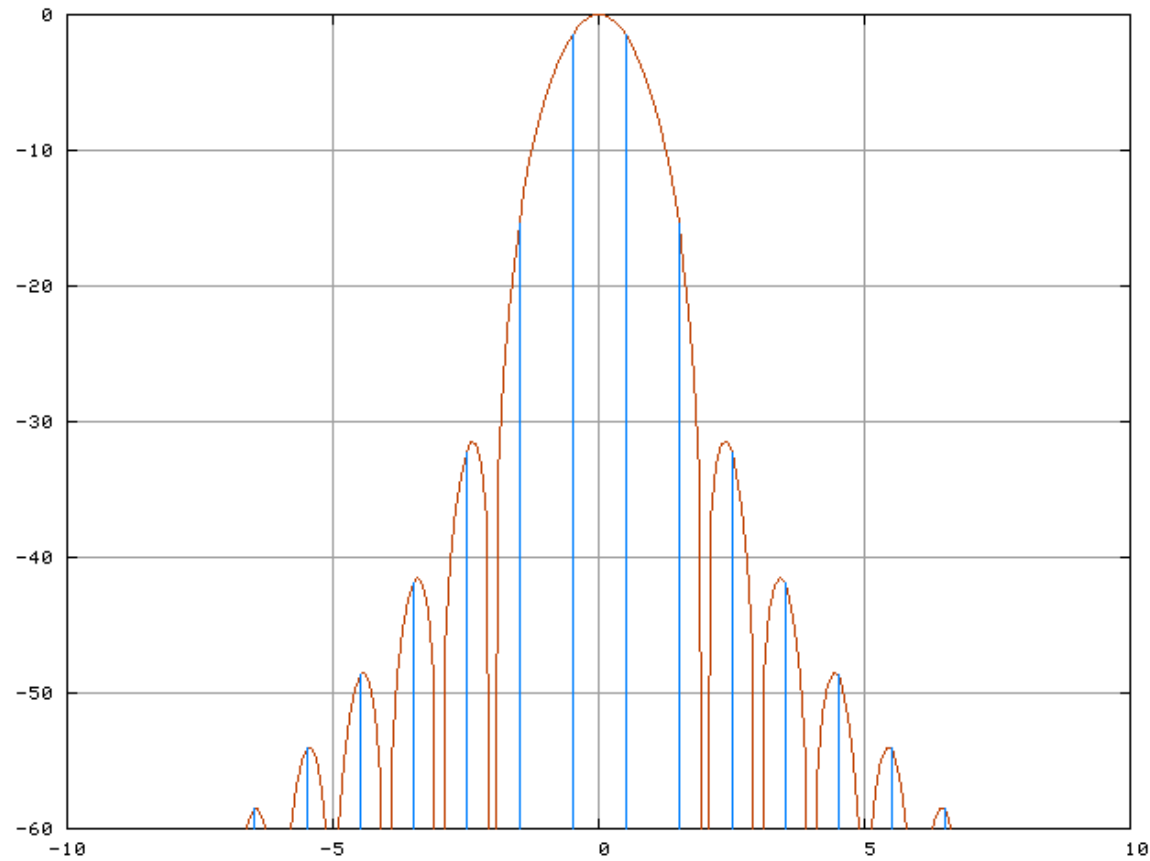
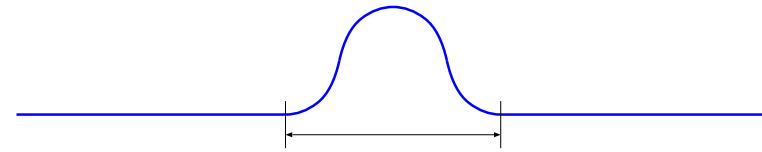
Filter shape is the FT of the input window.

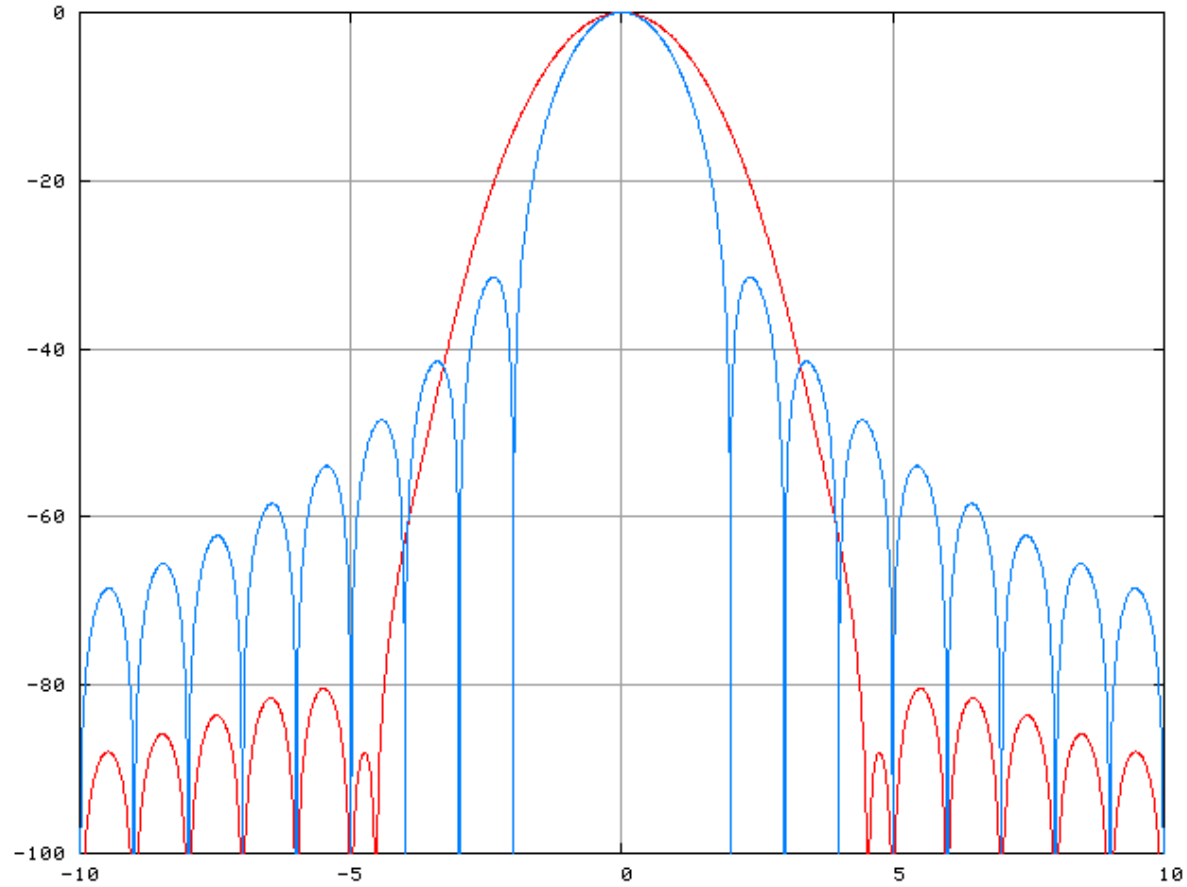
Rectangular window



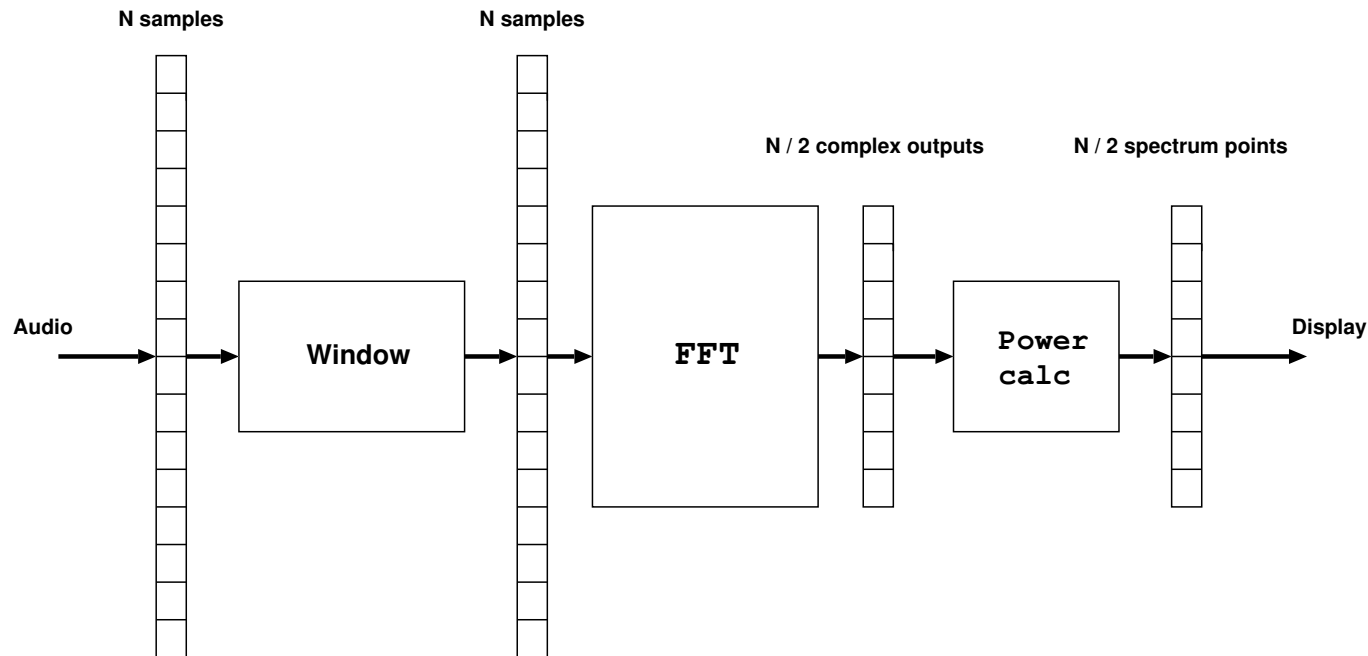


Raised cosine window



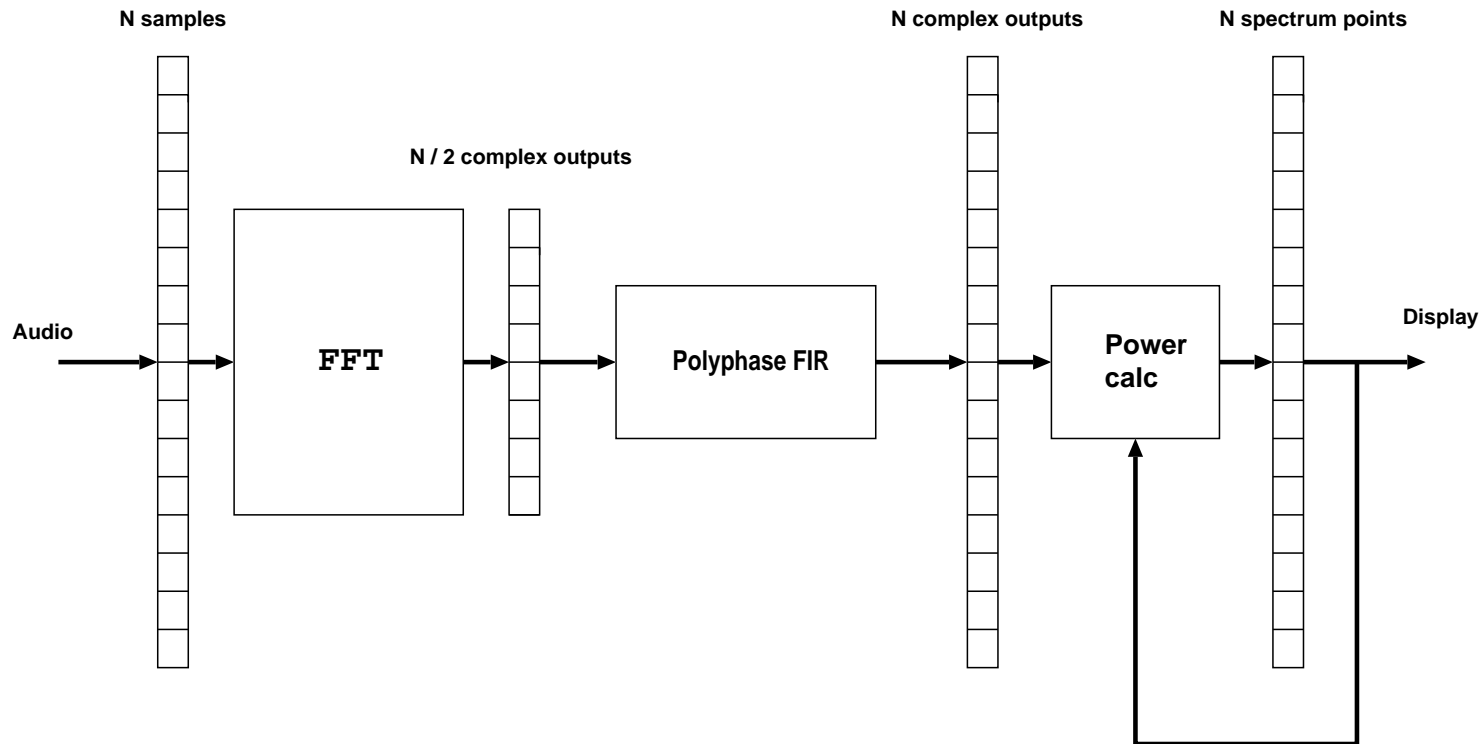


— Raised cosine    — JAAA window



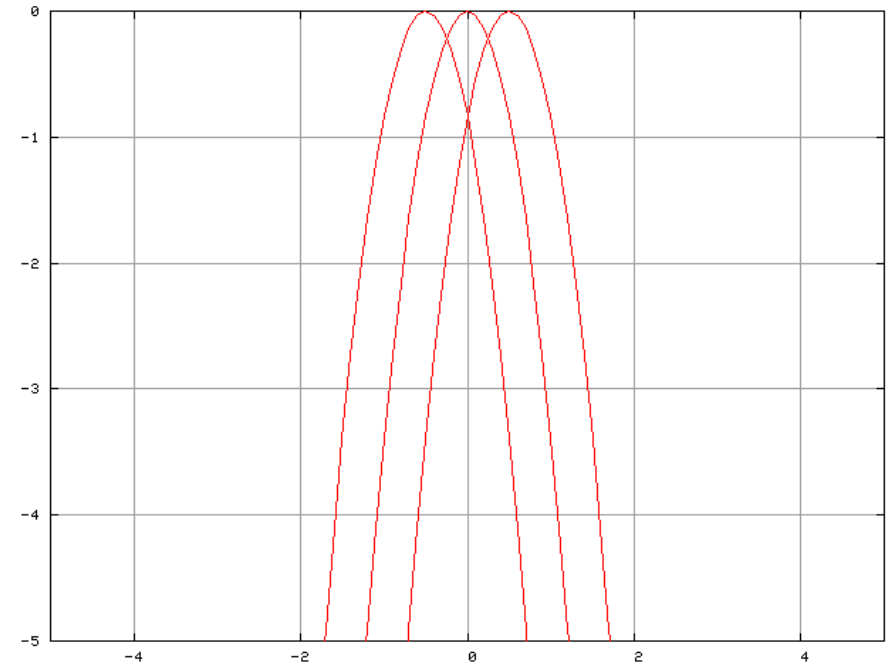
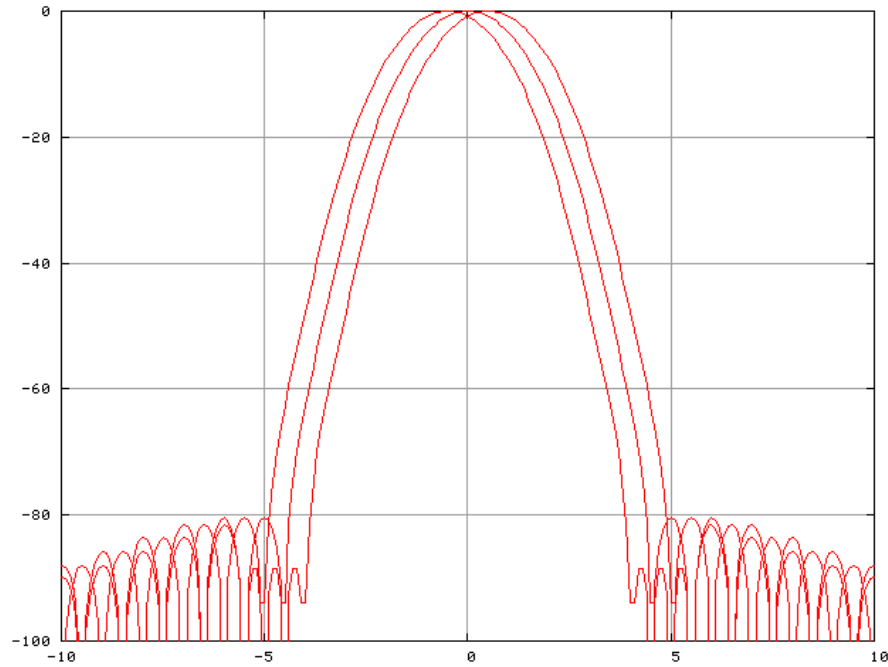
Analyser with windowing

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



JAAA analyser

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



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

How can we measure noise ? Let's try...

How can we measure noise ? Let's try...

Apparent noise level depends on FFT length, or bandwidth.

How can we measure noise ? Let's try...

Apparent noise level depends on FFT length, or bandwidth.

A spectrum analyser can be used to measure noise density,  $N_0$ .

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

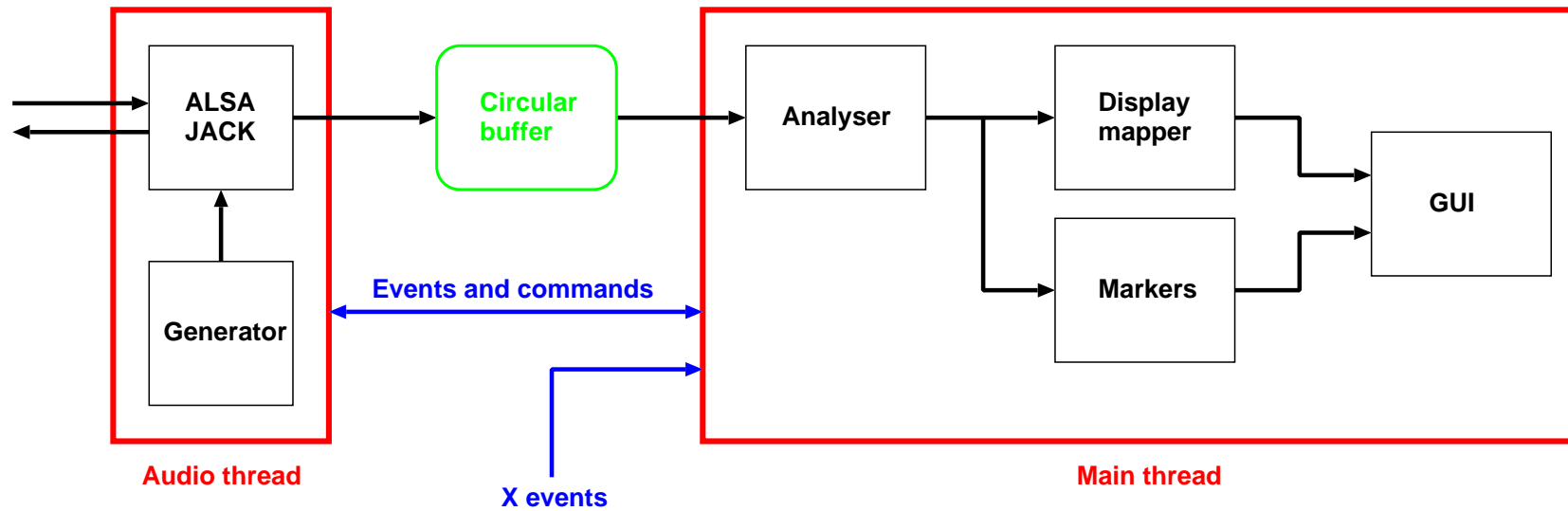
$$\text{Total noise power} = N_0 \times B.$$

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

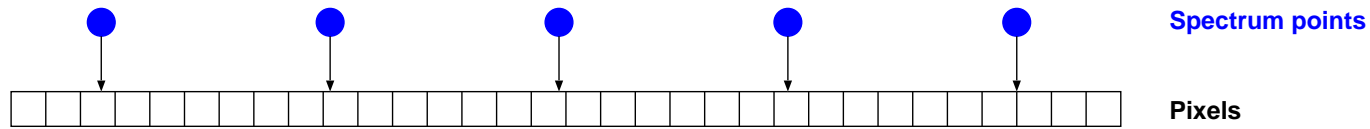
$$\text{Noise level} = -10 \text{ dB}, F_{\text{sample}} = 44.1 \text{ kHz} \rightarrow B = 22.05 \text{ kHz} = 43.43 \text{ dBHz} \rightarrow N_0 = -53.43 \text{ dB/Hz}$$

$$\text{Noise level} = -10 \text{ dB}, F_{\text{sample}} = 48.0 \text{ kHz} \rightarrow B = 44.00 \text{ kHz} = 43.80 \text{ dBHz} \rightarrow N_0 = -53.80 \text{ dB/Hz}$$

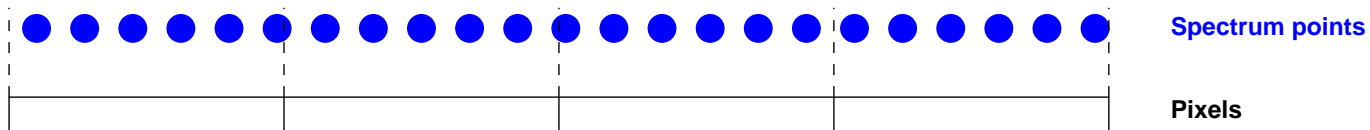




JAAA program architecture



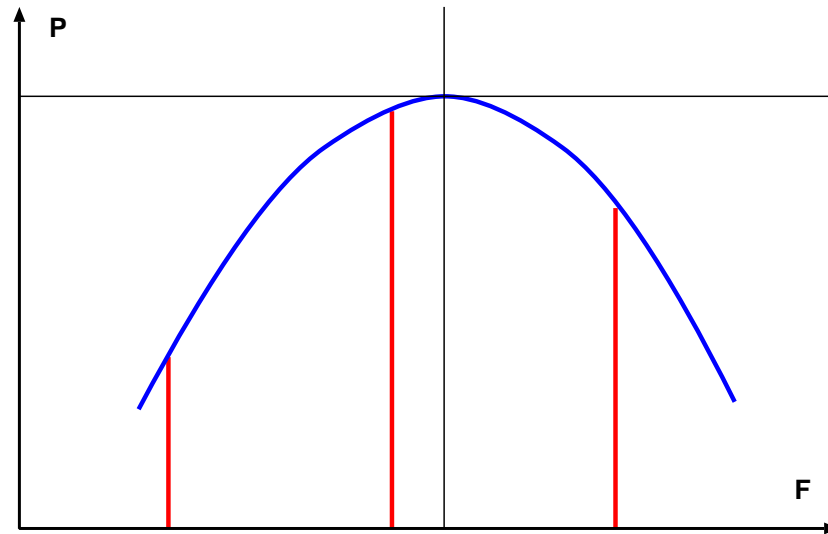
More pixels than spectrum points, the easy case.



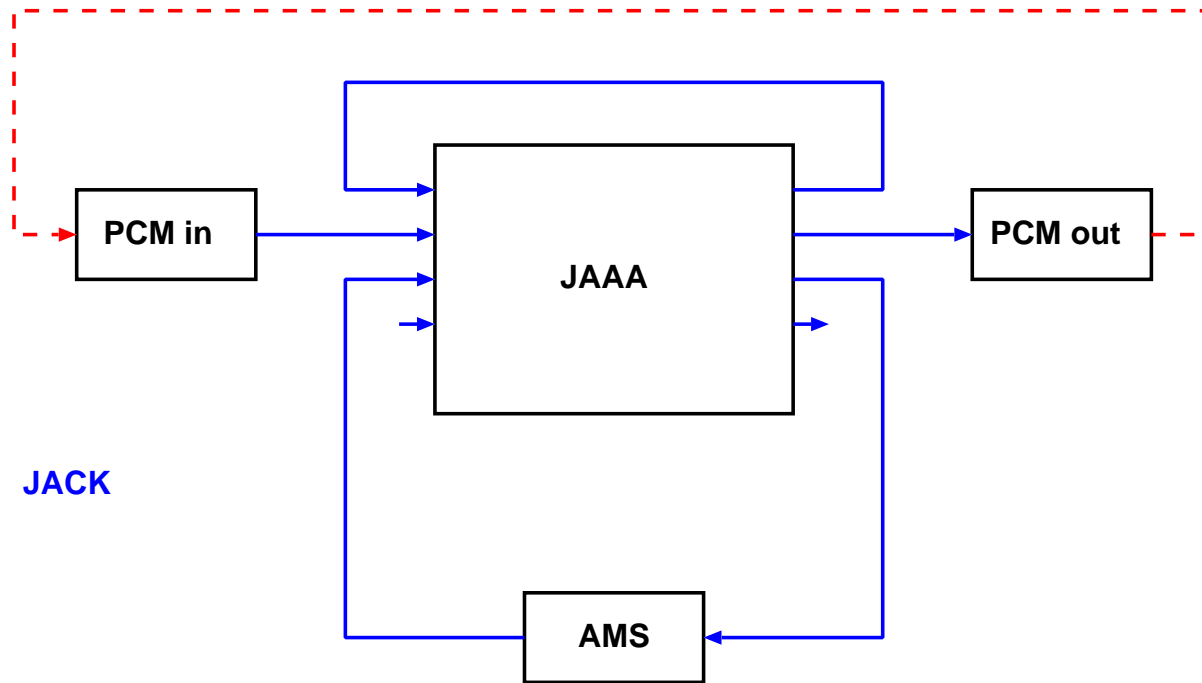
More spectrum points than pixels.

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.

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

## Audio Measurements using JAAA

Question time !