Experimental study of potentialities of clock instability analysis on the basis of event timing

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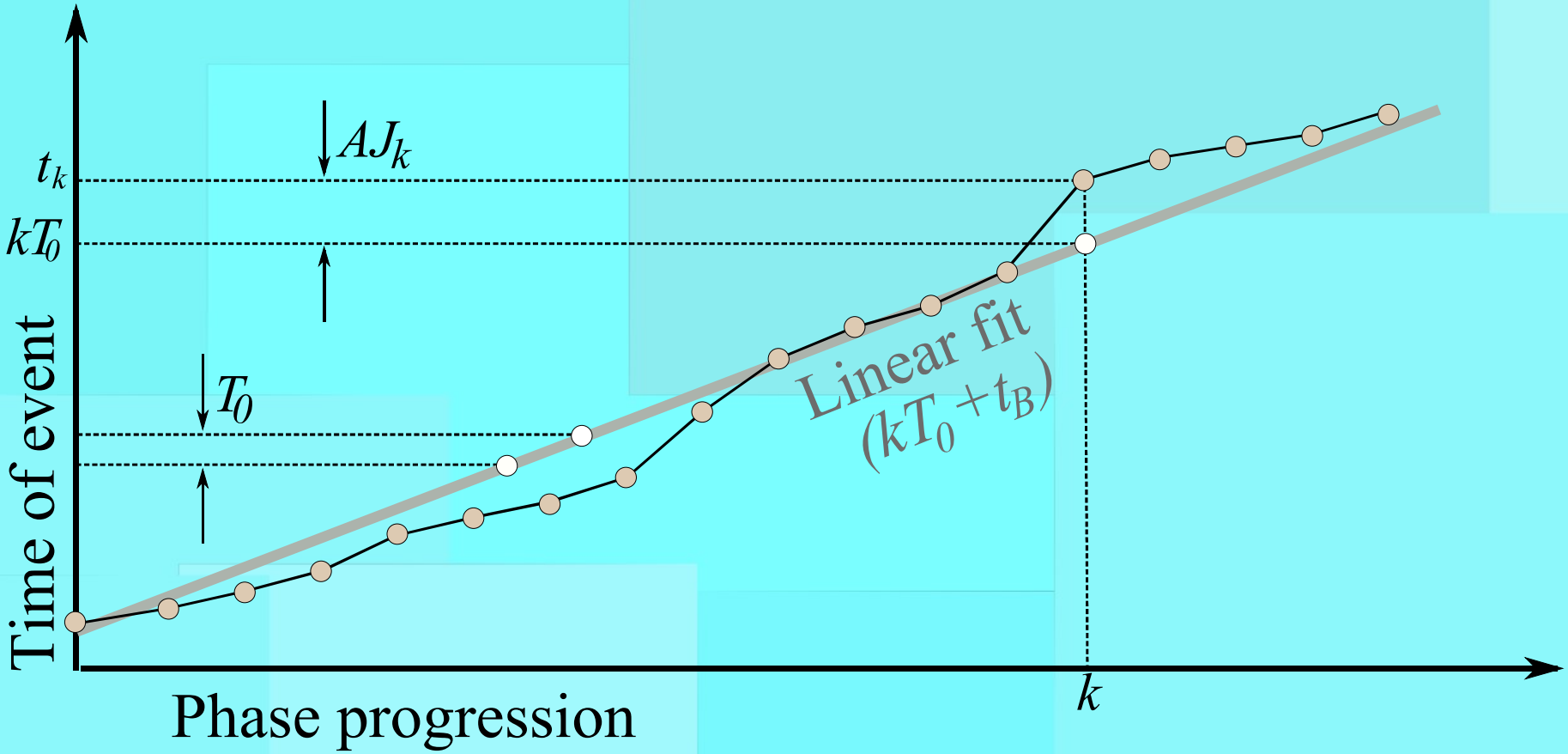
Objectives of the research:

- **Defining the way to measure the clock instability on the basis of high-precision event timer**
- **Specification of the clock instability on the basis of the measurement results**
- **Experimental research concerning the clock instability analysis including:**
  - **Random Jitter analysis**
  - **Long-term instability analysis**
  - **Signal modulation analysis**

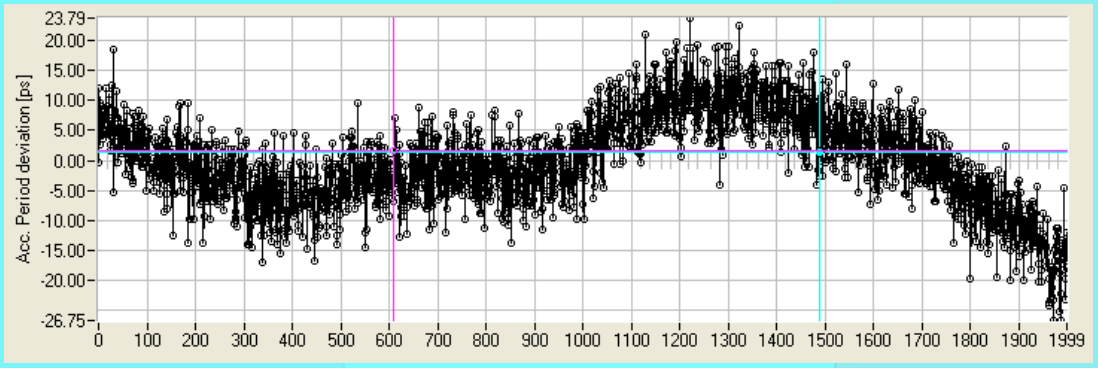
Analysis of experimental data to evaluate potentialities of the approach

Clock instability measurement by means of event timing



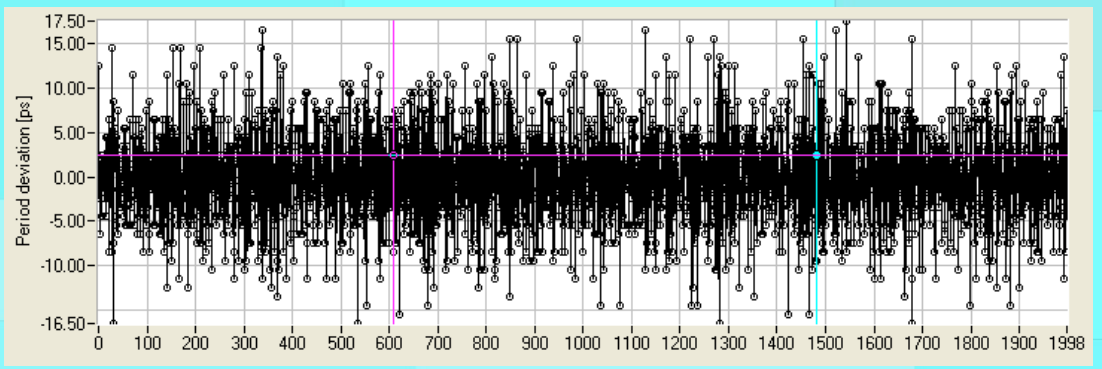
- Events are defined as clock signal edge crossings at specified level.

Clock instability characterization



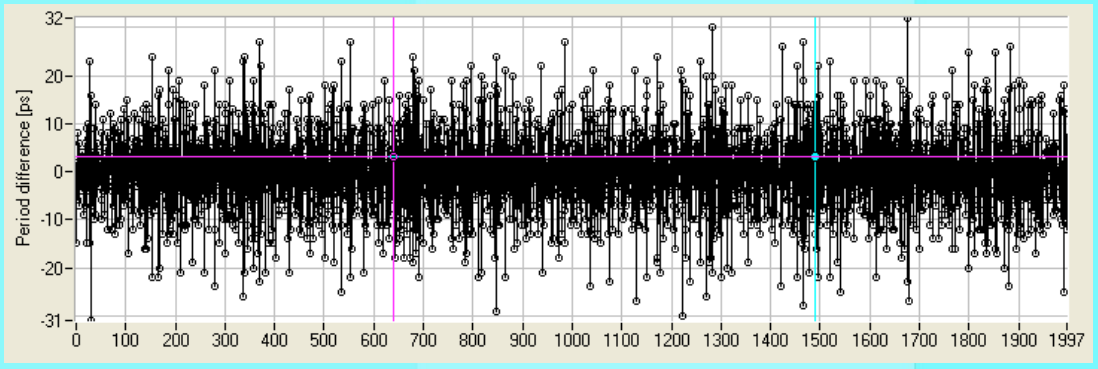
Primary function
(*Phase instability*)

$$\{AJ_k = t_k - (kT_0 + t_B)\}^N$$



Derived first difference function
(*Period instability*)

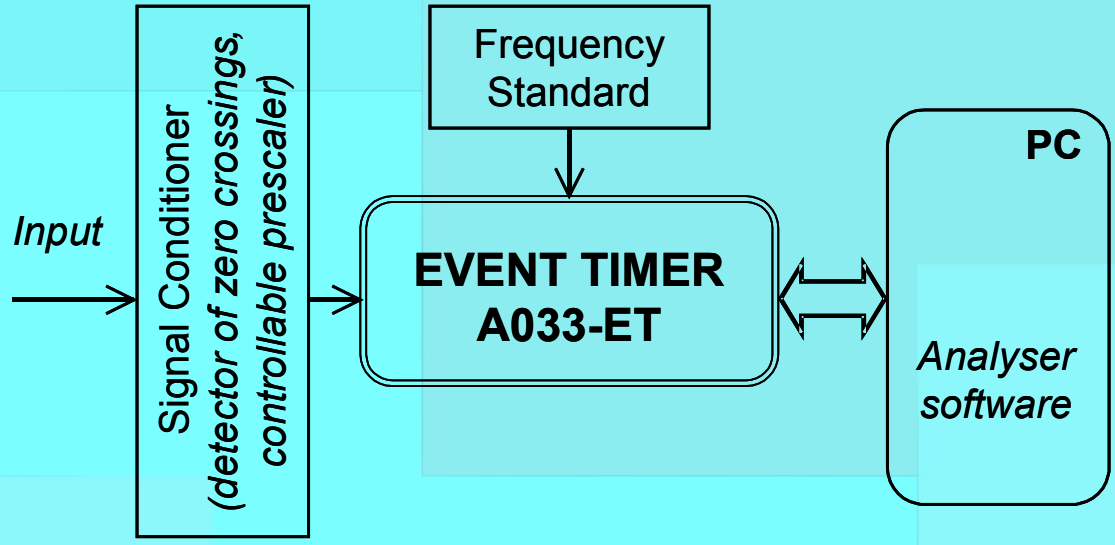
$$\{PJ_k = AJ_k - AJ_{k-1}\}^N$$



Derived second difference function
(*Cycle instability*)

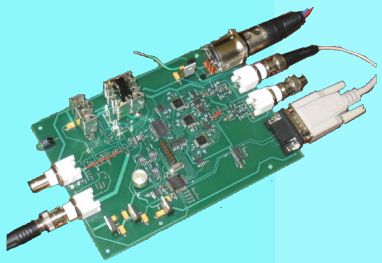
$$\{CJ_k = PJ_k - PJ_{k-1}\}^N$$

Experimental setup



Conditioner

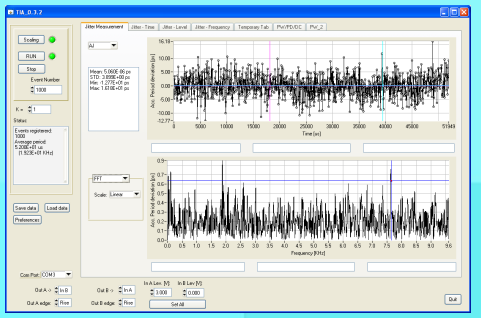
- Crossing level adjustment



Event Timer

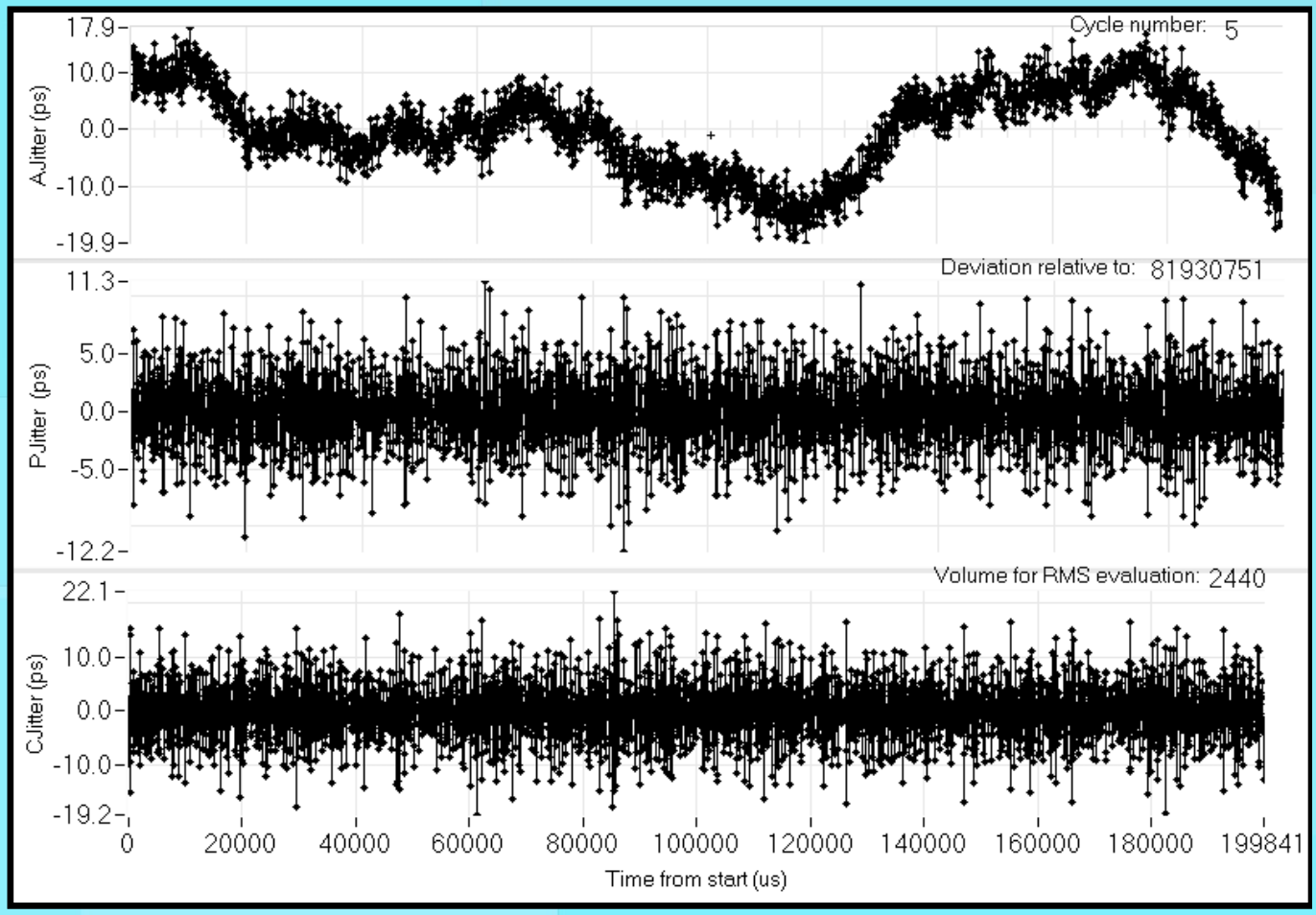
- RMS Time resolution: ~1.9 ps
- Measurement rate: 20 Mevents/s

Analyser Software



Jitter measurement

Random jitter of crystal clock generator

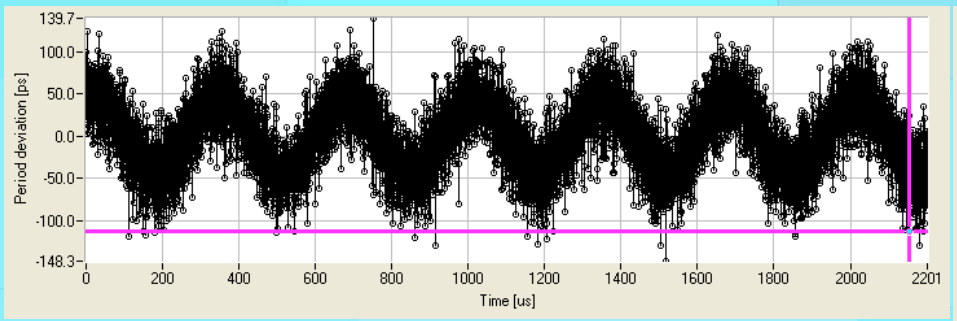


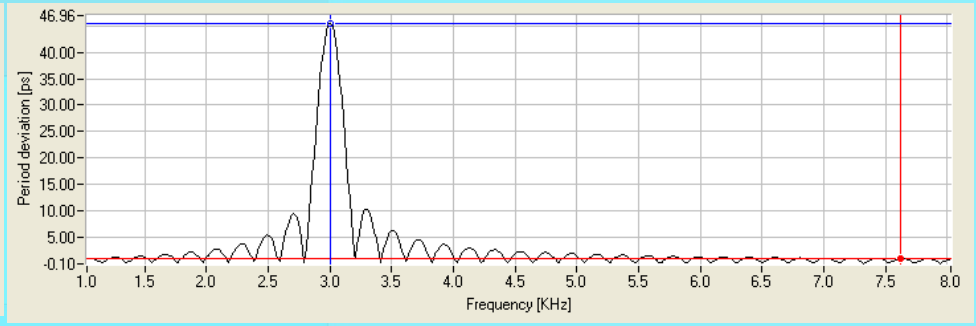
Single-shot measurement with picosecond resolution
Simultaneous determination of multiple jitter characteristics

Frequency modulated (FM) signal analysis

Period deviation → Frequency deviation

$$\Delta f(t) \approx -\frac{1}{T_0^2}\Delta T(t)$$





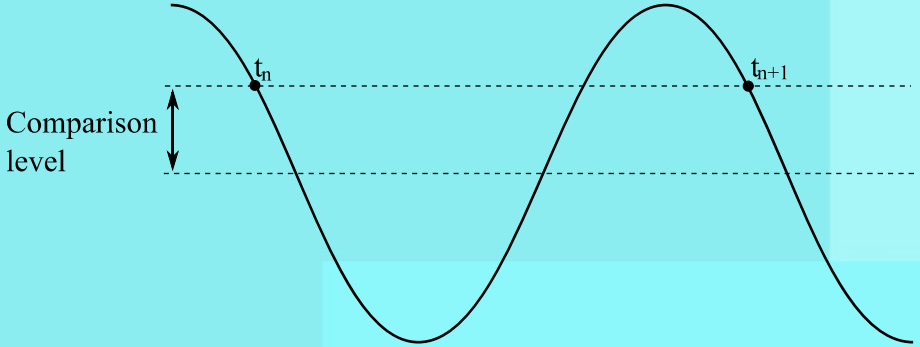
3.3 MHz carrier signal; 500 Hz deviation (period deviation - 45.9ps)

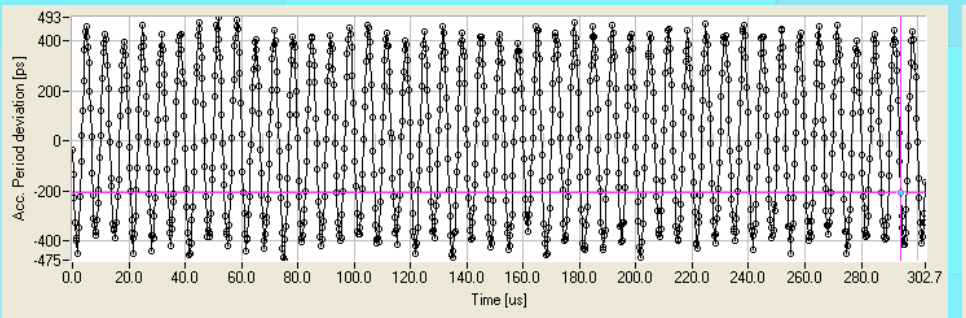
Characterizes modulation frequency and its deviation

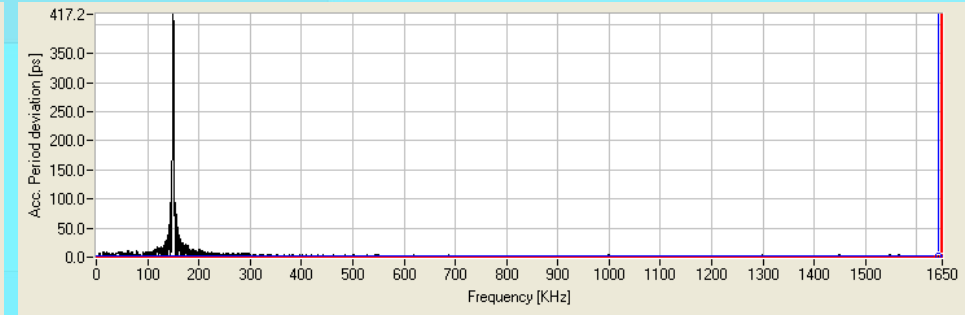
Reveals frequency deviation less than 0.1 Hz

Amplitude modulated (AM) signal analysis

Amplitude modulation is detected by adjustment of comparison level





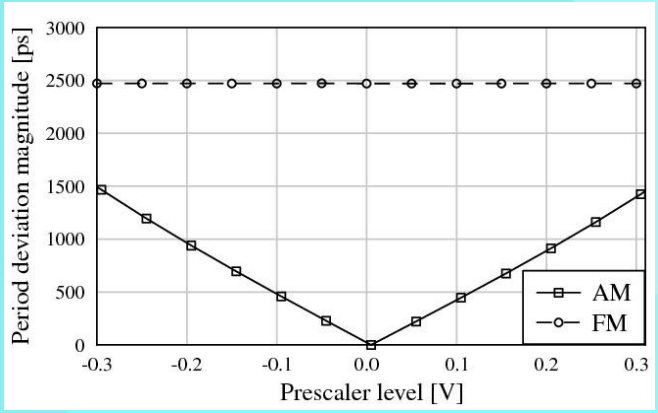


3.3 MHz carrier signal; 5% AM depth

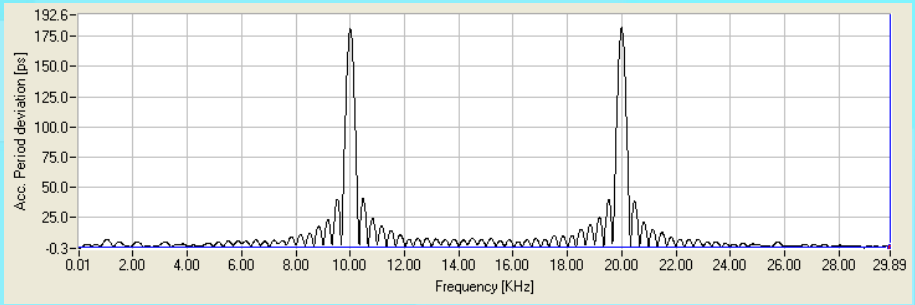
Reveal AM modulation depth less than 0.1%

AM + FM signal analysis

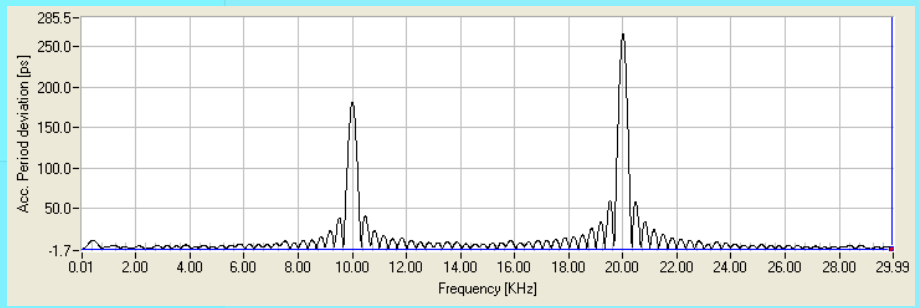
Crossing level adjustment of the Conditioner module effects only amplitude modulated signals.



Spectrums of P-jitter function at different comparison levels



Level change

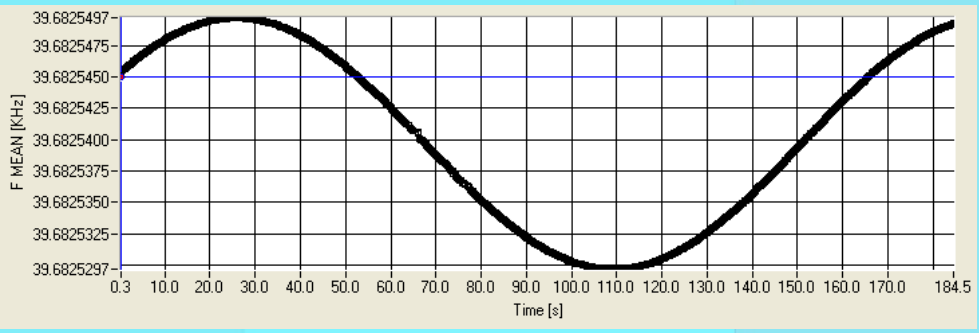


3.3 MHz signal with 28 Hz frequency deviation (modulation frequency 10 KHz) + 1% AM depth (modulation frequency 20KHz)

Distinguishes AM and FM spectral components of the signal

Frequency instability measurement

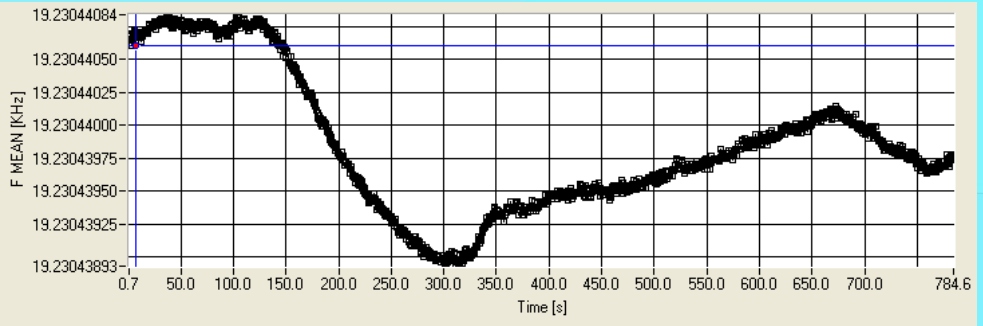
Long-term frequency deviation



Min = 39682.53 Hz,
Max = 39682.55 Hz,
Pkp = 0.02 Hz,
Mean = 39682.54 Hz,

Total time = 184.5 sek

Frequency over time measurement of signal modulated by 0.006 Hz sine signal.



Min = 19230.439 Hz,
Max = 19230.441 Hz,
Pkp = 0.002 Hz,
Mean = 19230.44 Hz,

Total time = 784.594000 sek

Frequency over time measurement of function generator.

Reveals very slow frequency deviations

Measures the signal frequency deviation with extremely high precision

Summary

- Relatively simple unified technique of clock instability analysis based on high-precision event timer application is discussed.
- This technique offers clock instability characterization in different views, including random deviation and spurious modulation of different kinds.
- The experimental research of technique showed such facilities as
  - high-precision jitter measurement;
  - single-shot and long-term frequency instability measurement;
  - ability to determine and analyse modulation characteristics of clock;
  - potential ability to distinguish and determine modulation characteristics of clock signal with amplitude and frequency modulation

The study is associated with ERDF project Nr. 2DP/2.1.1.1.0/10/APIA/VIAA/084 "Experimental development of Multi-functional Time Analyser "