Oscilloscope Skills

CM AND DM NOISE – OPTIMIZING EMI FILTER AND DEBUG WITH OSCILLOSCOPES

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Application Engineer

ROHDE&SCHWARZ
Make ideas real

INDEX

- CM DM noise and EMI filter.
- EMI debugging with R&S Oscilloscopes.

CM DM NOISE AND EMI FILTER

THE CHALLENGES IN TODAY'S ELECTRONIC DESIGN

Trend for Embedded System Design

- ► Faster clock speed
- ► Smaller form factor
- ► More data lines for communications
- ► More design include RF technology
- ► Power has more impact on signals with smaller amplitude

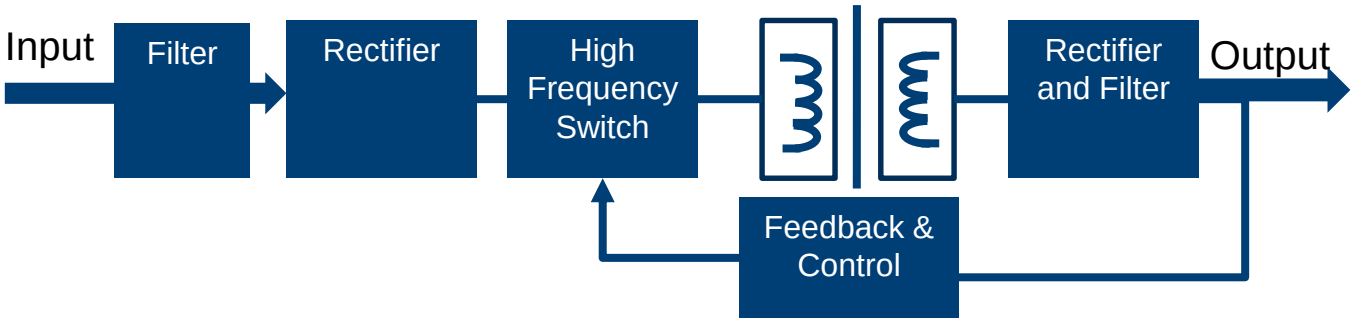
Via's Tiny-ITX motherboard

More EMI issues

- ► Switched mode power supply causes the most EMI issue.
- ► Higher speed design introduces EMI issues
- ► Bad PCB Layout (stacking) causing worse EMI
- ► RF features impact & be susceptible to EMI
- ► Driven by the discontinuities and resonances of the transmission path
- ► Extends to much higher harmonics than SI issues

Smart Watch

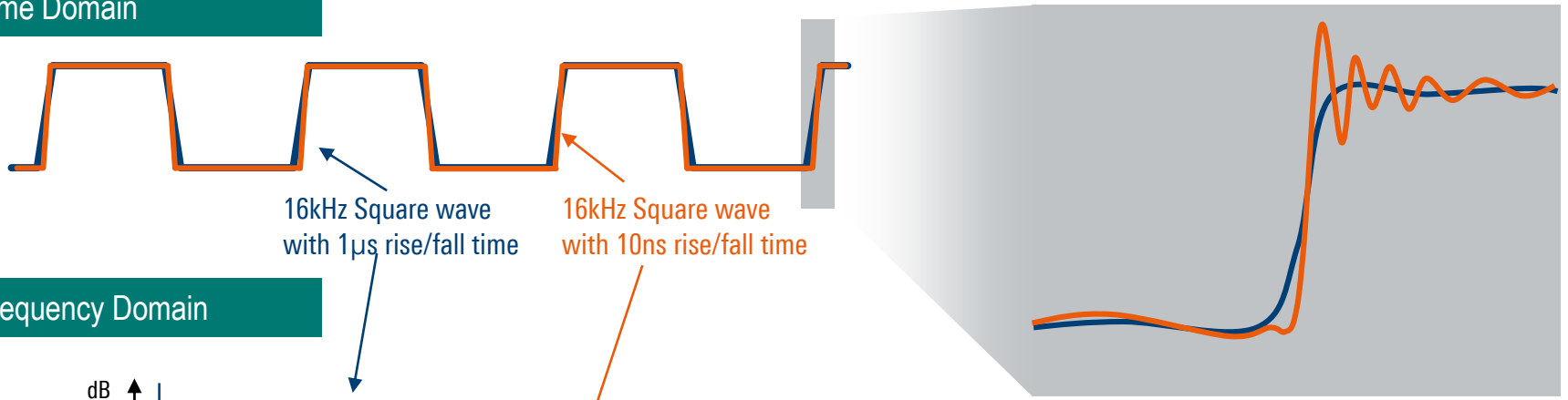
SWITCHED MODE POWER SUPPLY PRINCIPLE



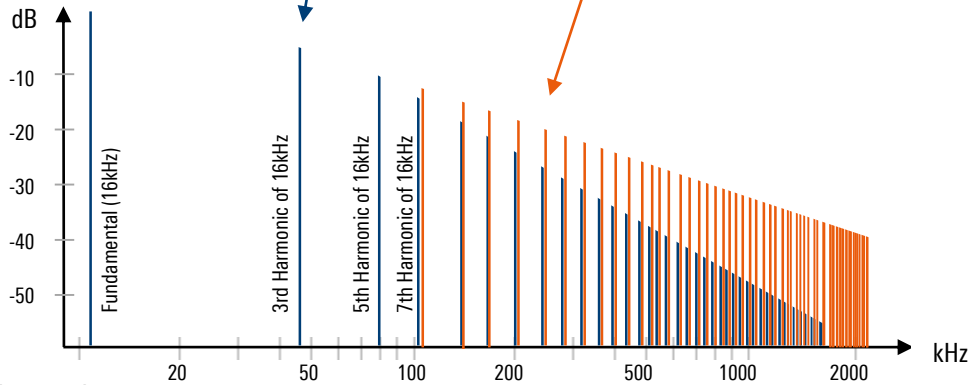
Advantages	Disadvantages
Efficiency is as high as 85 to 95%	Noise present due to high switching frequency
Device is small and compact	It produces electromagnetic interference

IMPACT OF SWITCHING AND FAST EDGES OF CONVERTER ON EMI EMISSIONS

Time Domain



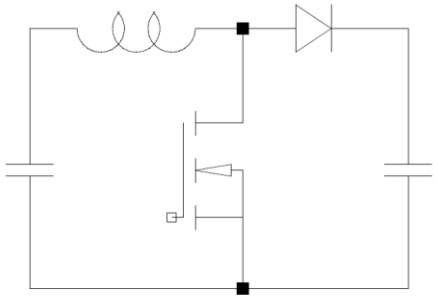
Frequency Domain



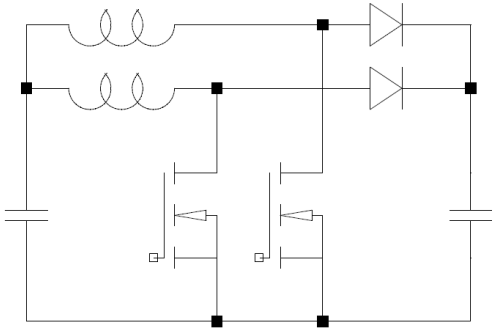
High frequency Harmonics come with higher levels

CONVERTER TOPOLOGIES AND EMI EMISSIONS

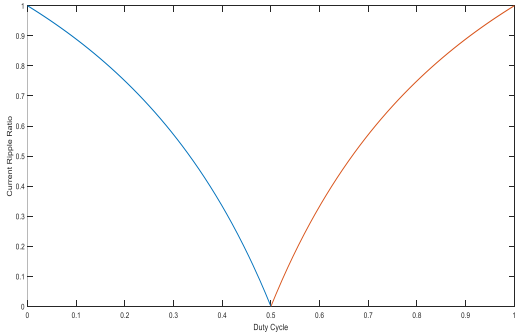
- The choice of the converter topology depends on various design parameters like power level, efficiency and each topology come along with its typical EMI behaviour.



Boost Converter



Interleaved Boost Converter



Input Current Ripple Reduction

The EMI filter design depends on the selected topology

TRANSMISSION MODES

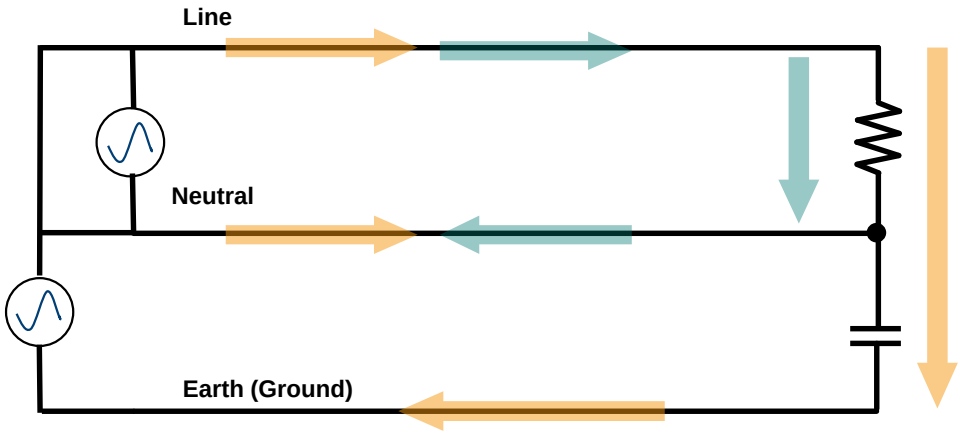
- Propagation methods of noise

Differential Mode

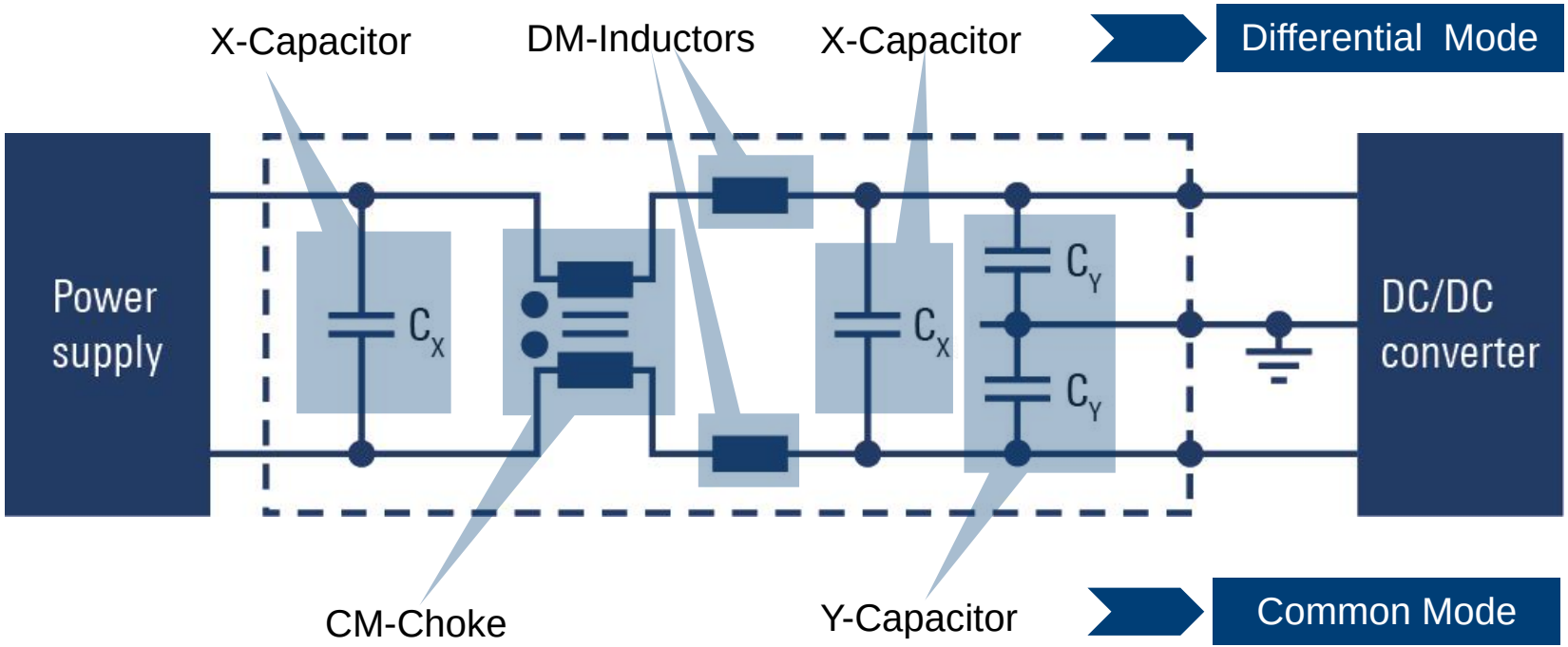
noise or signals on a line(s) with a return path

Common Mode

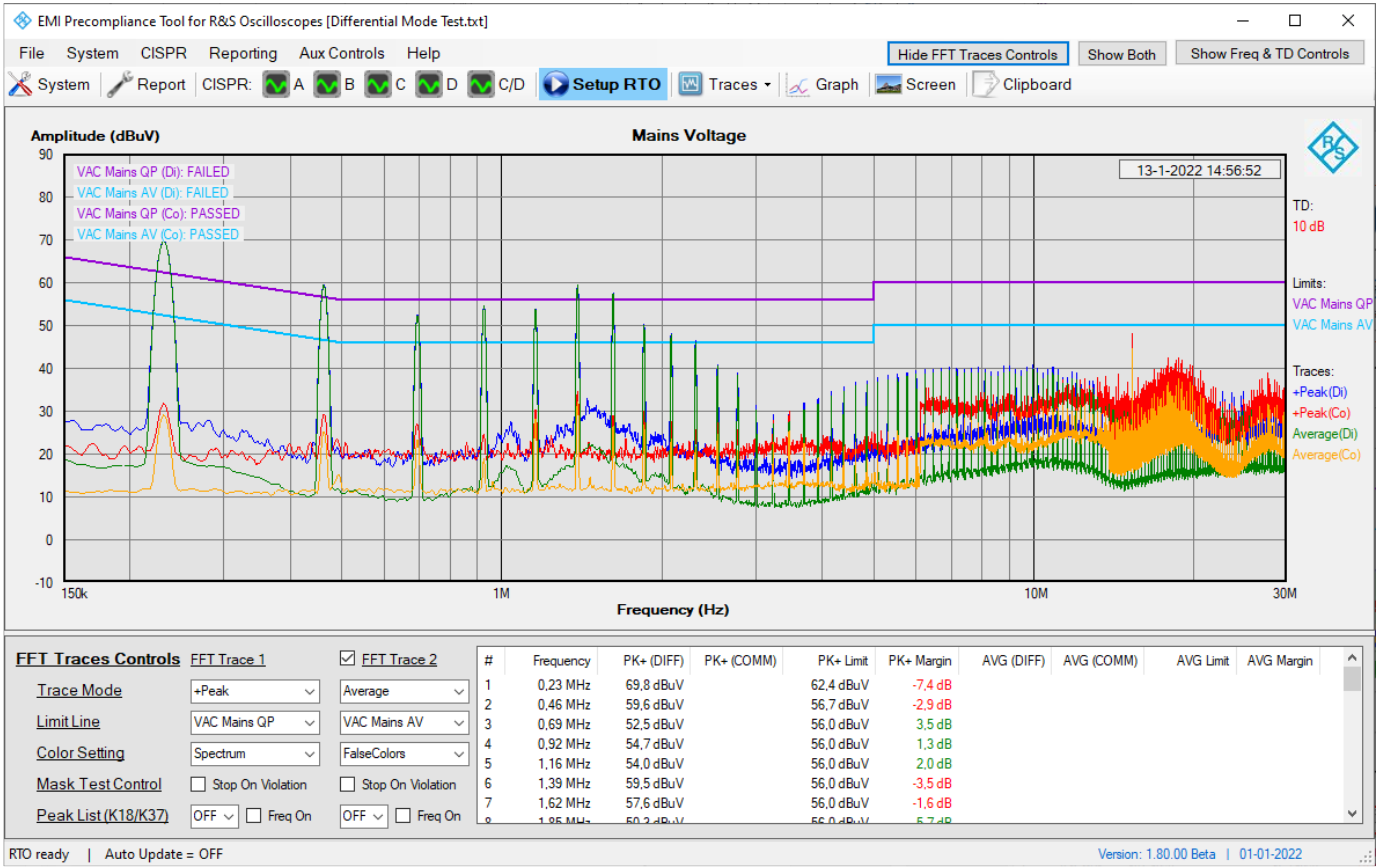
noise on all lines propagating in the same direction with respect to earth



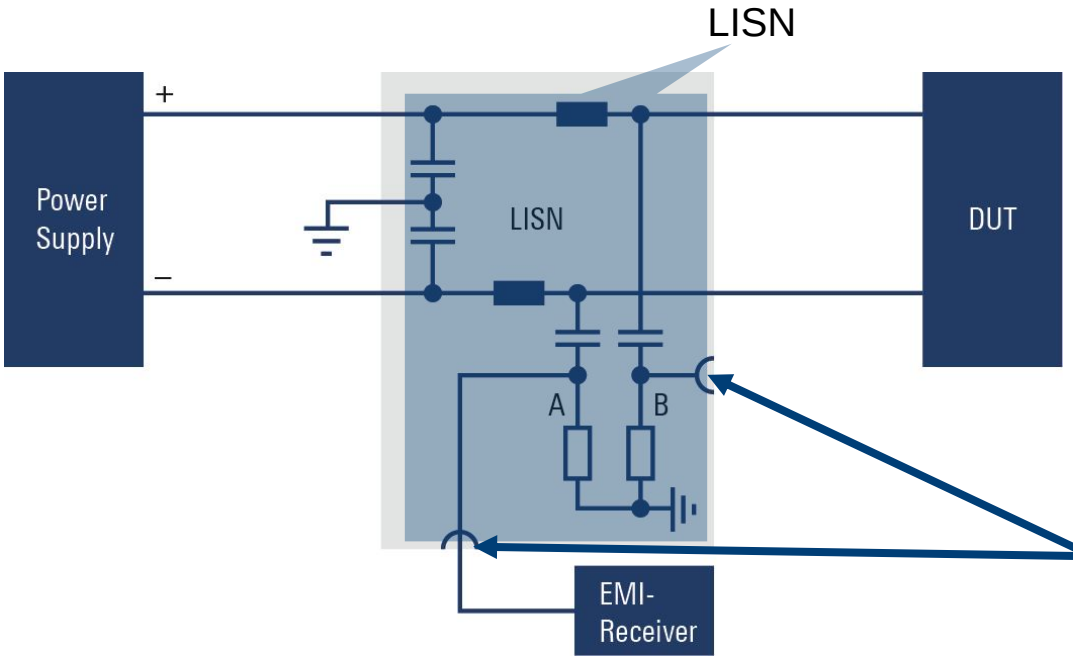
EMI INPUT FILTER STRUCTURE



RESULT OF PRE-EMI COMPLIANCE TEST



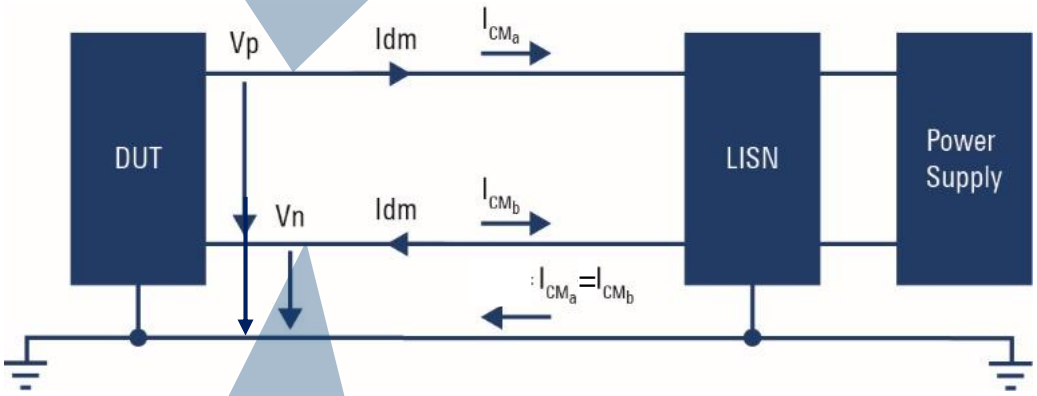
CONDUCTED EMISSION SETUP



In case of a failed CE test, this setup is not sufficient for EMI debugging purpose

COMMON AND DIFFERENTIAL MODE THEORY

$$V_P = (I_{CM_a} + I_{DM}) * Z_{LISN}$$



$$V_N = (I_{CM_b} - I_{DM}) * Z_{LISN}$$

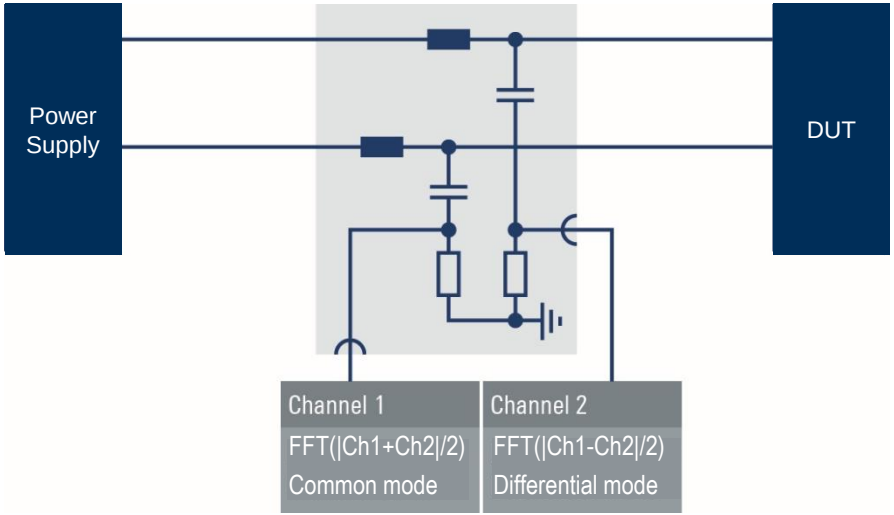
$$V_{CM} = \frac{|V_P + V_N|}{2}$$

$$V_{DM} = \frac{|V_P - V_N|}{2}$$

For optimizing EMI Filter very important

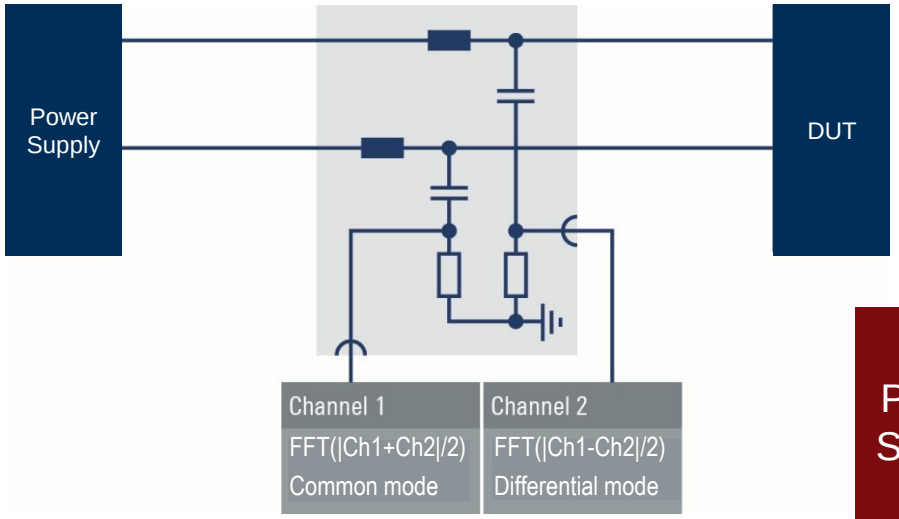
ENHANCED MEASUREMENT SETUP FOR DEBUGGING

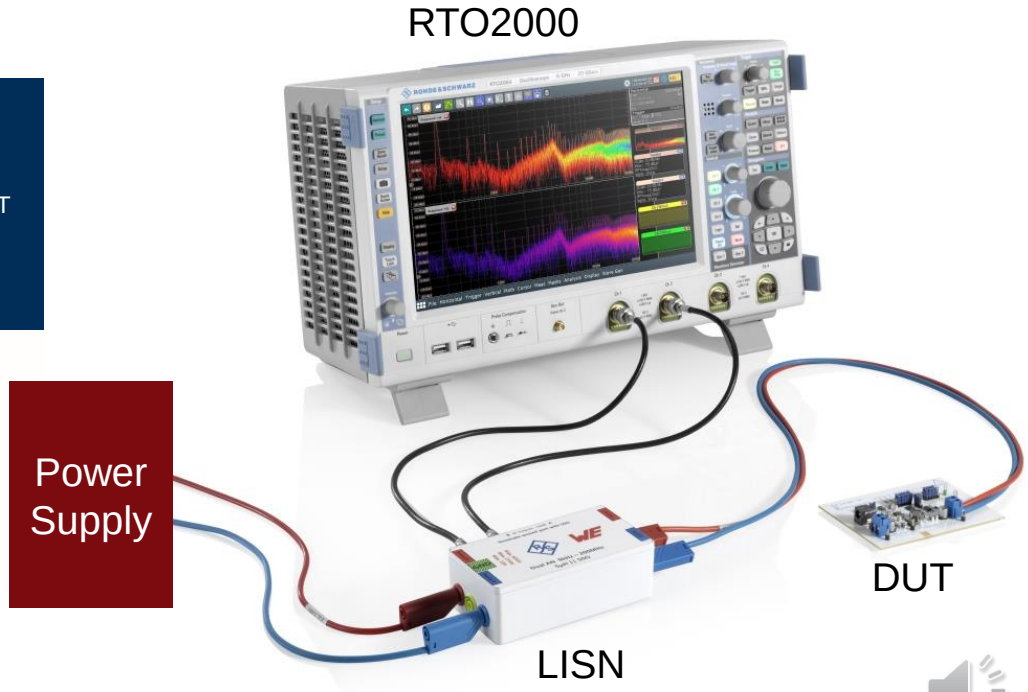
- Requires a Dual-LISN or 2 x a single LISN
- Requires a measurement instrument with 2 input channels



Oscilloscope with powerful and multichannel FFT

ENHANCED MEASUREMENT SETUP FOR DEBUGGING





EMI DEBUGGING WITH R&S OSCILLOSCOPE

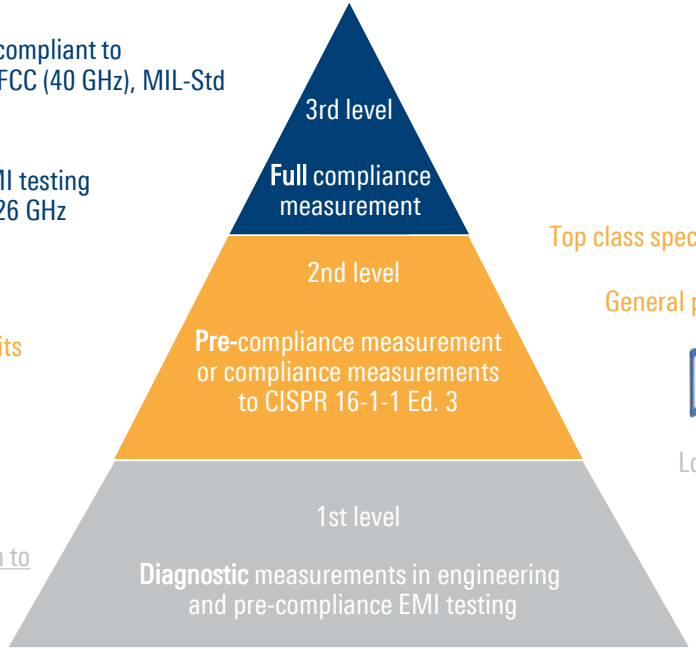
PERFORMANCE LEVELS OF INSTRUMENTATION
SELECTING THE RIGHT TOOL

ESW
EMI receivers compliant to CISPR 16-1-1, FCC (40 GHz), MIL-Std

ESR
Compliance EMI testing CISPR 16-1-1, 26 GHz

ESRP
EMI testing referring to limits

ESL
Diagnostic measurements without relation to limits



Top class spectrum analyzers FSW

General purpose spectrum analyzers FSV FSVR

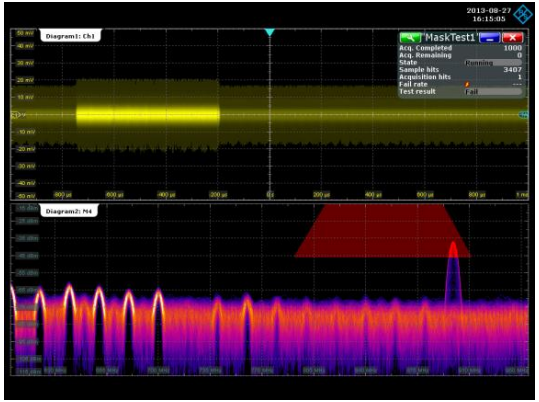
Low cost spectrum analyzers, voltmeters, oscilloscopes

Receivers

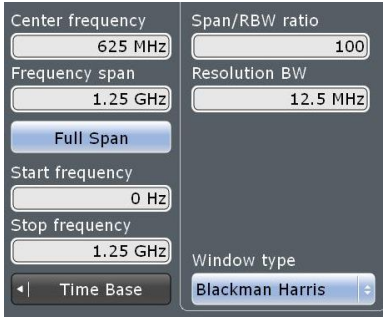
Scopes & Spectrum Analyzer

EMC DEBUGGING WITH OSCILLOSCOPES?

YES, WE CAN! (AND ITS VERY HELPFUL)



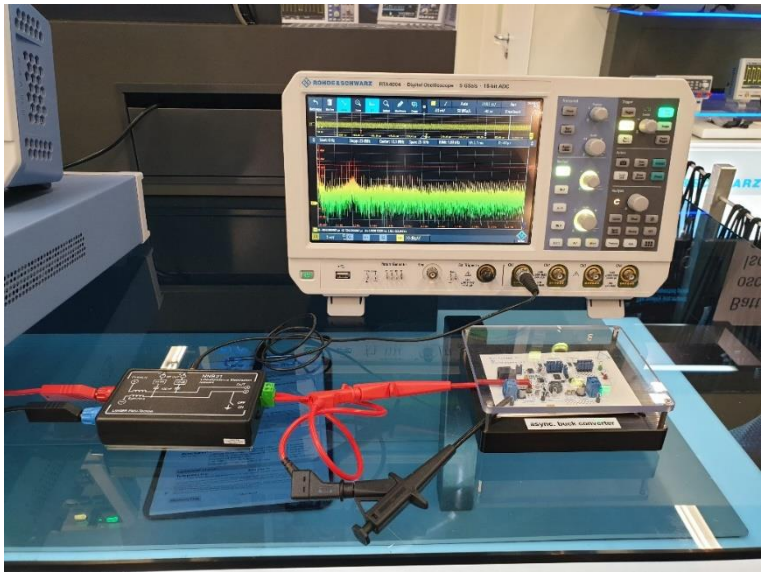
- Available on every R&D engineers desk
  - Easy debugging of EMI problems in R&D
  - Improvements can easily be tested
- Oscilloscopes show both time and frequency domain
  - Correlation between unwanted spectral emission and time-domain signal parameters easily possible
  - Time-domain trigger has advantages for capturing intermittent signals
- Today's oscilloscopes provide excellent sensitivity and usability
  - 1 mV/Div corresponds to DANL ~0dBuV (R&S®RTO at 500 MHz, 120 kHz RBW, 50 Ω)
  - Direct input of frequencies and resolution bandwidth



EMI DEBUGGING WITH OSCILLOSCOPES

- Radiated Emission
  Debugging after failed Pre-Compliance or Compliance

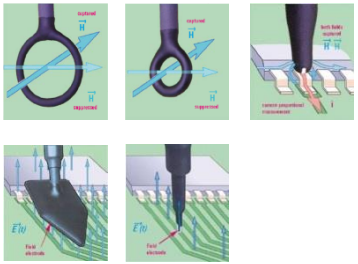
- Conducted Emission
  Pre-test and debugging in the R&D lab



EMI DEBUGGING WITH OSCILLOSCOPES – ACCESSORIES

Near-Field Probes

Complete Sets
E- and H-field

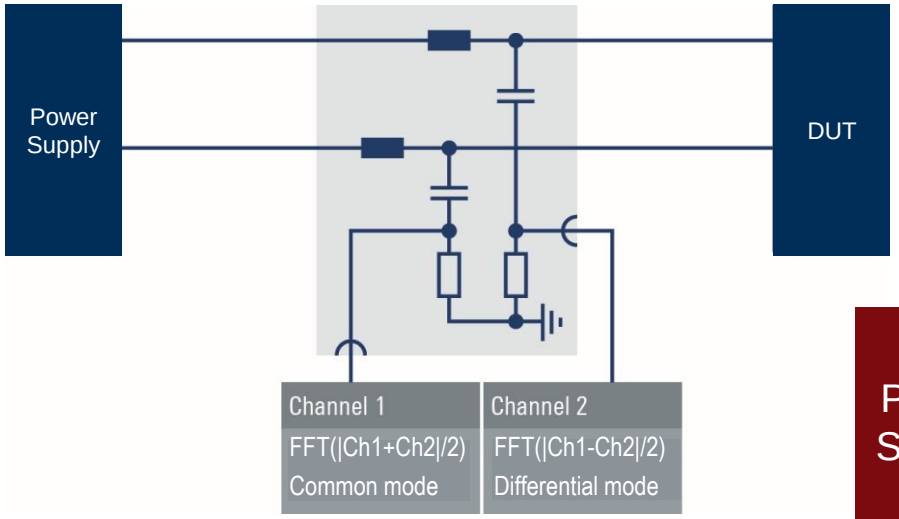


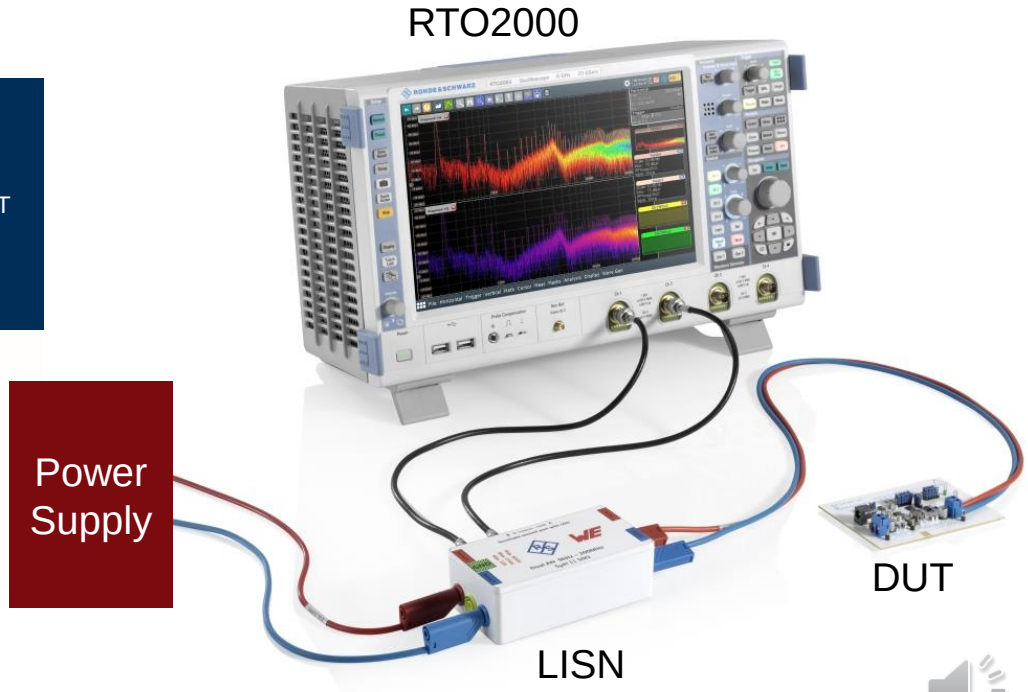
H-field-only Sets

30 MHz – 3 GHz

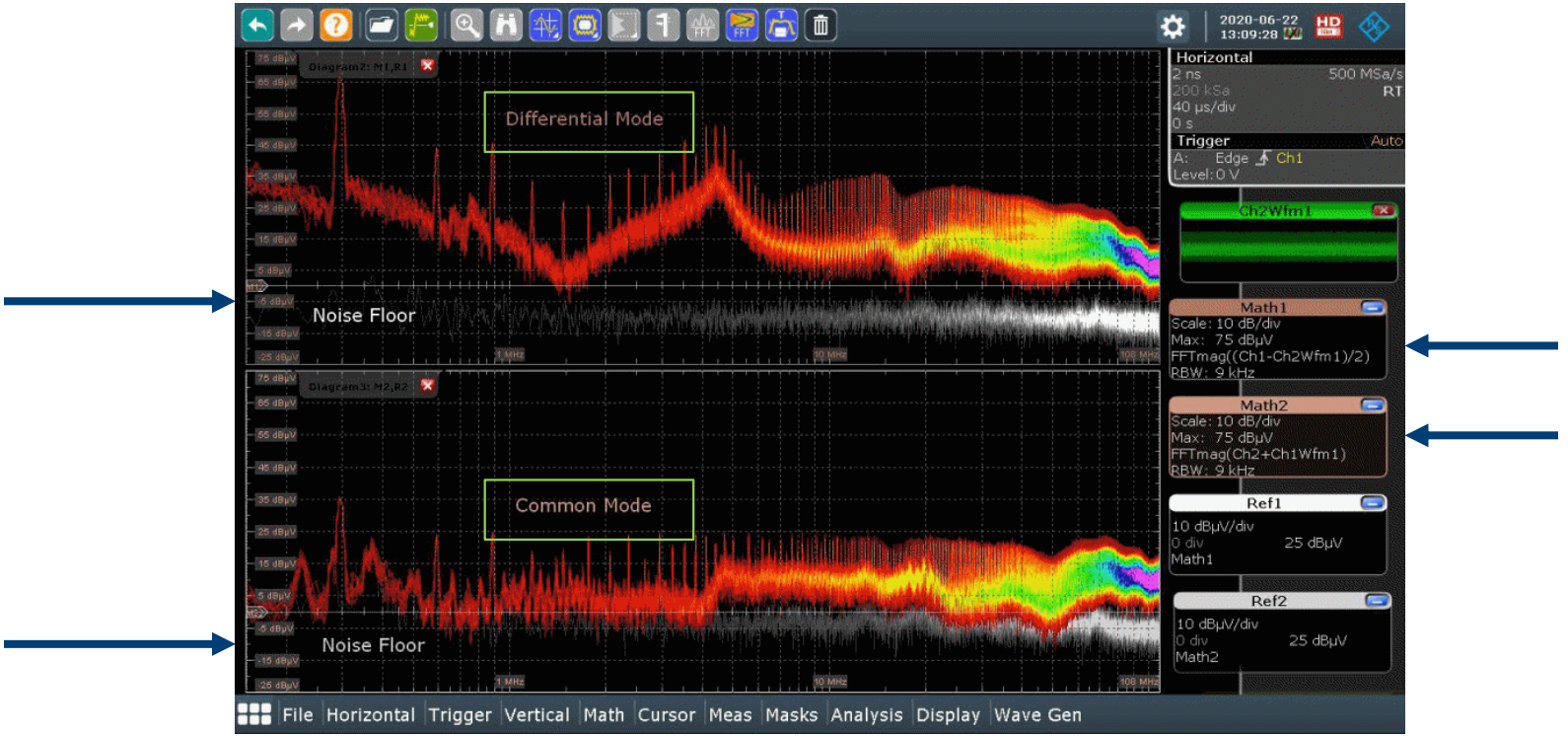
LISNs

ENHANCED MEASUREMENT SETUP FOR DEBUGGING





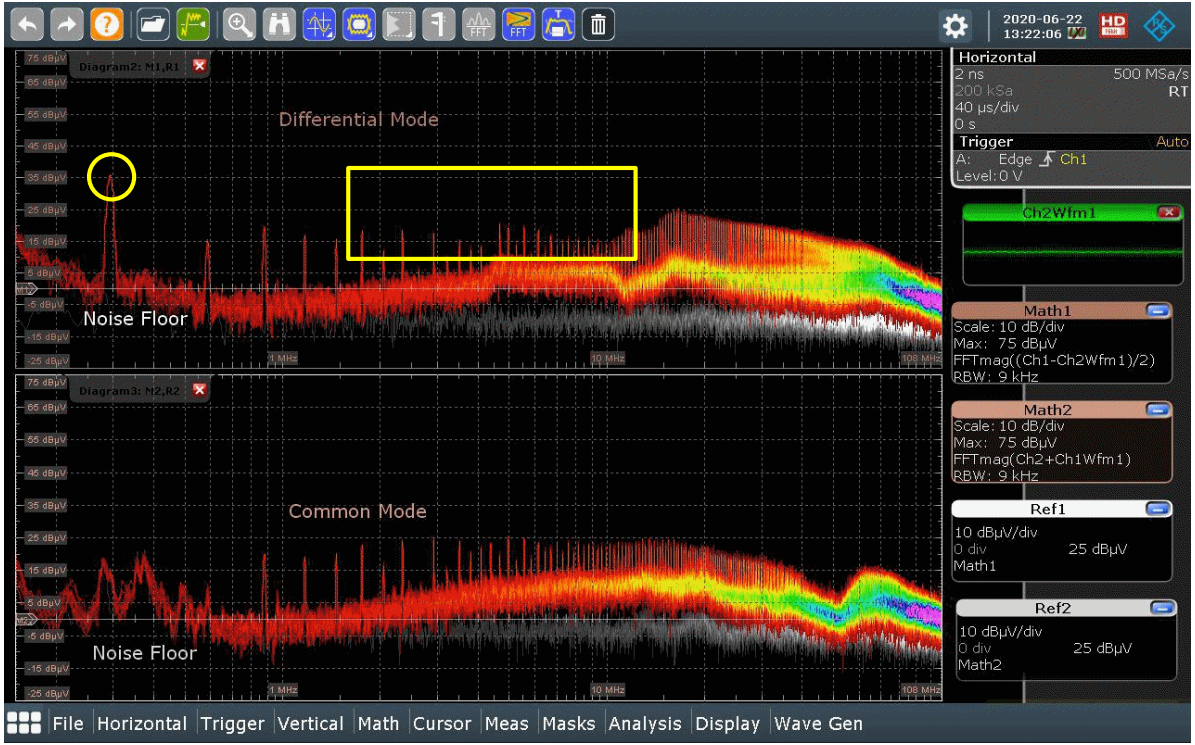
EMI SPECTRUM - NO FILTERING



EMI SPECTRUM – DM FILTER APPLIED

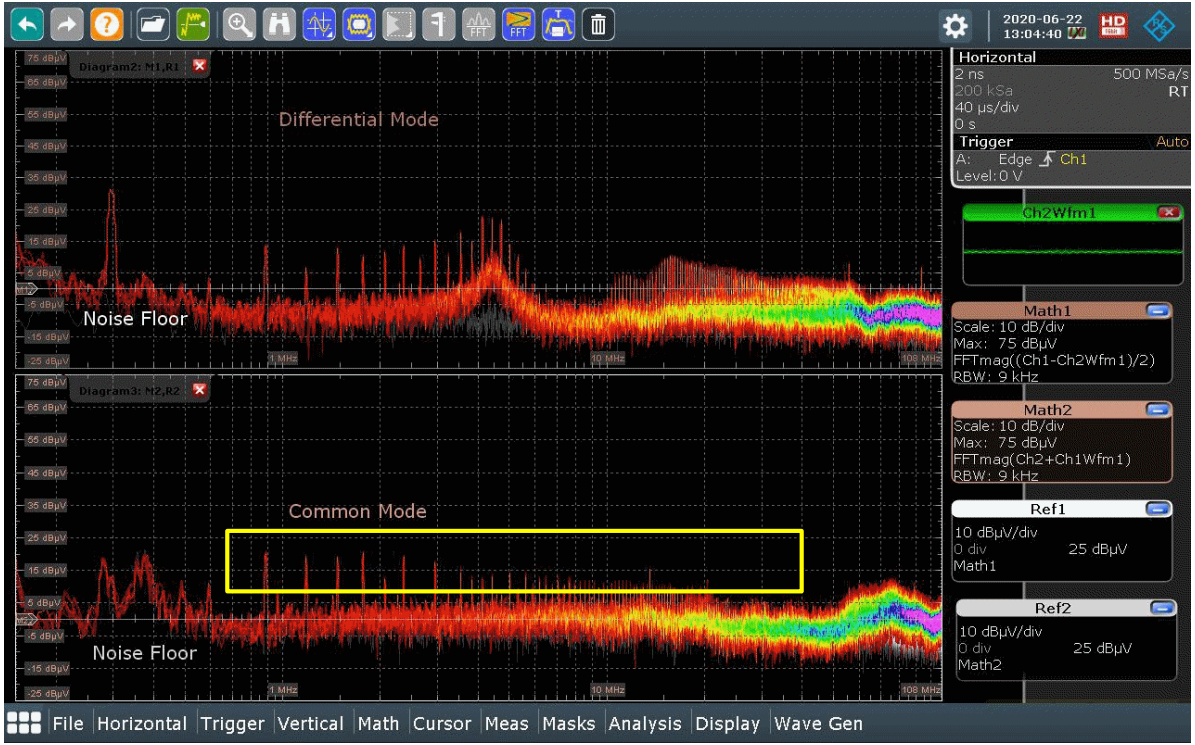
DM-Inductor

2 x X-Cap

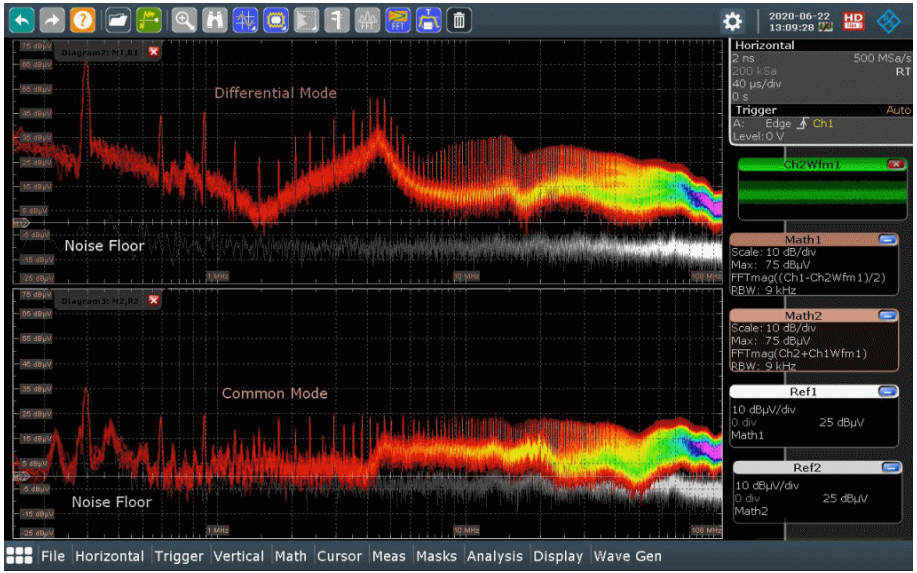


EMI SPECTRUM – CM AND DM FILTER APPLIED

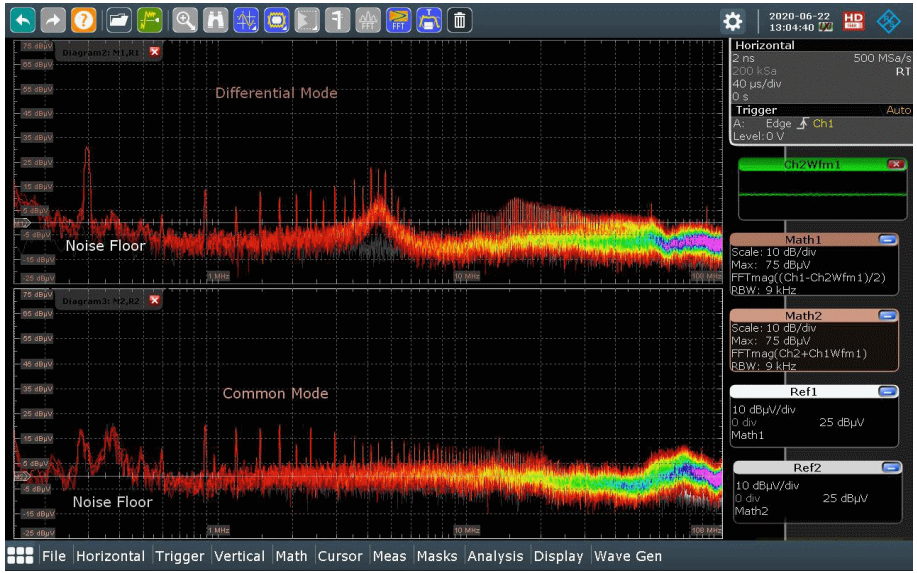
CM-Choke



EMI SPECTRUM – WITH AND WITHOUT FILTER



Without filter



With filter

CONCLUSION

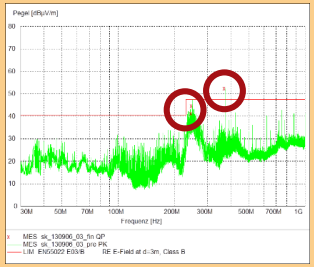
- To split differential mode signals from common mode (CM) is valuable for EMI Filter optimization.
- A powerful multiple channels FFT may help to differentiate between common mode and differential mode noise.

EMI DEBUGGING ANALYSIS STEPS
HOW TO USE NEAR-FIELD PROBES

EMI compliant testing / Test lab

EMI Debugging / R&D

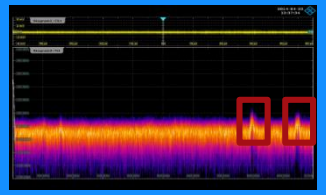
A) Far-field measurement



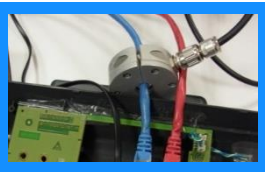
B) “Know your DUT”: List of potential interferer sources

Source	Frequency
Clock frequency	e.g. 25 MHz + Multiples
Ethernet PHY	e.g. 125 MHz + Multiples
Voltage converter / power adapter	broadband
…	

C) Reference measurement without DUT



D) Interferer current measurement to find out the coupling type

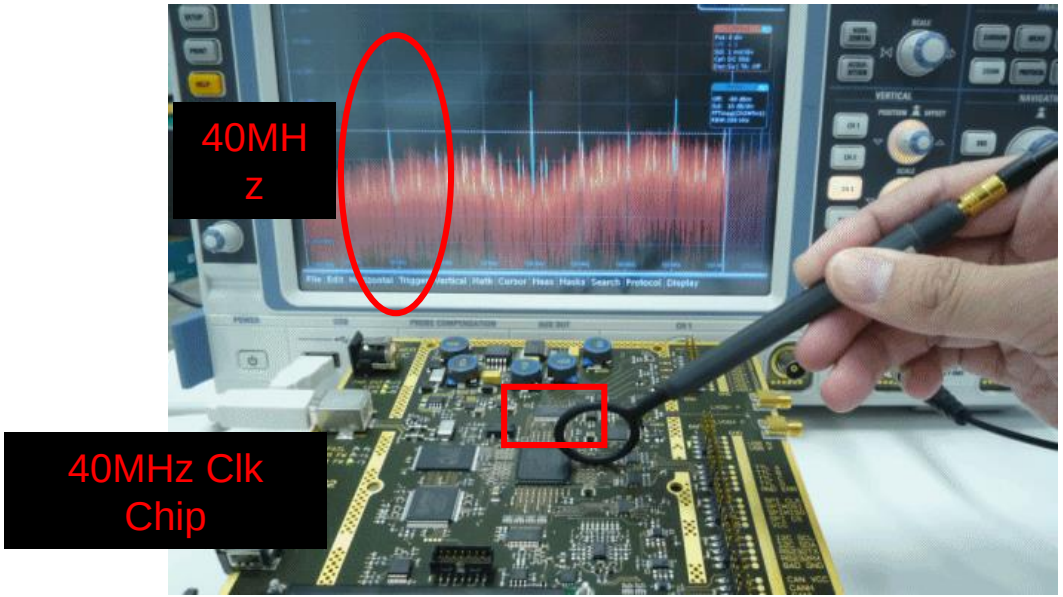


E) Nearfield probe to localize the interferer source

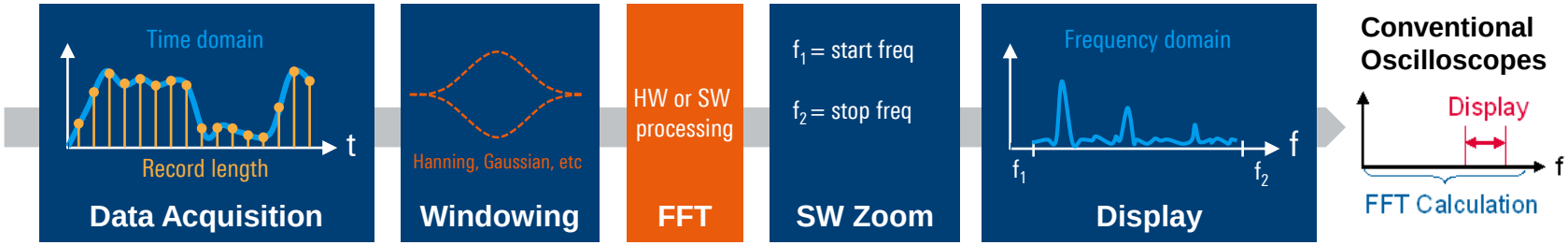
F) Analysis of counter-measures

EMI DEBUGGING ANALYSIS
NEAR-FIELD PROBES

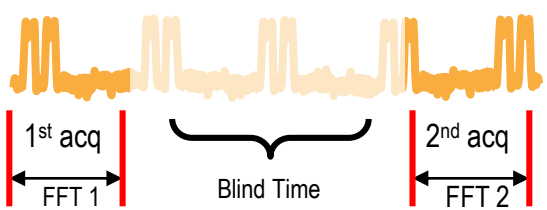
RTP/ RTO2000



SPECTRUM MEASUREMENTS
OSCILLOSCOPE USES FFT



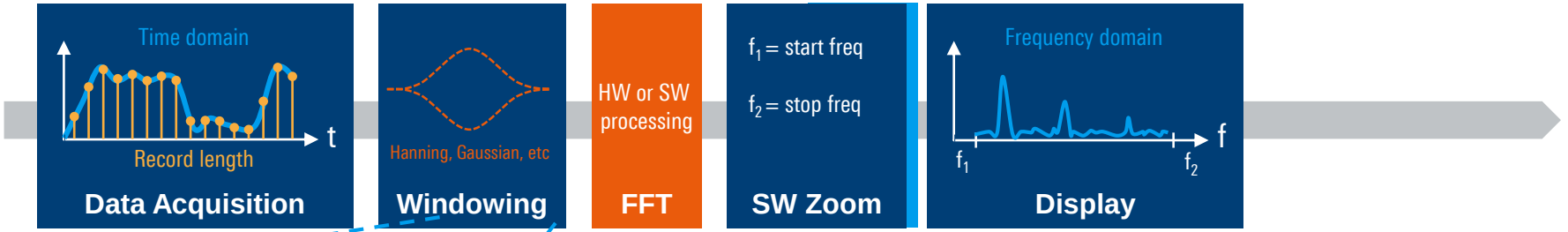
- Calculate FFT over entire acquisition
- Conventional Scope usually acquire one RL and reconstruct FFT then go on to acquire the next RL to compute the next FFT → Missing sporadic event

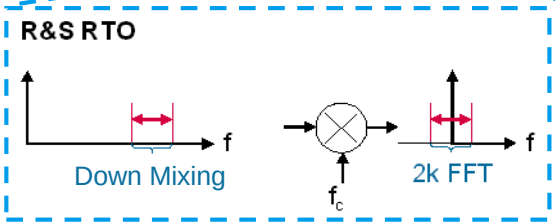


Disadvantages of conventional FFT :

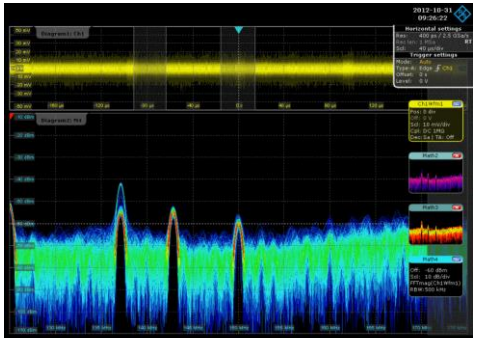
- Very slow speed / update rate
- Limited RBW due to insufficient RL
- Complex configuration (TD settings)

SPECTRUM MEASUREMENTS
R&S MODERN OSCILLOSCOPE SPEEDING UP FFT





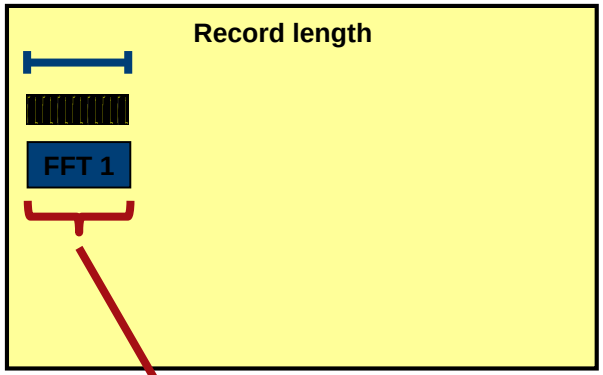
- Calculate only FFT over span of interest
- f_C = center frequency of FFT

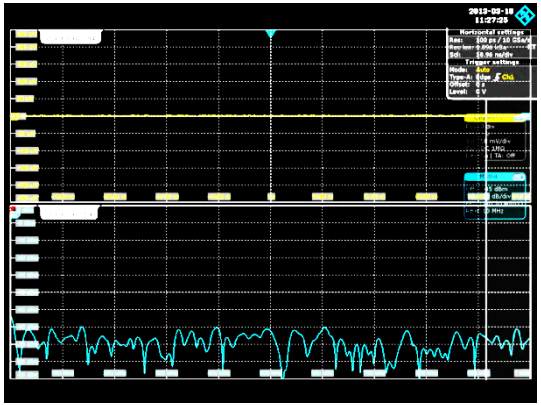


Advantages of R&S approach:

- Higher speed / update rate
- Good RBW without magnification
- Flexible configuration
- Multiple overlapping FFT able to find spurious faults

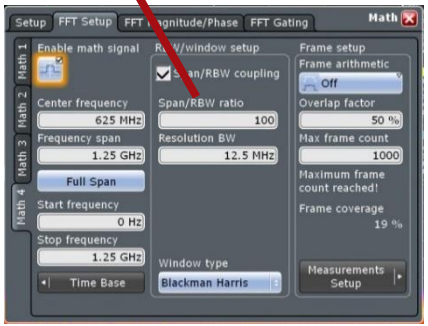
ADVANCED EMI DEBUGGING
OVERLAPPING FFT FUNCTIONALITY



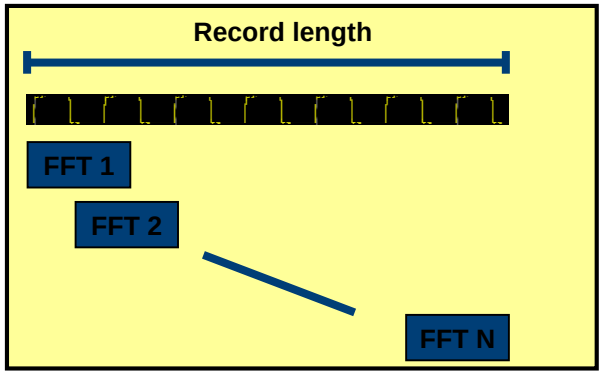


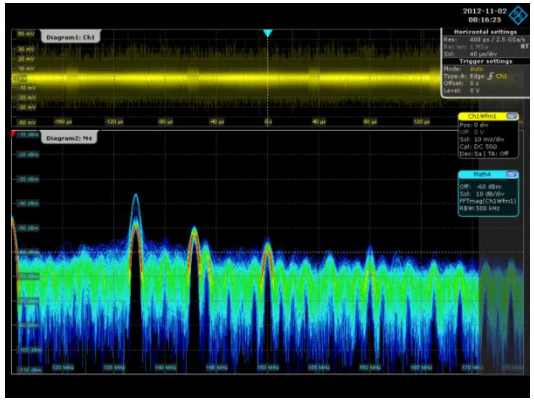
Record length
=
FFT Length

1 FFT



ADVANCED EMI DEBUGGING
OVERLAPPING FFT FUNCTIONALITY



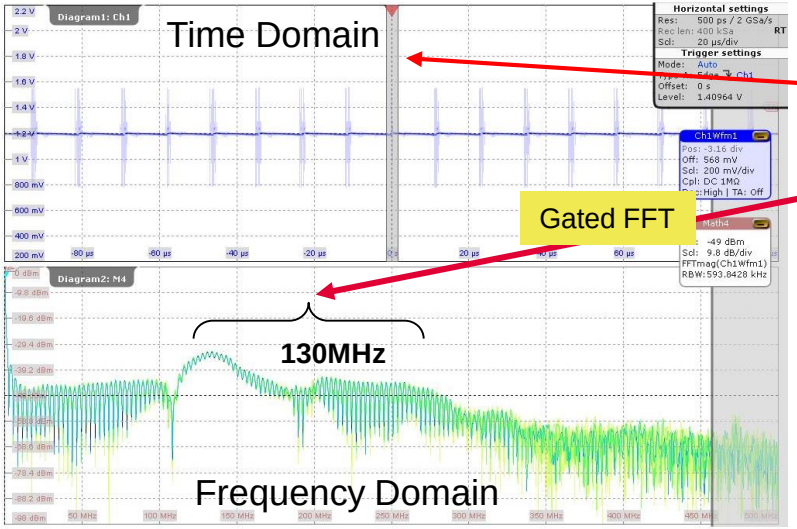


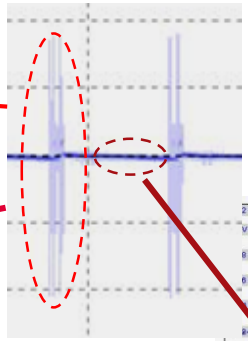
Record length
>>
FFT Length

~440 FFTs

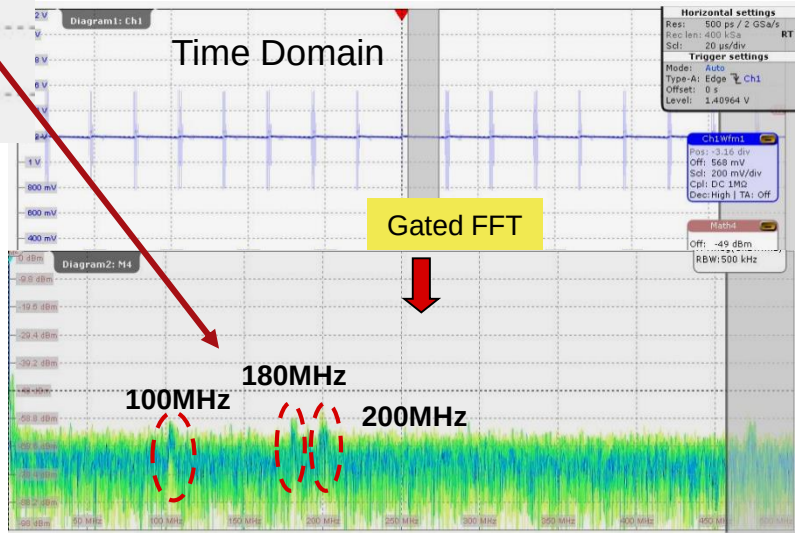
- **The time structure of the signal becomes visible (color coding) by overlapping FFT.**
- **High sensitivity for short emissions**
- **Correlated time-frequency analysis**
- **Semi-independent control of time domain and frequency domain**

ADVANCED EMI DEBUGGING
TIME-GATED FFT APPLICATION



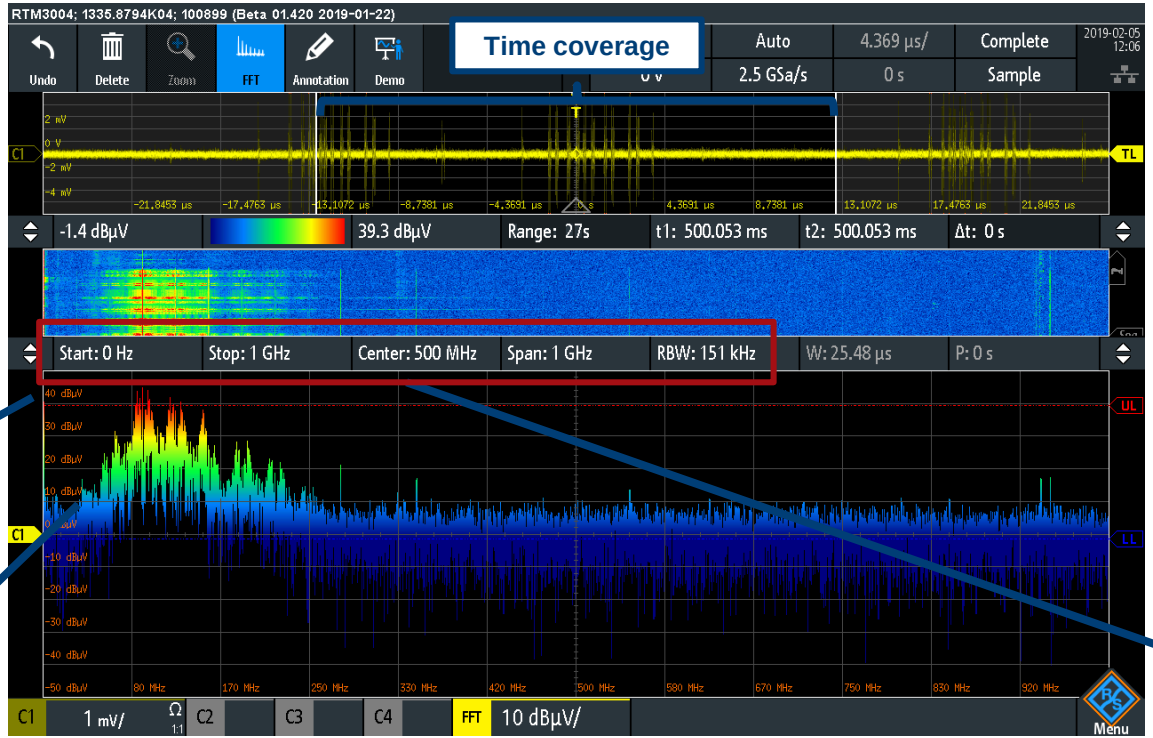


400ns Pulse



RTM3000 / RTA4000

BASIC EMI DEBUGGING WITH OSCILLOSCOPES



Waterfall diagram helps to show short emissions

dBuV scaling like in EMI measurements

Color coding display for better visibility

Time-frequency correlation of emissions

Directly set start, stop and resolution bandwidth

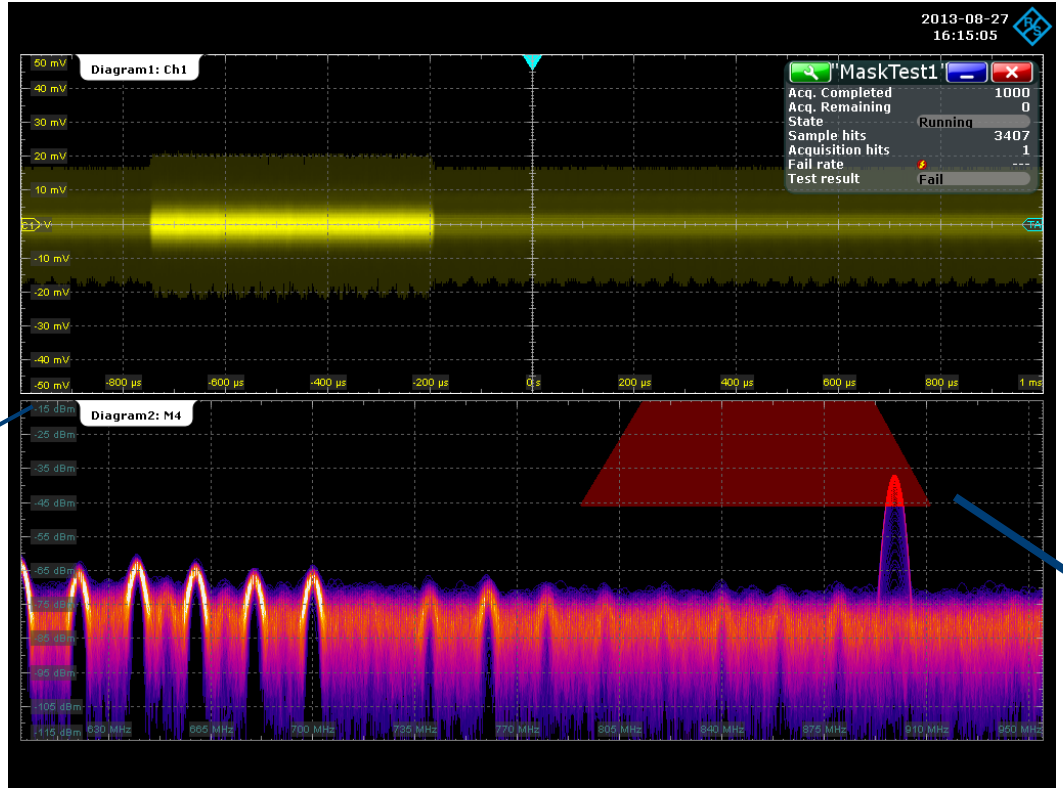
ADVANCED EMI DEBUGGING WITH OSCILLOSCOPES

RTP / RTO2000

Waterfall diagram (not shown here)

Flexible scaling, dBuV, dBm

Color coding display shows how often disturbance happens



Time-frequency correlation of emissions

Spectral mask allows „stop-on-violation“

RTP/ RTO2000

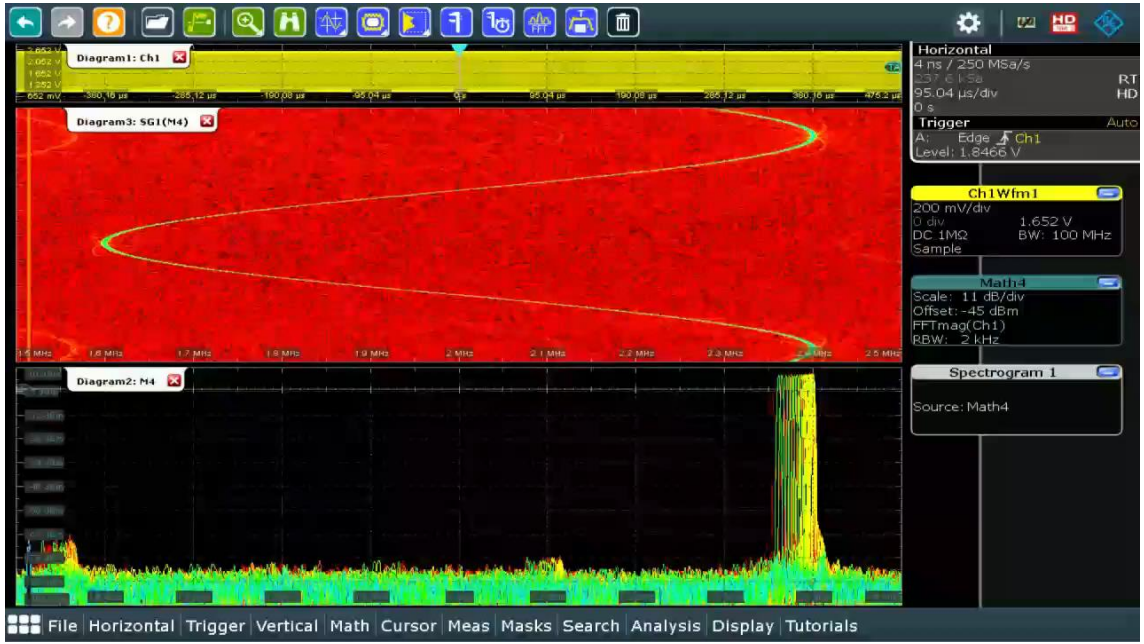
RECORDING OF OSCILLOSCOPES FFT FUNCTION

REAL TIME

Time Zone waveform

Waterfall diagram

Frequency Zone waveform



CONCLUSION

- Switched mode power supply causes the most EMI issue, EMI filter is important.
- EMI filter design depends on the selected topology.
- CM and DM noise can be analyzed separately with R&S Oscilloscope, to optimizing EMI filter.
- Oscilloscope is a general equipment and available on every R&D engineers desk.
- R&S Oscilloscope performs powerful EMI debugging ability with the advanced FFT technology.
- Both radiated and conducted emission can be tested well.
- R&S Oscilloscope is an excellent measurement equipment for EMI debugging.

THANK YOU!