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Near-Field Measurement Techniques to Debug EMC Emission Problems

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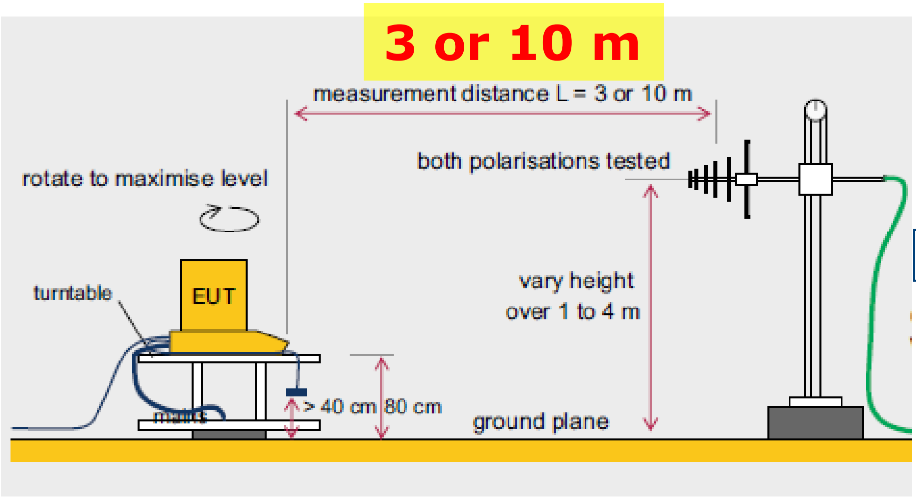
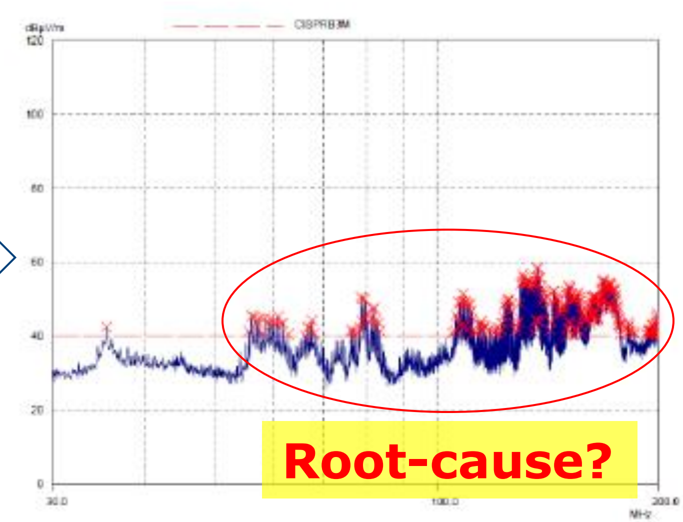
EMC-ESD in de Praktijk

4 november 2014

“Far-field” EMC Measurements

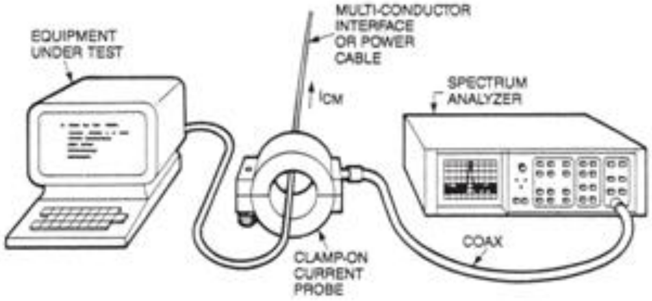


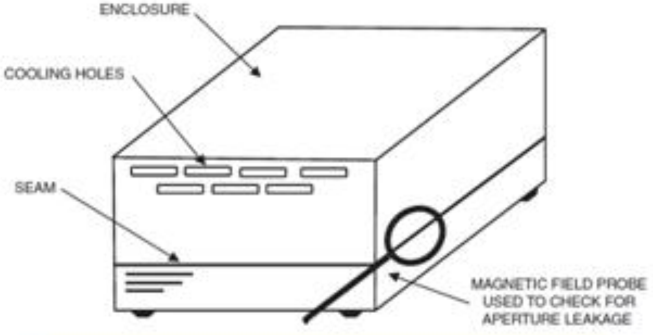


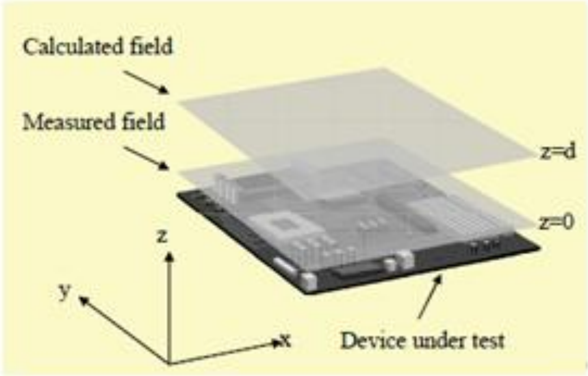
Disadvantages:

- 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





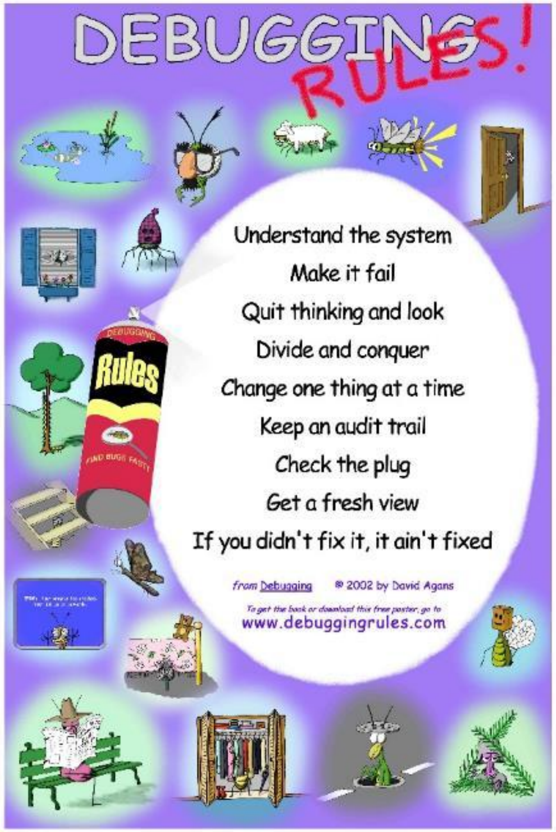


“Near-field” EMC measurements

- Advantages:
  - No real need for anechoic or reverberation room
  - Detailed information about EM “hot-spots” above device
  - Can be easily done on sub-parts or early prototypes
  - Can be used to build EM models for the device
- Applications:
  - Debug-method to quickly find root-cause
  - In-house pre-compliance test method (submodules, choice components,…)
  - Test method intra-system EMC
  - Basis for up-to-date design rules!

NEATH-Project (IWT 120131)

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



http://www.kuleuven.be/samenwerking/remi/projects/neath

IWT

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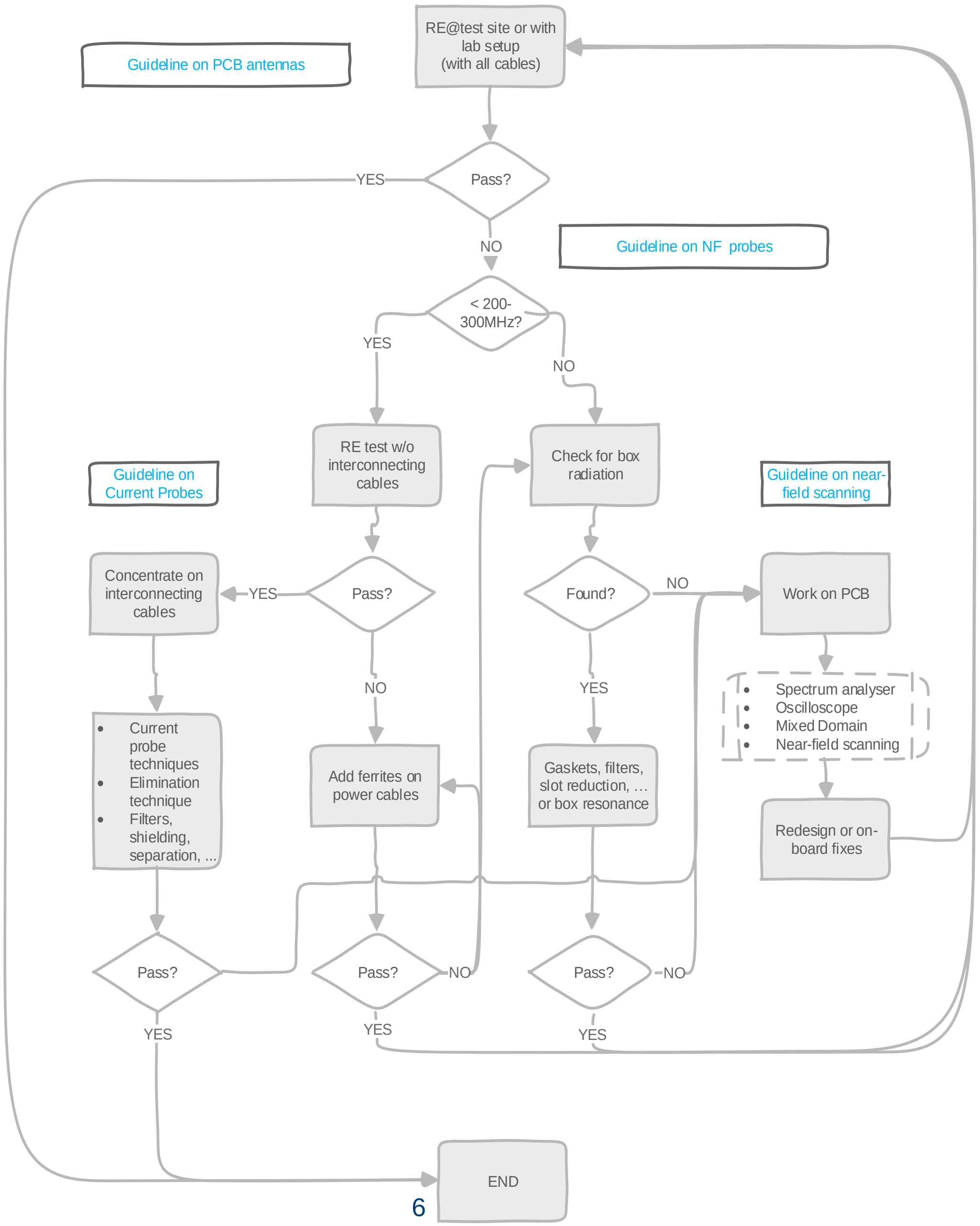
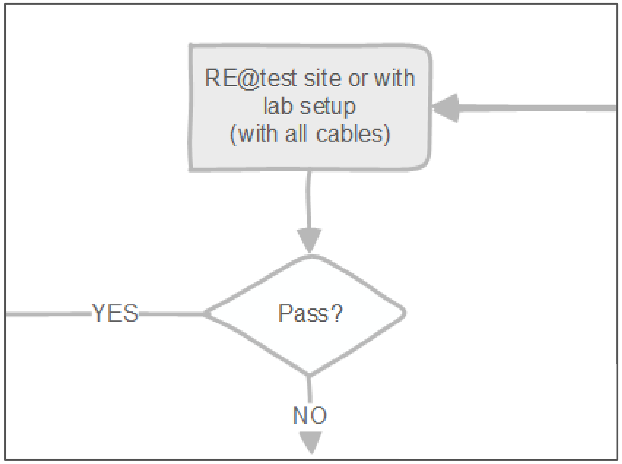
General EMC debug workflow



Debugging during EMC Testing

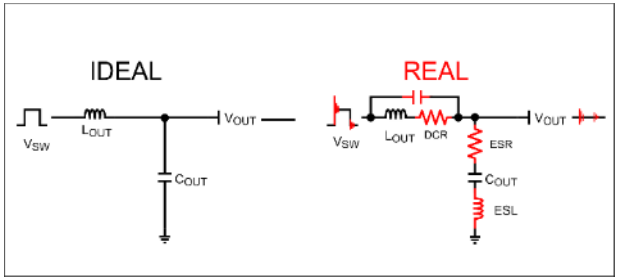


Go inside the EMC test chamber and attach antenna to spectrum analyzer:

- 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/

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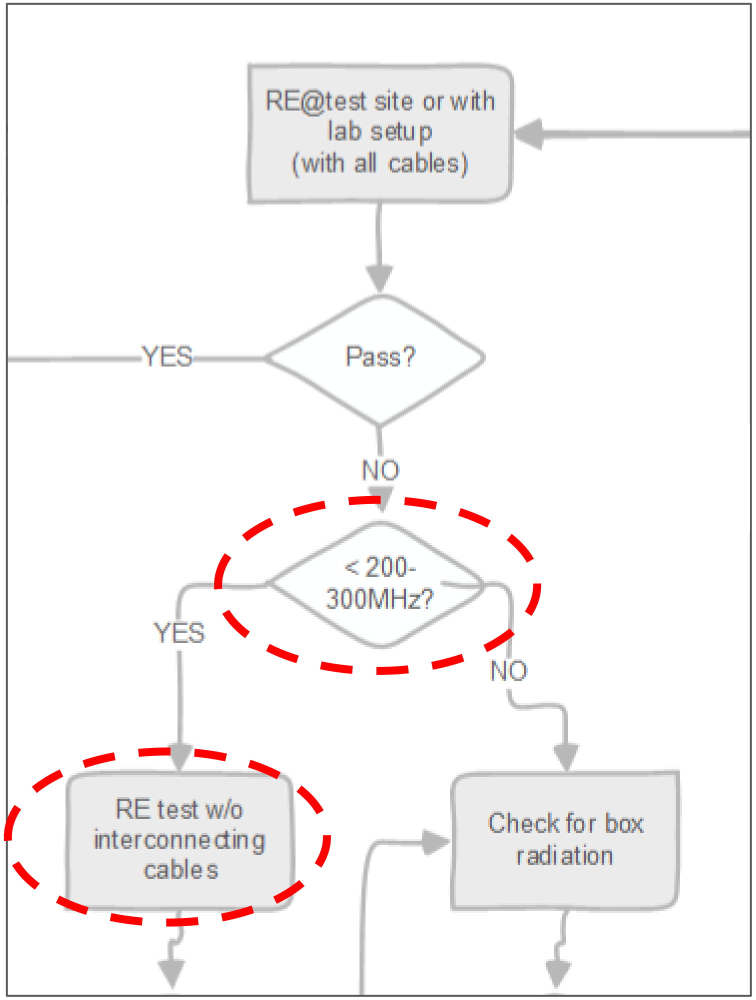
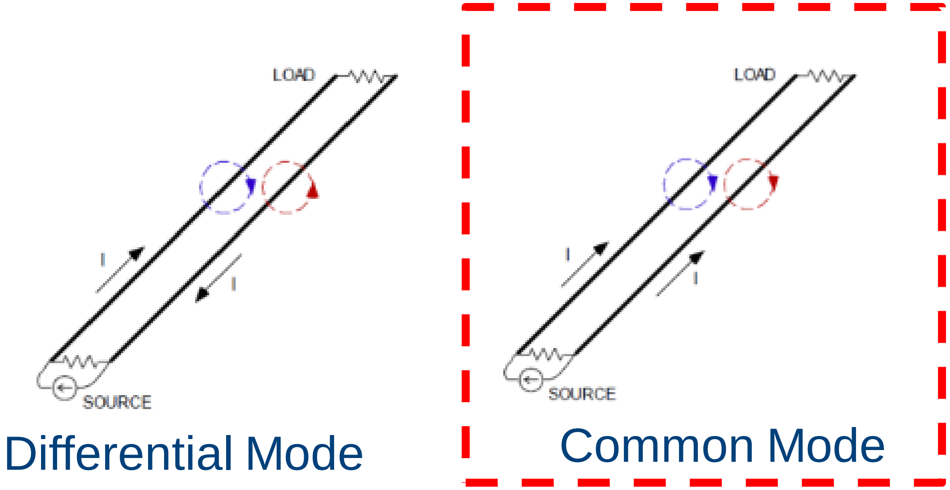
Four basics of troubleshooting (H. Ott)

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

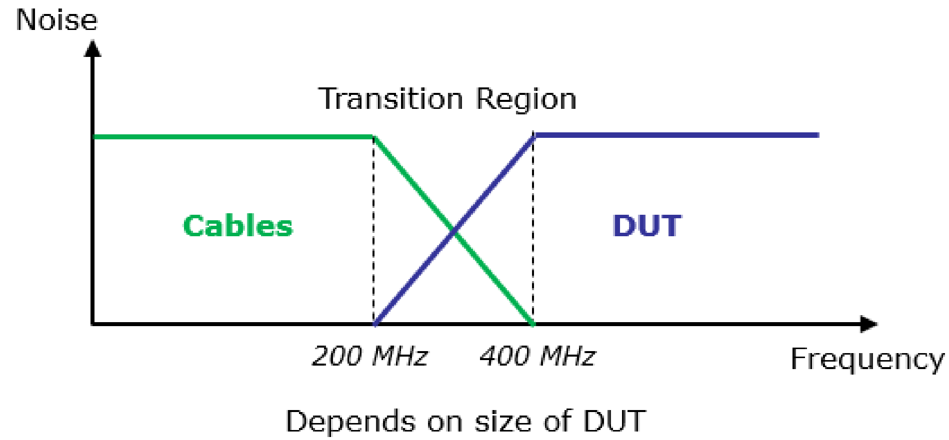
http://hottconsultants.wordpress.com/category/troubleshooting/

General Debug Workflow: Cables





Simplified view:



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How to Measure CM Currents?

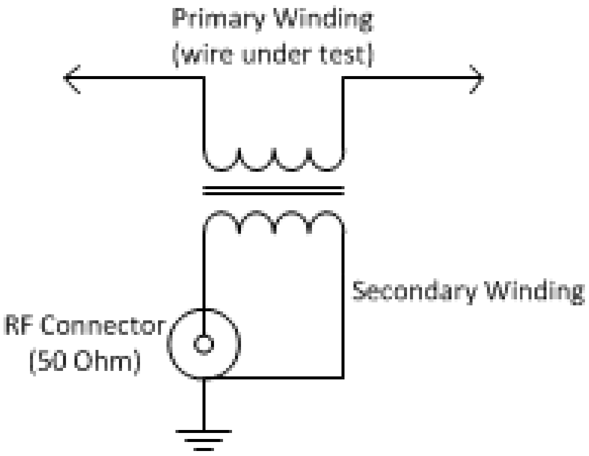
- Current Probe

- CDNE (CISPR 15 *& 16*)

- Work-Bench Faraday Cage

- …

Current Probes?



Schematic diagram

Commercial Current Probes

DIY Current Probes

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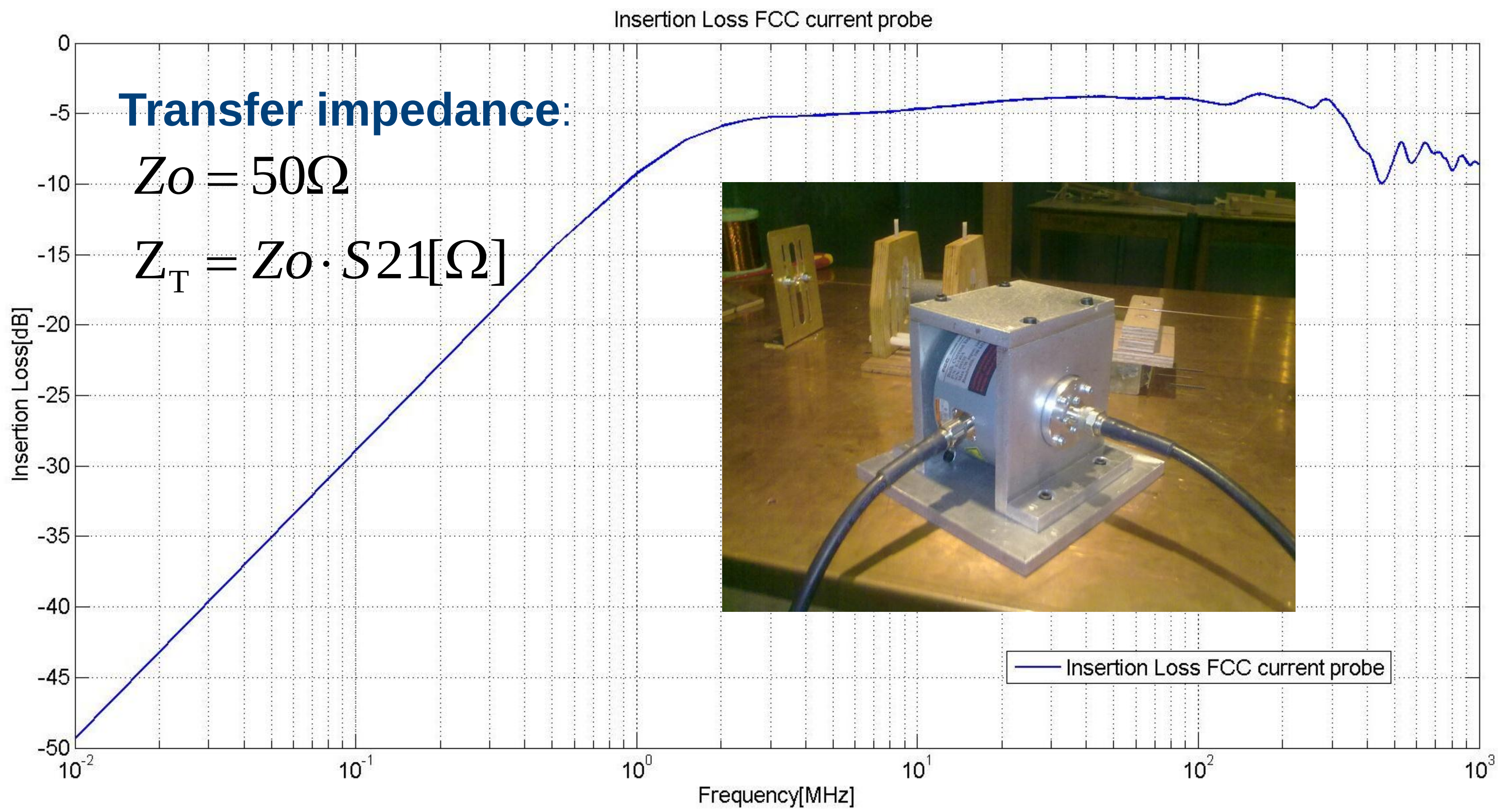
Characterization of a Current Probe

Transfer impedance:

$$Zo = 50\Omega$$

$$Z_T = Zo \cdot S21[\Omega]$$



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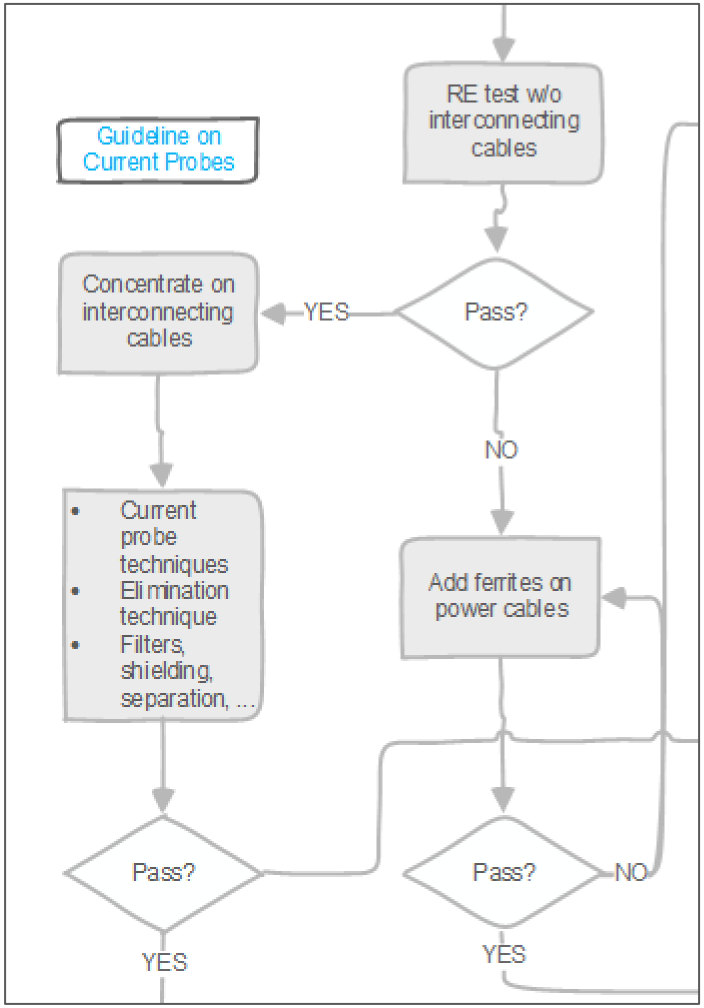
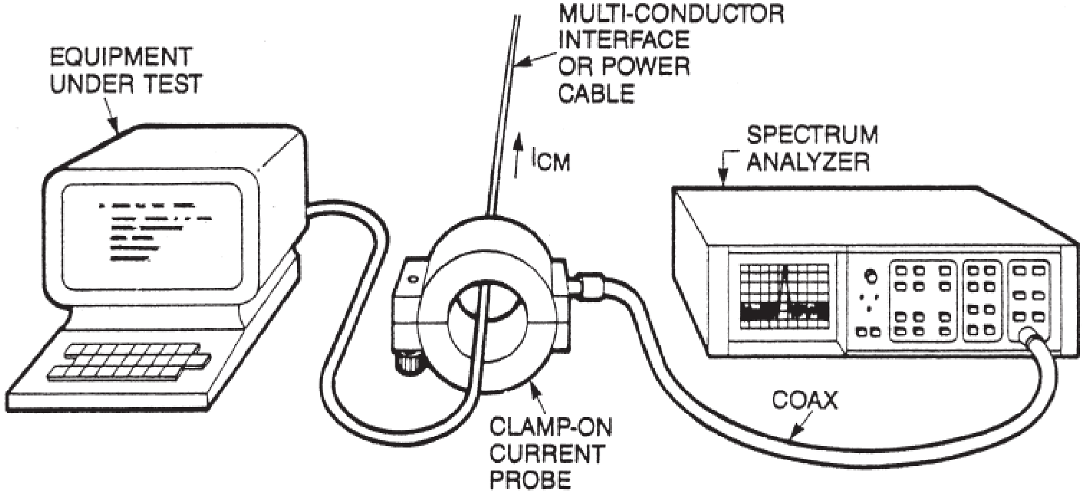
Proposal Workflow Current Probe



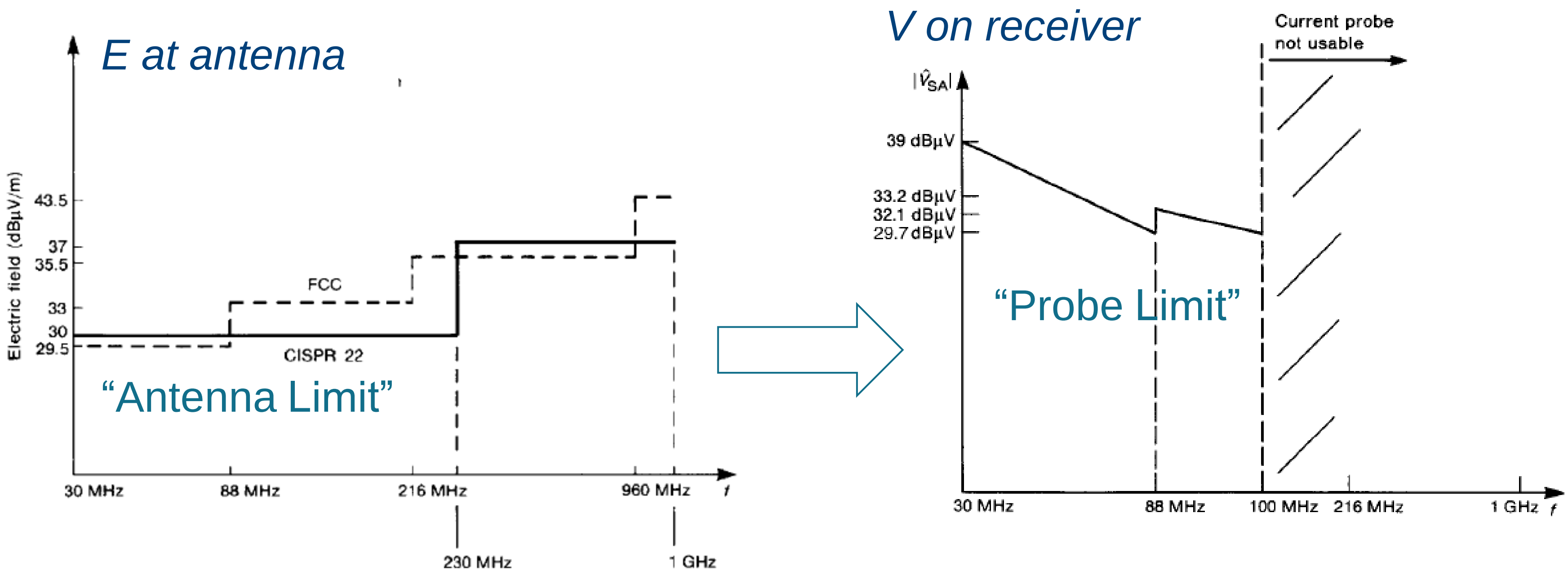


- Move probe over length cable
- Keep track of maximum (max-hold)

? How large can the CM current be ?

Source: *H. Ott*

Limit Line for CM Current?



$$E_{ant} = RTF \times I_{CM} = RFT \times V_{rec} / Z_T$$

RTF = Radiation Transfer Function

Z_T = Transfer impedance current probe

Source: *C. Paul*

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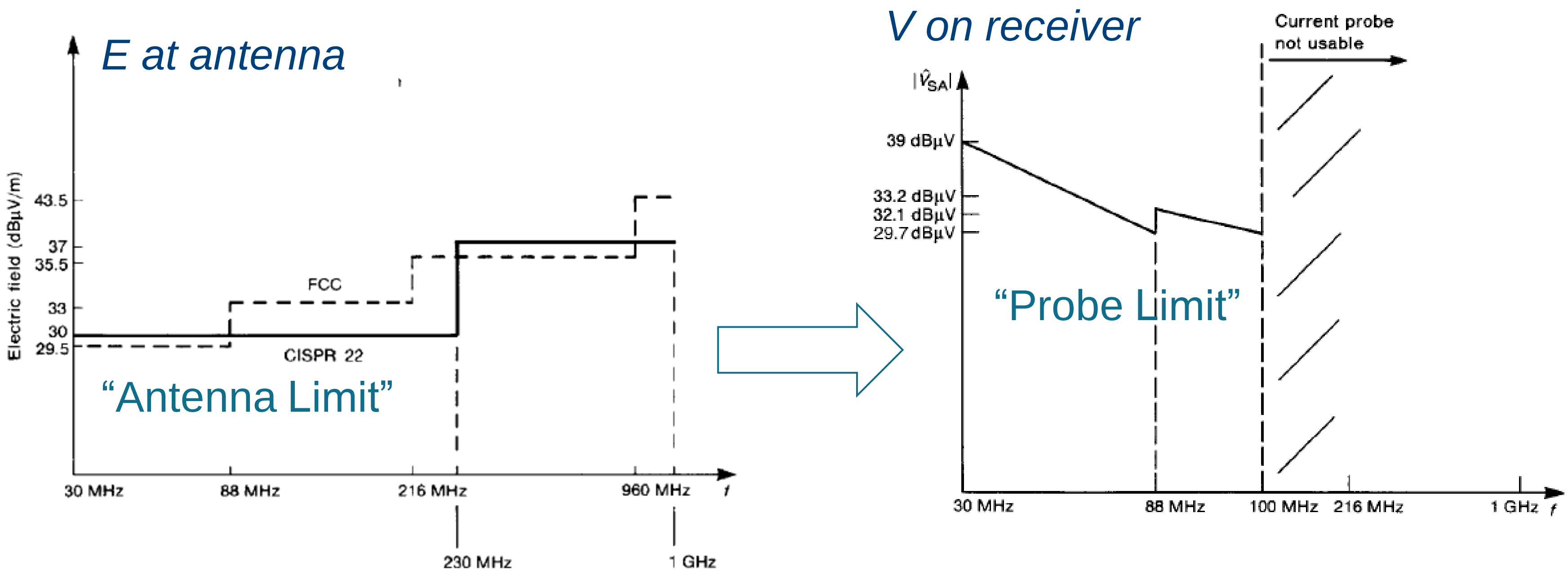
Limit Line for CM Current?



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

Source: *C. Paul*

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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

$$P_{\text{rad}} = 150 \cdot \left|I_{\text{CM}}\right|^2$$

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

$$S = \frac{\left|E\right|^2}{377}$$

$$\text{RTF} = \frac{\left|E\right|}{\left|I_{\text{CM}}\right|} \approx \frac{67}{r}$$

So, for 40dBuv/m at 3m this means that the max CM current would be about 4.5 uA (13 dBuA)

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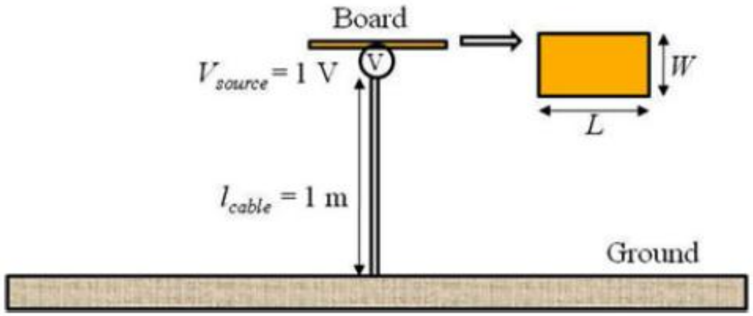
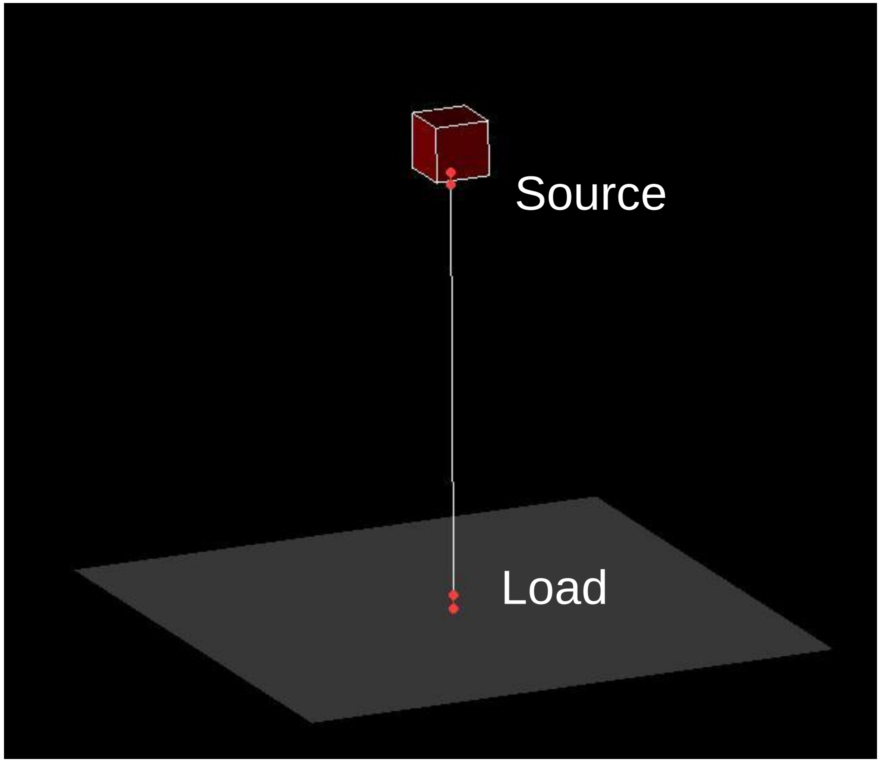
RTF Reasoning 2: Simulation Based



- Source and load impedance unknown in practice
- Source impedance doesn't have influence on RTF
- Load impedance does have influence on RTF



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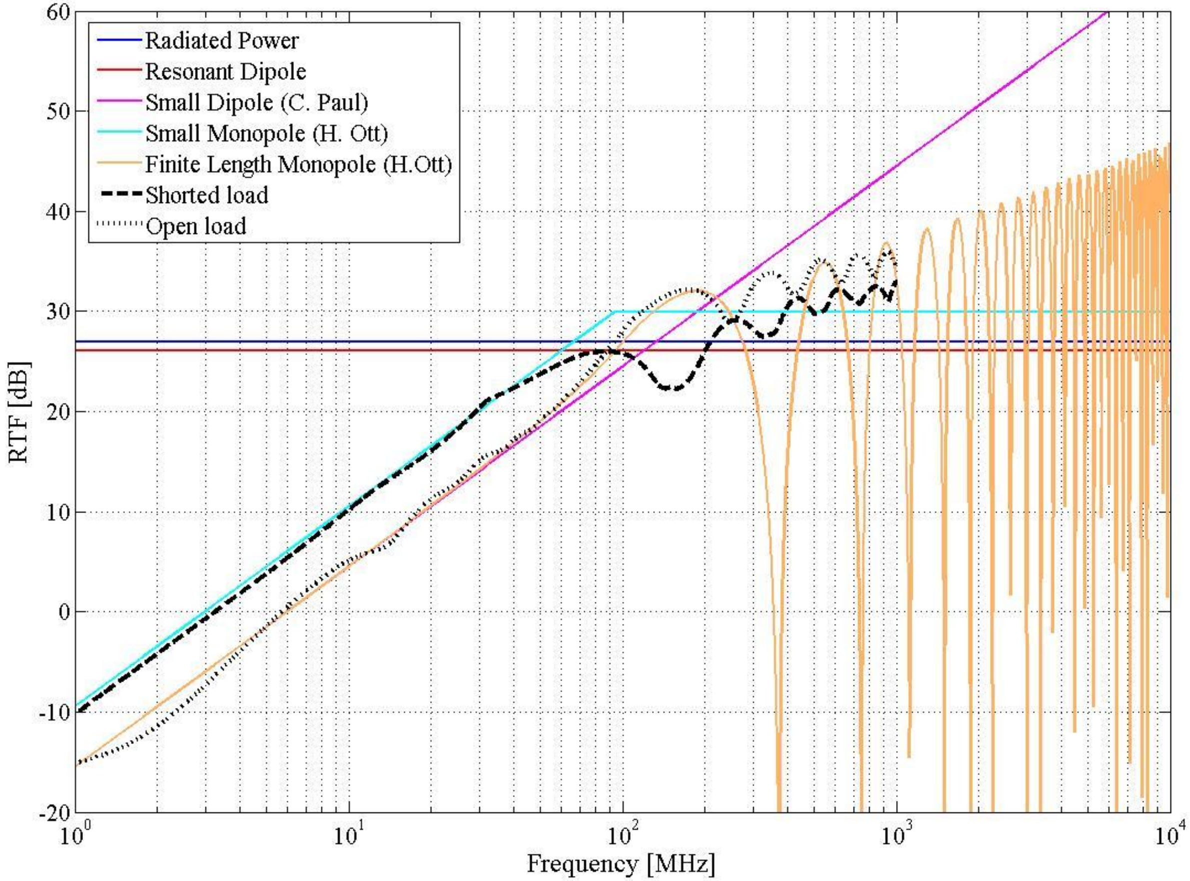
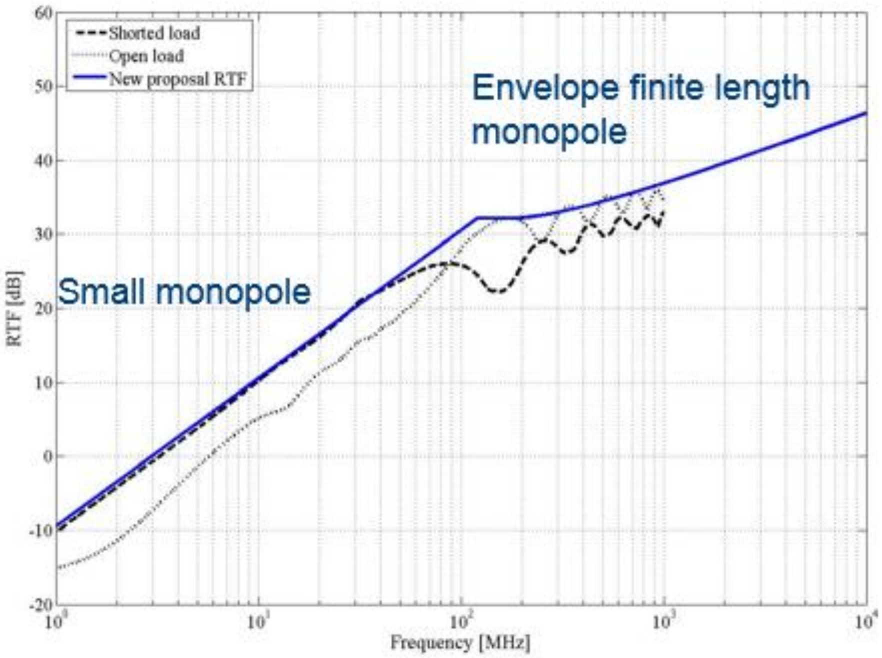
Simulation Result



New Proposal RTF



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

$$\text{Else if } l \le \frac{\lambda}{2} : \text{RTF} = \frac{60}{r}\frac{2}{\sin\left(\sqrt{2}\right)}$$

$$\text{Else RTF} = \frac{60}{r}\frac{2}{\sin\left(\sqrt{\lambda/l}\right)}$$

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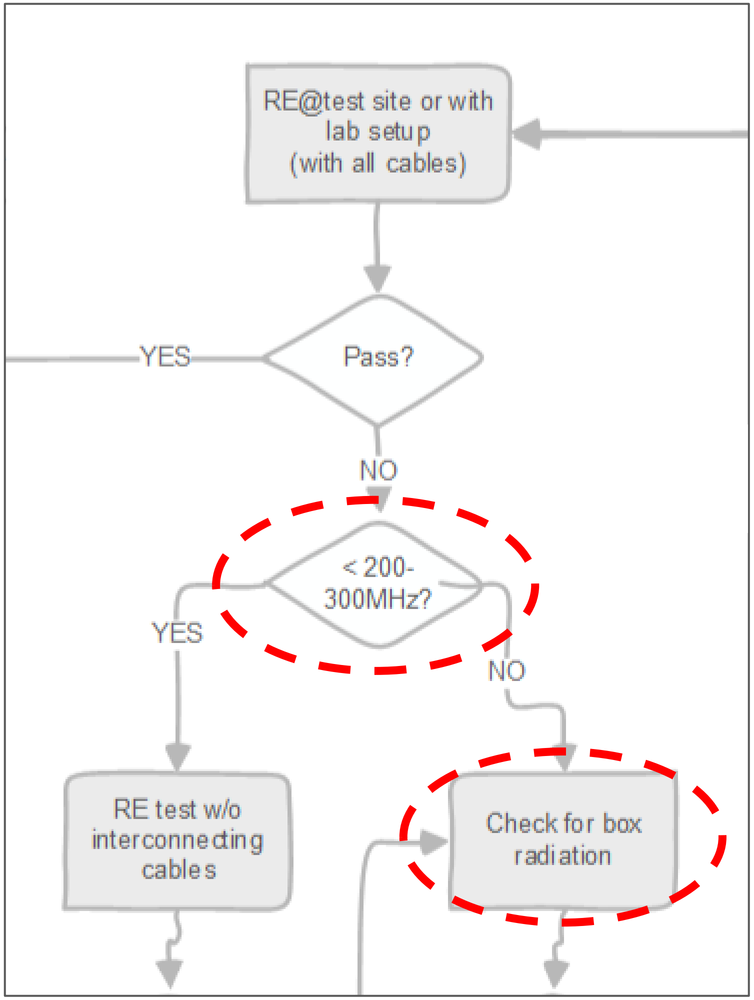
General Debug Workflow: Enclosures

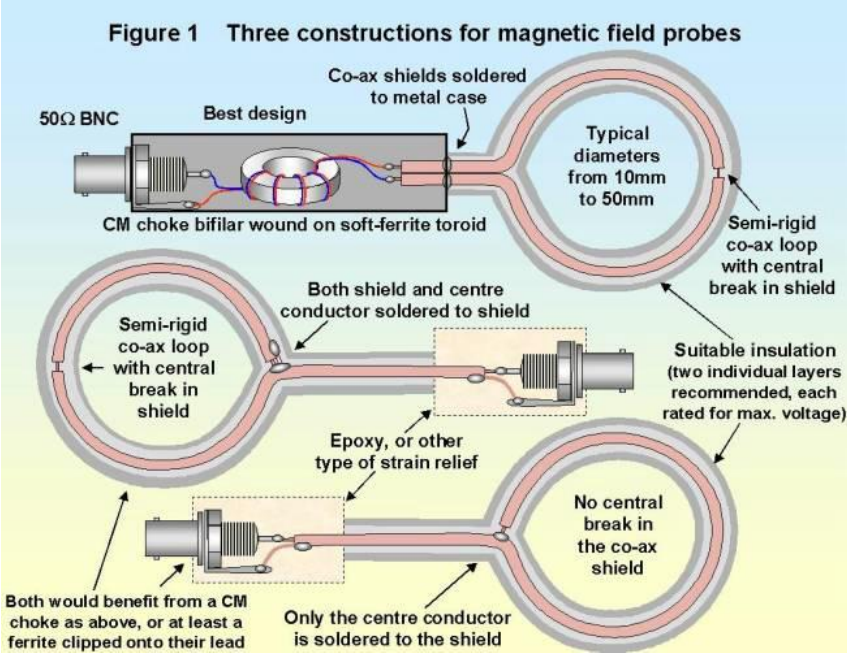


Hand-held Near-Field Probes

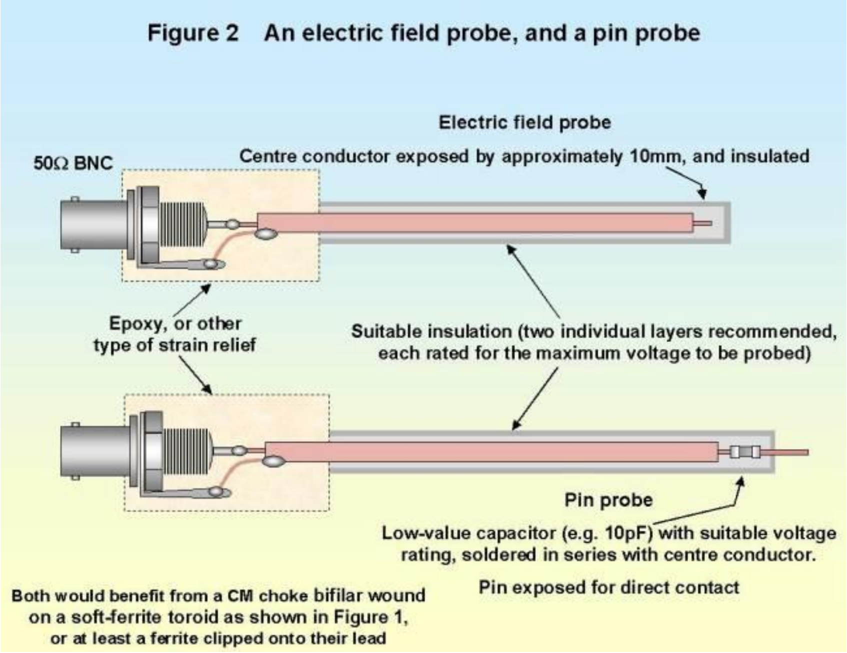
Source pictures: A. Mediano, EMC Europe 2013, Brugge

Basic Types of Near-Field Probes

Magnetic field probes



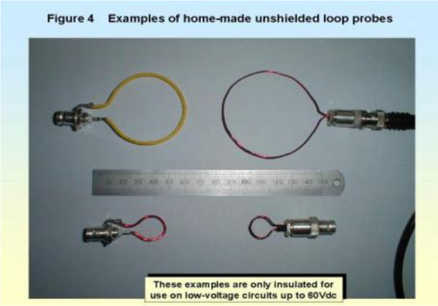
Electric field probes



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
  - Not an issue when locating emission hotspots
- Below: probes made from insulated (≠ shielded!) wire and paperclip (right)
  - Care needed for short circuits or electrocution when not insulated



Source: Keith Armstrong

Source: Doug Smith

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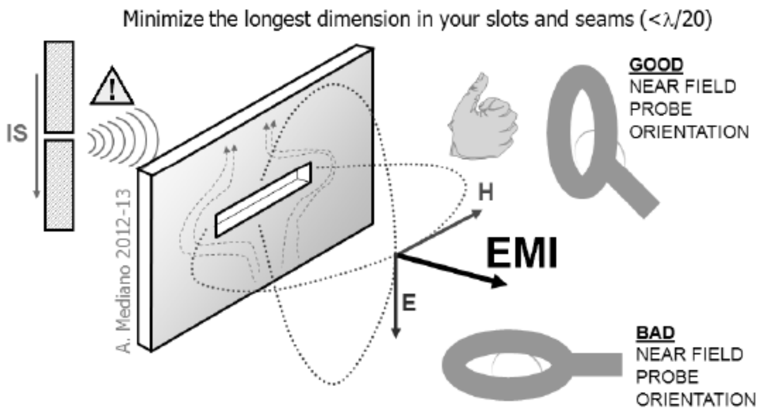
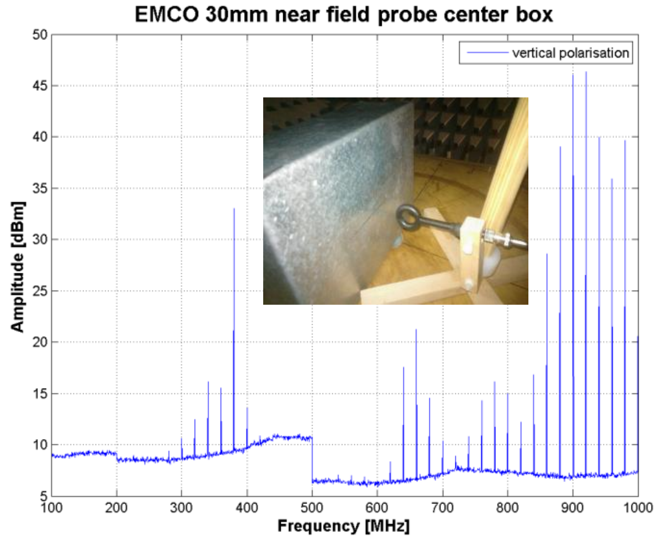
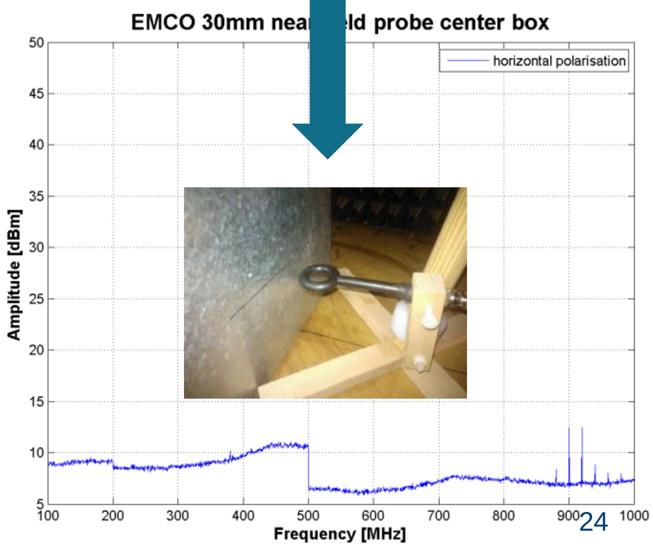
Debugging - Enclosures







Try different orientations!

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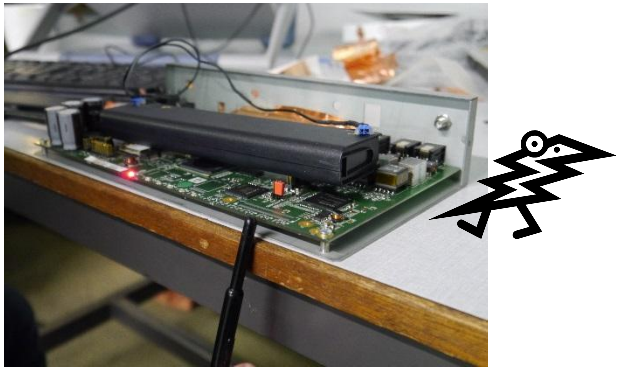
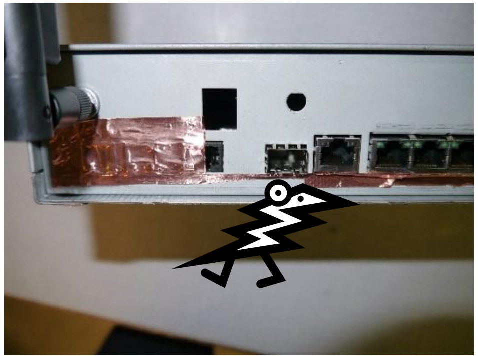
NF Measurement Set-Up

- Nearfield probes:
  - Magnetic (loop) probe
  - Electric (dipole) probe



Which probe do we use?

- Slot radiation: Z=E/H<<< → Magnetic (loop) probe
- PCB edges: Z=E/H>>> → Electric (dipole) probe



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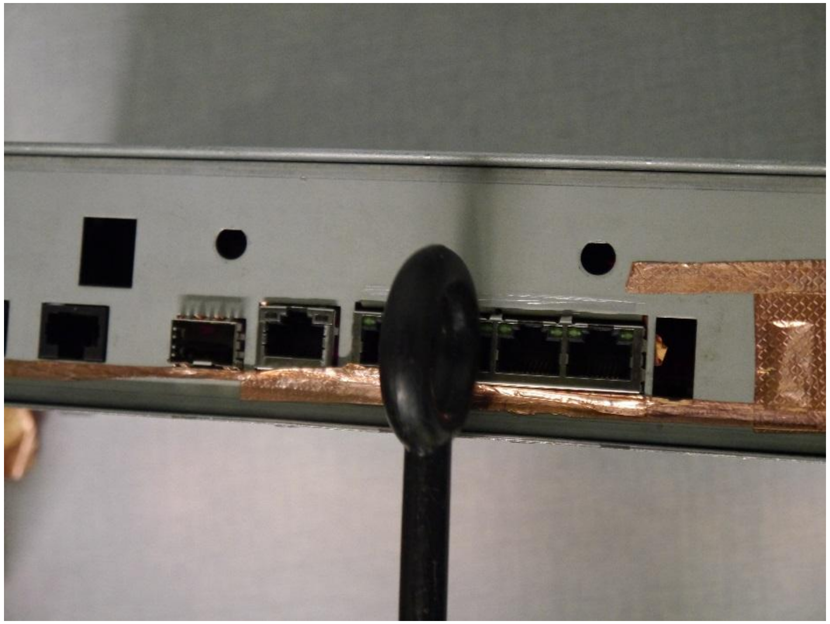
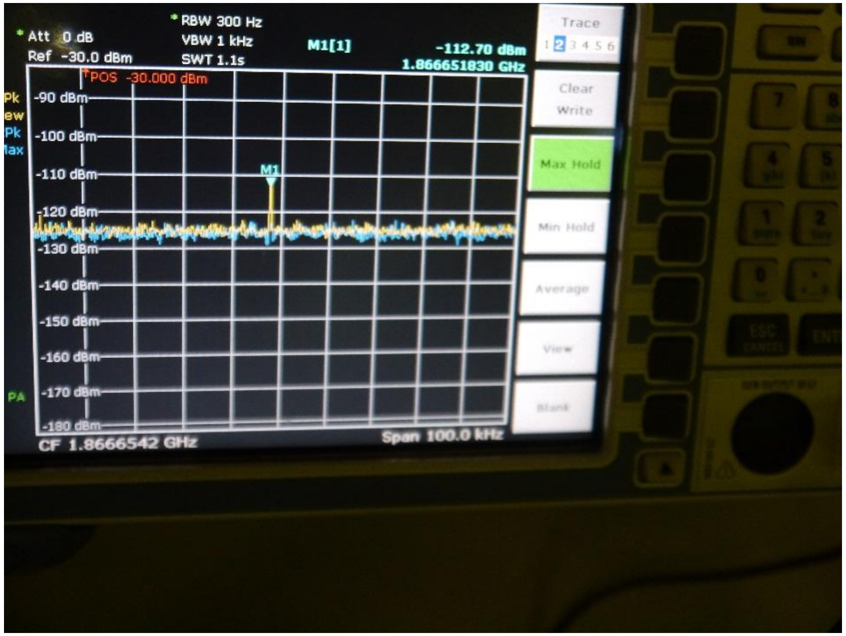
NF Probing: Front panel (Slot radiation)





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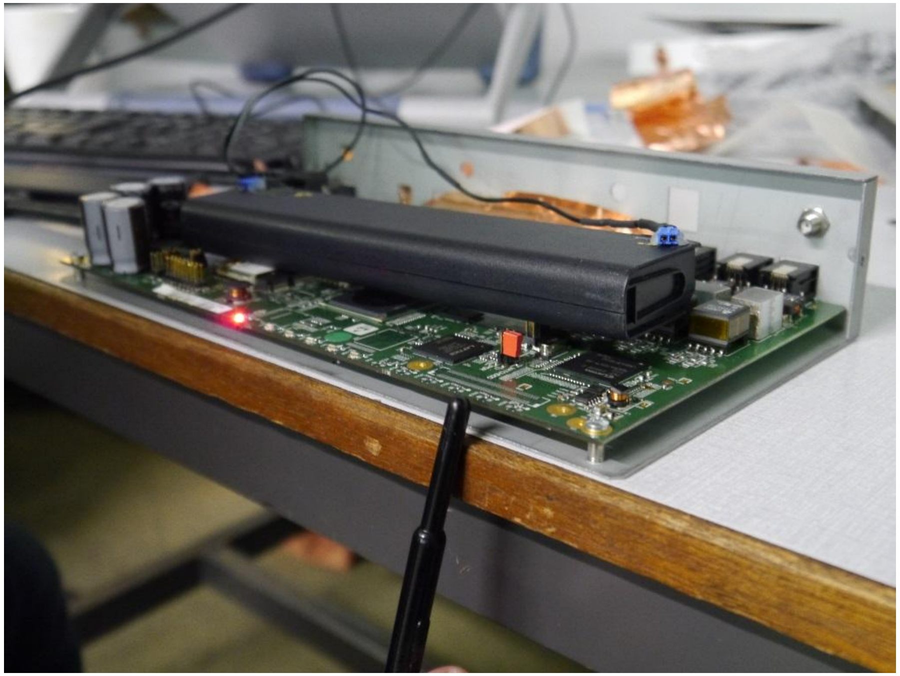
NF Probing: PCB edges



- 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.

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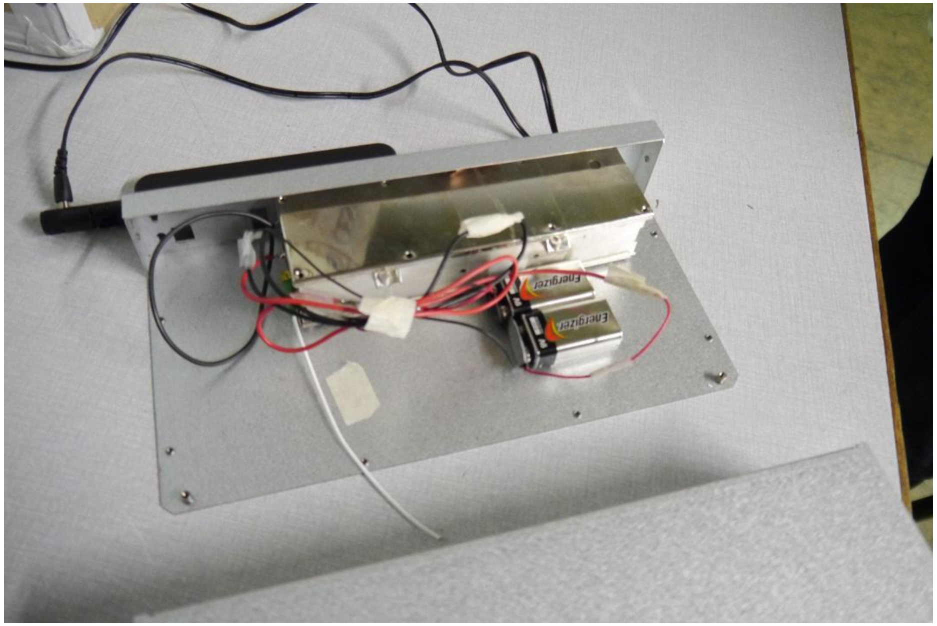
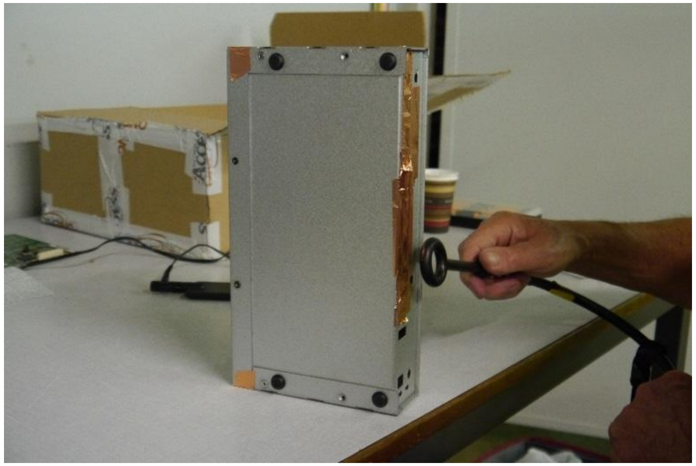
Use of Comb generator



No cable that exits the casing, which allows us to analyze the shielding of the casing correctly.



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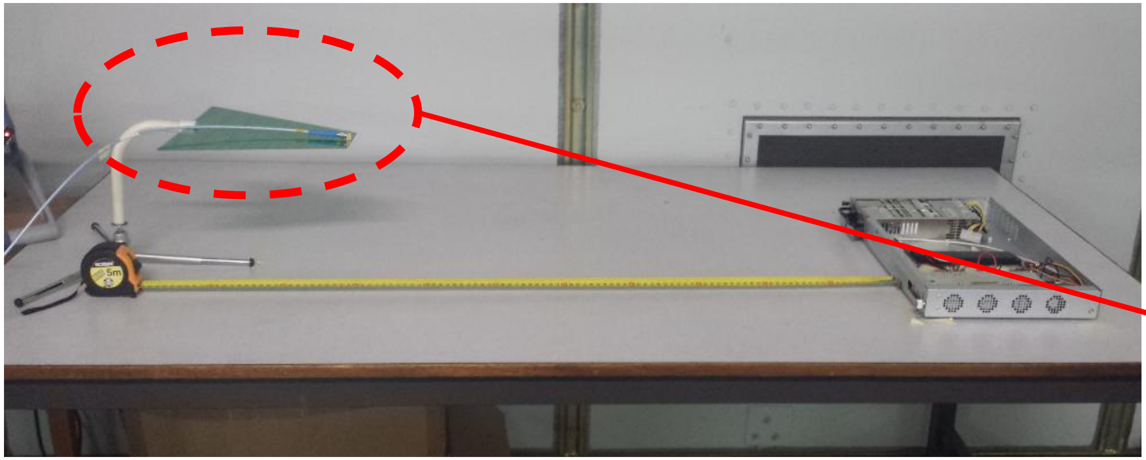
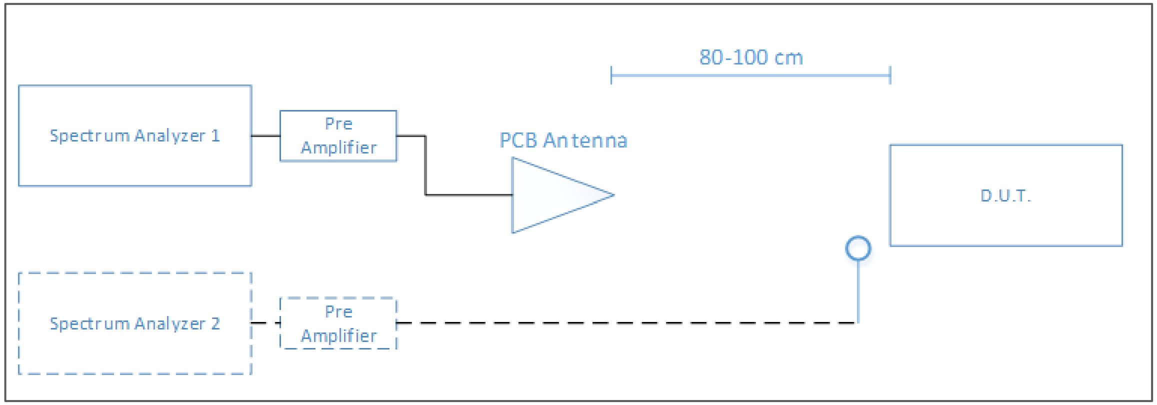
NF / FF Test Set-Up



www.wa5vjb.com



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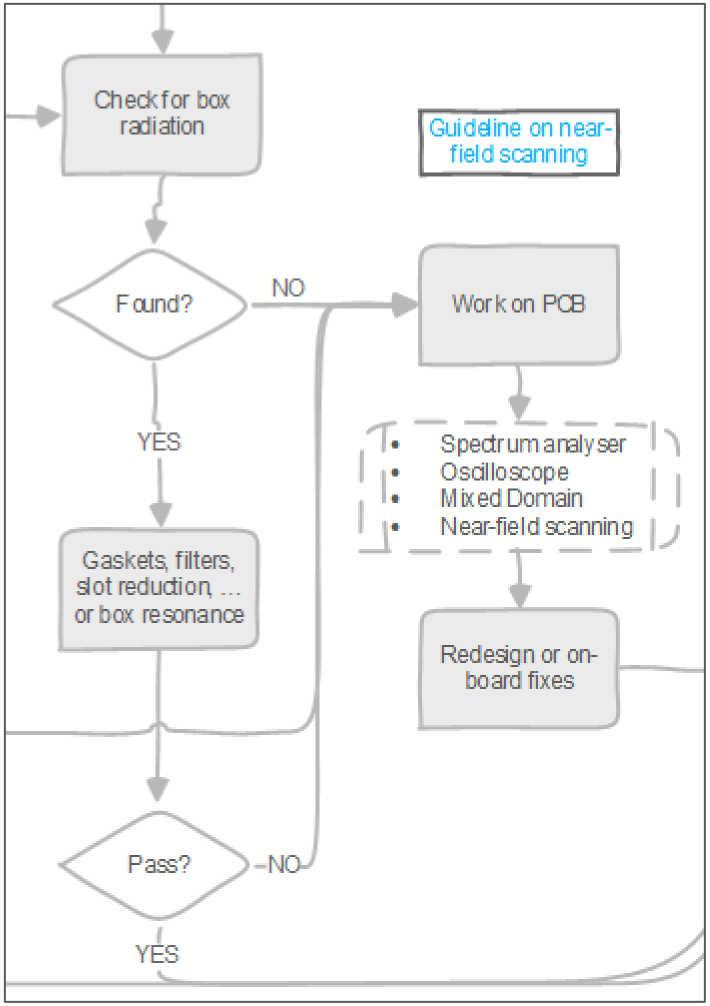
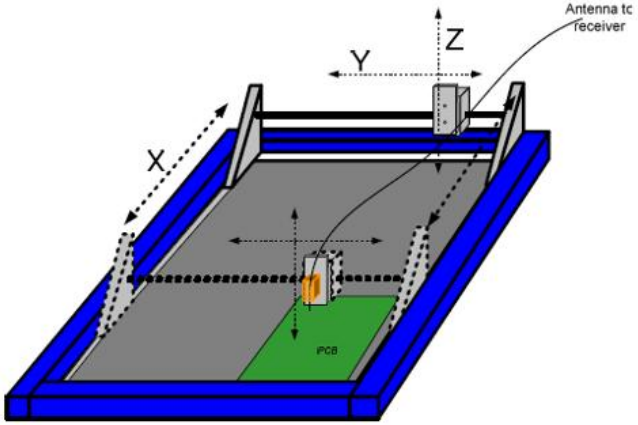
General Debug Workflow: PCB



Hand-held Near-Field Probes

Near-Field Scanner



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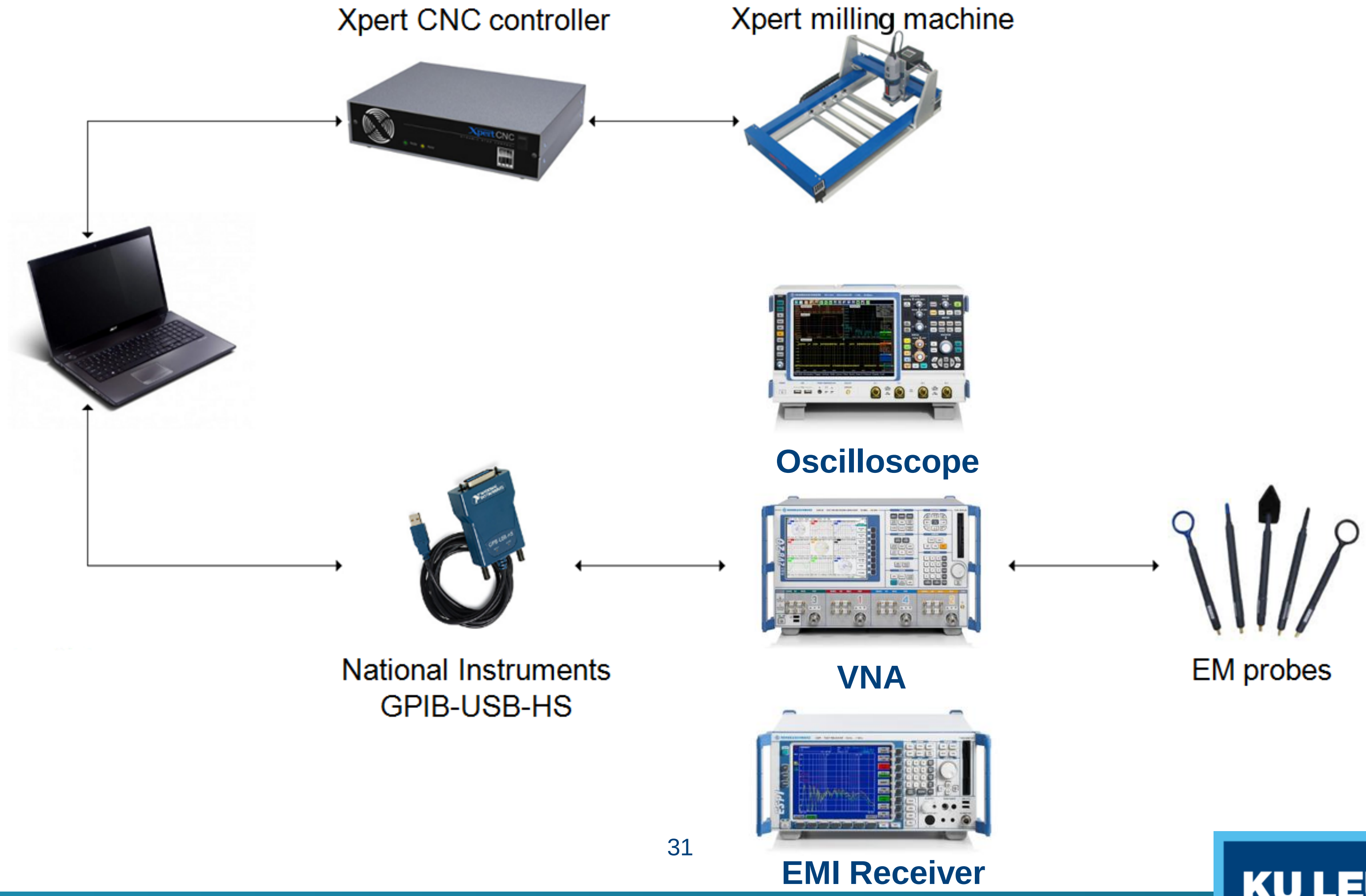
Near-Field Scanning System



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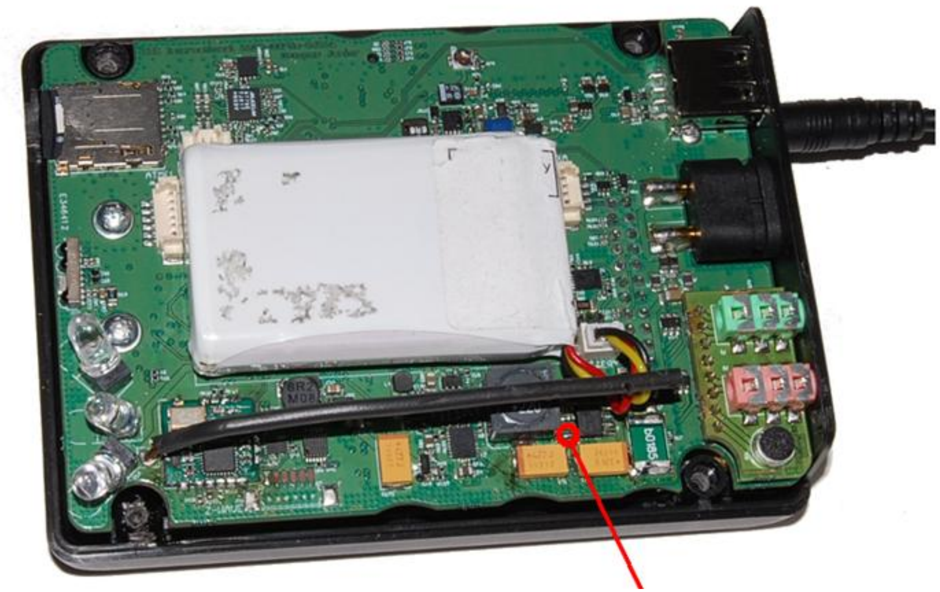
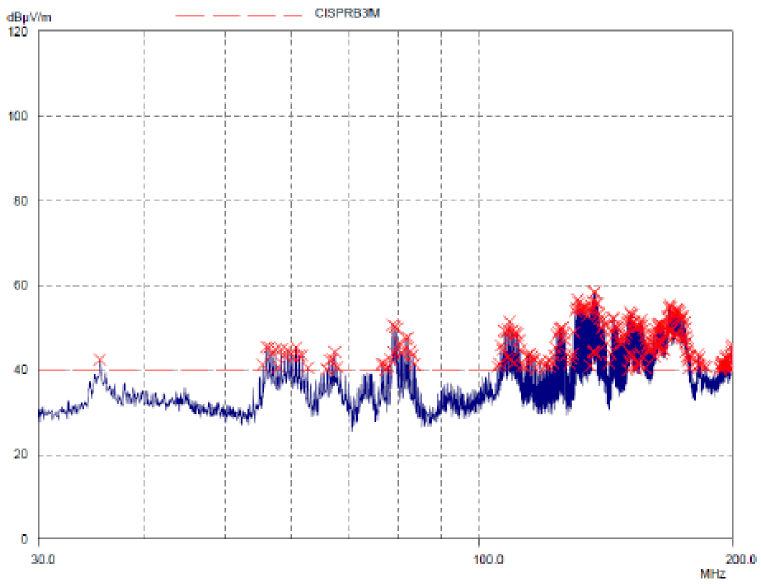
DUT Far-Field Emissions





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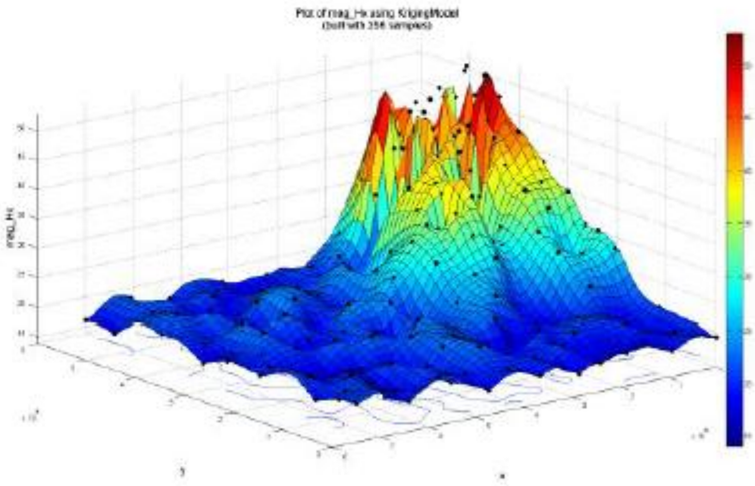
DUT Near-Field Emissions at 114 MHz



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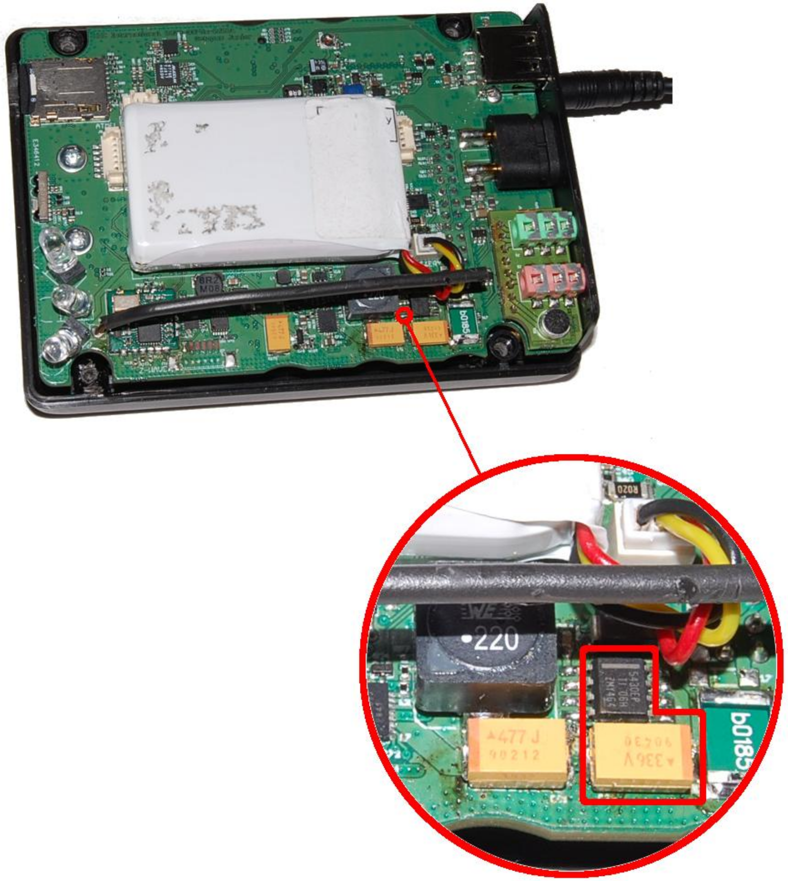
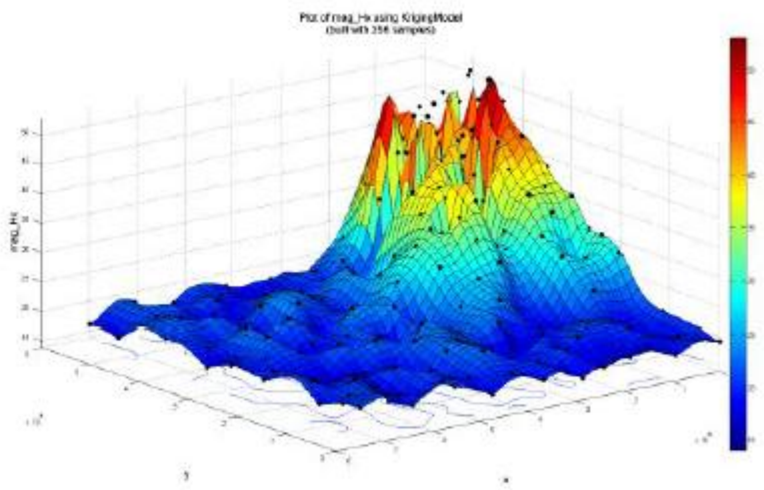
Culprit?





FMEC

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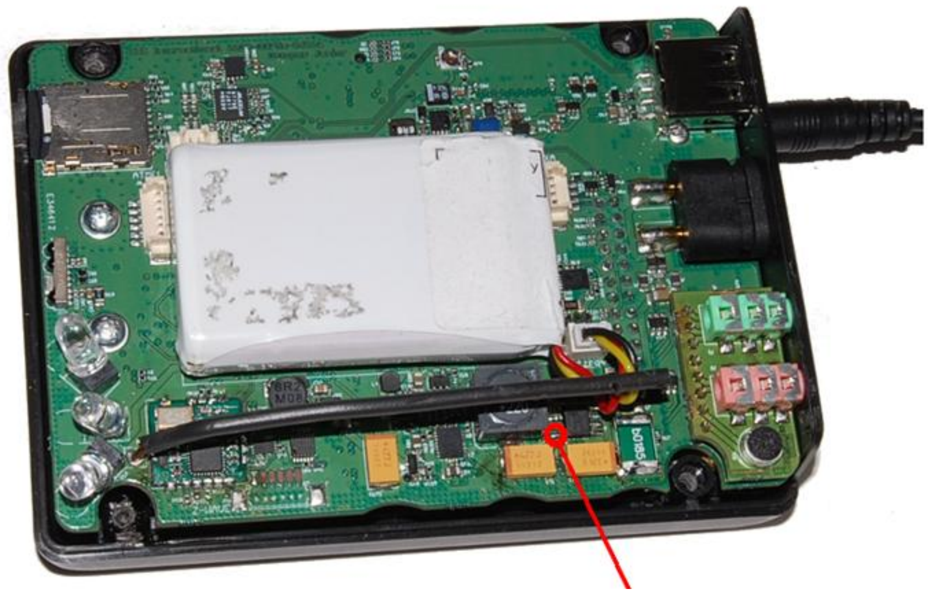
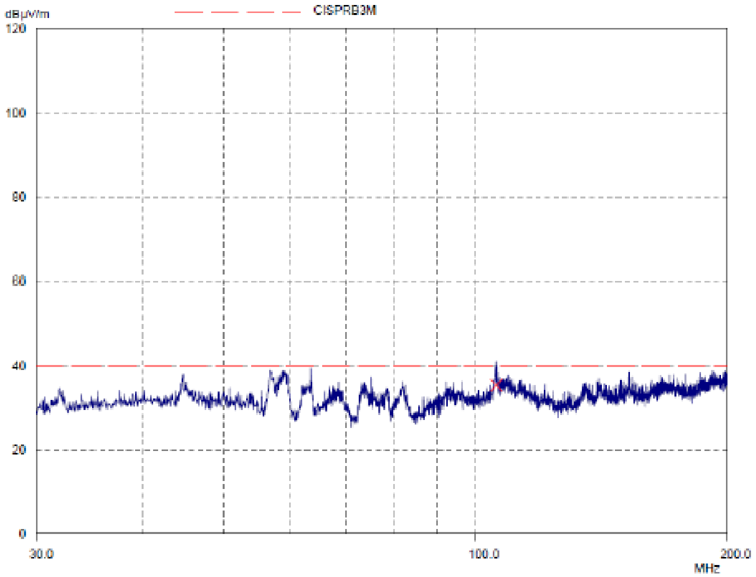
Adjusted DUT: Far-Field Emissions





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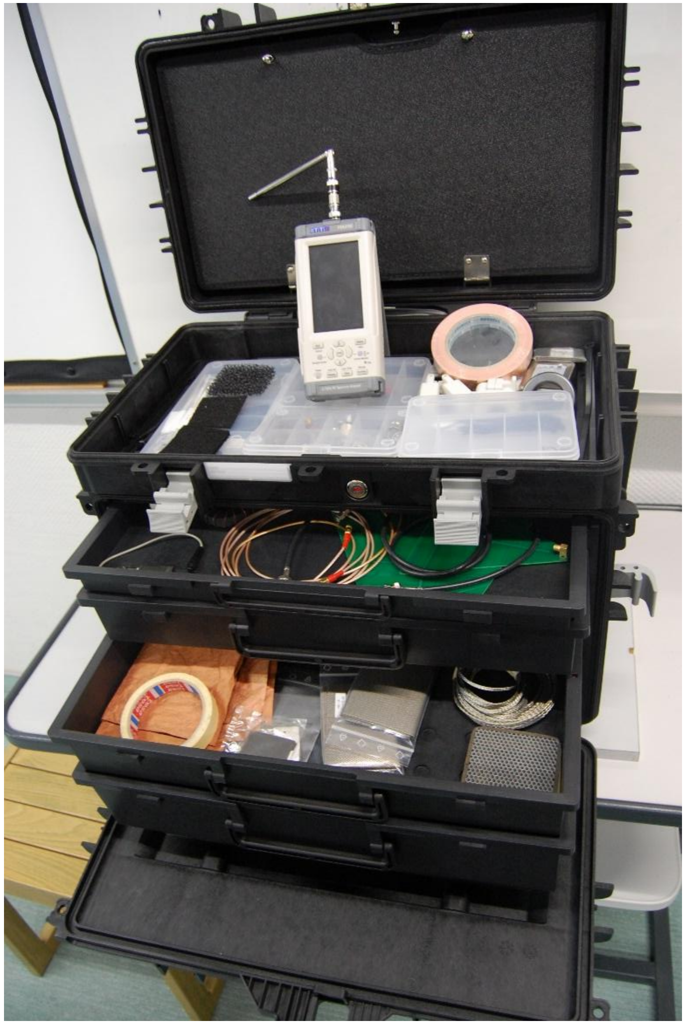
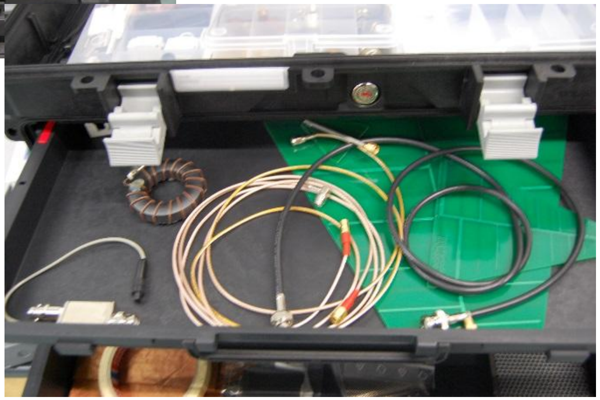
EMC Debug kit





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Recommended literature

- This presentation is based on:
  - "EMI Troubleshooting Cookbook for Product Designers" by K. Wyatt and P. André, 2014

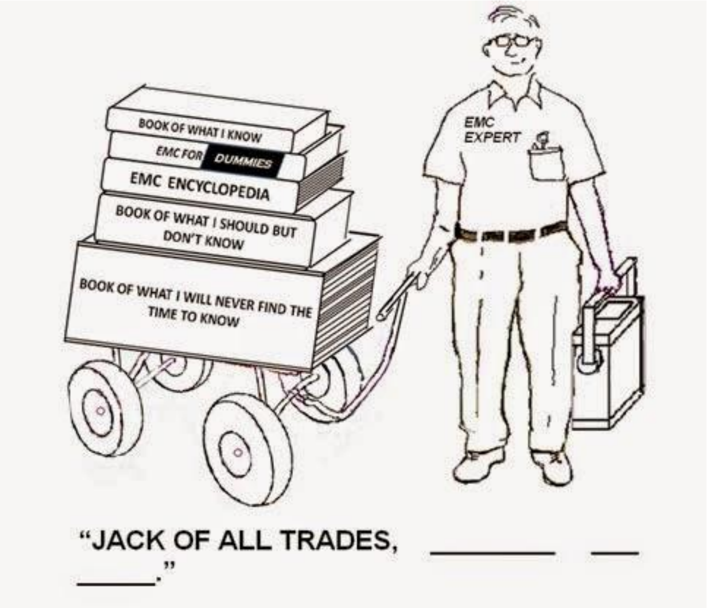
- "EMC for Product Designers" by T. Williams (4th Ed. 2006)

- "EMI Troubleshooting Techniques" by M. Mardiguian (1999)

- "Testing for EMC Compliance: approaches and techniques" by M. Montrose (2004)

Recommended literature

- Online:
  - Doug Smith
    - http://emcesd.com/
  - Keith Armstrong
    - http://www.cherryclough.com/home
    - http://www.compliance-club.com/
  - Ken(neth) Wyatt
    - http://www.emc-seminars.com/



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The end

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