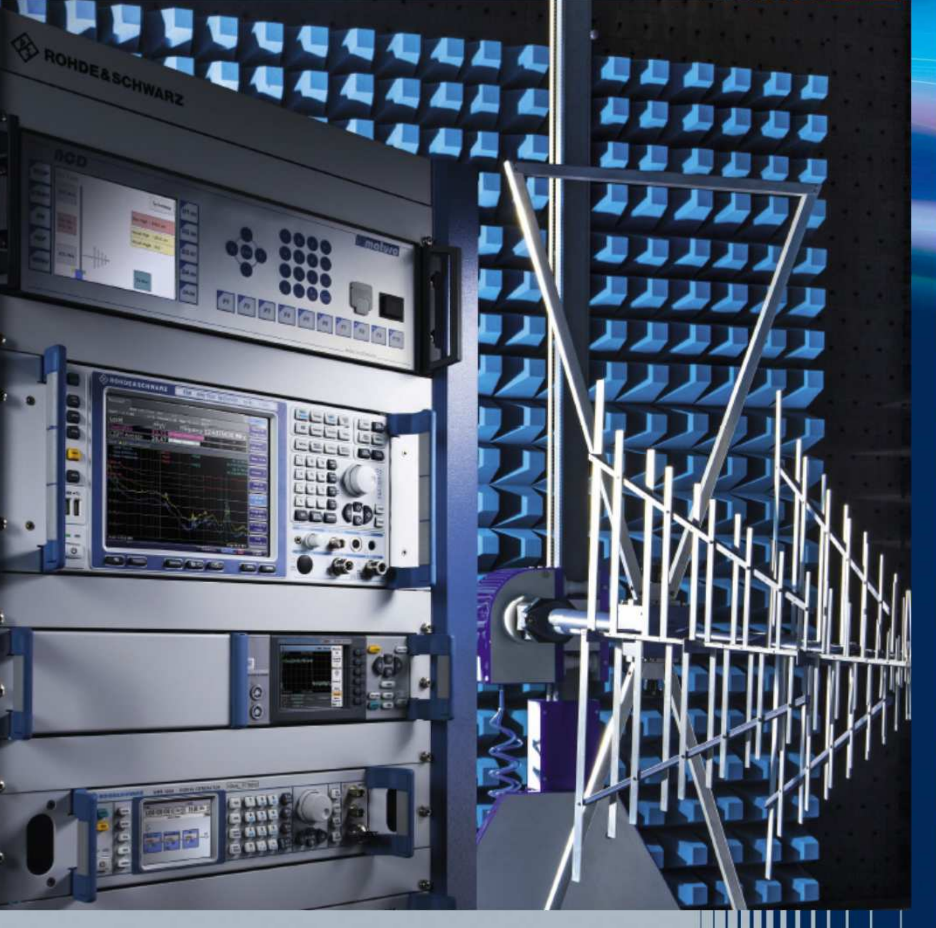
EMC Seminar 2014

Time-domain based EMI measurements



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EMC & Tempest Solutions
Rohde & Schwarz
04/2014

ROHDE&SCHWARZ

Introduction to EMI
Today's Electronic Design & EMI

Nowadays we are facing…

- Faster clock speeds & smaller form factors
- More data lines for communications
- Included RF technology
- Power has more impact on signals with smaller amplitude
- PCB Layout stacking – multilayer design
- Rise & fall times go down to fractions on nano-seconds
- So all this is **high frequency**

Introduction to EMI

Understand your Equipment

Clock rates, possible harmonics,
frequency of power supplies, shielding, grounding …

EMC Design TOOLS

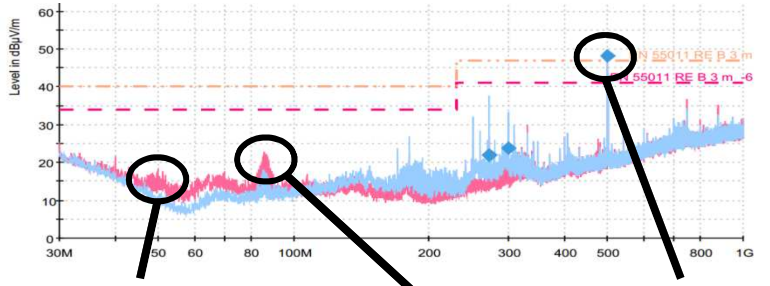
Software Prediction
Pre-scanning
Near field scanning

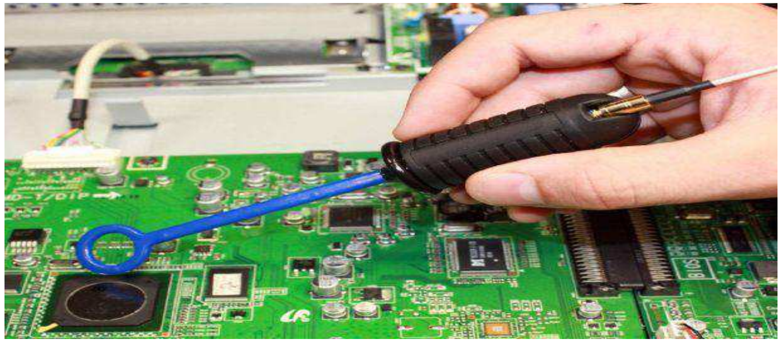
EMC Lab

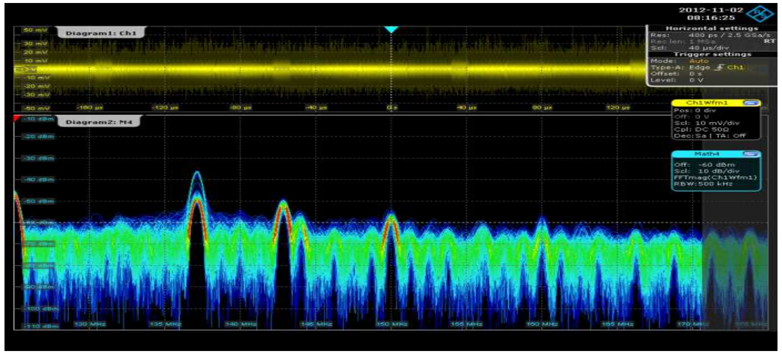
Inhouse testing
Outsourcing (EMC lab)
EMC Consultants

I know my system and
can solve the EMI issue

By using fast and accurate
EMI TOOLS



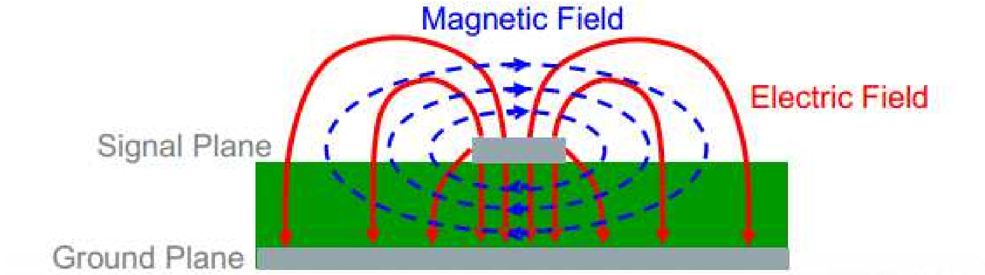




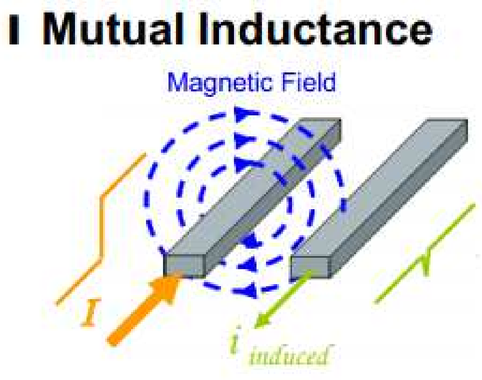
Introduction to EMI

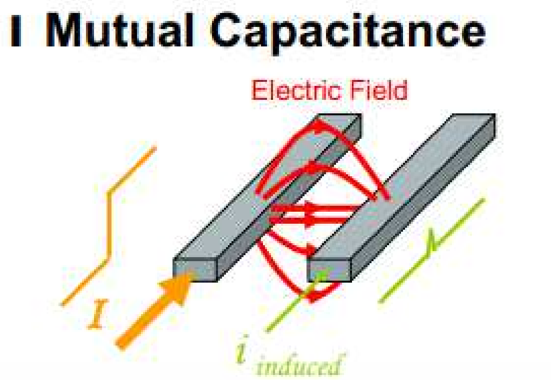
The impact of Electromagnetism

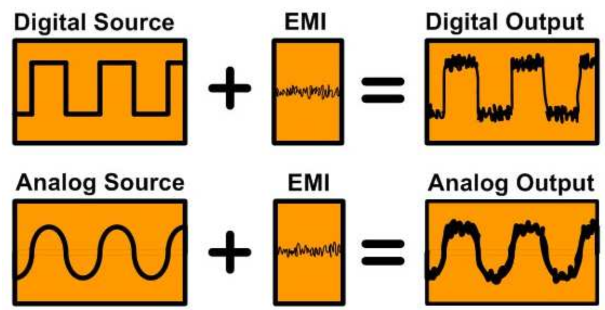
Even on a simple PCB circuit, Magnetic & Electric Field are generated as long as current passes through the conducting medium



Both the E & H-field will penetrate adjacent conducting medium and induce noise on it



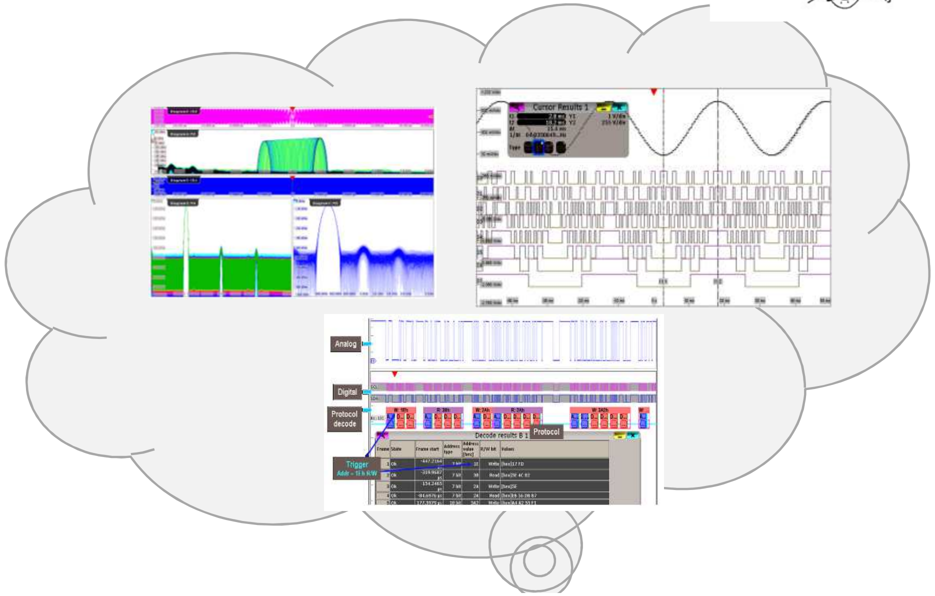




The EMI bubble… How to test efficiently?

EMC engineers are concerning about:

- Analog Signals, Digital Busses
- Parallel, Serial Bus Analysis & Decode
- Mix Signal Analysis
- FFT Analysis
- Triggering
- Time Correlated Events
- Acquisition rate (frequency range)
- Dead time (missed intermittent faults)
- Dynamic Range (sensitivity)
- EMI Filters, Detectors, Windowing
- EMI Limit lines
- EMI transducer correction factors
- EMI appropriate accessories / infrastructure



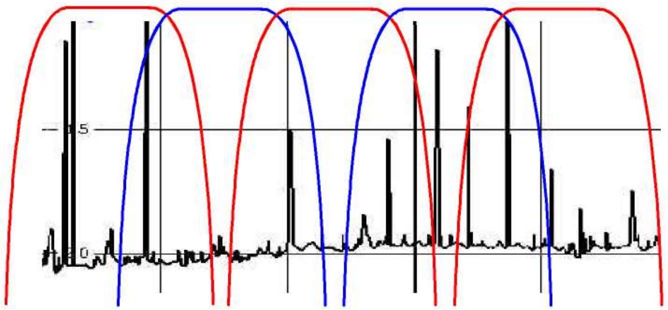
Agenda

- Using Time-domain Instruments for EMI testing
  - FFT principles and possible causes for errors
    - Sampling
    - Windowing
    - Pixel fence
    - Leakage
  - Time Domain Scan in **EMI Receivers**
  - FFT in **Oscilloscopes**

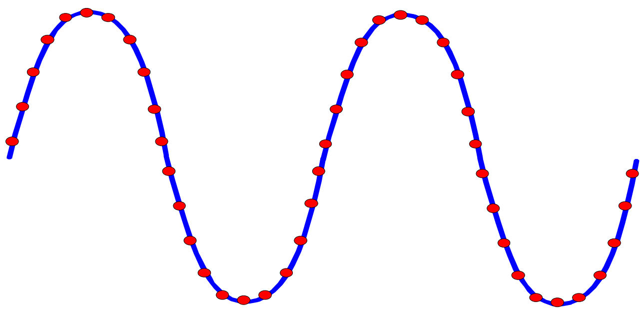
Annexes:

- Practical examples
- Some links to Youtube

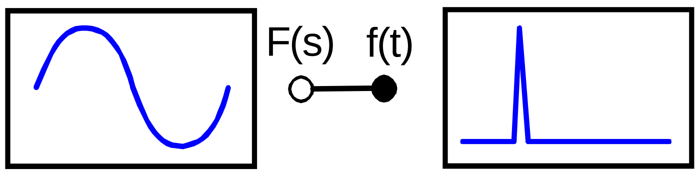
Principle of time domain scan in EMI receivers



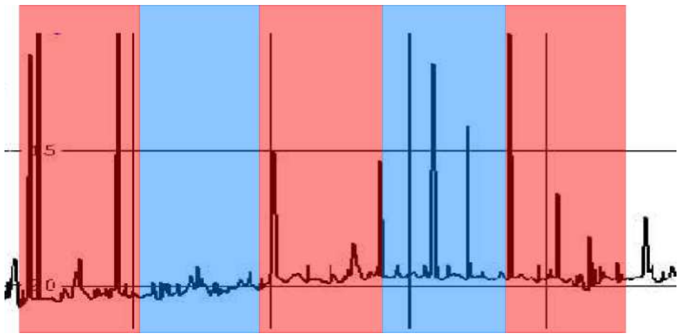
Frequency domain
Division of the measured frequency range in consecutive frequency intervals and filtering



Time domain
Temporal sampling of the filtered signals with high sampling rate/resolution and windowing

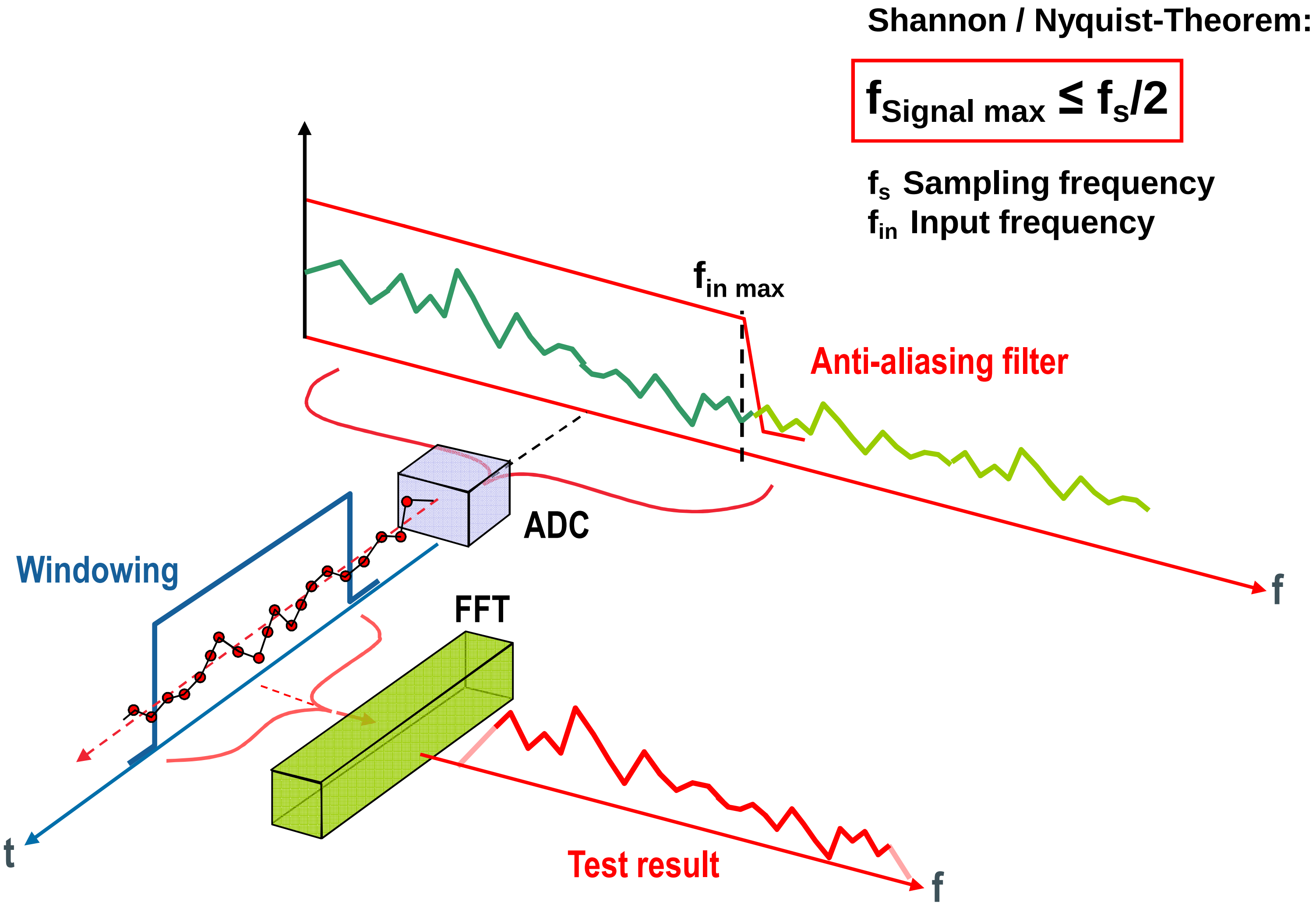


Fast Fourier transform
Signal transformation of the filtered signals from time domain to frequency domain



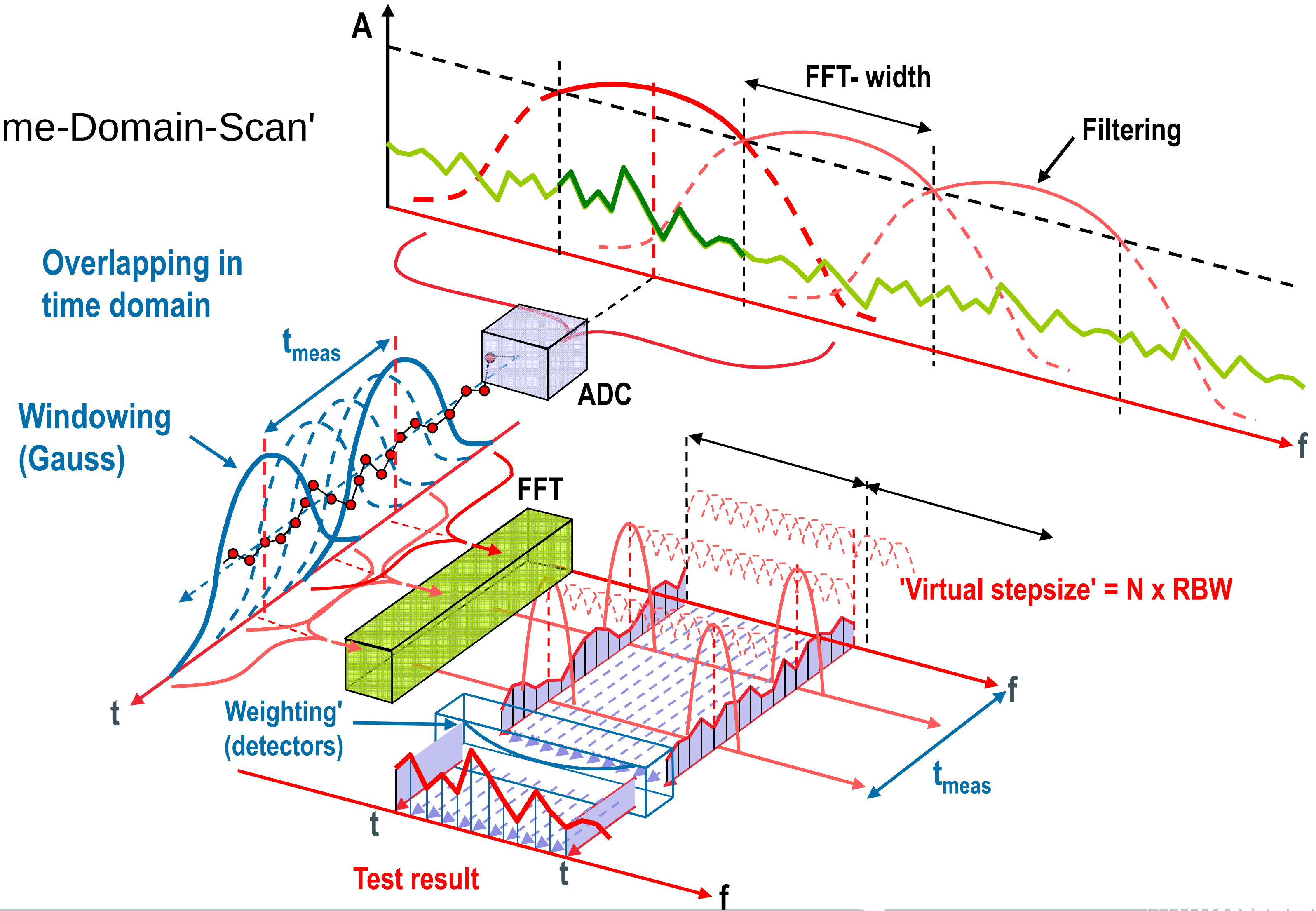
Frequency domain
Merging the spectral distributions of all partial frequency ranges

Standard 'Realtime Analyzer' with FFT



R&S Superhet. receiver using the 'Short-time FFT'

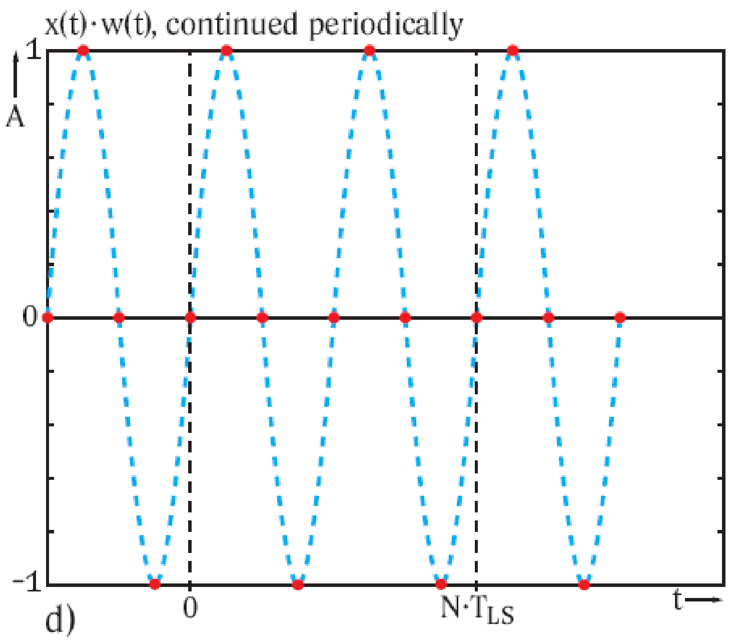
'Time-Domain-Scan'



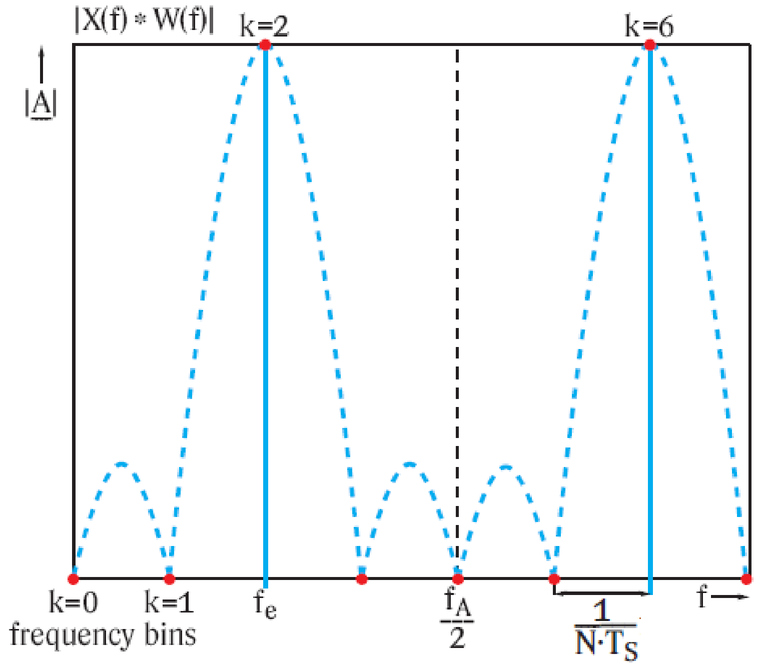
Fast Fourier transform (FFT)

- Only a certain number of the discrete signals in the time domain are used for calculation of the frequency spectra (windowing)
- The calculated spectrum is made up of individual components at the frequency bins (discrete frequency spectrum)

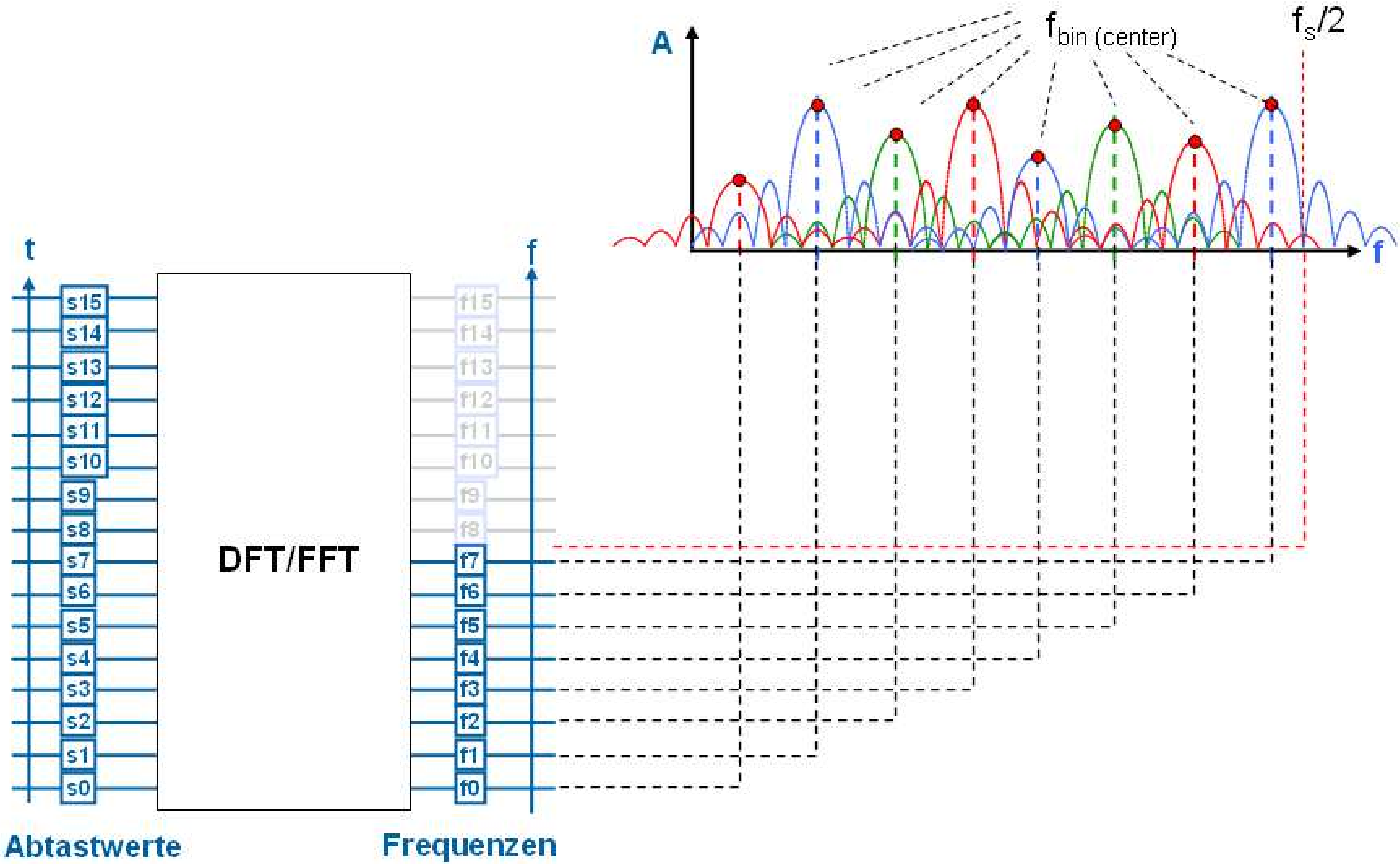
time domain



frequency domain

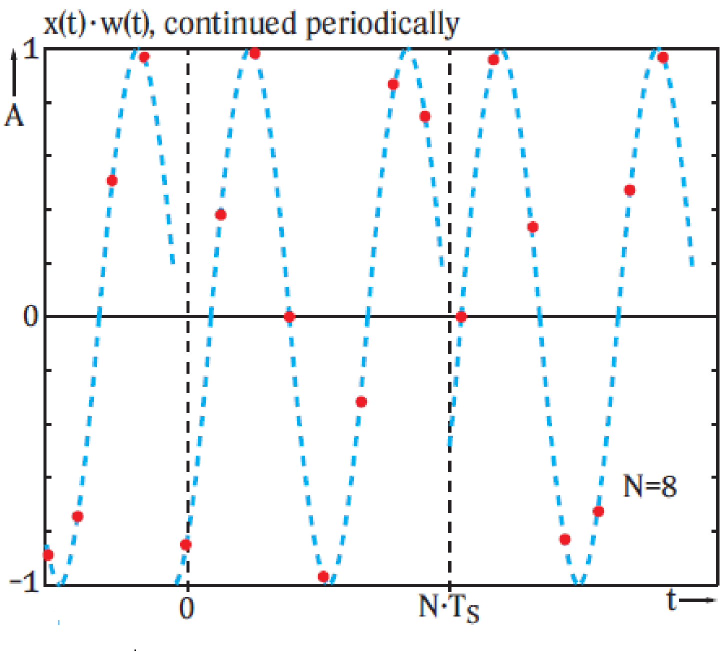


Fast Fourier transform (FFT)

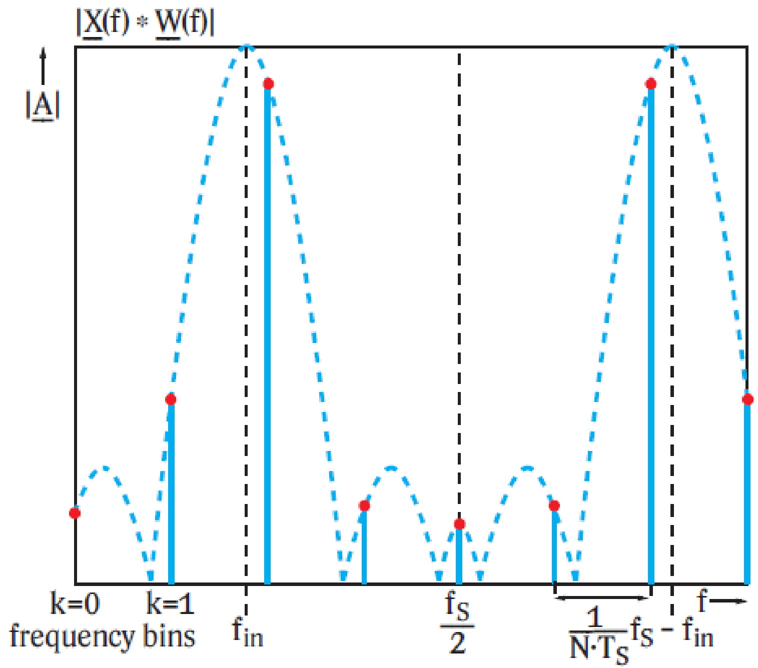


FFT - leakage effect

time domain

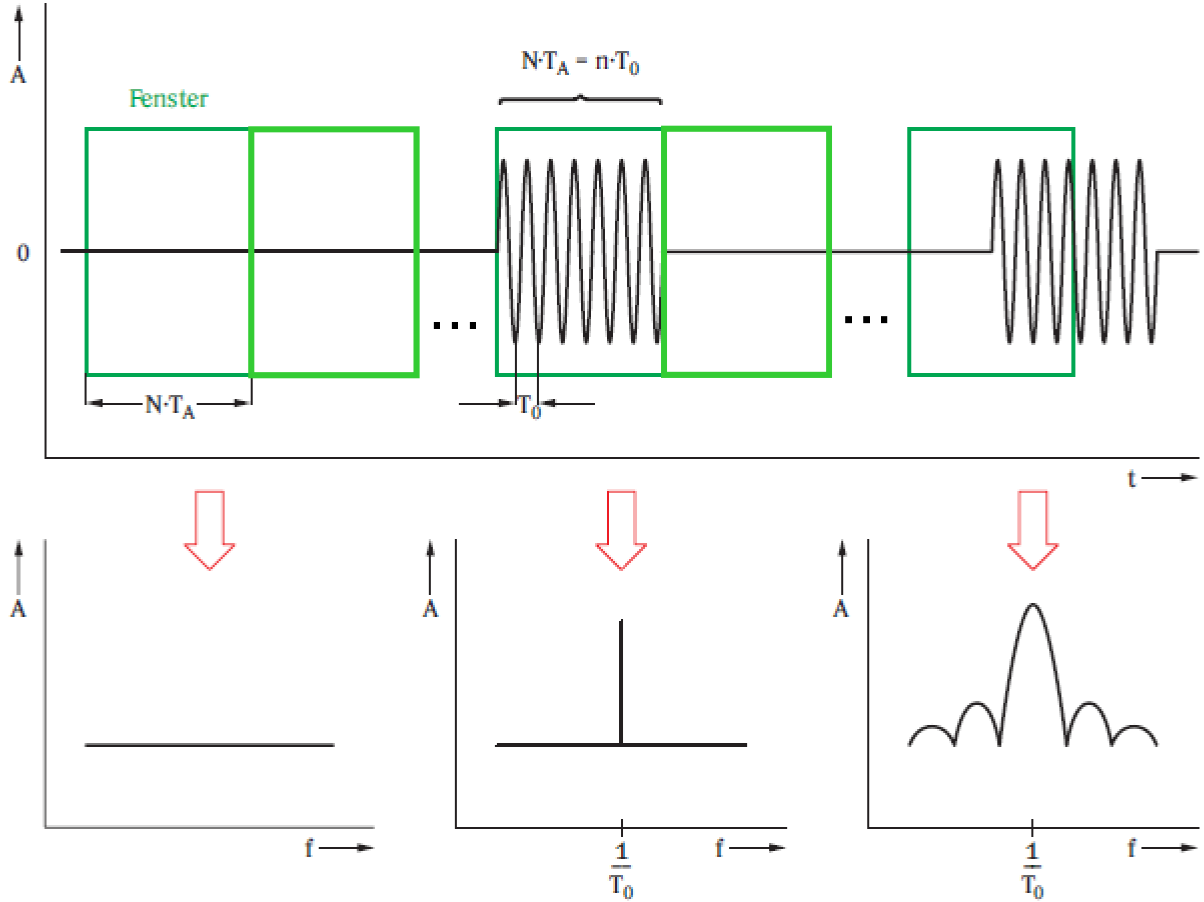


frequency domain

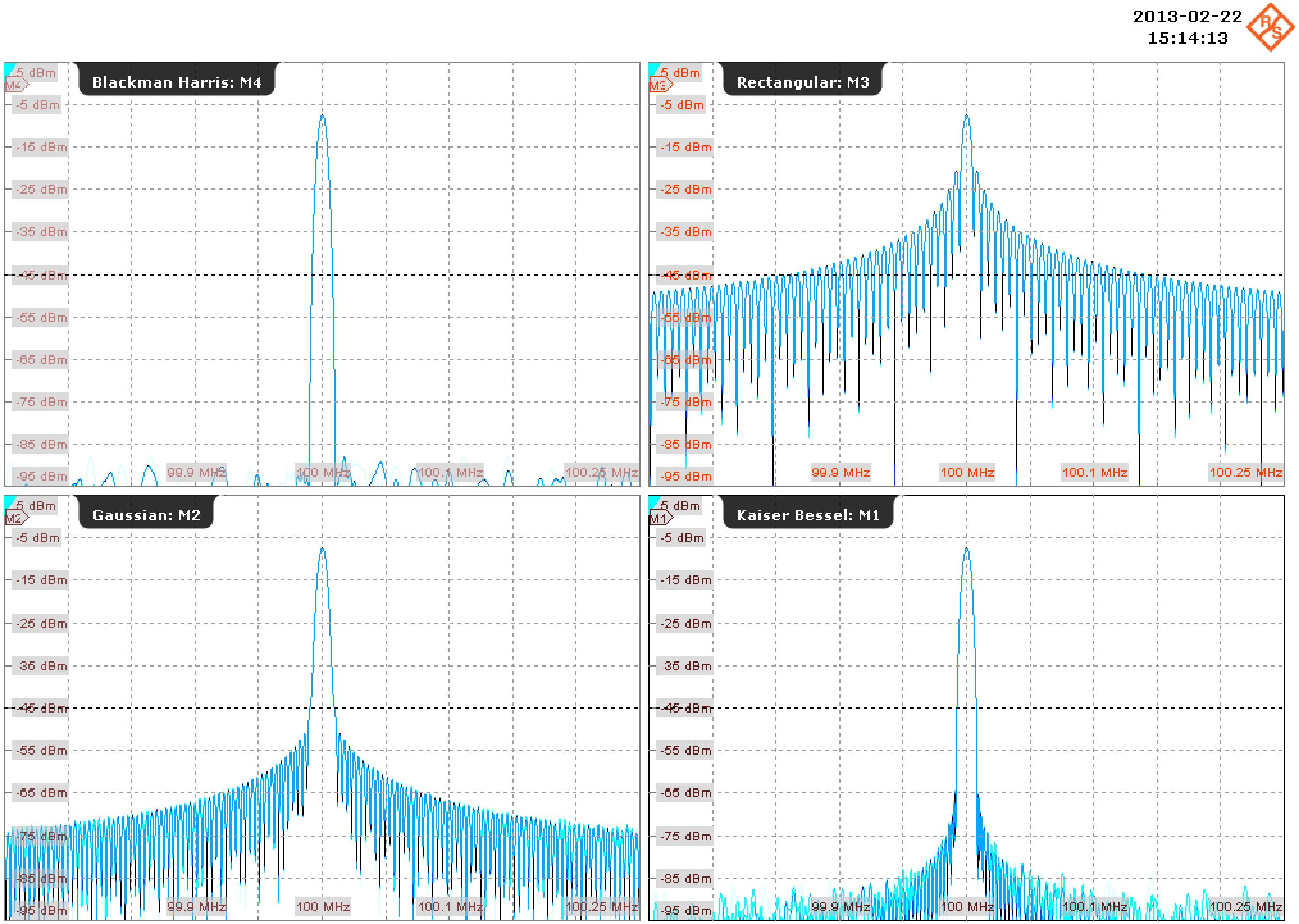


FFT of transient/intermitting signals

- An FFT with rectangular windowing is not suitable to correctly measure transient signals/pulses
- Short pulses might be only partly captured by the window in the time domain
- The FFT algorithm interprets the signal in different ways depending on the captured signal interval



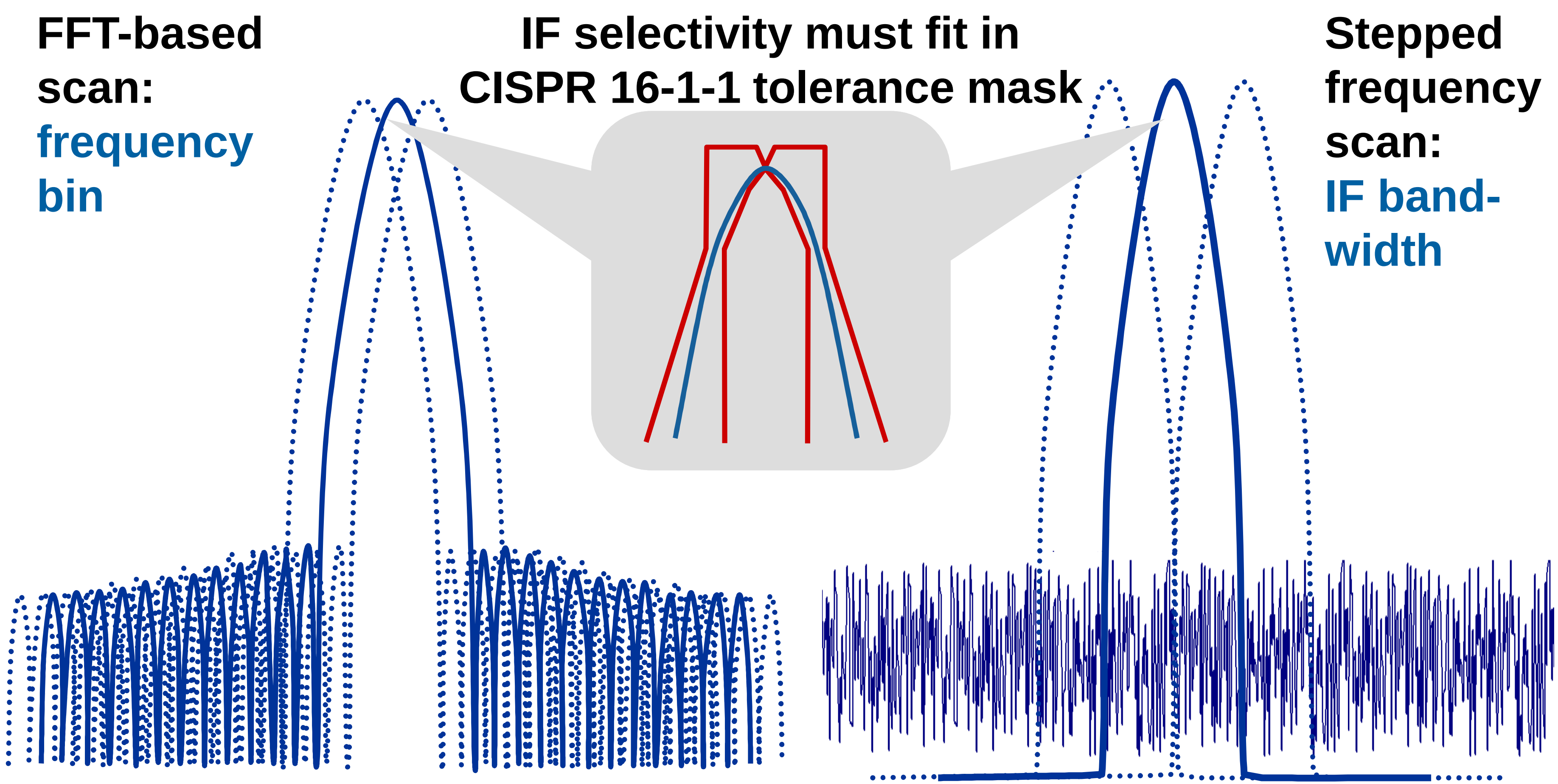
Characteristic of different window functions



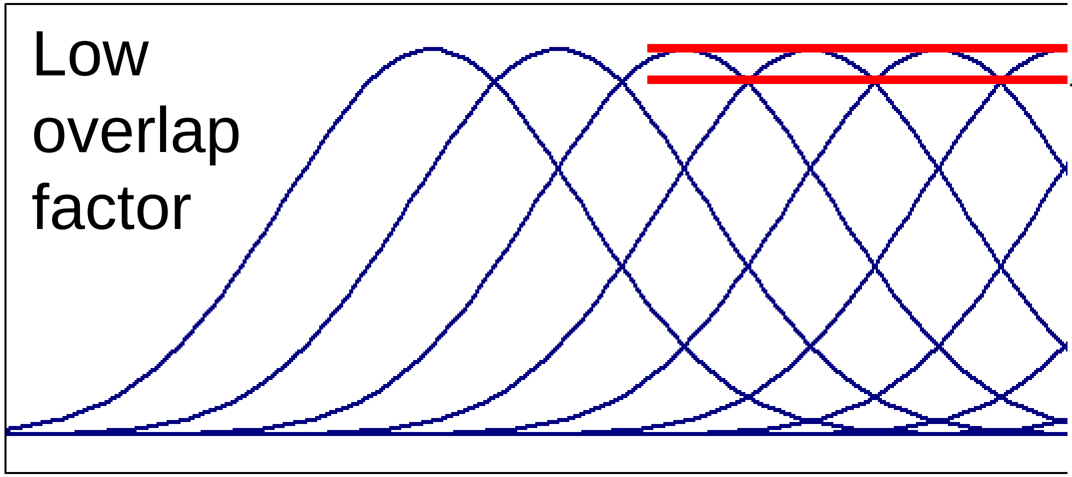
Window functions comparison

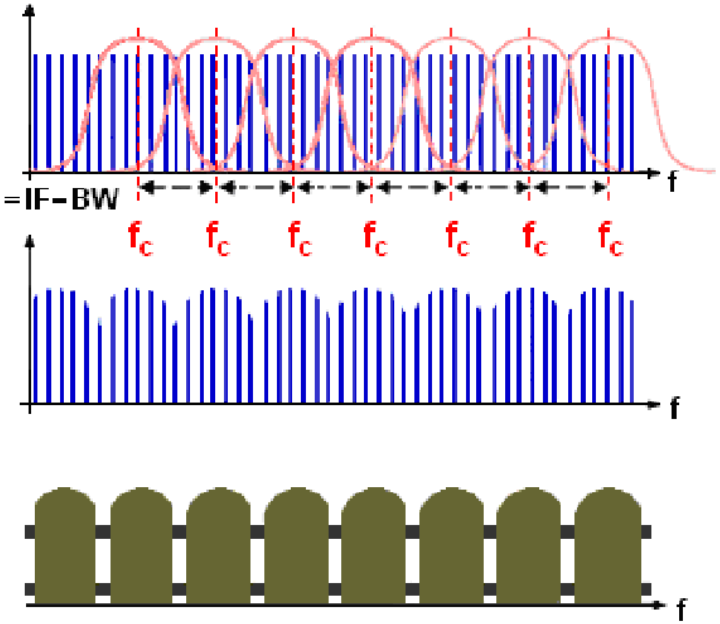
Window function	Frequency resolution	Magnitude resolution	Recommended for measurements of…
Rectangular	Best	Worst	Separation of two tones with almost equal amplitudes and small frequency distance
Hamming, Hanning	Good	Poor	Frequency response measurements Sine waves, periodic signals and narrow-band noise
Blackmann Harris (default)	Worst	Best	Mainly for signals with single frequencies to detect harmonics Accurate single-tone amplitude measurements
Kaiser- Bessel	Poor	Good	Separation of two tones with differing amplitudes and small frequency distance
Gaussian	Good	Good	Weak signals and short duration uses

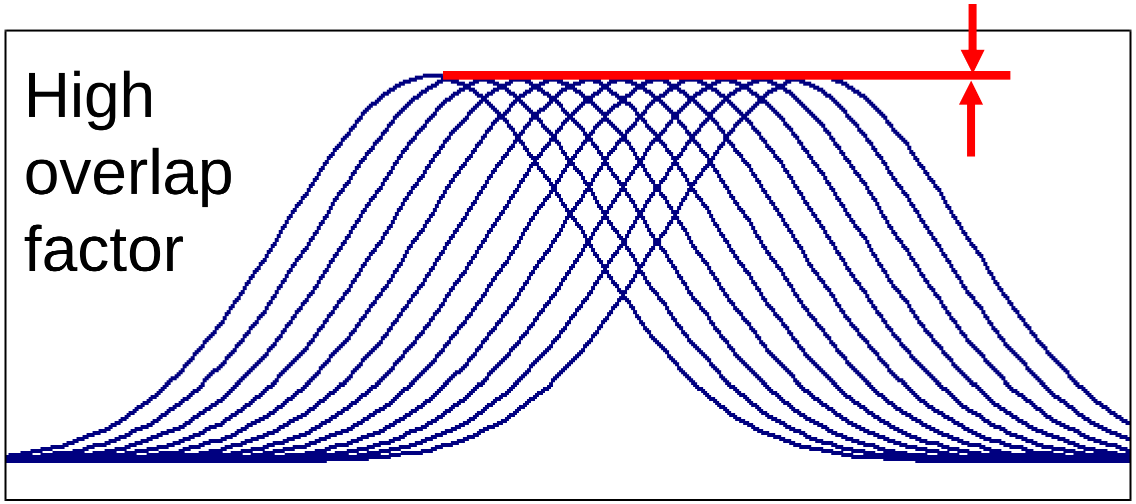
Gaussian-shaped windowing



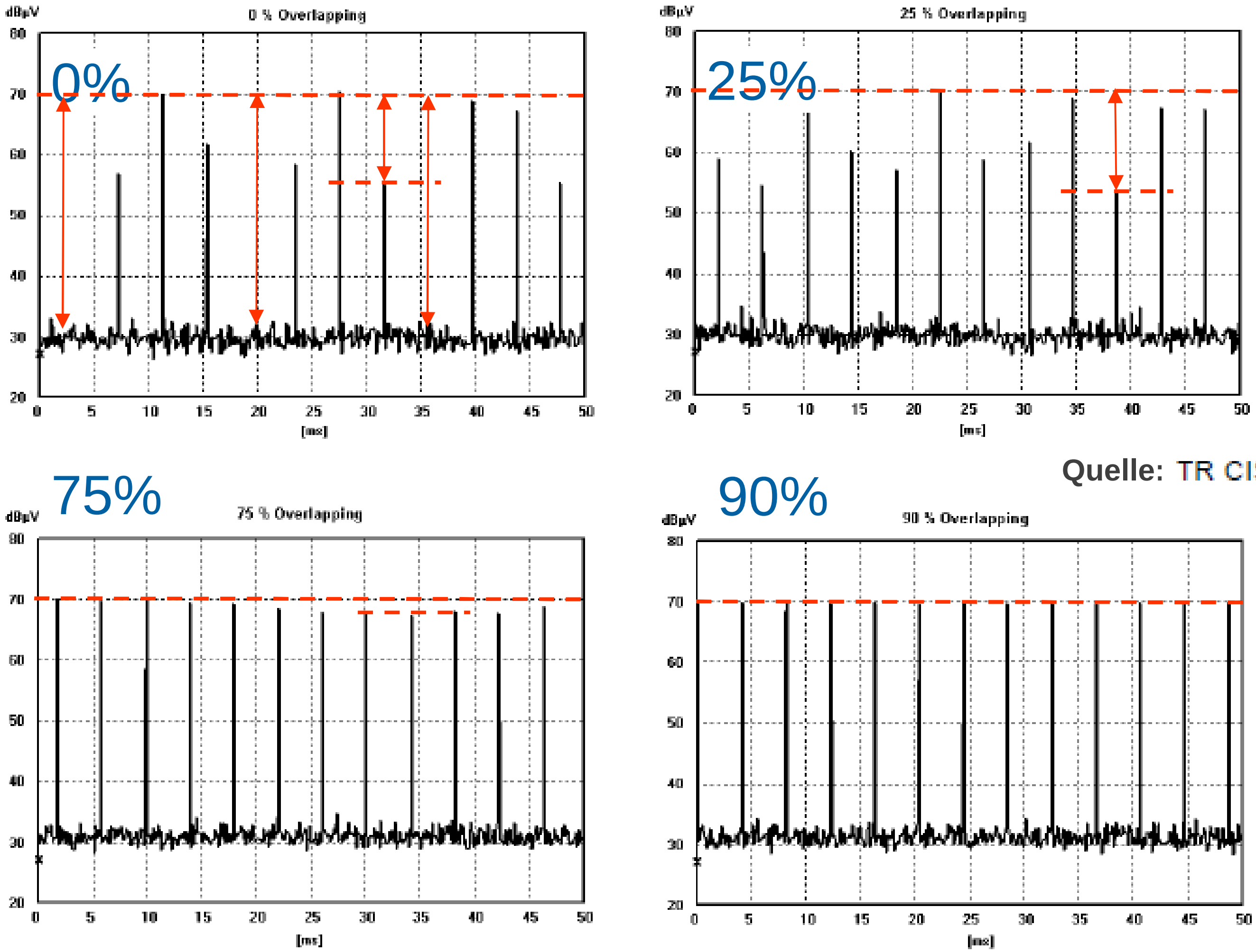
Picket fence effect







Overlapping factor vs. amplitude uncertainty

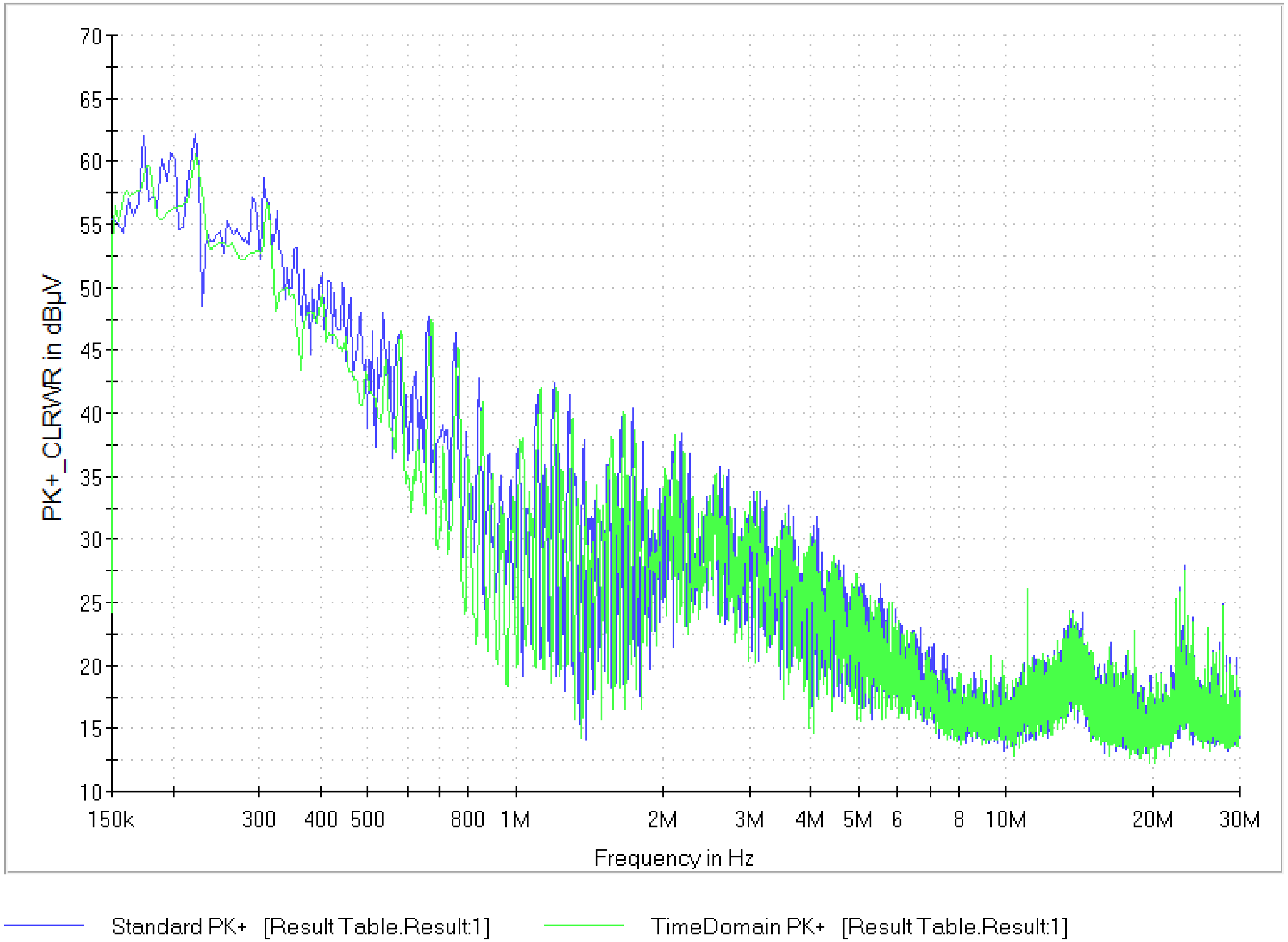


Quelle: TR CISPR 16-3 © IEC:2010(E)

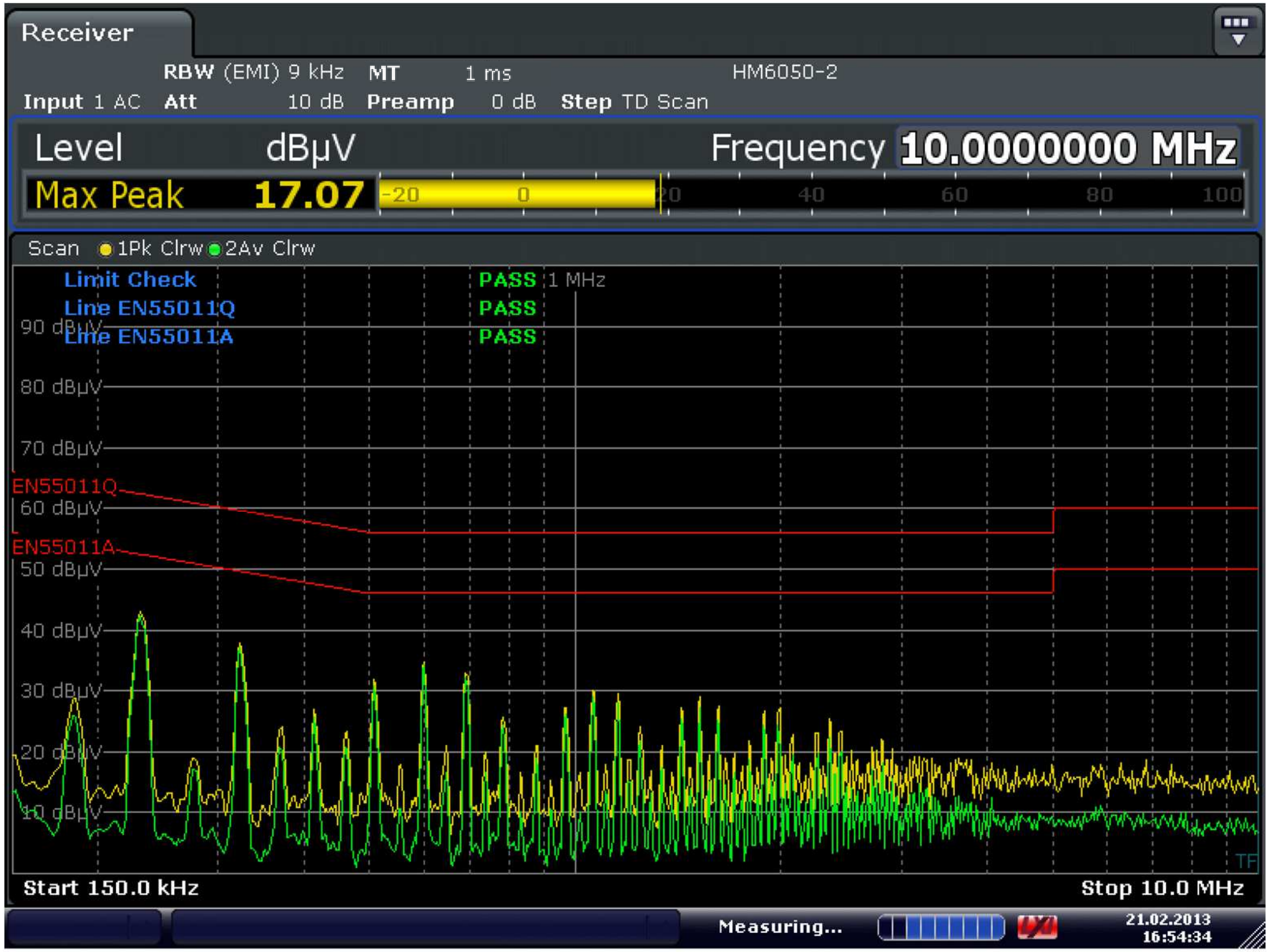
Response of a pulse sequence for different overlapping factors and Gauss windowing

EMC32 – Standard Scan vs. Time-Domain Scan

20 ms measure time, PK+ detector



Importance of Measurement Time in Receiver mode



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FFT fundamentals for **Oscilloscopes**

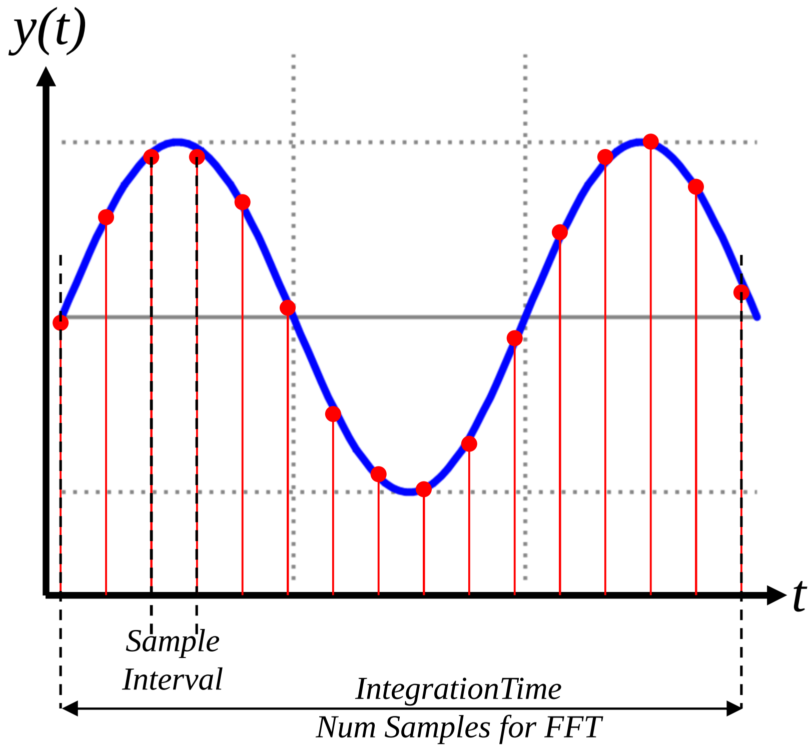
$$IntegrationTime = NumSamples * SampleInterval$$

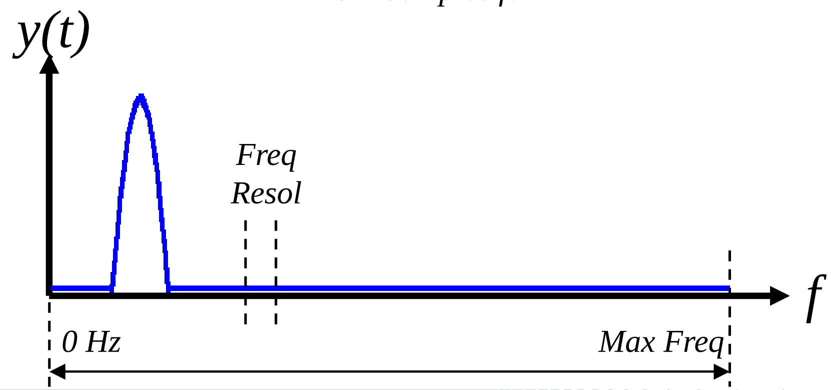
$$IntegrationTime = \frac{NumSamples}{SampleRate}$$

$$MaxFrequency = \frac{NumSamples/2}{IntegrationTime}$$

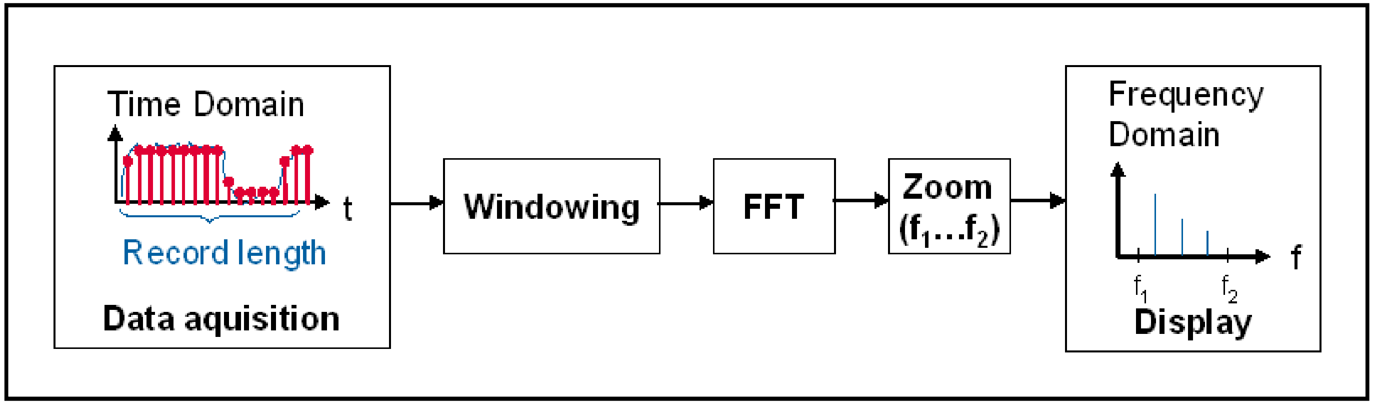
$$FreqResolution = \frac{SampleRate}{NumSamples}$$

$$FreqResolution = \frac{1}{IntegrationTime}$$



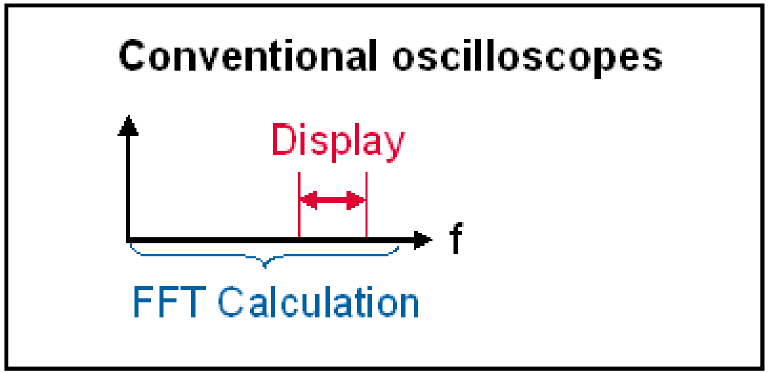


FFT Implementation in conventional Oscilloscopes



$$F\max = \frac{Samples/2}{Time}$$

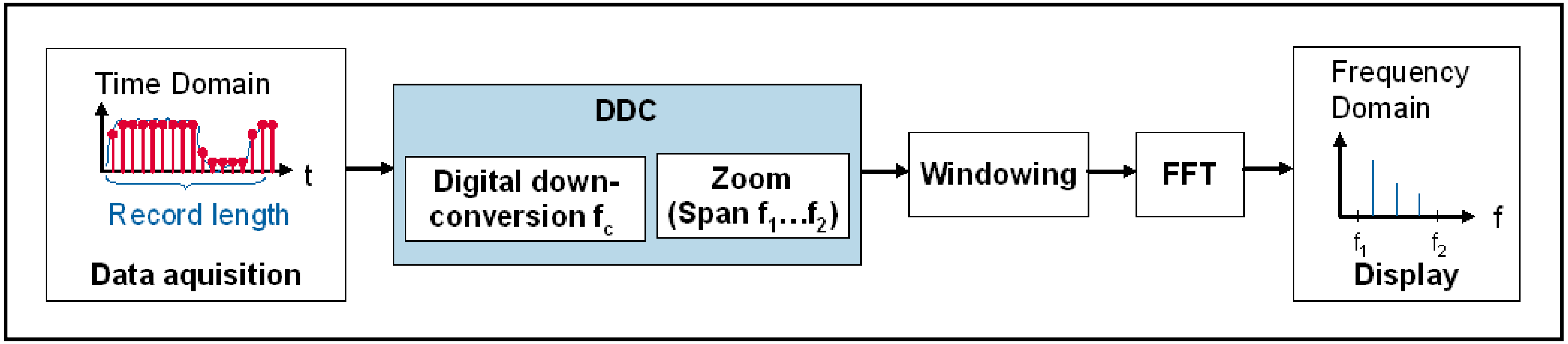
- The FFT calculation will produce a frequency domain result from 0 Hz to max Freq.
- Optionally Windowing is applied before the FFT calculation
- After FFT, the user can select the desired frequency range to be displayed



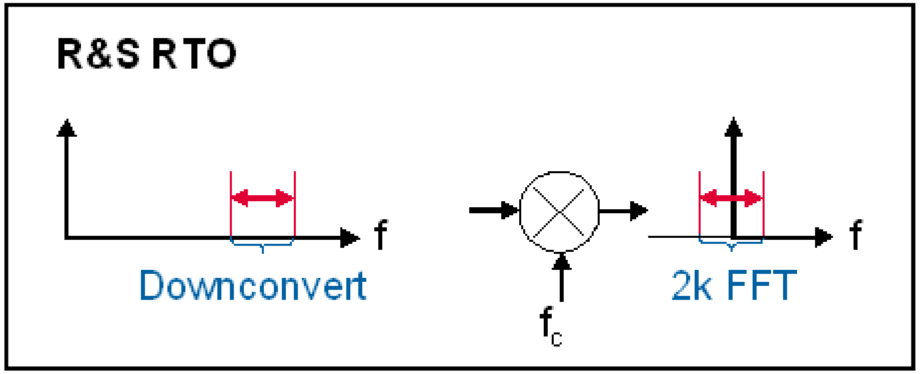
Disadvantages of conventional FFT:

- Slow speed / update rate
- Poor resolution (zooming after FFT)
- Complex configuration (need to know how TD settings affect the FFT result)

FFT Implementation in the RTO



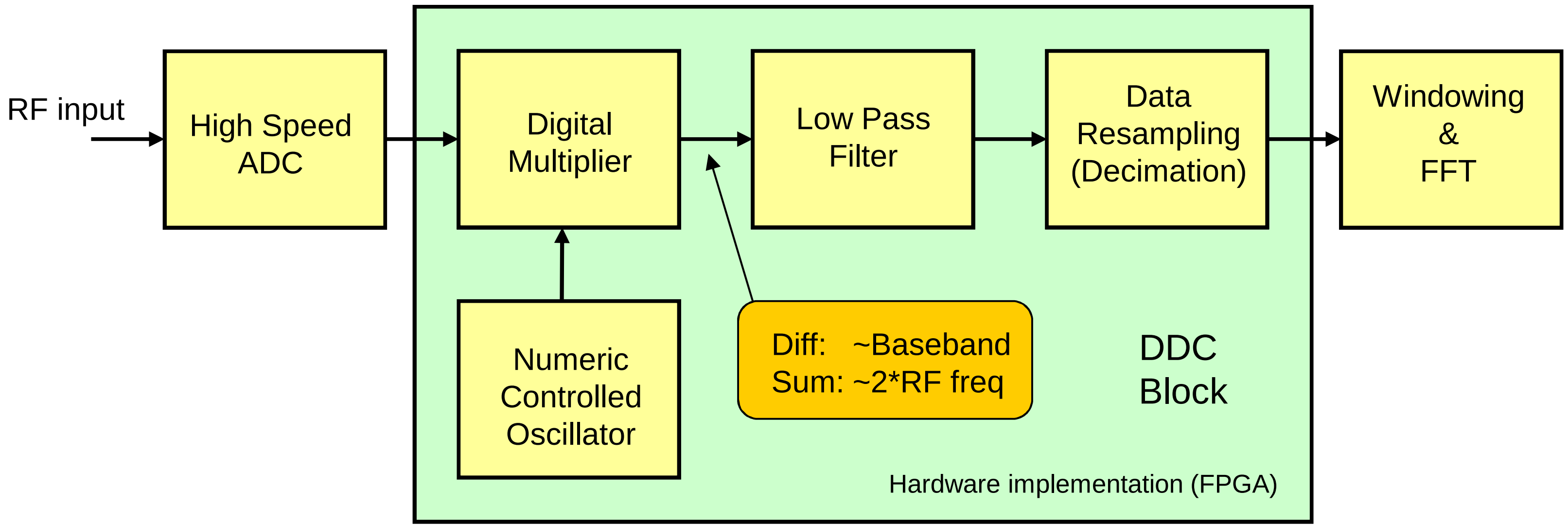
- ➢ Desired frequency range is selected and down-converted to baseband using Digital Down Conversion (DDC) technique
- ➢ FFT is calculated over the selected (or zoomed) frequency range
- ➢ Optionally windowing is applied before the FFT calculation



Advantages of RTO approach:

- ✓ Higher speed / update rate
- ✓ Better resolution (zooming before FFT)
- ✓ Higher dynamic range
- ✓ Flexible configuration

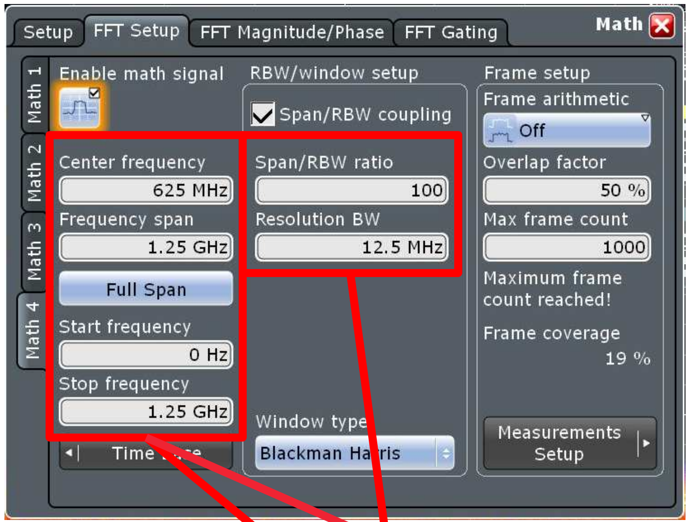
Digital Down Conversion (DDC) block (simplified)



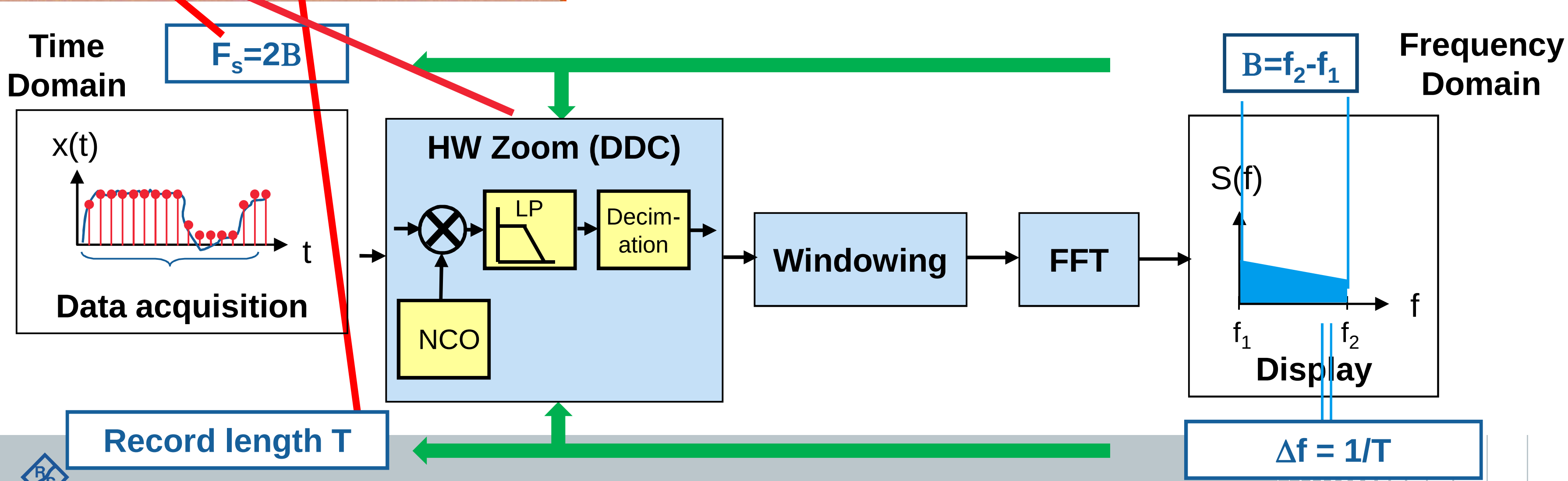
- The Multiplier is ”equivalent” to the analog mixer and produces sum & difference signals
- The NCO frequency is a close approximation to the original carrier (LO =~ RF)
- Multiplier difference freq is a baseband signal from 0 Hz to desired span freq.
- Low Pass Filter prevents aliasing by only passing the difference frequency (~Baseband)
- The Data Resampling reduces the sample rate prior to the FFT transformation

FFT by R&S Oscilloscopes

Spectrum Analyzer Model



- **Frequency domain controls time domain**
  - Time domain parameters (record-length / sampling rate) automatically changed as necessary
- **Downconversion FFT (DDC) zooms into frequency range *before* FFT**
  - Largely reduced record length, much faster FFT

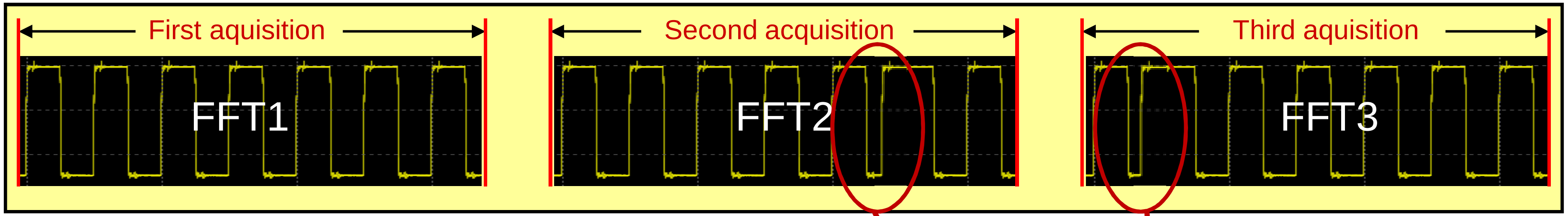


Segmented FFT. What's that?

Some visual examples

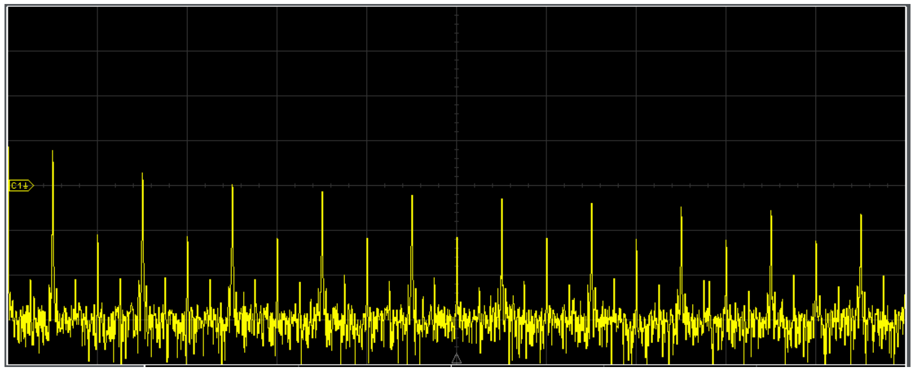
Classic FFT approach

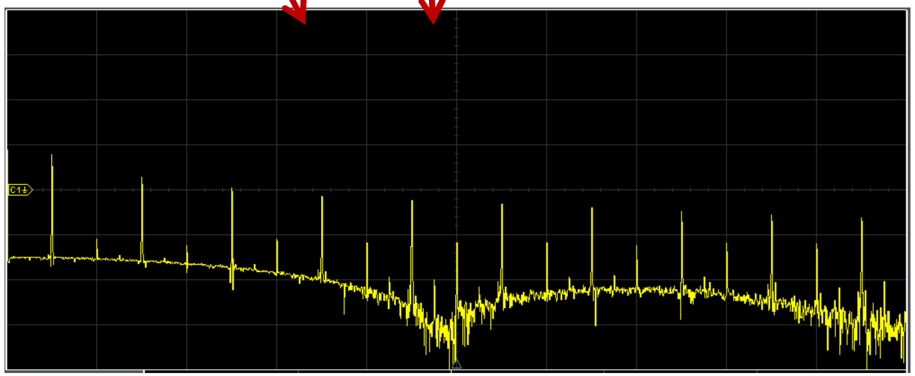
Classic FFT approach in Oscilloscopes:



- Classic oscilloscopes capture a signal and calculate its FFT
- Afterwards the next section of the signal is captured and the FFT is calculated again
- Thus, they always use the FFT **sequentially**.

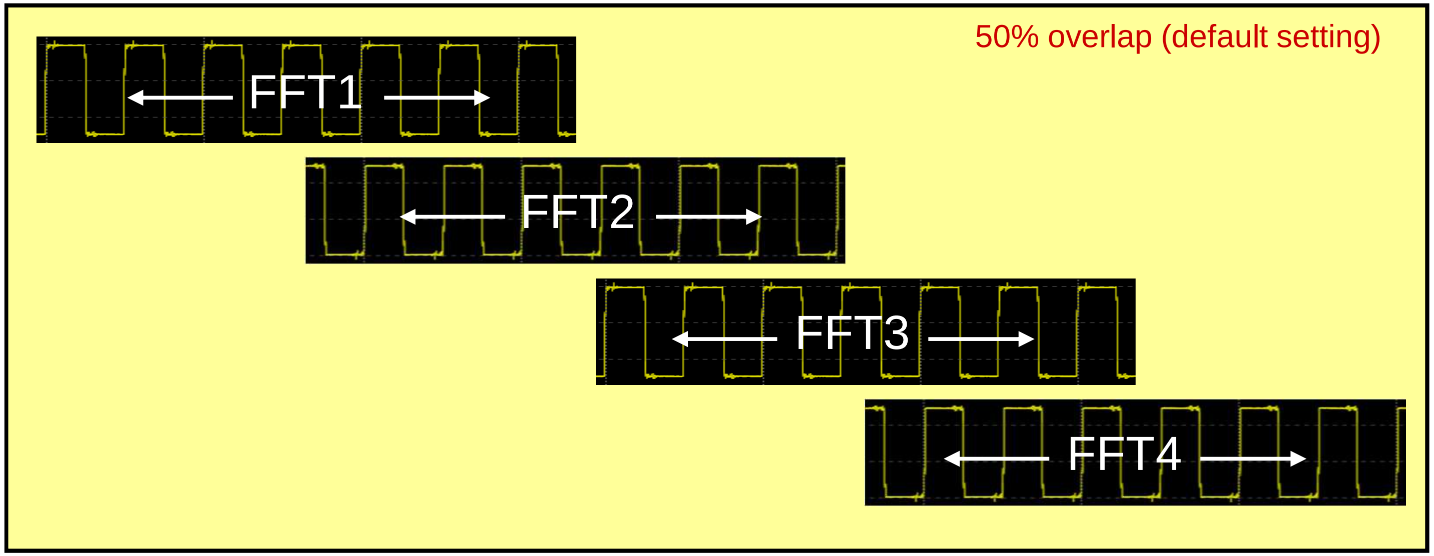
- The FFT result indicates a problem, but we are often unable to pinpoint where in the time-domain signal it happened.

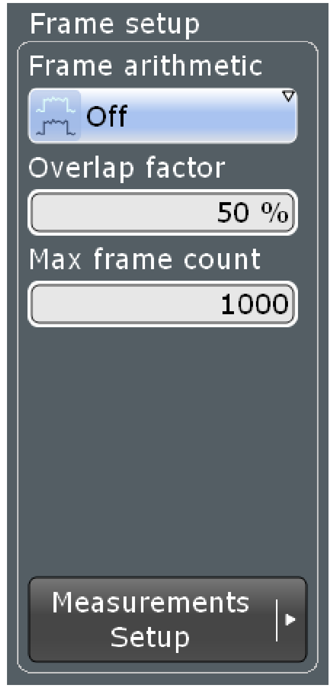




Segmented and Overlapping FFT in the RTO

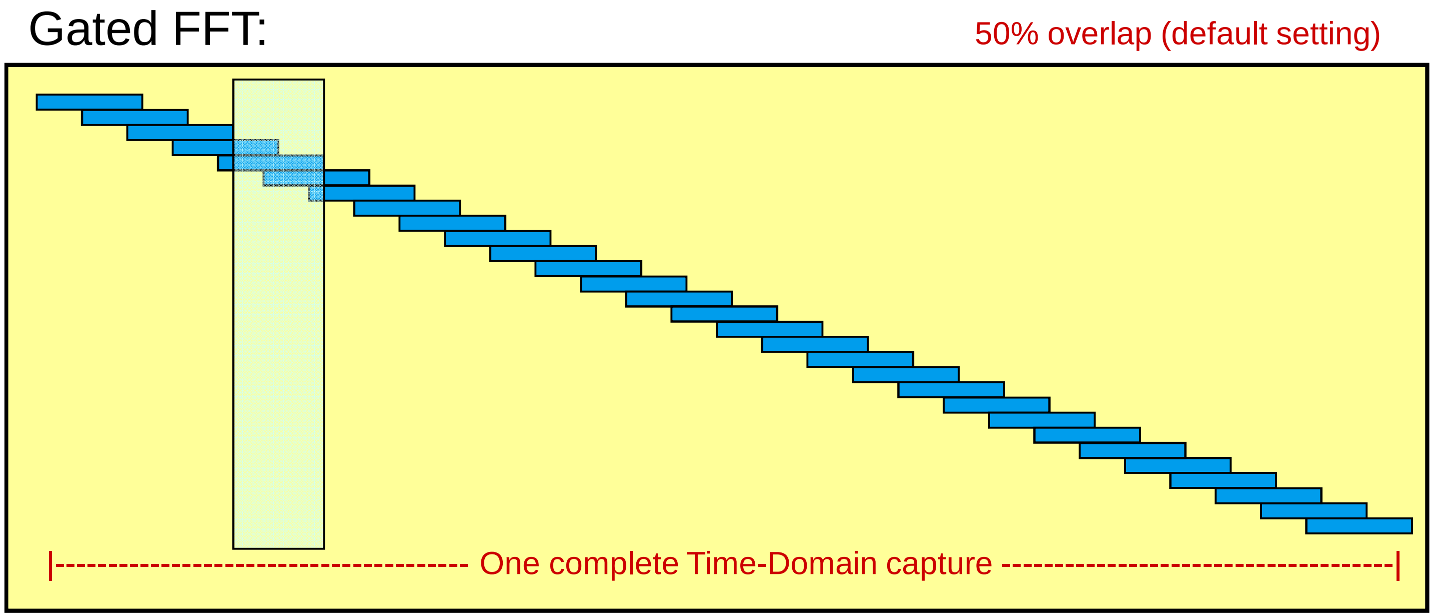
Overlapping FFT:

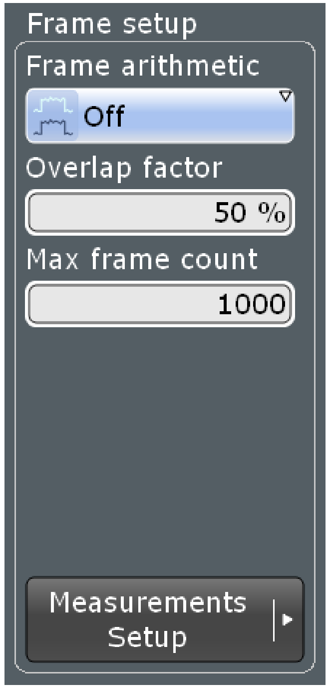




- To improve the FFT results further and to be independent of this windowing effect, the Oscilloscope offers the possibility to overlap frames.
- **Overlap factor** can be configured from 0% to 90%
- **Max frame count** can be configured from 1 to 10000

Gated FFT in the RTO





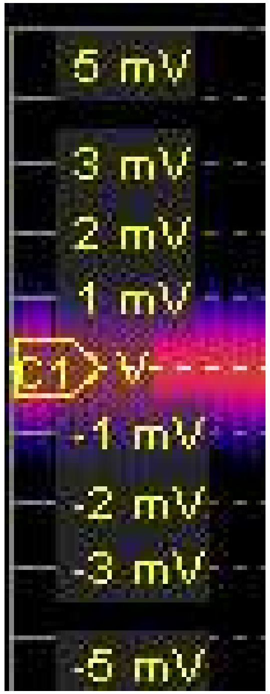
➢ The FFT gate can be adjusted in both width and position, allowing the engineer to analyze only a portion of the time-domain capture

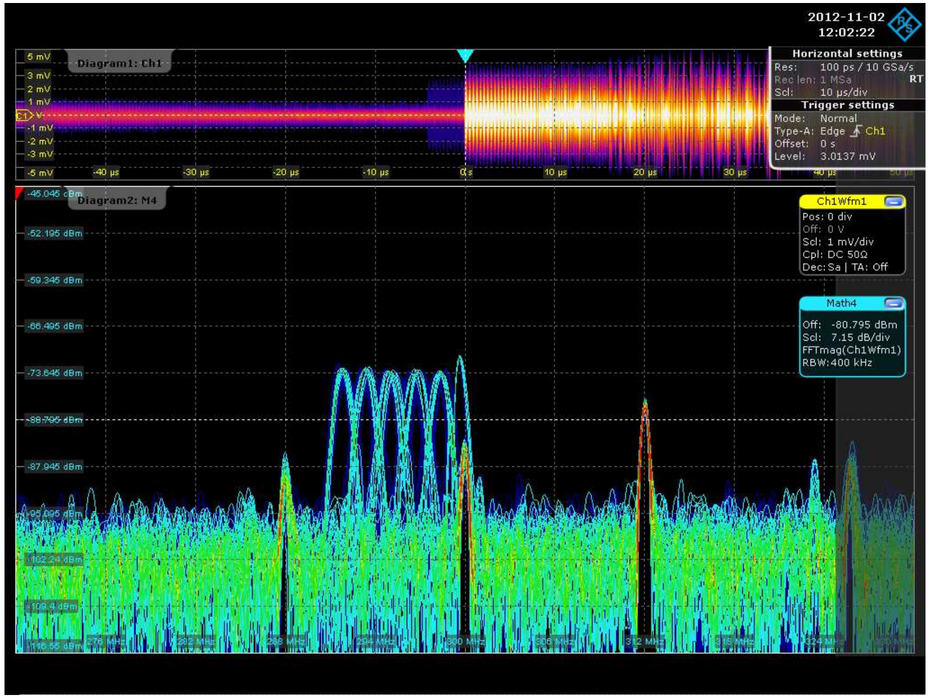
EMI Debugging with R&S Oscilloscope

Ability to detect weak signals

EMI tend to be weak, to detect such signals

Oscilloscopes need to be able to detect them without limiting the bandwidth

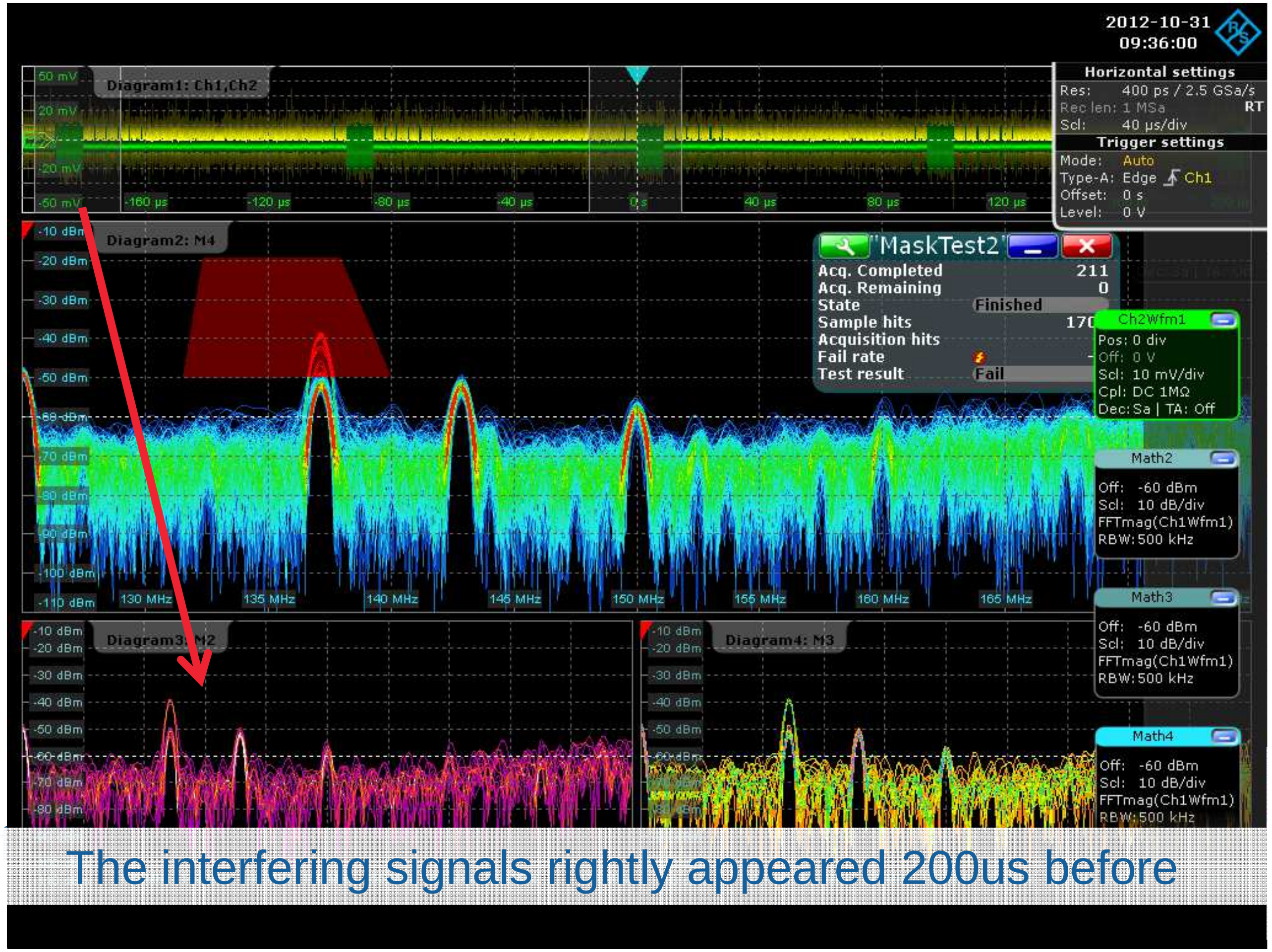




Low Noise and High Sensitivity at Full Bandwidth

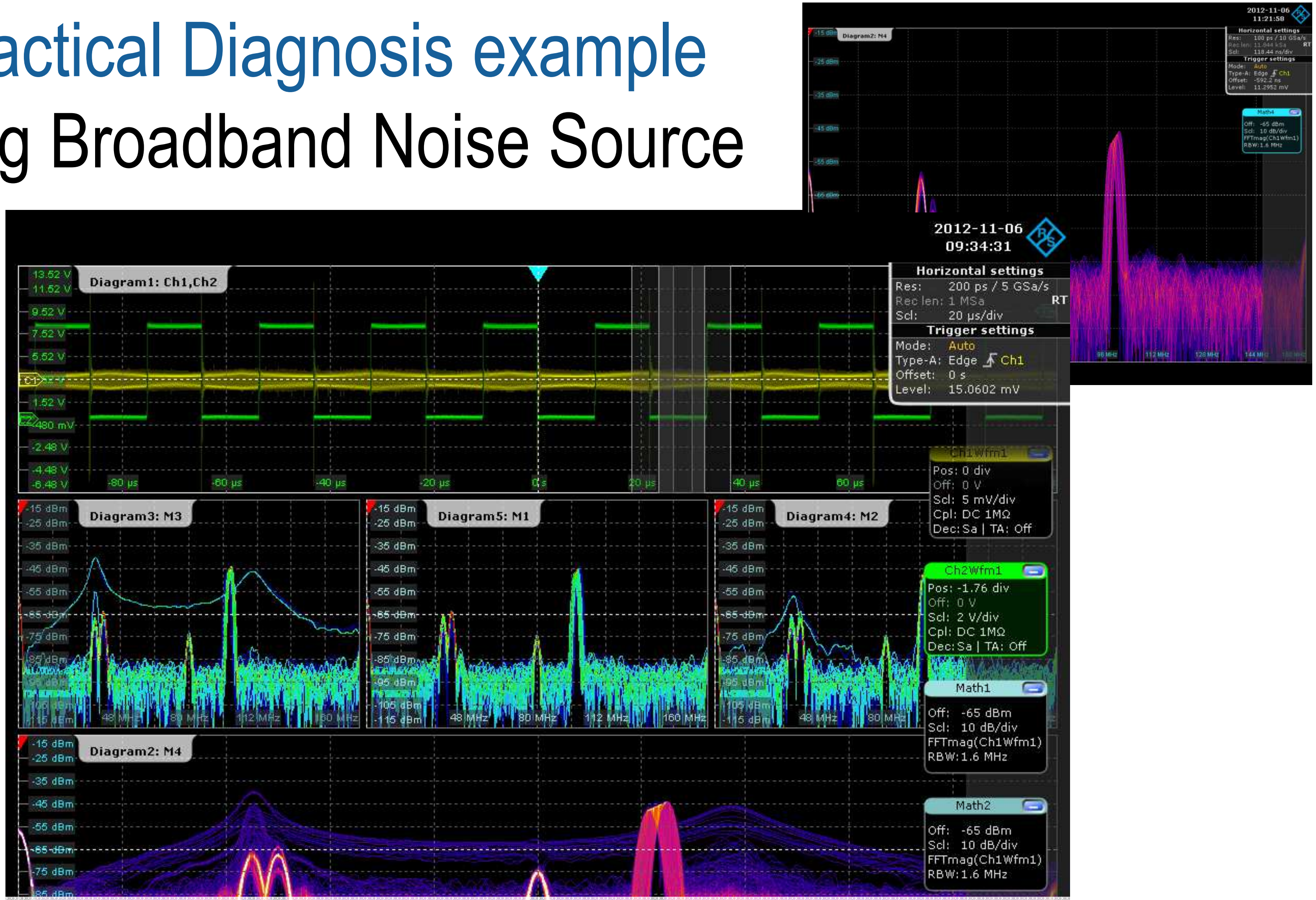
EMI Practical Diagnosis example

Locating Abnormal Spike Source with FFT Gating



EMI Practical Diagnosis example

Locating Broadband Noise Source

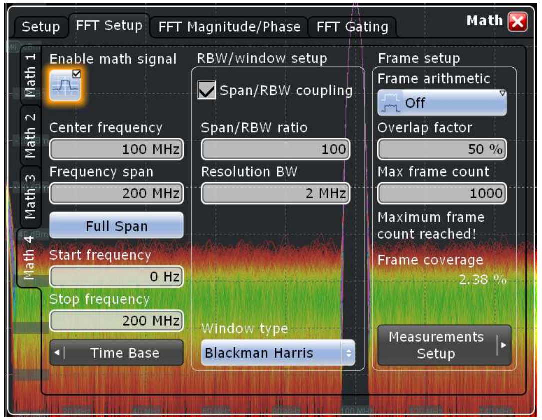


Discover the interfering clock with spikes
occurred at both rising and falling edges

Summary

R&S oscilloscope for EMI Debugging

- **Fast and easy to use FFT**
  - The modern oscilloscope with hardware DDC and overlapping FFT is capable to do more than what the traditional oscilloscope is meant for.
  - Can be used like a spectrum analyzer
  - No need to care about #FFT points, etc
- **High sensitivity of 1mV/div**
  - Use near-field probes without preamp
- **Intensity grading reveals signal characteristics**
  - Easily distinquish cw signals, spurious events or bursts
- **Correlation analysis with gated FFT**
- **Frequency mask with stop-on-violation**
  - Capture spurious events in frequency domain and analyze



Debug EMI problems on your desk, even if no spectrum analyzer is available

EMC & RTO

www.rohde-schwarz.com or google on Youtube

Some useful links…:

- **R&S®RTO Oscilloscope Spectrum Sensitivity and FFT Capability**
  - http://www.youtube.com/watch?v=LHAdy9oo0Uo
- **R&S®RTO oscilloscope frequency analysis part 1 (3): The implementation**
  - http://www.youtube.com/watch?v=SrWFmL12RQc
- **R&S®RTO oscilloscope frequency analysis part 2 (3): AM and FM**
  - http://www.youtube.com/watch?v=SrWFmL12RQc
- **R&S®RTO oscilloscope frequency analysis part 3 (3): Frequency, time**
  - http://www.youtube.com/watch?v=HaWqSCapZwU
- **R&S®RTO Intuitive User Interface and Operation**
  - http://www.youtube.com/watch?v=xFO3rPHGGNY
- **R&S®RTO Family, the digital oscilloscopes from Rohde & Schwarz**
  - http://www.youtube.com/watch?v=rrYEFtgK_kg

Thank you for your attention !

Any questions

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