

Design for EMI

Troubleshooting and Debugging EMI failures

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ROHDE & SCHWARZ

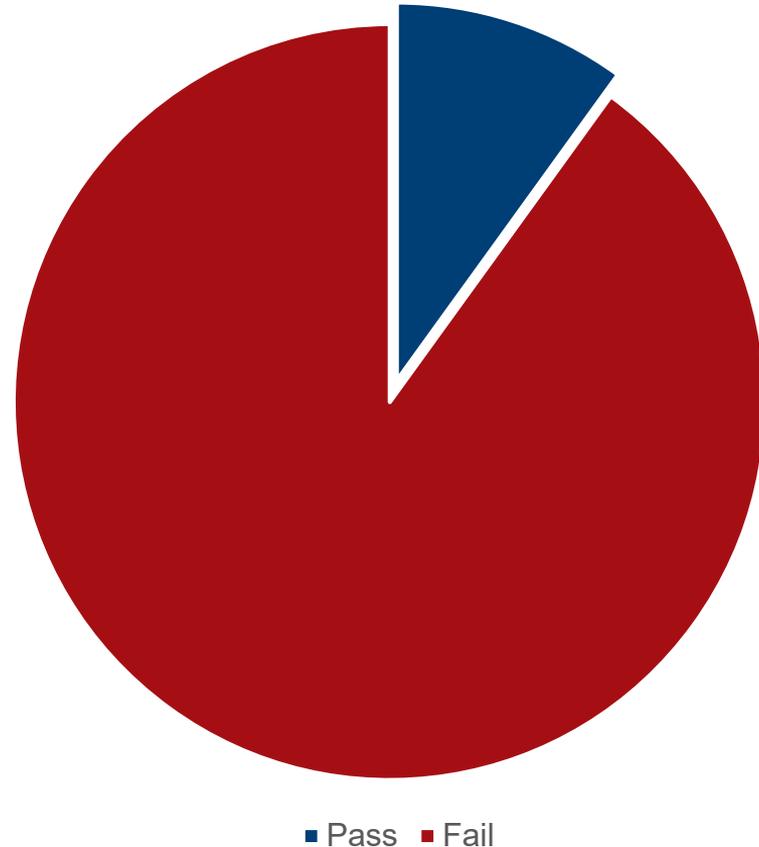
Make ideas real



EMI Agenda

- ▶ EMC Standards Overview
- ▶ Traditional EMI Test
 - Compliance test with a spectrum analyzer
- ▶ EMI Debug and Troubleshooting
 - Troubleshooting with a spectrum analyzer
 - Troubleshooting with a oscilloscope
- ▶ Measurement solution comparison

First pass compliance test:
Devices can have a **90% failure rate**



EMI is not new

- ▶ Faster Clocks
- ▶ Smaller Form Factors
- ▶ RF Sources
- ▶ High frequency switching supplies
- ▶ Plastic vs Metal Housing



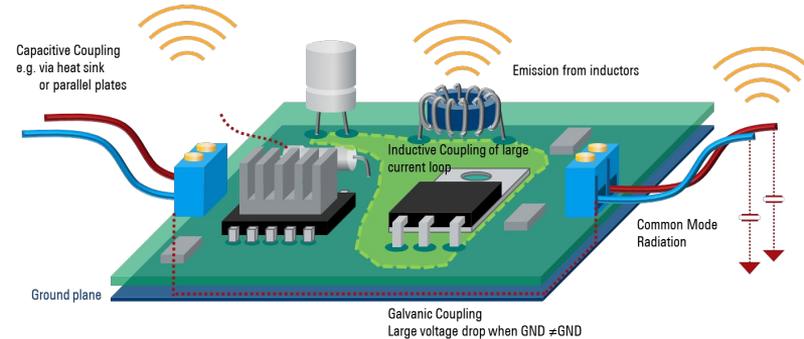
EMI Considerations for Your Design

- ▶ Specify known frequency source (clock and etc.)
- ▶ Generate a list of possible harmonic frequencies
- ▶ Determine the frequency of switching powers supplies
- ▶ Identify miscellaneous periodic waves

Causes of EMI

EMI is often caused by switching of signals:

- ▶ Power Supply
- ▶ Clocks
- ▶ DDR memory interface
- ▶ etc.



These are referred to as narrowband interference and generally occurs at very specific frequencies related to components on your board.

Application Example: Power Supply Design Compliance



RTO



Pre-compliance



Receiver
or
Spectrum Analyzer



Compliance

Application Example: Optimizing Wide Band-Gap Switching



Fast gate driver signal



Shaped gate driver signal

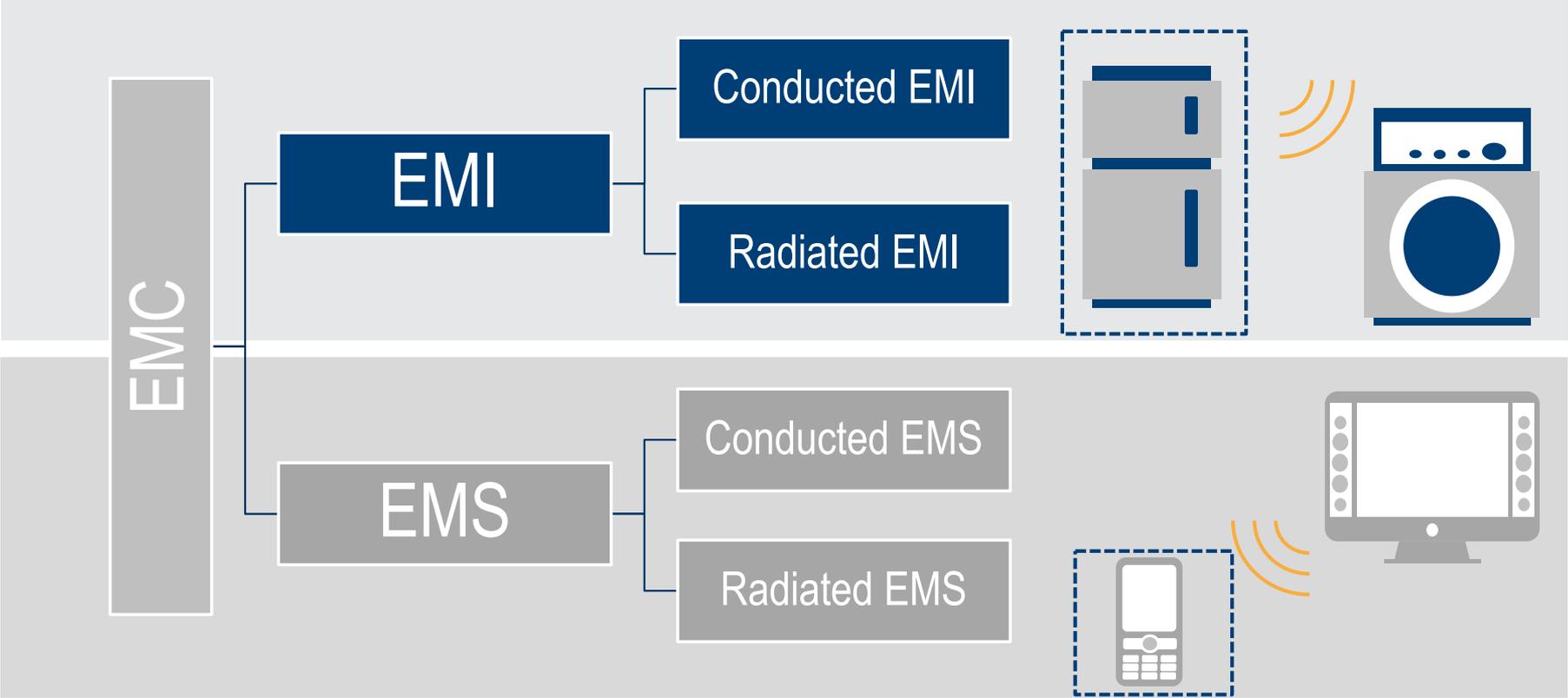


Significantly reduced emissions

EMC Standards and background



What is EMC?



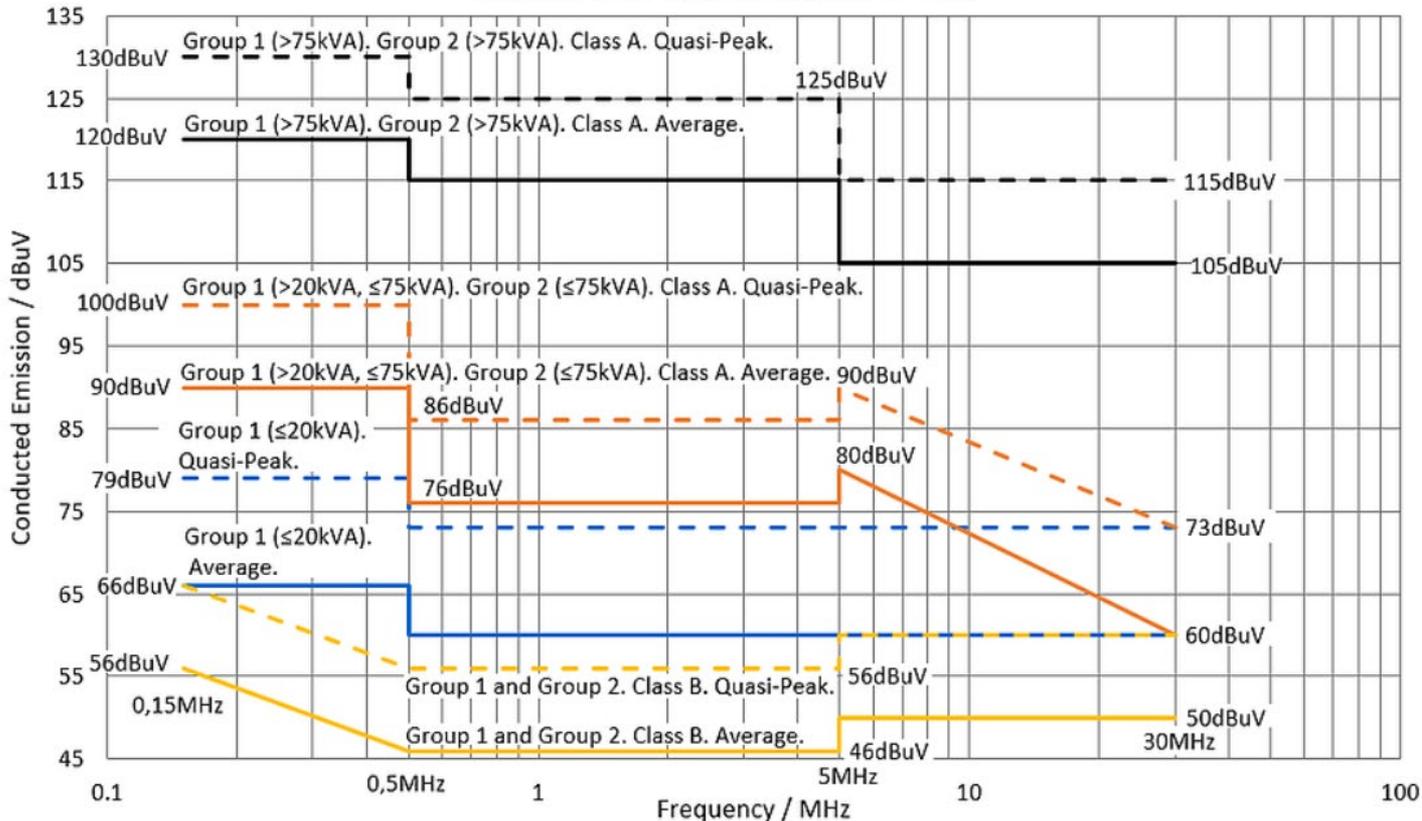
Standards

International Electrotechnical Commission (IEC)

Comité International Spécial des Perturbations Radio (CISPR)



Group 1 and Group 2. Class A and Class B.
Conducted Emission Limits [Mains Ports]



CISPR 11, ISM



ISPR 14-1, Appliances



CISPR 15, Lighting



CISPR 32, Multimeter



Concept

Design

Prototype

Verify

Pre-production

Simulation

Prototyping & Debugging

Pre-compliance

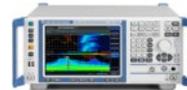
Compliance

Oscilloscopes

Spectrum Analyzer

(Precompliance) EMI Receiver

Compliance EMI Receiver



Often iterative

Preventive measures

Cost-effectiveness & available measures

Cost incurred

Phase

R&D

Prototype

Pre-Production

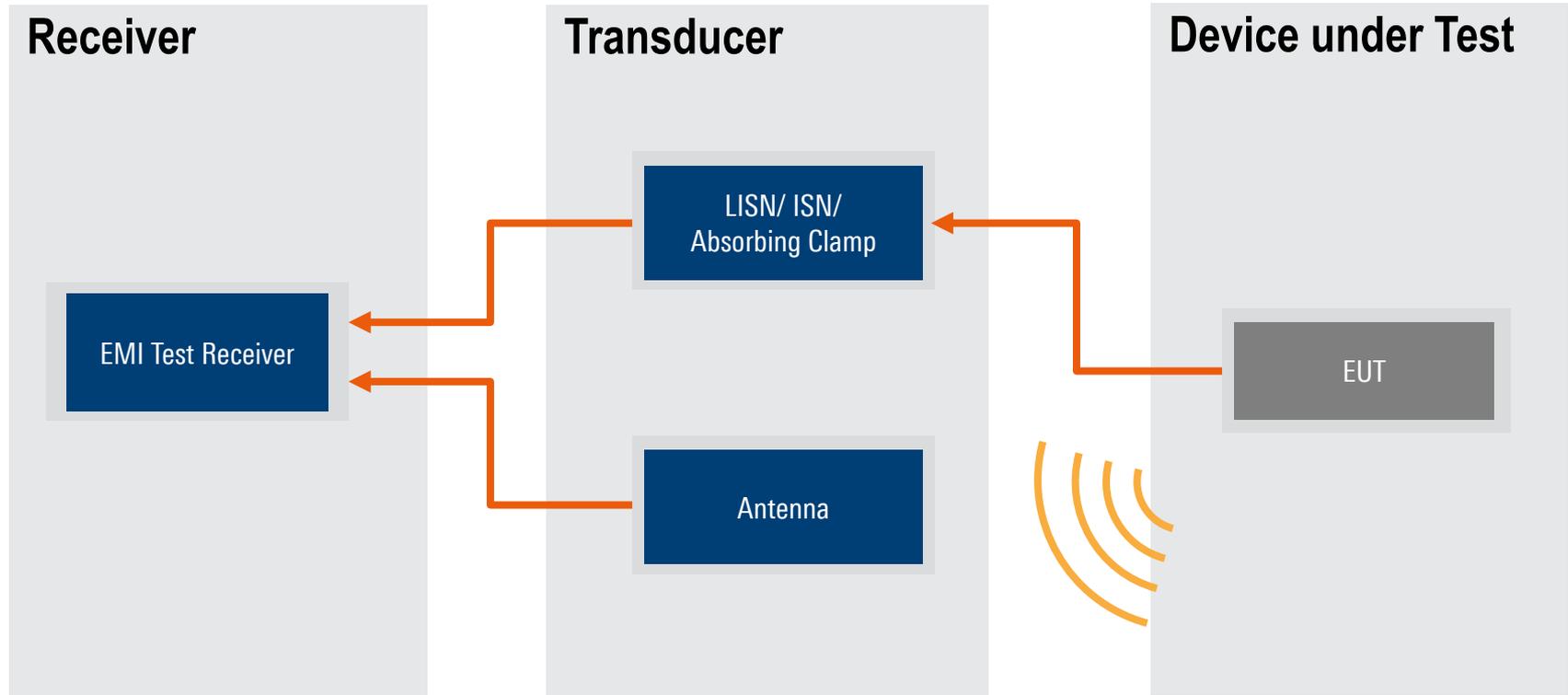
Manufacturing

Design

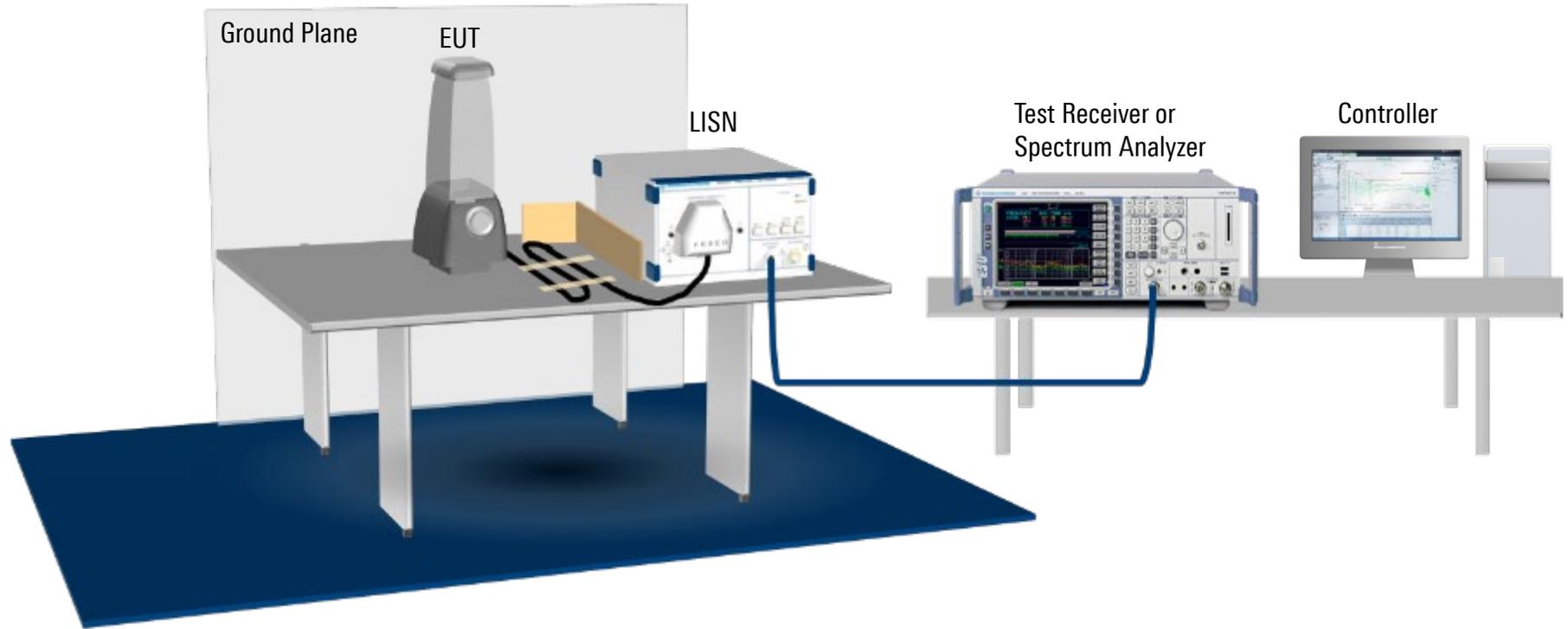
EMI Testing Traditional Approach



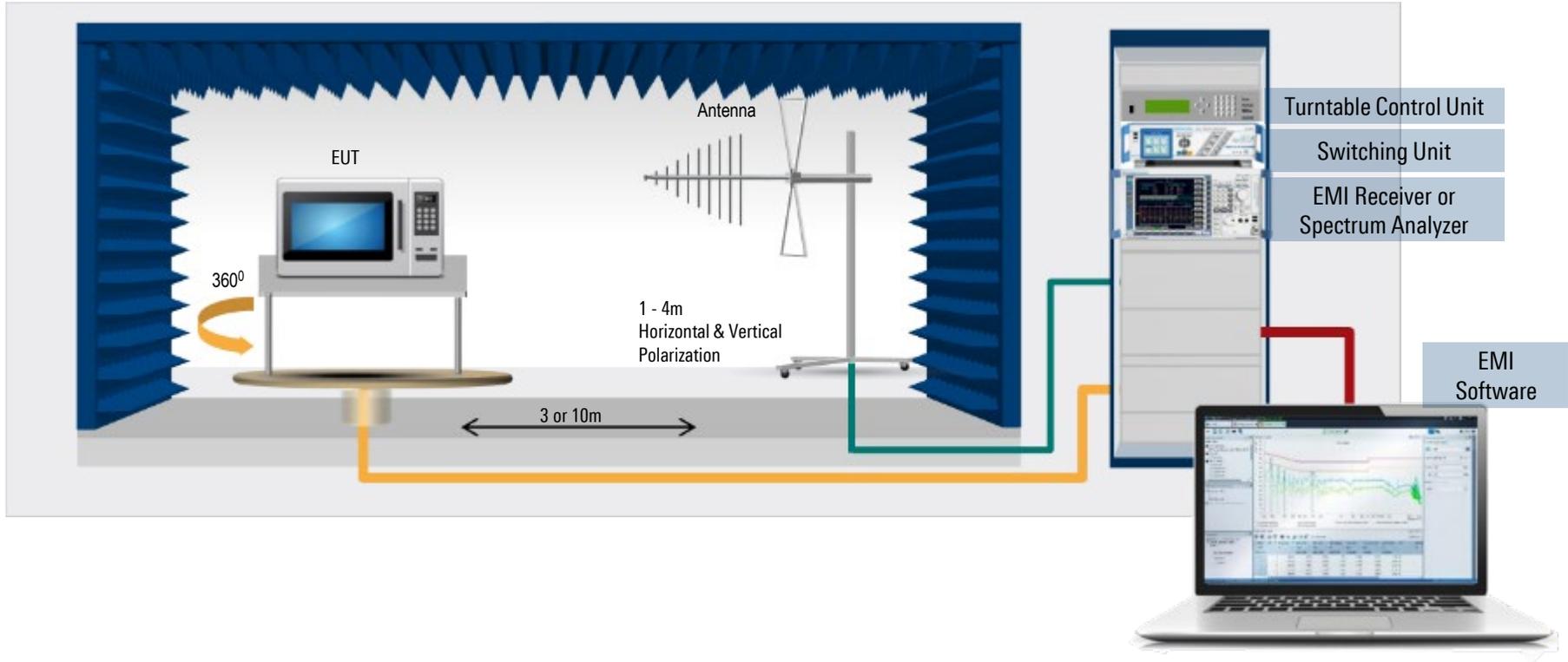
System Configuration



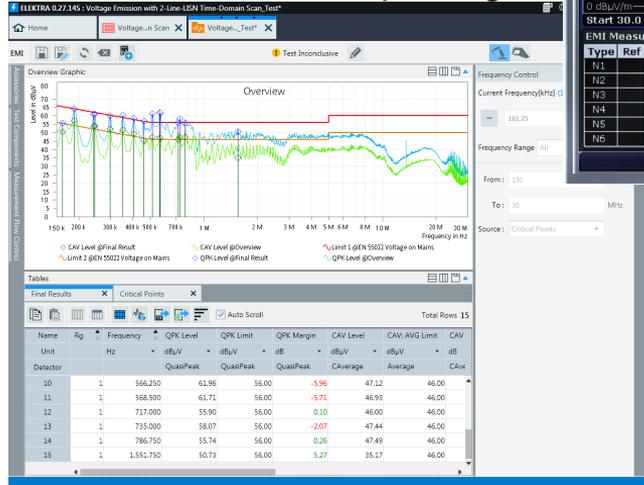
Conducted emissions test (AC Mains)



Radiated Emissions Test



ELEKTRA: PC Software for better automation, reporting



FSx-K54: EMI Measurement Application

EMI Scan with a Spectrum Analyzer

- ▶ Full compliance means full chamber, CISPR 16 compliant receiver
- ▶ Want results that will match these
- ▶ Start with the limit lines for the standard you are testing against
- ▶ Finding a quiet area is more and more challenging
- ▶ Consider use of a full compliance chamber



Compliance EMC Testing: Measuring Equipment Transducers



Antenna – electric radiated emission



Antenna – magnetic radiated emission



Artificial Network – Conducted voltage



ISN - Conducted voltage

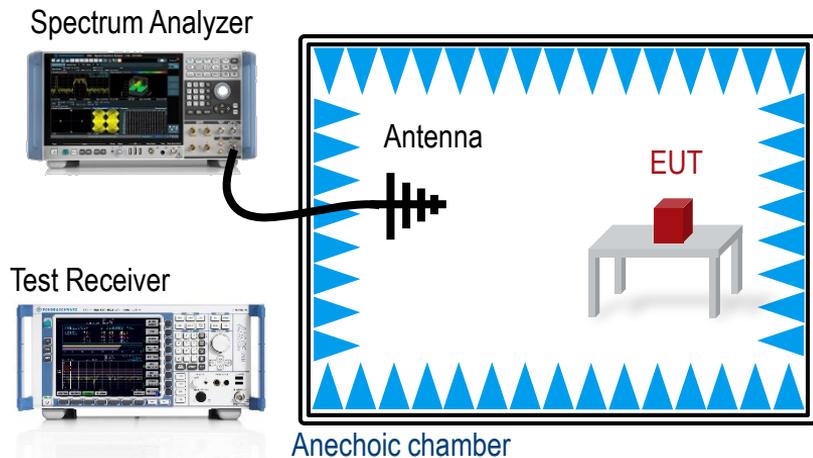


Current probe – conducted current



Absorbing clamp – disturbance power

EMC Standards vs EMI Measurements



Typical EMC Measurement

- ▶ Mostly far field in nature
- ▶ More accurate with less ambience noise
- ▶ More expensive to setup

Spectrum Analyzer



Oscilloscope



Near Field Probe

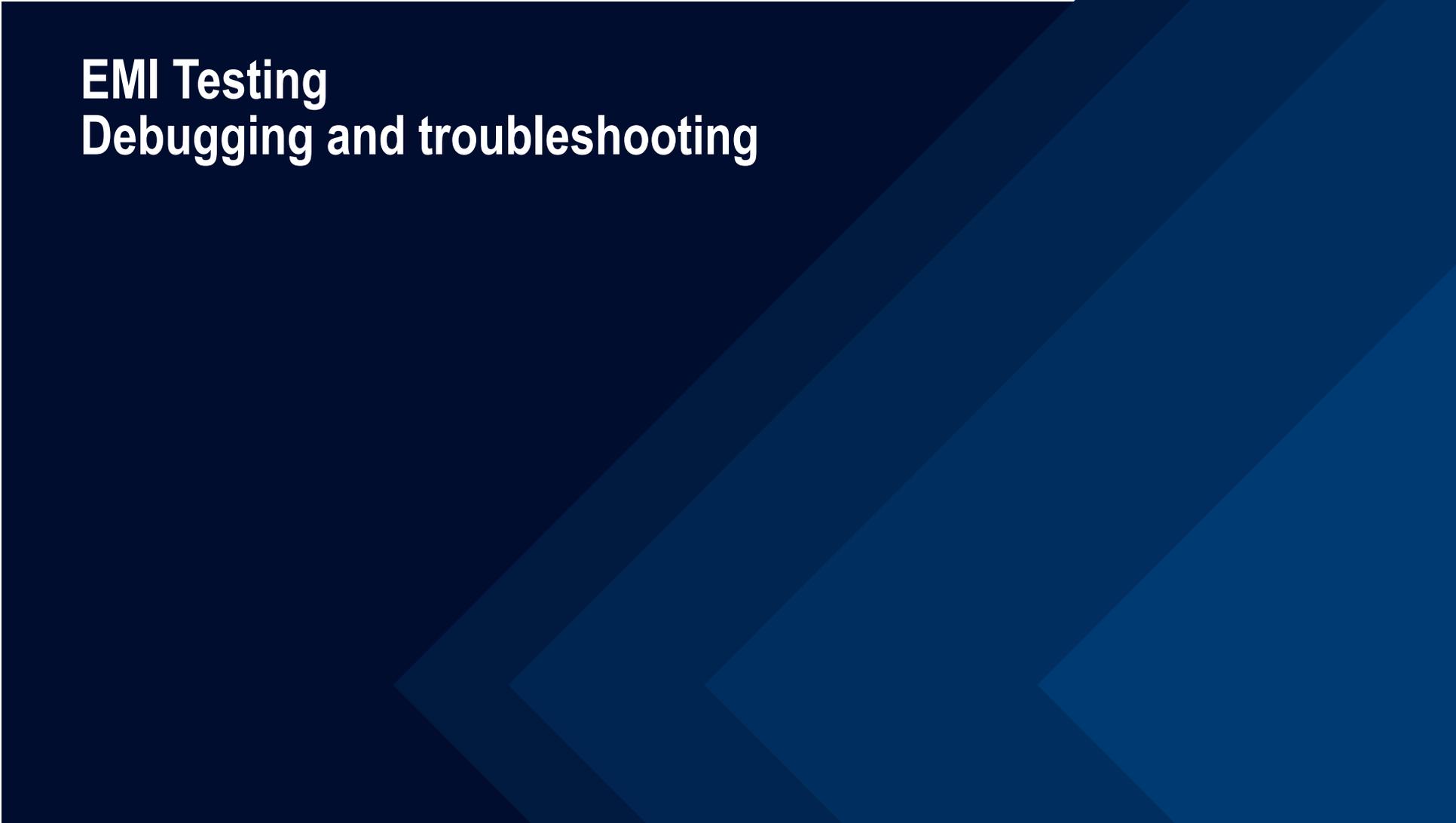


EUT

EMI Measurement with Scope or Spectrum Analyzer

- ▶ Near field measurements
- ▶ More noise and less accurate
- ▶ Cheap and flexible

EMI Testing Debugging and troubleshooting



Basic EMI Debug Process

Understand your DUT



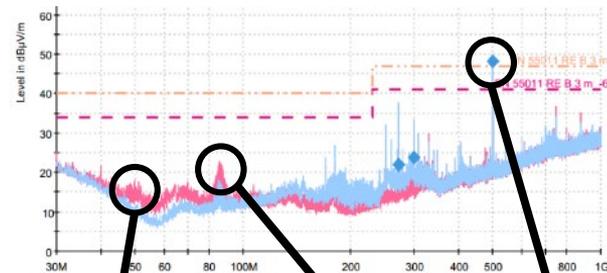
Measure DUT in anechoic chamber



Understand signal behavior of critical frequencies



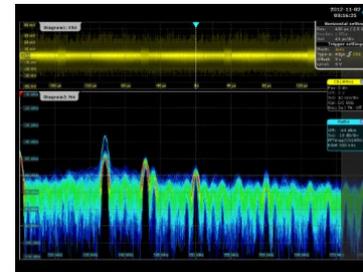
Identify signal sources with Near-field probes



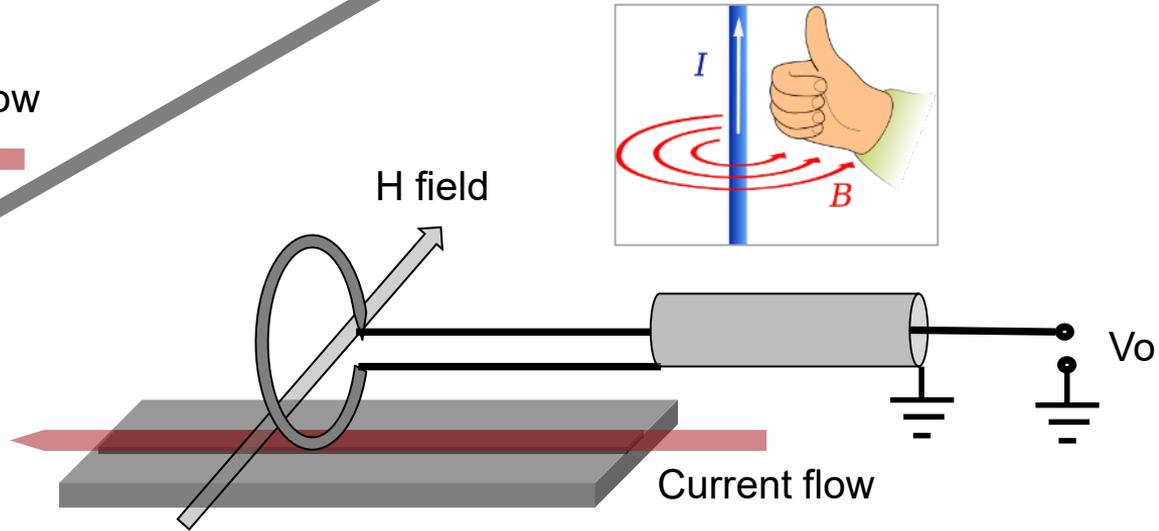
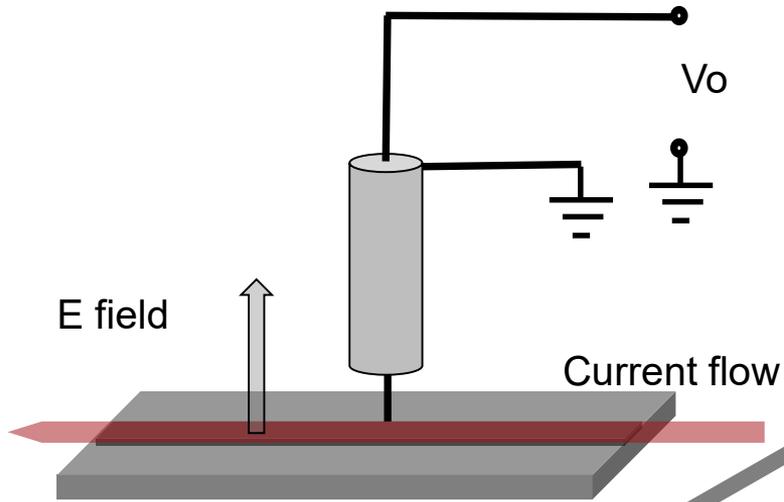
Noise from power supply

Unknown broadband noise peak

CW Emission



Near Field Probe Types





Near Field Probing

- ▶ Check for EMI issues periodically to make sure no obvious issues
- ▶ Can use a Spectrum Analyzer or Scope with 50 Ohm Input
- ▶ Scopes with 1 mV/div settings do not need pre-amplifier

Choosing an approach



Spectrum Analyzer or Oscilloscope for EMI debugging



?



Laptop
Power Supply

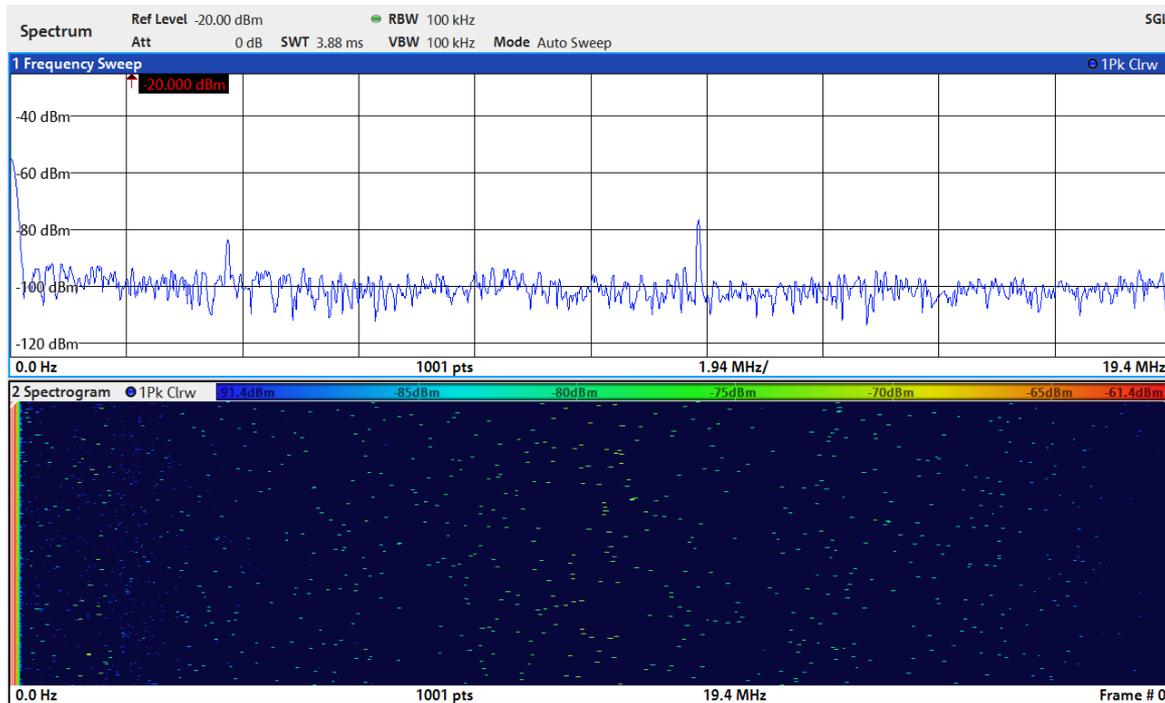


Troubleshoot with a Spectrum Analyzer

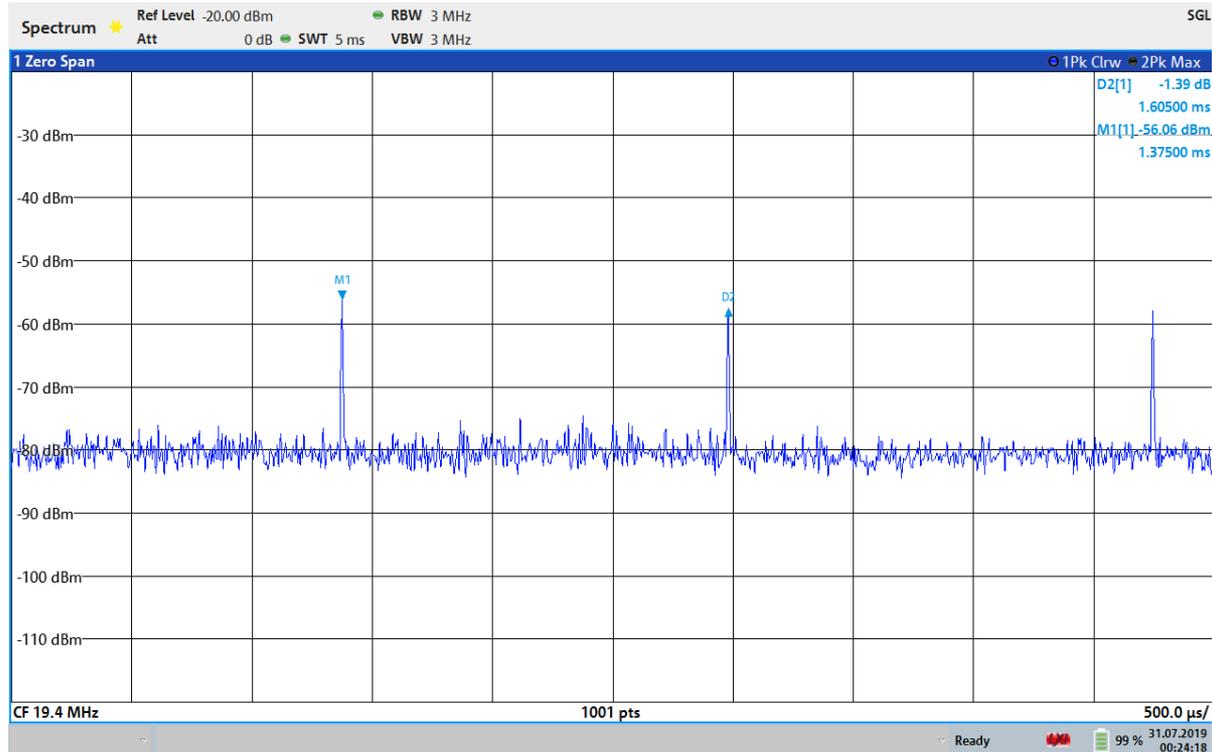
▶ DUT is a switching power supply

▶ Looking for “offending” signals that would fail a standards based limit line

▶ **Step 1:**
Hunt for the offending signals – use markers to find the highest power levels in the spectrogram (lower display)



Laptop
Power Supply



Troubleshoot with a Spectrum Analyzer

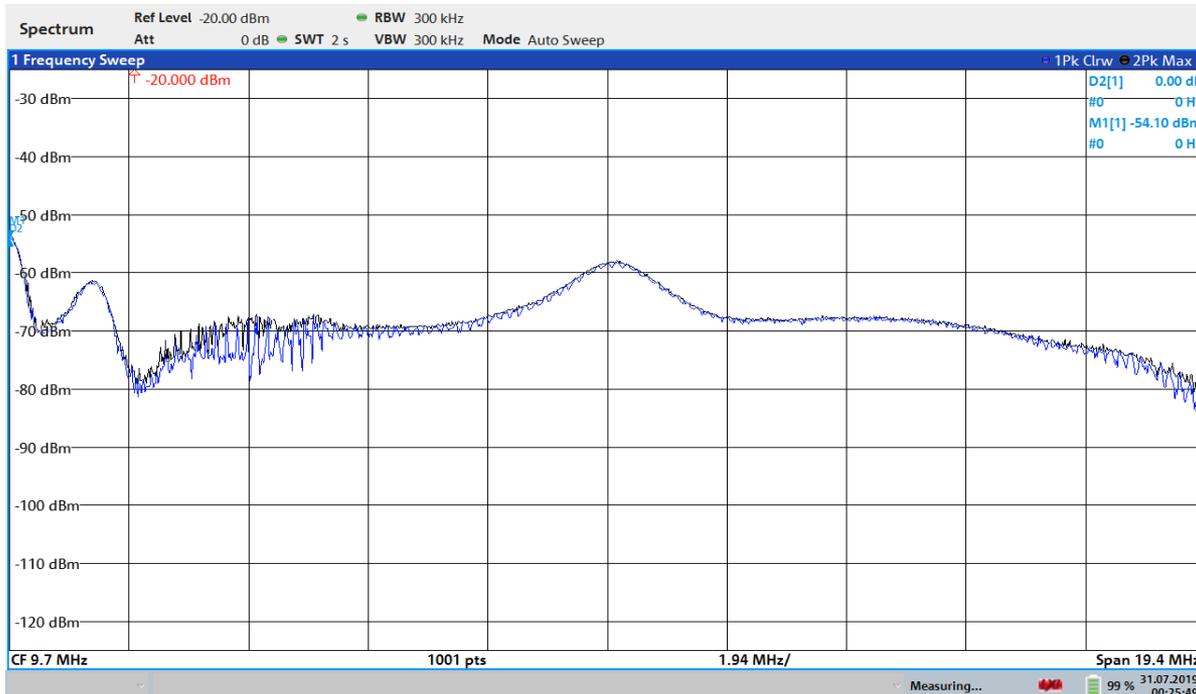
- ▶ **Step 2:**
Use Zero Span at the same frequency the offending signal occurs
 - 19.4 MHz in this case
- ▶ Zero span shows the RF envelope power
- ▶ Use markers to measure the time between pulses (clock signal) – 1.6 msec in this case

Laptop
Power Supply



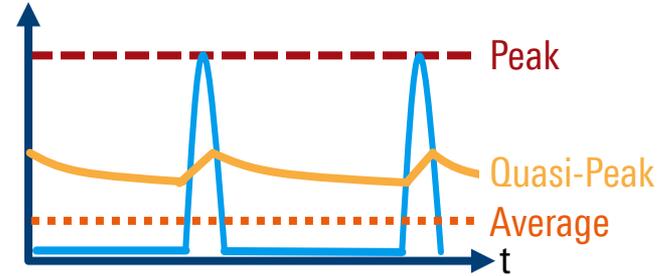
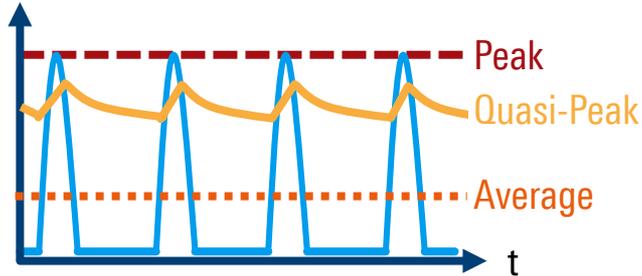
Troubleshoot with a Spectrum Analyzer

- ▶ **Step 3:**
Spectrum display
Set Sweep time to $>1000\times$
the measured time interval
(1.6 msec)
- ▶ $1000\times$ ensures enough
points in the spectrum trace
display to see the “pulse”
- ▶ (Or use a real time spectrum
analyzer)
- ▶ This is the worst case signal:
actual quasi-peak detector
might show a lower level
- ▶ Work to address this
offending emission



Quasi Peak

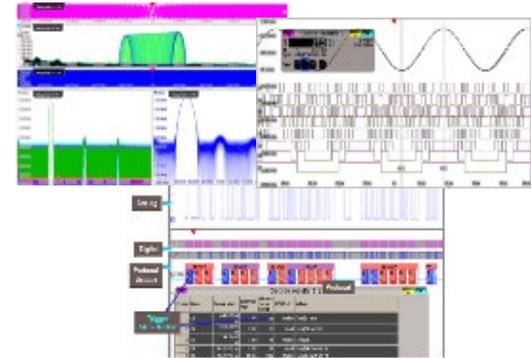
- ▶ Quasi-peak means 'not quite peak', or 'aiming towards peak but not actually peak'
- ▶ Quasi-peak detector was believed to better indicate the subjective annoyance level experienced by a listener hearing impulsive interference to an AM radio station



Spectrum analyzers and EMI receivers
both have a quasi-peak detector

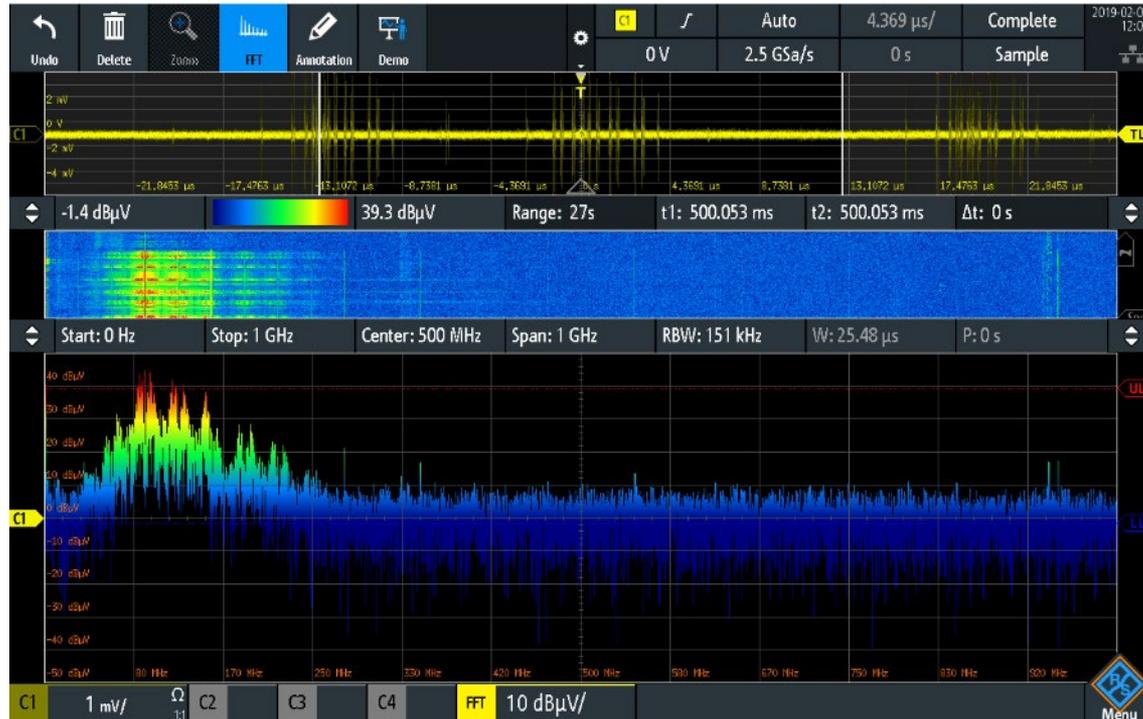
Important Scope-Parameters for EMI Debugging

Bandwidth	100 MHz to 4 GHz	Analog capture range of the EMI signals
Sample rate	> 2X Analog BW	Max FFT Frequency is half the sample rate
Coupling	50 Ohm	Near Field Probes are designed for 50 Ohm systems
Vertical sensitivity	1 – 5 mV/div	Check HW settings, larger requires a pre-amplifier
<hr/>		
FFT Span / RBW	Span to Resolution bandwidth factor (100 – 1000)	
FFT gating	Easily isolate spurious spectral components in time domain	
FFT Zone Trigger	Draw a mask or area on an FFT to trigger the oscilloscope	



Modern Scope FFT Capabilities

Correlation of time and frequency information

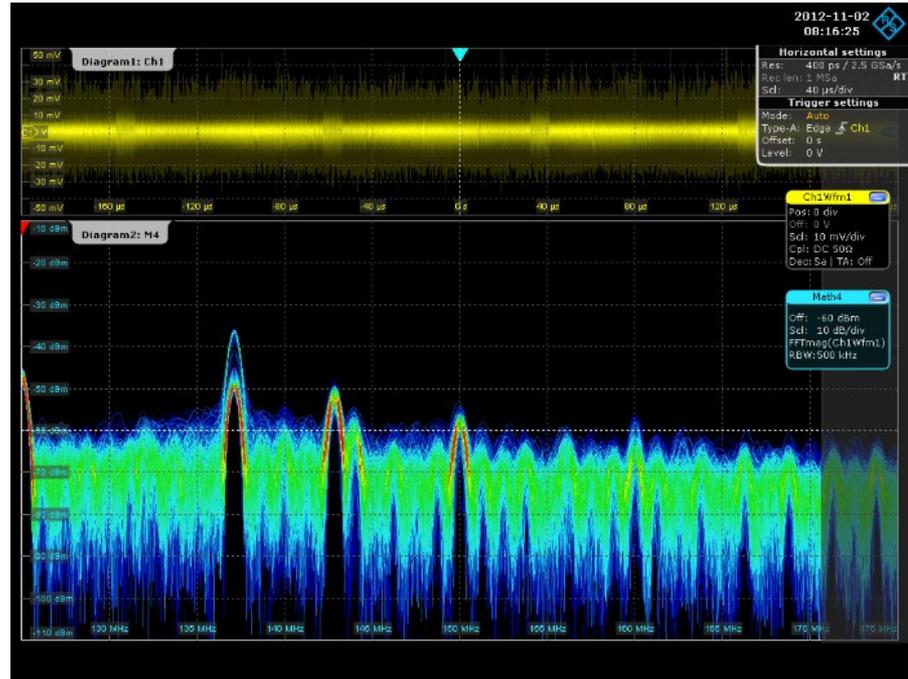
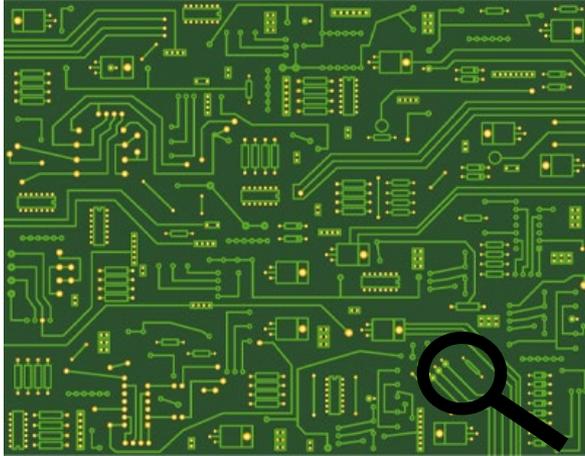


Modern Scope FFT Capabilities

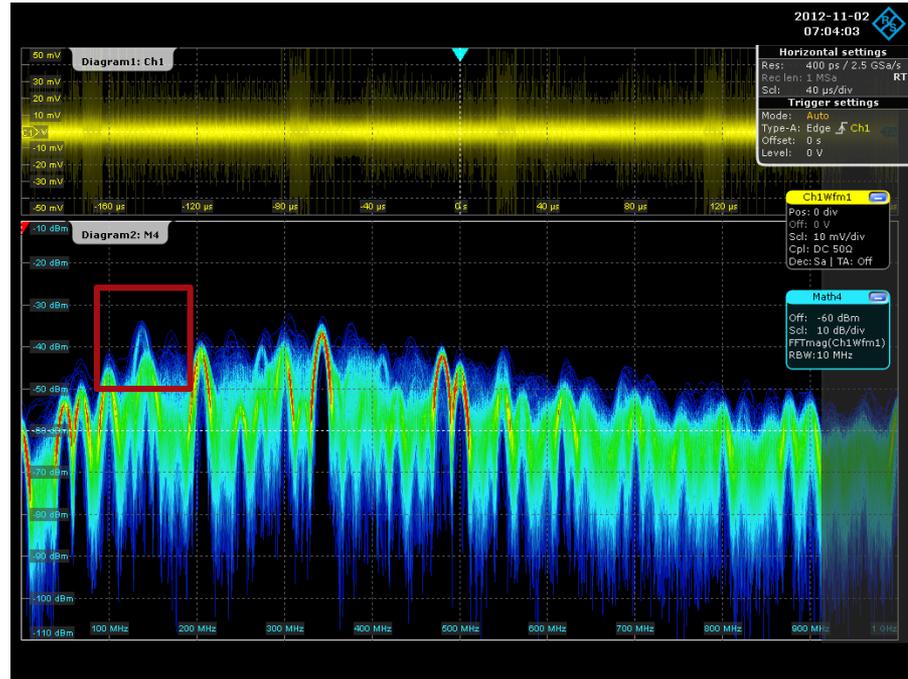
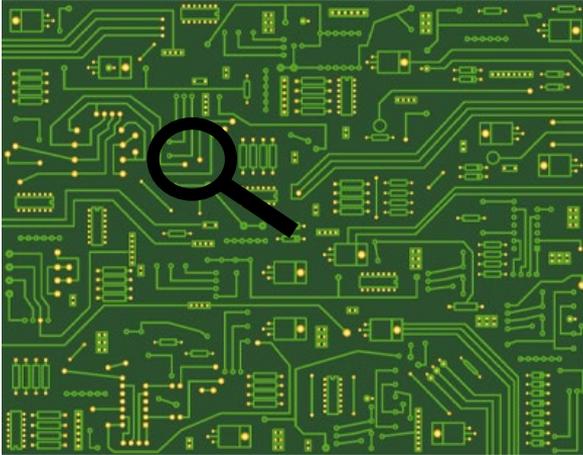
Correlation of time and frequency information



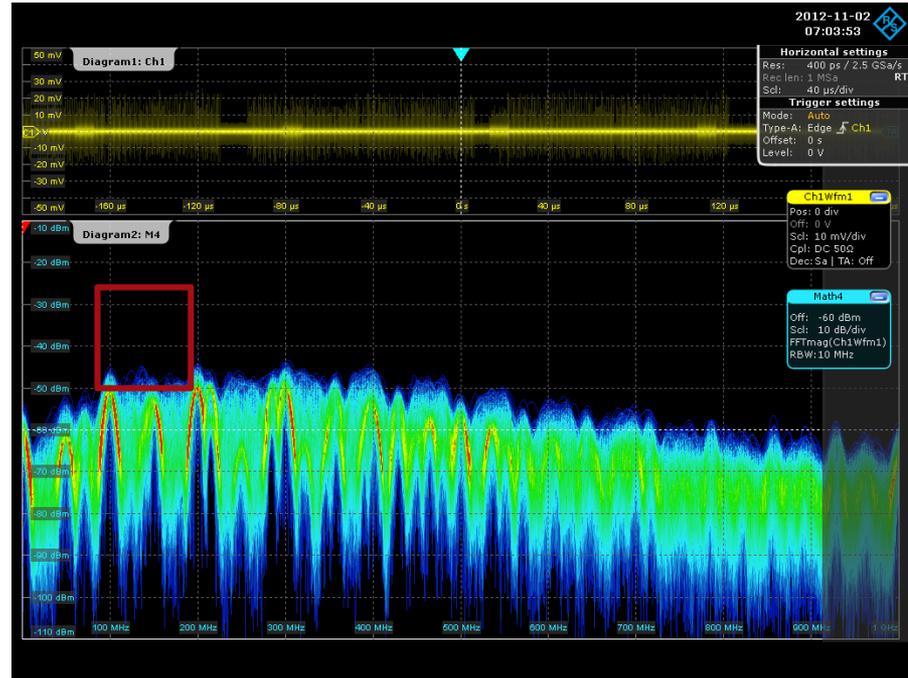
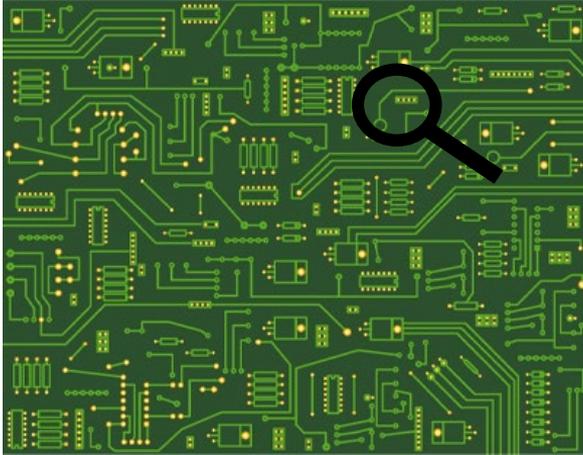
Observe the Spectrum While Scanning With a Near-Field Probe



Observe the Spectrum While Scanning With a Near-Field Probe

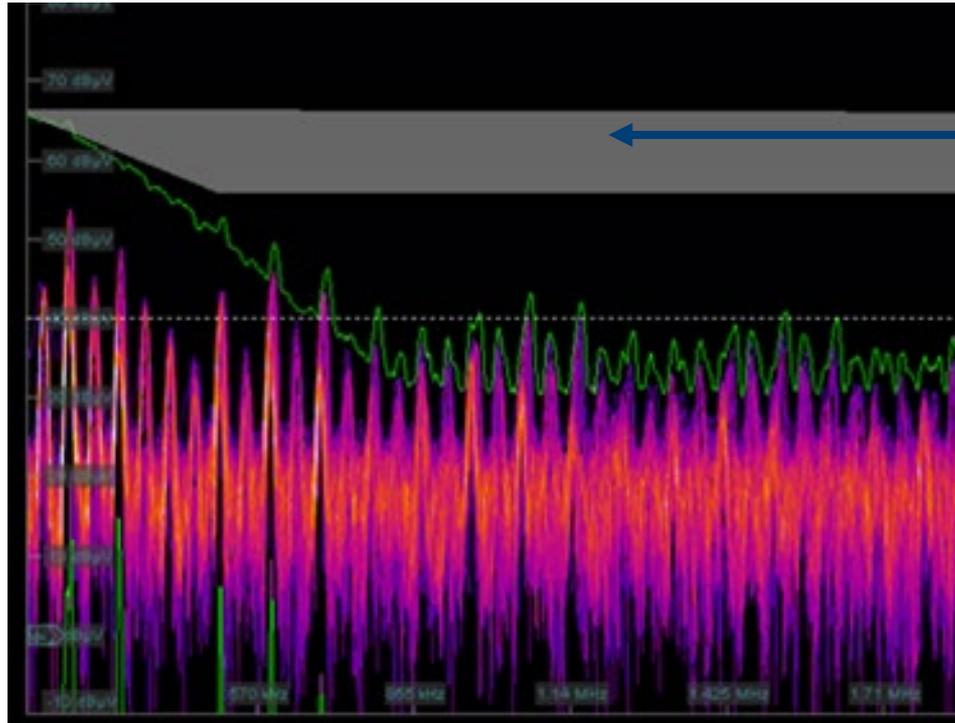


Observe the Spectrum While Scanning With a Near-Field Probe



Modern Scope FFT Capabilities

Mask Test / Zone Trigger



User-defined
spectrum mask

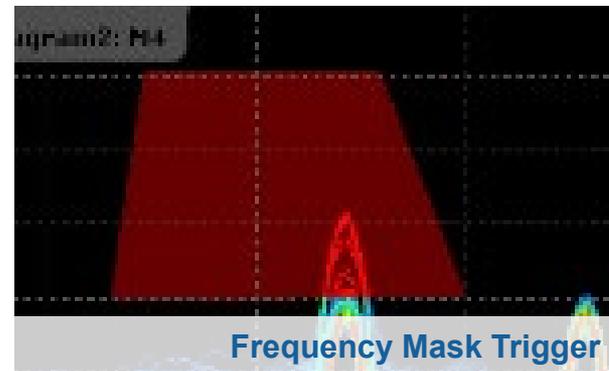
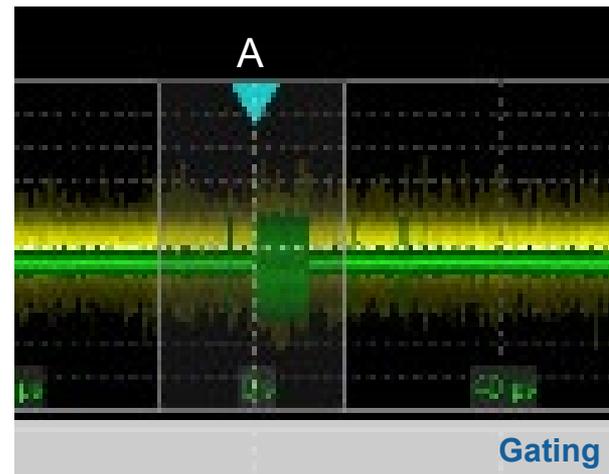
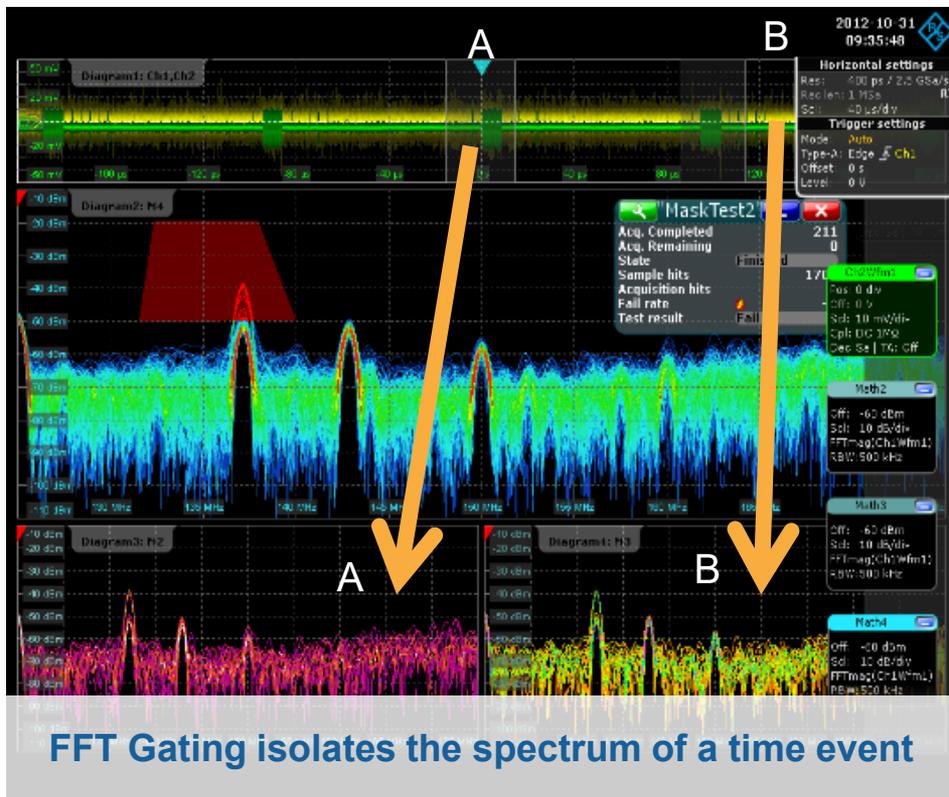


“Stop-on-violation”
function



Analyze underlying source

FFT Gate specific moments in time



EMI Receiver, Spectrum Analyzer and Oscilloscope

Feature	EMI Receiver	Spectrum Analyzer	Oscilloscope
General purpose RF	-	✓	✓
Wireless standards WLAN, IOT, Cellular	-	✓	✓
Serial data bus decode	-	-	✓
EMI detectors / bandwidths (incl. QP)	✓	✓	-
EMI Meas. Dynamic Range & Sensitivity	Very high / Very high	High / Very high	Medium
Log-scale & limit lines	✓	✓	(✓)
Scan Types	All (Sweep, step, time-domain, zero-span)	Some (Sweep, zero-span)	No scan
Time/frequency correlation possible	✓	✓	✓
Gapless recording	Very long	Long	Medium
Auto ranging	✓	-	-

R&S Solutions



R&S Solutions for EMI from R&D to final conformance test

Oscilloscopes

- ▶ From 50 MHz Handheld to high performance 16 GHz
- ▶ Integrated instruments: logic analyzer, protocol decoder, arbitrary waveform gen, TDR
- ▶ RTM, RTE, RTO, RTP



Spectrum Analyzers

- ▶ Full line up from high performance to economy class and hand held
- ▶ Spectrum Analyzers starting at \$1,880 US



Accessories to EMC Systems

- ▶ From Near Field Probes, antennas and LISNs to full test chambers & EMC Receivers

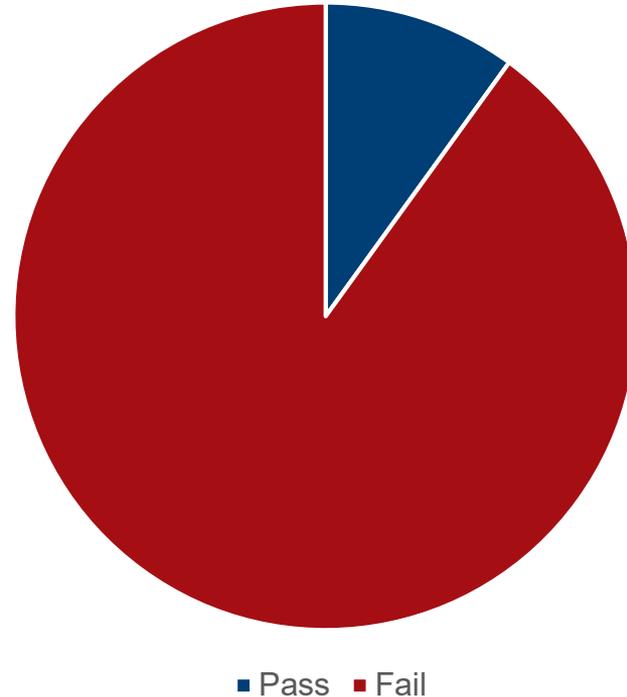


Summary

1. EMI is complex but can be tested easily
2. Test EMI early in the design process
3. Oscilloscopes and Spectrum Analyzers can be used for EMI

R&S has full product portfolio from probes to chambers with technical experts to help!

First pass compliance test:
Low cost IOT device
90% failure rate



BACKUP SLIDES

Why Pre-compliance? EMI testing workflow

**50% of projects fail EMI/EMC testing the first time?
~\$800-2500 per day test**

First level debugging (In House)

- Identify source of problems
- Design review

Pre-compliance (In House/3rd party)

- Catch significant failure early
- Save time, cost \$

Compliance (Test House)

- Cost \$\$\$\$\$
- Time consuming



EMI pre-compliance measurements
helps to reduce risk of failure
before compliance testing!

HZ-14 and HZ-15



CISPR EMI Standards (Commercial Products)

CISPR 11



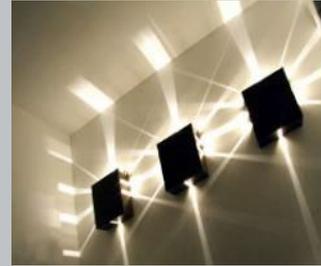
Industrial, Science
and Medical

CISPR 14-1



Household
Appliance

CISPR 15



Lightings

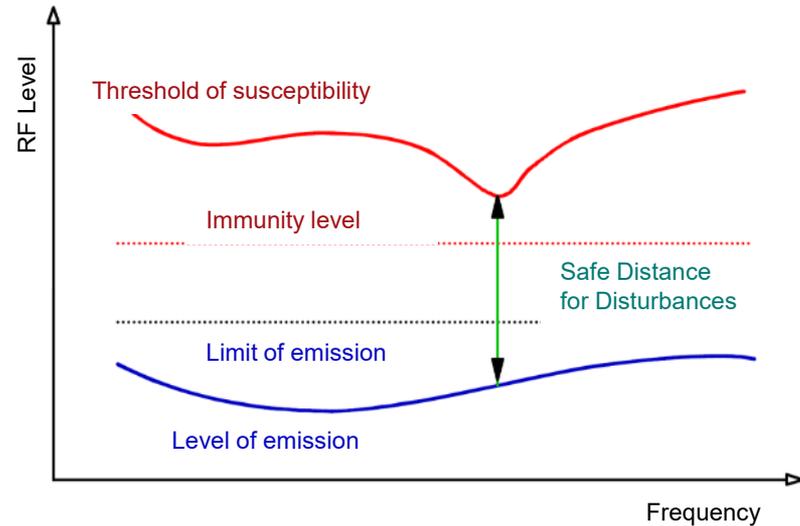
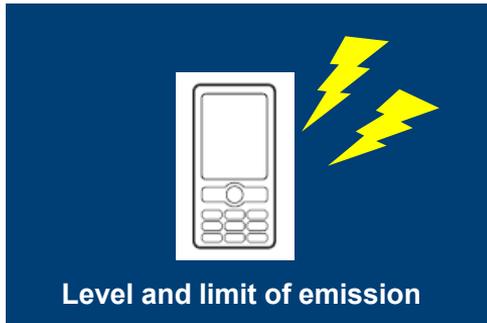
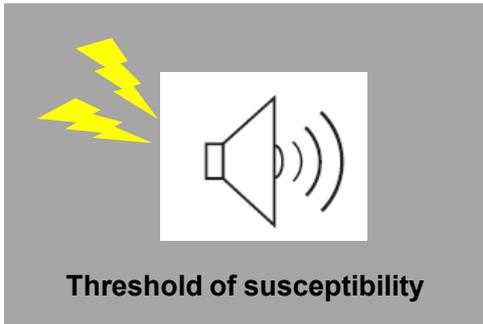
CISPR 32



Multimedia
Equipment

It's all about Immunity and Emission

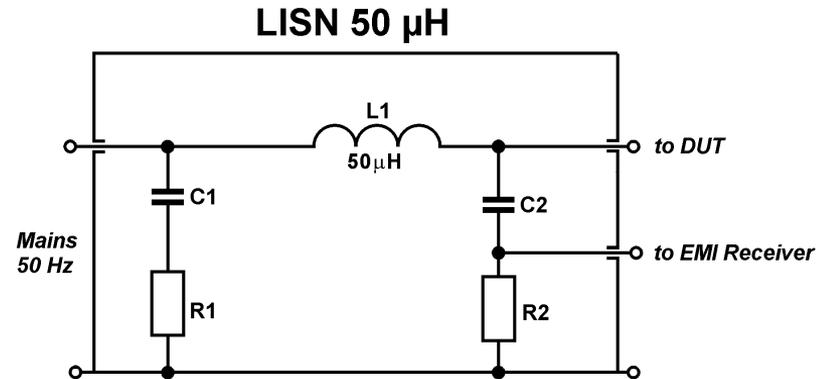
Example: FM radio Interference by GSM phone



Note: Example is not 100% correct as GSM signal is intended emission, but it illustrates problems

Line and impedance stabilizing network (LISN)

- ▶ Stable Line Impedance as a function of frequency on the power line
- ▶ Prevent External Noise (from the power line) Coupling in
- ▶ Provide an RF noise measurement port (50 ohm)
- ▶ Characteristics are defined in CISPR 16-1-2



Performance Levels of Instrumentation

Selecting the right Tool

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



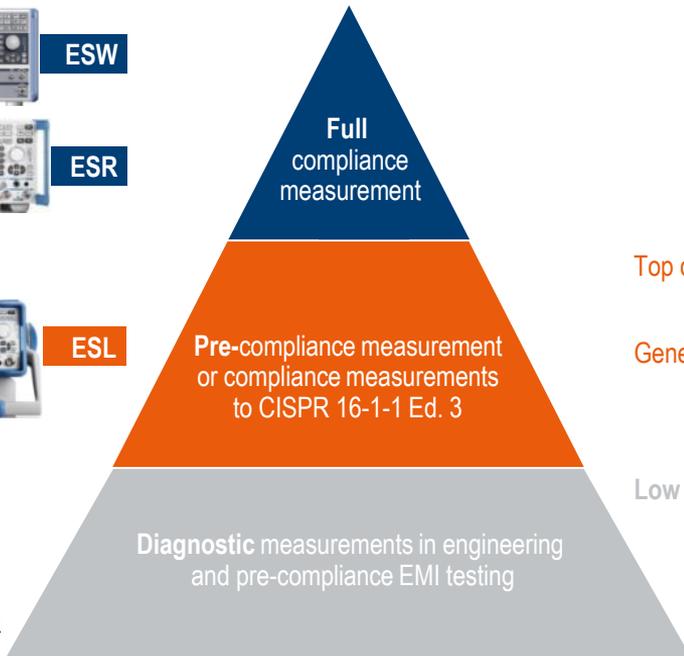
Compliance EMI testing
CISPR 16-1-1, 26 GHz



EMI testing referring to limits



Diagnostic
measurements
without relation
to limits



Top class spectrum analyzers



General purpose spectrum analyzers



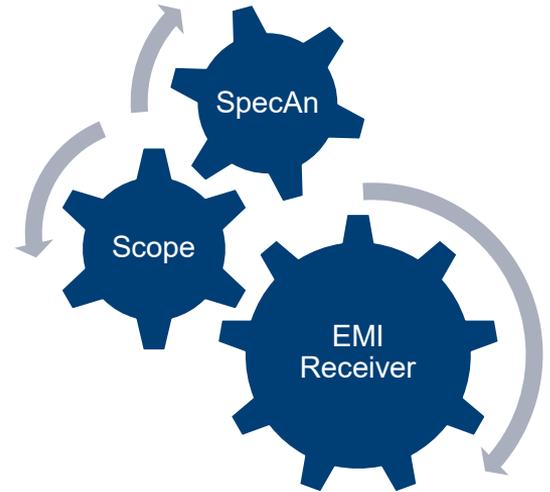
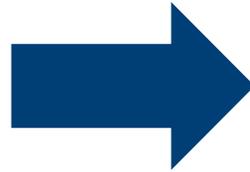
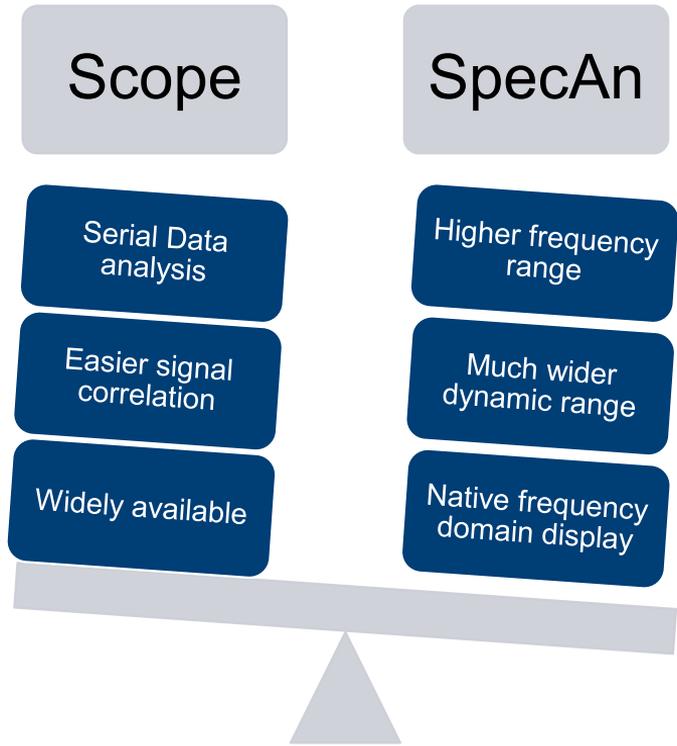
Low cost spectrum analyzers, voltmeters, oscilloscopes



Receivers

Scopes & Spectrum Analyzer

Spectrum Analyzer or Oscilloscope for EMI debugging?

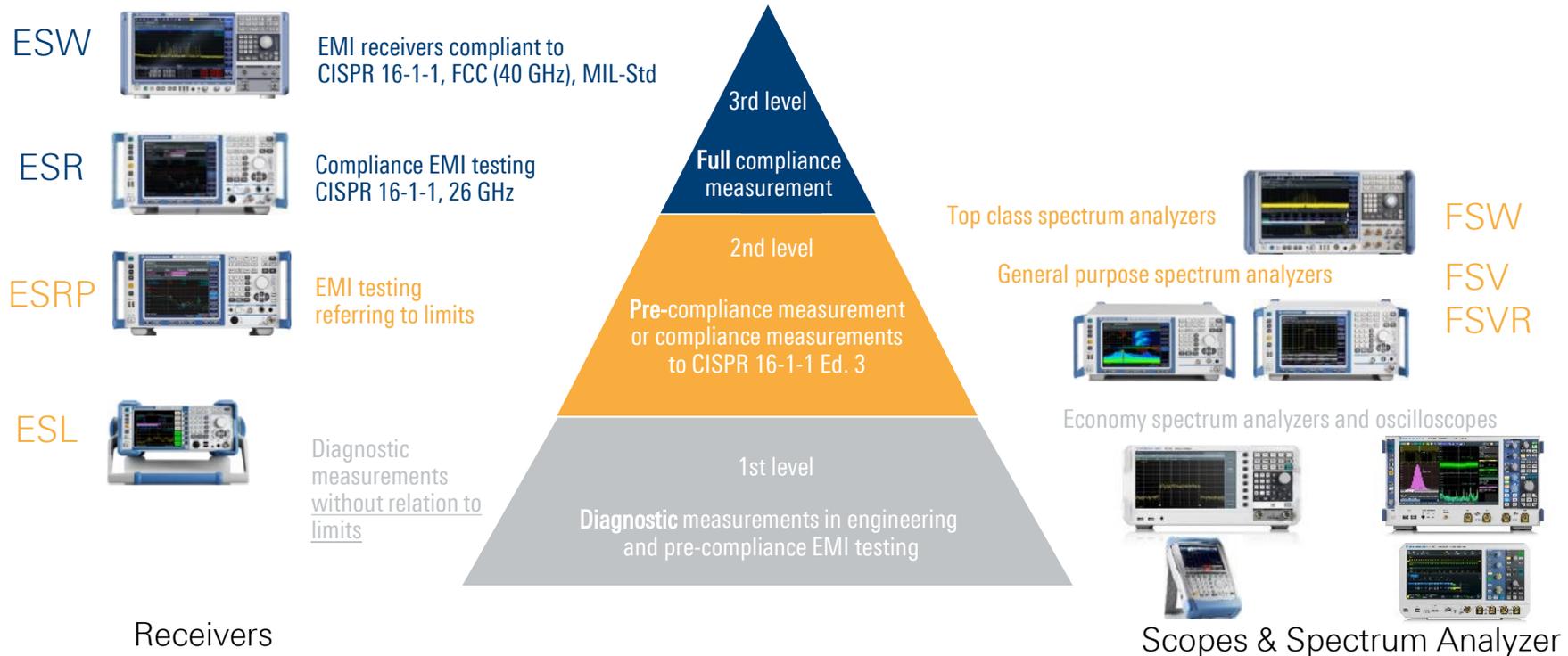


EMI Tests In Summary

	CISPR 11 ISM	CISPR 14 HOUSEHOLD EQUIPMENT	CISPR 15 LIGHTINGS	CISPR 32 MUTLIMEDIA EMC
CONDUCTED EMI (MAINS PORTS)	✓	✓	✓	✓
CONDUCTED EMI (TELECOM PORTS)				✓
RADIATED EMI (MAGNETIC FIELD)	✓	✓	✓	
RADIATED EMI (ELECTRIC FIELD)	✓	✓	✓	✓
POWER DISTURBANCE		✓		

Performance Levels of Instrumentation

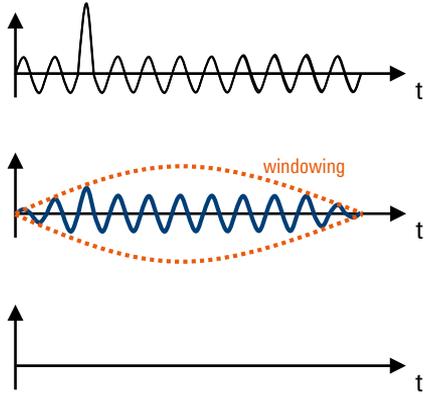
Selecting the right Tool



Modern Scope FFT Capabilities

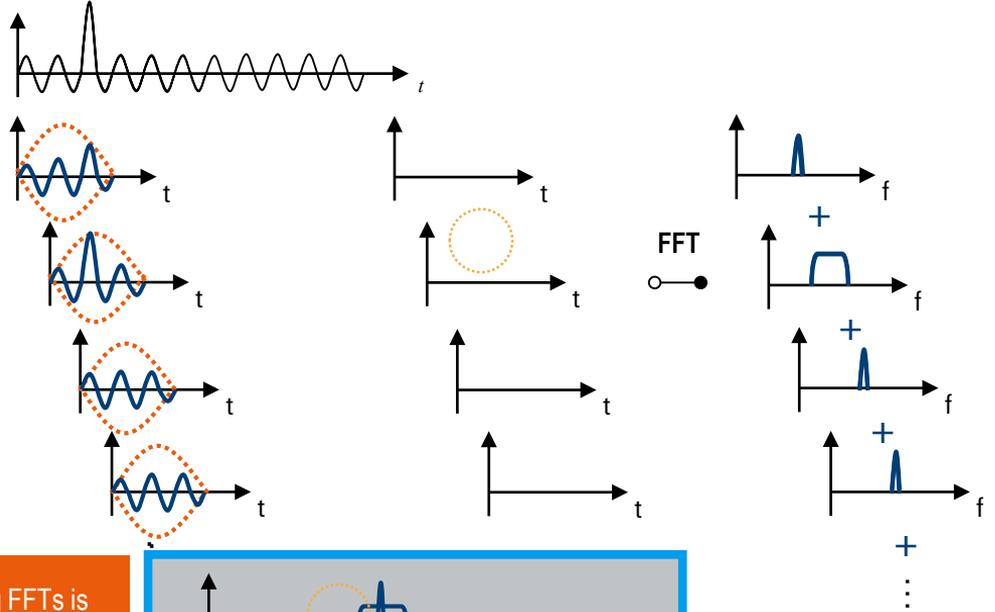
Using overlapping FFTs

Single Acquisition

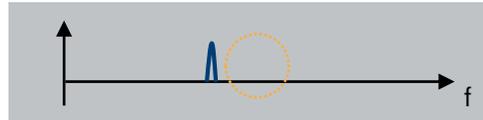


○ FFT
●

Single Acquisition



○ FFT
●



Multiple Overlapping FFTs is able to see spurious event !!!

