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How to Significantly Reduce EMI Test Time

Bill Wangard
Bill Wangard is the EMI Receiver and Radio monitoring Product Manager at Rohde & Schwarz. He has 20+ years of RF and Receiver experience at Motorola and Rohde & Schwarz. Bill authored numerous patents at Motorola. - See more at: http://emclive2014.com/how-to-significantly-reduce-emi-test-time/#sthash.1duTpsgv.dpuf

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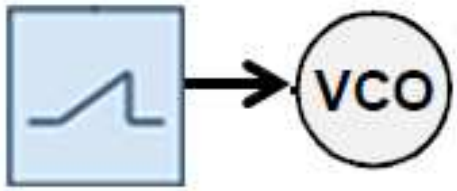
Speed Improvement of FFT Scan

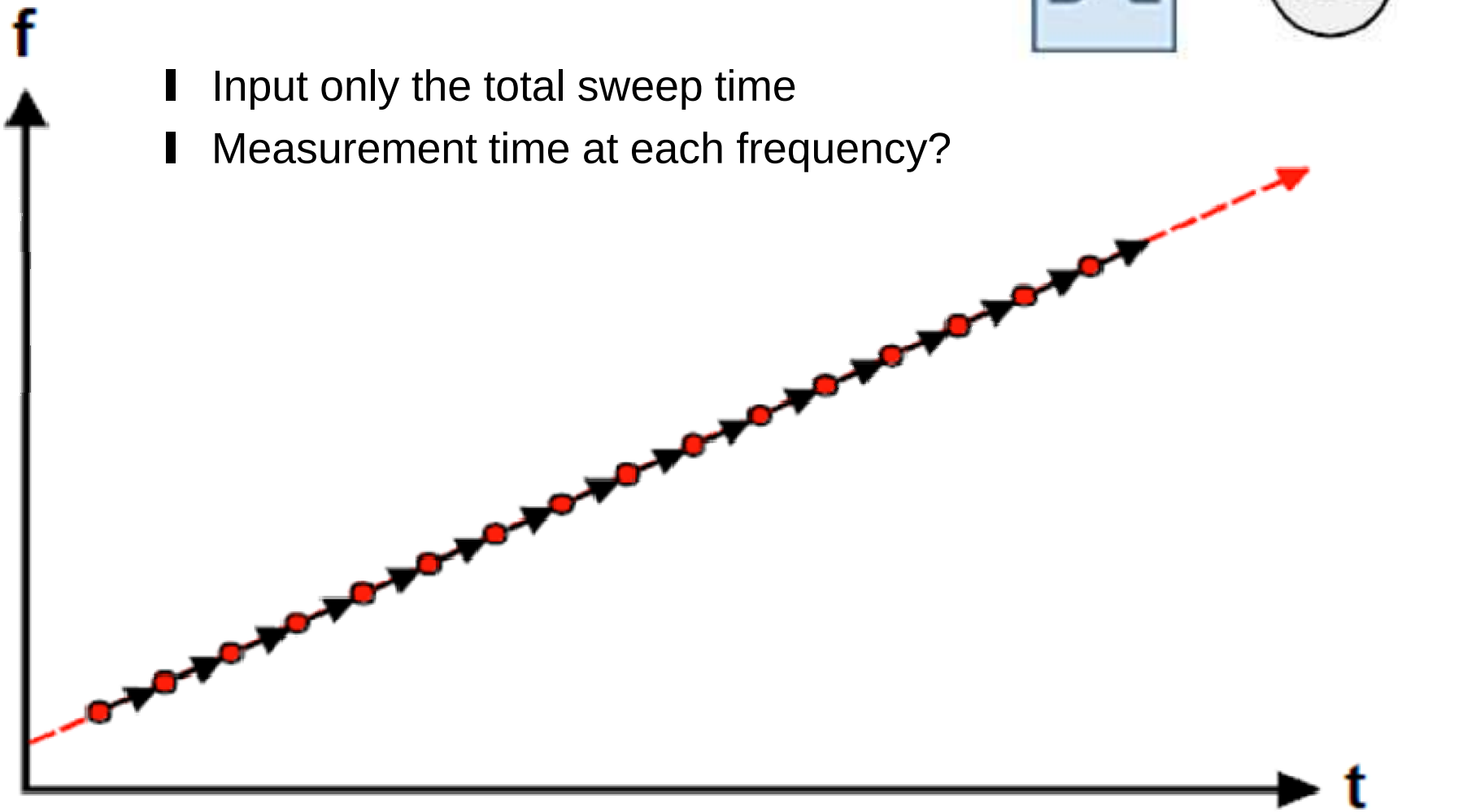
Freq Range	Weighting Detector	Measurement Time	Meas BW	# Points Freq Stepped	# Points Time Domain	Time (sec) Freq Stepped	Time (sec) Time Domain *R&S ESR*	Speed Factor Increase	Time Savings (minutes)
CISPR Band B 150K - 30MHz	Pk	100ms	9kHz	6633	13267	663	0.11	6030	11
CISPR Band B 150K - 30MHz	QP	1sec	9kHz	4975	9950	4975	2	2488	83
CISPR Band C/D 30M - 1000MHz	Pk	10ms	120kHz	16167	32333	162	0.52	311	3
CISPR Band C/D 30M - 1000MHz	Pk	10ms	9kHz	215556	431111	2156	0.82	2629	36
CISPR Band C/D 30M - 1000MHz	QP	1sec	120kHz	16167	32333	16167	80	202	268

- # Points Frequency Stepped → Freq Step of IF BW / 2
  - Step 4.5kHz for 9KHz IF BW
- # Points Time Domain → Freq Bin of IF BW / 4
  - Freq Bin of 2.25kHz for 9kHz IF BW

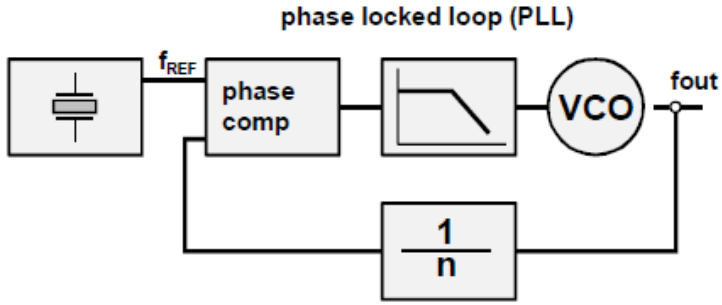
Frequency Swept



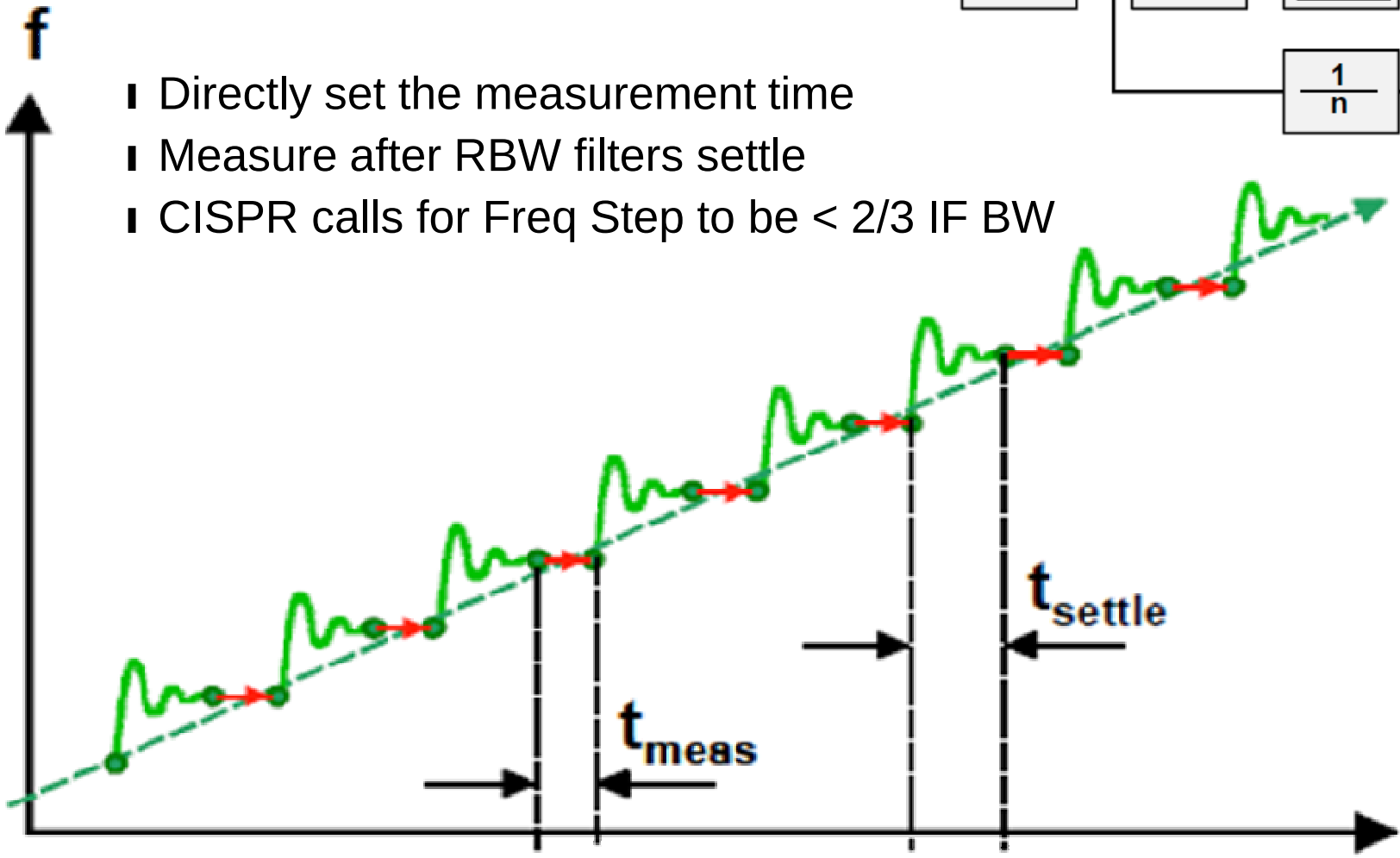
- Input only the total sweep time
- Measurement time at each frequency?



Frequency Stepped

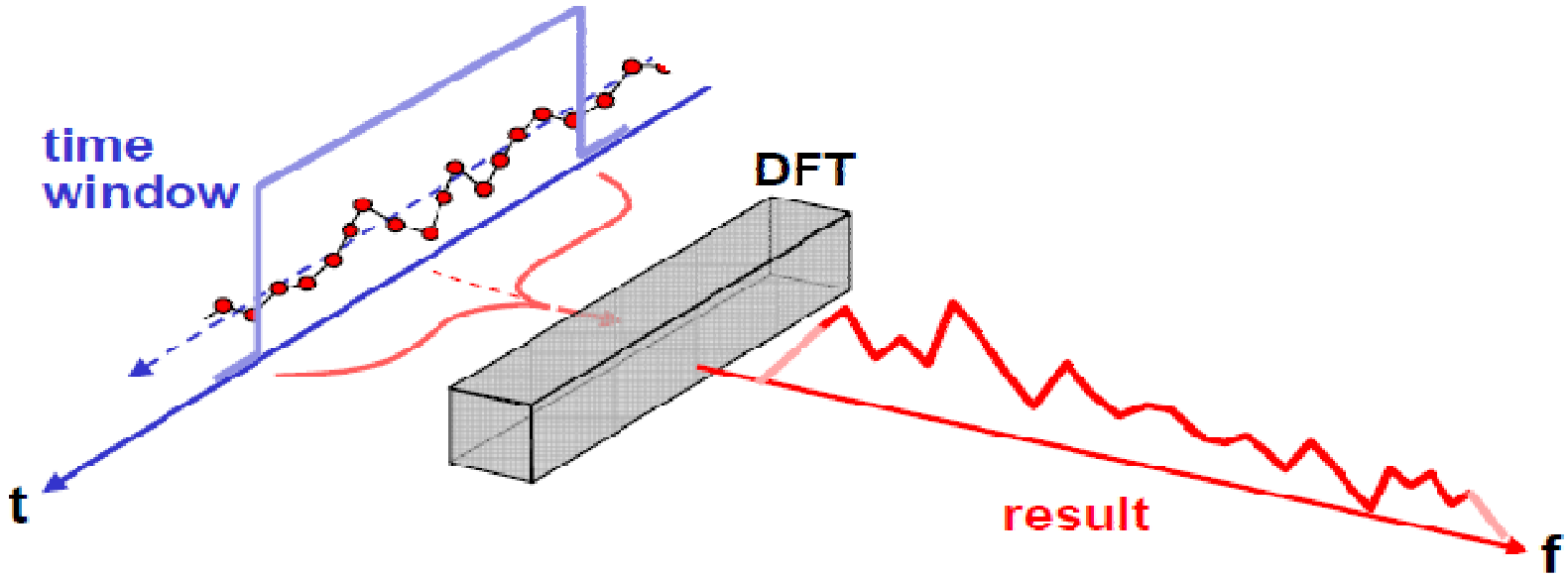


- Directly set the measurement time
- Measure after RBW filters settle
- CISPR calls for Freq Step to be < 2/3 IF BW

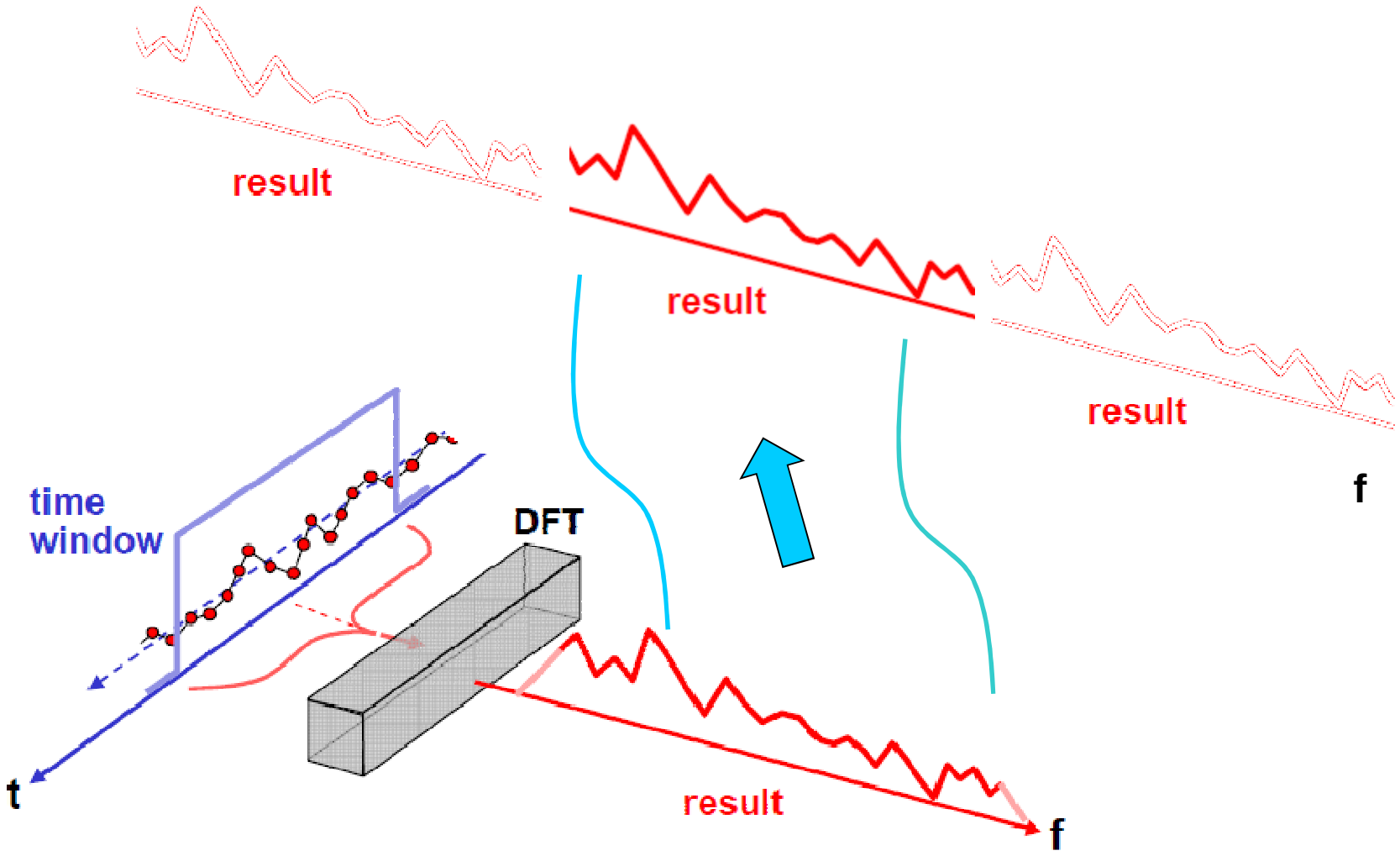


Time Domain Scan

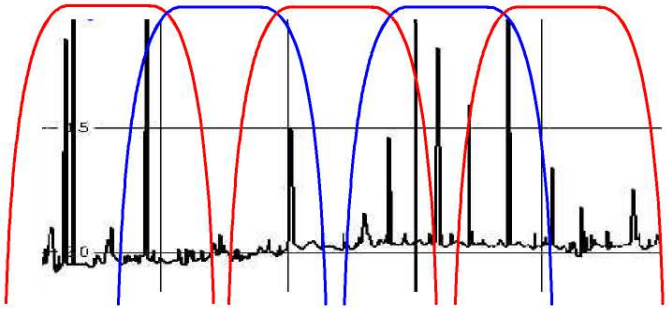
- Use DFT to simultaneously measure many frequencies in parallel
- The Discrete Fourier Transform (DFT) is a numerical mathematical method that calculates the spectrum for a periodic signal
- The Fast Fourier Transform (FFT) is an efficient algorithm to compute the DFT using symmetry and repetition properties
- FFT is much faster than DFT due to reduced number of multiplications



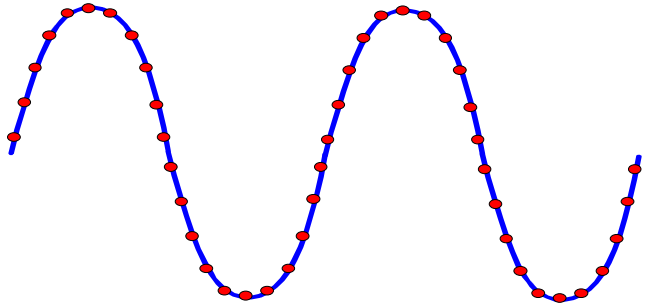
Time Domain Scan



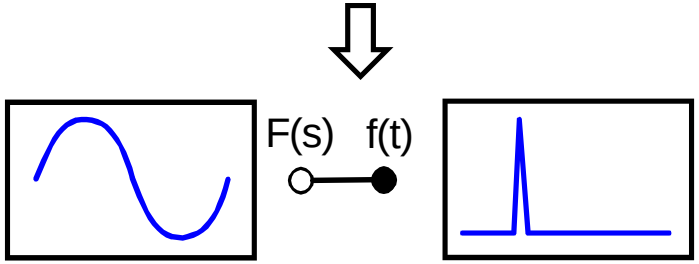
Time Domain Scan



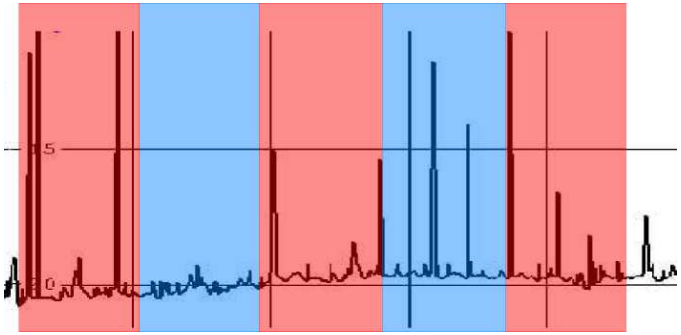
Frequency domain
Split the measured frequency range into consecutive frequency intervals



Time-domain
Sample the frequency interval with high sampling rate



Fast-Fourier transformation
Transform the signals from time domain to frequency domain



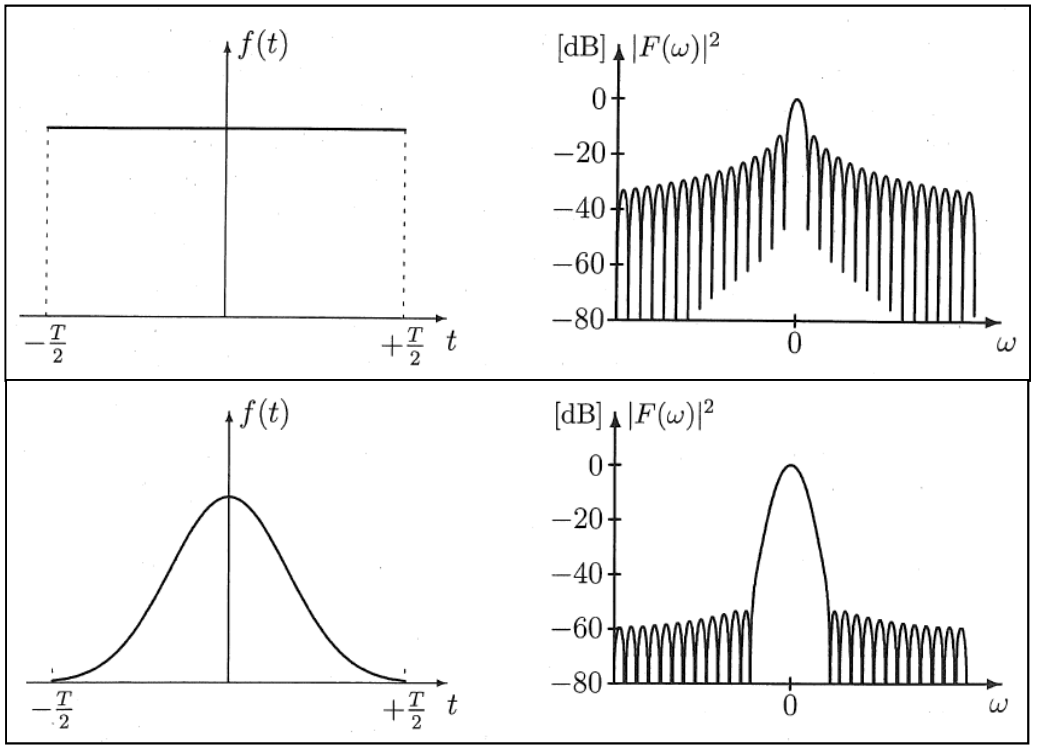
Frequency domain
Merge the spectra of all frequency blocks

Time Domain Parameters

- End goal is frequency resolution and amplitude accuracy to be compliant to standards

- How to accomplish?

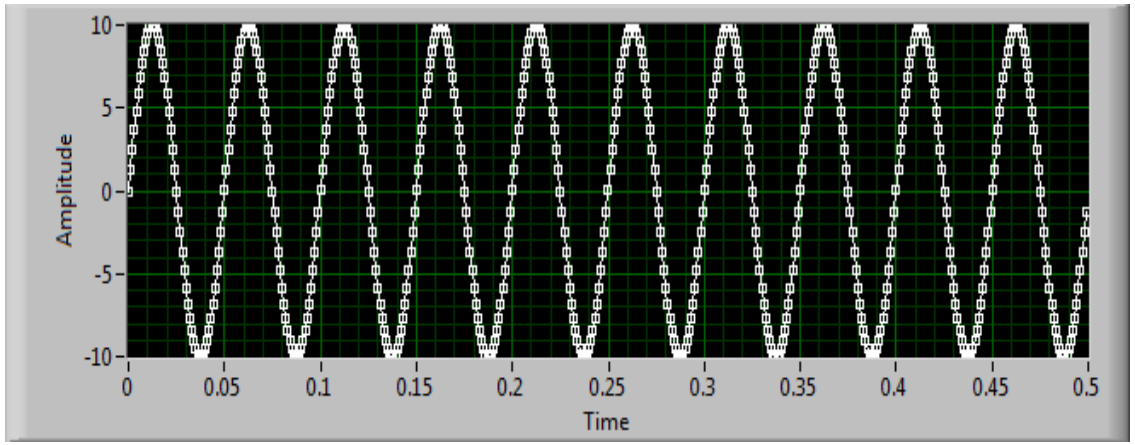
- **Windowing**
  - What is it?
  - Leakage Effect
  - Measurement BW
- **Picket Fence**
- **FFT Time Overlap**



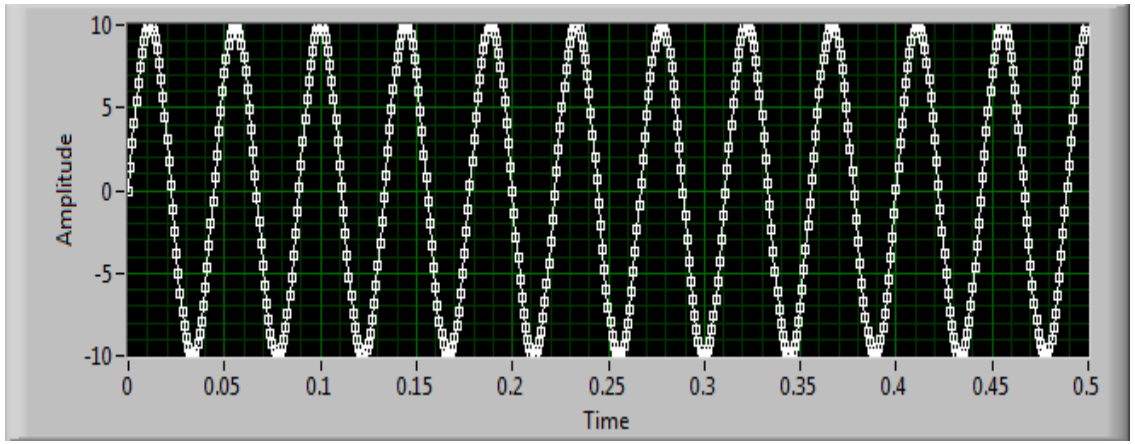
Windowing

- **Fourier Series**
  - Yields discreet spectrum for Periodic Signals
- **Fourier Transform**
  - Yields continuous spectrum for Non-Periodic Signals
  - Requires the signal to be known for all time as the integral is from -∞ to + ∞
  - Bound the integral in the time domain and approximate signal to be periodic

Periodic

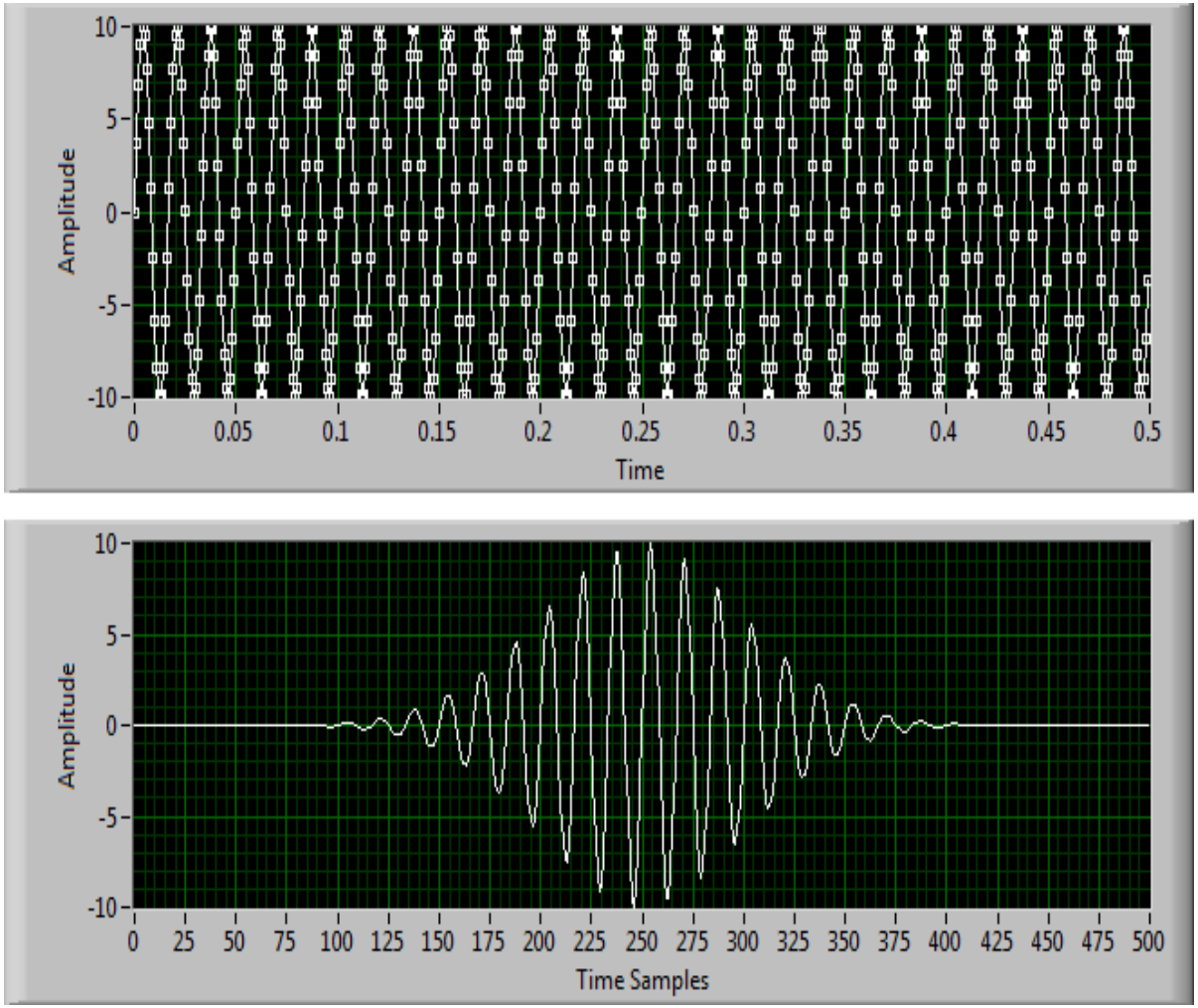


Nonperiodic



Windowing

- Multiplication in the Time Domain by a ‘Window Function’
- If Window is zero at beginning and end of time array of samples, then the multiplied result will be zero at beginning and end
- Now Signal is Periodic and ready for FFT calculation
- But Wait: How is the Measurement Filter Implemented??



Windowing

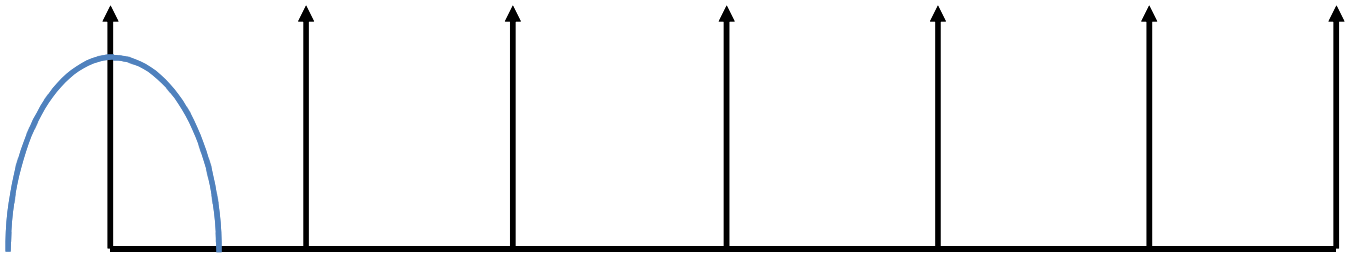
- Convolution in the time domain of two signals corresponds to multiplication in the frequency domain

$$y(t) = x(t)*h(t) \Leftrightarrow Y(\omega) = X(\omega)H(\omega)$$

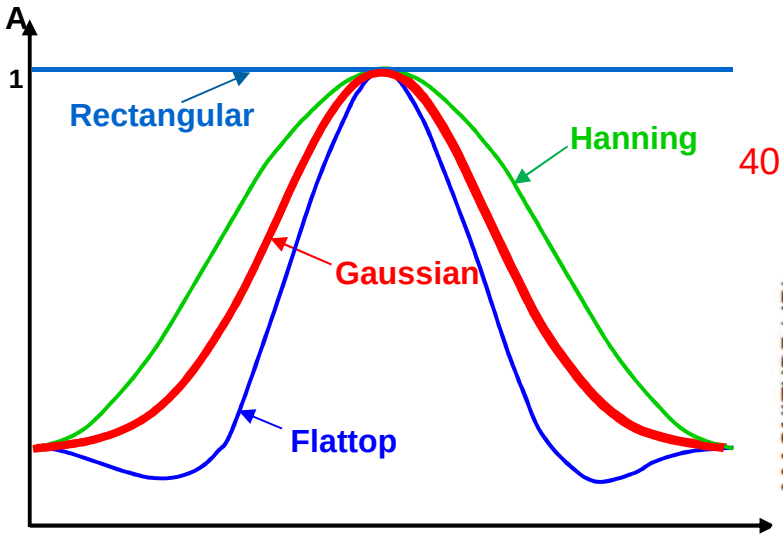
- The inverse is true

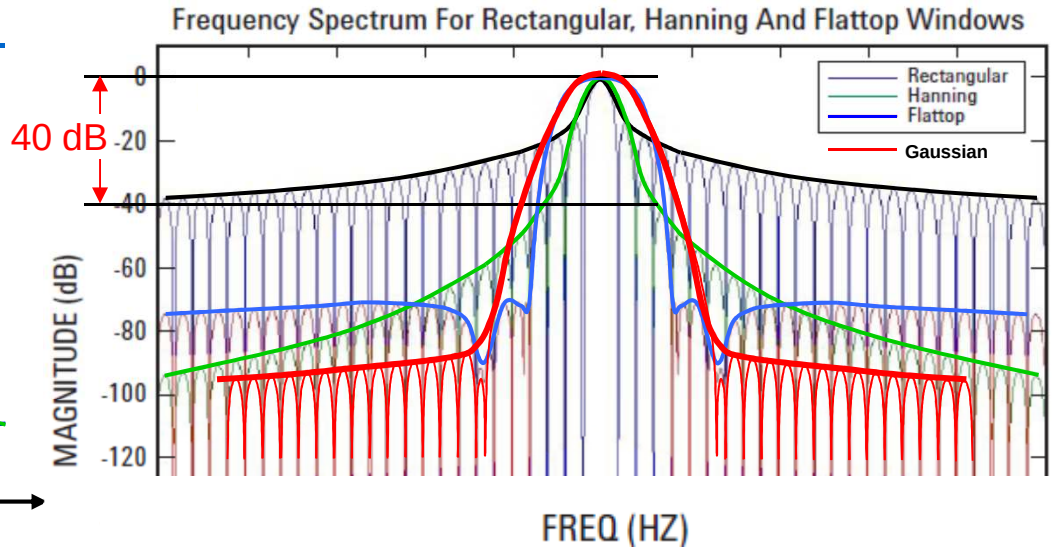
- Multiplication in the time domain corresponds to convolution in the Frequency Domain

$$y(t) = x(t)h(t) \Leftrightarrow Y(\omega) = X(\omega)*H(\omega)$$

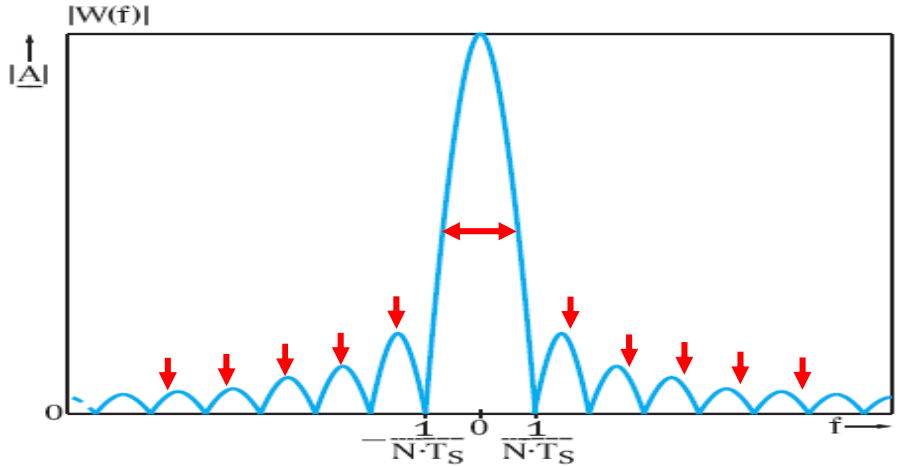


Windowing – Leakage Effect

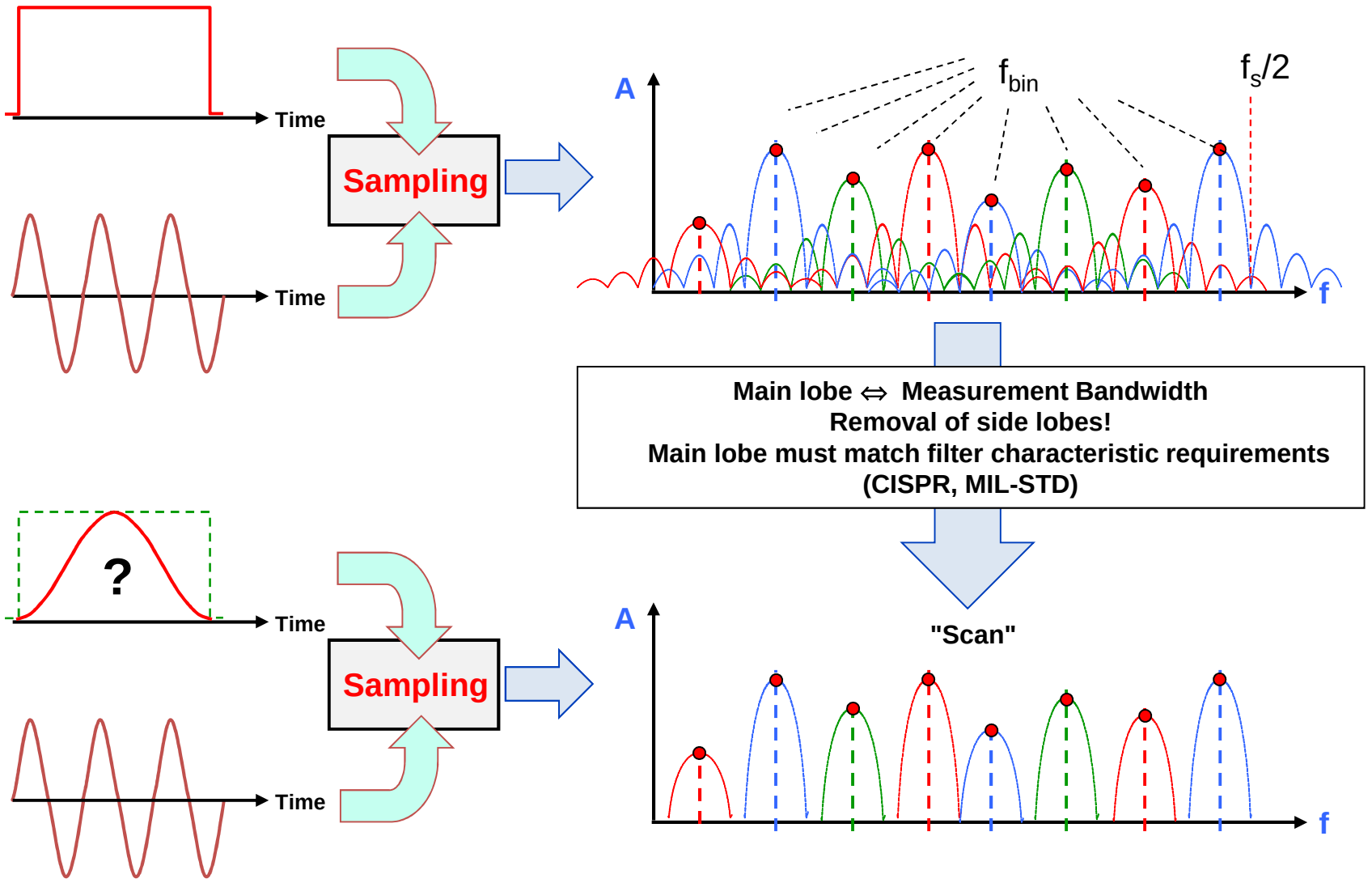




- The width of the main lobe and the amplitude of the side lobes depend on the type of the window function
- CISPR 16 requires a suppression of the additional spectral components (side lobes) of at least 40 dB

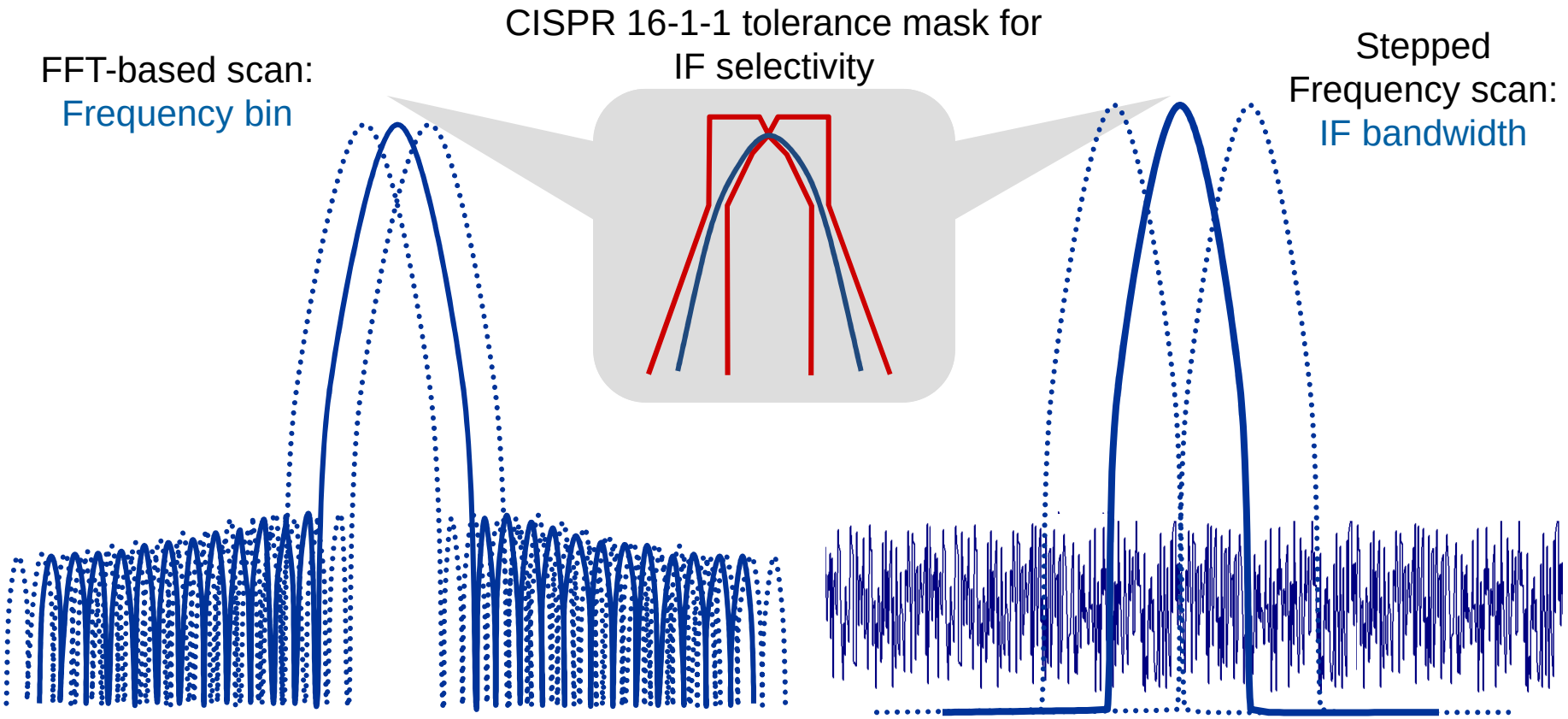


Windowing - Leakage Effect

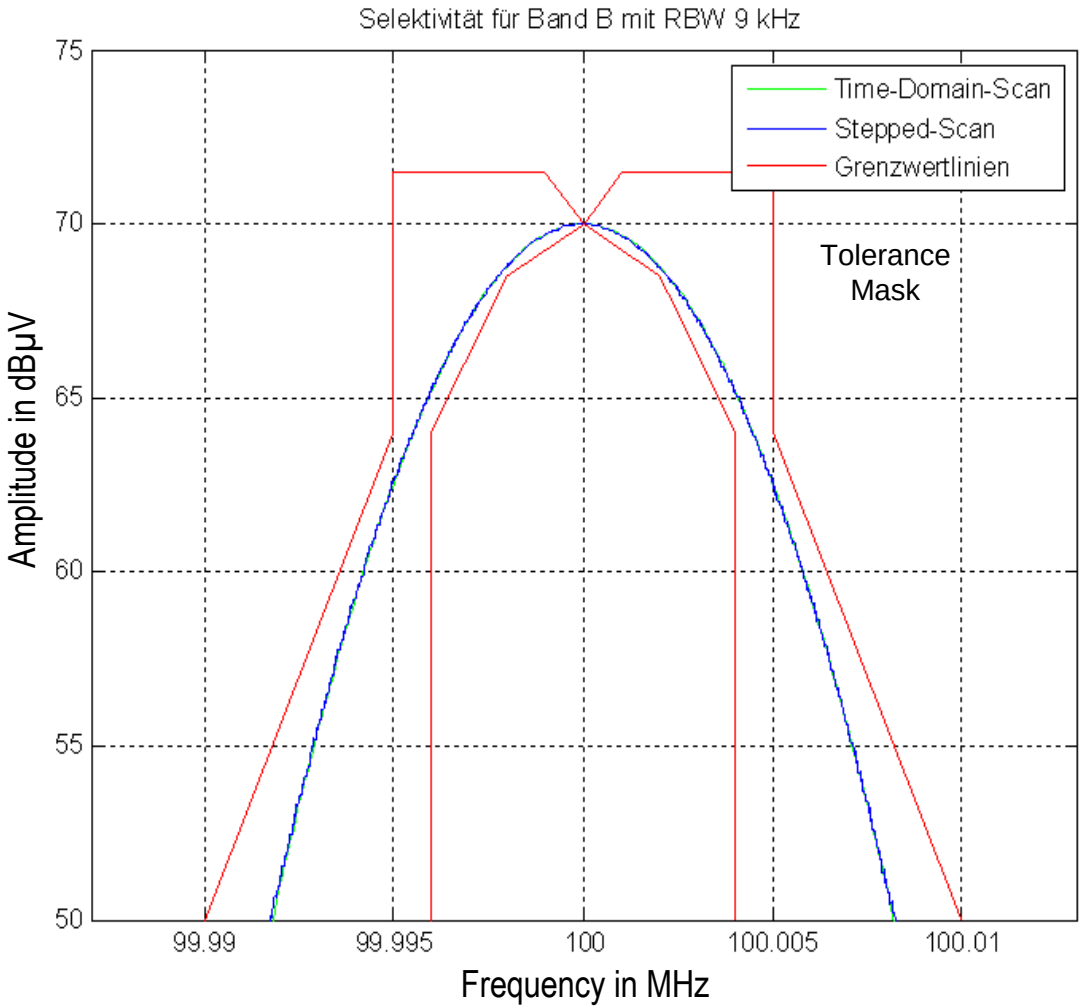


Windowing – Measurement BW

Gaussian Window Type



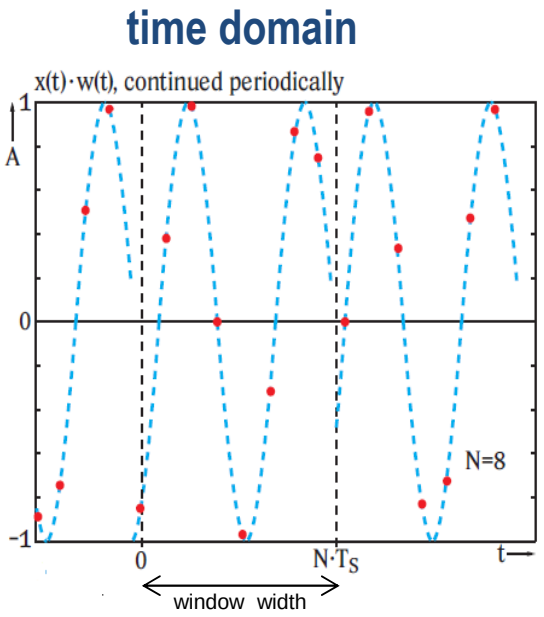
Windowing - Measurment BW

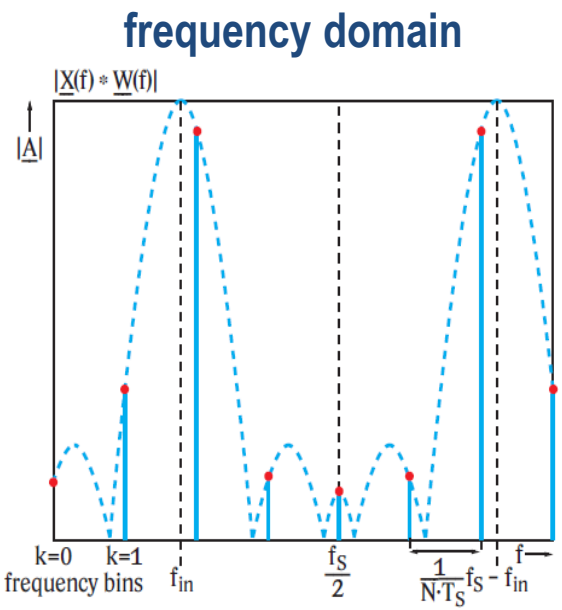


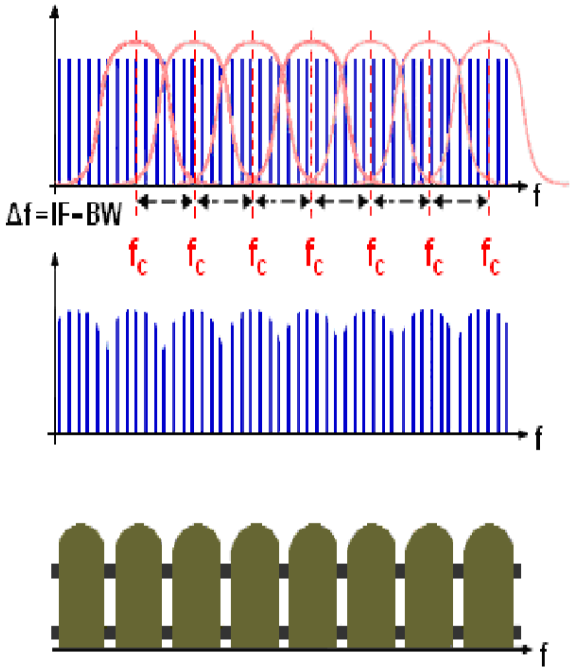
- Selectivity for CISPR Band B
- Measurement BW 9 kHz

Picket Fence Effect

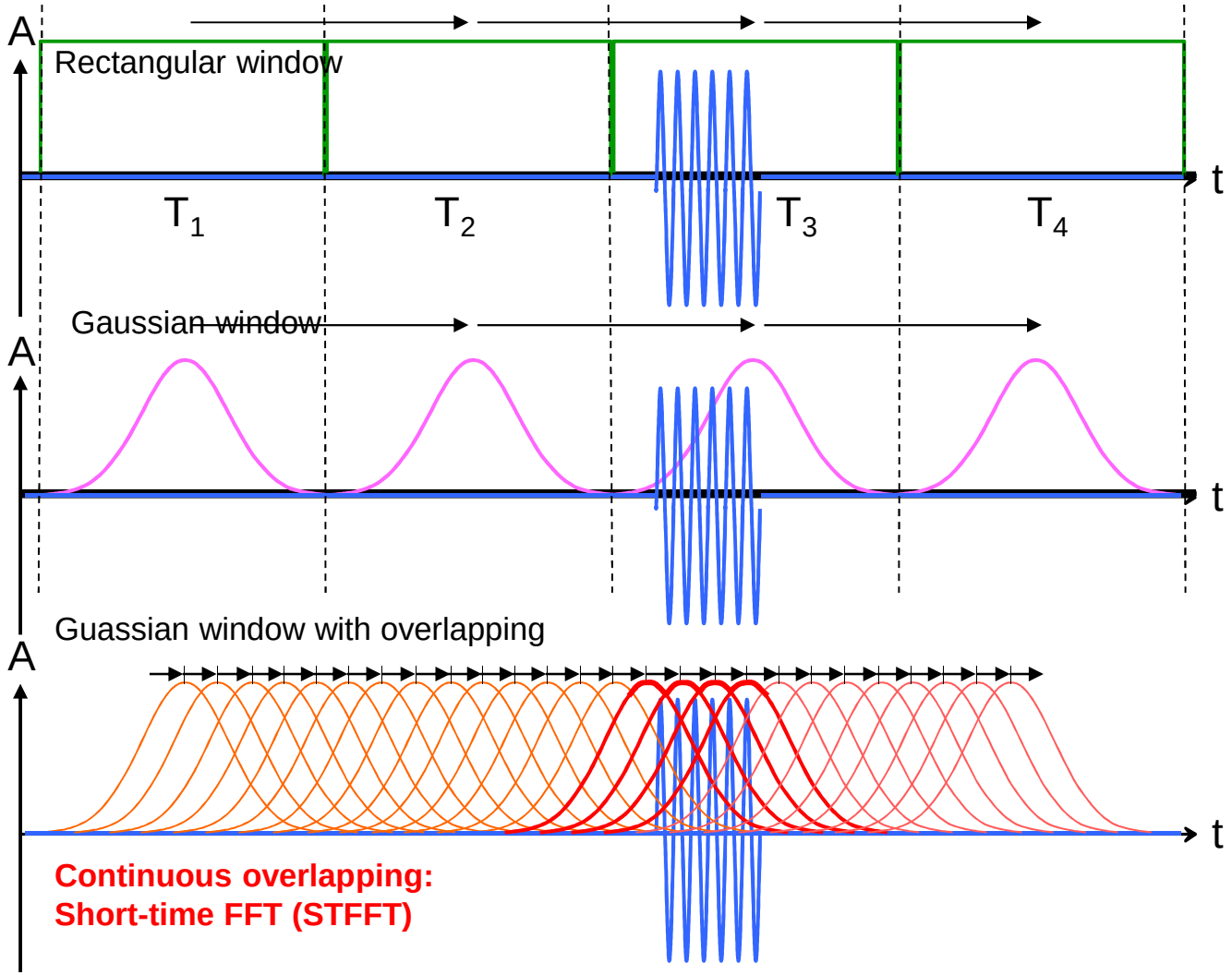
- The FFT calculates a discrete line spectrum at the frequency bins
- If the sampled sine wave signal is at a frequency that doesn't align with a calculated frequency point an amplitude error appears
- The amplitude error is known as "picket fence effect"







FFT Time Overlap



FFT Time Overlap

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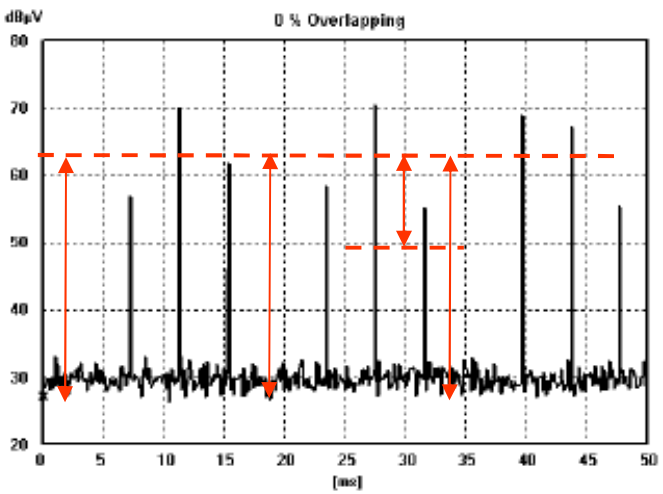
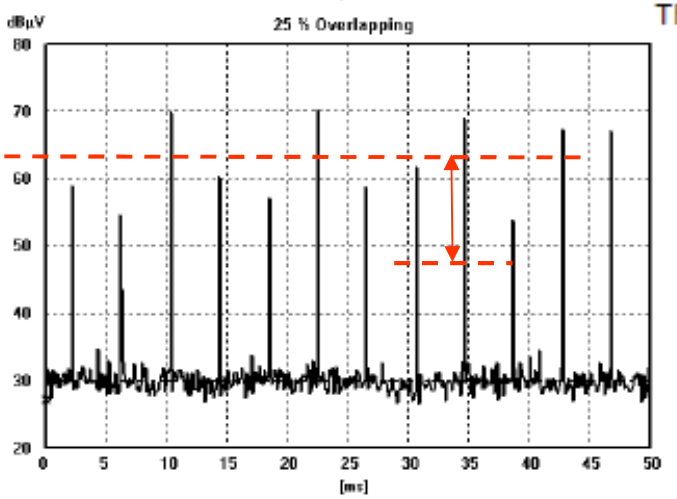
0%



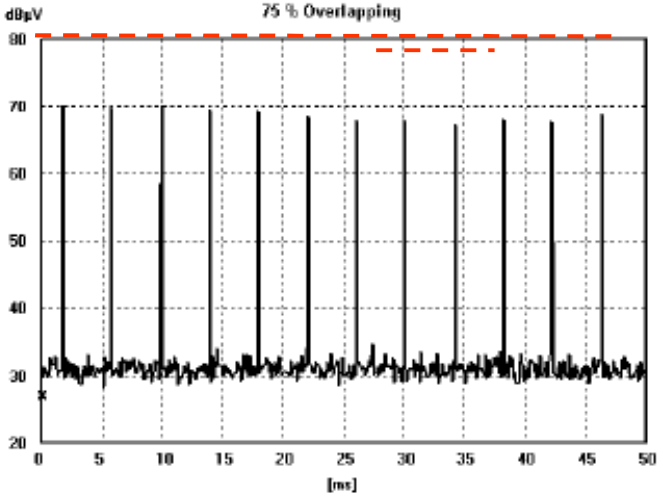
25%



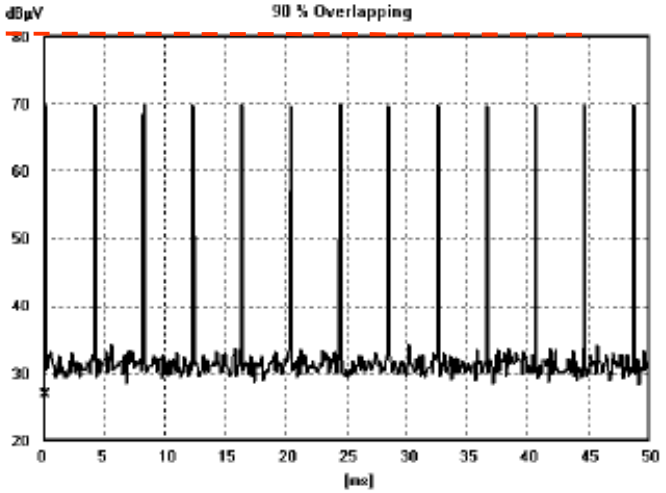
Reference:

TR CISPR 16-3 © IEC:2010(E)

75%

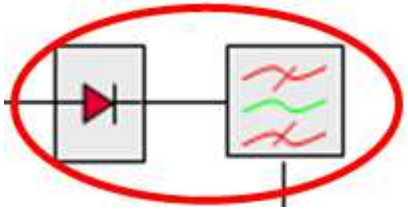


90%



Detector Weighting

Freq Swept / Stepped



RMS detector (power average)

$$V_{rms} = \sqrt{\frac{1}{N}\sum_{i=1}^{N} s_i^2}$$

- Perform a power average of the results by squaring the voltage readings before averaging, then taking square root after.

Ave detector (voltage average)

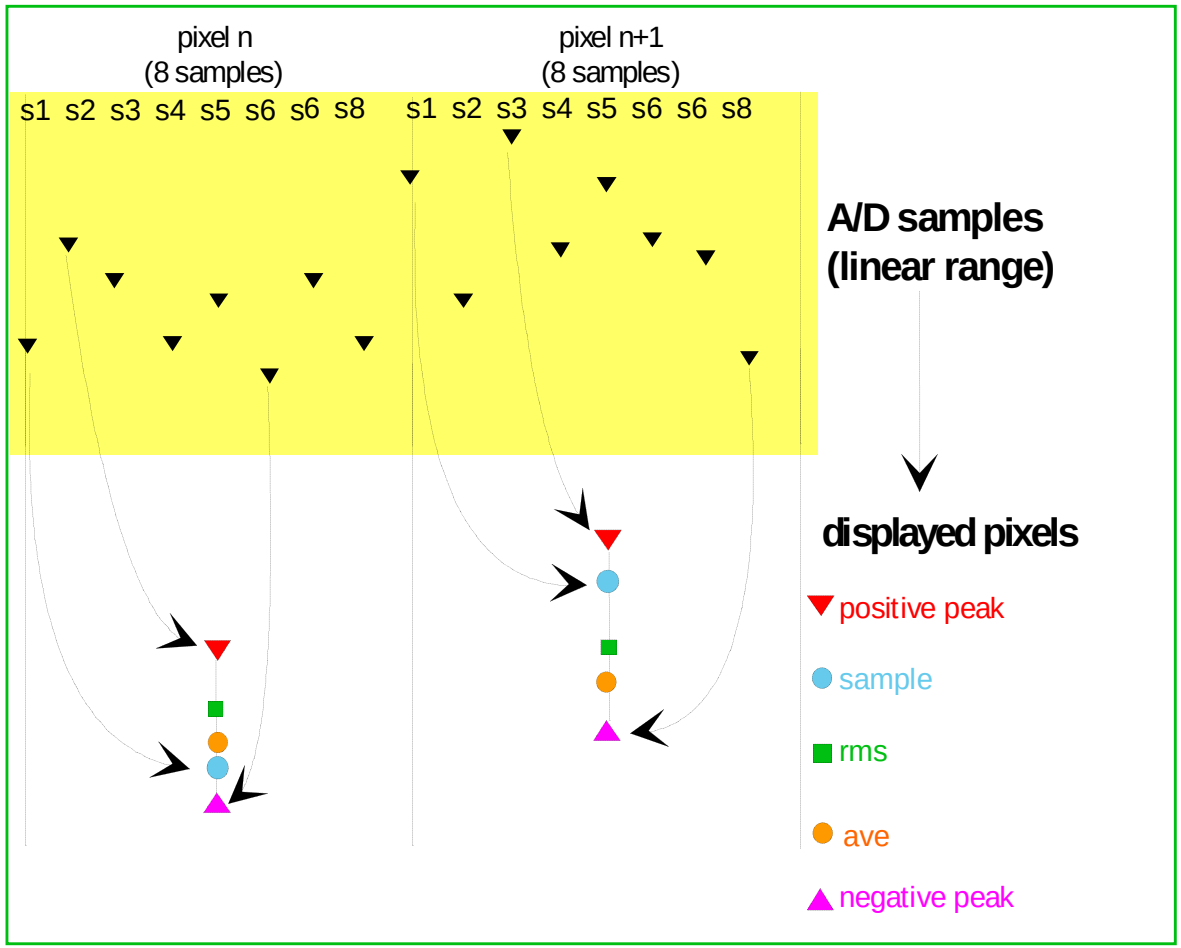
$$V_{ave} = \frac{1}{N}\sum_{i=1}^{N} s_i$$

- Perform a linear average of the results before they are converted to LOG scale for display on the screen

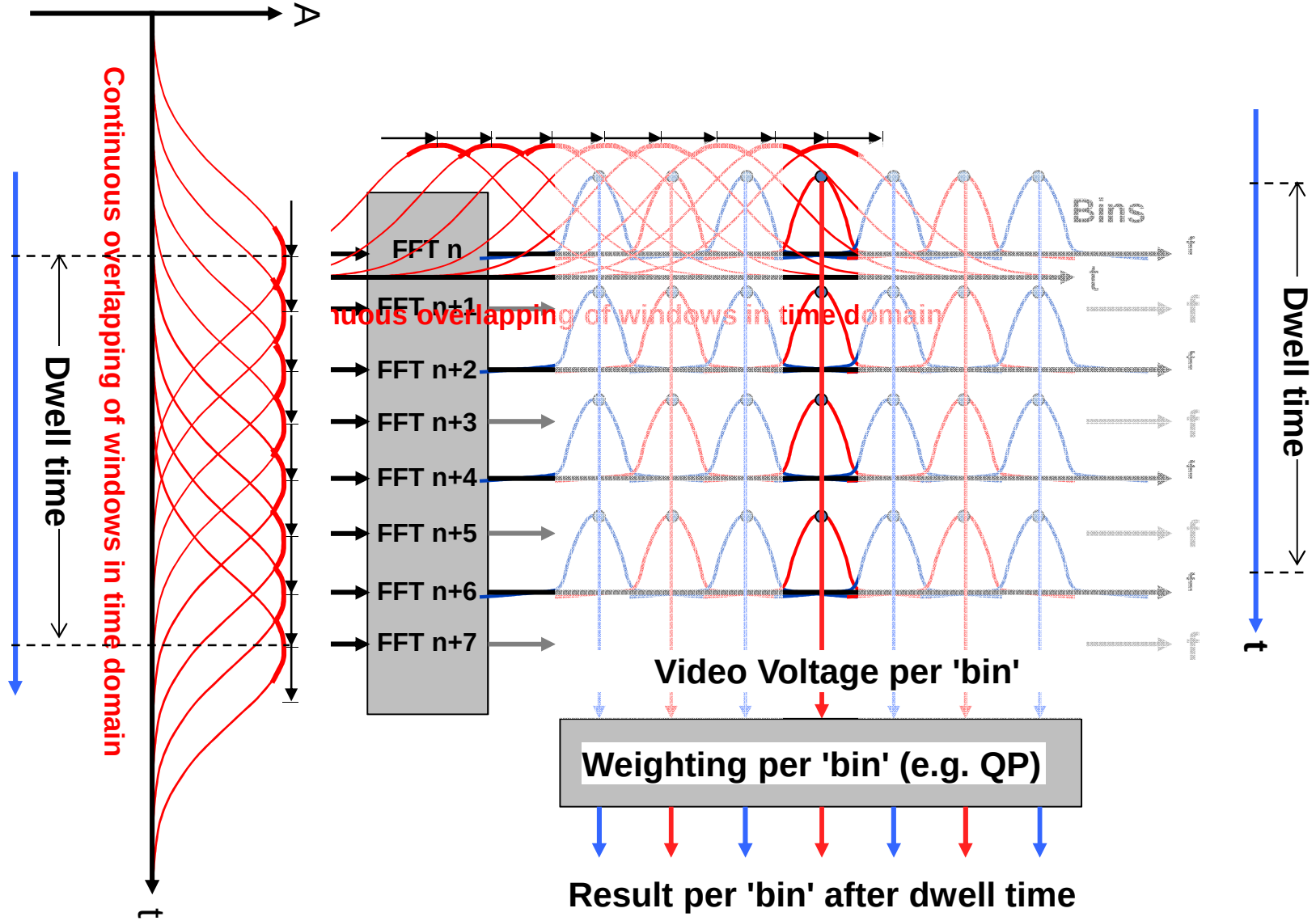
Sample detector

- Take the first sample
- Randomly located between peaks

Samples / pixel is determined by sweep time and sample rate



Detector Weighting



Measurement Time

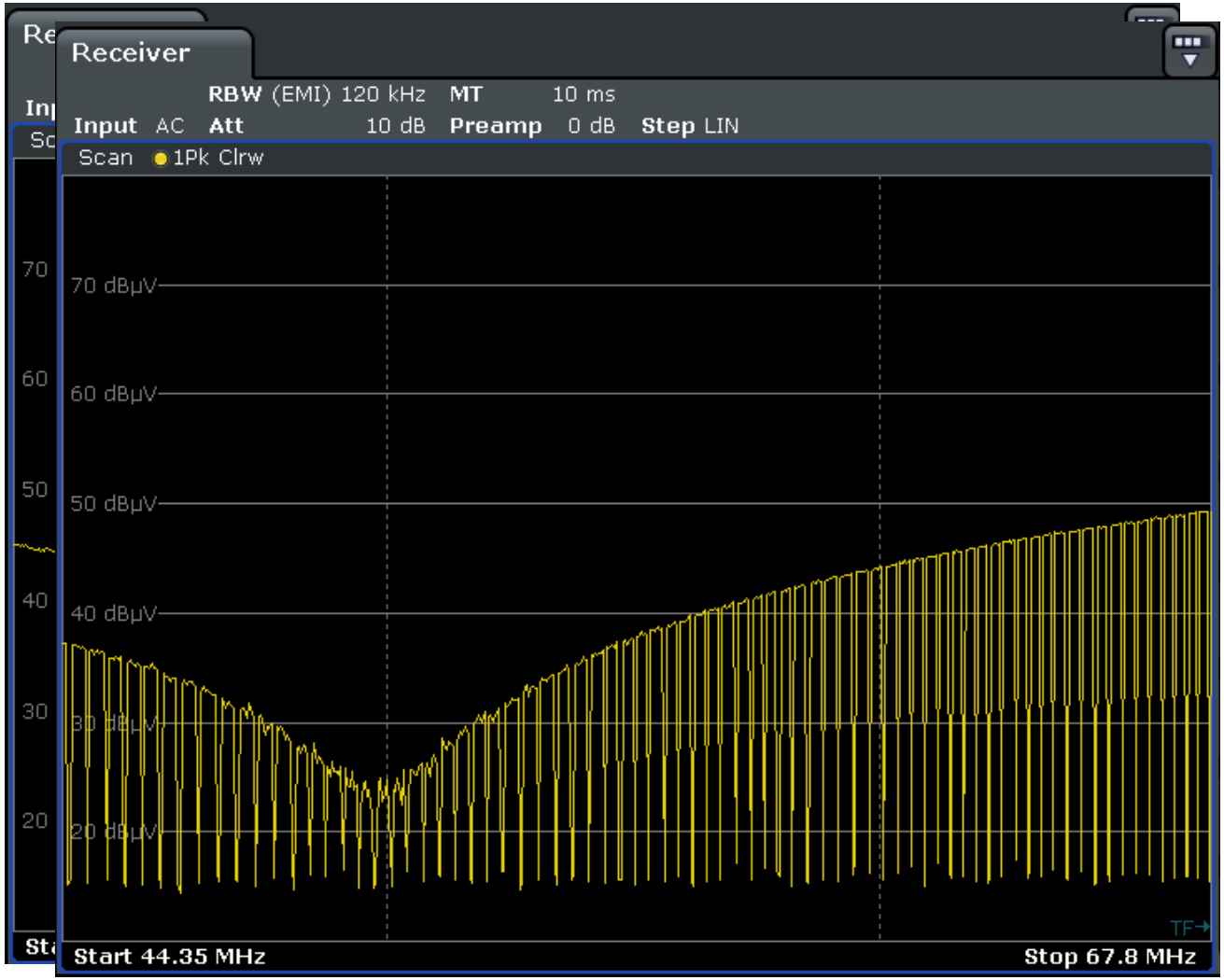
Frequency Stepped

Input Signal

- Pulse Modulated
- 12 ms pulse period

Even 10 ms measurement time yields a closed trace

Zooming in reveals gaps in the trace



Measurement Time

Time Domain

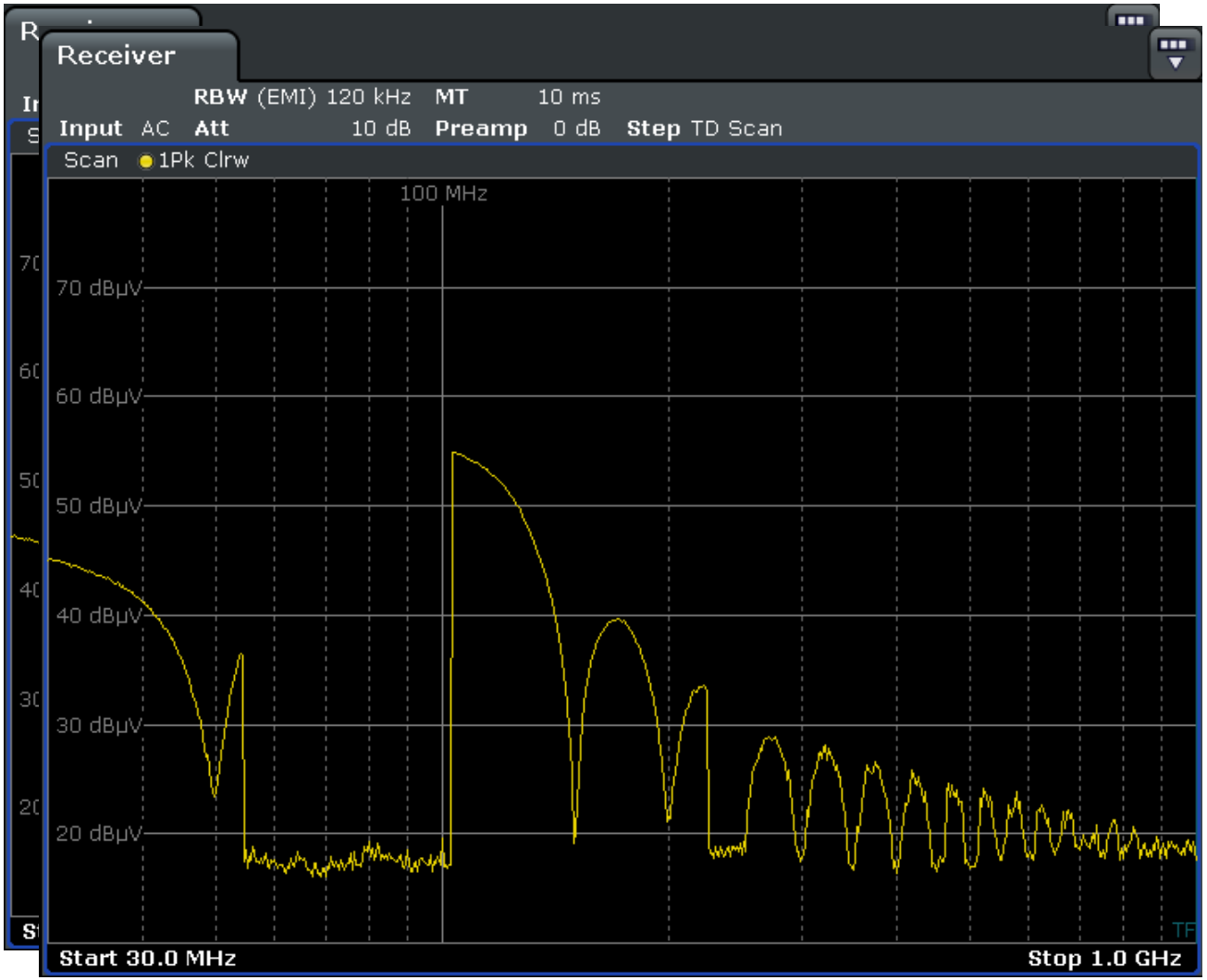
Input Signal

- Pulse Modulated
- 12 ms pulse period

Closed trace with 12 ms measurement time

Gaps in trace with 10 ms measurement time

Important:
Measurement time ≥ signal period



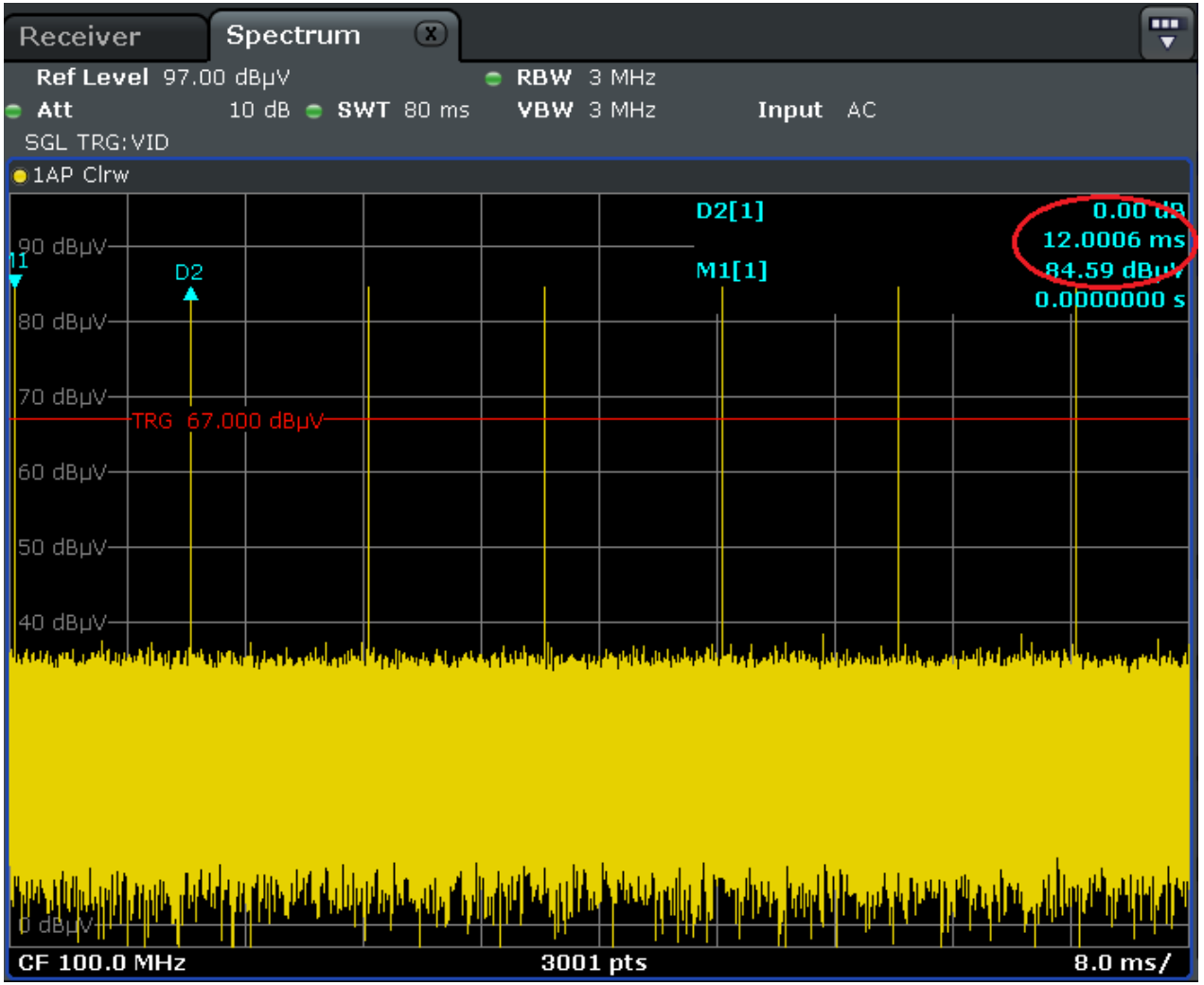
Measurement Time

Spectrum Analyzer Zero Span Mode

Input Signal

- Pulse Modulated
- 12 ms pulse period

Zero span display in spectrum analyzer measures signal period



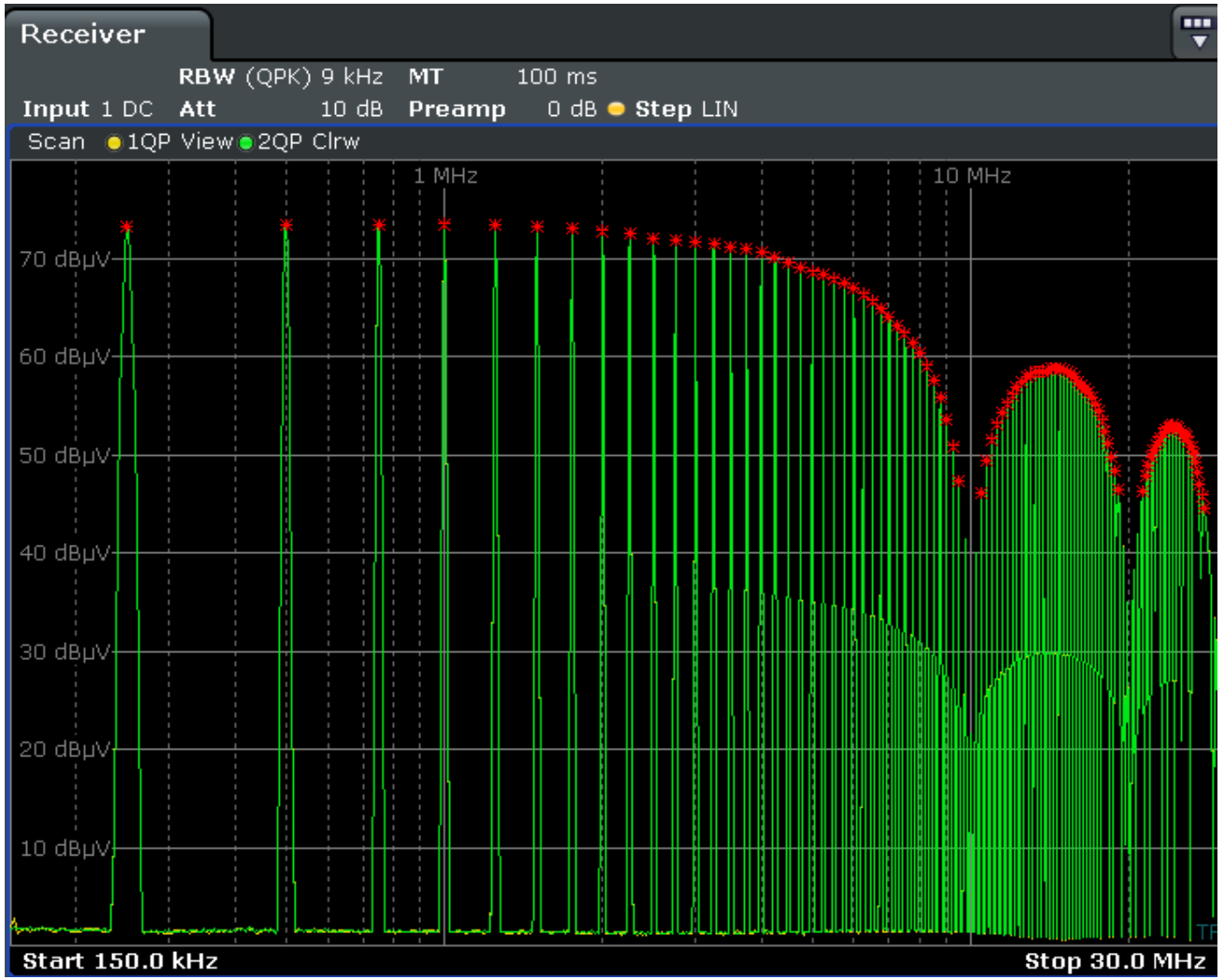
Level Accuracy

Time Domain Scan versus Stepped Scan

Pulse Input

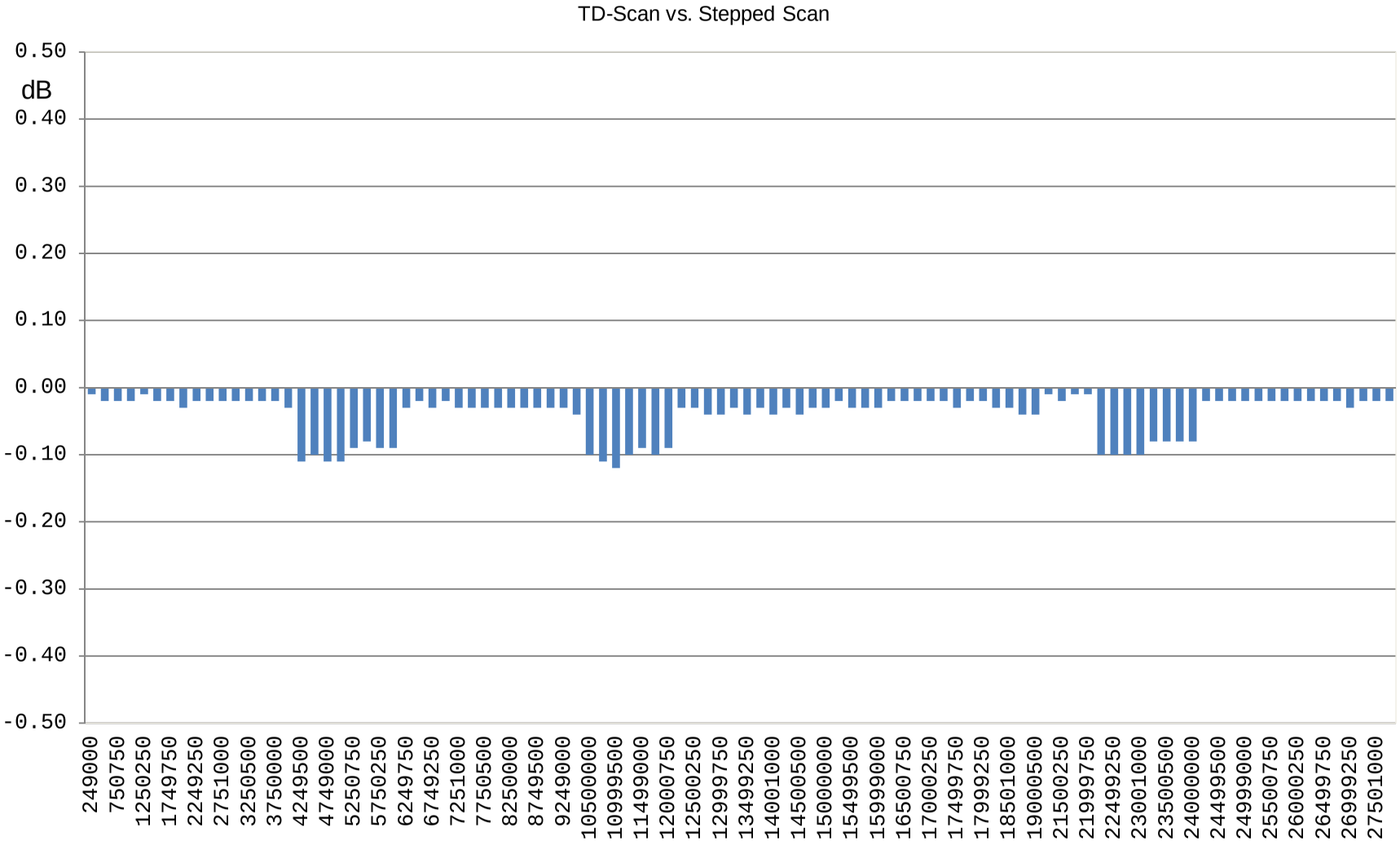
- 4.00 µs Pulse Period
- 0.10 µs Pulse Width
- Detector Quasi Peak

- **Yellow Trace**
  - Time-Domain
- **Green Trace**
  - Freq Stepped



Level Accuracy

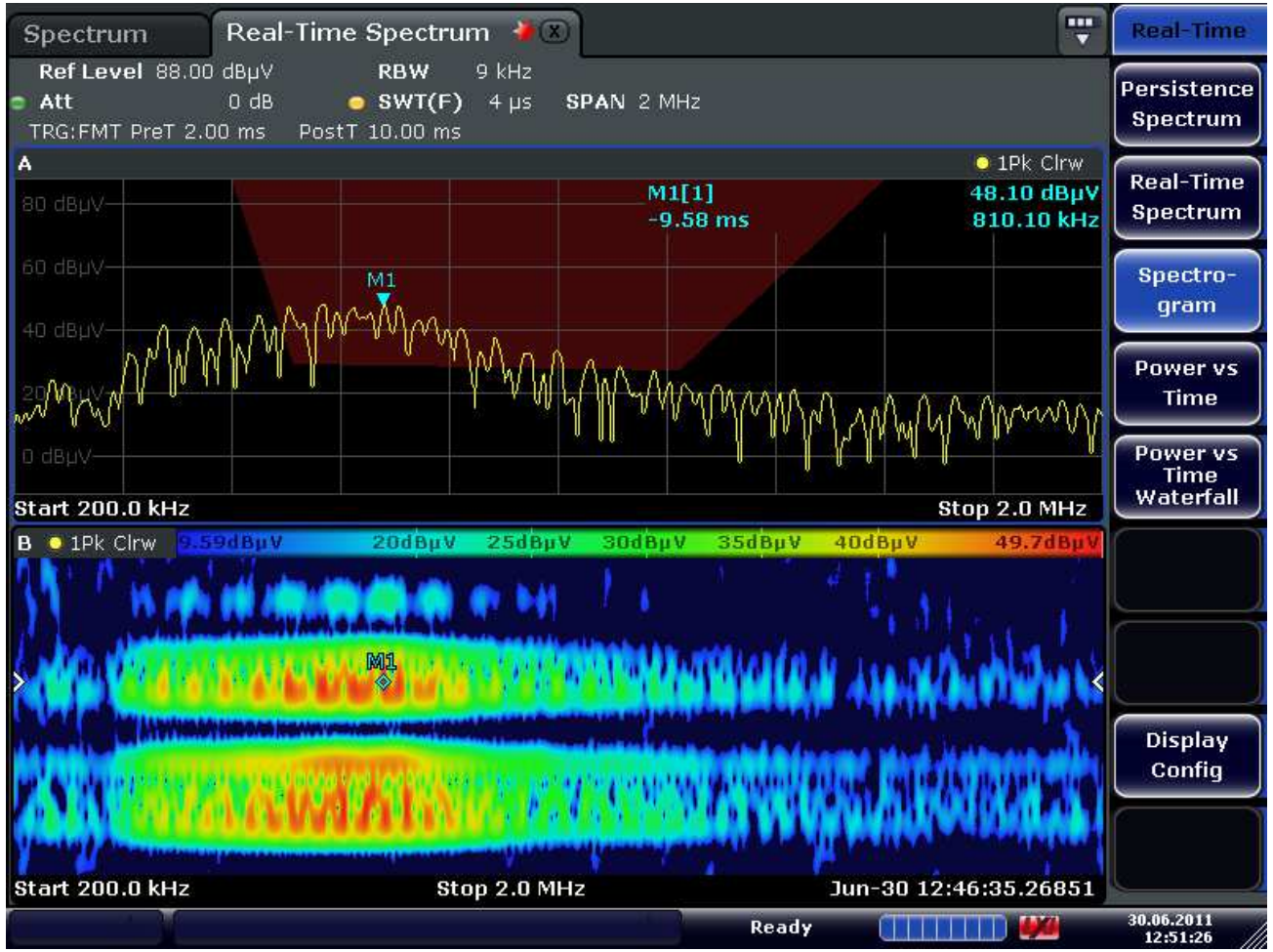
Time Domain Scan versus Stepped Scan



Reduce EMI Test with EMI Diagnosis

Scan Spectrogram

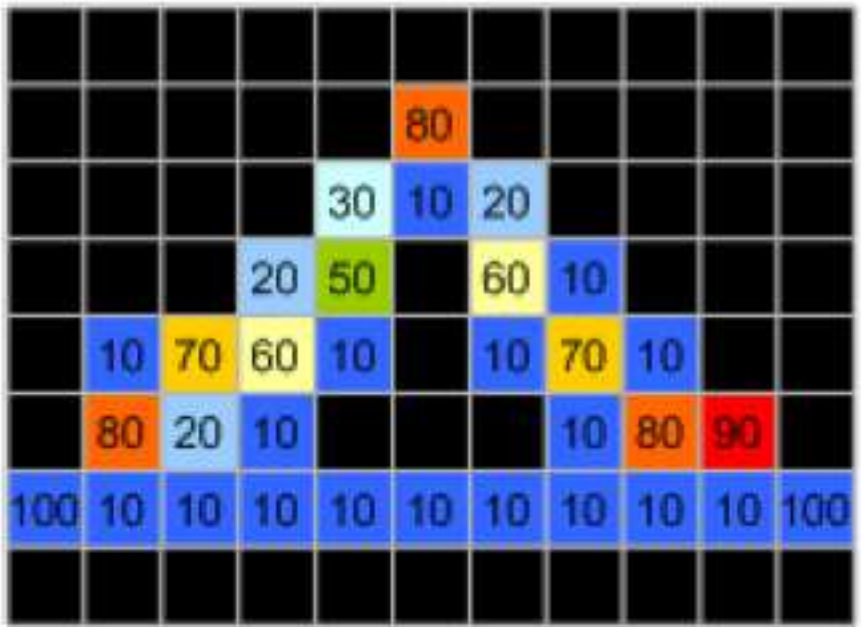
- Gapless Spectrogram of Quasi Peak trace
- EUT is a laptop power supply
- Different load conditions change the spectrum over time

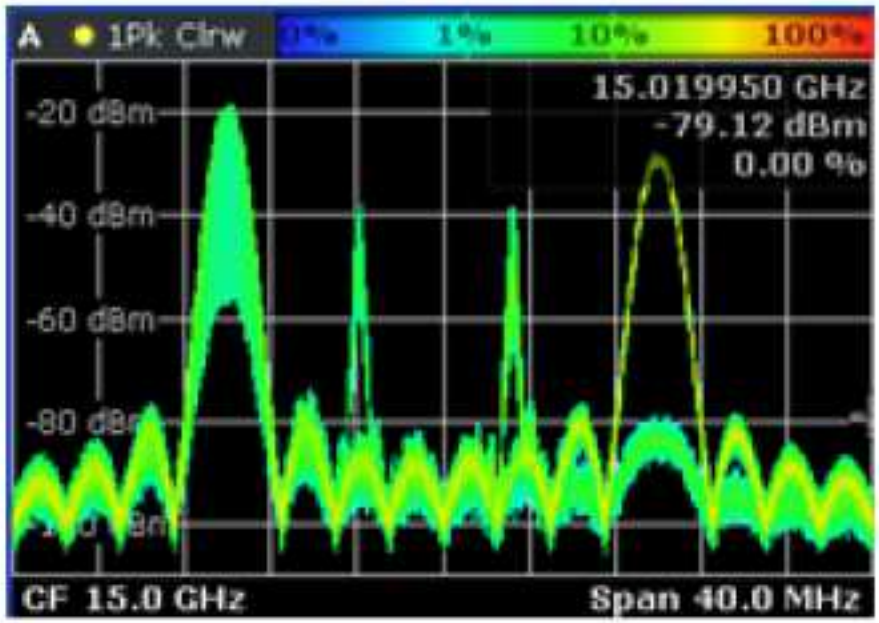


Reduce EMI Test with EMI Diagnosis

Persistence Spectrum

- The trace color shows how often a signal occurs at a specific frequency and level
- ⇒ Spectral histogram
- Virtual table and result display

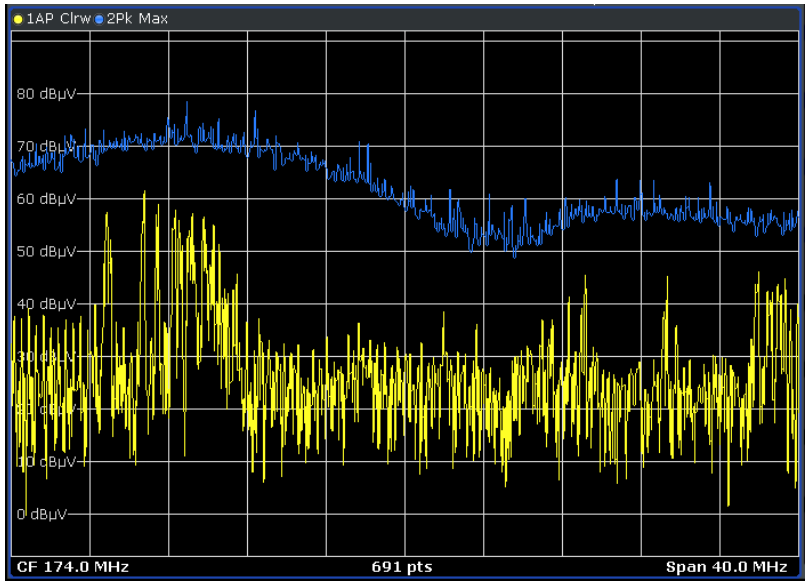




Reduce EMI Test with EMI Diagnosis

Persistence Spectrum

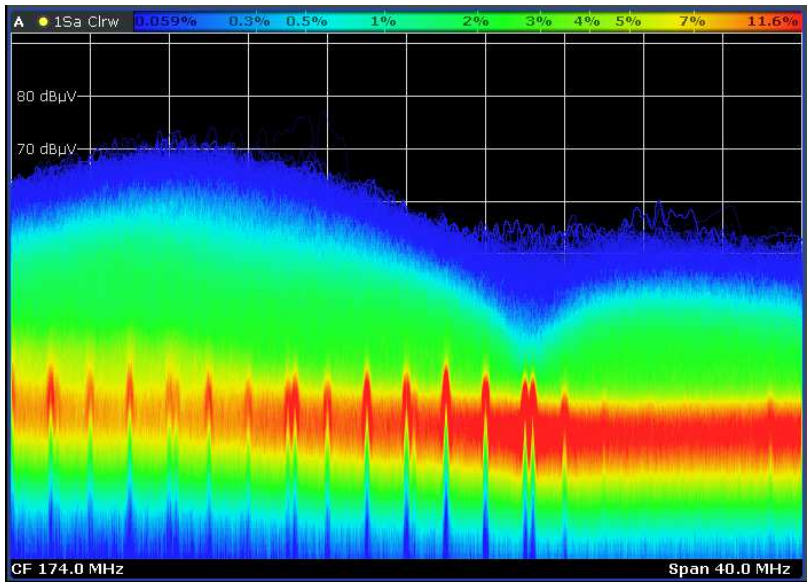
Broadband interferer (windshield wiper motor) with conventional spectrum analysis



Yellow Trace: Clear write display
Blue Trace: Max hold display

The same disturbance signal in persistence spectrum mode:

A second pulsed disturbance signal hidden by the broadband noise and not detectable by conventional spectrum analysis



Summary

- The test time needed for an EMI measurement is significantly reduced with the FFT-based time-domain scan
- The measurement uncertainty of the time-domain scan is equivalent to the uncertainty of the frequency stepped scan
- EMI diagnosis real-time functions offer new and powerful measurement and analysis capabilities that reduce EMI test by seeing everything the 1st time

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www.emclive2014.com