

Common-Mode Current, Ground Loops, and Low Frequency Signal Integrity



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EMC course instructor **University of Oxford**, England



Solutions for your noisy world.



Instructor Biography

Lee Hill is Founding Partner of SILENT Solutions LLC, an independent electromagnetic compatibility (EMC) and RF design firm he established in 1992. Besides providing EMC design review and troubleshooting services, Lee is also a member of adjunct faculty at Worcester Polytechnic Institute (WPI) where he teaches graduate courses in EMC. He is also an EMC class instructor at the University of Oxford (England), and for the IEEE EMC Society's annual Global University program and EMC Fundamentals workshop. In past years Lee was also an EMC course instructor for UC Berkeley Extension as well for Hewlett Packard and Agilent Technologies. Previously Lee was Principal EMC and Systems Engineer at Digital Equipment Corporation's Workstation Systems Engineering Group in Palo Alto, CA. In 2017 Lee founded SILENT Solutions GmbH in Munich, Germany.

Lee received the Master of Science Degree in Electrical Engineering & Electromagnetics with highest honors from the University of Missouri-Rolla, (now Missouri University of Science and Technology). He is an inventor of three US patents for EMI control in electronic systems, and provides expert witness services for patent litigation.

In the past fifteen years he has been a frequent featured speaker at IEEE EMC Society fundraising events in cities throughout the US including Santa Clara, Seattle, Portland, Chicago, Milwaukee, Dallas/Fort Worth and Detroit. He has also provided technical presentations to Society chapters in Los Angeles, San Diego, Santa Clara, Boston, Austin, Colorado Springs, Pittsburgh, and Orange County, CA. He served a term as an IEEE EMC Society Distinguished Lecturer from 1994-1996.

Lee has over twenty-five years of experience in the EMC design and retrofit of complex electronic systems. He has been teaching short courses on EMC design and troubleshooting for twenty years. Lee consults and teaches worldwide, and has presented classes in Taiwan, Singapore, Mexico, Norway, Canada, South Korea, France, Germany and United Kingdom. He has completed a three-year term on the Editorial Review Board of Printed Circuit Design Magazine.. He is an avid father, runner, motorcyclist, table tennis player and Amateur Radio operator, and has served as an officer on the board of directors of several non-profits.

Lee is past member of the IEEE EMC Society Board of Directors (2004-2007). From 1999-2006 he chaired the IEEE EMC Society's Distinguished Lecturer Program, and served as Co-Technical Chair of the 2003 IEEE Symposium on EMC in Boston, MA. In 1999 Lee received a Certificate of Appreciation from the EMC Society for significant contributions to education through his annual participation in the Demonstrations and Experiments portion of annual IEEE EMC Symposia.

Thank You! Free Bonus Technical Presentation Available

Dear Demystifying EMC 2020 Attendee:

Randal and I would like to thank you again for taking time out from work to attend Lee's presentation(s) this year.

Please let us know if you would like to bring a SILENT EMC course to your work location. We offer intensive two, three, and four day format EMC courses for electrical hardware designers, PCB designers, mechanical engineers, and EMC engineers.

We have delivered these courses around the world to companies that develop a wide variety of electronic products and systems.

If you would like to receive a free bonus technical presentation from SILENT, please just follow this link, [Bonus Presentation](#)

**then enter your name and email, and we'll send you an updated pdf copy of Lee's very popular talk
"Mastering the Details of EMI Suppression Ferrites."**

This bonus presentation discusses the performance characteristics and high frequency EMI suppression ferrites and important considerations for practical applications. When this talk is given live, Lee includes a hardware demonstration of the effect of DC bias on a ferrite's impedance, using a network analyzer, power supply, and bias network. Lee has given this presentation throughout the US, Germany, and at DeMystifying EMC 2019 at Silverstone in the UK.

Warm Regards,



Lee Hill



Randal Vaughn

SILENT Training Events - Europe 2020

Please get in touch and visit with me if you are traveling to one of these cities in 2020

Find more info at www.silent-solutions.com

EMV, Cologne, Germany

Posnań, Poland

University of Oxford, England

IEEE Symposium on EMC, SI+PI

SILENT EMC Courses

Dresden, Germany

March 2020

May 5-9, 2020

June 2020

July 2020 (Reno, Nevada)

May, October 2020 (Boston, Silicon Valley)

October 2020

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9 – 10 JUNE

Tutor: Lee Hill, SILENT Solutions LLC & GmbH, USA & Germany

Advanced Printed Circuit Board Design for EMI & Signal Integrity

9 AND 11 JUNE

Tutor: Lee Hill, SILENT Solutions LLC & GmbH, USA & Germany

Mechanical Design for EMC

9 AND 12 JUNE

Tutor: Lee Hill, SILENT Solutions LLC & GmbH, USA & Germany

Mastering High Speed Serial I/O Technology

22 – 24 JUNE

Tutor: Ransom Stephens, Signal Integrity Specialist

Resetting Your Signal Integrity Knowledge

24 – 26 JUNE

Tutor: Dr Istvan Novak, Senior Principal Engineer, Oracle

Making Successful Power Distribution Designs

29 JUNE – 1 JULY

Tutor: Dr Istvan Novak, Senior Principal Engineer, Oracle

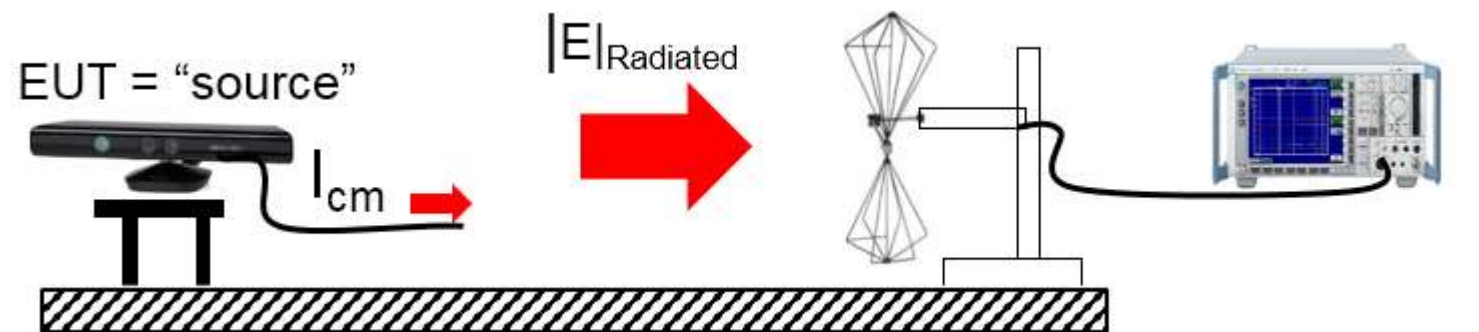
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Outline

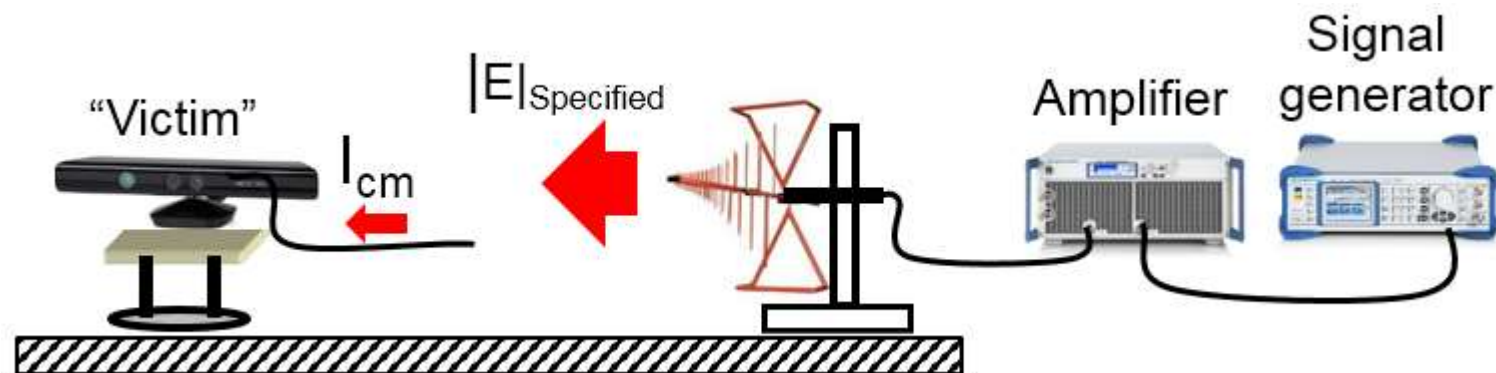
- Common-Mode Current I_{cm}
- Ground Loops
- Low Frequency Signal Integrity
- Demonstrations
- Please feel free to interrupt me during the presentation



Motivation to Understand Icm Source of Radiated and Conducted Emissions and Immunity (Susceptibility)



Radiated Emissions

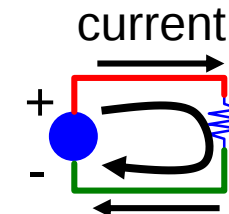


Radiated Immunity

Review of Some “Noise Talk” and Common-Mode Current

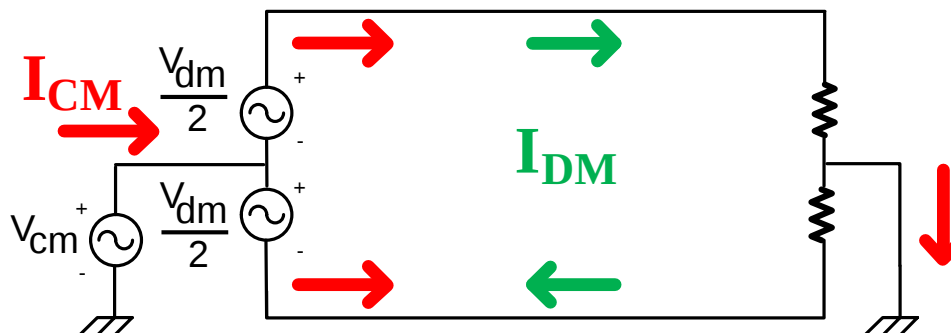
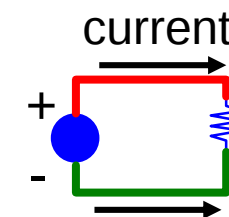
SIGNAL CURRENT = “Differential Mode” (Intended Current)

- An “equal and opposite pair” of currents
- The obvious, intended conducted loop of current on schematic
- Easy to accurately predict in advance



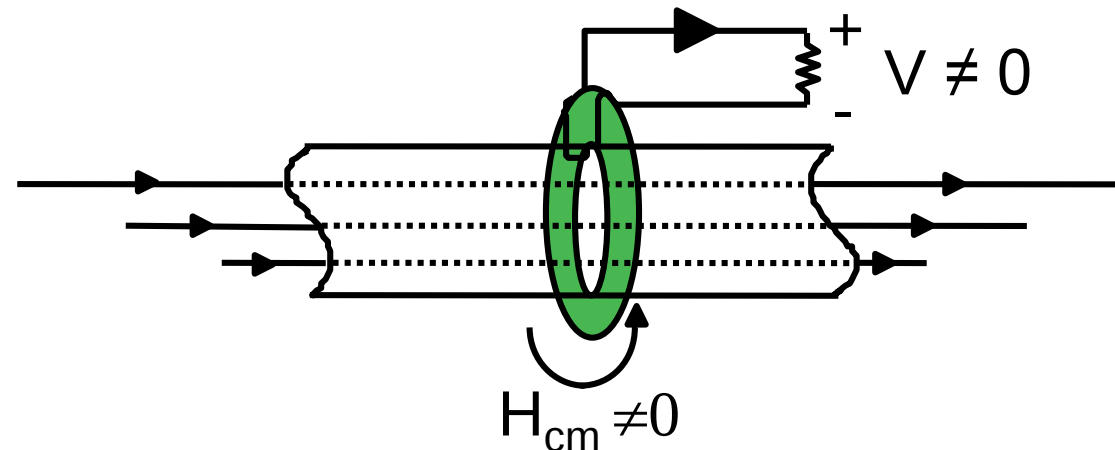
NOISE CURRENT = “Common-Mode Current”

- The NET current flowing in one direction only
- It's presence & path are not obvious, NOT shown on the schematic
- An unintended noise current that causes EMI emissions & susceptibility problems
- Very tough to accurately predict in advance



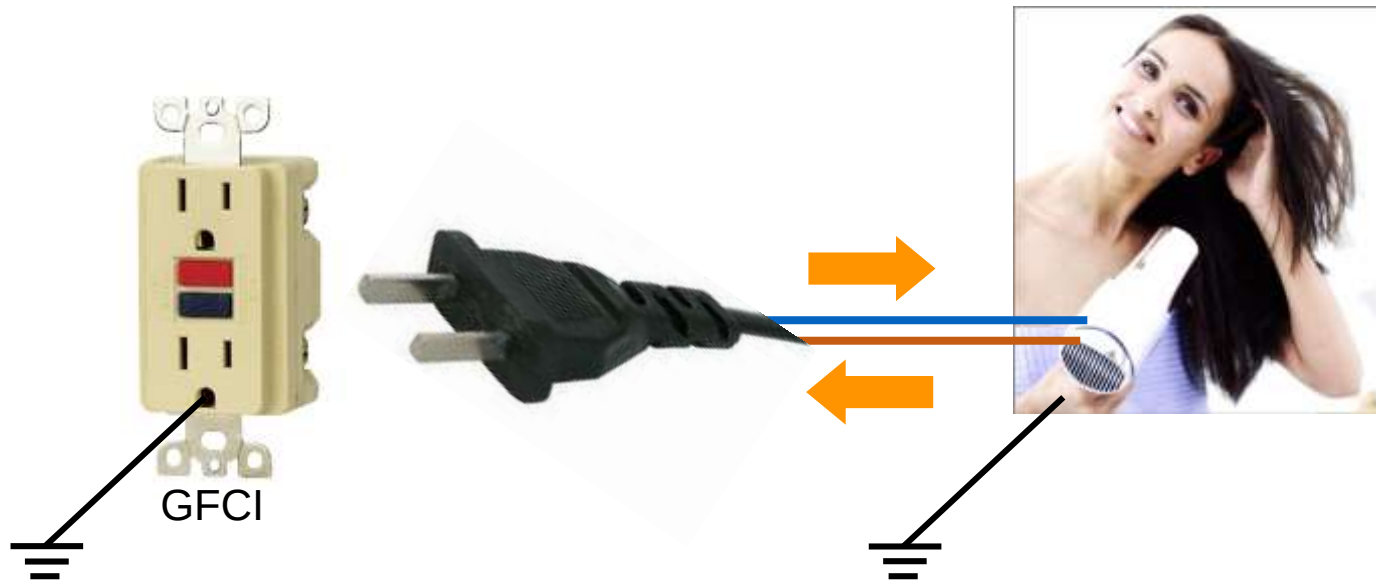
Common-Mode Current = NOISE

- The unintended component of signal current.
- Common-mode currents - set of identical currents flowing in the same direction on a group of conductors.
- A current probe around THIS cable will show a non-zero net current – an unintended common-mode “noise” current.

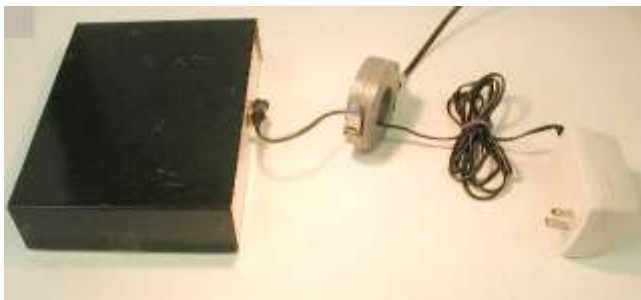
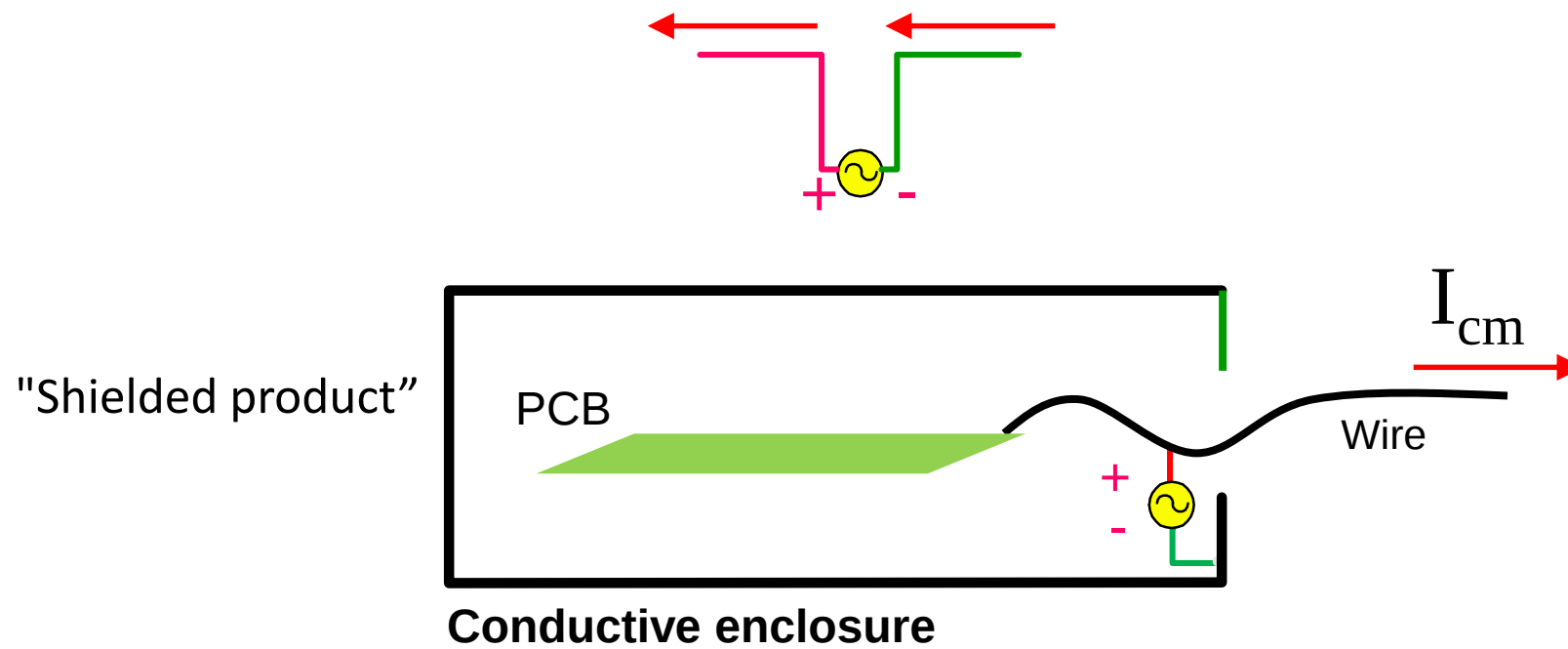


A Way to Visualize Common-Mode Current

Can you guess what's going to happen?



SILENT's Favorite Dipole Antennas, Driven by I_{cm}



Questions on Common-Mode Current?

Ground Loops

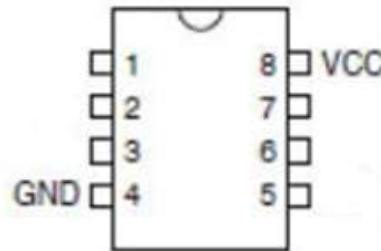
The word "Ground"....Where New Product Designs Go Wrong

"There is no neutral ground in the universe; every square inch, every split second, is claimed by God and counter-claimed by Satan."

C.S. Lewis 1898-1963, British Scholar and Novelist

"When I look at a circuit schematic, if I see two or more different ground symbols, I know I have [EMI] consulting work."

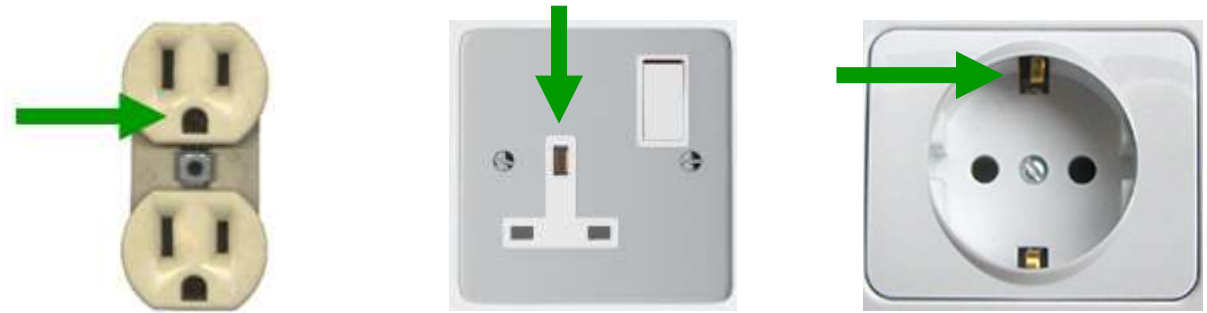
Dr. Tom Van Doren, Professor Emeritus, Missouri University of Science & Technology



GroundING Conductors are NOT the Same as Signal Return Conductors

A Safety GroundING Conductor
provides electrical safety

Normally, $I = 0$



A Signal Return Conductor
provides a signal path from
load back to source.

Normally, $I = \text{signal}$



A Test to Determine Whether a Conductor is a “Signal Return” or a “Ground” :



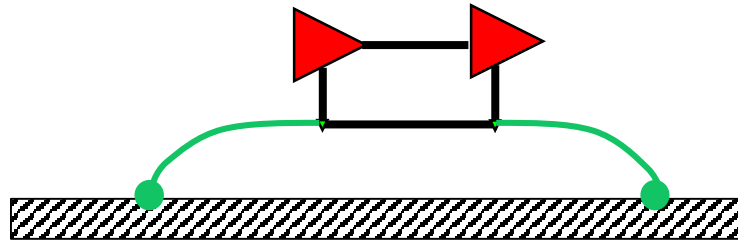
If you cut the conductor, and the circuit STOPS working, then you have cut a _____

If you cut the conductor, and the circuit CONTINUES to work, then you have cut a _____

Definition of a “Ground Loop”

Definition: A ground loop is a closed current path that consists of

- 1) signal path (usually the “return”), and
- 2) ground structure



“Ground Structure” examples:

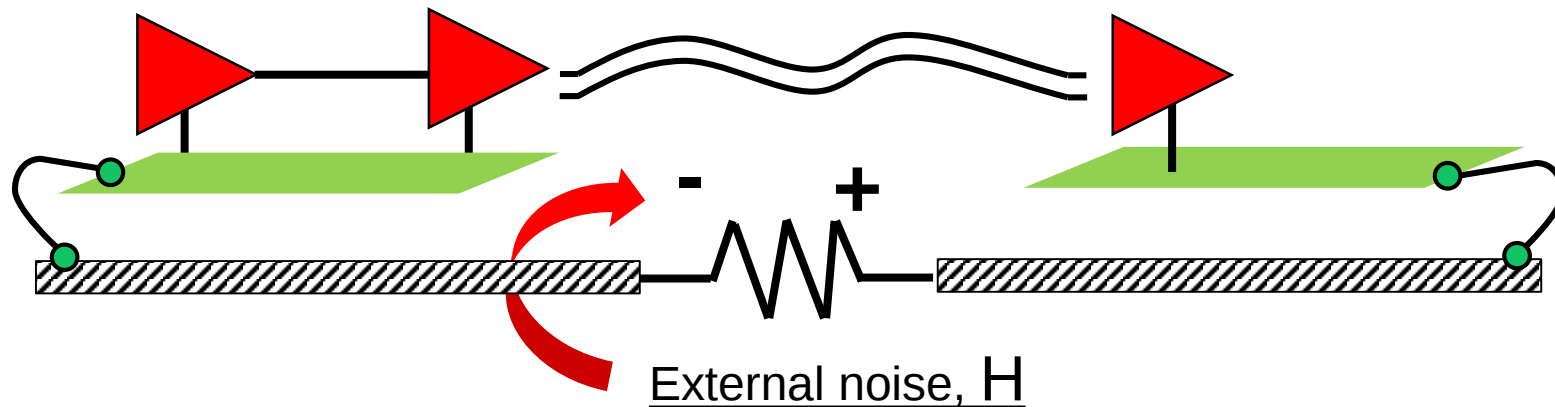
- 1) 3rd wire of AC power cord
- 2) chassis of system
- 3) AC wiring in wall

Source: © Grounding and Shielding in Electronic Instrumentation, Dr. Tom Van Doren

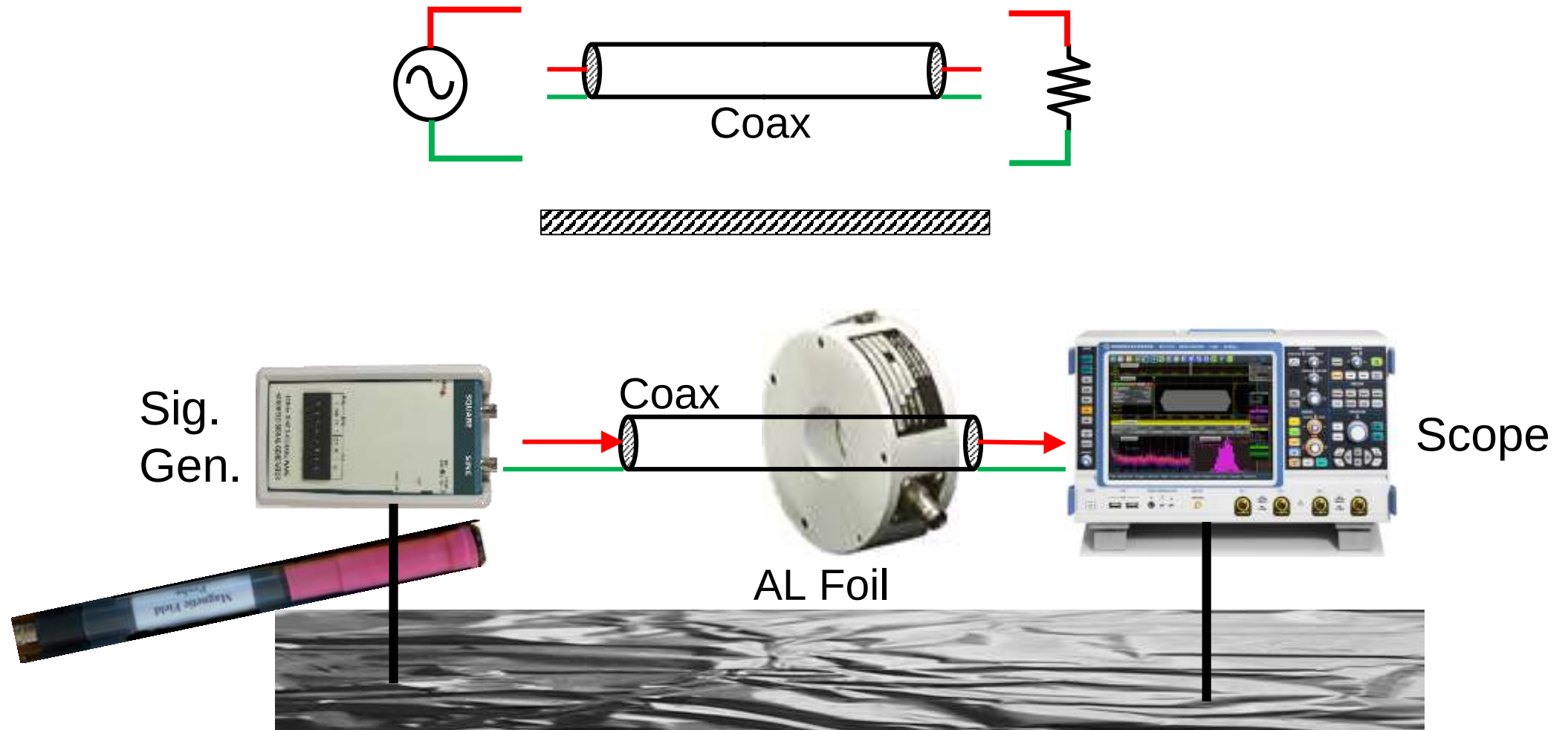
Low Frequency Signal Integrity, $F < 1$ MHz



- Cable type does not matter
- Current unbalance is cause and symptom



Demonstration Low Frequency Signal Integrity, $F < 1$ MHz



Summary

Common-mode Current

- Flows in the same direction along a group of conductors
- Almost always is “noise” current
- Fundamental cause of almost all EMC test failures

Grounds Loops

- Low Frequency, $F < 1$ MHz
- Usually present: Long cables, small analog signals, ground structure

Bad Low Frequency Signal Integrity is caused by

- Lack of balance in signal path. Susceptibility to conducted and magnetic noise coupling
- Incorrect use of balanced and unbalanced cabling and receivers
- Many design techniques can ensure good low frequency signal integrity.

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