Modulation domain – the third dimension

1. Background

Why are oscilloscopes such popular instruments? They do not measure voltages very accurately. Even the lowest cost DVM can produce more accurate results when measuring static voltages. Yes, that's it: Oscilloscopes let you view *dynamic* voltages, voltages that vary over time. This ability makes oscilloscopes very suited to view and analyze most types of dynamic signals. And the absence of this dynamic signal view makes voltmeters limited in use, except for verification and calibration of static voltages. In a similar way a Modulation Domain Analyzer, or shorter MDA, presents *dynamic* frequency variations, frequency that varies over time. You could think of an MDA as "Frequency scope"

Dynamic signal analysis of amplitude and frequency

Amplitude and frequency contents are the two most important signal properties of any signal, and to get a complete picture of the signal under test, you need three types of instruments.

- **Oscilloscopes** are used to analyze changes in amplitude but not to analyze changes in frequencies. Oscilloscopes gives the *Voltage vs time* (V vs t) relation in the *time domain*
- **Spectrum Analyzers** are the traditional tools for analyzing the frequency contents of a signal. They can find static frequency components or give a statistical (averaged) picture of dynamic frequencies. Spectrum Analyzers gives the *Voltage vs frequency* (V vs f) relation in the *frequency domain*
- **Modulation Domain Analyzers** (MDA) give the *Frequency vs time* (f vs t) relation in the *modulation domain*

See fig.1, which illustrates a frequency modulated signal, where the

- carrier is sinusoidal (see time domain V vs t)
- modulation is pulse shaped (see modulation domain f vs t)
- frequency deviation jumps between two distinct levels - hi freq. and lo freq (see frequency domain V vs f for power contents and modulation domain f vs t for exact frequency).

All three tools are needed for a complete signal analysis that covers all three axis; Voltage, Frequency and Time.

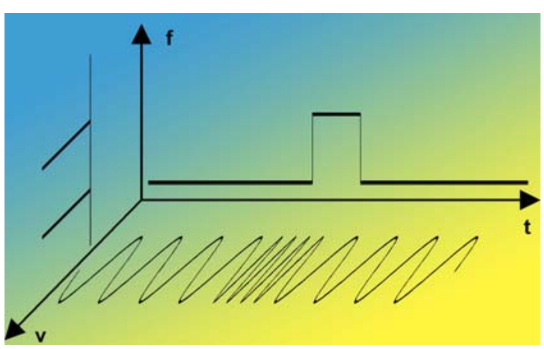

Figure 1: Complete signal analysis covers all three axis; Voltage, Frequency and Time.

International: Pendulum Instruments AB
PO Box 20020
SE-16102 Bromma
Sweden
Voice: +46 8 598 51057
Fax:+46 8 598 51040

US: Pendulum Instruments Inc
5811 Racine Street
Oakland
CA 94609-1519, USA
Voice:(510)-428-9488
Fax: (510)-428-9469

- Experts in time & frequency calibration, measurement and analysis
E-mail: info@pendulum.se
Internet: www.pendulum-instruments.com

2. Applications

The basic function of a Modulation Domain Analyzer (incl. TimeView™) is to show frequency variations over time, in the same way that an oscilloscope shows voltage variations over time. This way you can visualize and analyze, for example, frequency agile communications, frequency-locked-loops, jitter, frequency modulation, frequency transients and sweep, frequency instabilities over short or long times etc.

An MDA is a very versatile tool, especially suited for R&D engineers, but an MDA also fits in the RF service lab and in metrology labs. A few applications that otherwise would be impossible, or very expensive to carry out are:

- Visualize Frequency hopping patterns in FHSS frequency agile communication, missile guidance systems etc.
- Measure freq stability per individual channel in TDMA communication systems
- Measure frequency droop on individual channels in frequency hopping systems
- Analyze chirp radar performance
- Measure pulse jitter and view distribution histogram
- Calibrate frequency sweep signals.
- Calibrate intentional modulation (FM or FSK)
- Analyze PLL's and Frequency locked-loops
- Discover phase jumps in synchronization clocks
- Discover missing periods from rotational encoders
- Measure frequency settling times of VCO's
- Characterize start-up/warm-up of oscillators
- Measure frequency stability (short-term, offset, drift) including graphs
- Detect unwanted noise/interference sources on oscillators
- Zero-dead-time measurements to calculate Allan Deviation vs τ
- Analyze CD pulse patterns
- And much much more

3. TimeView™

TimeView from Pendulum Instruments is an MDA solution where a fast frequency sampler does the raw data capture and a PC program makes the presentation, calculation and analysis. Pendulum Instrument's concept of TimeView has been around for some time. It was first developed some 10 years ago in a DOS version for the CNT-81 timer/counter, but is now available in a modern 32-bit Windows version, using the company's newest frequency measurement platform, the CNT-90 Timer/Counter/Analyzer instead.

The CNT-90 acts as a fast sampling front-end with up to 250k computed frequency samples/s in real-time capture, and an equivalent sample rate of up to 100M samples/s in repetitive capture mode. The frequency range is from DC and up to 20 GHz, depending on installed options. CNT-90 uses internally a so-called continuous timestamping measurement technique, with zero-dead-time counting. It connects to the PC, running the TimeView SW, via USB or GPIB.

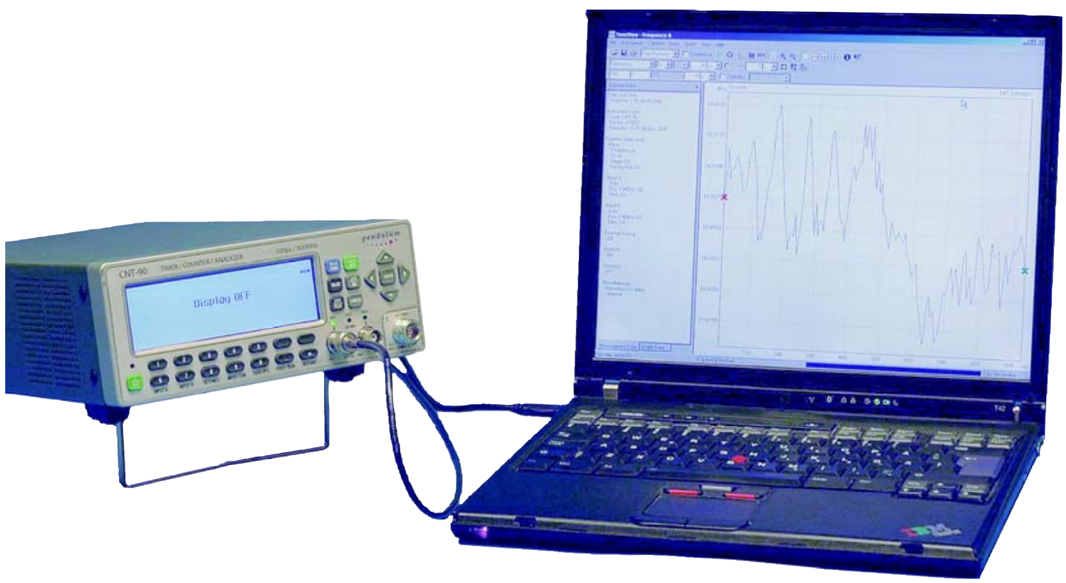

Figure 2: A PC running TimeView software connected to a CNT-90 counter.

International: Pendulum Instruments AB
PO Box 20020
SE-16102 Bromma
Sweden
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Fax:+46 8 598 51040

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5811 Racine Street
Oakland
CA 94609-1519, USA
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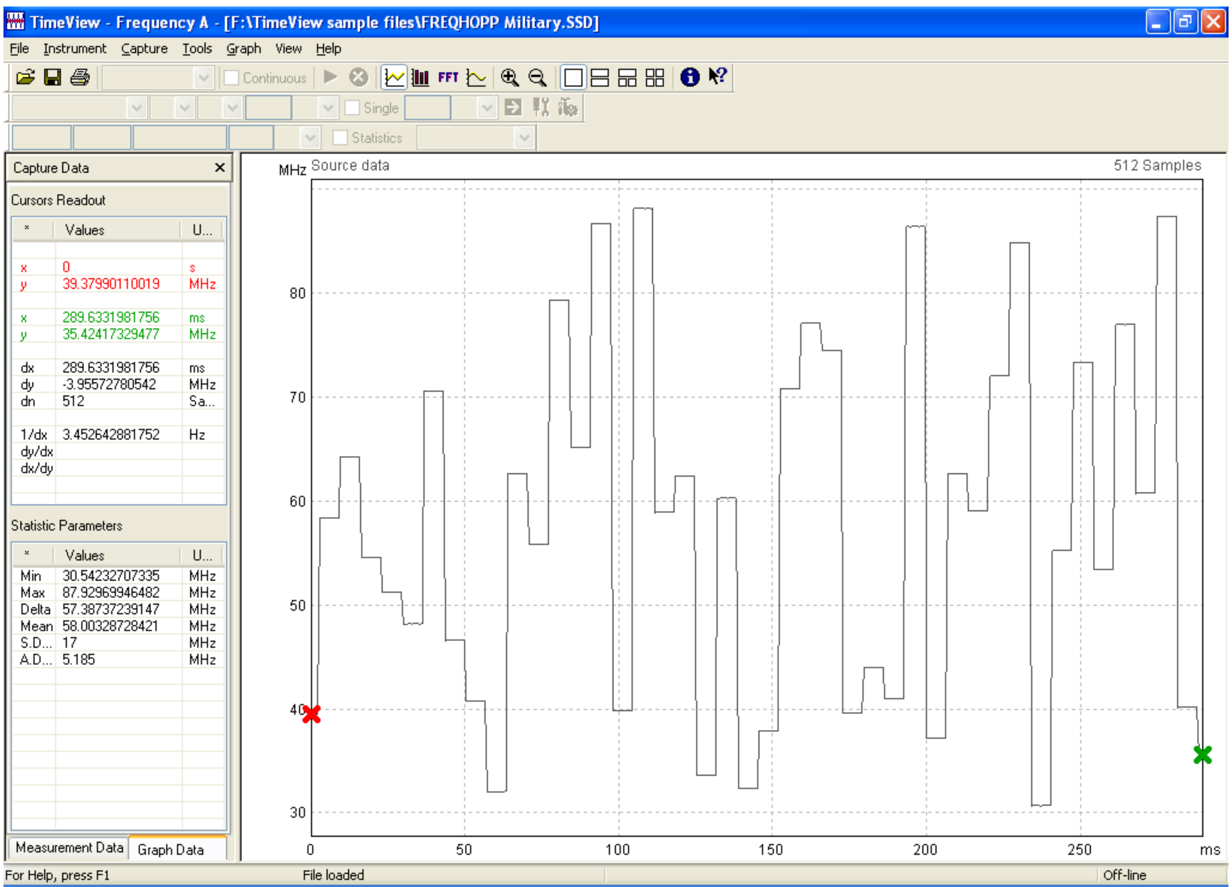
4. Measurement examples using TimeView

Example 1. Carrier frequency hopping in military troop radio

Note the distinct channel switching and the exact channel time. This information can only be obtained from an MDA, not from an oscilloscope, nor a spectrum analyzer.



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Sweden
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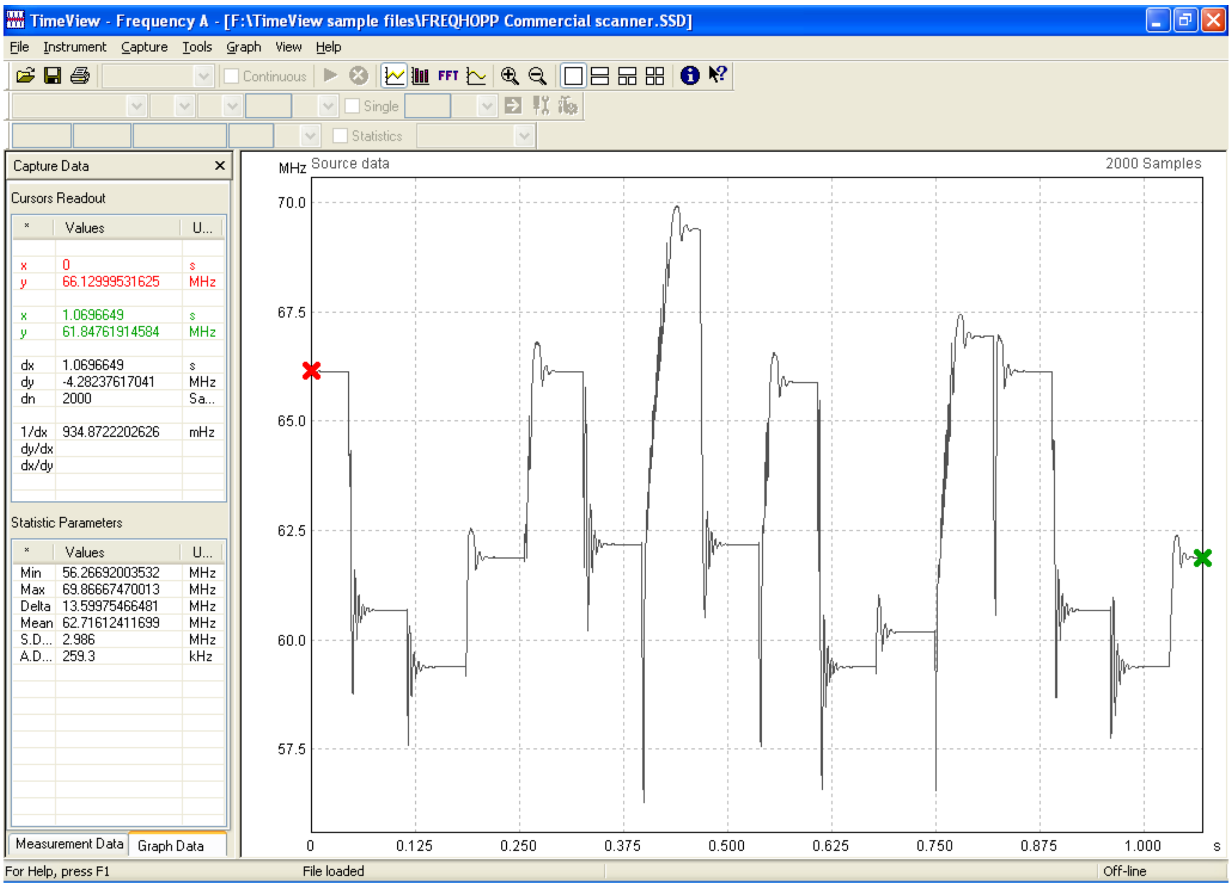
Example 2. Local oscillator channel search in commercial low-cost radio scanner

Local oscillator channel search in commercial low-cost radio scanner for the rescue service channels (police, fire brigade, etc). Note the frequency overshoots, ringings and the varying channel occupancy. This information gives a valuable insight of the design, and is impossible to obtain with traditional oscilloscopes or spectrum analyzers.



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PO Box 20020
SE-16102 Bromma
Sweden
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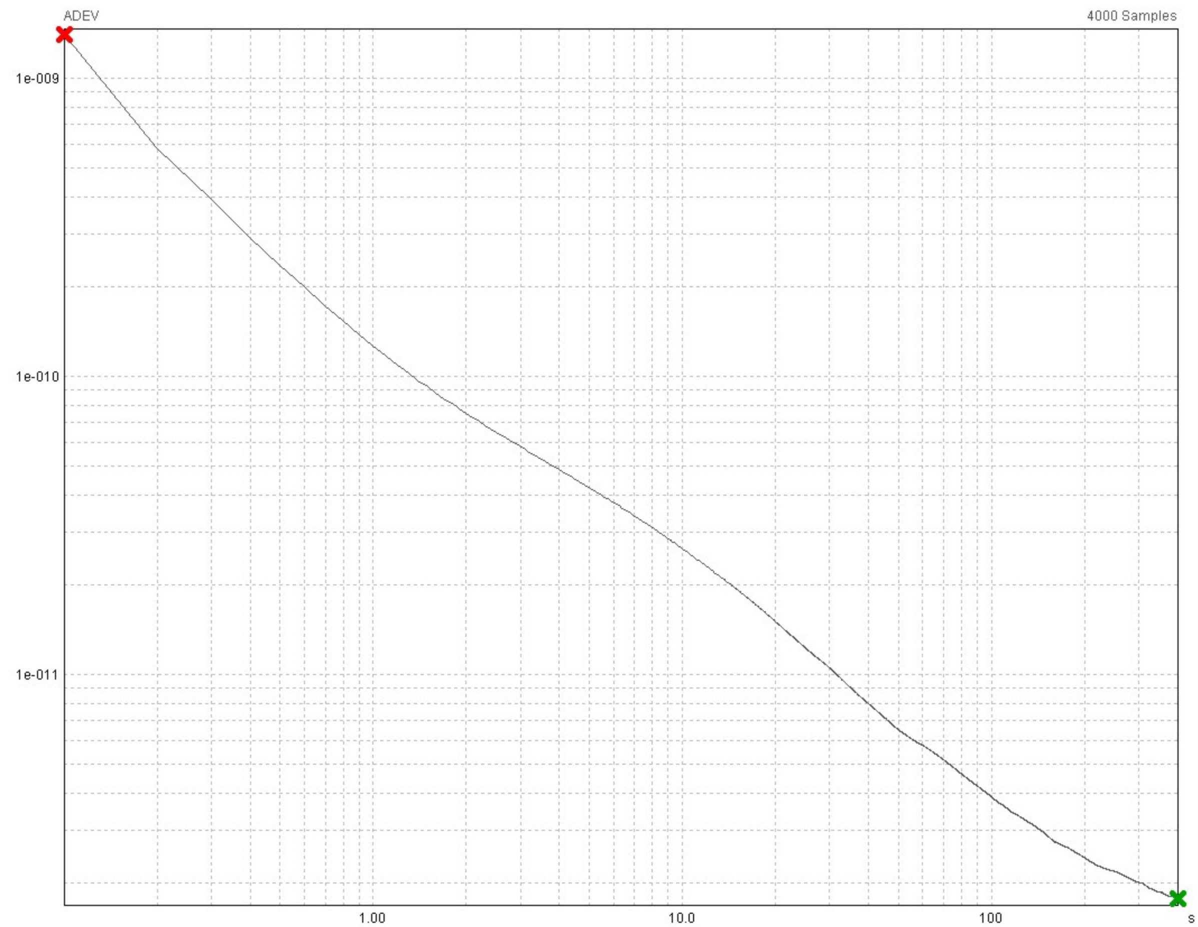
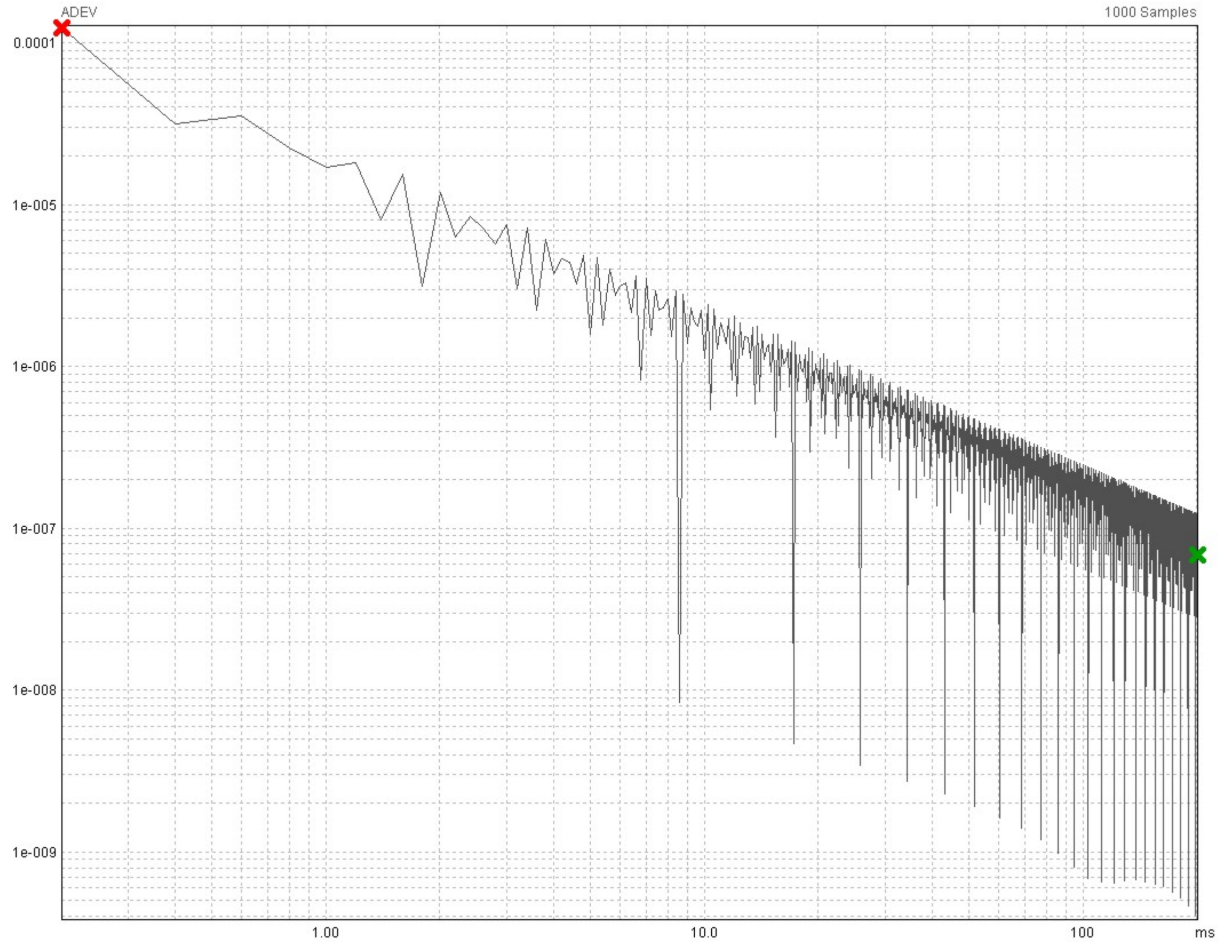
Example 3. **Short term stability of crystal oscillator**

Short term stability of crystal oscillator expressed as Allan Deviation over τ. The frequency samples are captured "back-to-back, without dead-time (impossible for normal frequency counters). To measure and present this function (ADEV vs t) normally requires very expensive equipment and SW packages.



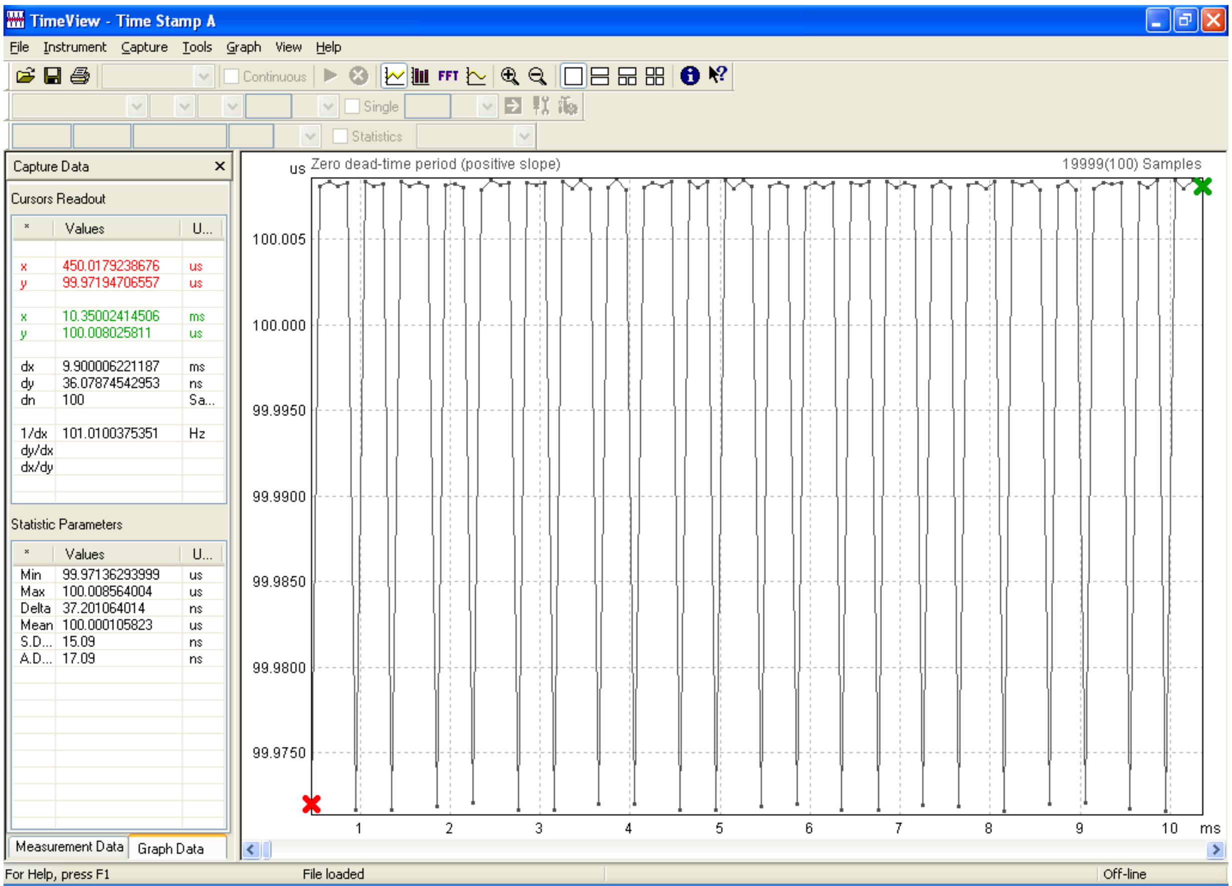
Example 4. **Short-term stability of a DDS Synthesizer**

This model generates big period steps and fine-tunes the period by switching between two adjacent period values so that the average period is correct. This method gives a very noisy output spectrum, which is shown in the Allan Deviation vs τ graph.



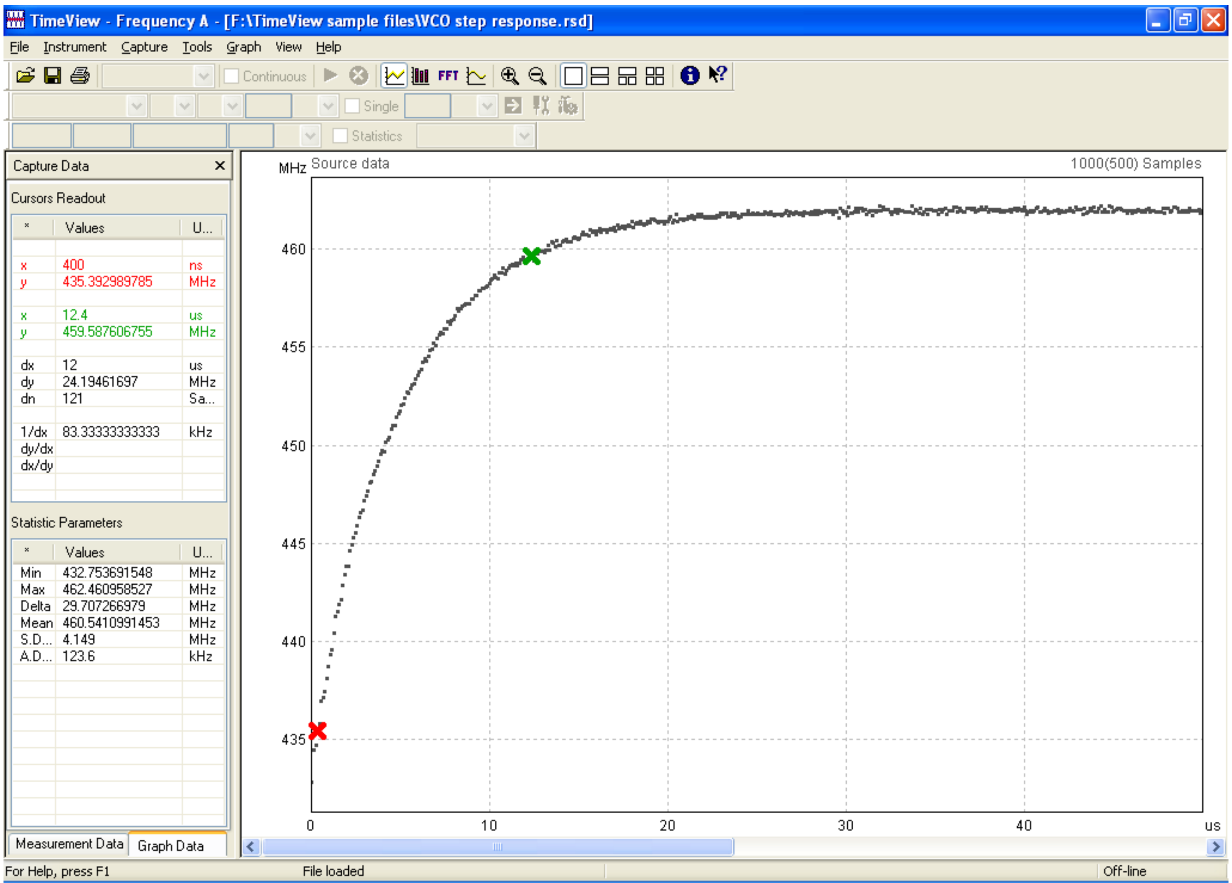
Example 5. Period back-to-back variation

Period back-to-back variation of the DDS synthesizer from Example 4. Here you clearly see that the output period is switching between two period values separated by 36 ns and at a switching rate of approx 2 kHz. There are 3 or 4 “high periods” for every “low period”. This information gives valuable insight in the design and is impossible to obtain with a normal oscilloscope.



Example 6. VCO switching

VCO frequency settling, that is the frequency output response to a step change of the control voltage, is easily measured in the modulation domain. The graph reveals a “frequency rise time” of approx 12 us, when switching between 432 and 462 MHz. Also this information is impossible to obtain from a DSO or a spectrum analyzer.



Pendulum Instruments

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International: Pendulum Instruments AB

PO Box 20020
SE-16102 Bromma
Sweden
Voice: +46 8 598 51057
Fax:+46 8 598 51040

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