Practical EMI Troubleshooting

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Overview

- EMI/EMC Definitions
  - Radiated and Conducted Emissions
  - Pre-compliance vs. compliance
  - Basic configurations
- Pre-Compliance Scanning
  - Instrument Architectures
  - FFT-based Spectrum Analysis
  - Visibility and Speed
- Debugging EMI Issues
  - Correlation of EMI to other signals and events
  - Measuring RF power
  - Near field vs. far field
- Summary
EMI/EMC Definitions

- **EMI Specifications**
  - Country/Region specific
    - FCC, IC, EU
  - Industry specific
    - Manufacturer
  - Military

- **Conducted Emissions**
  - Unwanted signals coupled to AC mains
  - 9 kHz to 30 MHz

- **Radiated Emissions**
  - Unwanted signals broadcast from DUT
  - 30 MHz to 6 GHz

- **Susceptibility/Immunity**
  - Region dependent
Conducted Measurements

- EMI receiver
  - CISPR 16-1-1
- Software
- Line Impedance Stabilization Network (LISN)
  - Isolate DUT from mains
- Limiter
  - Front end protection for instrument
Radiated Measurements

- EMI receiver
  - CISPR 16-1-1
- EMI software
- RF Isolation
  - Characterized anechoic chamber
  - Open-air test site
- Turntable
- Antenna’s

- Characterize emissions 360° around DUT
EMI Characterization

- **Compliance Measurements → Test House**
  - Often used to avoid expense of setting up in-house lab
  - Expensive
    - “one time” expense?
  - Time consuming
    - How full is the schedule?
  - Will report an EMI failure, but not where in the design it came from

- **Pre-Compliance Measurements → In House**
  - Test for EMI issues throughout the design process
  - Catch problems early, before they become bigger later
  - You still need to go to an EMI test house
  - Scanning doesn’t have to take a long time!

*EMI Pre-Compliance testing will save time/money by identifying problem areas before they become expensive re-design issues*
EMI Pre-Compliance Scanning

- Substitute spectrum/signal analyzer for EMI receiver
  - RBW (shape factor)
  - Dwell Time
  - Antenna factor (≠ equal gain)
  - # Trace Points
  - Detectors (CISPR ?)

- Antenna requirements
  - Biconical
  - Log-periodic
  - Pre-amp
  - Tripod

- No chamber or test site ?
  - Boardroom
  - Parking garage

- *It is very difficult to completely duplicate EMI lab conditions*
  - We are making an accurate approximation
  - Understand the compromises in the measurements
  - Pay attention to detail as much as possible
Swept-Tune Spectrum Analyzer

- Traditional architecture
- Basic triggers
- Good dynamic range
- Good sensitivity
- Single measurement domain
  - Frequency vs. Amplitude
  - Amplitude vs. time
- Models available across a wide price/performance range
Real Time Spectrum Analyzer

- Wide capture bandwidth – not RBW limited
- Advanced triggers
- High speed spectrum measurements
- Good dynamic range
- Good sensitivity
- Correlated measurement domains
  - Frequency, Amplitude, Phase vs. Time
  - At the same time
- Models available across broad price/performance range
Scope Block Diagram

- Wide capture bandwidth
- Large selection probes
- Advanced triggers
- Limited RBW
- Limited detectors
- Limited dynamic range
- Limited sensitivity
- High resolution for low frequency operation (< 1 MHz)
- Models available across broad price/performance range
Spectrum Analyzer Sweep Speed

- Swept Spectrum Analyzers
  - Speed varies with square of RBW
- FFT Spectrum Analyzers
  - Speed varies with RBW
- Cross-over is between 100kHz and 30kHz
- FFT Analyzers are typically dramatically faster when RBW < 30kHz

Remember:
- Dwell time is required for EMI detectors
- EMI Rx & SA do NOT sweep the same way

Examples:
- 1GHz SPAN with 10kHz RBW
  - Swept: 25 seconds
  - FFT: 2.6 seconds
- 200MHz SPAN, with 1kHz RBW
  - Swept: 500 seconds
  - FFT: 5.2 seconds

FFT Update Rate X times faster than Swept Spectrum Analyzers
Spectrum Analyzer Sweep Speed

- **EMI Detector types**
  - EMI-Peak (or Peak)
    - Worst case
    - **Safest detector**
  - EMI-Average
    - Incorporates dwell
    - ~100ms common
  - EMI-Quasi-Peak
    - Incorporates dwell
    - ~1second
    - VERY long sweep time

- **Filter Shape Factor**
  - EMI RBW More selective
Example: Pre-Compliance Scan → Tektronix RTSA

- 30 MHz – 26.5 GHz
- 41604 Trace Points
- ~ 15s (CISPR Peak)
Example: Pre-Compliance Scan → Tektronix RTSA

- 30 MHz – 216 MHz
- 20802 Trace Points
- ~ 117s (CISPR QPeak)
Example: Sub-Ranging → Tektronix Basic SA

- Break Scan Into Ranges
- 30 MHz – 88 MHz
- 1001 Trace Points
- ~ 1s (Peak)
De-Bugging EMI Issues

- **Switching Power Supplies**
  - Switching frequencies and harmonics
  - Load-dependent emissions

- **Clock and Data**
  - High speed clocks, data, edges
  - High speed interfaces
  - Switching controls

- **Resonances**
  - Board and conductor geometries
  - Wiring lengths, routing, termination
  - Shielding and mechanical connections

- **Radiated EMI problems are defined by**
  - Sources
  - Antenna’s
De-Bugging EMI Issues → Near Field Probing

- **E-Field**
  - Stub
  - High voltage, low current source
  - Max sensitivity perpendicular to source

- **H-Field**
  - Loop
  - Low voltage, high current source
  - Max sensitivity parallel to source

- Isolate sources of energy
- Measure relative changes
- Be Careful
De-Bugging EMI Issues → New Tools

- **MDO4000 Mixed Domain Oscilloscope**
  - Combines
    - Spectrum Analyzer
    - Oscilloscope
    - Basic Logic Analyzer
  - 21 Inputs ALL TIME CORRELATED

- **Discrete Fourier Transform Analyzer**
  - Dedicated HW: 50kHz-3/6GHz
  - Digital down converter
  - Sensitive/wide band
  - Record length

- **Spectrum Analysis &**
  - Spectrogram
  - AM/FM/PM
  - Voltage
  - Current
  - Logic
Dedicated Hardware Optimized for Analog & RF

<table>
<thead>
<tr>
<th>Span</th>
<th>RF Acquisition Time</th>
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<tbody>
<tr>
<td>&gt;2 GHz</td>
<td>2.5ms</td>
</tr>
<tr>
<td>&gt;1 GHz – 2 GHz</td>
<td>5ms</td>
</tr>
<tr>
<td>&gt;800 MHz – 1 GHz</td>
<td>10ms</td>
</tr>
<tr>
<td>&gt;500 MHz – 800 MHz</td>
<td>12.5ms</td>
</tr>
<tr>
<td>&gt;400 MHz – 500 MHz</td>
<td>20ms</td>
</tr>
<tr>
<td>&gt;250 MHz – 400 MHz</td>
<td>25ms</td>
</tr>
<tr>
<td>&gt;200 MHz – 250 MHz</td>
<td>40ms</td>
</tr>
<tr>
<td>&gt;160 MHz – 200 MHz</td>
<td>50ms</td>
</tr>
<tr>
<td>&gt;125 MHz – 160 MHz</td>
<td>62.5ms</td>
</tr>
<tr>
<td>&lt;125 MHz</td>
<td>79ms (max)</td>
</tr>
</tbody>
</table>
Time Correlated Multi-Domain Display

- The amount of time captured in the top is referred to as Analog Time.

- The orange bar is referred to as Spectrum Time.

- The orange bar indicates the time period for the spectrum from RF input.
Time Correlated Multi-Domain Display

- Simple Radio
  - SPI bus turns on the transmitter
  - PLL voltage controls frequency
  - Watch as radio turns on and changes channel
Example: Switch Mode Power Supply

- RF: P6158
- DC-DC converter output
- Spectrogram shows PSD over time
Example: Switched Class D Amp

- RF: H-field probe
- Amp vs. Time
- Spectrum display

Power Vs. Time Peaks Correlated To Spectrum Content
Example: Switched Class D Amp

- RF: H-field probe
- Ch1 = Switch signal (HR)
- Spectrum
- Direct Correlation

Spectrum Peaks On Rising/Falling Edges Of Switch Control
Example: USB Interference

- RF: H-field probe (USB cable interface)
- CH1: USB HS line
- *Direct Correlation*

Spectral peak occurs during burst

Narrow & Broad level changes
EMI Diagnostics → Tektronix MDO4000

- Spectrum Analyzer
  - Far field antennas
  - Near Field RF Probes
  - Passive Probes
    - 50ohm and Z0 divider probes
  - Active Probes
    - Single-ended and differential
    - Current probes

- Oscilloscope analog channels
  - Wideband passive high-Z probes
  - (all of the above)

- Digital channels
  - Integrated digital probe
Advanced EMI Diagnostics: Tektronix RTSA

- Full span available
- User defined step and dwell time
- >> Probability of intercept
Advanced EMI Diagnostics: Tektronix RTSA

- Parallel spectrum engines
- Fast & Wide DPX
- Narrow & Deep
EMI Diagnostics: Tektronix RTSA + ?

- Trigger on signal using frequency mask trigger
- Seamless capture into memory
- Cross-trigger other instruments for root cause debug
Advanced EMI Diagnostics ➔ Board Level Scanning

- APREL Inc. EM-iSight
- Automated scan, single near-field probe, 20 GHz coverage
- Far-field estimation
- www.aprel.com
Summary

- EMI diagnostics and troubleshooting of modern designs presents unique challenges → what’s in your product?
- Pre-compliance scanning will save $$$ and time
- Be careful of the tools you select, know the limitations
- Near-field scanning can pinpoint trouble areas
- Analysis in multiple, time-correlated domains speeds troubleshooting and debugging
- Real-Time Spectrum Analysis can provide deeper insight to transient phenomenon
- Coincidence is KEY to identifying sources of EMI
Contact us today at 1(888)880-6804 or sales@testforce.com