Near-Field Measurement Techniques to Debug EMC Emission Problems

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“Far-field” EMC Measurements

Disadvantages:

- Have to be performed in anechoic or reverberation room (costly and not always available)
- Only pass/fail test
- Little insight in root-cause
- Limited debug possibilities
- Normally only on ‘finished’ prototype
“Near-field” EMC measurements
“Near-field” EMC measurements

• Advantages:
  o No real need for anechoic or reverberation room
  o Detailed information about EM “hot-spots” above device
  o Can be easily done on sub-parts or early prototypes
  o Can be used to build EM models for the device

• Applications:
  o Debug-method to quickly find root-cause
  o In-house pre-compliance test method (submodules, choice components,…)
  o Test method intra-system EMC
  o Basis for up-to-date design rules!
NEATH-Project (IWT 120131)

• General EMC debug workflow
  o Where to start?
    • Iteratively locating the origin and/or cause(s) of EMI
  o What to use?
    • Guidelines
    • Debug kit
  o How to measure?
    • Instrumentation
    • NF probes, current probes, antennas, …
  o How to interpret?
  o How to solve?

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Debugging during EMC Testing

Go inside the EMC test chamber and attach antenna to spectrum analyzer:

- Make sure to see the SA display
- Don’t stand between antenna and DUT
- Be aware of safety!!
- Start by grabbing cables either by hand or with a stick
- Disconnect cables one at a time
- Measure CM currents on cables
- Place hands on the chassis: press and squeeze
- Wrap things up in conductive foil and slowly peel back
- Make a list of harmonics, resonance frequencies,…
Four basics of troubleshooting (H. Ott)

• **DIVIDE AND CONQUER:**
  - elimination technique

• **PREDOMINANT EFFECT:**
  - Locate dominant source
  - Leave all fixes in place!!

• **IMPLEMENTATION OF FIXES:**
  - HF parasitic effects!!
  - Lumped components, pigtails, …

http://hottconsultants.wordpress.com/category/troubleshooting/
Four basics of troubleshooting (H. Ott)

- “KILL IT DEAD”: make compliant no matter what it takes

http://hottconsultants.wordpress.com/category/troubleshooting/
General Debug Workflow: Cables

- RE@test site or with lab setup (with all cables)
  - Pass?
    - NO
    - < 200-300 MHz?
      - NO
      - RE test w/o interconnecting cables
      - Check for box radiation
    - YES
  - YES

Simplified view:

Differential Mode

Common Mode

Noise

Transition Region

Cables

DUT

Depends on size of DUT

Freqency

200 MHz  400 MHz
How to Measure CM Currents?

• Current Probe

• CDNE (CISPR 15 & 16)

• Work-Bench Faraday Cage

• …
Current Probes?

Schematic diagram

Commercial Current Probes

DIY Current Probes
Characterization of a Current Probe

Transfer impedance:

$$Z_0 = 50\Omega$$

$$Z_T = Z_0 \cdot S21[\Omega]$$
Proposal Workflow Current Probe

- Move probe over length cable
- Keep track of maximum (max-hold)

? How large can the CM current be? 

Source: H. Ott
Limit Line for CM Current?

\[ E_{\text{ant}} = \text{RTF} \times I_{CM} = \text{RFT} \times \frac{V_{\text{rec}}}{Z_T} \]

RTF = Radiation Transfer Function

\[ Z_T = \text{Transfer impedance current probe} \]

Source: C. Paul
Limit Line for CM Current?

\[ V_{\text{rec}}(\text{dBuV}) < E_{\text{max}}(\text{dBuV/m}) + Z_T(\text{dB}) - \text{RTF (dB)} \]

Source: C. Paul
RTF Reasoning 1: Radiated Power

- Assumptions:
  - CM impedance of cable is about 150 Ohm
  - At “low” frequency radiation is equal in all directions
  - CM current constant over length cable
  - Antenna is in far-field

\[
P_{\text{rad}} = 150 \cdot |I_{\text{CM}}|^2
\]

\[
S = \frac{P_{\text{rad}}}{4\pi r^2}
\]

\[
S = \frac{|E|^2}{377}
\]

\[
RTF = \frac{|E|}{|I_{\text{CM}}|} \approx \frac{67}{r}
\]

So, for 40dBuV/m at 3m this means that the max CM current would be about 4.5 uA (13 dBuA)
RTF Reasoning 2: Simulation Based

- Source and load impedance unknown in practice
- Source impedance doesn’t have influence on RTF
- Load impedance does have influence on RTF
Simulation Result
New Proposal RTF

If \( kl \leq \frac{2}{\sin(\sqrt{2})} \): \( \text{RTF} = \frac{120\pi}{r} \frac{l}{\lambda} \)

Else if \( l \leq \frac{\lambda}{2} \): \( \text{RTF} = \frac{60}{r} \frac{2}{\sin(\sqrt{2})} \)

Else \( \text{RTF} = \frac{60}{r} \frac{2}{\sin\left(\frac{\lambda}{l}\right)} \)
General Debug Workflow: Enclosures

Hand-held Near-Field Probes

Source pictures: A. Mediano, EMC Europe 2013, Brugge
Basic Types of Near-Field Probes

Magnetic field probes

Electric field probes

Source: Keith Armstrong, EMC Testing Part 1
DIY Near-Field Probes

• Shielded (magnetic) probes prevent coupling of the E-field
• Gap in shield to prevent shield currents from flowing
• Unshielded probes: coupling of electric and magnetic field
  o Not an issue when locating emission hotspots
• Below: probes made from insulated (≠ shielded!) wire and paperclip (right)
  o Care needed for short circuits or electrocution when not insulated

Source: Keith Armstrong

Source: Doug Smith
Debugging - Enclosures

Minimize the longest dimension in your slots and seams (<λ/20)

GOOD NEAR FIELD PROBE ORIENTATION

BAD NEAR FIELD PROBE ORIENTATION

Try different orientations!
NF Measurement Set-Up

• Nearfield probes:
  o Magnetic (loop) probe
  o Electric (dipole) probe

Which probe do we use?
  o Slot radiation: $Z = E/H <<<$  → Magnetic (loop) probe
  o PCB edges: $Z = E/H >>>$  → Electric (dipole) probe
NF Probing: Front panel (Slot radiation)
NF Probing: PCB edges

- Idea is to **detect Common-Mode voltage** between board and casing
- Helps to **understand the need for sufficient fixations** between board and casing
- Not interested in ‘edge radiation’, but rather common-mode voltages that exist between the board and the casing.
Use of Comb generator

No cable that exits the casing, which allows us to analyze the shielding of the casing correctly.
NF / FF Test Set-Up

www.wa5vjb.com
General Debug Workflow: PCB

Hand-held Near-Field Probes

Near-Field Scanner
Near-Field Scanning System

- Xpert CNC controller
- Xpert milling machine
- National Instruments GPIB-USB-HS
- Oscilloscope
- VNA
- EMI Receiver
- EM probes
DUT Far-Field Emissions
DUT Near-Field Emissions at 114 MHz
Culprit?
Adjusted DUT: Far-Field Emissions
EMC Debug kit
Recommended literature

• This presentation is based on:
  o “EMI Troubleshooting Cookbook for Product Designers” by K. Wyatt and P. André, 2014

• “EMC for Product Designers” by T. Williams (4th Ed. 2006)

• “EMI Troubleshooting Techniques” by M. Mardiguian (1999)

Recommended literature

• **Online:**
  - Doug Smith
    - [http://emcesd.com/](http://emcesd.com/)
  - Keith Armstrong
    - [http://www.cherryclough.com/home](http://www.cherryclough.com/home)
  - Ken(neth) Wyatt
    - [http://www.emc-seminars.com/](http://www.emc-seminars.com/)
Upcoming seminar

PCB Design and Layout Techniques for Cost-Effective SI, PI and EMC, in 2015

Main goal of this course:
Every two years, on average, every type of semiconductor that is available on the market goes through a die-shrink, which makes their emissions and immunity worse. This applies to older device types, like 74-series TTL and HCMOS, as well as to the latest microprocessors and memories, so designing with the same old parts does not protect us from this problem.
So PCB technology must continually advance, to design PCBs in a way that doesn’t create problems for Signal Integrity (SI), Power Integrity (PI) and ElectroMagnetic Compatibility (EMC).
In this course several proven PCB design techniques are shown in order to reduce EMC problems

Who should come to this course:
This course is open to all interested people, especially electronic hardware and PCB designers and their managers

Dec 2-3, 2015
The end