EFFICIENT USAGE OF MEASUREMENT EQUIPMENT FOR EMC ANALYSIS

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ROHDE&SCHWARZ

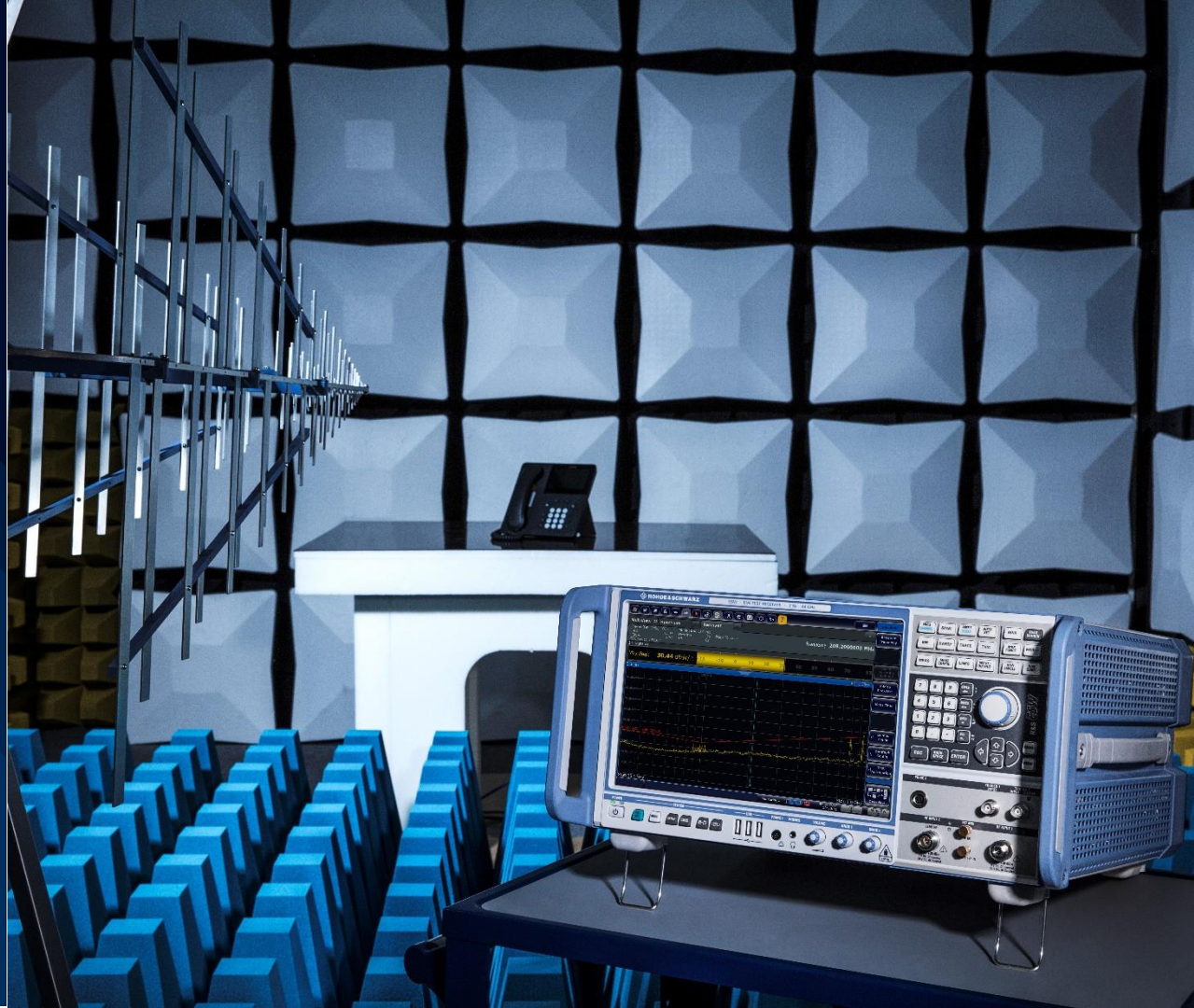
Make ideas real

AGENDA

- EMI Receivers vs. Spectrum Analyzers
  - Full vs. Pre-compliance
  - Preselection
  - RBW Filter
  - Detectors
  - Stepped/sweeped vs time-domain scan
- Oscilloscope
  - Comparison of measurement results

EMI RECEIVER VS. SPECTRUM ANALYZER

- Block diagram
- Preselector
- RBW
- Detector



DIFFERENCES BETWEEN ANALYZER AND EMI RECEIVER

EMI Receiver

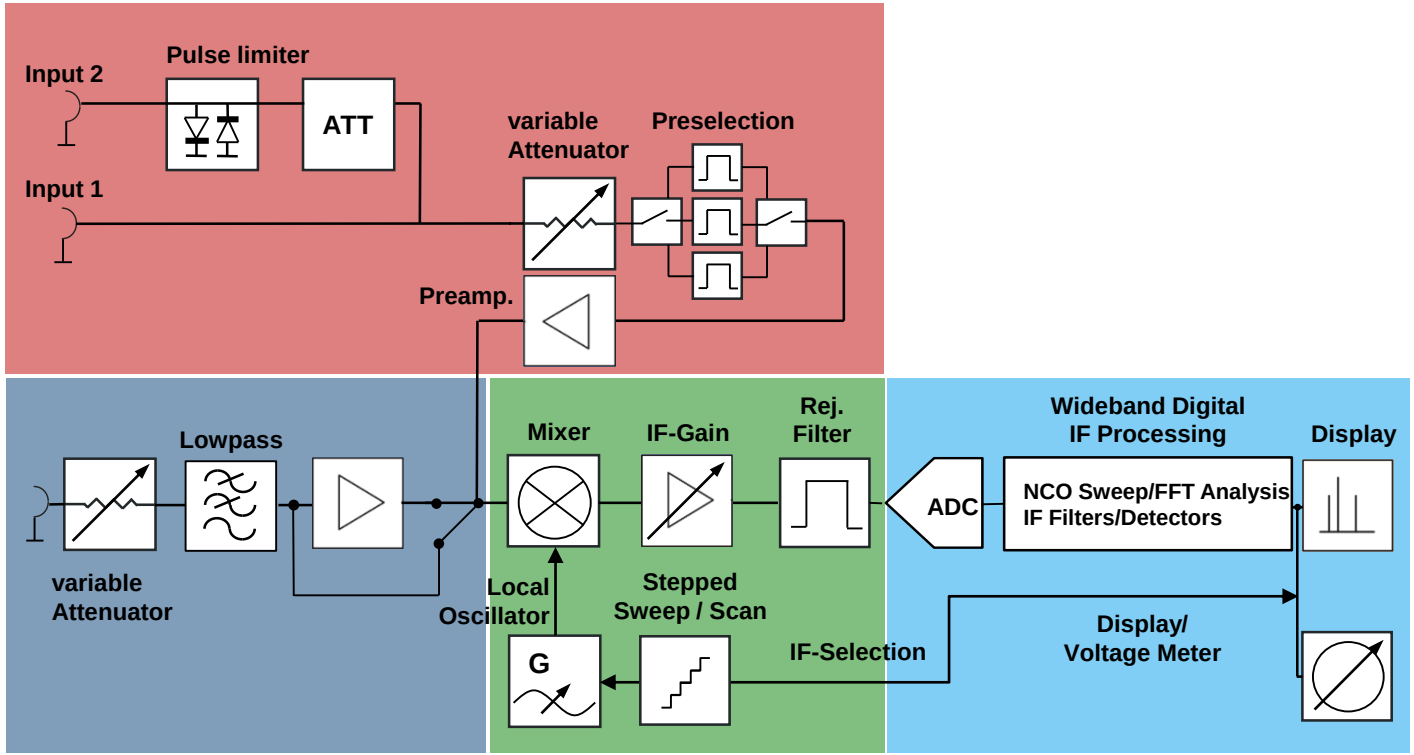
+ Highest Dynamic range
+ Robust against pulses
+ CISPR/EN conform

- Low analysis bandwidth

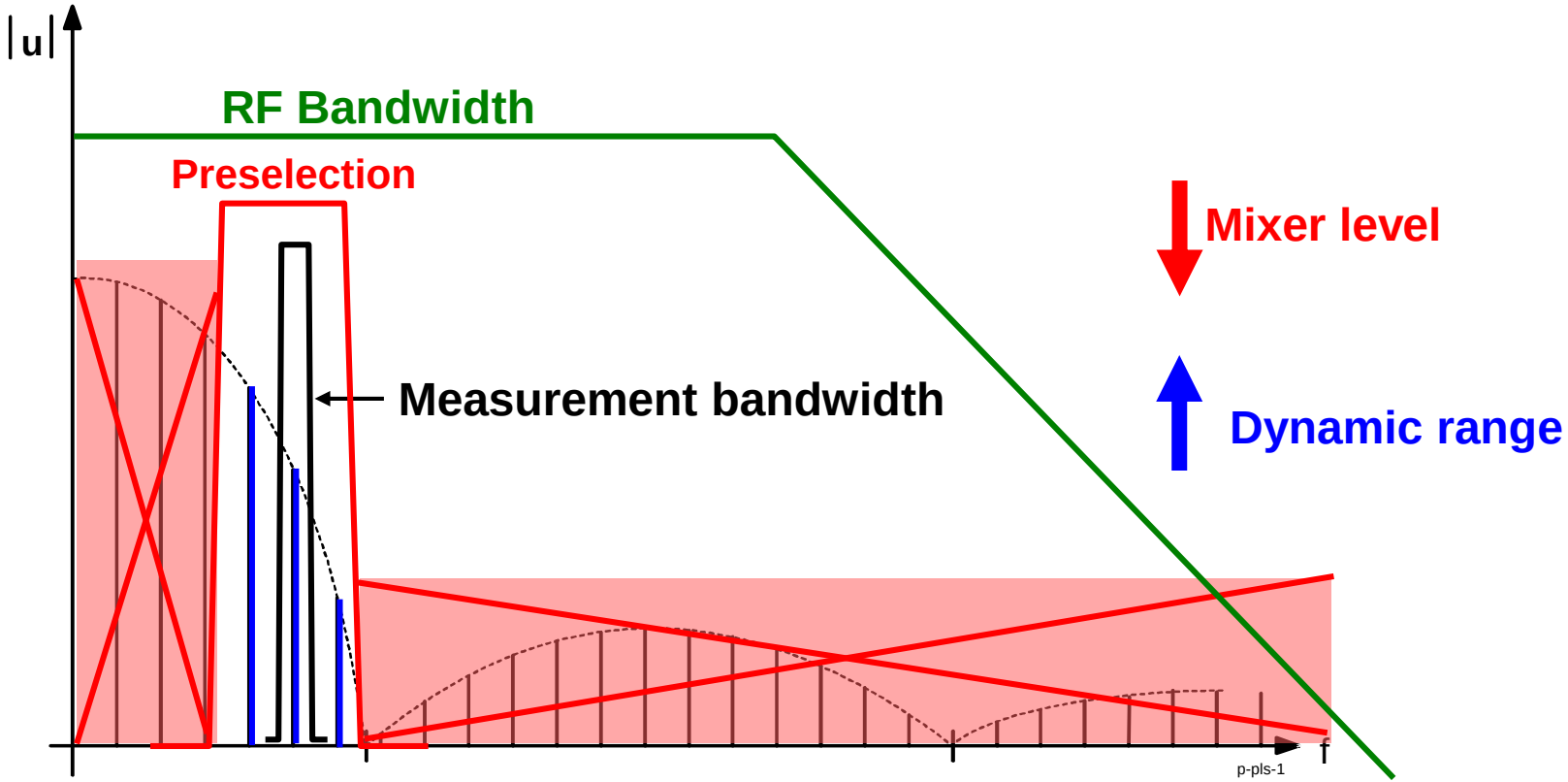
Spectrum analyzer

+ Dynamic range
+ High analysis bandwidth
+ Fast measurement time

– Not conform to CISPR*

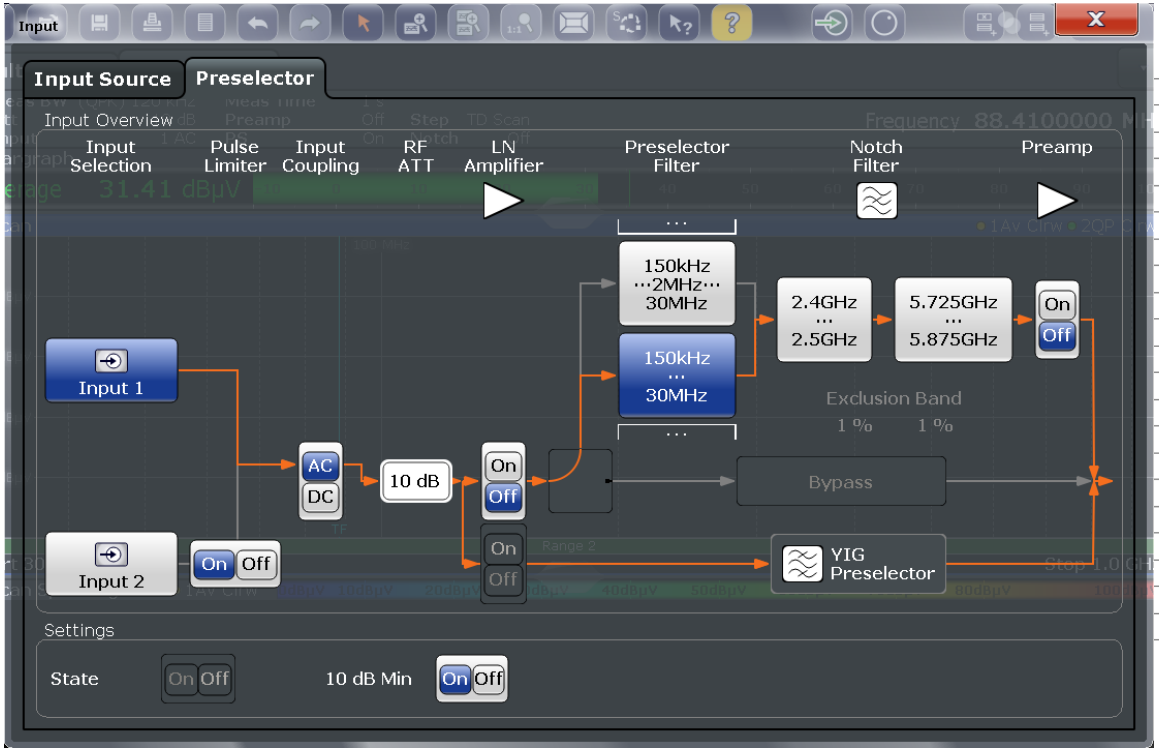


PRESELECTOR – PRINCIPLE



PRESELECTOR – REALIZATION

- **What is a preselector?**
  - Filter bank
  - Filters are switched automatically based on frequency
  - Filter bandwidths are wide enough to not reduce the desired frequency range
- **Purpose of the preselector?**
  - Higher dynamic range



PRESELECTOR – CALCULATION

Dynamic range

Without preselection

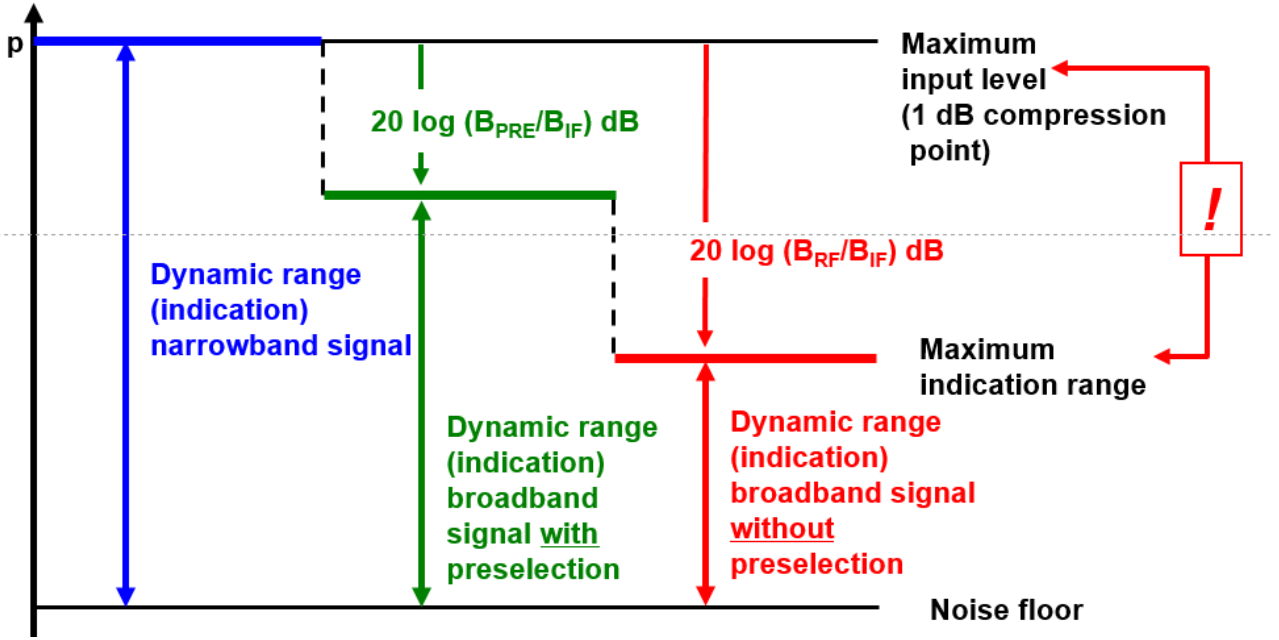
$$L_{max} - 20 \cdot \log\left(\frac{B_{RF}}{B_{IF}}\right)[dB]$$

With preselection

$$L_{max} - 20 \cdot \log\left(\frac{B_{PRE}}{B_{IF}}\right)[dB]$$

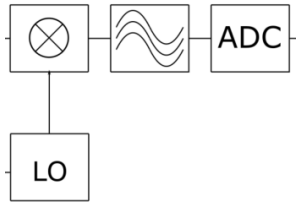
L_{max} : Maximum input level

B_{RF} : Bandwidth of RF input sig



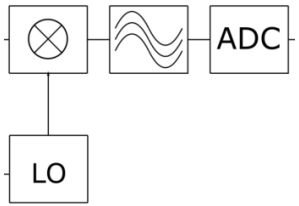
RBW FILTER SHAPE WITHIN THE EMI RECEIVERS AND SPECTRUM ANALYZER

EMI Receiver



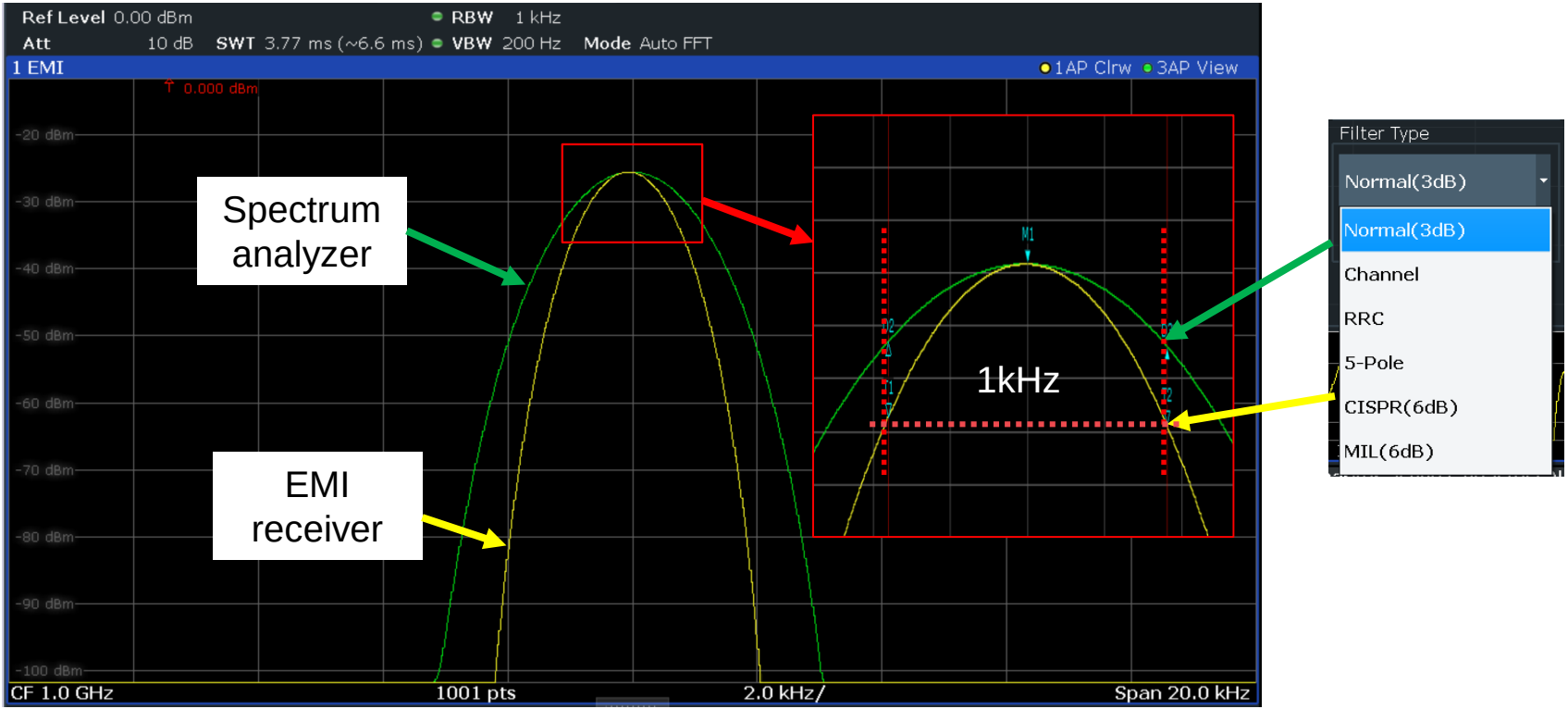
- Gauss filter
- 6 dB definition
- CISPR 16-1-1: 200 Hz, 9 kHz, 120 kHz, 1 MHz
- MIL-STD-461: 10, 100 Hz, 1, 10, 100 KHz, 1 MHz

Spectrum analyzer

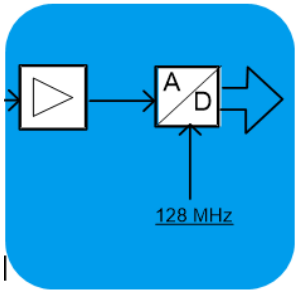


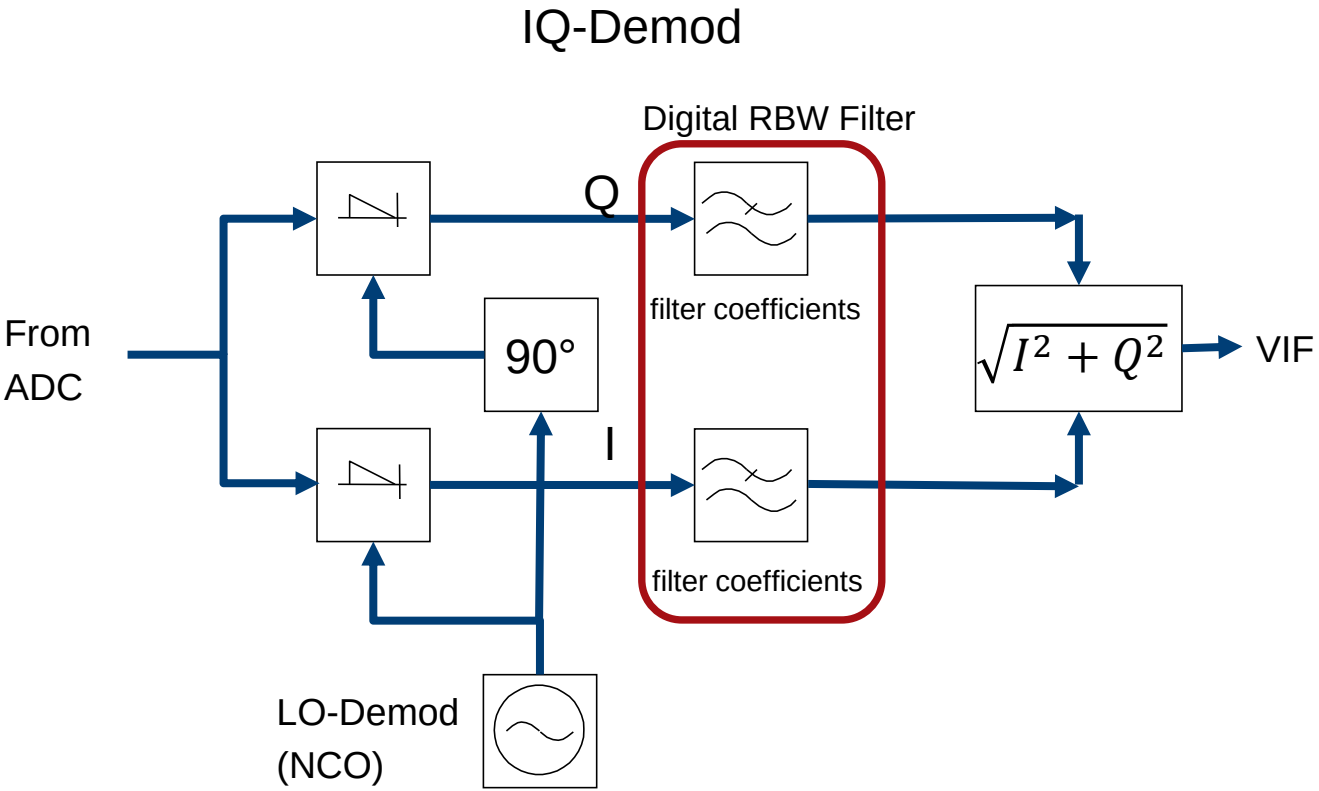
- Support of different filters
- 3 dB definition
- Bandwidths: 1/2/3/5 sequence (example)

FILTER SHAPE EMI RECEIVER / ANALYZER



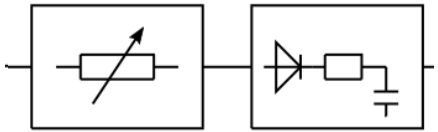
REALIZATION OF RBW FILTER



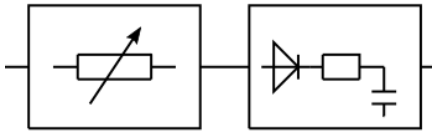


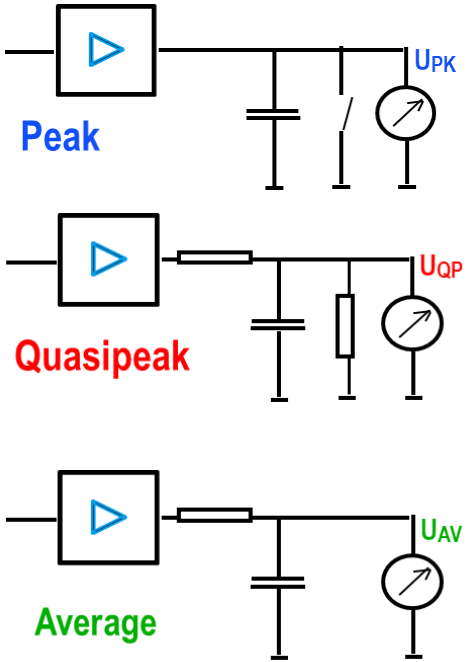
DETECTORS WITHIN EMI RECEIVERS AND SPECTRUM ANALYZER

EMI Receiver



Spectrum analyzer

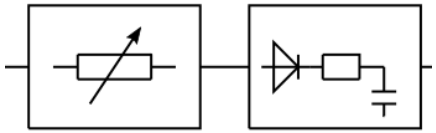




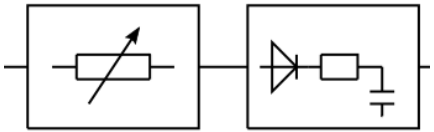
- **Peak detector:**
  Display the max value within its detector time
- **Quasipeak detector:**
  Display the weighted value within its detector time (typical >= 1s time)
- **Average detector:**
  Display the avg value within its detector time

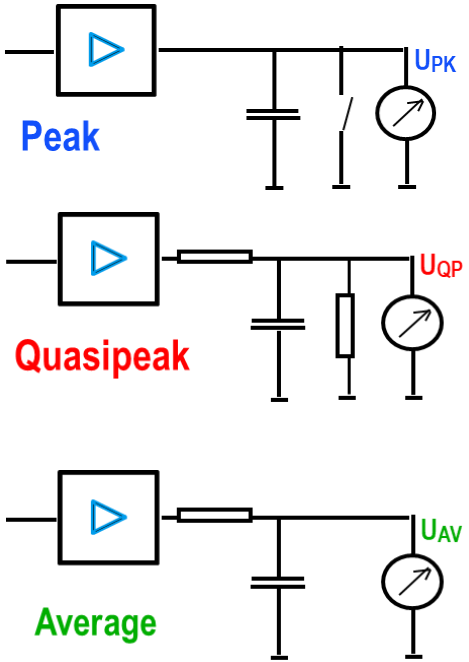
DETECTORS WITHIN EMI RECEIVERS AND SPECTRUM ANALYZER

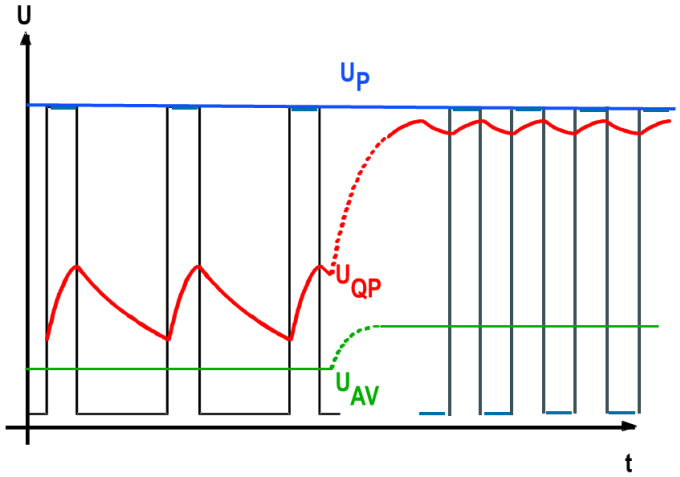
EMI Receiver



Spectrum analyzer

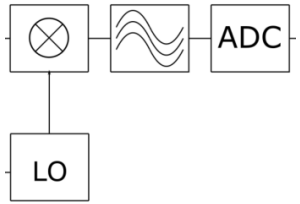


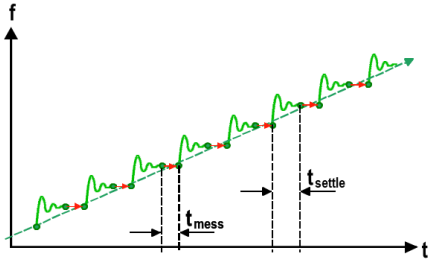




DIFFERENT SWEEP MODES

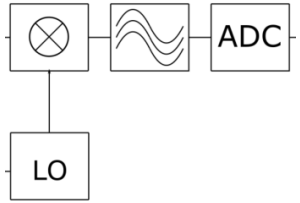
EMI Receiver

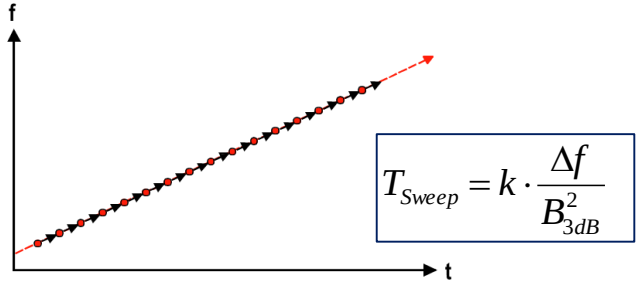




- **Stepped mode:**
  - Available at receiver and spectrum analyzer
  - Stepped through the spectrum in discreet steps
  - Measurement time (tmeas) will be directly set

Spectrum analysator

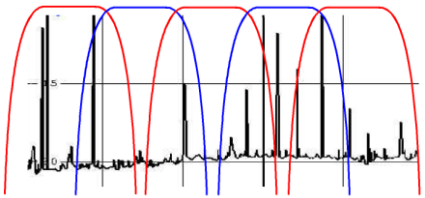




- **Swept mode:**
  - Available at spectrum analyzer
  - Sweep through the spectrum continuously
  - Measurement time (tmeas): time = Sweep Time / Sweep points

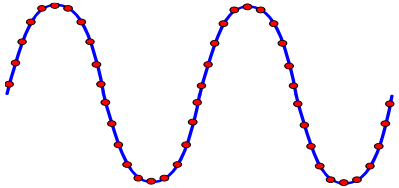
IMPROVING SWEEP TIME: TIME DOMAIN SCAN

1



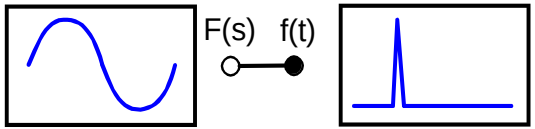
- **Frequency domain**
  Signal spitted into sequential frequency parts

2



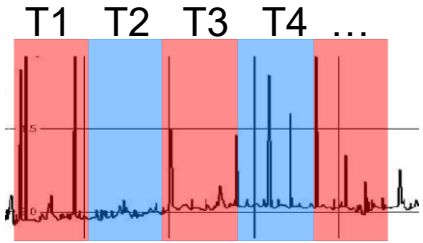
- **Time domain**
  Sampling of windowed parts in time domain

3



- **Time to Frequency**
  FFT of the time based signal into frequency range

4



- **Frequency range**
  Combination of spectra

TIME DOMAIN SCAN

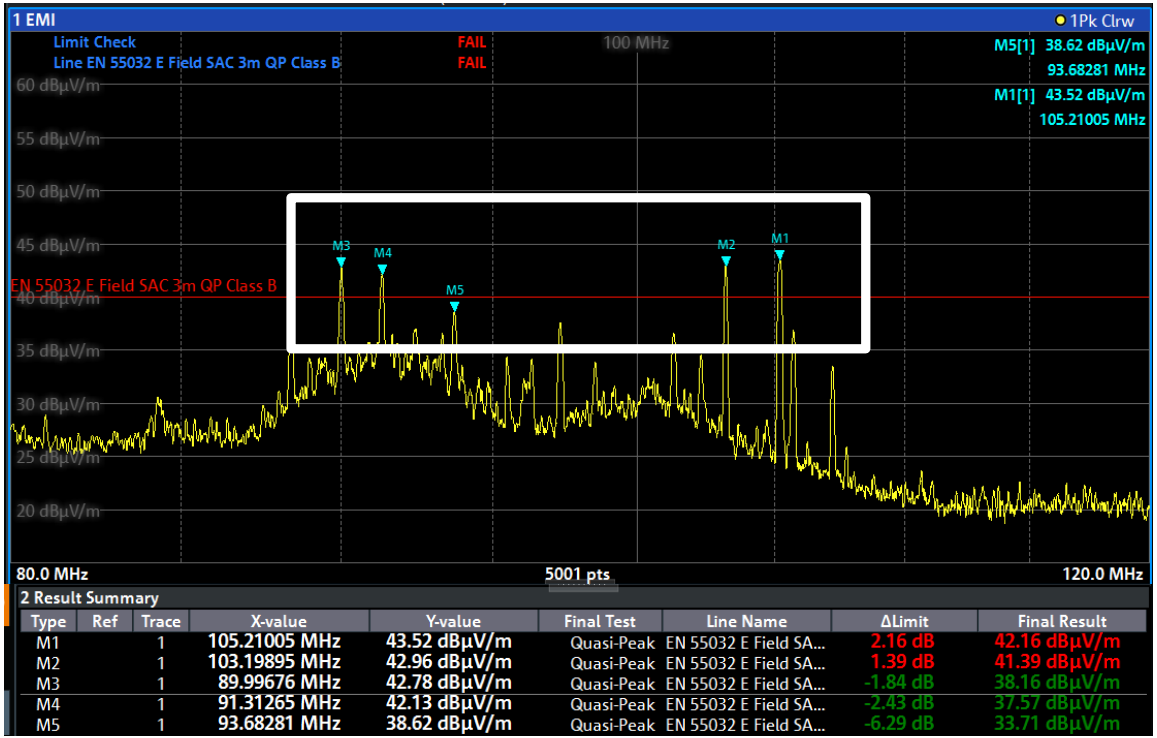
- Speed improvement
  - Degree of improvement depends on detector type, dwell time, and measurement bandwidth
- Higher probability of intercept for short duration (intermittent / pulsed) signals
  - Higher confidence that signals with low repetition rates are not being missed

Measurement Times

Frequency Range	Detector, Dwell Time, Measurement BW (Number of Points)	Stepped Scan	Time Domain Scan
CISPR Band B 150 kHz – 30 MHz	Pk, 100 ms, 9 kHz (13.267)	22 min	117 ms
CISPR Band B 150 kHz – 30 MHz	QP, 1 s, 9 kHz (13.267)	3.6 h	2 s *
CISPR Band C/D 30 MHz – 1 GHz	Pk, 10 ms, 120 kHz (32.334)	5 min, 23 s	630 ms
CISPR Band C/D 30 MHz – 1 GHz	Pk, 10 ms, 9 kHz (431.000)	71 min, 50 s	850 ms
CISPR Band C/D 30 MHz - 1 GHz	QP, 1 s, 120 kHz (32.334)	~ 3 h	80 s *

* incl. 1 s settling time per FFT segment

MEASURING FAST AND REPRODUCIBLE

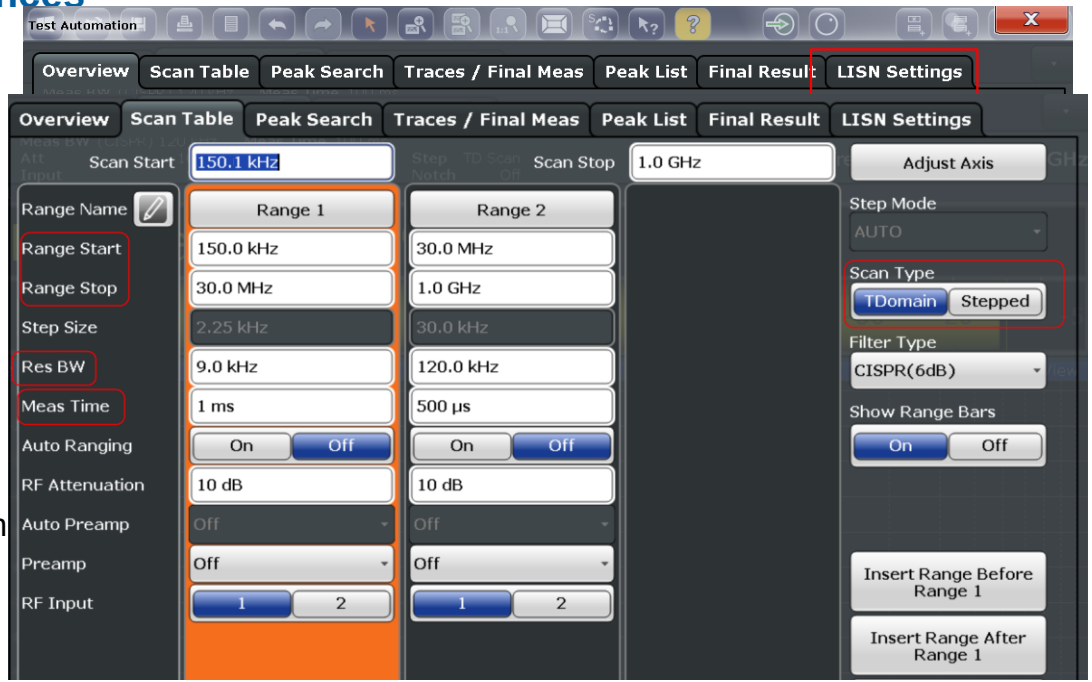


- Peak detectors used for a broad frequency sweep
- Limit lines set according to standard
- At frequency points beyond limit lines, quasi-peak detector measurement is used

TEST AUTOMATION

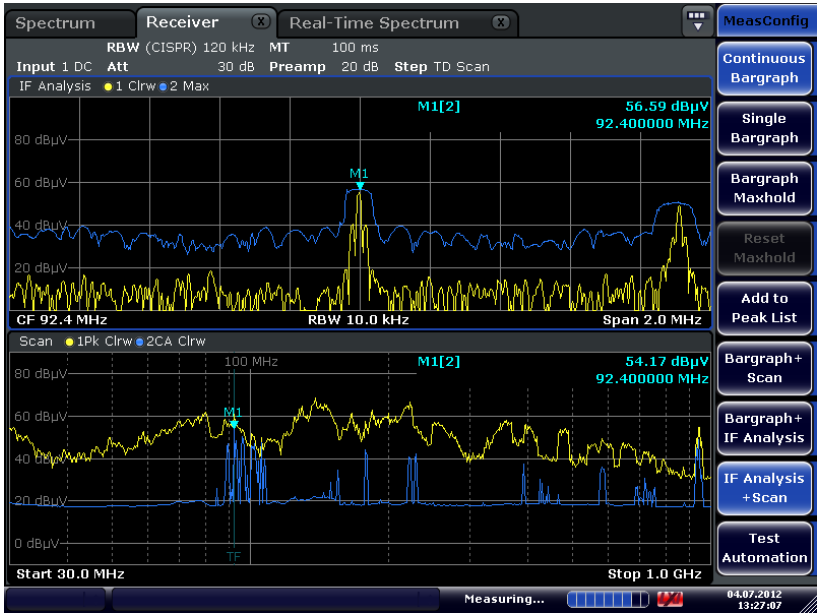
Semi / fully automatic EMI test sequences

- **Fast preview measurement**
  - PK or PK/AVG detection
  - TD scan or stepped frequency
- **Data reduction**
  - Evaluation of the critical frequencies for final measurement
- **Final measurement**
  - Quasipeak or Quasipeak/CAV detection
  - Measurement on a frequency list
- **Remote control for automatic phase switching artificial mains networks (LISNs)**



PERFORMING IN DEPTH SIGNAL ANALYSIS

- Logarithmic frequency sweep – analyze lower frequencies in more detail
- AM and FM demodulation with audio output
- IF analysis
- Zero span
- Real-time function (persistence mode, spectrogram, frequency mask trigger)
- (Scan) Spectrogram

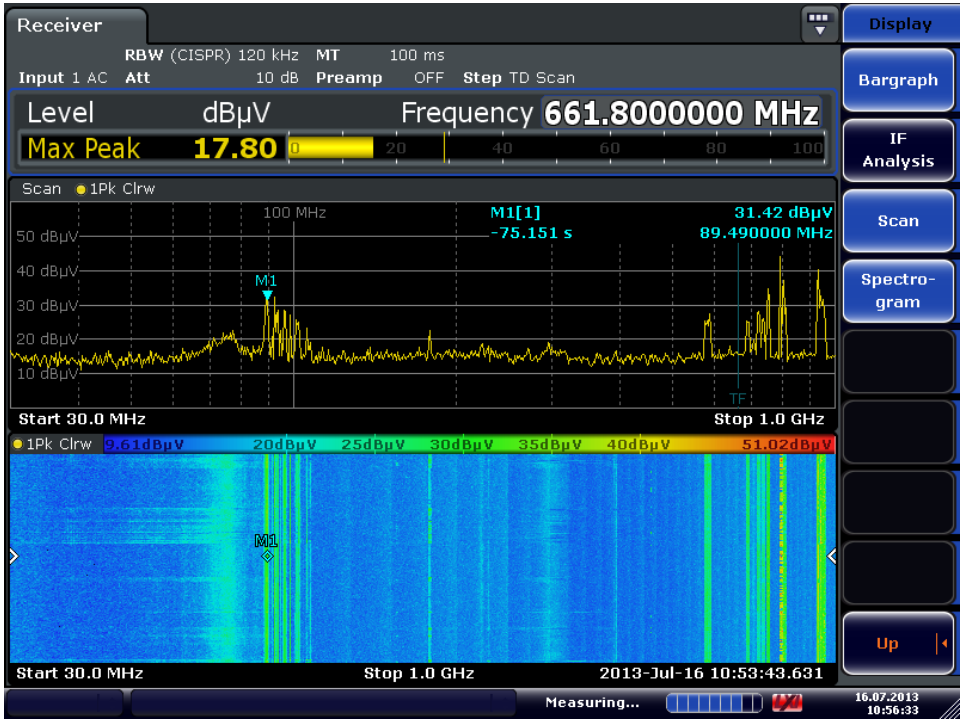


TIME DOMAIN SCAN SPECTROGRAM

Spectrogram in receiver mode

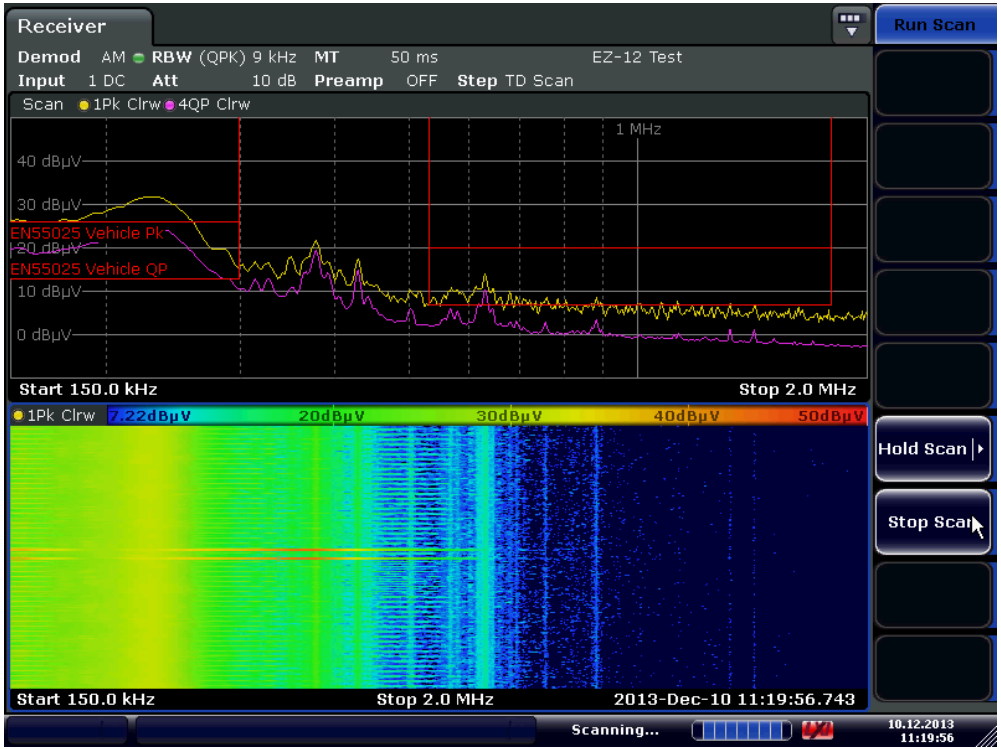
Spectrogram in split screen mode can be combined with:

- **Time Domain scan**
- **Stepped frequency scan**
- **IF analysis**
- **Bargraph on/off**



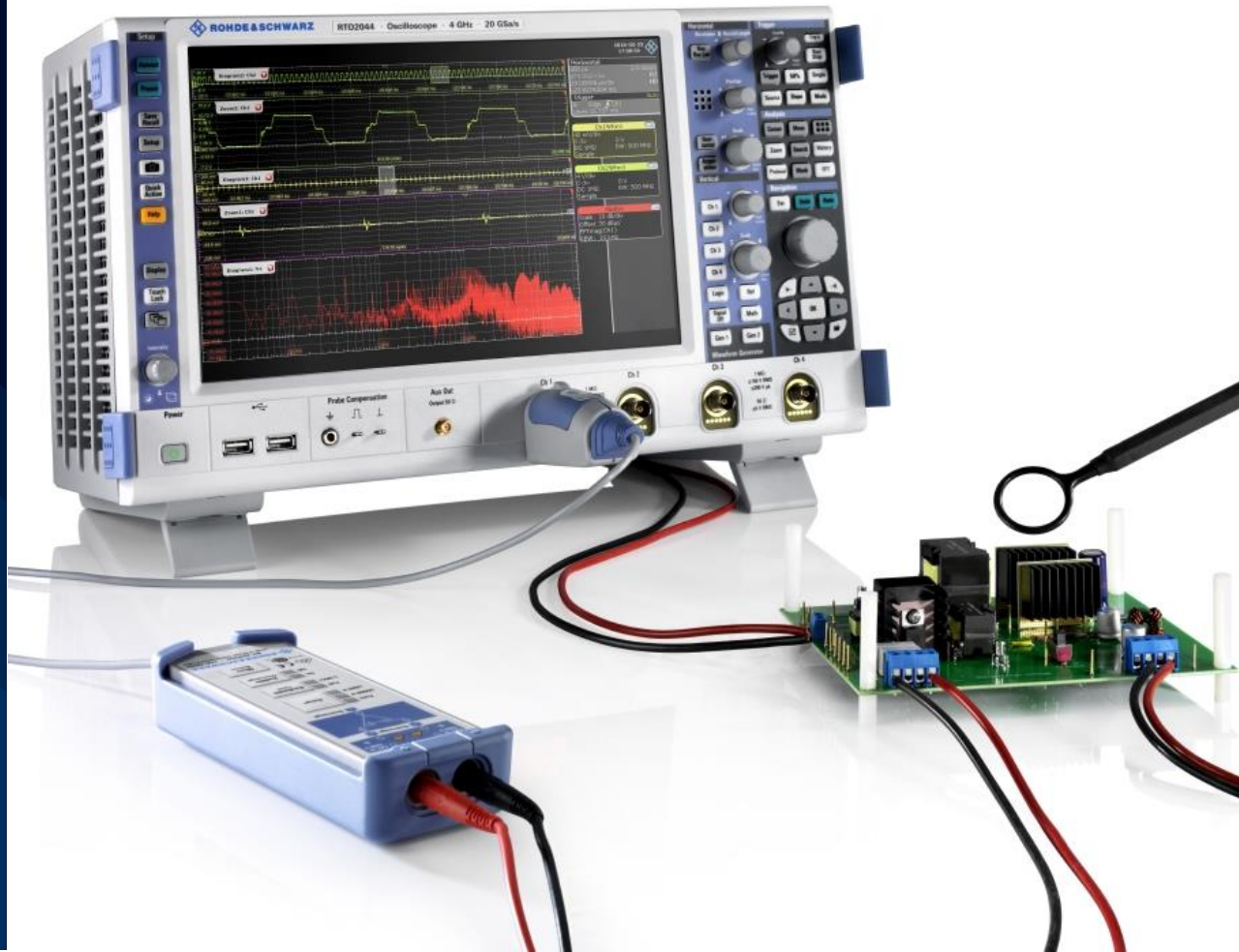
PERFORMING IN DEPTH SIGNAL ANALYSIS EXAMPLE: SCAN SPECTROGRAM

- Pressing the horn of a car:
  3 short, 1 long

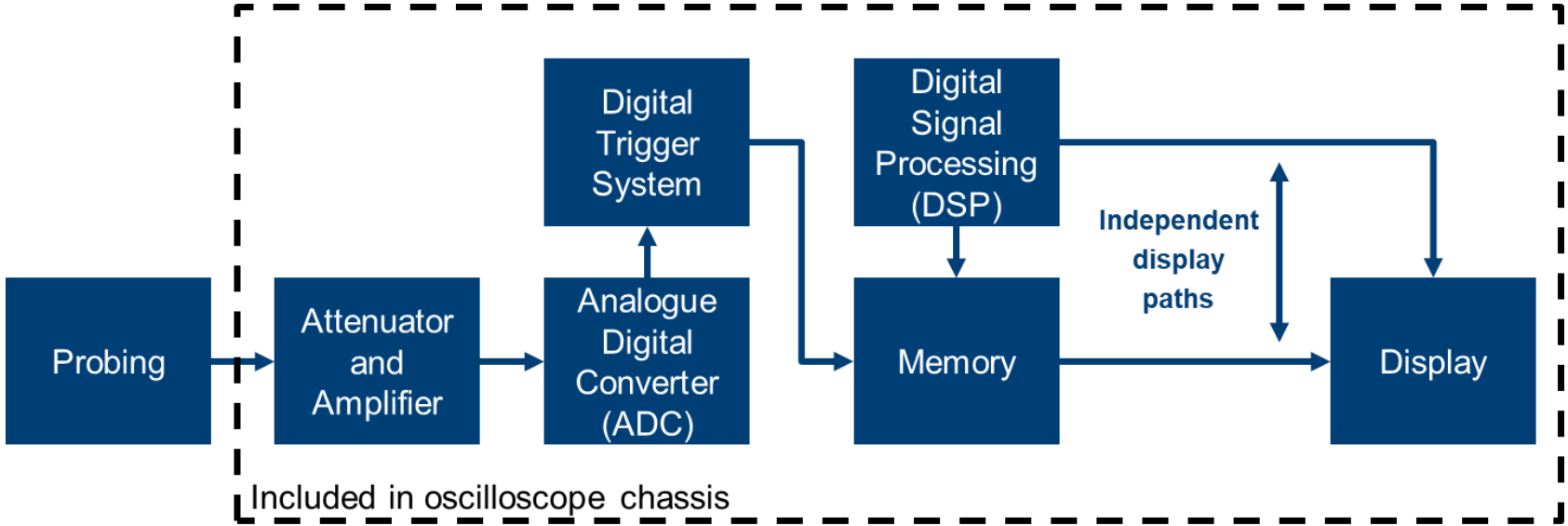


OSCILLOSCOPE

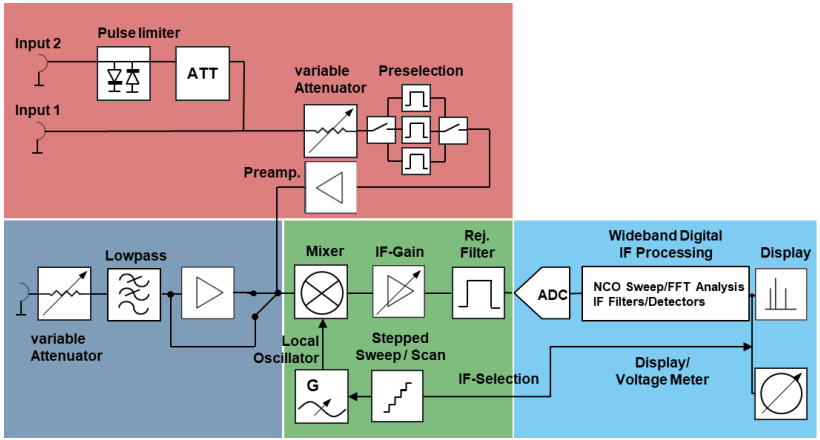
- Block diagram
- Time domain to frequency domain

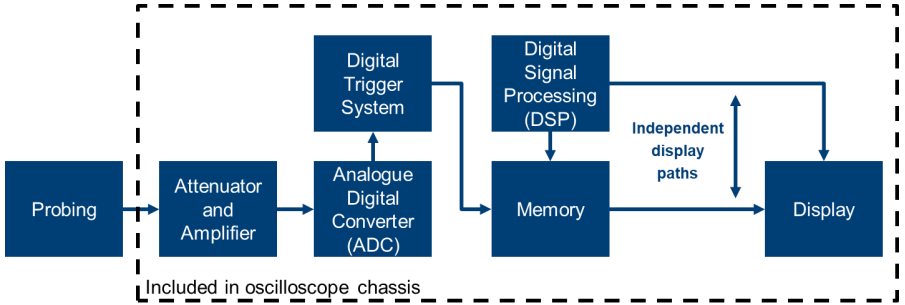


BLOCK DIAGRAM



OSCILLOSCOPE FOR EMI MEASUREMENTS / DEBUGGING





EMI Receiver

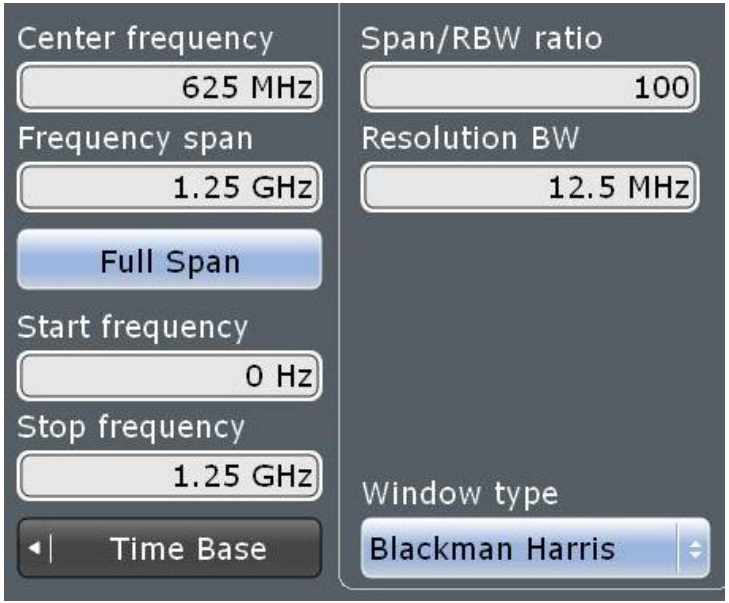
- Frequency domain
- Preselector and RBW available
  → Narrowband measurements

Oscilloscope

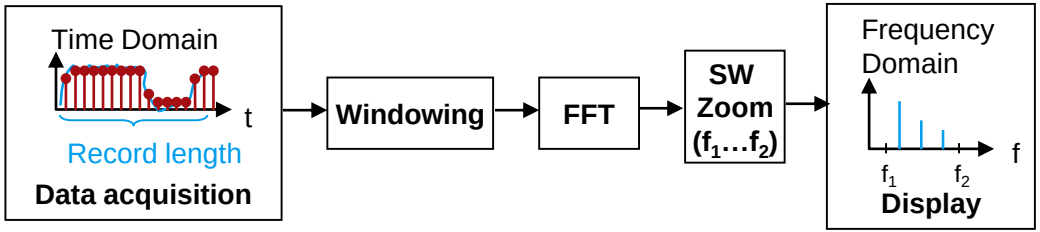
- Time domain
- No Preselector and no IF
  → Broadband measurements
- Not compliant to EMI standards

OSCILLOSCOPE FOR EMI DEBUGGING TYPICAL OBJECTIONS

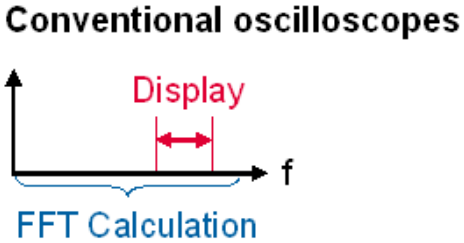
- **… is the scope sensitive enough?**
  - Yes: 1mV/Div gives **DANL** of ~0 dBµV = -107 dBm (@500 MHz, 120 kHz RBW, 50 Ω)
- **… what about a (6 dB) EMI filter?**
  - Not necessary for EMI debugging
- **… what about limit lines?**
  - The mask tool includes limit line functionality



OSCILLOSCOPE FOR EMI DEBUGGING
TRADITIONAL FFT APPROACH

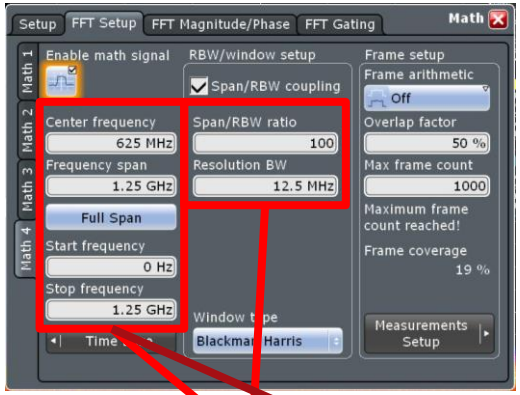


1. The FFT calculation will produce a frequency domain result from 0 Hz to max Freq.
2. Optionally Windowing is applied before the FFT calculation
3. After FFT, the user can select the desired frequency range to be displayed

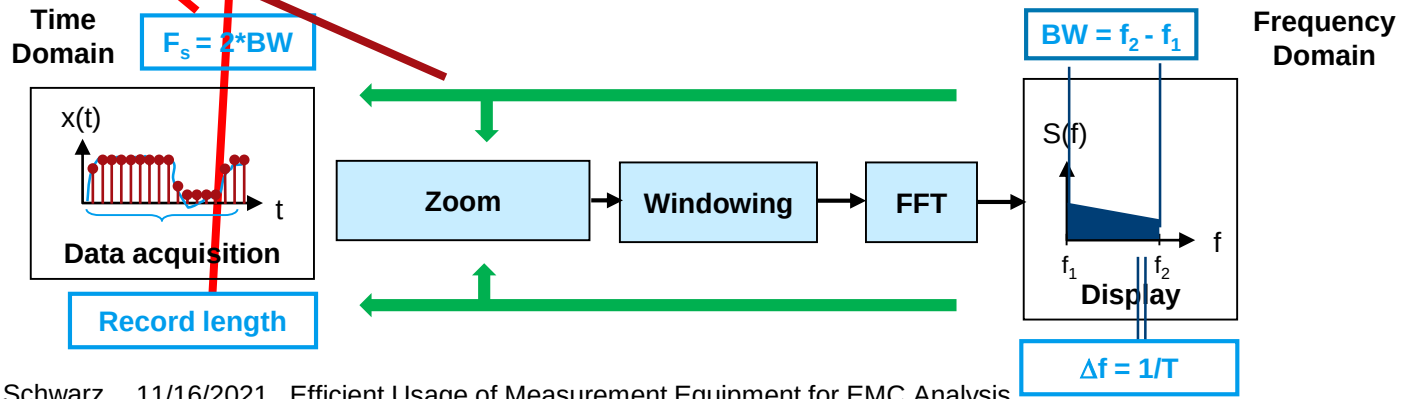


Disadvantages of conventional FFT :
- Very slow speed / update rate
- Limited RBW due to insufficient RL
- Complex configuration (TD settings)

OSCILLOSCOPE FOR EMI DEBUGGING
FFT IMPLEMENTATION AT R&S

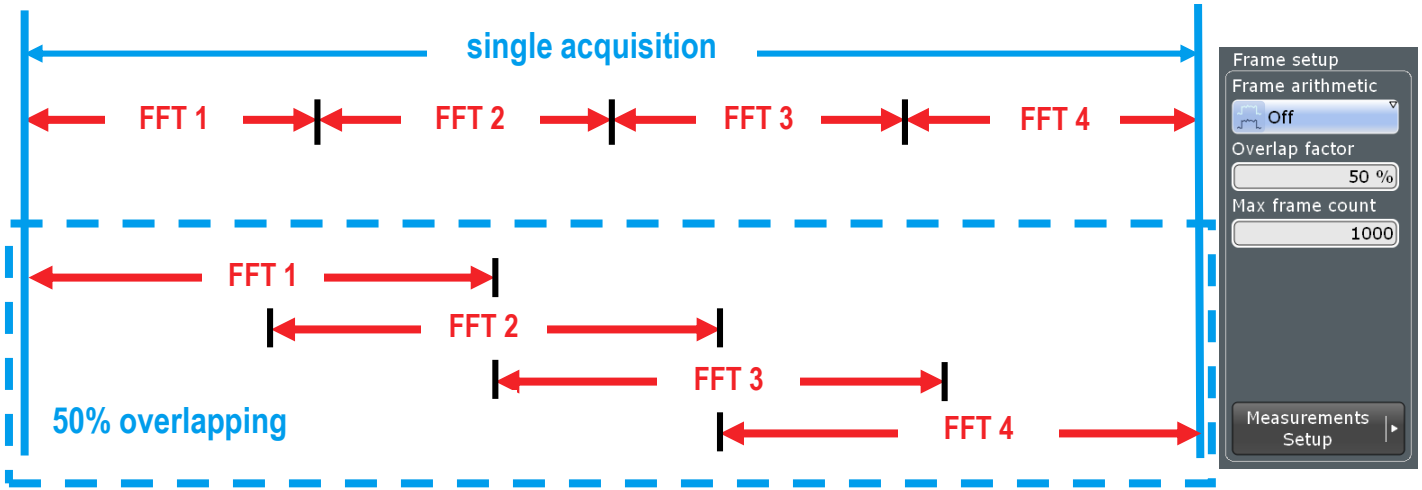


- **Spectrum Analyzer Use Model**
  - Frequency domain controls time domain:
    Record length and sampling rate are updated automatically
- **FFT for maximum performance**
  - Frequency zoom *before* FFT:
    e.g. 500 MHz center / 10 MHz span: 20 MS/s instead of 1 GS/s



OSCILLOSCOPE FOR EMI DEBUGGING
MULTIPLE & OVERLAPPING FFT

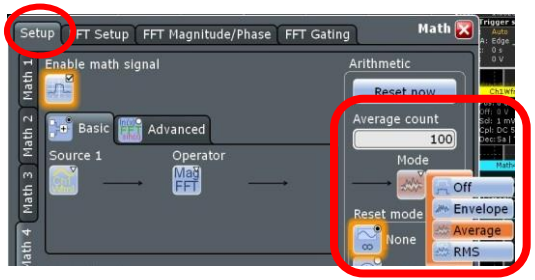
- Faster processing & faster display update rate
- Ideal for finding sporadic signal details
- Get a deeper look how the spectral energy is spread within a single acquisition.



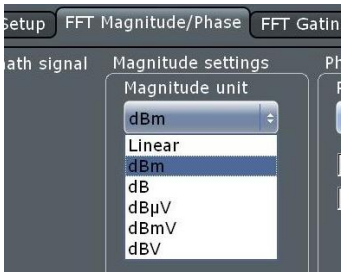
Multiple overlapped FFT's help to differentiate spectral occurrence of signal components!

OSCILLOSCOPE FOR EMI DEBUGGING

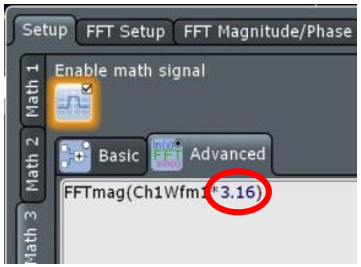
Max hold, AVG and RMS



Spectrum units

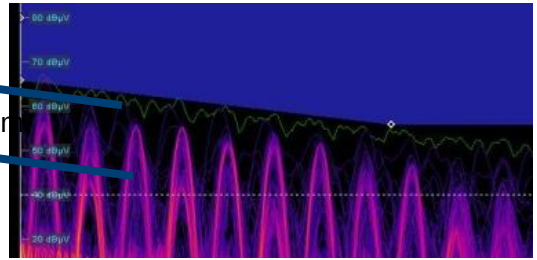


Correction factor for a LISN



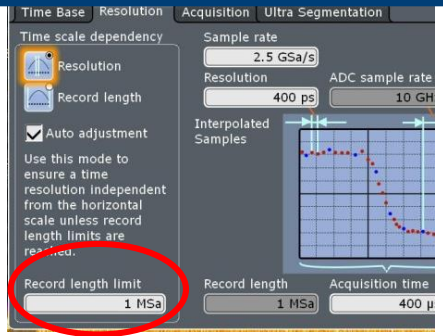
Multiple FFTs

Green: Max-Hold
Purple: Current spectrum intensity graded



***Note:** Envelope = Max Hold

Record Length < 1MS

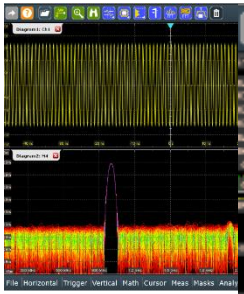


OSCILLOSCOPE FOR EMI DEBUGGING

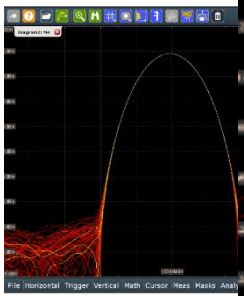
Use FFT gating to identify signal source

FFT gating on ringing part of the pulse shows frequency component

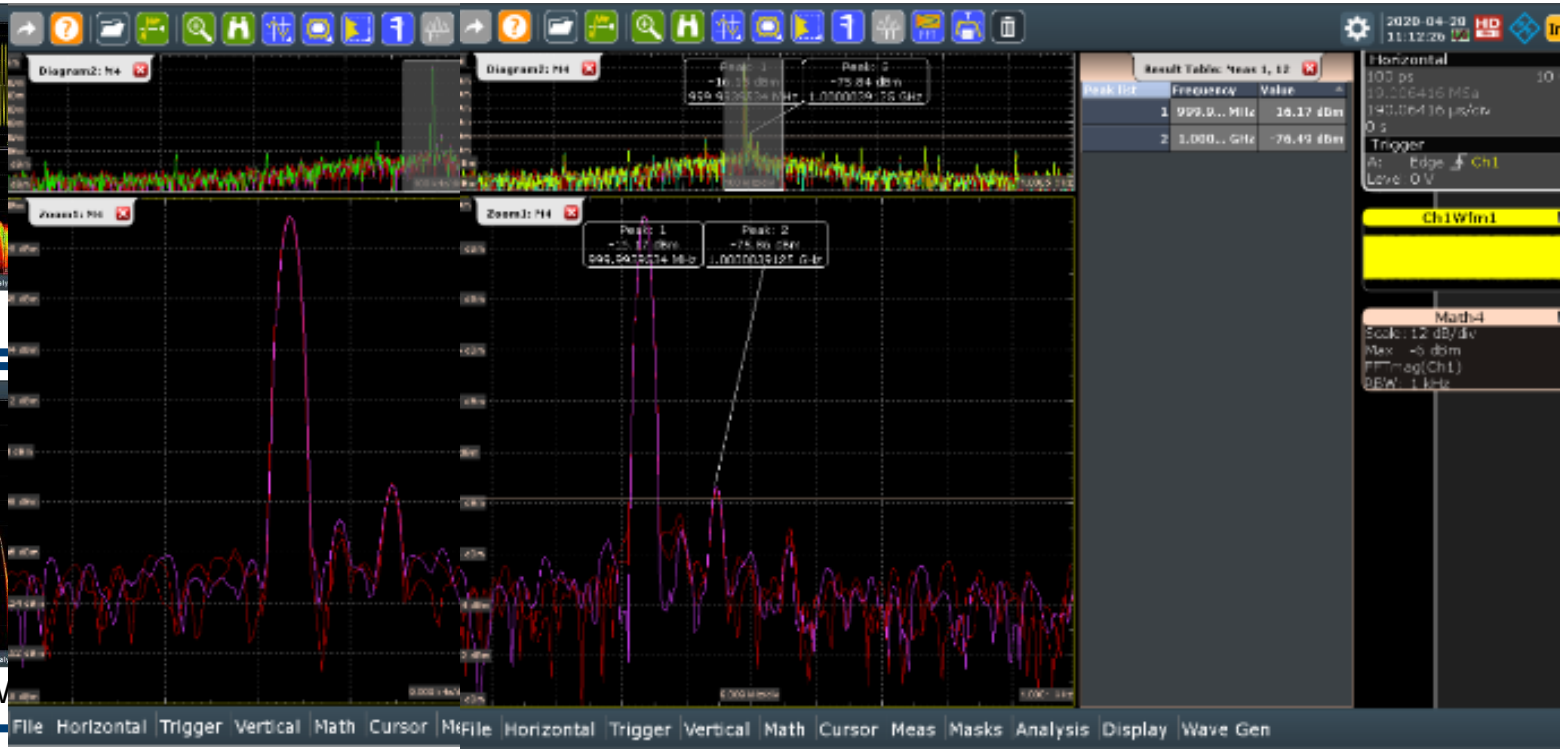
EMI DEBUGGING WORKFLOW



Activate FFT



Signal with RBW

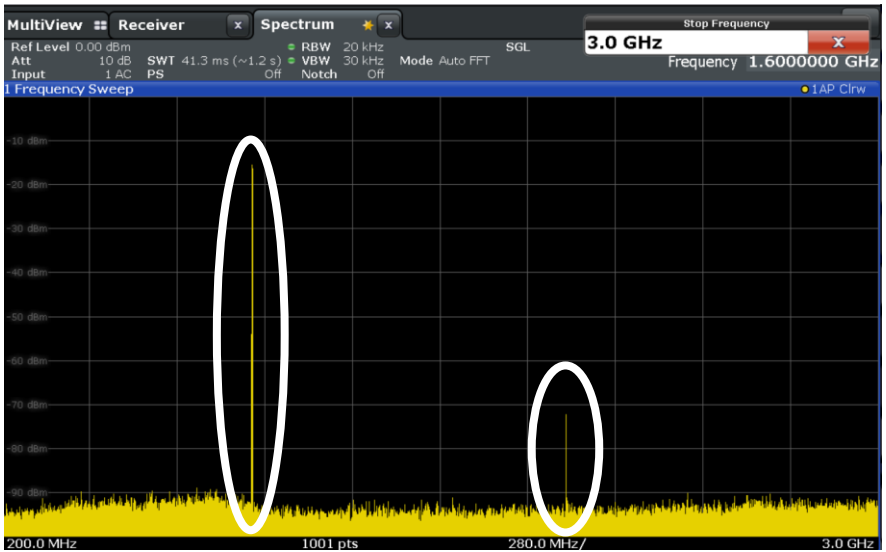


COMPARISON MEASUREMENT RESULTS

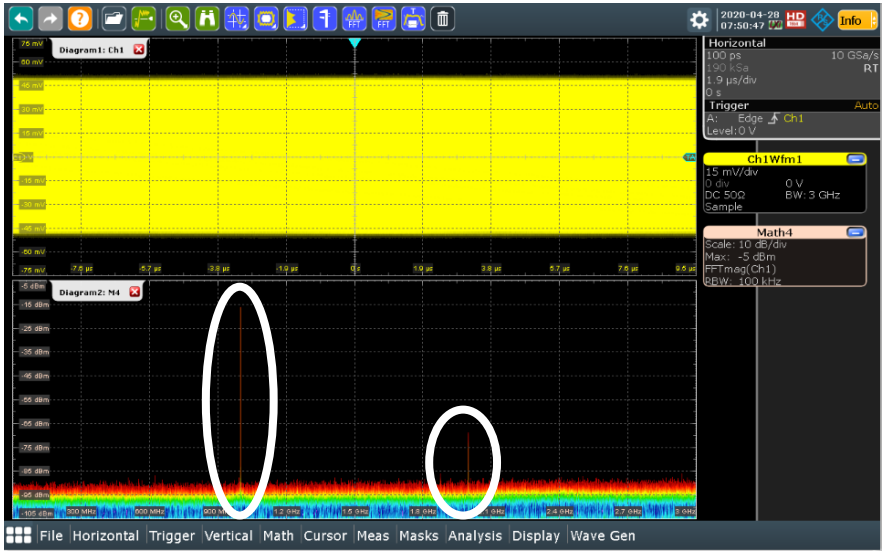
- What Signal was analyzed?
  - Signalgenerator: R&S SMBV100B
  - Signaltype: 2 Carriers with 100 kHz Spacing
  - Center frequency: 1 GHz
  - Attenuation between the 2 carriers: 60 dB
  - Power splitter provided same signal to EMI Receiver and Oscilloscope

COMPARISON MEASUREMENT RESULTS

EMI Receiver

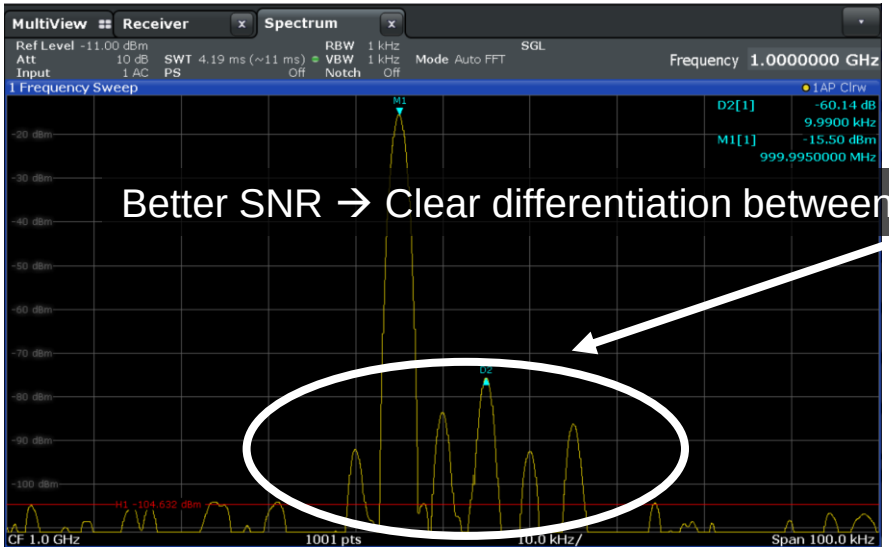


Oscilloscope

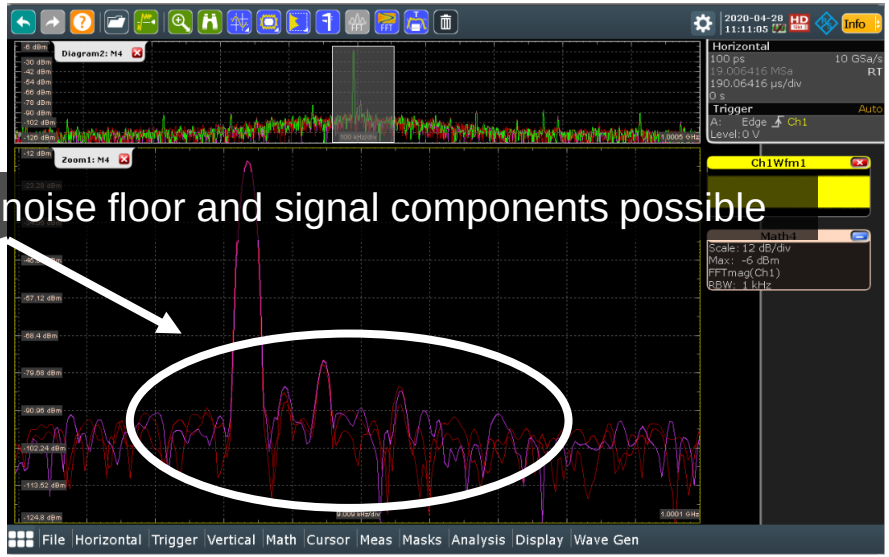


COMPARISON MEASUREMENT RESULTS

EMI Receiver



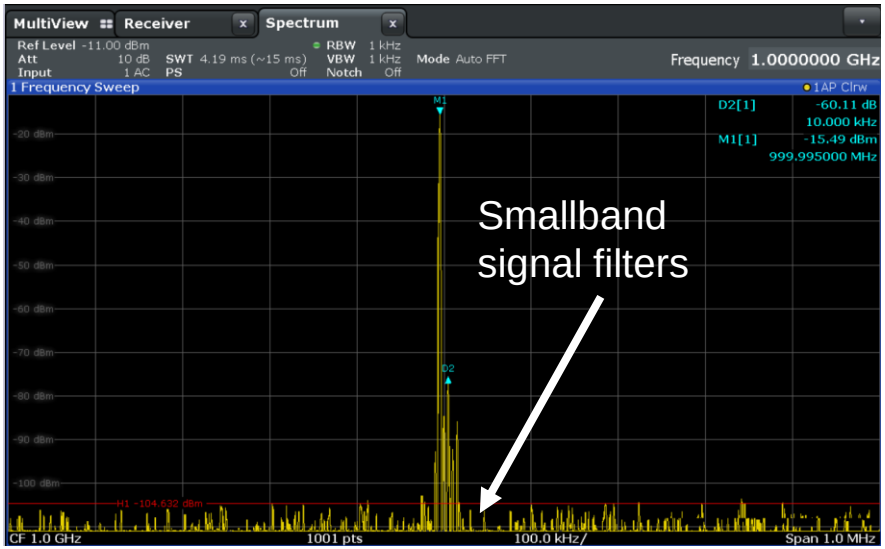
Oscilloscope



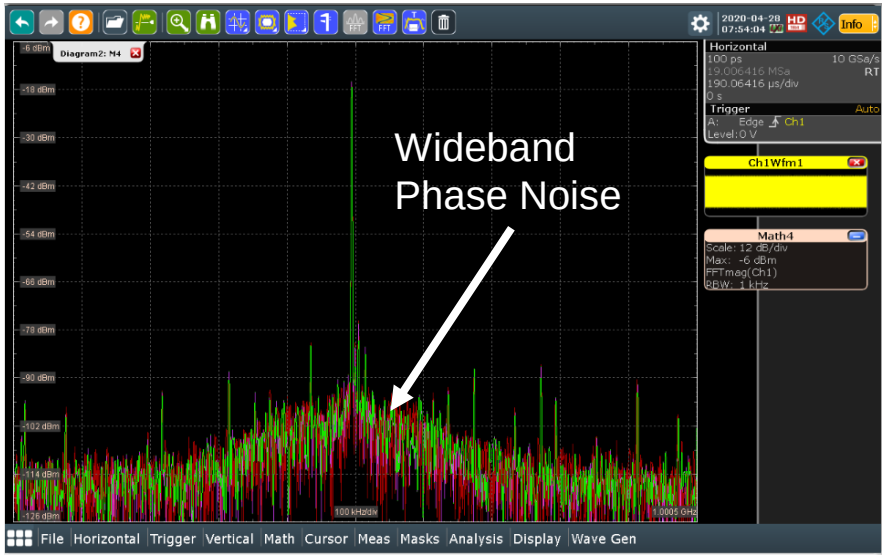
Better SNR → Clear differentiation between noise floor and signal components possible

COMPARISON MEASUREMENT RESULTS

EMI Receiver



Oscilloscope



WHEN TO USE WHICH INSTRUMENT? FROM COMPLIANCE TO EMI DEBUGGING

EMI Receiver

- 6 dB Filters
- Preselector avialable
- Highest selectivity
- CISPR compliant detectors
- Demodulation of signals possible
- Time domain scan reduces sweep time to a minimum

Spectrum-/ Signalanalyzer

- 3 dB Filters
- High selectivity
- High sensitivity
- Analysis on wide frequency range possible (today up to 8 GHz internal analysis BW available)
- Demodulation of signals possible

Oscilloscope

- 3 dB Filter
- One shot analysis of whole frequency range
- Measures down to DC
- Trigger capabilities for signal separation
- Mask testing in frequency and time domain
- Gated FFT possible
- Multichannel coherent receiver

WHEN TO USE WHICH INSTRUMENT? FROM COMPLIANCE TO EMI DEBUGGING

EMI Receiver

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Spectrum-/ Signalanalyzer

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Oscilloscope

- 3 dB Filter
- One shot analysis frequency ran
- Measures C
- Trigger es for signal sep
- ing in frequency ne domain
- ated FFT possible
- Multichannel coherent receiver

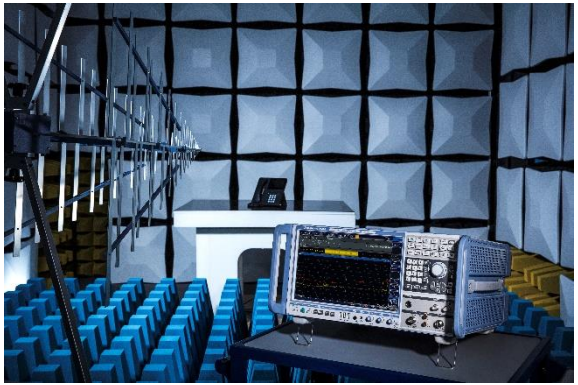
Full Compliance

(Pre-) Compliance

EMI Debugging

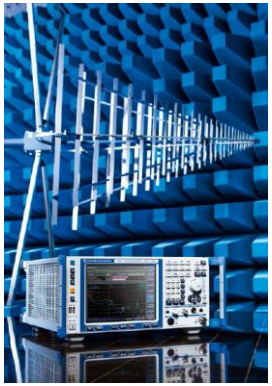
INSTRUMENT POSITIONING

COMPLIANCE



EMI Compliance Test Receiver

PRE-COMPLIANCE



EMI Precompliance Receiver

Spectrum Analyzer with EMI Application

DEBUGGING

Oscilloscope

Value spectrum analyzer

QUESTIONS

Sales.germany@rohde-schwarz.com

Subject: „EMC Workshop 2021 “