A Calibration Scheme for a Non-uniform Sampling Driver Architecture

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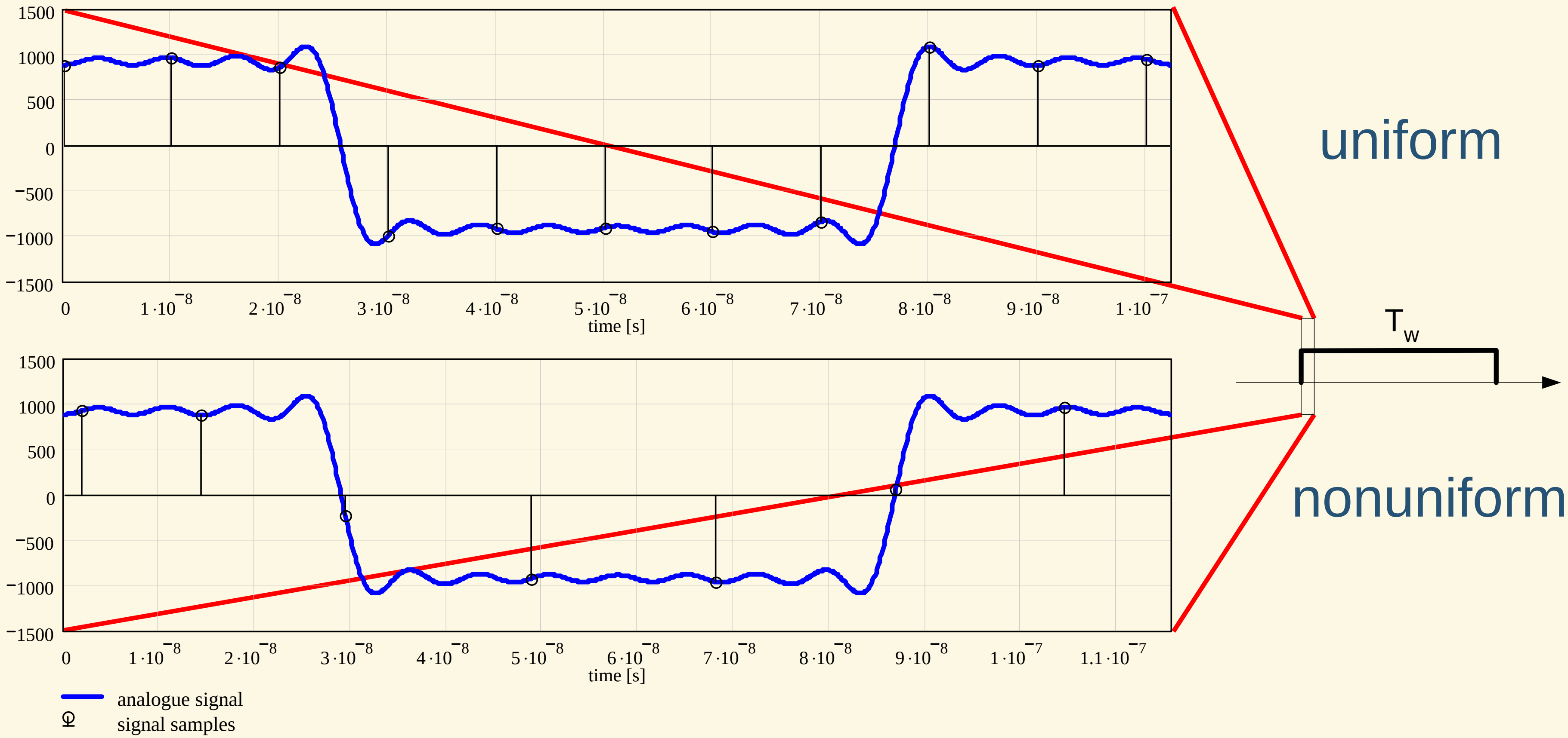
Presentation Overview

- Nonuniform sampling, main idea of approach
- Sequential (frequency) component extraction
  - Problem of sampling instance uncertainty
- **Calibration procedure**
- Measurement results
- Outlook

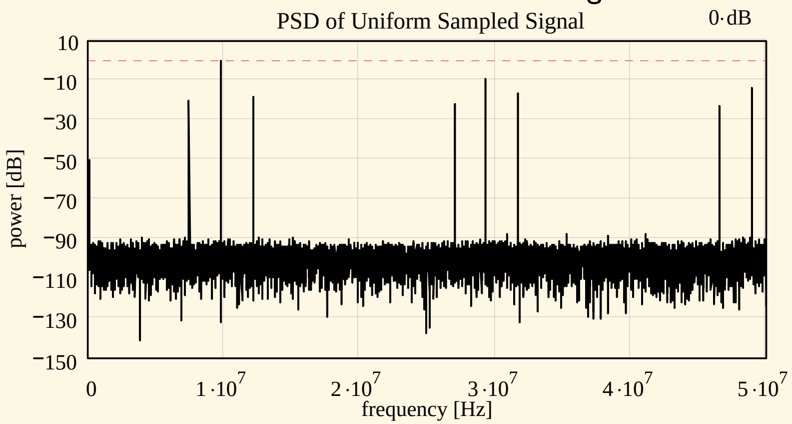
Nonuniform Sampling - Main Idea



- Signal stationary during observation is assumed
- Take samples **nonuniformly**, on a finer grid

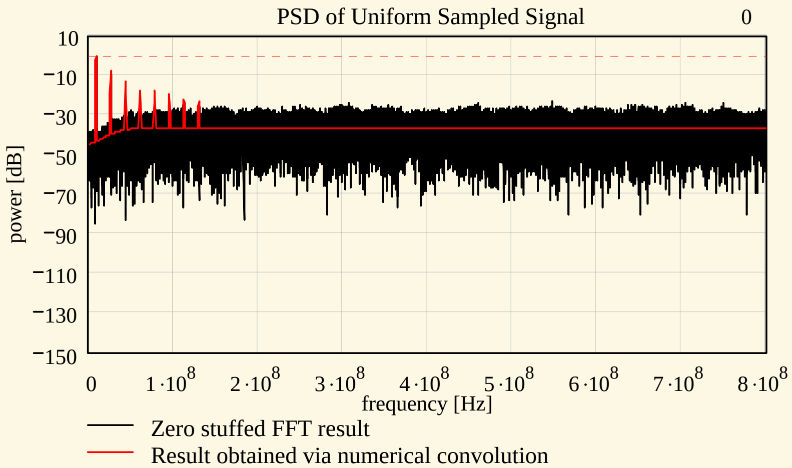
Nonuniform Sampling - Main Idea

BW = 50 MHz, B = 12 Bit, f_s = 100 MHz



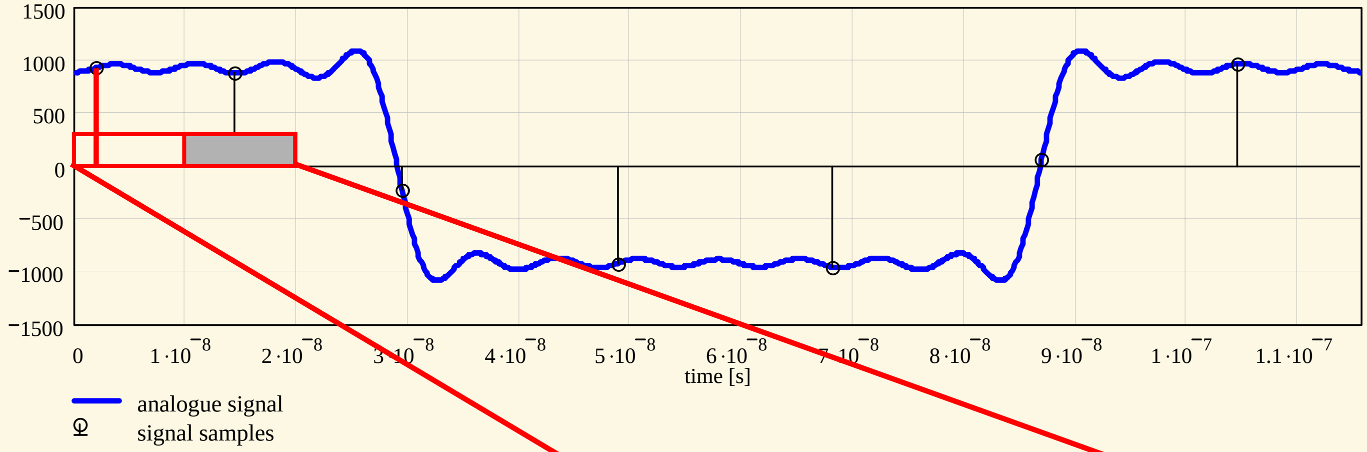
- Bandwidth determined by $f_s/2$
- Noise floor usually low at coherent frequencies
- **But signal is covering a bandwidth of 156 MHz!**

BW = 800 MHz, B = 12 Bit, f_{mean}= 66 MHz



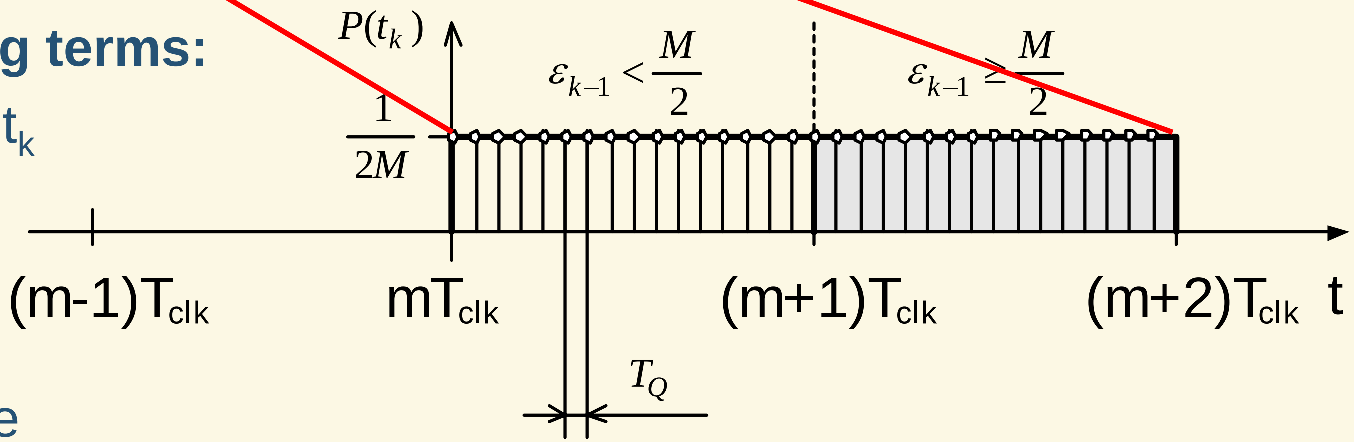
- Equivalent bandwidth determined by $f_Q/2$
- Noise floor high (around 30 dB) with respect to most powerful component
- **Low mean sampling rate!**

Nonuniform Sampling - Main Idea

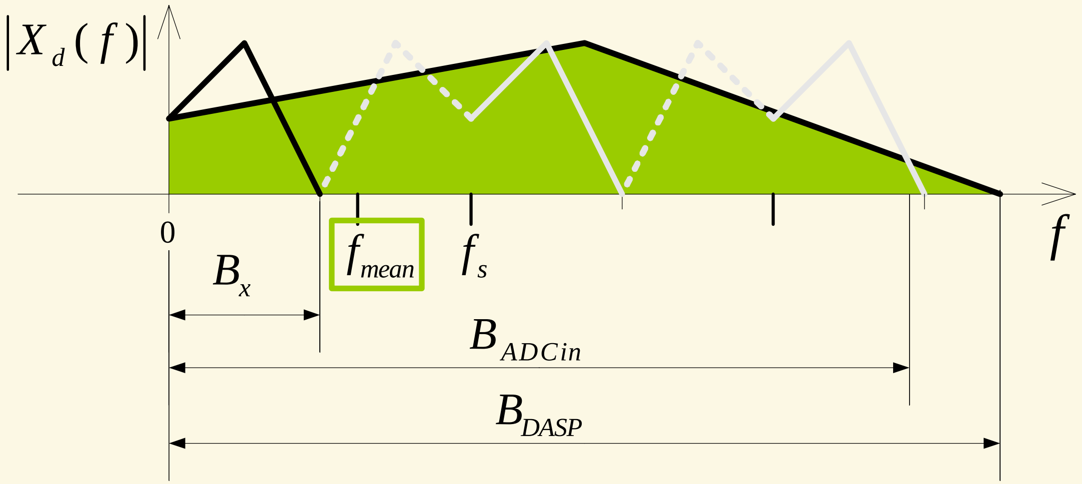


Nonuniform sampling terms:

- Sampling instance t_k
- Time quantum T_Q
- Equivalent bandwidth $f_Q=1/T_Q$
- Mean sampling rate $f_{mean}=1/E[t_k-t_{k-1}]$



Motivation for DASP[1]



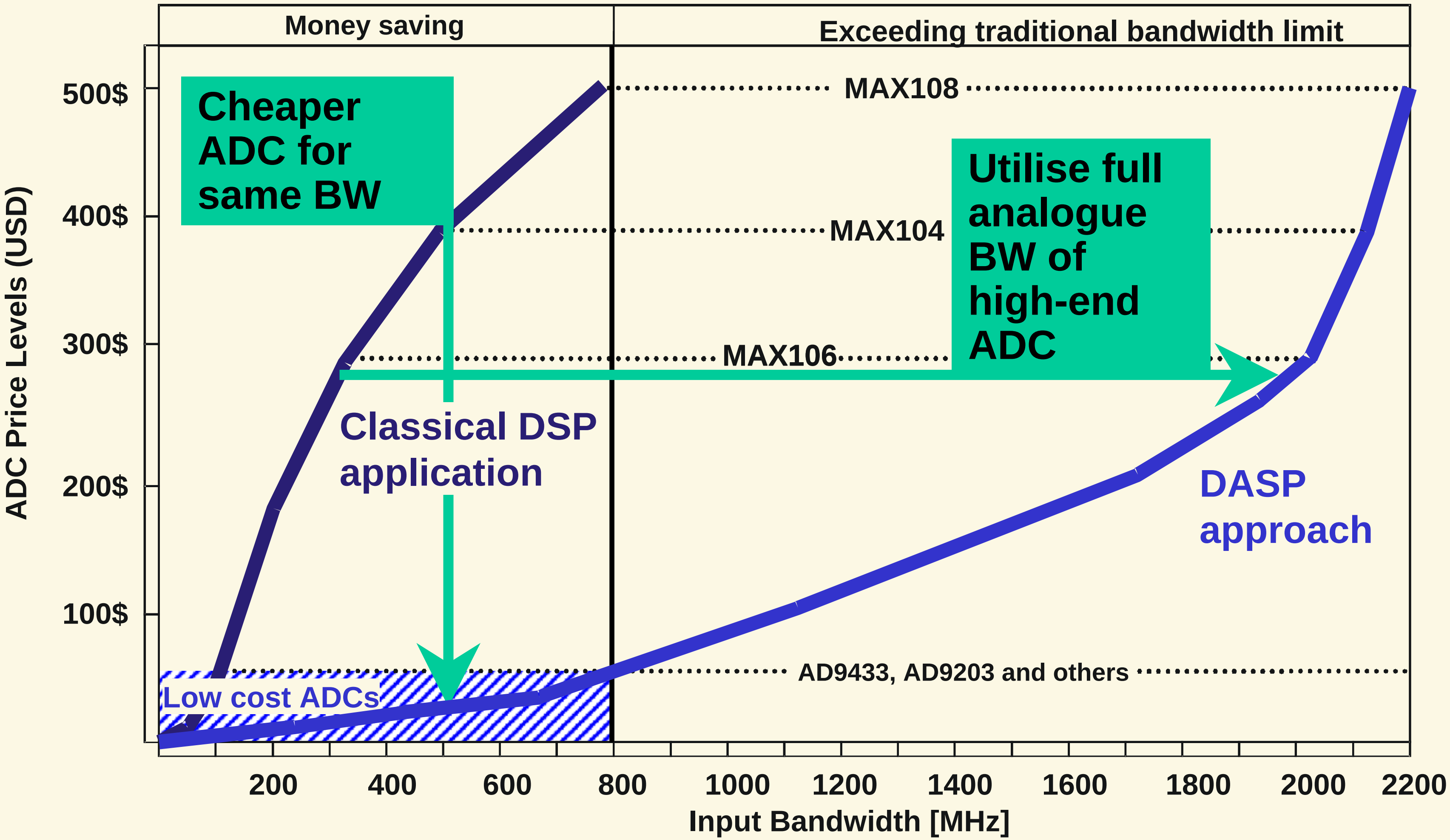
$$\frac{B_{DASP}}{B_x} = M$$

M : Bandwidth gain

- Expansion of analysable bandwidth (B) towards analogue bandwidth of AD-converter
- Use of cheaper AD-converters for a wider B

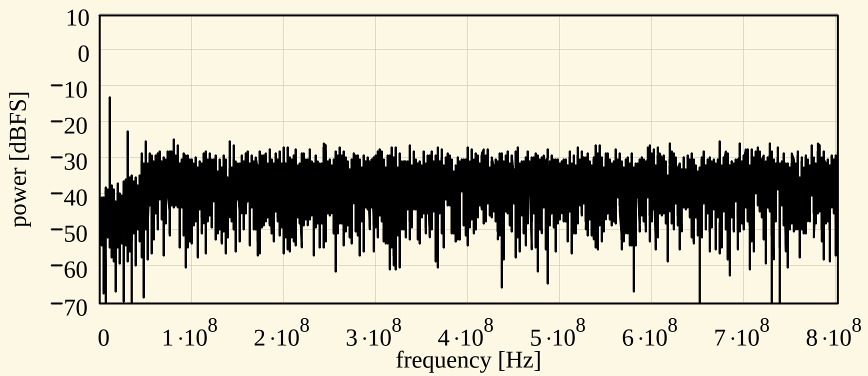
1: DASP: Digital Alias-free Signal Processing

Motivation for DASP

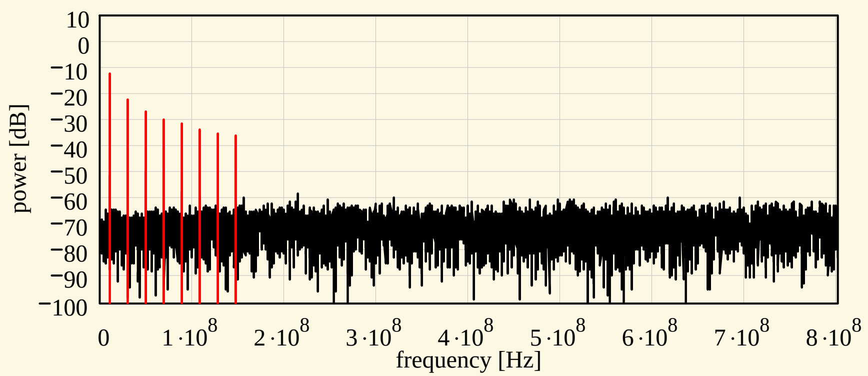


Source: IECS, Riga, Latvia April 2002

The Remedy to High Noise Floor – SeCoEx



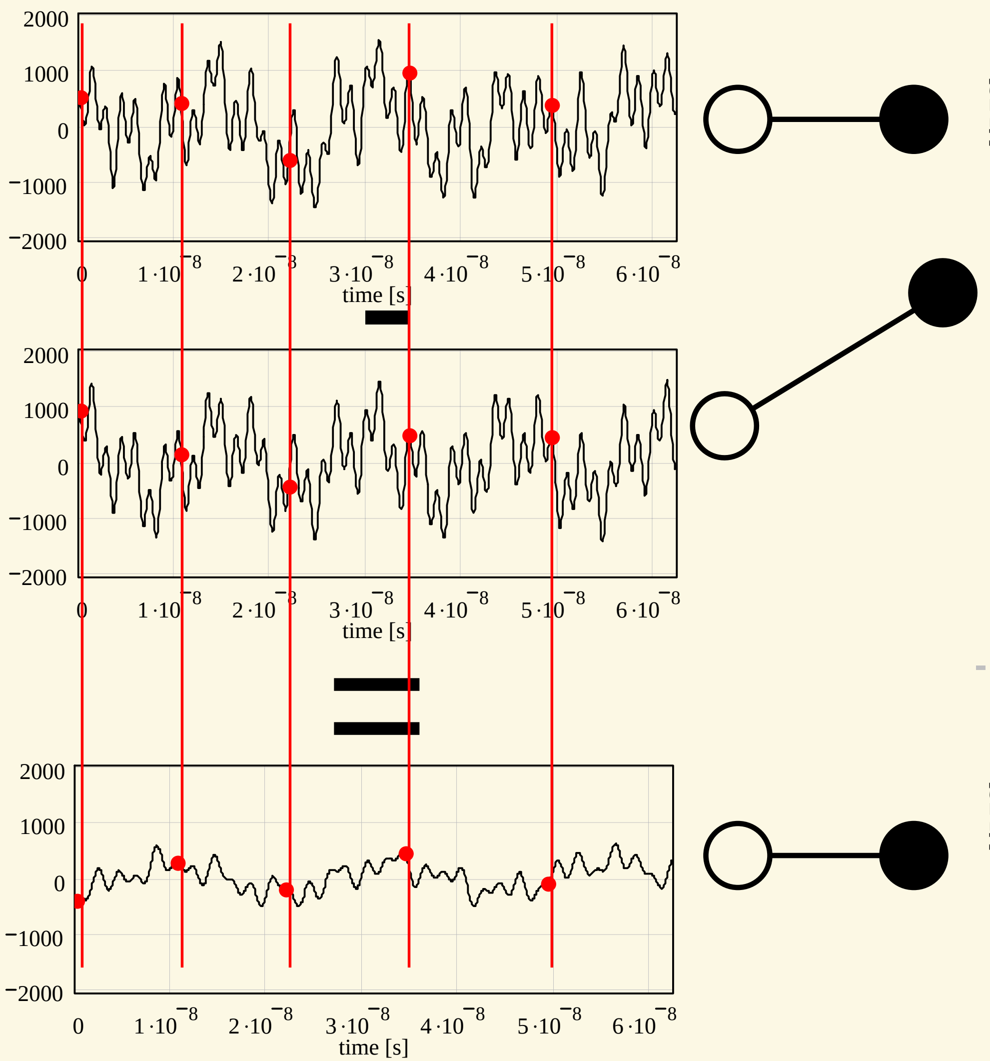
high noise floor – result of convolution with nonuniform sampling process

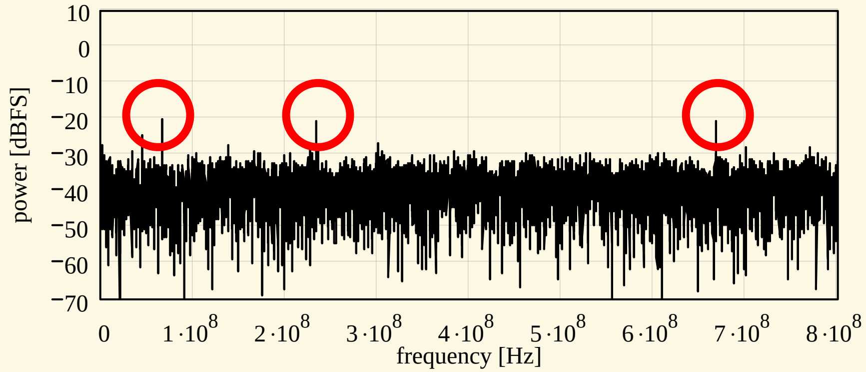


After 10 iterations

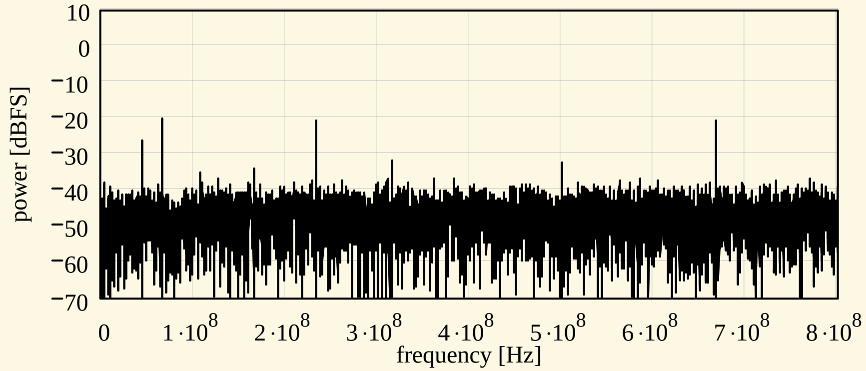
(idealized conditions, i. e. no sampling uncertainty errors)

The Remedy to High Noise Floor – SeCoEx

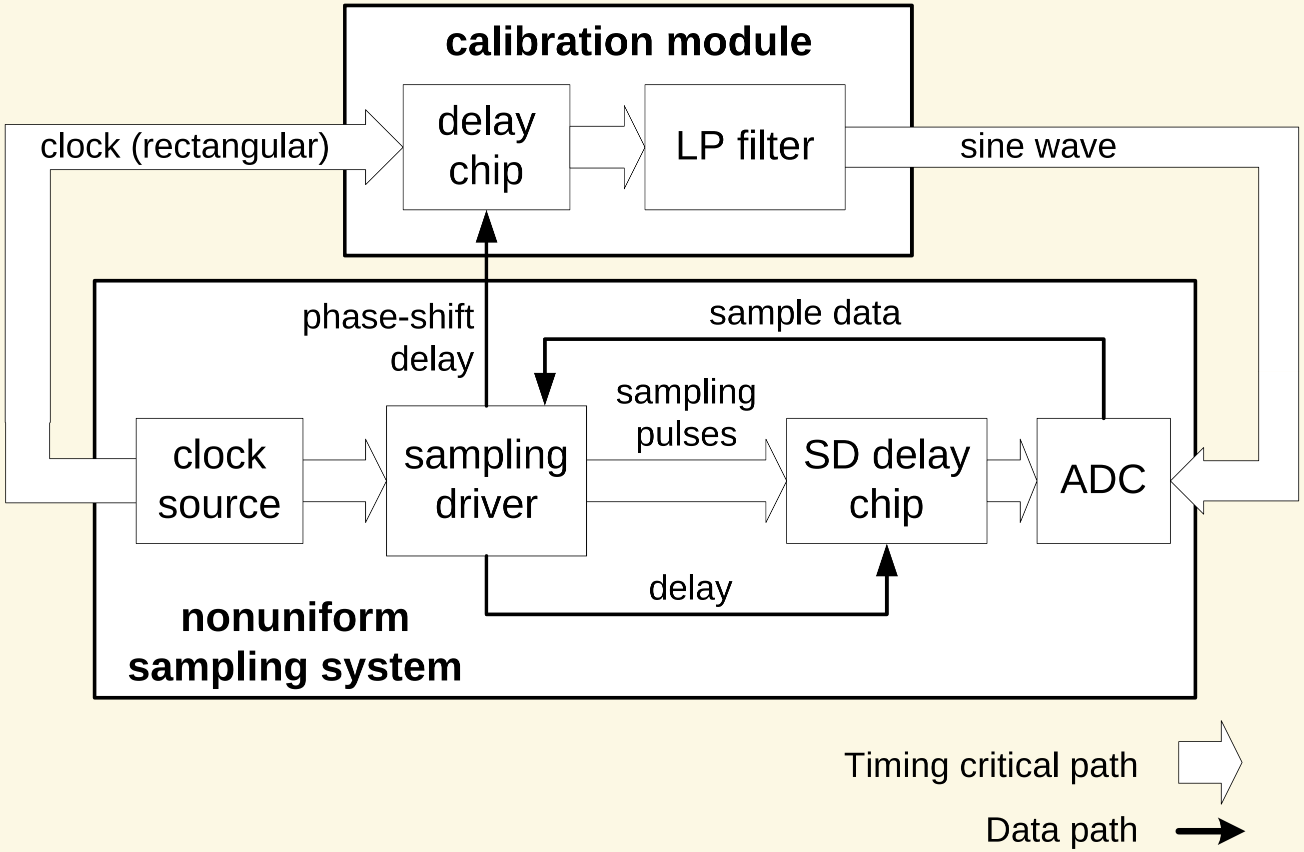




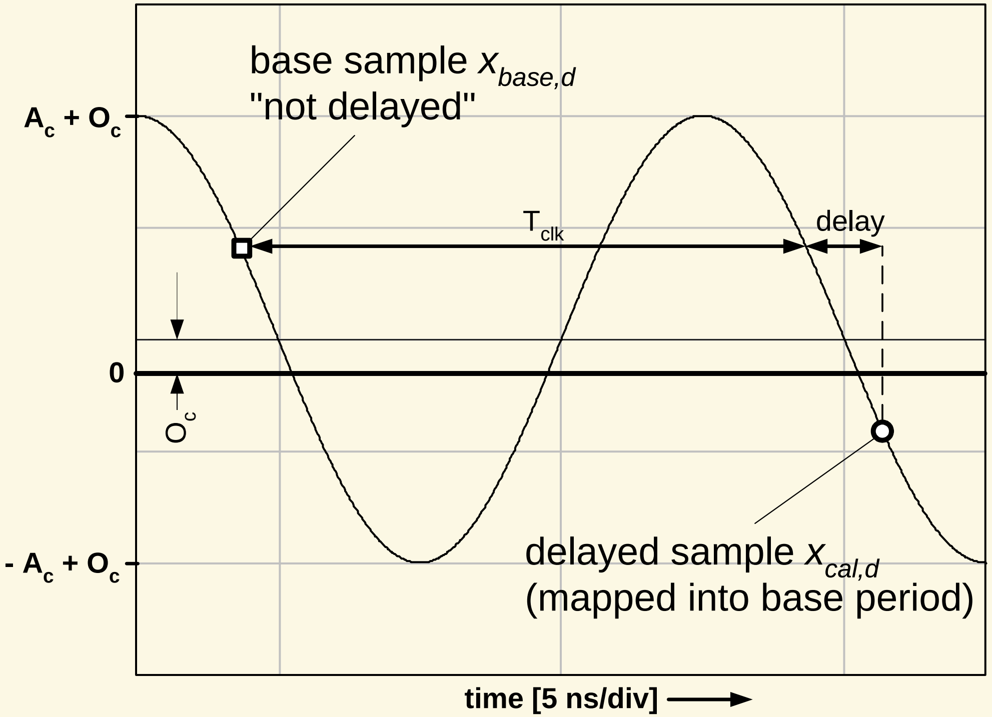
Problem: Time instances have to be known with ps precision! → an order of magnitude smaller than the time quantum step.

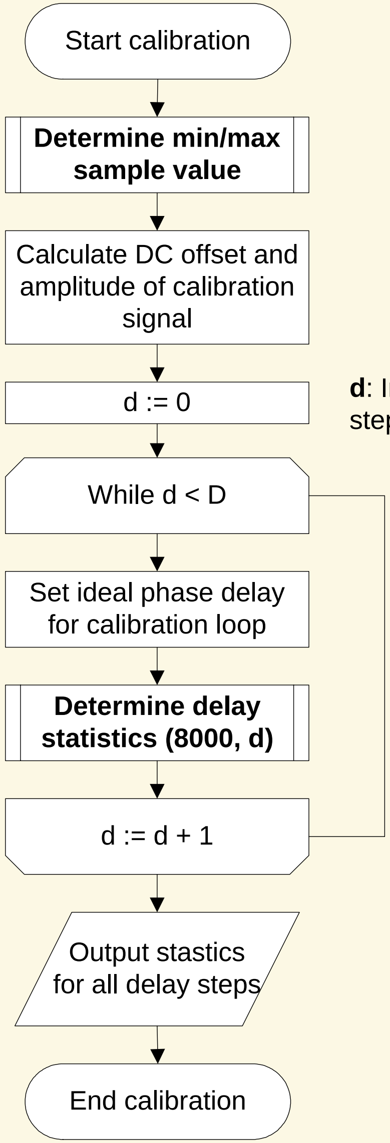


Calibration Setup



Calibration Procedure



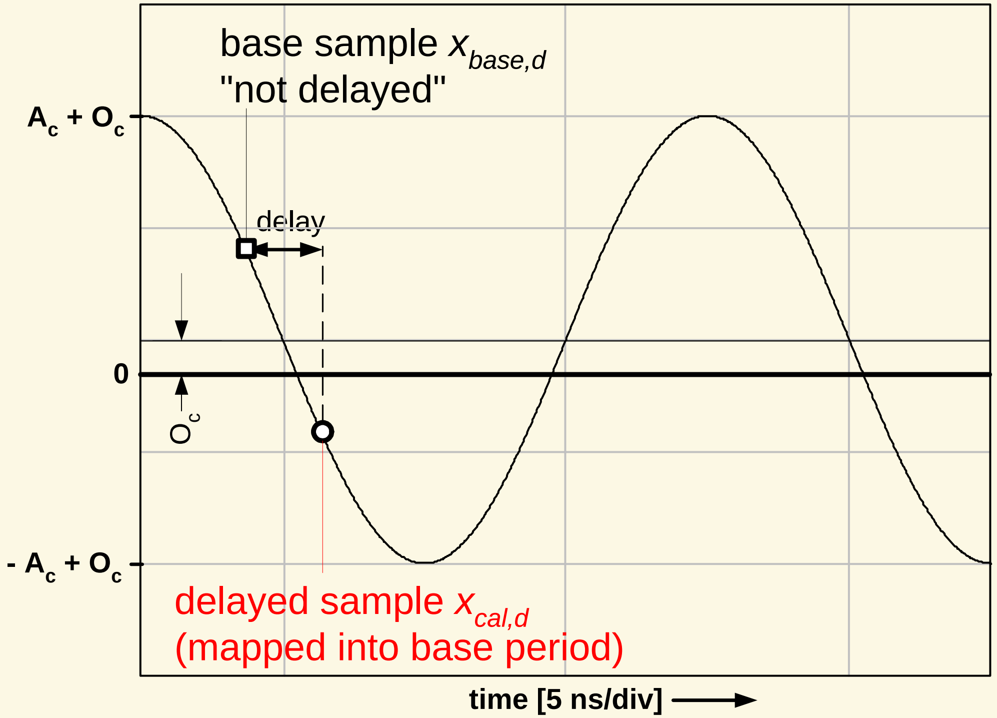


d: Index of current delay step to be evaluated

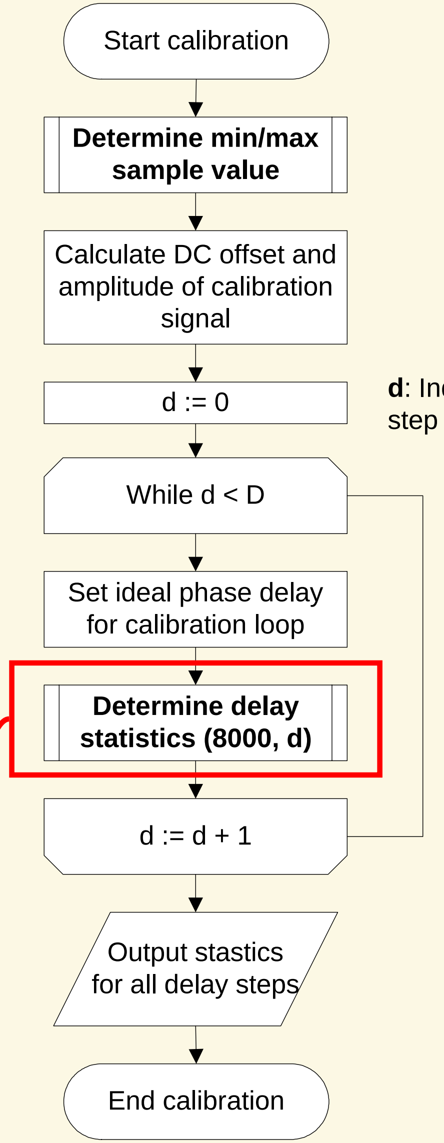
D: Total number of delay steps

Phase delay values have been determined beforehand.

Calibration Procedure



$$\Delta\hat{t}_d = \frac{\arccos\left(\frac{x_{cal,d} - \hat{o}_c}{\hat{A}_c}\right) - \arccos\left(\frac{x_{base.d} - \hat{o}_c}{\hat{A}_c}\right)}{2\pi f_{clk}}$$



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Results

Estimated delay values of used MC195EP100 tap bits:

1	2	3	4	5
PDL tap bit	*Ideal delay [ps]*	*Typical delay [ps]*	*Estimated delay [ps] with 95% confidence*	*RMS [ps]*
D6	625	650	644 ± 0.2	6.7
D7	1250	1180	1200 ± 0.2	7.6
D8	2500	2400	2450 ± 0.2	7.5
D9	5000	4800	4953 ± 0.2	6.9

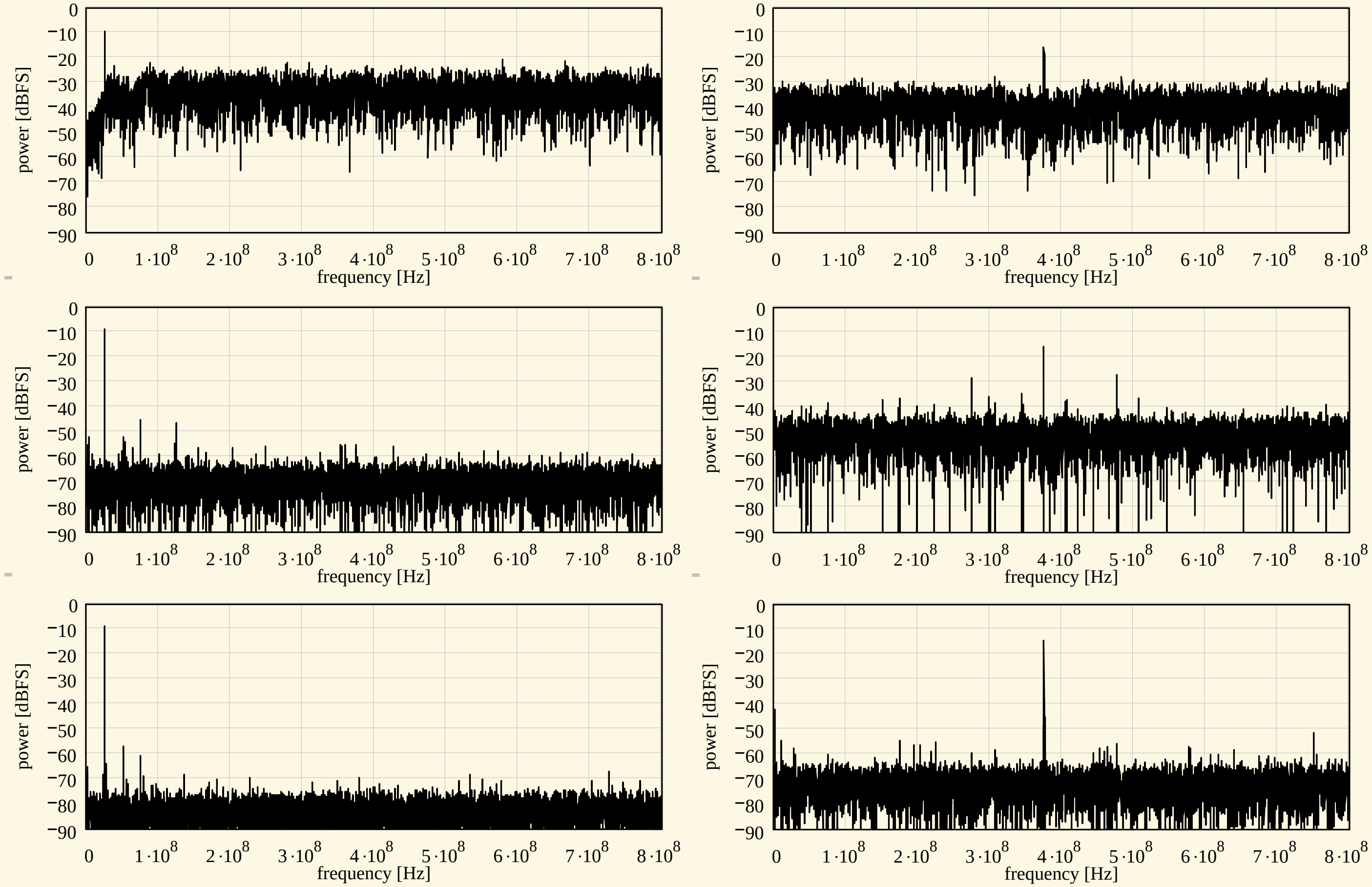
Results - Benefit of Calibration

Input frequency: 25 MHz | 375 MHz

Straight transformation

Typical delay data taken from data sheet

Delay values determined via **calibration**



Outlook

- Nonuniform sampling techniques interesting for SDR applications (environment characterisation function)
- Calibration
  - Always important part (technology enabler)
  - Has to be fully automated
  - Must be repeated under changed environment conditions (temperature, change in supply voltage)
- Nonuniform sampling technology will work better in a monolithic mixed signal realisation because of improved signal integrity (reduced jitter, reflections, ground bounce effects etc.)

Summary

- Nonuniform sampling widens processing bandwidth of DSP systems
- SeCoEx enhances spectral dynamic range
- "True" delay values have to be estimated (calibration procedure) to put SeCoEx to work
- Changed environment conditions cause calibration to be repeated (temperature, supply voltage)

Prototype Board