EMI Troubleshooting and EMI Mythbusters

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& Ken Hess Systems Engineer

Rockwell Collins

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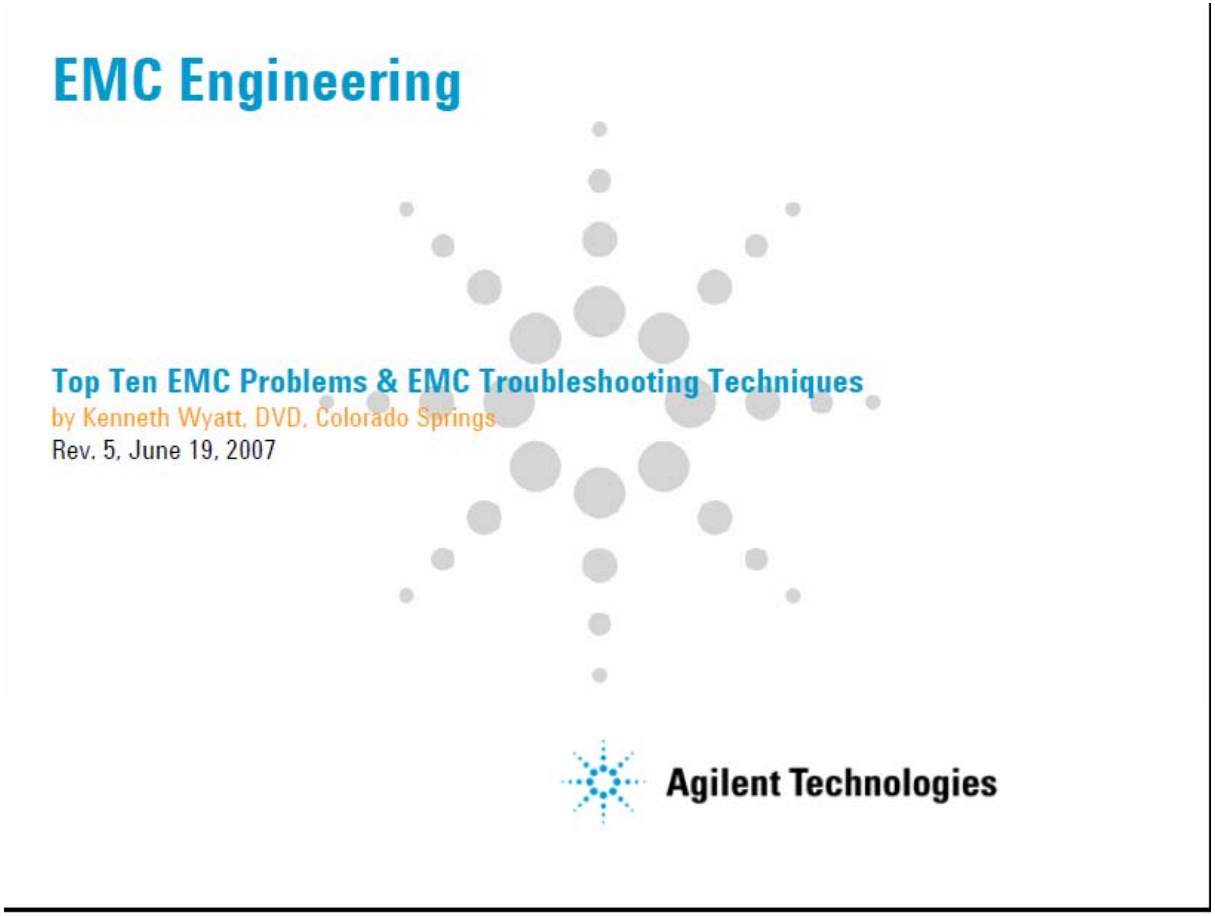
The presentation today will include the following:

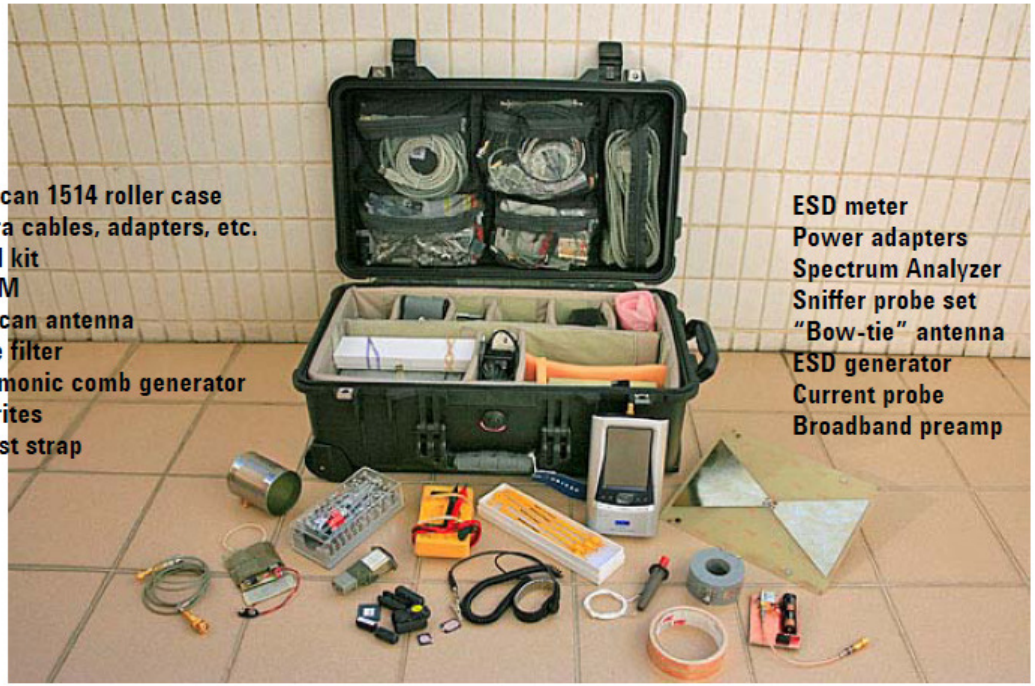
1. **Overview of an excellent presentation on EMI troubleshooting techniques written by Kenneth Wyatt at Agilent**
   http://ewh.ieee.org/r6/lac/emc/announcements/EMC_10_Top_Ten_EMC_Problems_with_EMC_Troubleshooting_Ver_5.pdf
   - **Includes**
     - **Top Ten EMC Problems (not addressed at this time)**
     - **& EMC Troubleshooting Techniques**
2. **Simple Relative Enclosure Shielding Effectiveness test method**
   - **Shows Relative Shielding Effectiveness of an enclosure with cables**
   - **Shows the degradation to Shielding Effectiveness caused by cables**
3. **Ethernet cable emissions**
   - **Standard Ethernet (CAT5)**
   - **Shielded Ethernet**
   - **Shielded Ethernet with shield terminated at one end only**
4. **EMI Mythbusters**
   - **EMI myths that I have heard here at Rockwell Collins**
   - **Using staged EMI problems, we will find out if they are true or "busted"**

1. Kenneth Wyatt's presentation (shortened version)



1. Kenneth Wyatt's presentation (shortened version)

EMC Troubleshooting Kit



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1. Kenneth Wyatt's presentation (shortened version)

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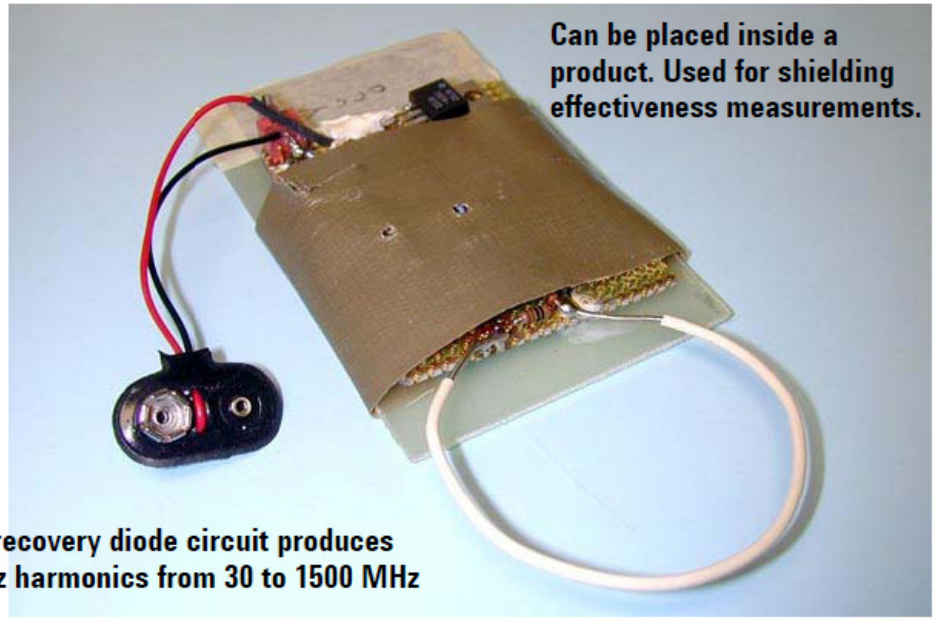
"Mini" Harmonic Comb Generator Used For Shielding Effectiveness Test



Wyatt/Chaney, RFI Measurements Using a Harmonic Comb Generator, RF Design Magazine, Jan. 1991

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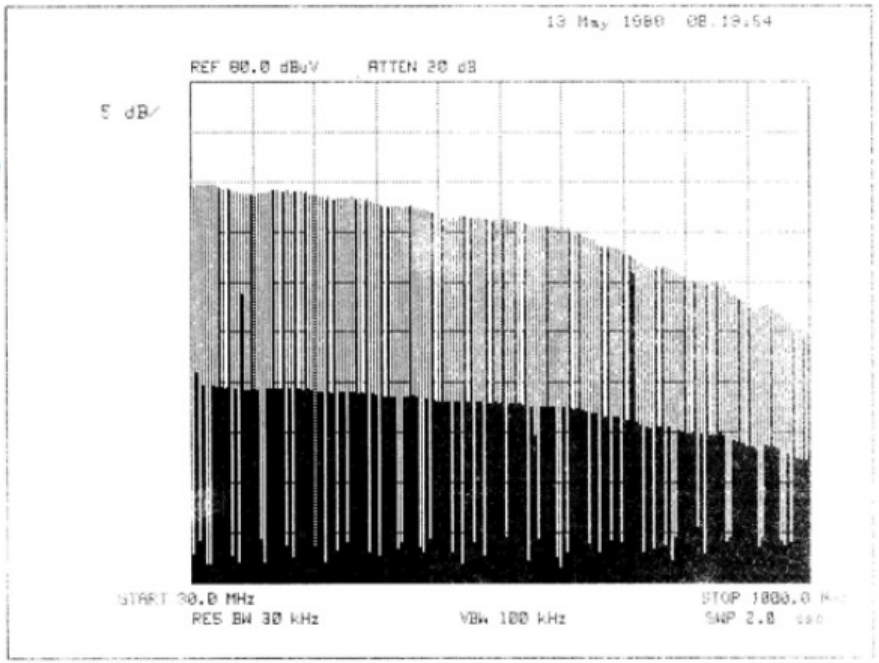
1. Kenneth Wyatt's presentation (shortened version)

Comb generator output

Direct output of the harmonic comb generator into a spectrum analyzer

30 to 1000 MHz
15 dB down @
1000 MHz



Wyatt/Chaney, RFI Measurements Using a Harmonic Comb Generator, RF Design Magazine, Jan. 1991

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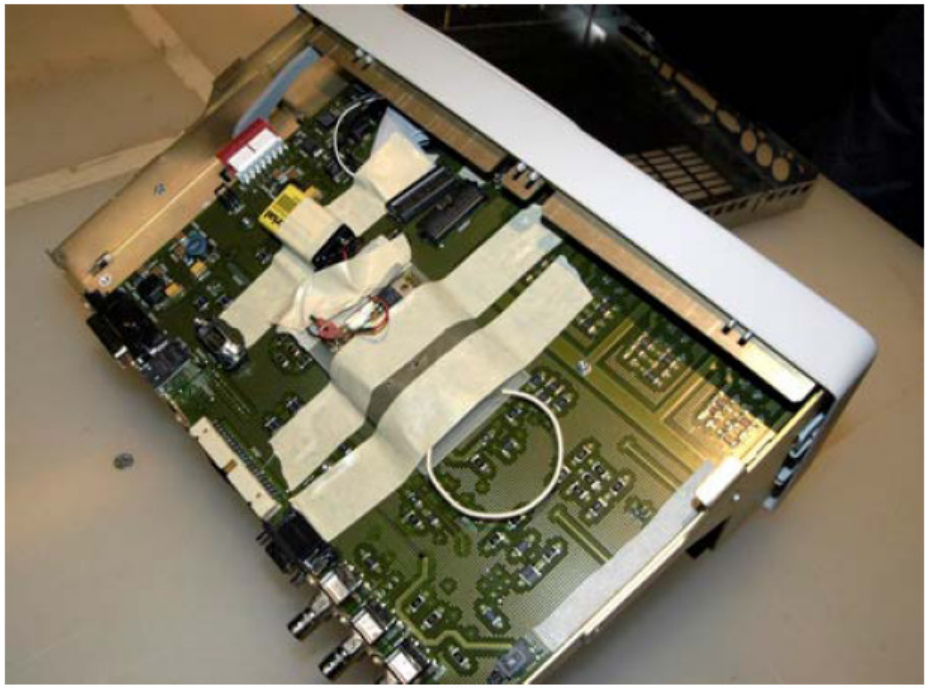
1. Kenneth Wyatt's presentation (shortened version)

Comb Generator Taped To Prototype Product



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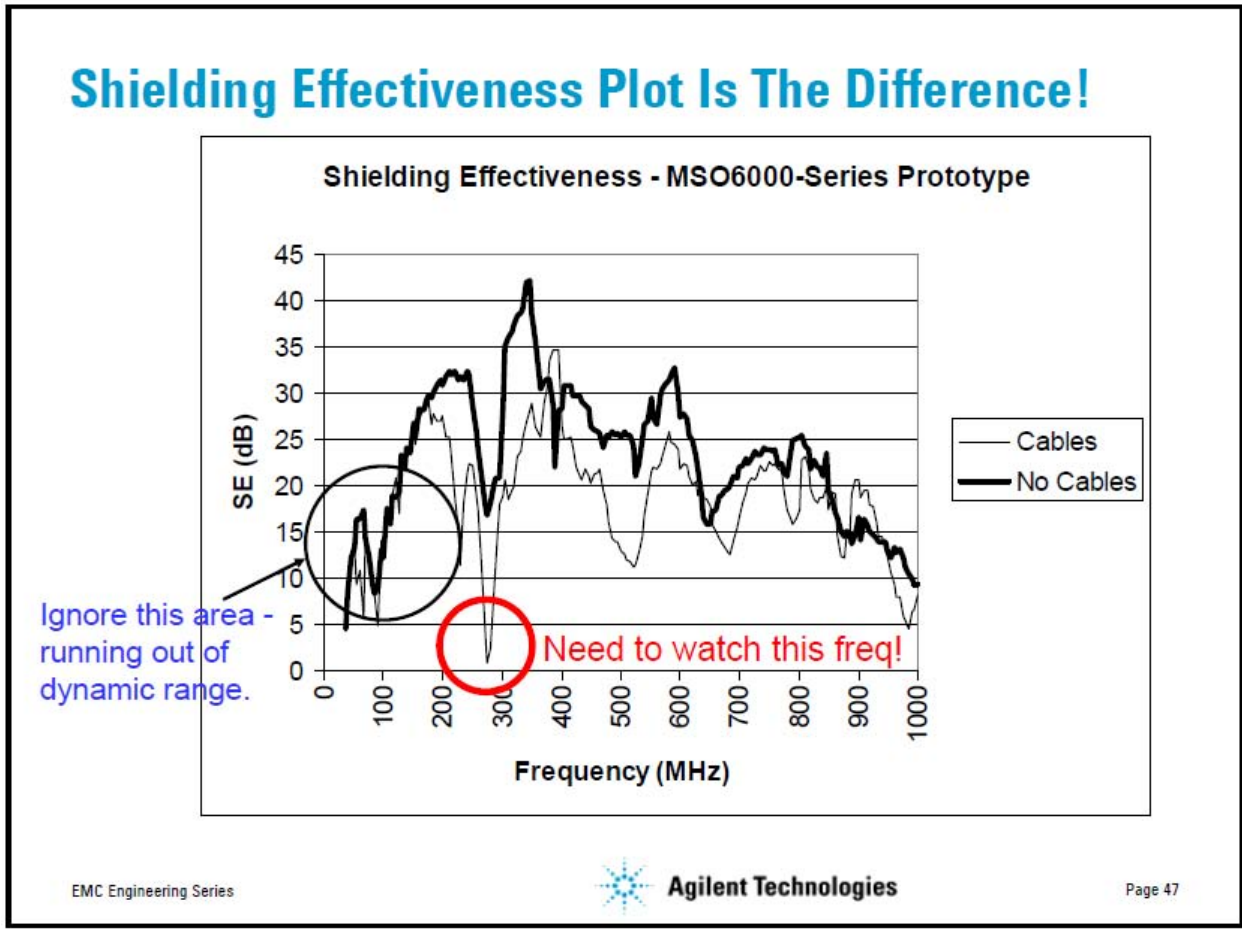

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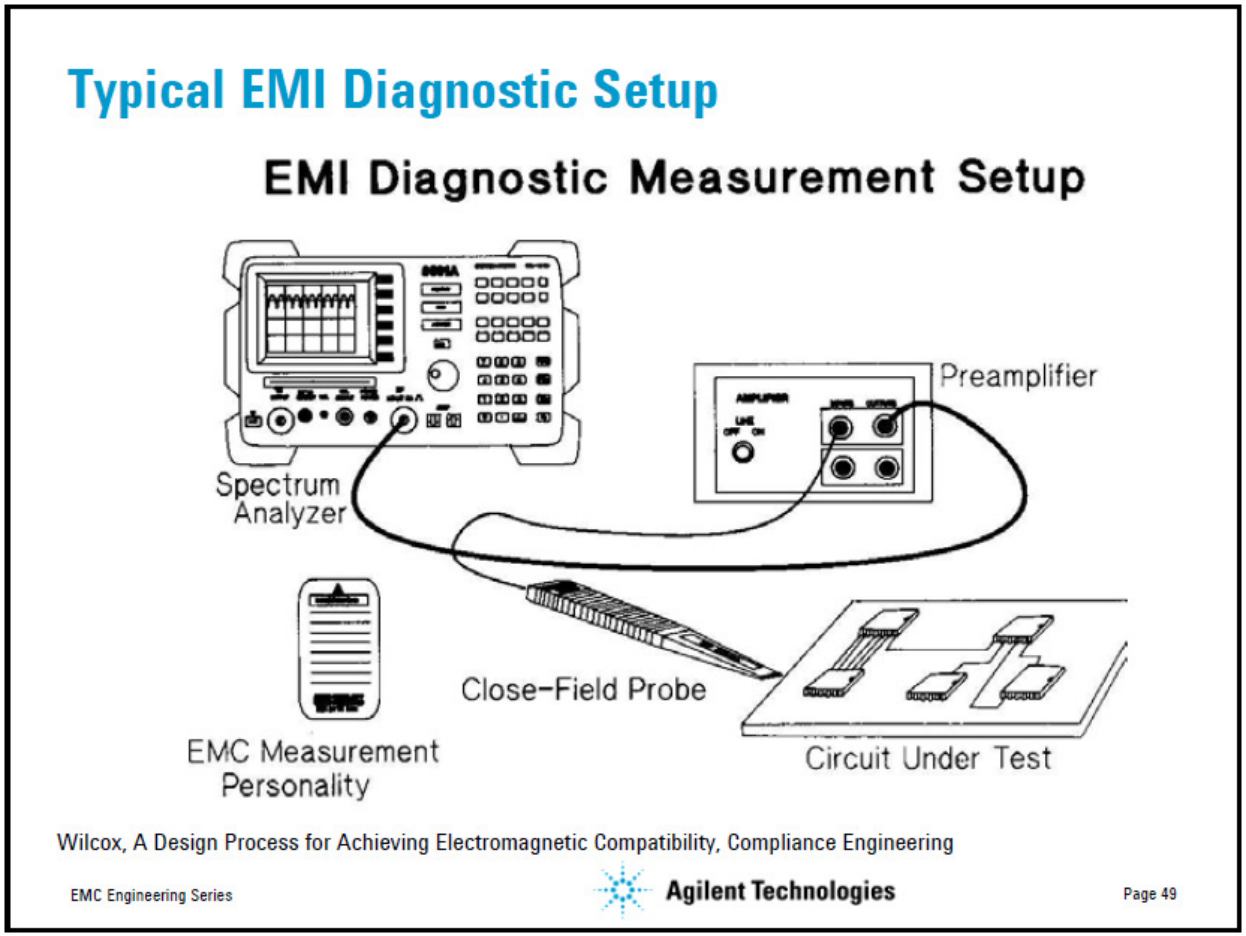
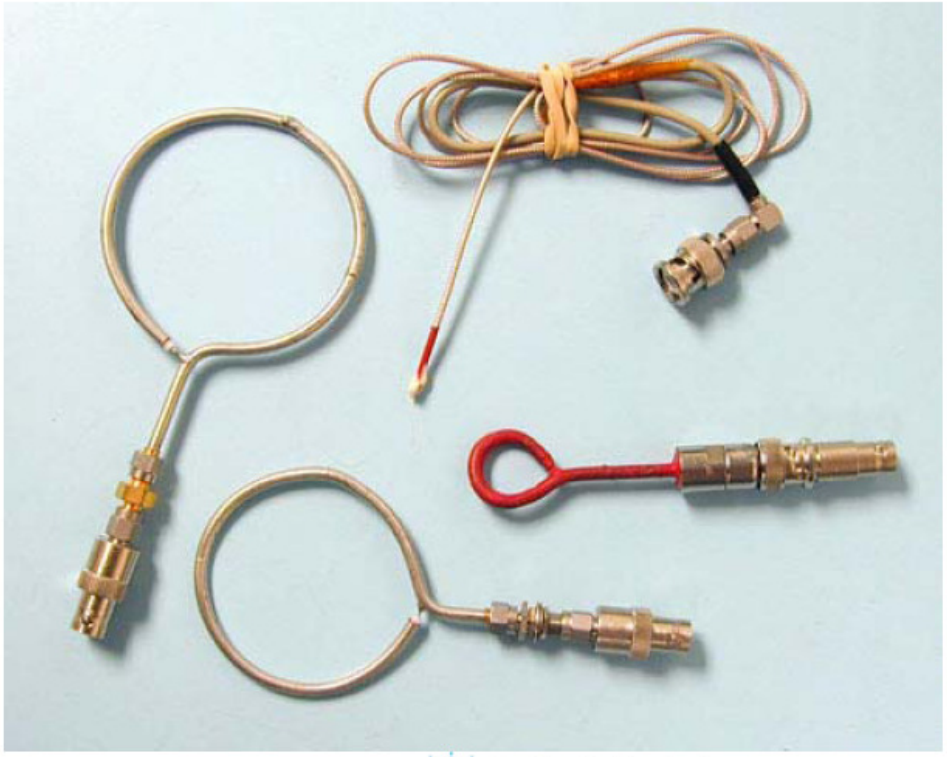


1. Kenneth Wyatt's presentation (shortened version)

Examples Of Home Made Loop (H-Field) Probes



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1. Kenneth Wyatt's presentation (shortened version)

Constructing a simple loop probe

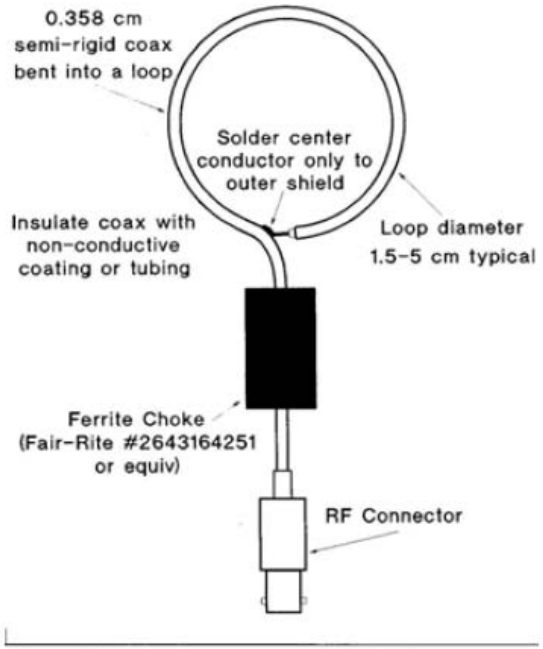

Figure 3. Simple, easy-to-make magnetic field probe.

Roleson, Finding EMI Resonances in Structures, EMC Test & Design, Jan/Feb 1992

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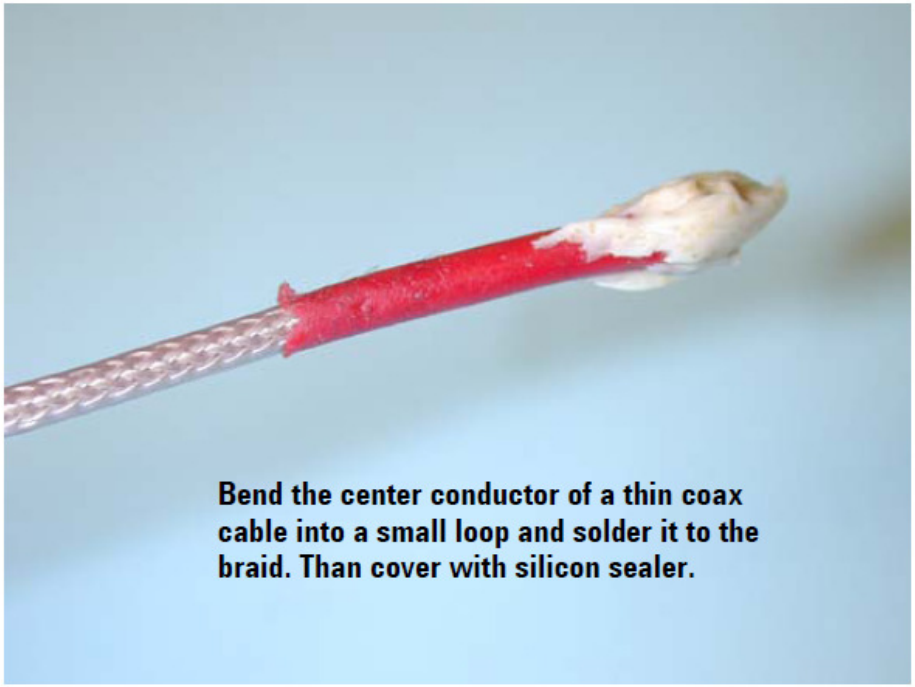
1. Kenneth Wyatt's presentation (shortened version)

"Mini" loop probe



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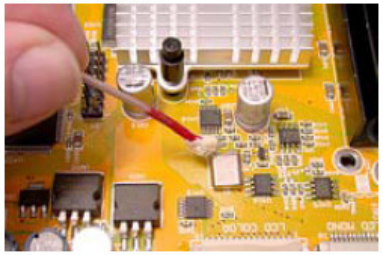
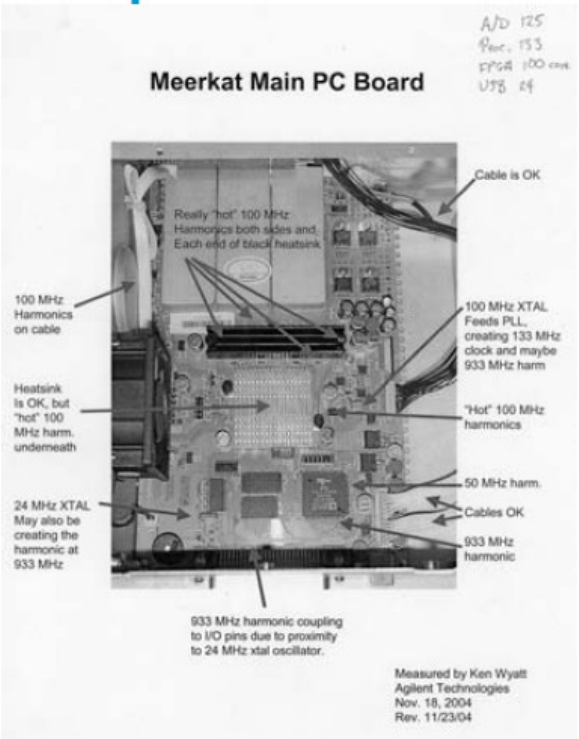
1. Kenneth Wyatt's presentation (shortened version)

Mapping Of PC Board "Hot Spots"

½" Magnetic field probe for course measurements

"Micro" magnetic field probe for fine measurements





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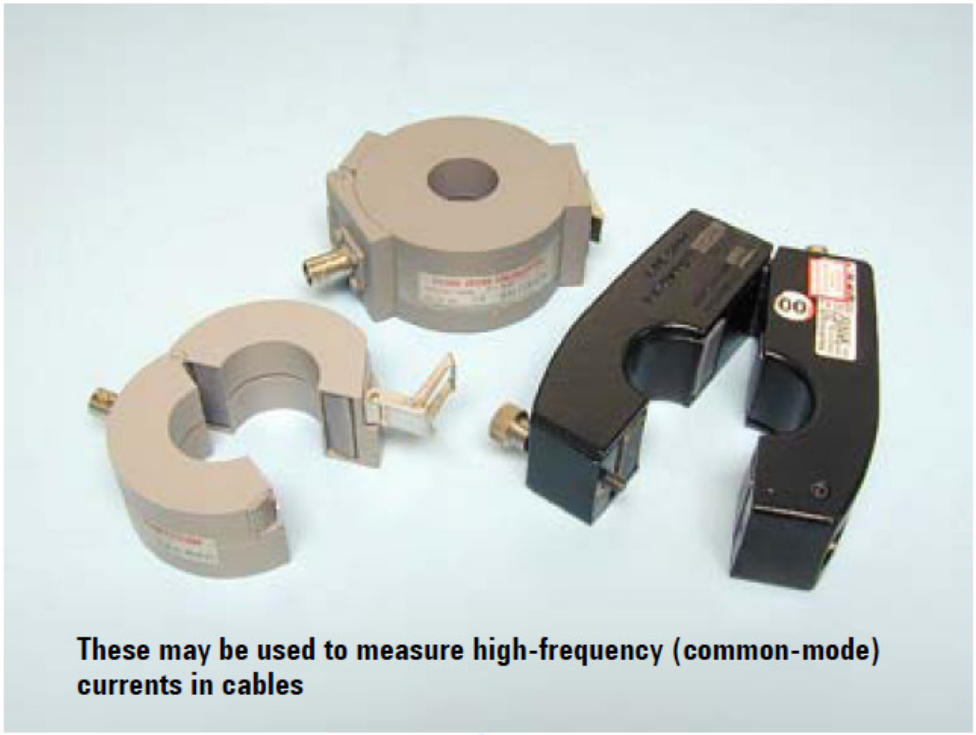
1. Kenneth Wyatt's presentation (shortened version)

Examples of current probes



These may be used to measure high-frequency (common-mode) currents in cables

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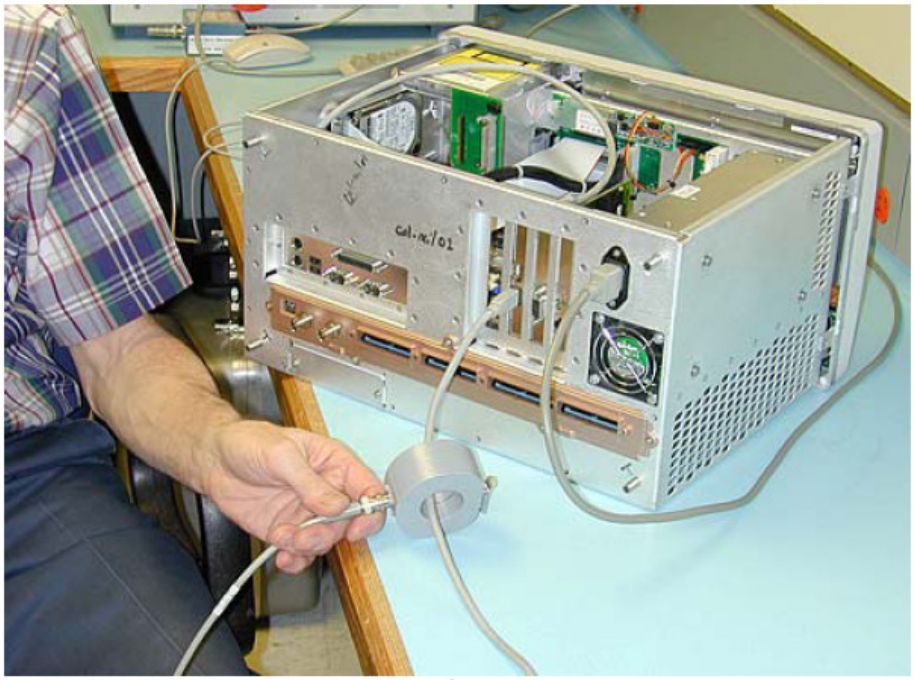
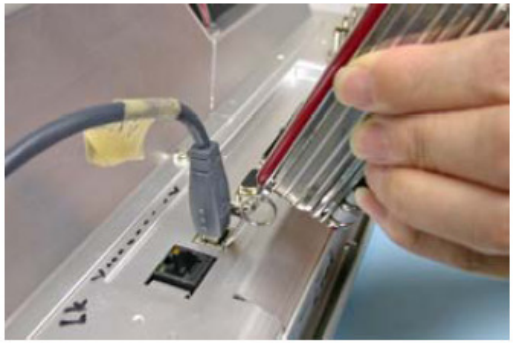
1. Kenneth Wyatt's presentation (shortened version)

Using A Current Probe To Measure Cable Common-Mode Currents



1. Kenneth Wyatt's presentation (shortened version)

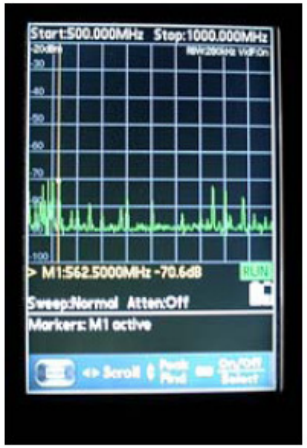
Result After Simple Connection to Chassis



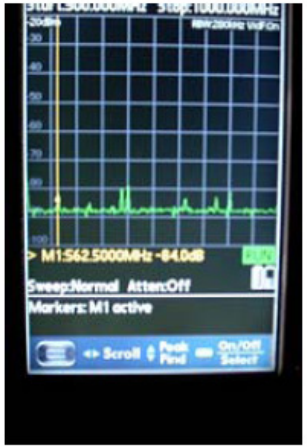
Test setup:

Current probe on USB cable. Connection between connector ground shell and chassis enclosure made with screwdriver blade.

Looking from 500 to 1000 MHz



Before



After

Some harmonics dropped by 10-15 dB!

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1. Kenneth Wyatt's presentation (shortened version)

Ferrite Chokes Block Common-Mode Currents

Often used on keyboard, mouse or video cables

Very useful for troubleshooting

Manufactures often provide free evaluation kits

Best used on low-Z cables

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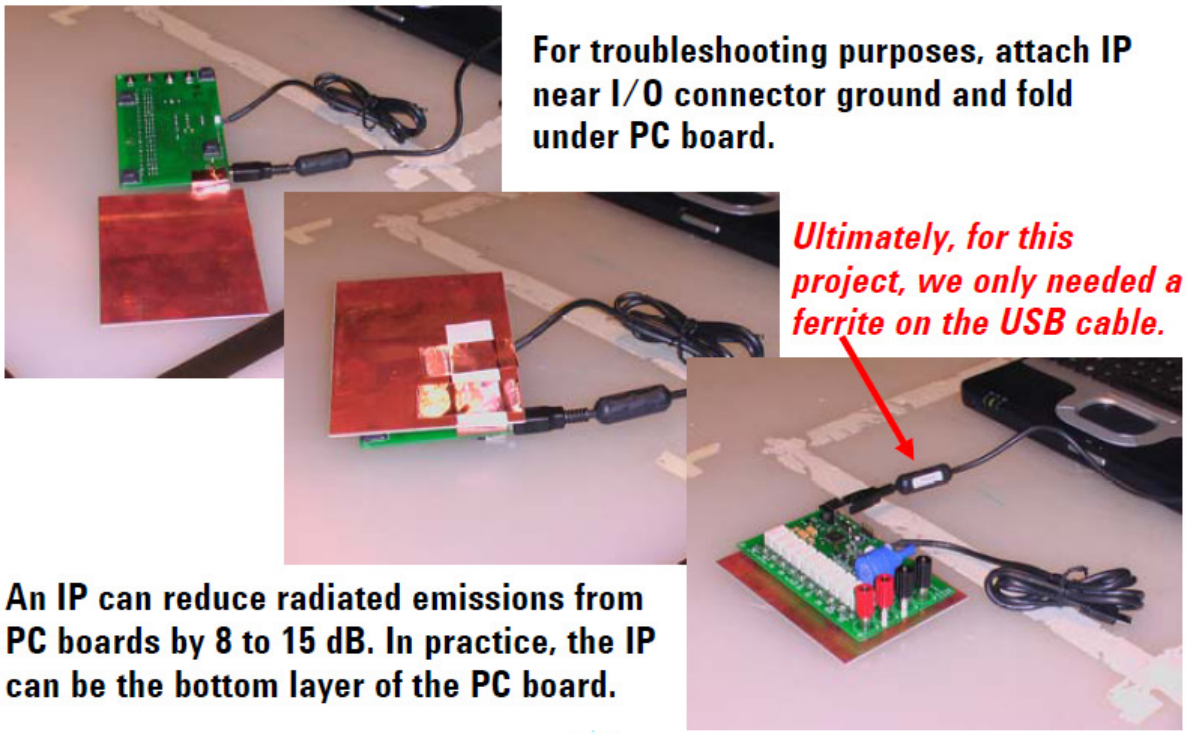
1. Kenneth Wyatt's presentation (shortened version)

Use Of an Image Plane (IP) to Reduce Emissions



For troubleshooting purposes, attach IP near I/O connector ground and fold under PC board.

Ultimately, for this project, we only needed a ferrite on the USB cable.

An IP can reduce radiated emissions from PC boards by 8 to 15 dB. In practice, the IP can be the bottom layer of the PC board.

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1. Kenneth Wyatt's presentation (shortened version)

Line Cord Emissions

If the line cord is suspected of emitting HF harmonics, insert an external line filter in series

If the emission level (or measured common-mode current) drops, then you need to design in better line filtering

An external filter may be made with an extra power line filter module and spare line cord

Cut the cord down to minimal size and carefully solder the stripped ends to the filter, observing the correct connections. Wrap with electrical tape.

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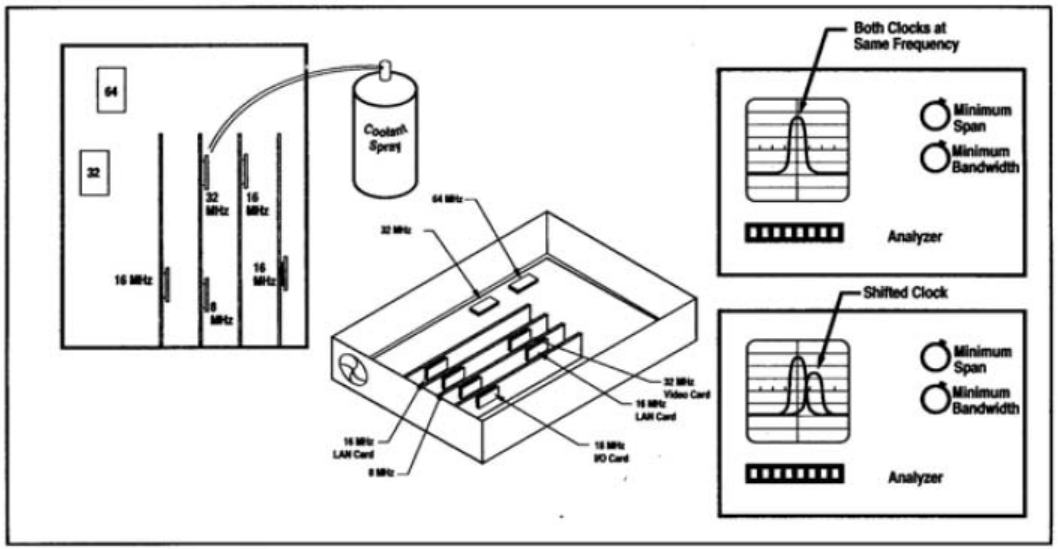
1. Kenneth Wyatt's presentation (shortened version)

Use coolant spray to determine which oscillator is contributing the most to the harmonic of concern



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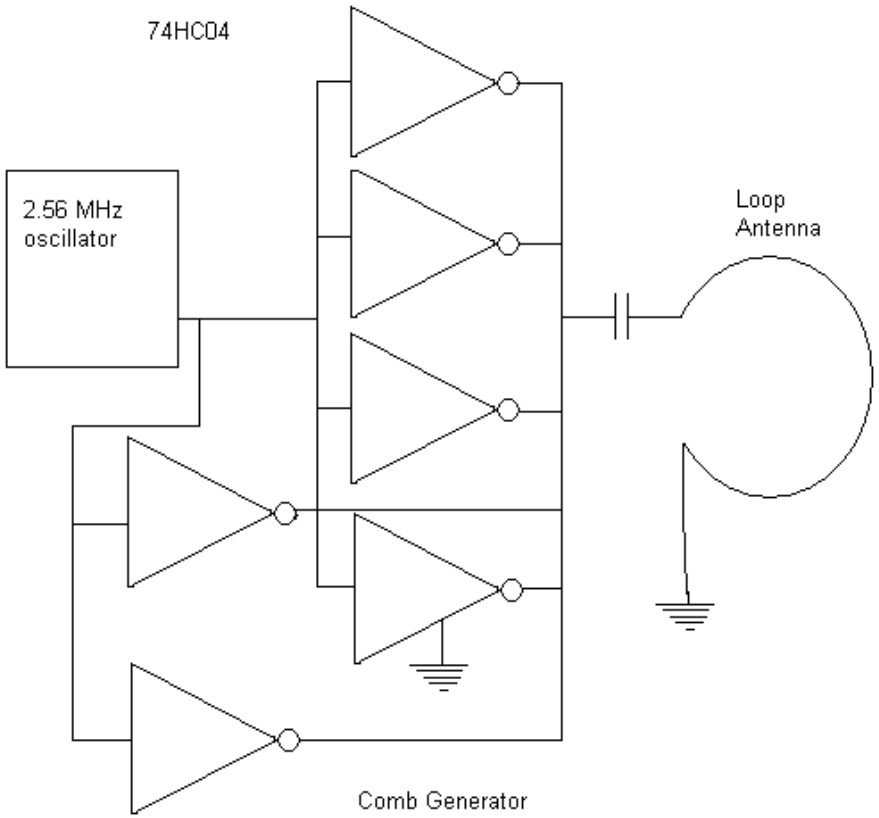
2. Relative Chassis Shielding Effectiveness test

- Simple comb generator with 2.56 MHz oscillator and 74HC04 buffer used to generate harmonics into internal loop antenna

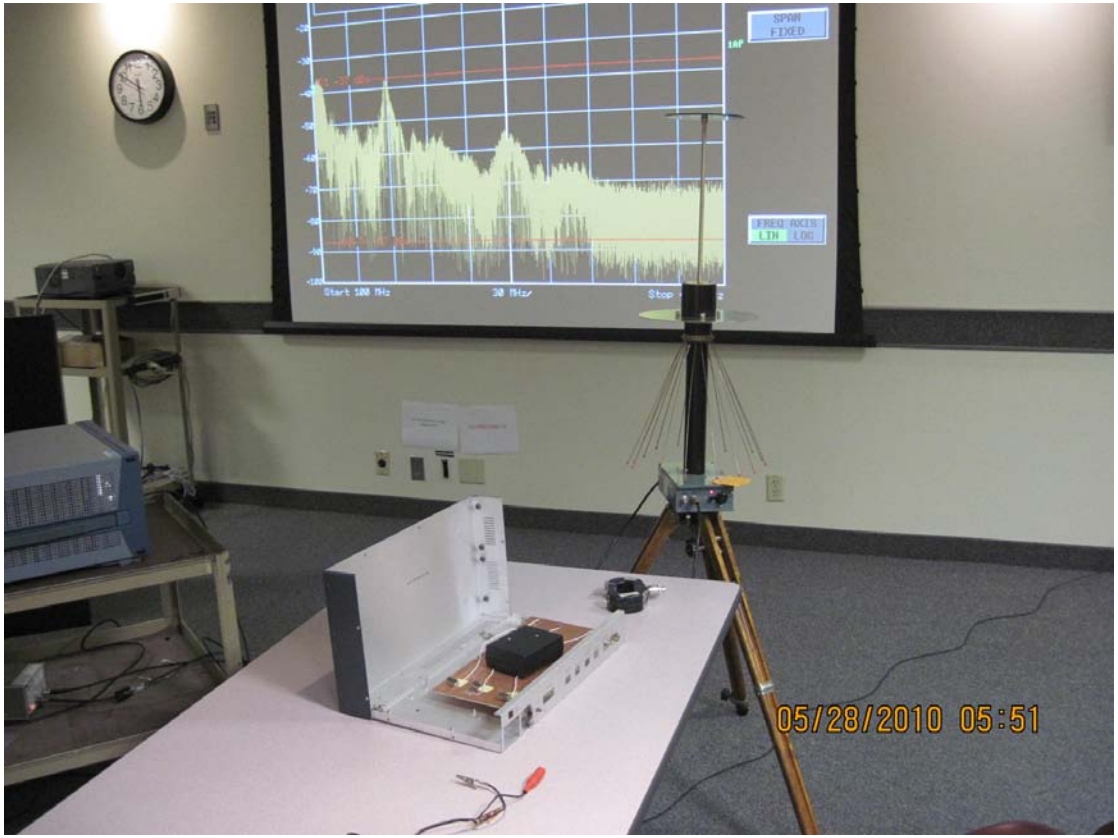
2. Relative Chassis Shielding Effectiveness test

- Schematic of comb generator



2. Relative Chassis Shielding Effectiveness test

- Generator is placed on circuit board and emissions are taken with cover off and with cover on and comparison made for relative chassis shielding effectiveness



2. Relative Chassis Shielding Effectiveness test

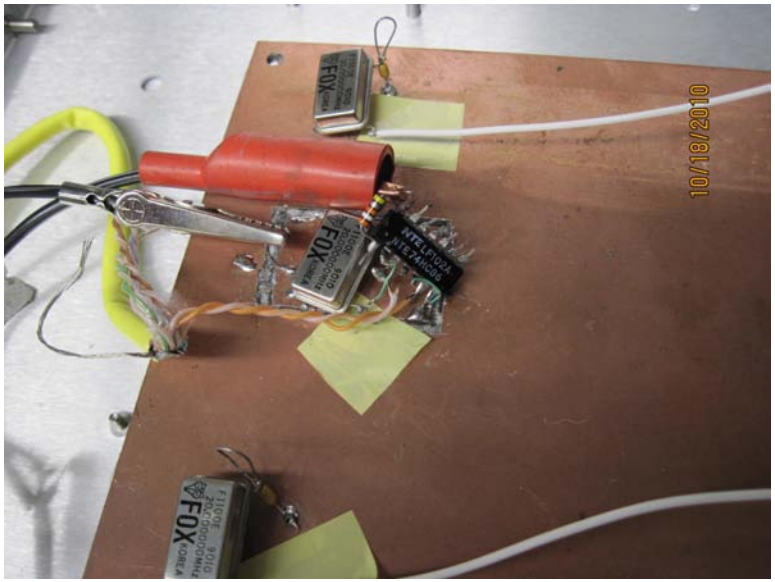
- Test is repeated with unterminated cable placed inside of box
- This shows that just because the enclosure is well sealed, attention must be paid to cables also

3. Ethernet Cable Emissions

Purpose is to show relative shielding effectiveness differences between:

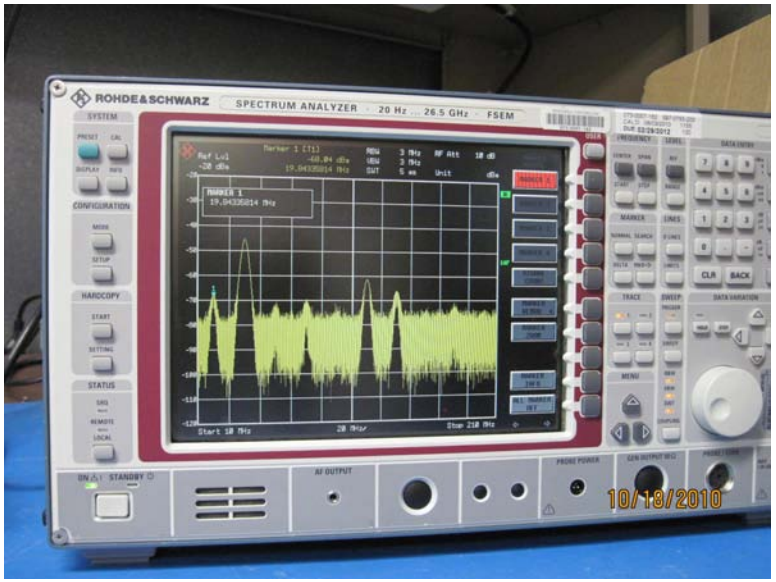
1. Unshielded CAT5E cable (Standard NIC Cable)
2. Shielded CAT5E cable with shield terminations at **both ends**
3. Shielded CAT5E cable with shield terminated at **source end only**
4. Shielded cable with shield terminated at **termination end only**

20 MHz clock differentially drives one pair in cable.



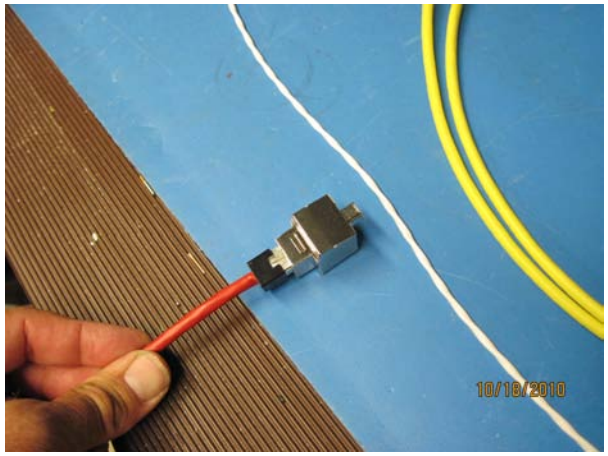
3. Ethernet Cable Emissions

Unshielded Ethernet



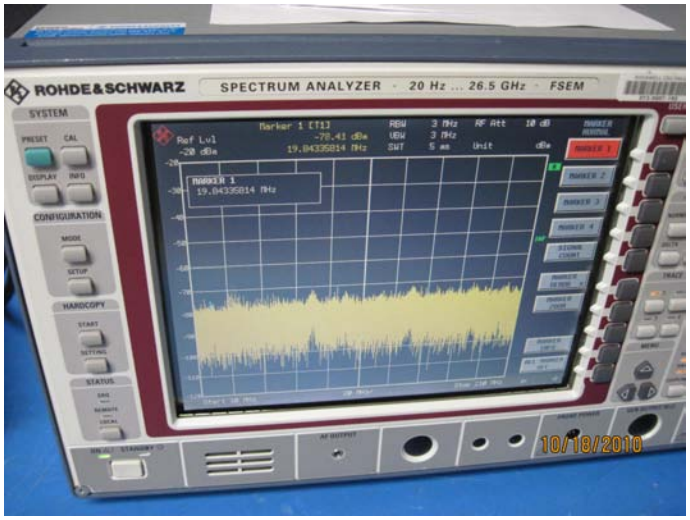
3. Ethernet Cable Emissions

Shielded Ethernet, shield terminated on both ends

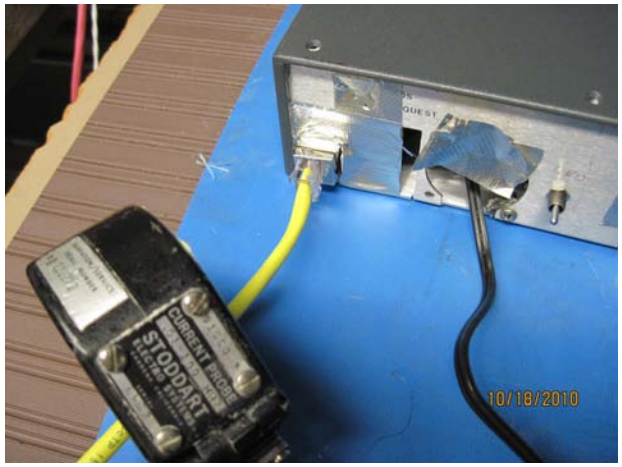


3. Ethernet Cable Emissions

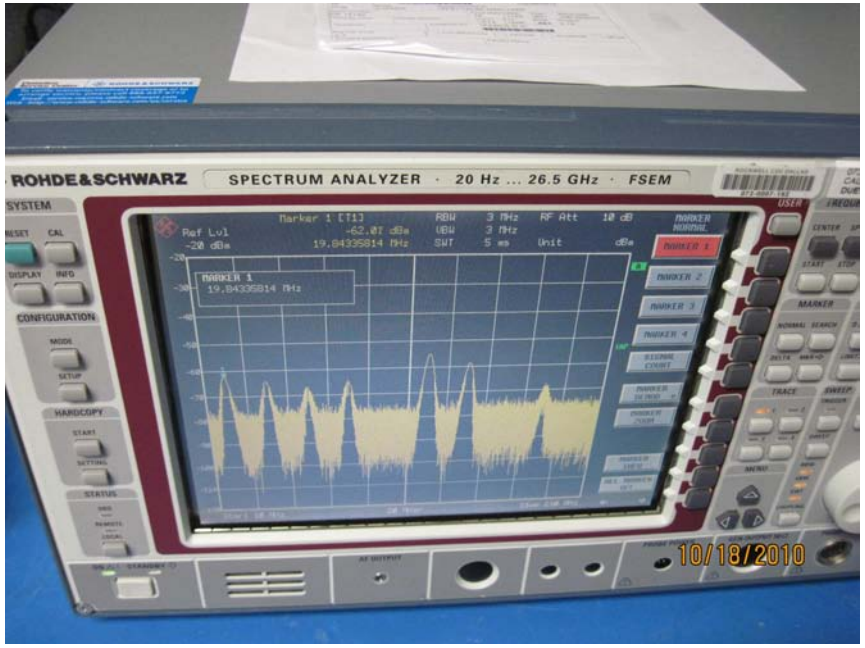
Shielded Ethernet shield terminated on end connected to source only



3. Ethernet Cable Emissions



Shielded Ethernet shield terminated on end connected to termination only



3. Ethernet Cable Emissions

Conclusions

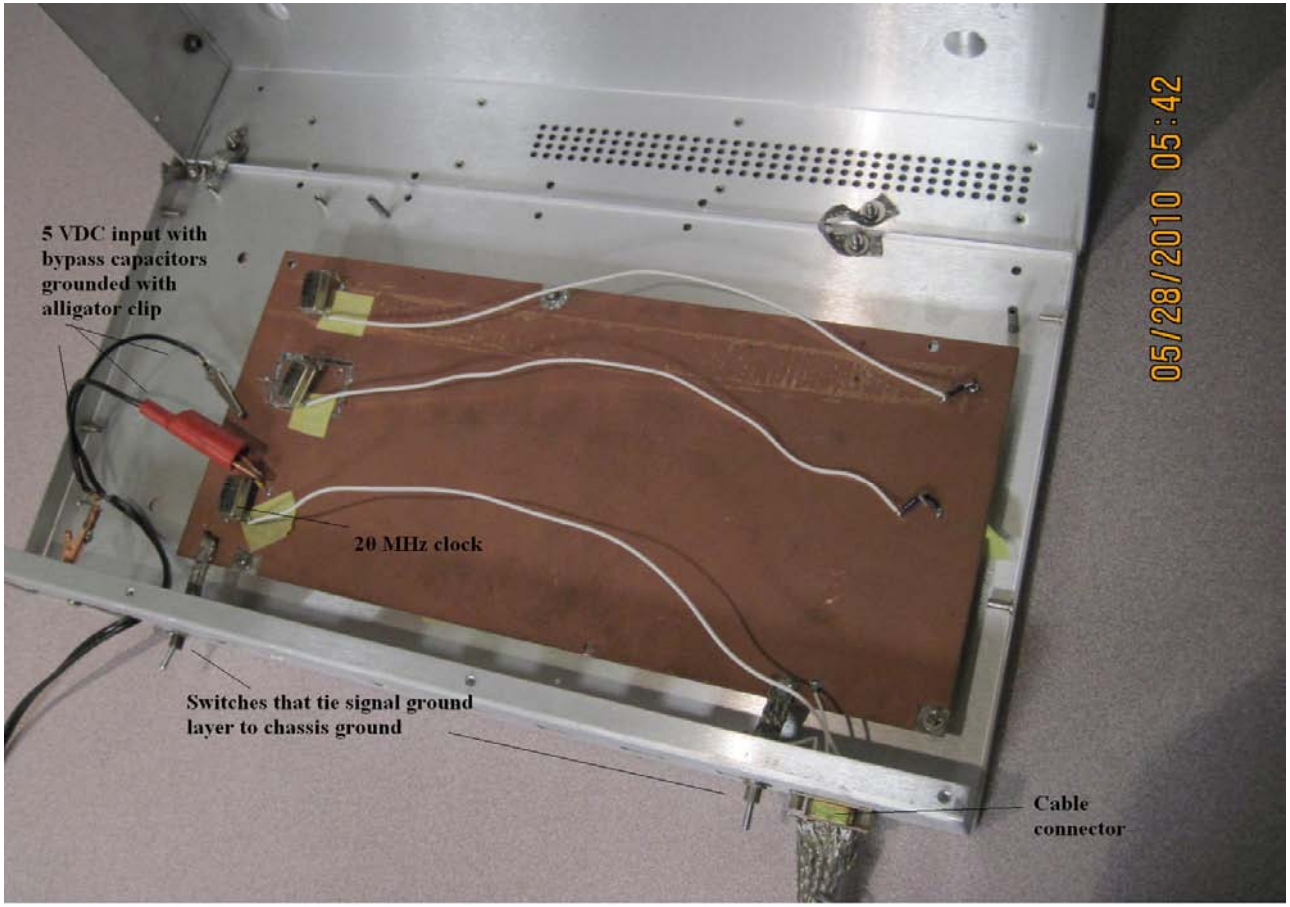
Unshielded Ethernet cable would need filtering

Shielded Ethernet has low emissions

Shielded Ethernet with only one end of shield terminated has emissions almost as high as unshielded Ethernet cable when the unterminated end of cable is at the signal source end. Since most Ethernet connections have sources at both ends, there is little advantage to using shielded Ethernet if both ends of the shield are not terminated.

4. EMI Mythbusters

- Staged EMI Equipment – 20 MHz clocks as EMI sources

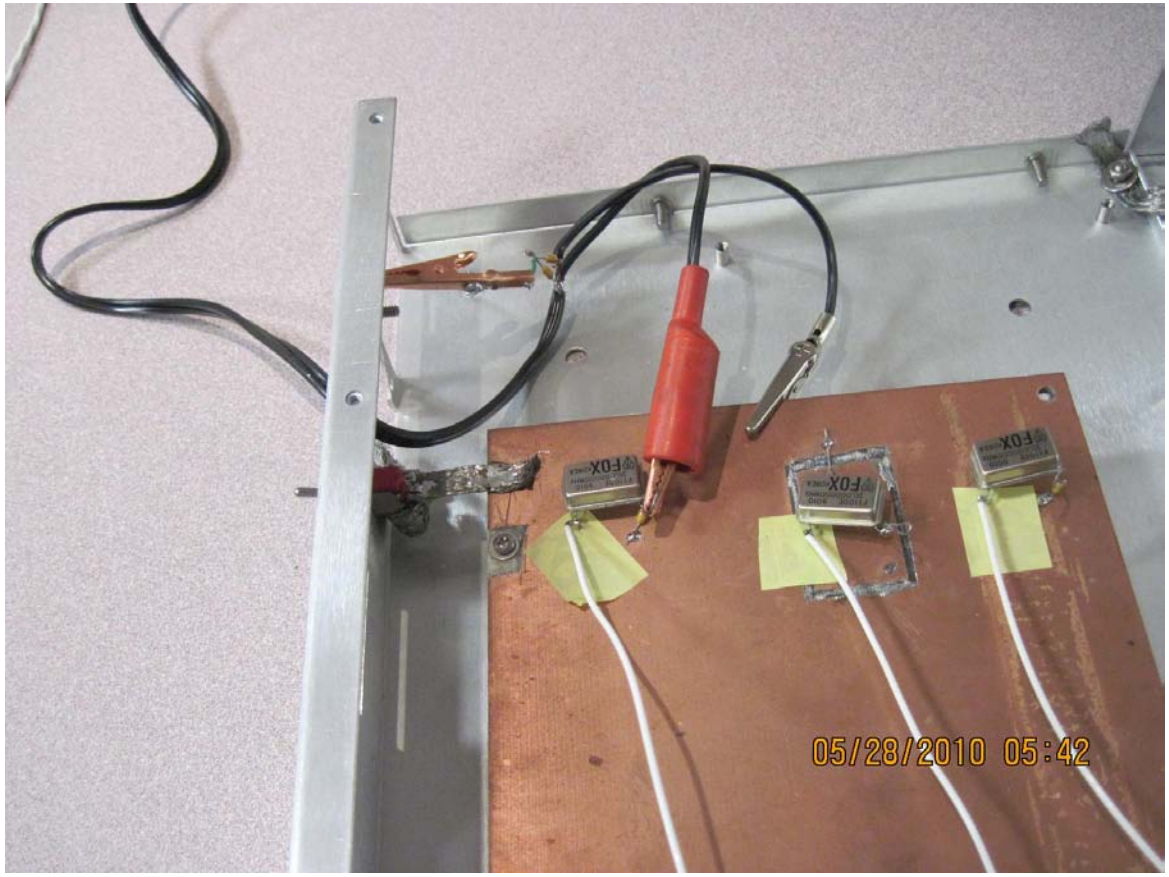


4. EMI Mythbusters

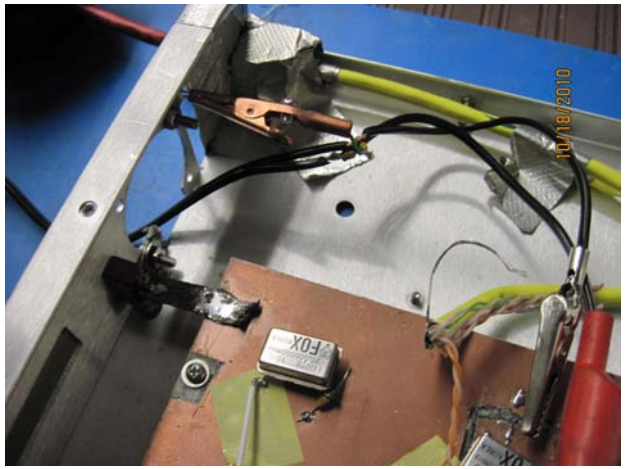
- Staged EMI Equipment – Cable termination box

4. EMI Mythbusters

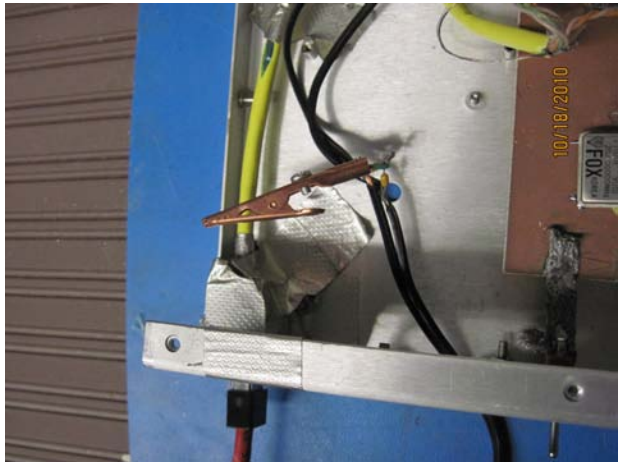
- **Myth #1**
  - *Hey, it's an AC or DC cable coming out of the box. It doesn't need filtering because there are no high speed signals on the cable.*
  - DC cable with and without bypass capacitors used for test



4. EMI Mythbusters



With bypass capacitors



Without bypass capacitors

4. EMI Mythbusters

Myth # 1 conclusion – Busted!

Any conductor that leaves an enclosure should be either bypassed to chassis at its exit point with capacitors or it should be shielded

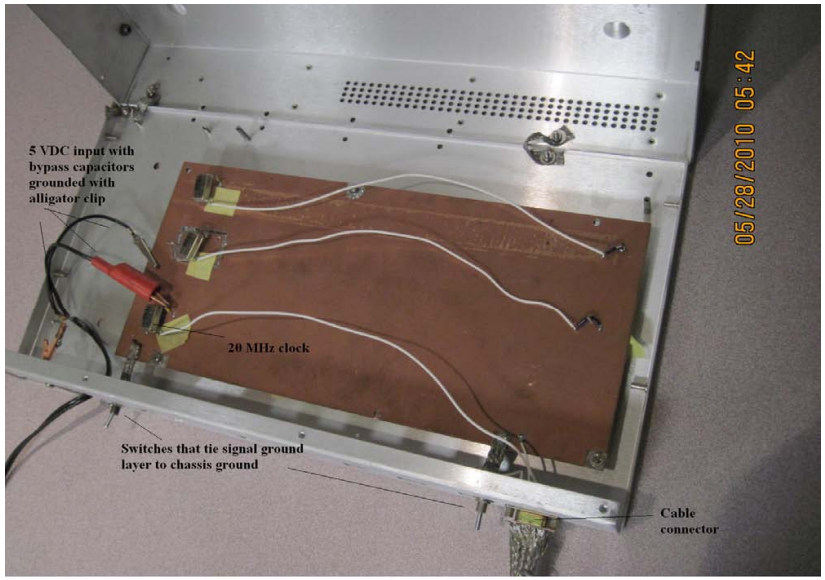
Emissions could “hitchhike” on the conductor and escape.

4. EMI Mythbusters

- **Myth #2**
  - *We have always isolated signal ground layers from chassis ground on a circuit board and never had an EMI problem.*
  - Switches on circuit board will be used to tie signal layer to ground

4. EMI Mythbusters

- **Myth #2**
  - Setup – Typical cable is used
  - Switches to ground circuit board signal ground are set to open to allow circuit board ground to float
  - Switches to ground board are set to closed to ground board to chassis in two places.



Mike Hollingsworth

4. EMI Mythbusters

Myth # 2 conclusion – Busted!

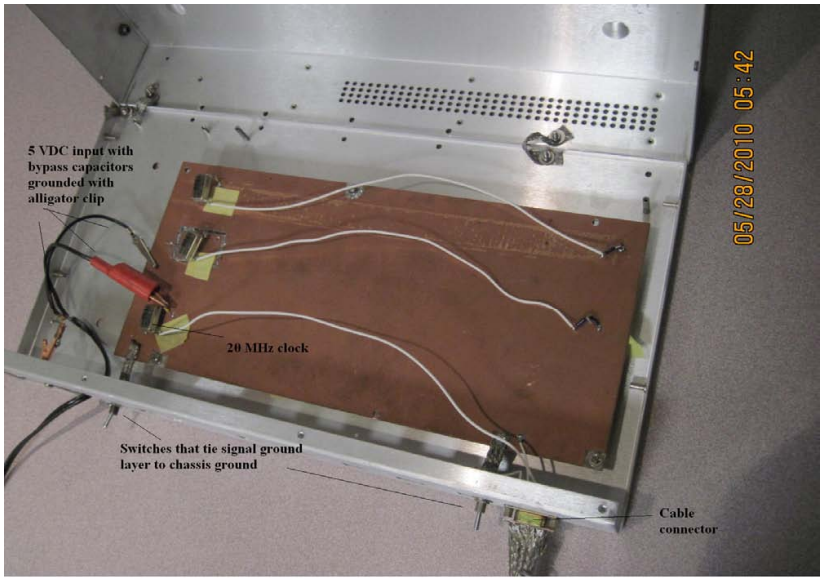
Emissions from cables are higher with circuit board ground floating than when tied to ground

Circuit board signal ground layer should either be connected to chassis ground directly or it should be connected to chassis ground through bypass capacitors

Common mode emissions on a floating circuit board signal ground are at a higher level than when not referenced to chassis ground

4. EMI Mythbusters

- **Myth #3**
  - *OK, I do need to tie the circuit board ground to the chassis, but one connection should be enough.*
  - Switches will be used to show the effects of grounding location to the ground return path and radiated emissions



4. EMI Mythbusters

Myth # 3 conclusion – Busted!

Emissions from cables are lower with both switches grounding board

Circuit board signal ground layer should be connected to chassis ground directly or it should be connected to chassis ground through bypass capacitors in as many places as possible especially around the periphery of the board and at cable connection points.

Common mode emissions on a circuit board signal ground tend to be higher the further away from a grounding point

4. EMI Mythbusters

- **Myth #4**
  - *We have always used pigtails to terminate the cable shield to the back shell or chassis ground and never had an EMI problem.*
  - Cable shields will be tied through a pin to chassis ground

4. EMI Mythbusters

Myth # 4 conclusion – Busted!

Pigtails should not be used to terminate shield to backshells especially on cables that contain signals with signaling rates over 1 MHz or that could be located near an RF source over 1 MHz

360 degree shield termination method is best

4. EMI Mythbusters

- **Myth #5**
  - *Due to interface requirements we have to tie only one end of a cable shield to chassis but there should not be an EMI problem.*
  - Cable with only one ended grounded to chassis ground will be tested

4. EMI Mythbusters

Myth # 5 conclusion – Busted!

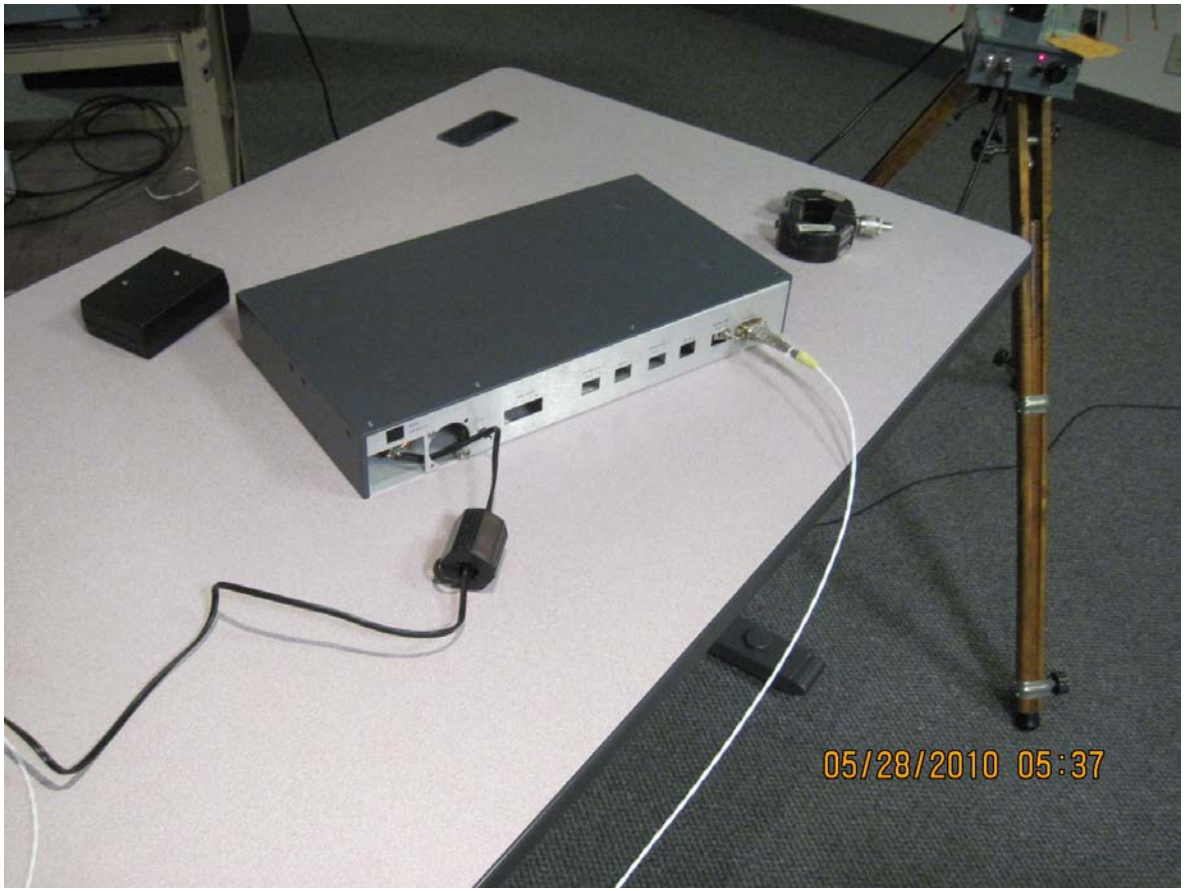
Ideally, cable shields should be terminated at both end of a cable.

If this is not practical due to possible potential differences of the enclosures at the ends of a cable, then the signals should be filtered as if the cable were unshielded.

Another method is to use a cable with 2 shields that are insulated from each other – one shield is connected to one chassis and the other shield connected to another chassis

4. EMI Mythbusters

- **Myth #6**
  - *Ferrites work wonders for EMI problems*
  - Ferrite clamp will be added to cable with known emissions problem



4. EMI Mythbusters

Myth # 6 conclusion – True!

While not a “cure-all” ferrites add impedance to a conductor at frequencies characteristic of the ferrite material

Ferrite work best on conductors with low RF impedances

AC or DC current can saturate core and/or reduce the effective impedance.

4. EMI Mythbusters

- **Myth #7**
  - *We don't have the time or budget to worry about EMI fixes at this time.*
  - **Not true** - All is not hopeless. There are "add-on" fixes that minimize the effect on cost and schedule.

1. Ferrites for cables
2. Copper tape to bridge gaps in enclosure
3. Cable adapters that contain filtering used between existing cable and existing enclosure connector

It is much more efficient to plan for EMI at the beginning of a project than to find EMI fixes after failing an EMI test at a lab.

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Questions?