Shielded Cable Assemblies and EMI Performance

Jim Nadolny

Audio Information
Dial: 1-800-944-8766 (within the US)
Dial: 1-317-713-0002 (outside the US)
Use Participant Code: 24075

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Outline

- EMI Compliance
- Shielding measurements
- Cable assembly shielding
  - Aperture leakage
  - Coax cables
  - Multi-pin cable assemblies
  - Differential shielding
  - Circumferential resonance
- Conclusions

EMI

- **What is it?**
  - **Electromagnetic Interference**

Electric Pencil Sharpener

Magnetic Fields from Motor

Video distortion on CRT

Source **Coupling path** **Victim**

EMI Compliance

- **Why we care…**
  - ***All active electronic systems have to pass an EMI test if they are sold in the world. Federal governments have departments to enforce this rule.***
  - **Connectors, flex assemblies and cable assemblies can cause electronic systems to fail the test.**

- **Imagine…**
  - **Your flight to California crashes because you turned on your laptop.**
  - **Your pacemaker stops because you used your new quad-band cell phone.**

EMI Compliance

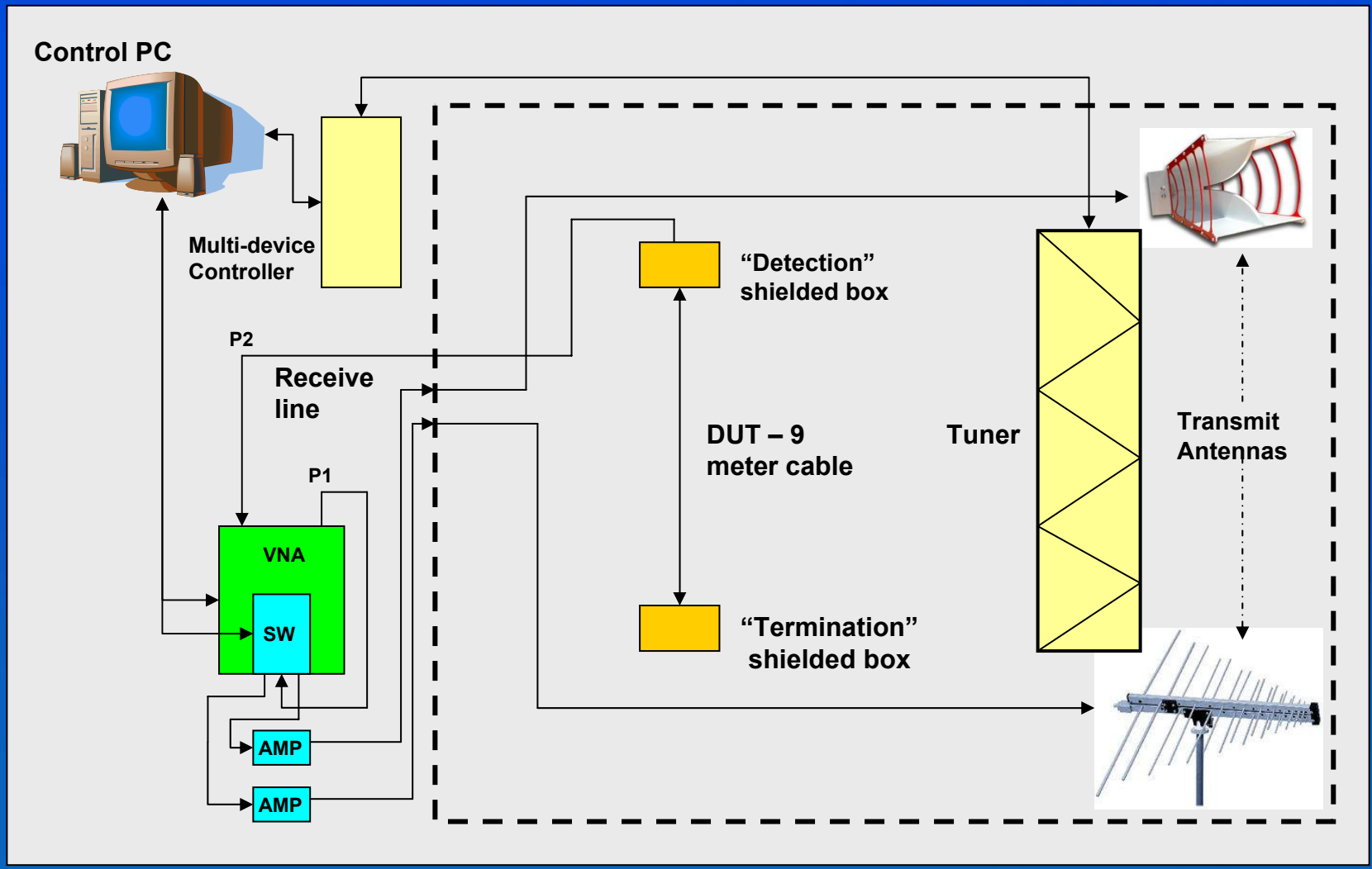
- EMI Compliance is critical in the Aviation, Transportation and Medical markets.
  - This is where lives are at stake.
- EMI Compliance is mostly an expense in the telecom/datacom markets.
  - This is where product functionality is at stake, or you have to pass a test before you can legally sell your product.

EMI Compliance

- Specifications for when you can't sleep…
- In the US
  - Federal Communications Commission (FCC)
  - Code of Federal Regulation (CFR)
  - Part 47, subpart A, Class B
  - FCC CFR 47 Class B EMI requirement for computing equipment
- Similar specs for Europe, Asia and Military

Shielding Measurements

(IEC 61000-4-21 Annex F, Reverberation Chamber)



Aperture Leakage
Semi-rigid cable

- Consider a "perfectly" shielded coaxial structure with a single hole.
- The hole (aperture) provides a means for current to transition from the inner surface to the outer surface of the shield.
- Apertures can be characterized by their electric and magnetic polarizabilty. In a coax cable, the polarizability can be related to a mutual inductance.
- The result is that:

$$SE = 45.76 - 20\log_{10}(Z_t)$$

Z_t = transfer impedance (Ω),
45.76=10*log (Z1*Z2),
Z1= impedance of free space (377Ω), Z2=cable impedance (50Ω)

$$Z_t = 2\pi f M_{12}$$

M_{12}=Mutual inductance due to aperture (H)

$$M_{12} = \frac{\mu_0 \alpha_m}{(\pi D)^2}$$

$\mu_0 = 4\pi \times 10^{-7}$, α_m=magnetic polarizability,
D=cable diameter (m)

$$\alpha_m = \frac{4a^3}{3}$$

A=aperture radius (m)

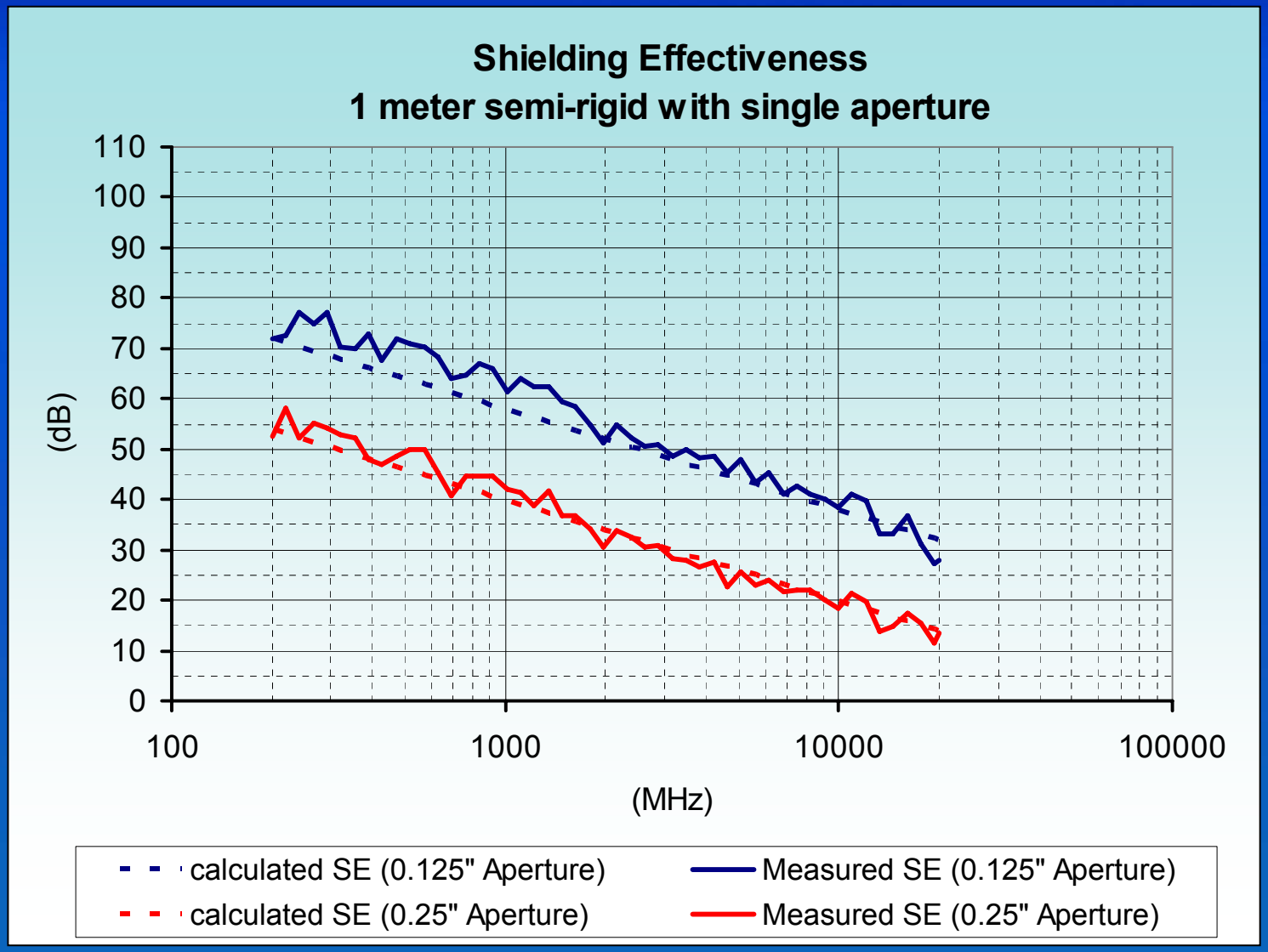
"Aperture Coupling to a Coaxial Airline:Theory and Experiment",D. A. Hill, NIST
"*A Simplified Relationship between Surface Transfer Impedance and Mode Stirred Chamber Shielding Effectiveness of Cables and Connectors"*, L.O. Hoeft, Consultant

Aperture Leakage

- To investigate the theory, we created two custom samples
  - 1 meter long
  - SMA connectors on both ends

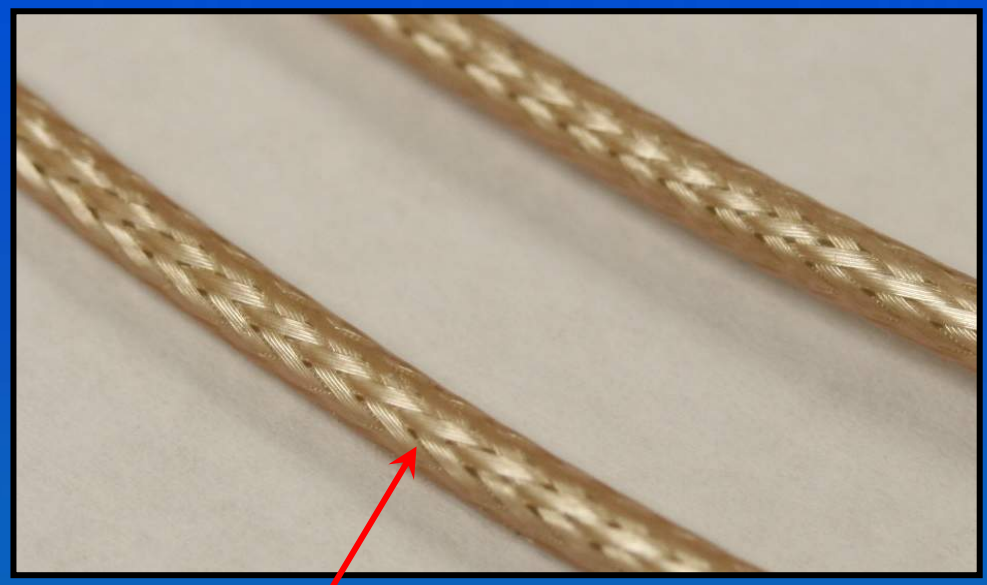
0.25” diameter semi-rigid cable with
0.25” diameter aperture

Aperture Leakage



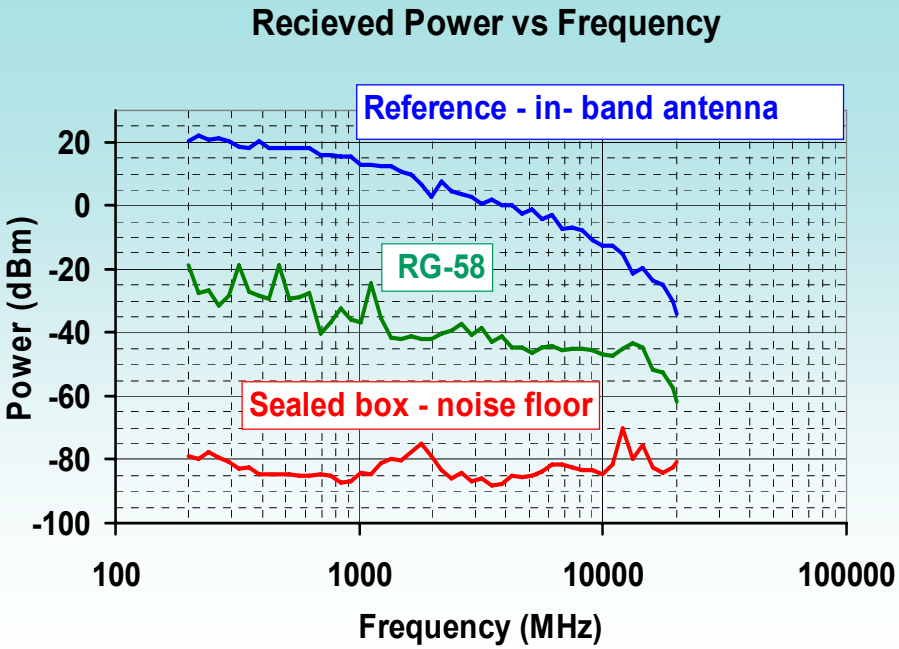
Coax Cable

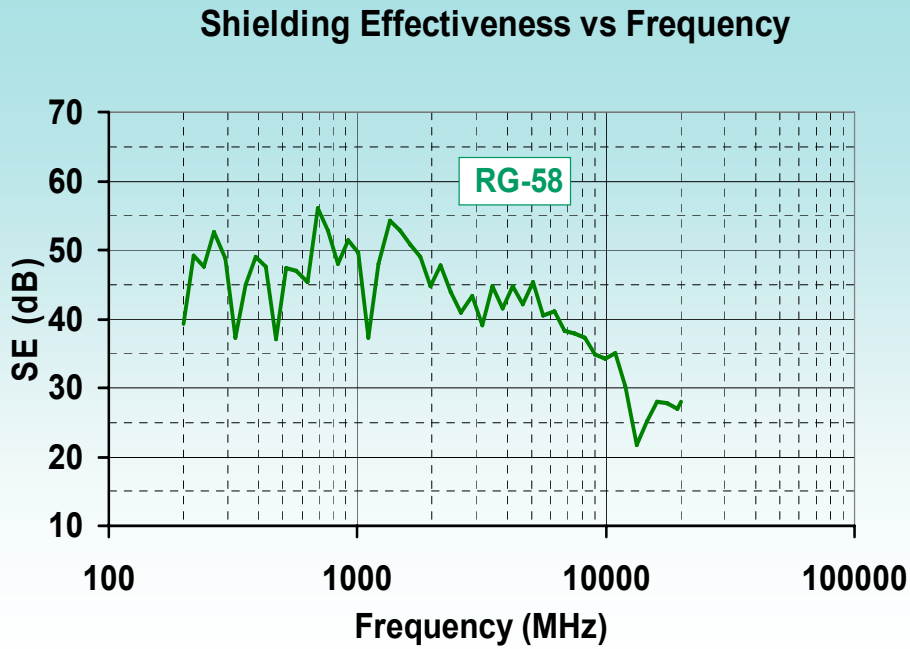
- Coax cable assemblies are the simplest cable assemblies to test
  - RF connector interface (SMA, N-type, etc.)
  - For single braid shields, the multiple openings act as an array of apertures



Opening in braid

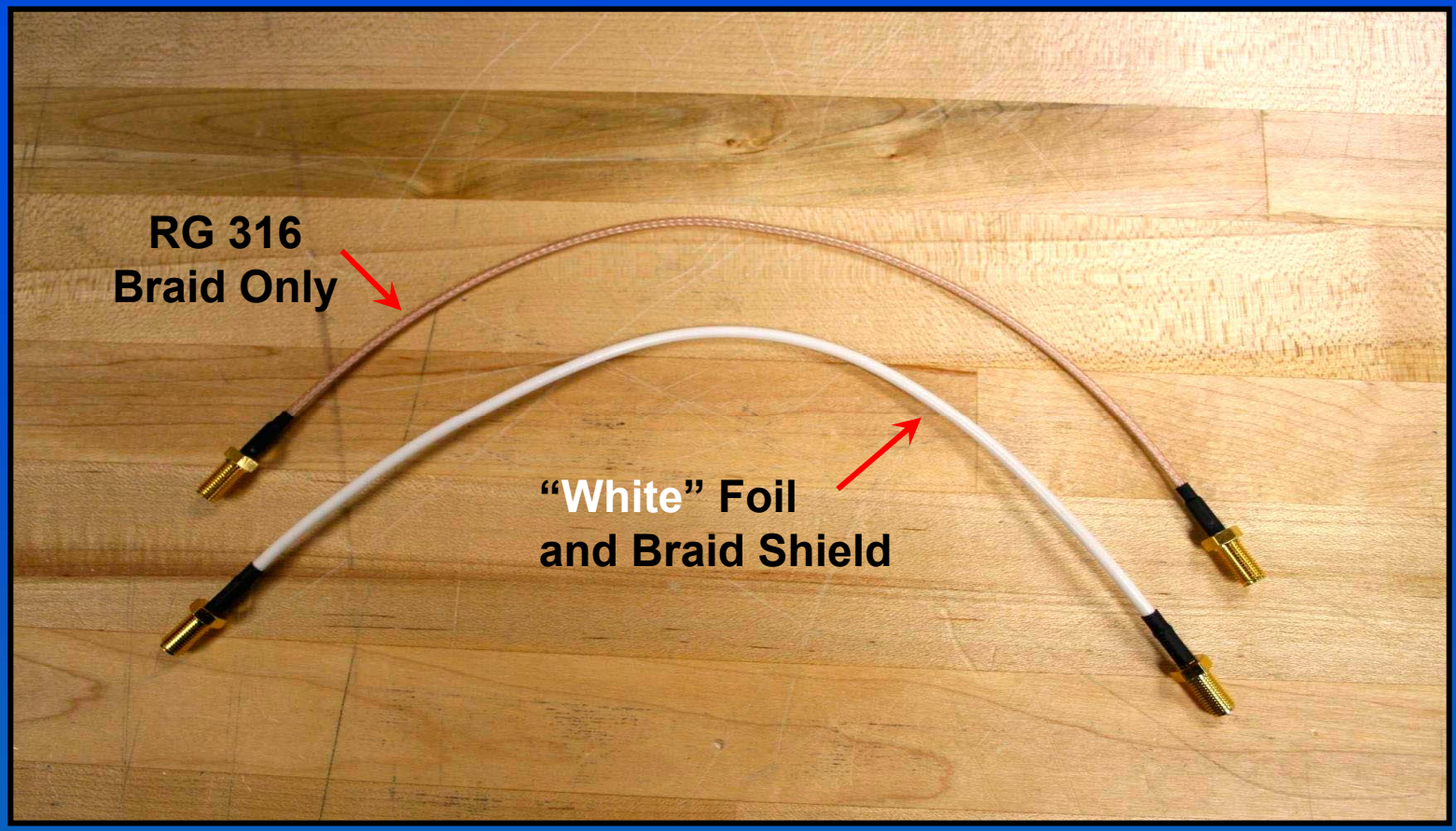
Measured Results – RG-58





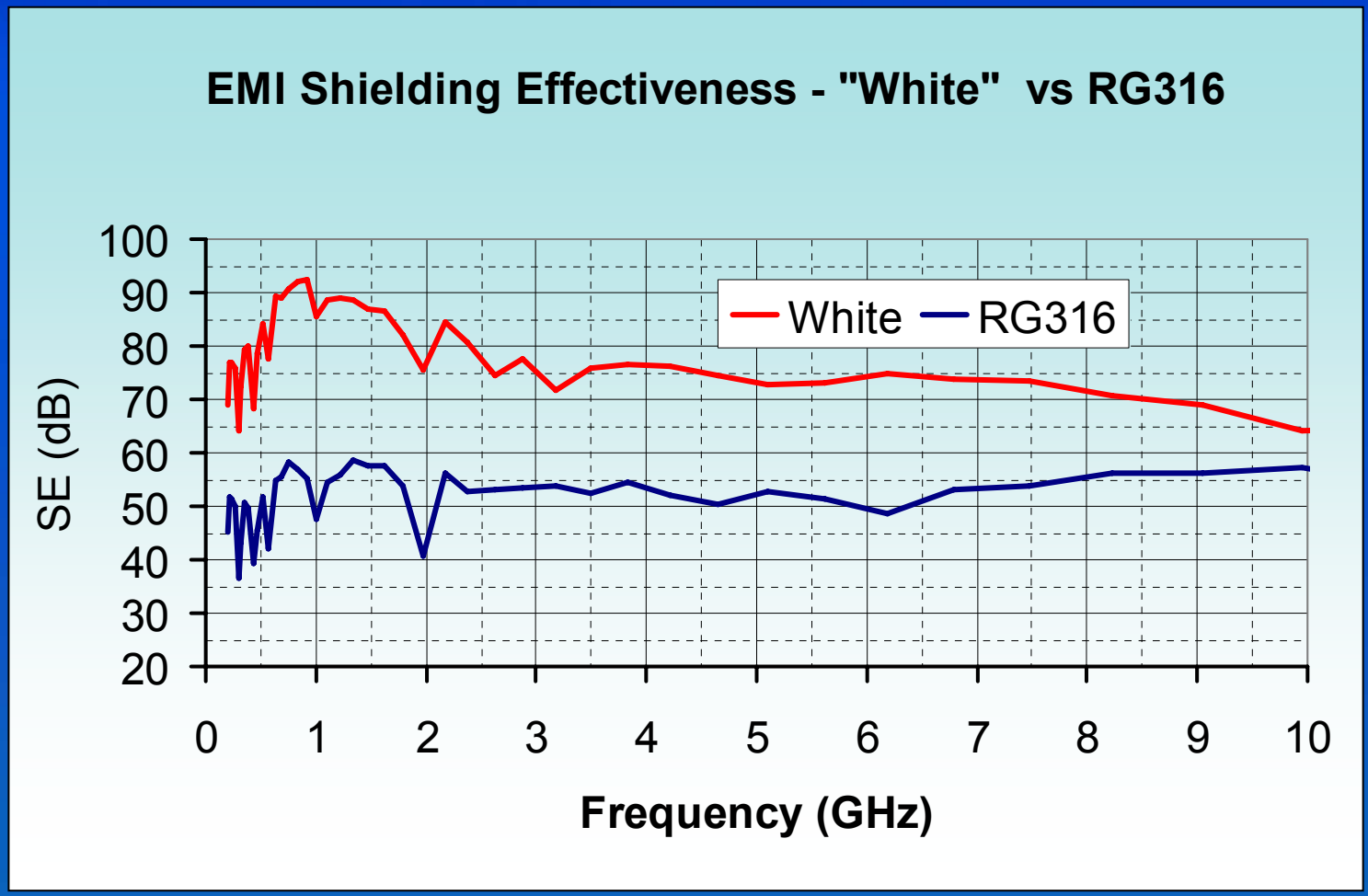
RG-58 sample was 1 meter long with SMA connectors and with a braided shield

Coax Cable



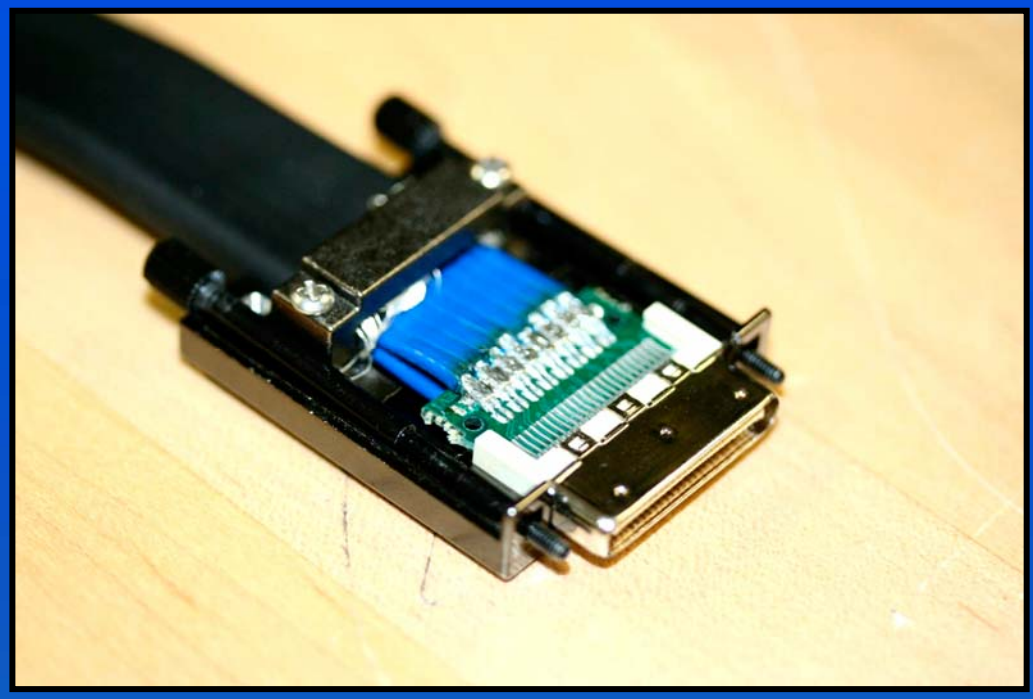
Let's compare two coax cables that use different shield constructions.

Coax Cable



The white cable had a foil and braid shield resulting in better SE performance

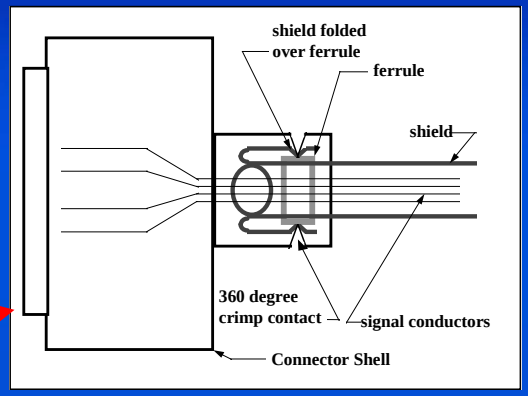
Multi-pin Cable Assemblies

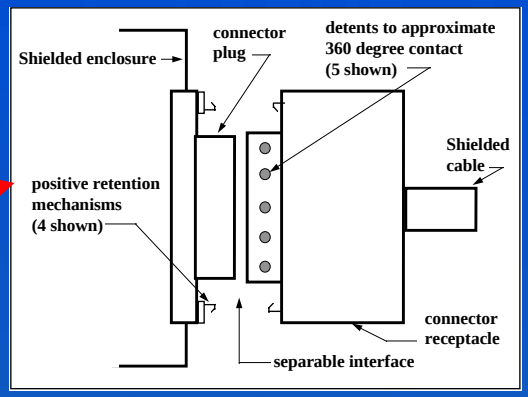


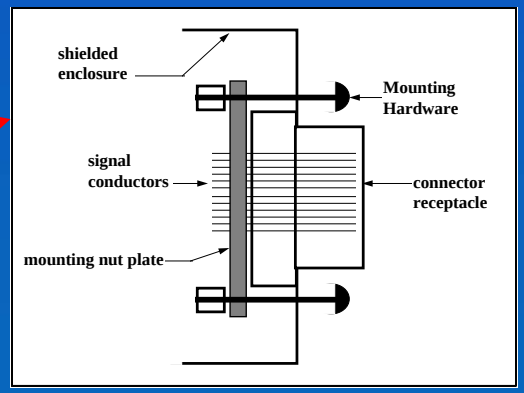
Samtec V-Port™ Plus

Cable Assembly Shielding

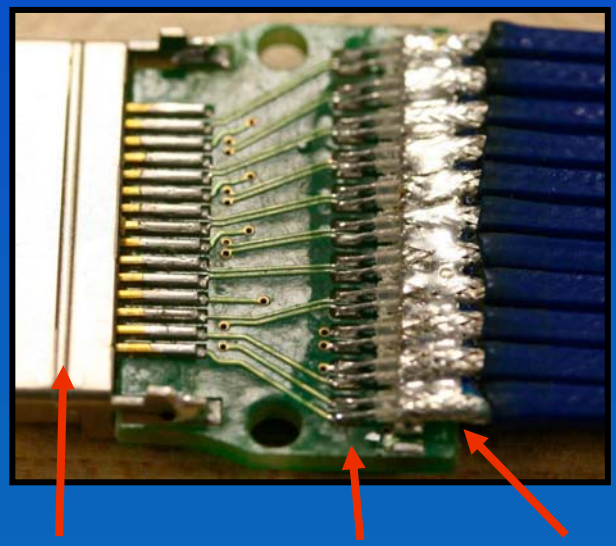
- What is needed for "excellent" performance?
  - Cable braid capture
  - Connection across separable interface
  - Connection to chassis







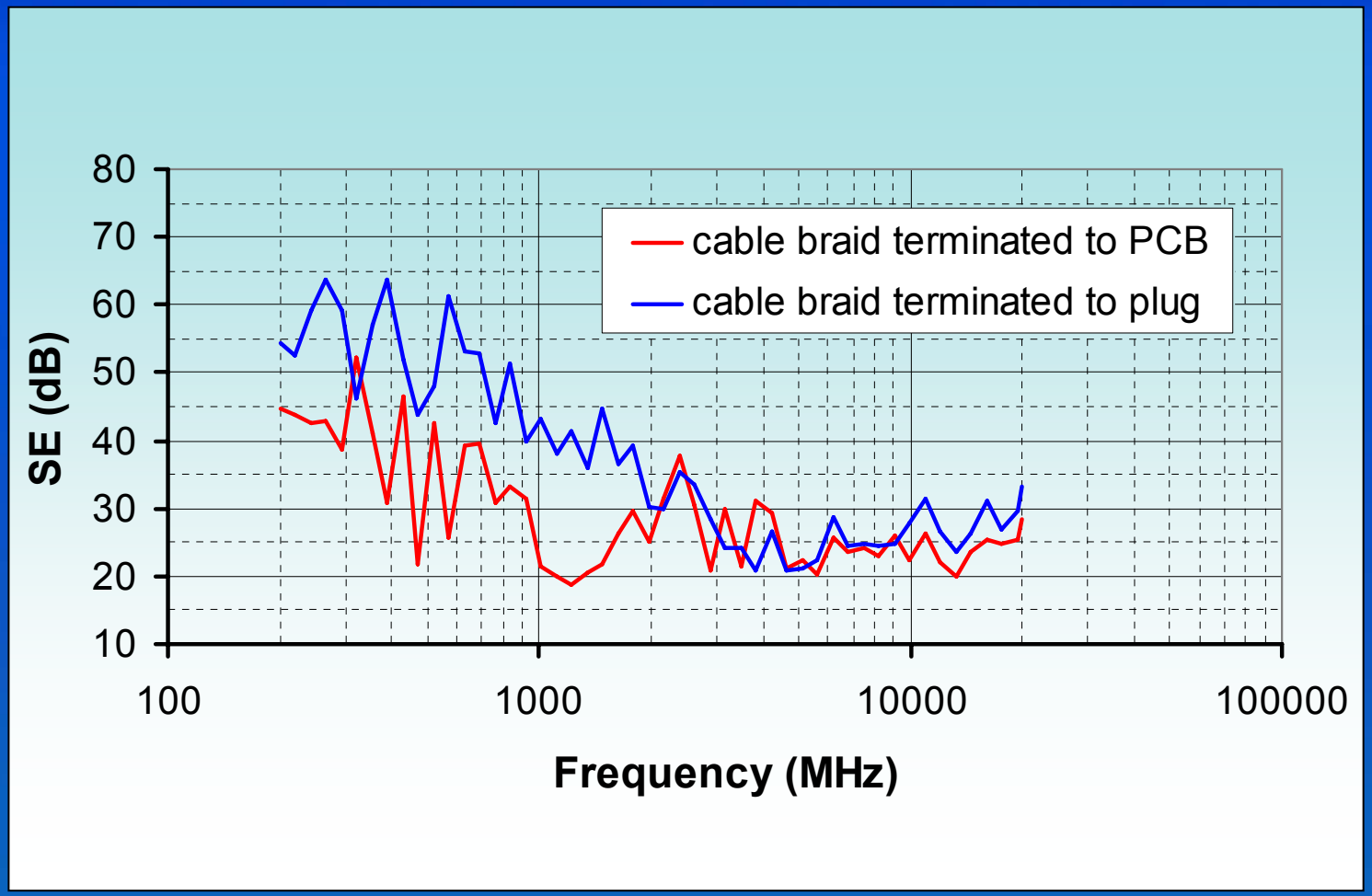
Influence of Cable Braid Capture…



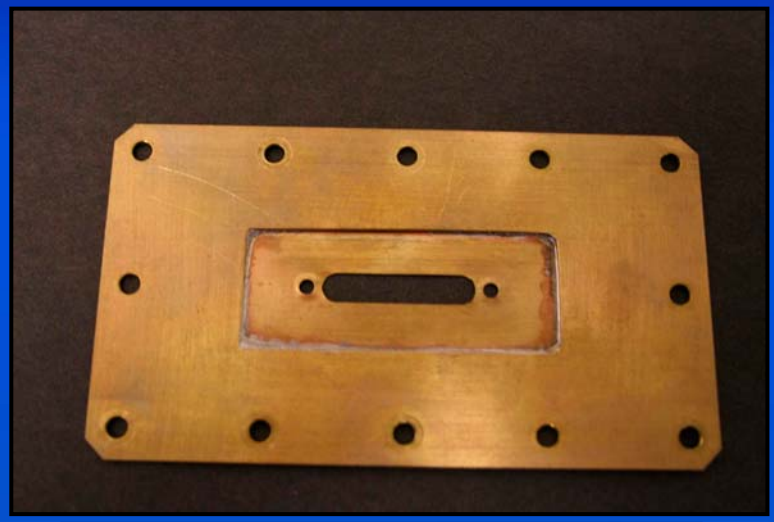
Connector shell to PCB to cable shield

Cable braid soldered to copper foil, foil soldered to connector shell

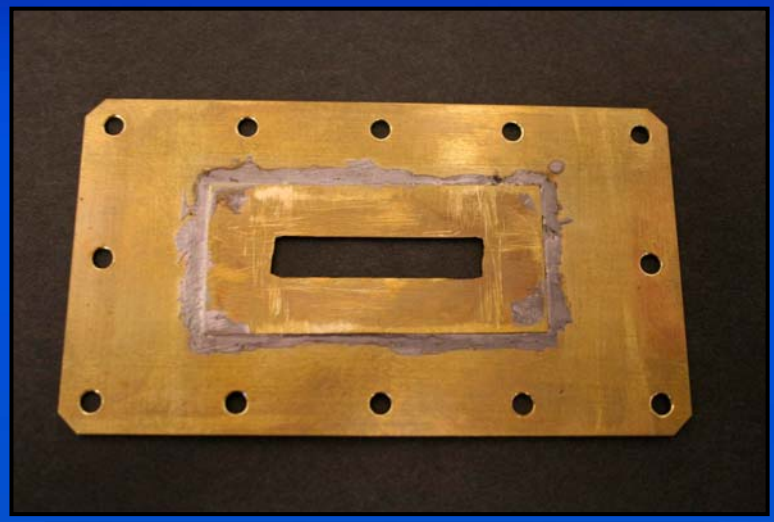
Influence of Braid Capture (HDMI)



Influence of Connection to Chassis



"Nominal" panel connection

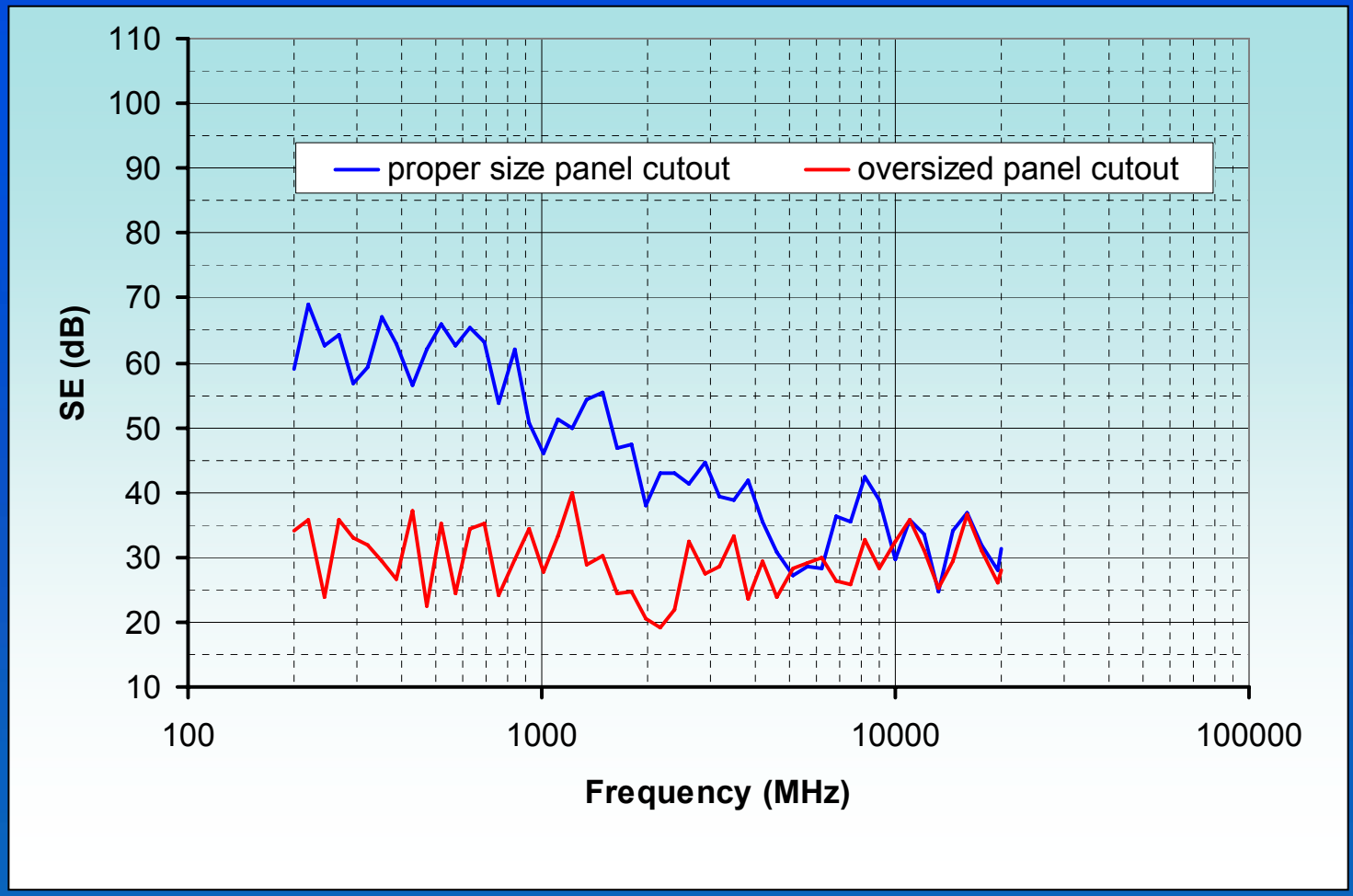


"Oversized" panel connection

- **What happens when the panel cutout for an I/O connector is "oversized"?**

VRDPC Cable Assembly used for this test

Shielding Effectiveness – Influence of Connector Cutout



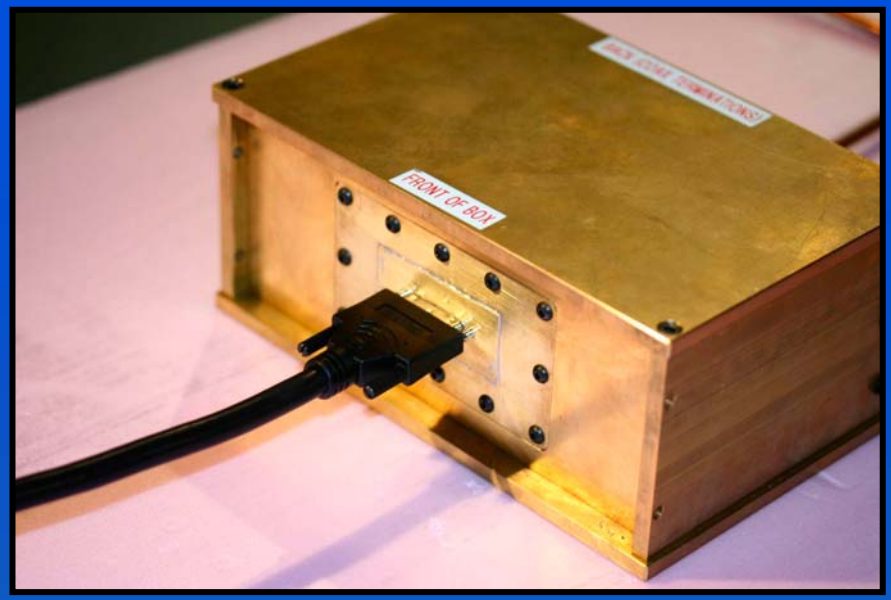
Conclusion - 20+ dB degradation in SE using an oversized panel cutout

I/O Connector Leakage

Do connectors degrade the performance of a shielded box? If so, how much?

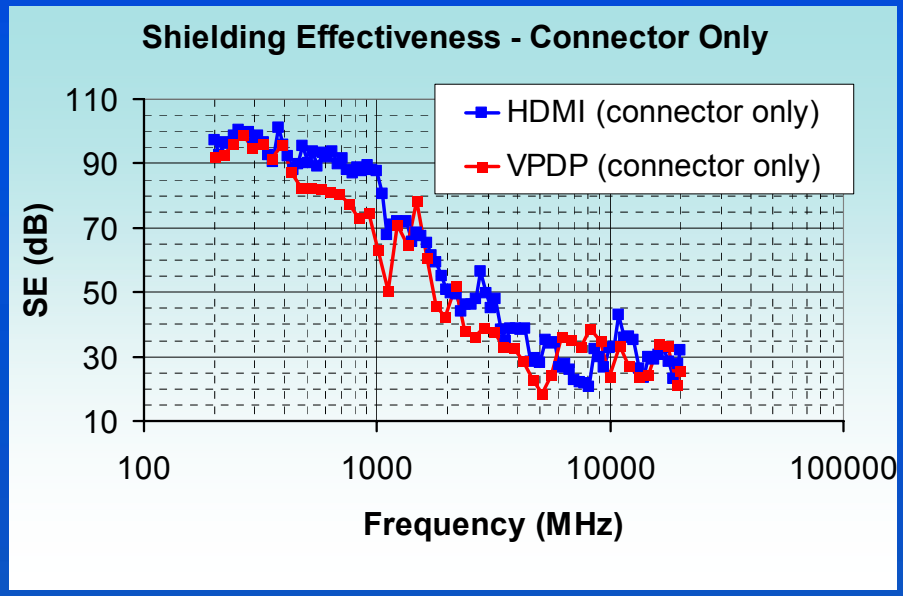
I/O Connector Leakage Test

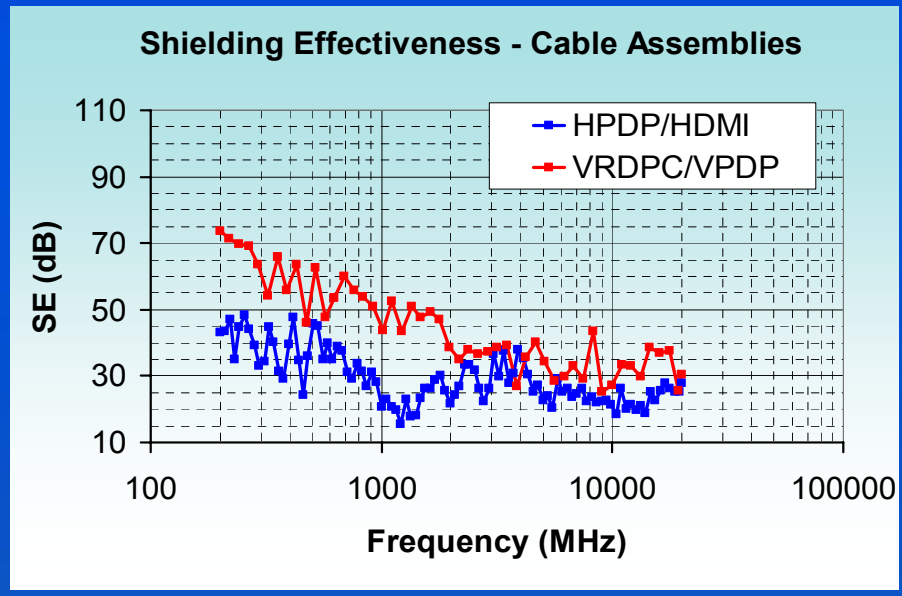
I/O connector without cable



I/O connector with cable

Connector Only vs. Cable Assembly





Conclusions –

Coupling to the pins of the connector is significant above 3.5 GHz.
Connector apertures degrade the SE of a shielded enclosure.

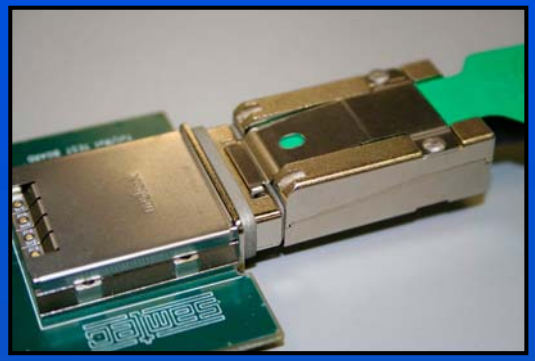
Raw Cable vs. Cable Assembly

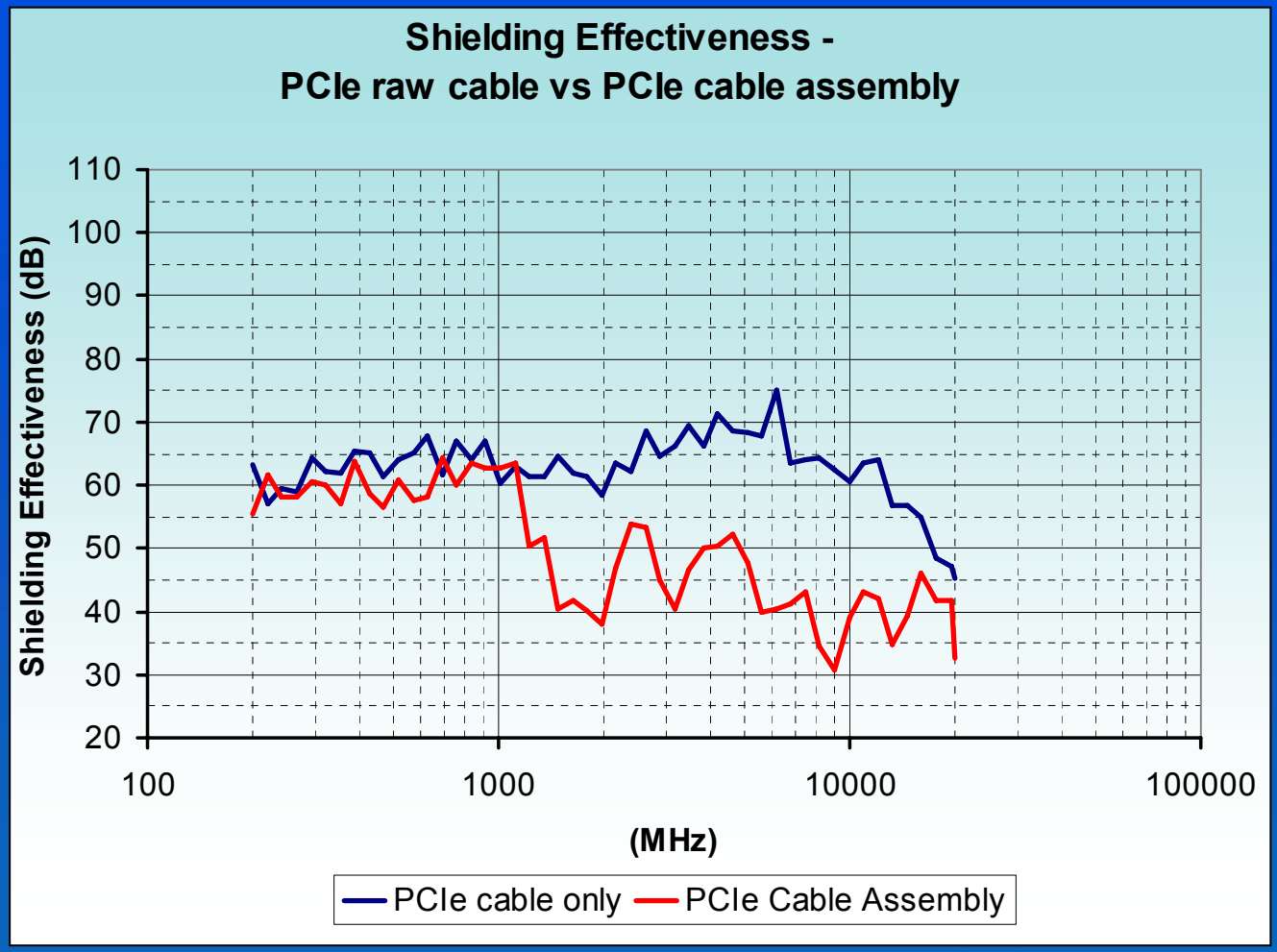
- Consider a state of the art shielded cable assembly
  - Foil and braid cable
  - Carefully engineered connector

- What type of shielding performance is achievable?
- How much (if any) does the connector degrade the performance of the cable?

Raw Cable vs. Cable Assembly

(PCIE 4x example)



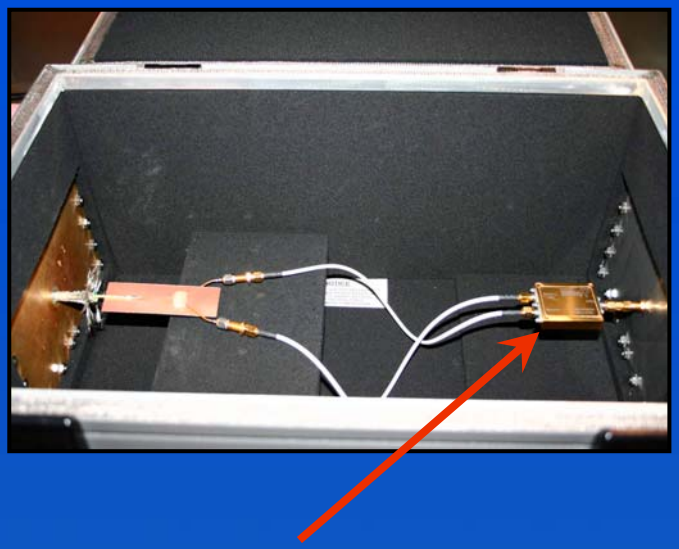


Common vs. Differential Shielding

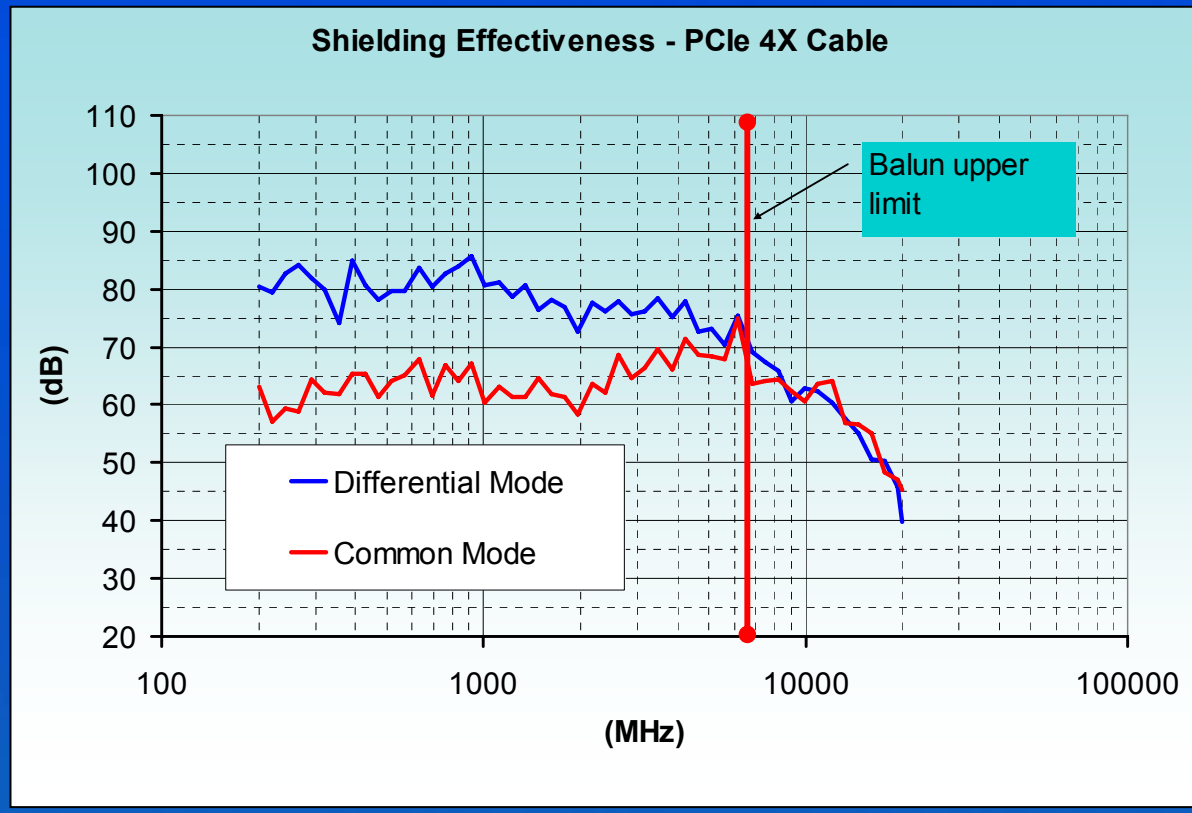
- High speed digital transmission across cables is typically differential.
  - To reduce crosstalk in the connector
  - To reduce EMI

- How much is the EMI reduced using differential signaling?

Effect of Differential Mode



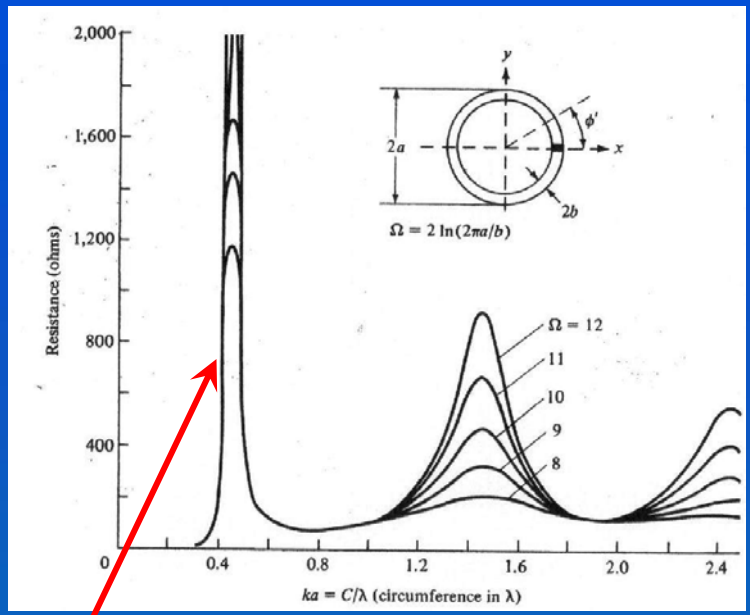
Wide bandwidth balun used for Differential response



An improvement of roughly 20 dB is achieved using differential signaling with zero source induced skew.

Circumferential Resonance

- When the cable circumference approaches λ/2, a peak in radiation is expected.
- For a PCIe 4x cable, the diameter is roughly 0.35”, equates to a resonant frequency of ~5 GHz.

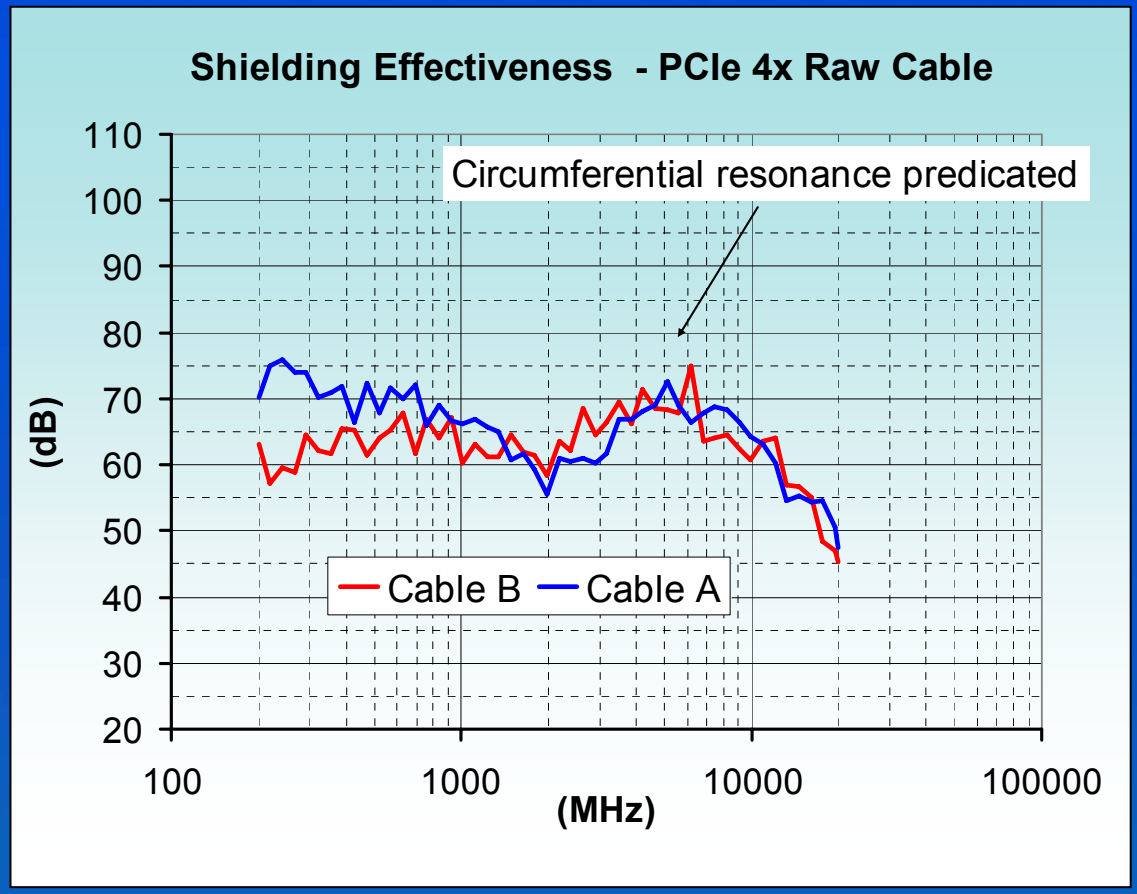


At C= λ/2, a loop antennas radiation resistance (and efficiency) peaks

“Antenna Theory, Analysis and Design”, C. Balanis

Example of Circumferential Resonance

"perfect" shield termination – cable braid soldered to brass plate



Conclusions

- The shielding effectiveness of a coaxial structure with single aperture can be predicted by simple equations.
- Real coax cable assemblies can have a range of shielding performance based on shield construction.
- Multi-conductor differential cable assemblies can have degraded shielding performance due to
  - Braid capture
  - Connection across the separable interface
  - Panel connection
- Theory predicts additional leakage mechanisms in the 5-10 GHz range due to circumferential resonance.

Thank You and Questions

- For additional questions regarding the information contained in today's presentation, please contact our Signal Integrity Group at SIG@samtec.com.

- For a copy of today's presentation, please contact us at ewebinar@samtec.com.