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Design for EMI
Troubleshooting and Debugging EMI failures

Kevin Tian
Application Engineer

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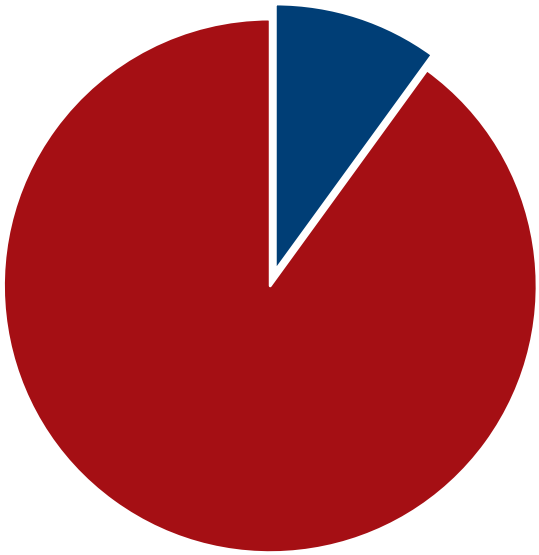
AGENDA

- EMC Standards Overview
- Traditional EMI Test
  - Compliance test with a EMI Test Receiver
- 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**



■ Pass ■ Fail

Source: EEtimes.com, "IoT Devices: Most initially Fail EMI testing"

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Image Credit: Timothy Colegrove
CCA-SA

Design for EMI

EMI is not new

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

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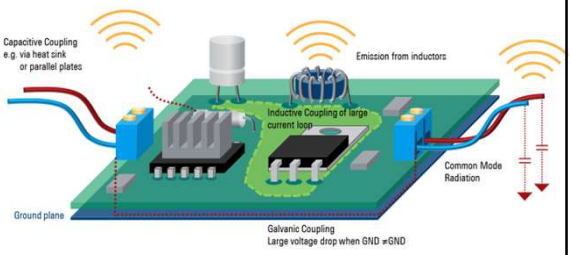
EMI CONSIDERATIONS FOR YOUR DESIGN

- 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

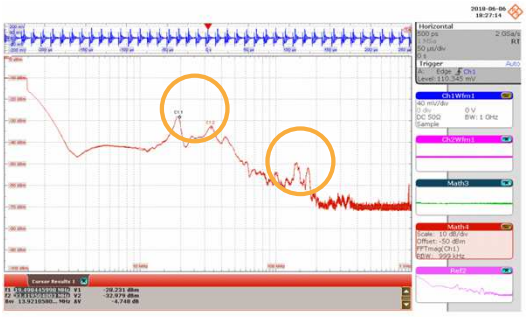
EMI is often caused by switching of signals:

- 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.

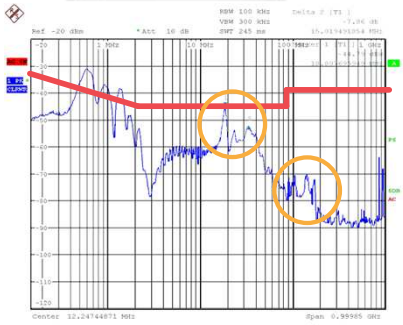
APPLICATION EXAMPLE:
POWER SUPPLY DESIGN COMPLIANCE

RTO6



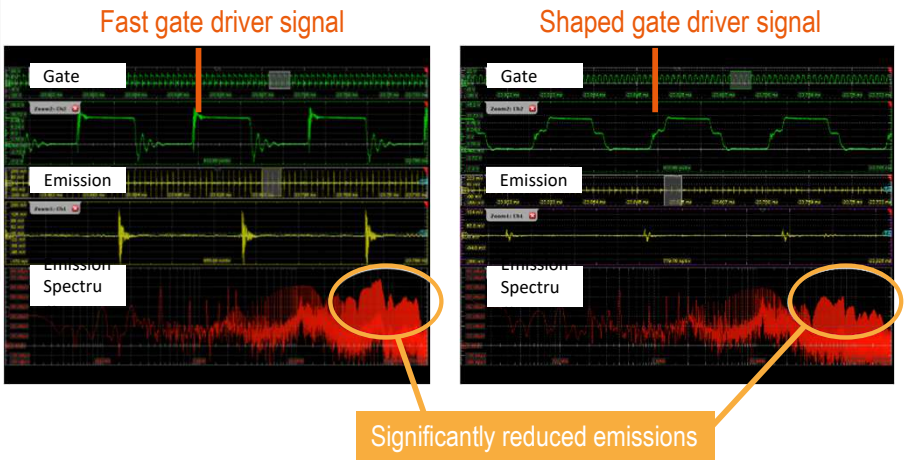
Pre-compliance

Test Receiver



Compliance

APPLICATION EXAMPLE:
OPTIMIZING WIDE BAND-GAP SWITCHING



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EMC Standards and background

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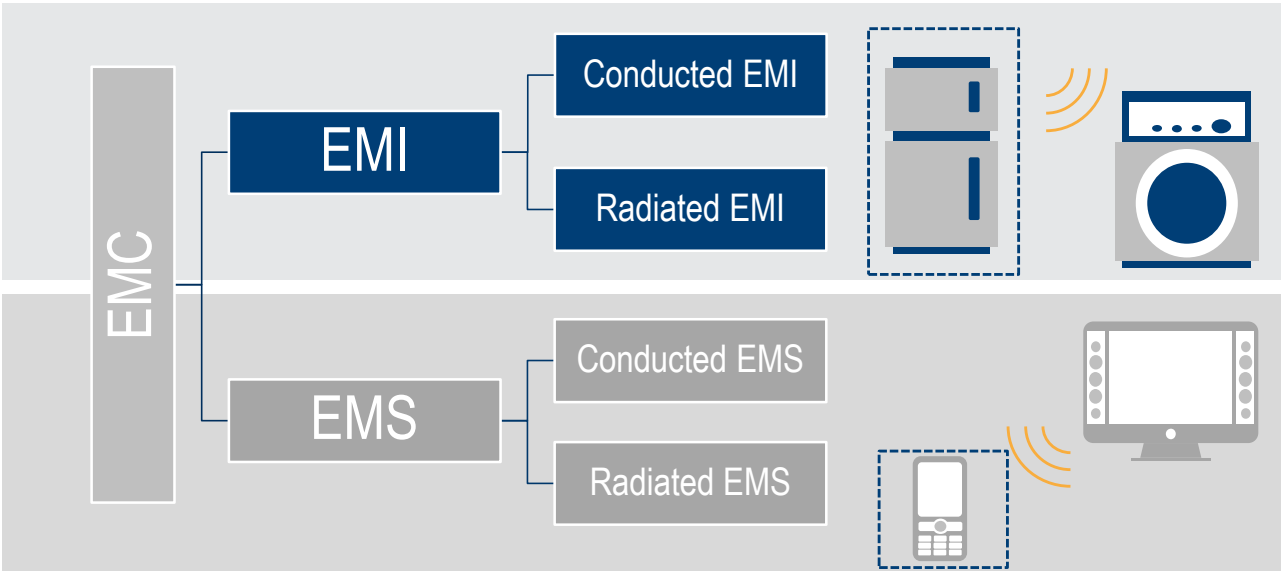
WHAT IS EMC?



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STANDARDS

International Electrotechnical Commission (IEC)

Comité **I**nternational **S**pécial des **P**erturbations **R**adio (CISPR)

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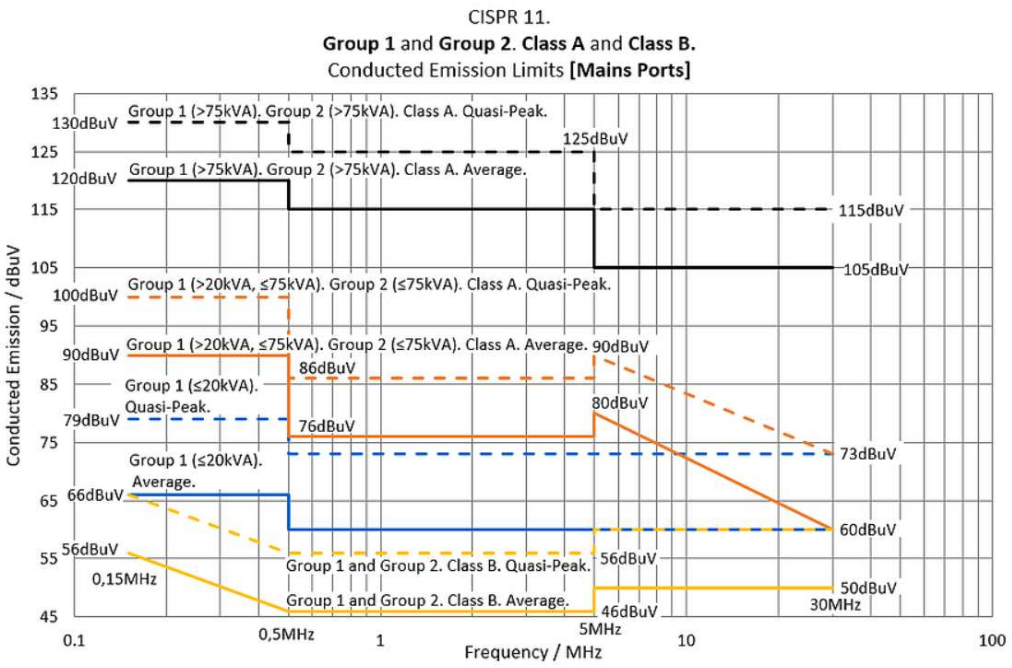

CISPR 11, ISM

CISPR 14-1, Appliances

CISPR 15, Lighting

CISPR 32, Multimeter

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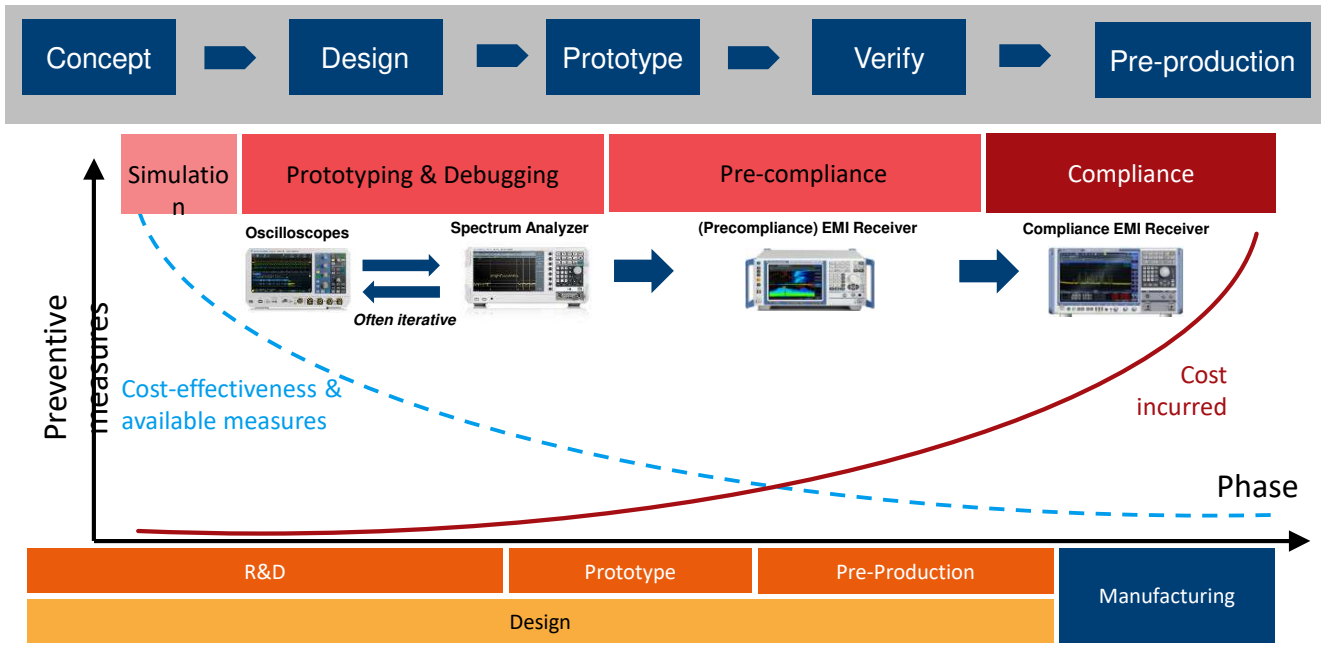

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EMI Testing
Traditional Approach

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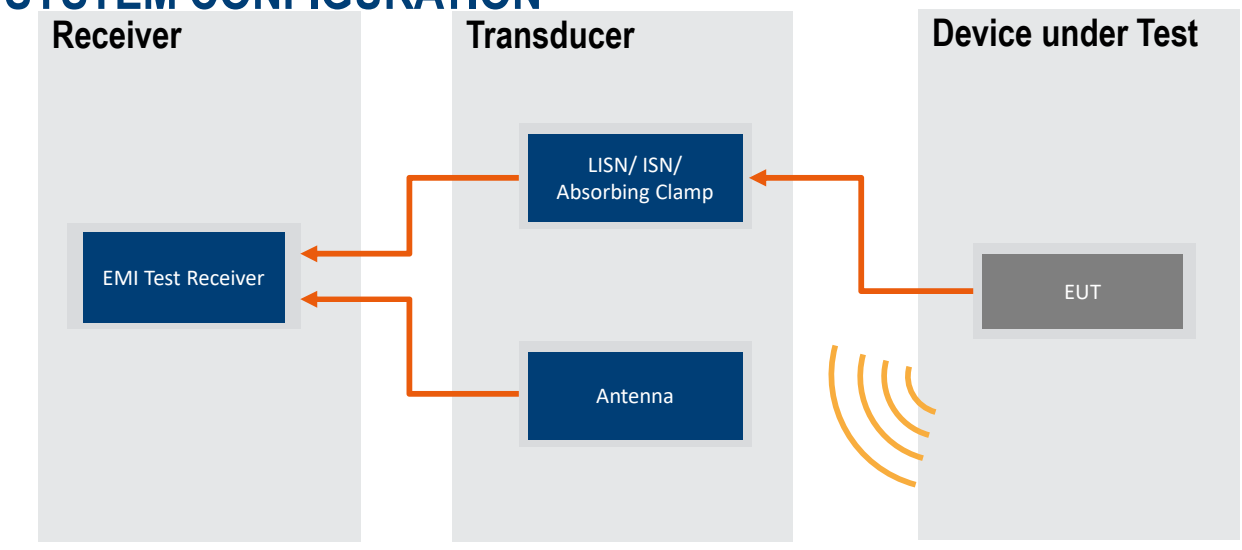
SYSTEM CONFIGURATION



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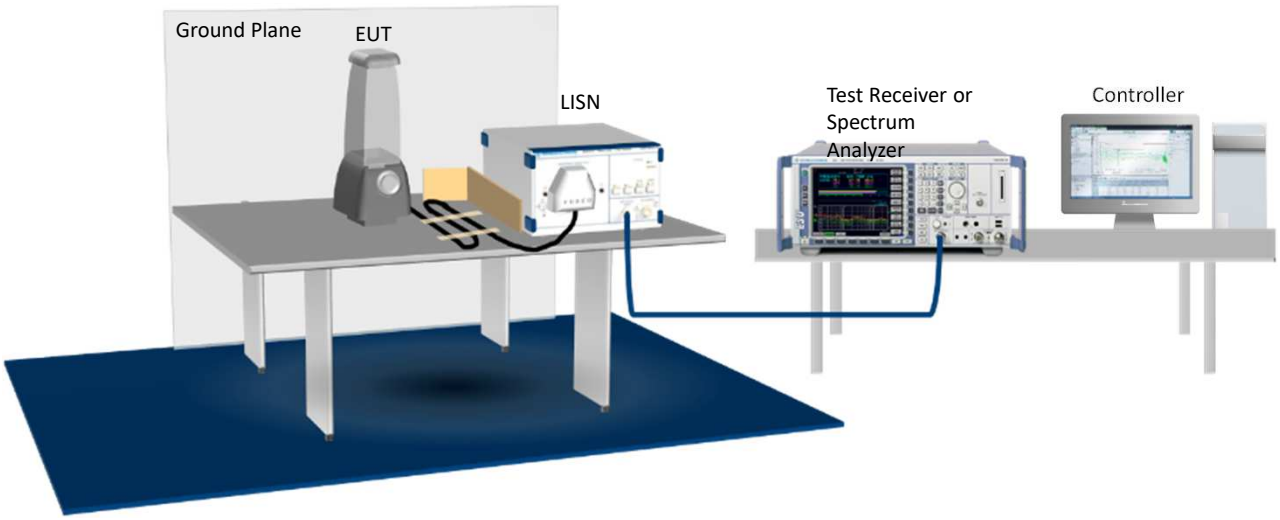
CONDUCTED EMISSIONS TEST (AC MAINS)



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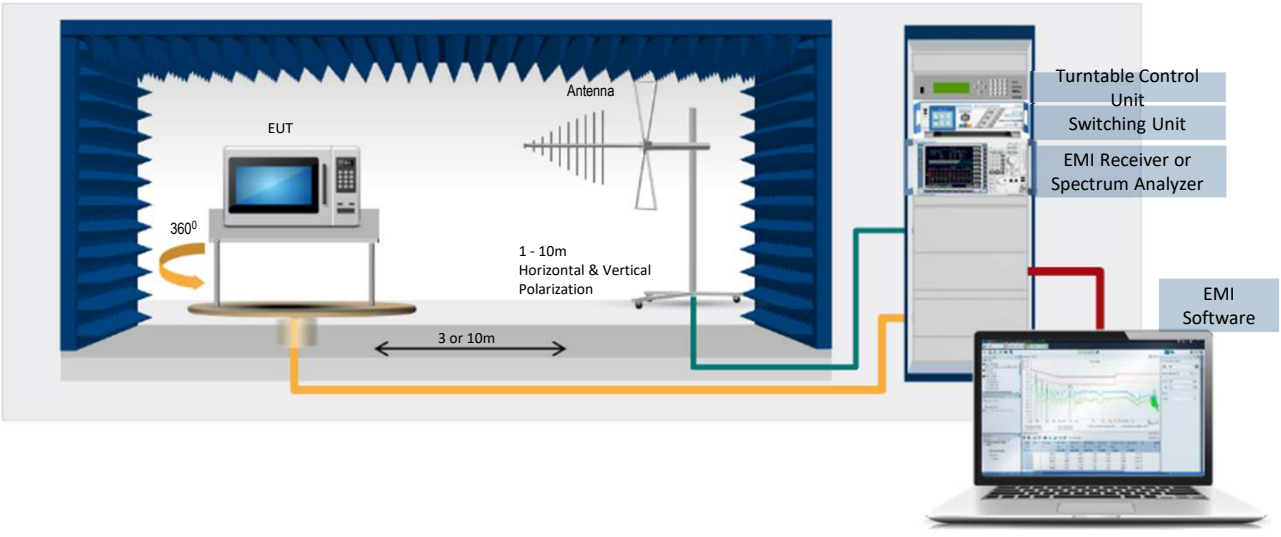
RADIATED EMISSIONS TEST



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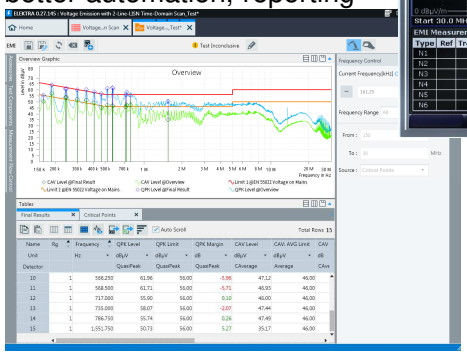
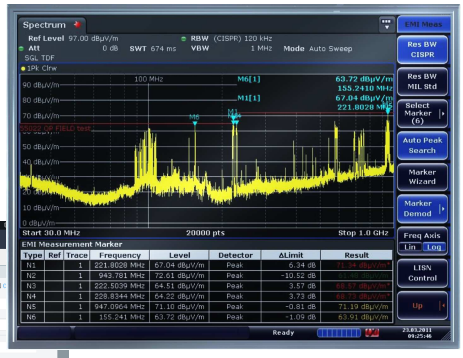
ELEKTRA: PC Software for better automation, reporting





FSx-K54: EMI Measurement Application

EMI SCAN WITH A TEST RECEIVER

- 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

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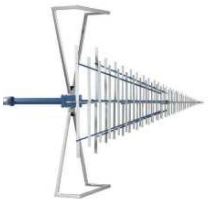
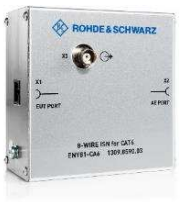
COMPLIANCE EMC TESTING: MEASURING EQUIPMENT
TRANSDUCERS



Antenna – electric radiated emission

Antenna – magnetic radiated emission

Artificial Network – Conducted voltage



ISN - Conducted voltage

Current probe – conducted current

Absorbing clamp – disturbance power

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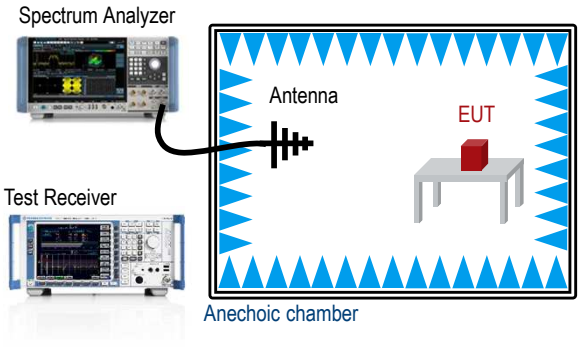
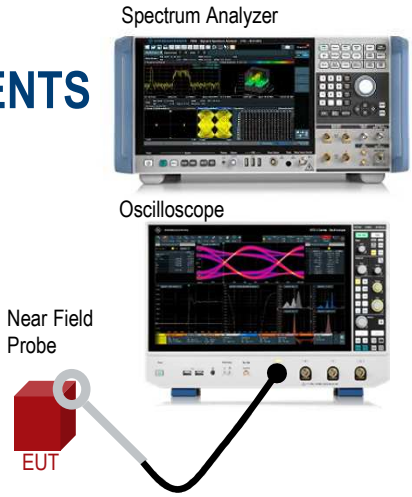
EMC STANDARDS VS EMI MEASUREMENTS





Typical EMC Measurement

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

EMI Measurement with Scope or Spectrum Analyzer

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

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EMI Testing
Debugging and troubleshooting

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BASIC EMI DEBUG PROCESS

Understand your DUT

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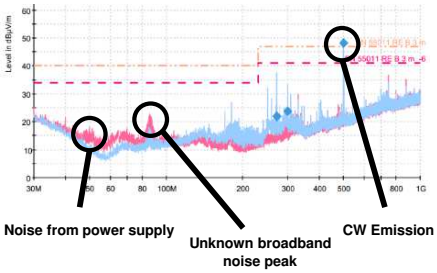
Measure DUT in anechoic chamber

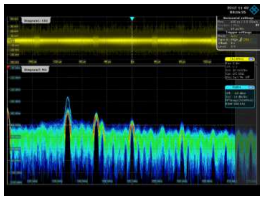
↓

Understand signal behavior of critical frequencies

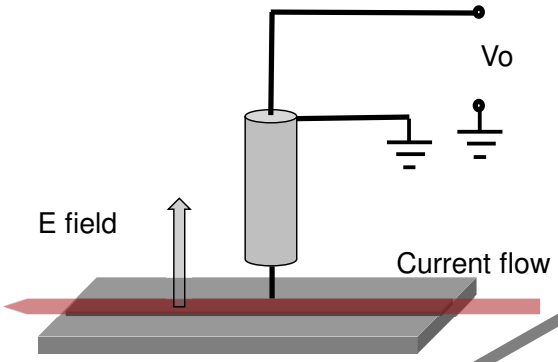
↓

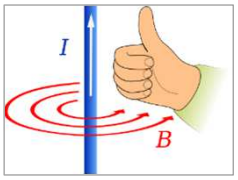
Identify signal sources with Near-field probes

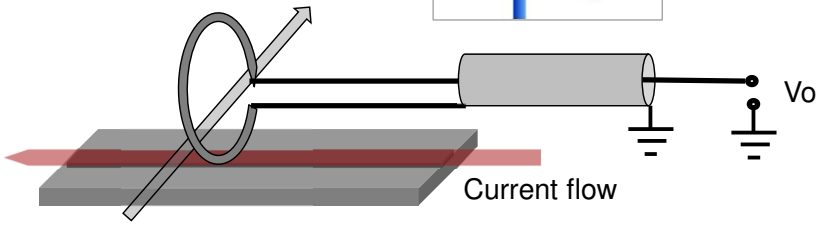


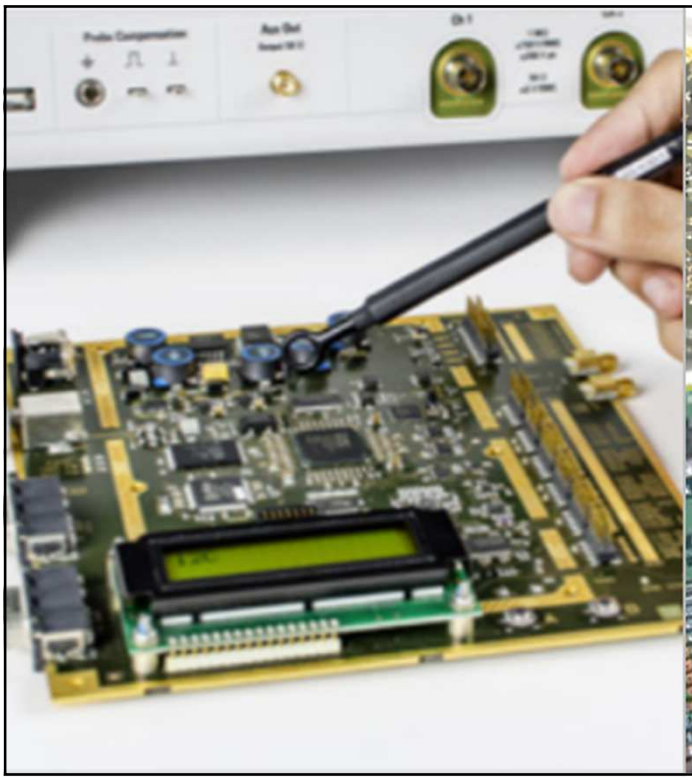


Near Field Probe Types









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

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Choosing an approach

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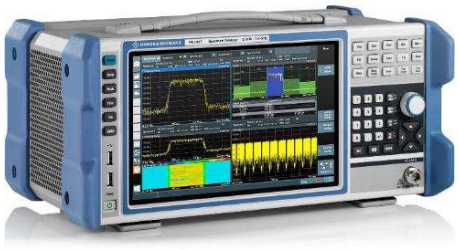
SPECTRUM ANALYZER OR OSCILLOSCOPE FOR EMI DEBUGGING



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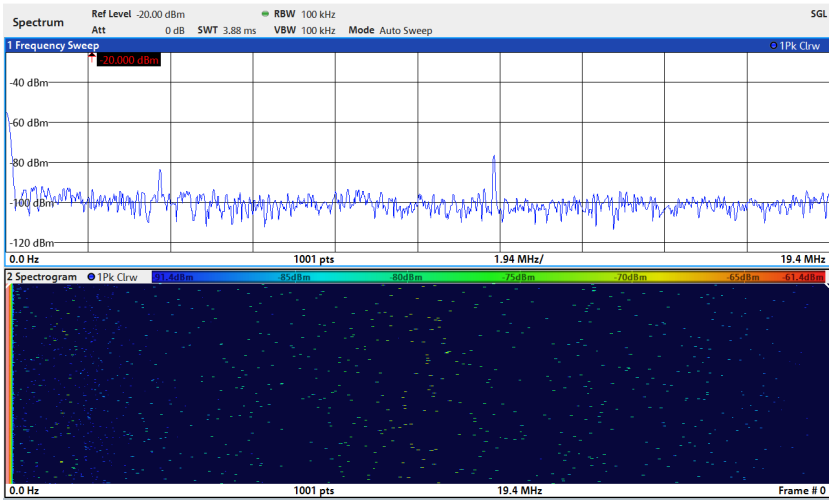
Laptop
Power Supply



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)

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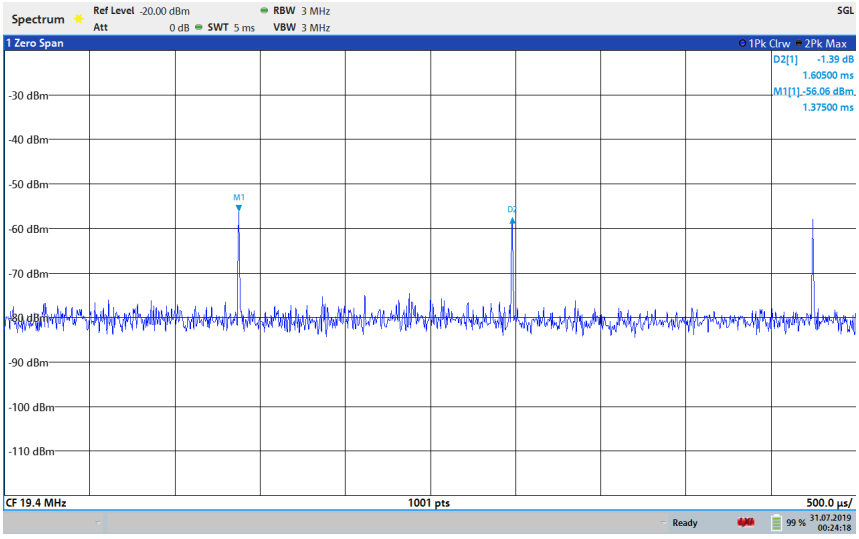
Laptop
Power Supply



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

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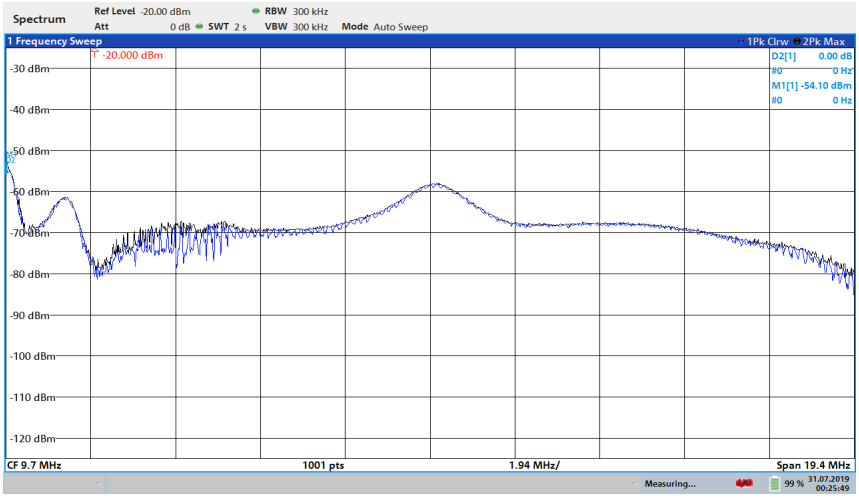
Laptop
Power Supply



TROUBLESHOOT WITH A SPECTRUM ANALYZER

- **Step 3**:
  Spectrum display
  Set Sweep time to >1000x the measured time interval (1.6 msec)
- 1000x 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

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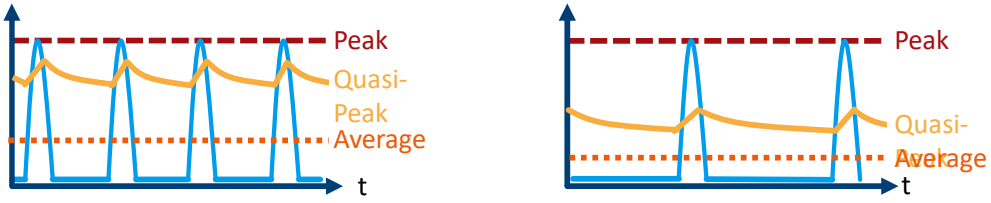
QUASI PEAK DETECTOR

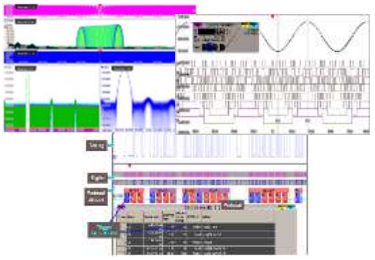
- Quasi-peak means 'not quite peak', or 'aiming towards peak but not actually peak'
- Quasi-peak detector was believed to better indicate the subjective annoyance level experienced by a listener hearing impulsive interference to an AM radio station



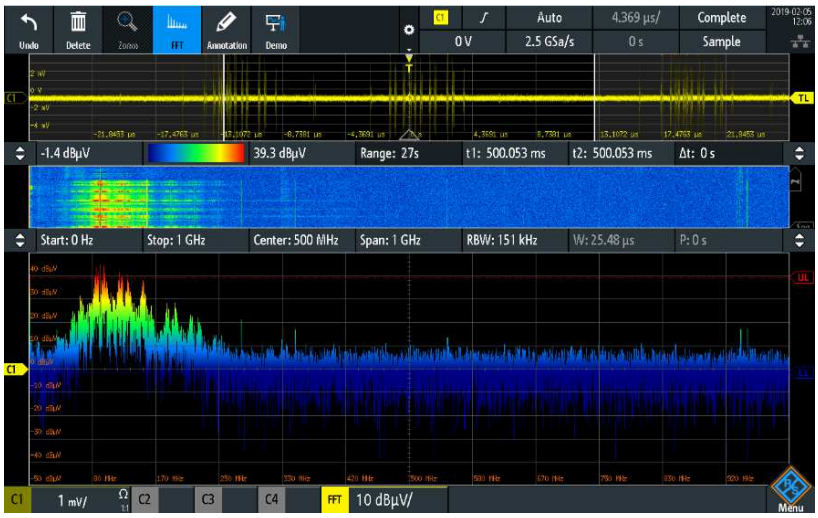
Spectrum analyzers and **EMI receivers**
both have a quasi-peak detector

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
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	

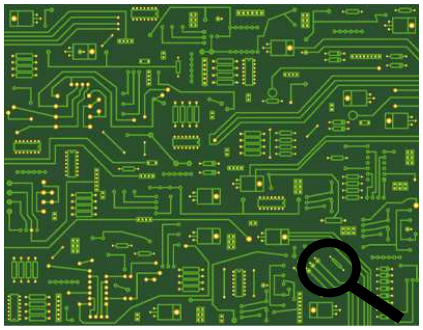


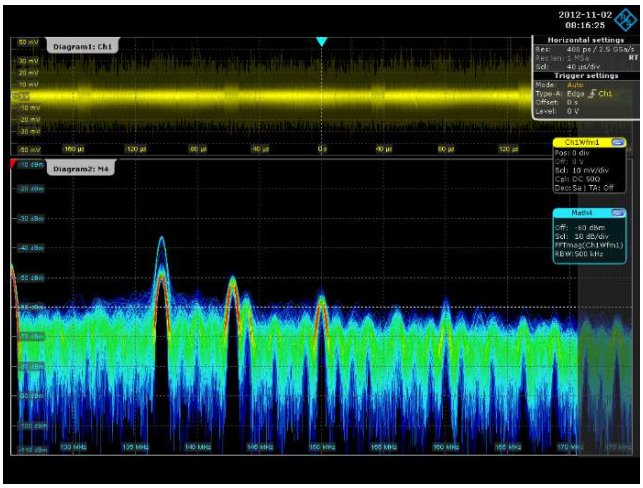
MODERN SCOPE FFT CAPABILITIES
CORRELATION OF TIME AND FREQUENCY INFORMATION



MODERN SCOPE FFT CAPABILITIES
CORRELATION OF TIME AND FREQUENCY INFORMATION

OBSERVE THE SPECTRUM WHILE SCANNING WITH A NEAR-FIELD PROBE





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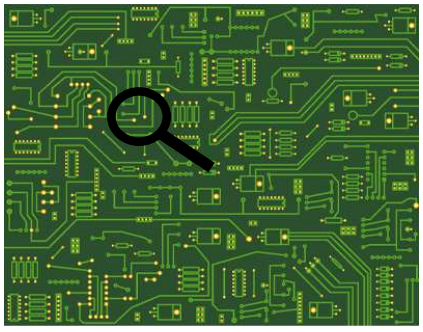

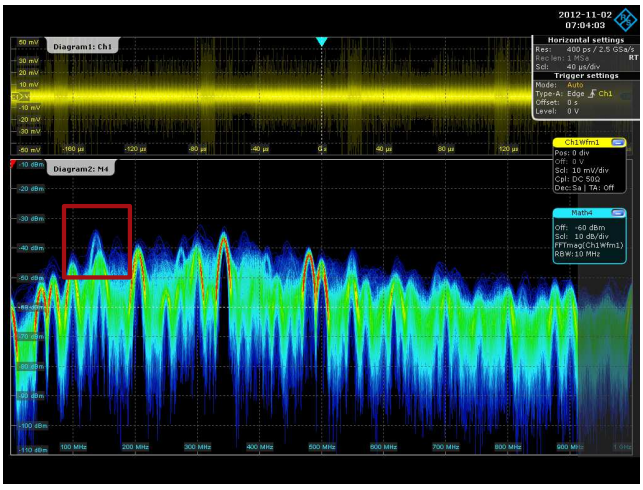

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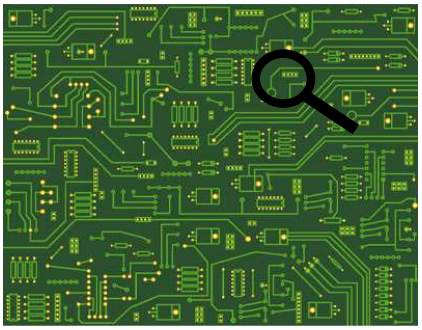
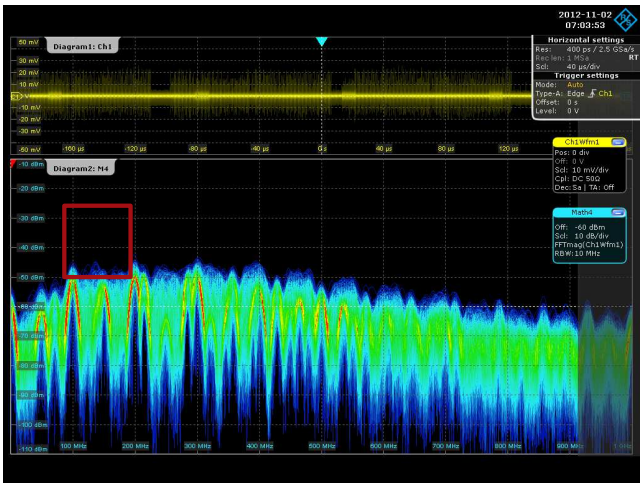
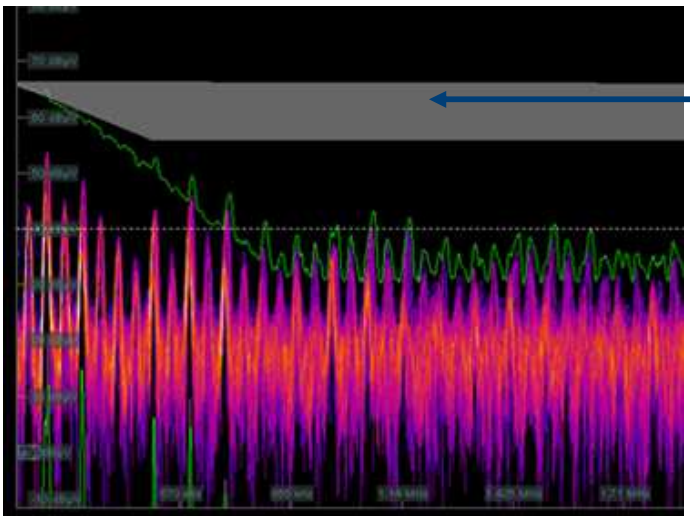




MODERN SCOPE FFT CAPABILITIES
MASK TEST / ZONE TRIGGER

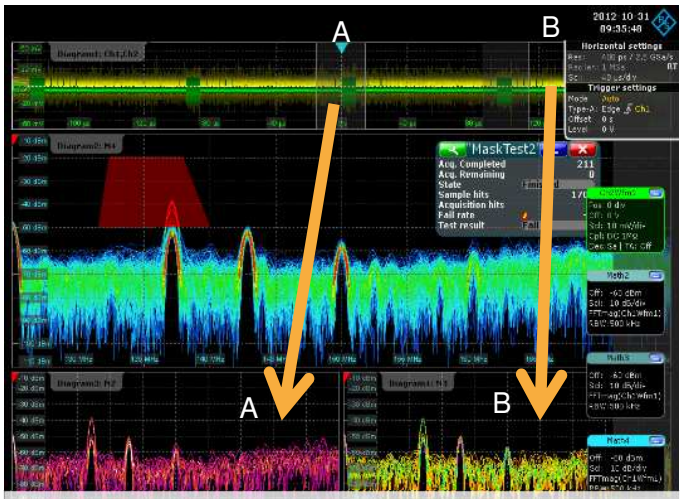


User-defined spectrum mask

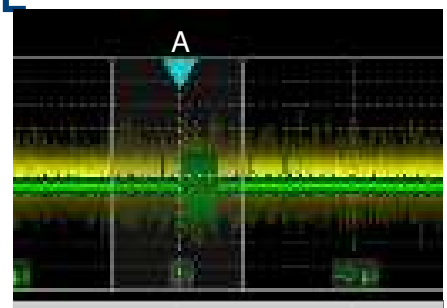
"Stop-on-violation" function

Analyze underlying source

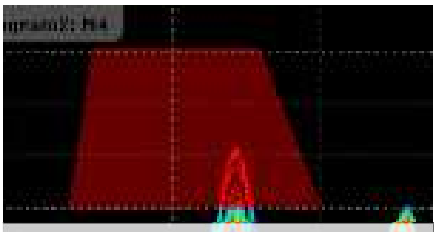
FFT GATE SPECIFIC MOMENTS IN TIME



FFT Gating isolates the spectrum of a time event



Gating



Frequency Mask Trigger

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

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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
- MXO4/MXO5, RTO6, RTP

Test Receiver/Spectrum Analyzers

- Full line up from high performance to economy class and handheld

Accessories to EMC Systems

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

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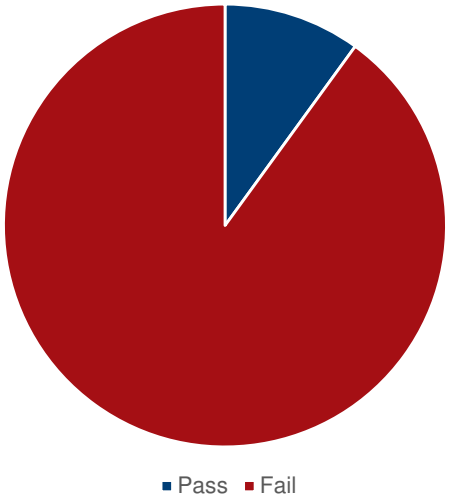
SUMMARY

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 debugging

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



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