Pass EMC the First Time: Design It Right, From the Start

A Mach One Design EMC Training Material
https://mach1design.co.uk/
Produced and Taught by Min Zhang, PhD
Updated: 06/10/2025

EDS, Coventry, 2026

About Us

TELONIC
TEST INSTRUMENTS & POWER SUPPLIES

MACHone
Expertise Propels Excellence

Dr. Min Zhang

- Focused on the automotive, home appliance, industrial, professional, and medical sectors
- Advanced knowledge in product research and development
- Strong background in electronics design and motor control for high-tech volume production
- In-depth experience in electromagnetic design
- Chair of the IEEE EMC Society UK & Ireland

About Us

- Telonic was established in the UK in 1966 as the sales and service arm of Telonic Industries Incorporated, a US company specializing in RF products.

- In 1976, Telonic became the UK distributor for Kikusui Electronics Corporation of Japan.

- In 1982, following a management buyout, Telonic became an independent company, continuing to sell Telonic Berkeley products and adding leading manufacturers of electronic test and measurement instruments and power supplies to its product range.

- Telonic holds a wide range of instruments in stock at its Wokingham premises, allowing for rapid delivery (usually overnight within the UK).

- Standard delivery to Europe takes around 3 working days, with faster options available upon request.

- Telonic is ISO 9001 certified by NQA (National Quality Assurance) and conducts quality assessments on all suppliers to ensure the highest standards are upheld.

Outline

- Radiated Emissions
- Narrowband vs Broadband Noise
- Design Techniques for Narrowband Noise - Demo 1
- Design Techniques for Broadband Noise - Demo 2

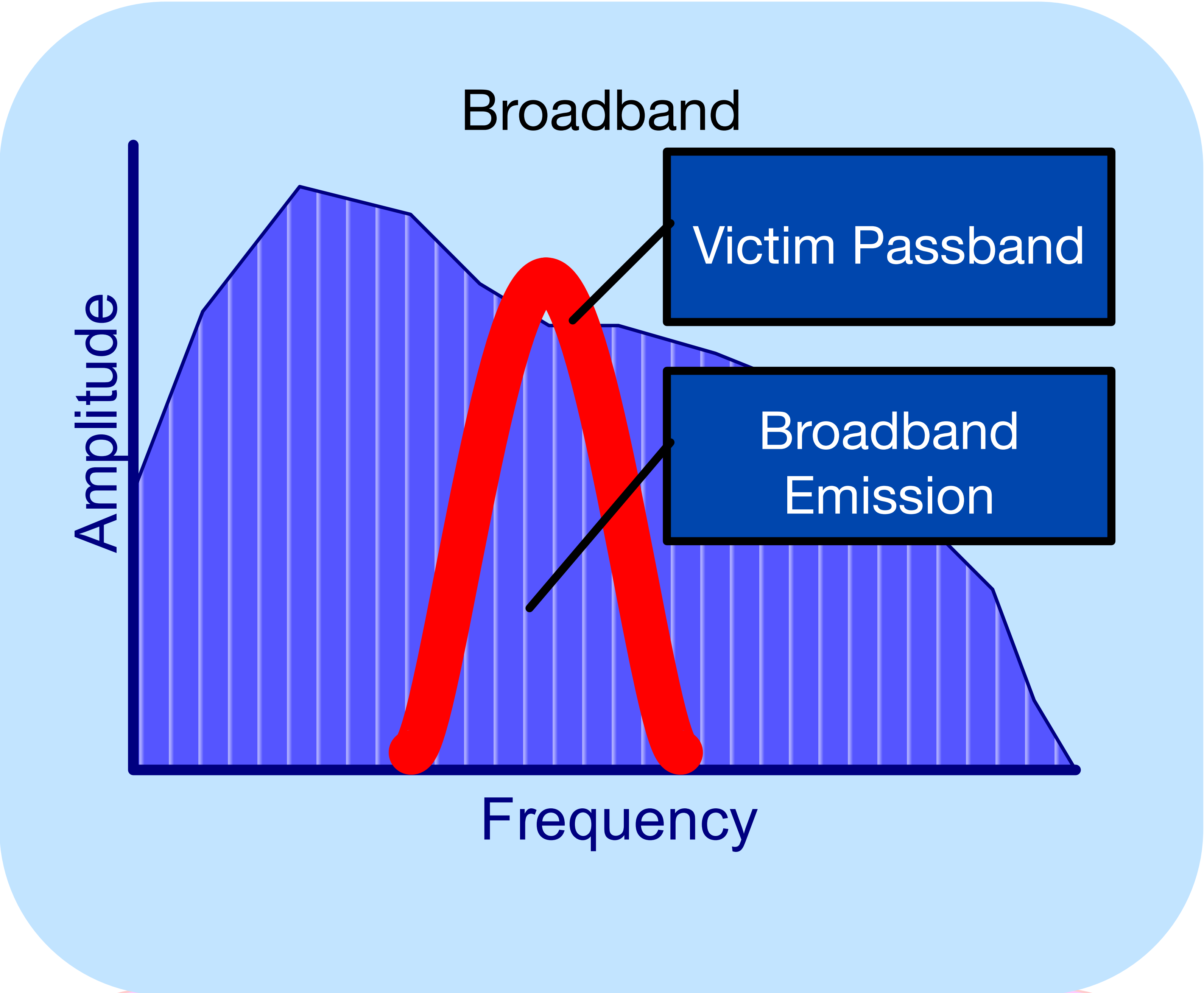
This is the printout version of the presentation. For the full presentation with notes enabled, please contact the author.

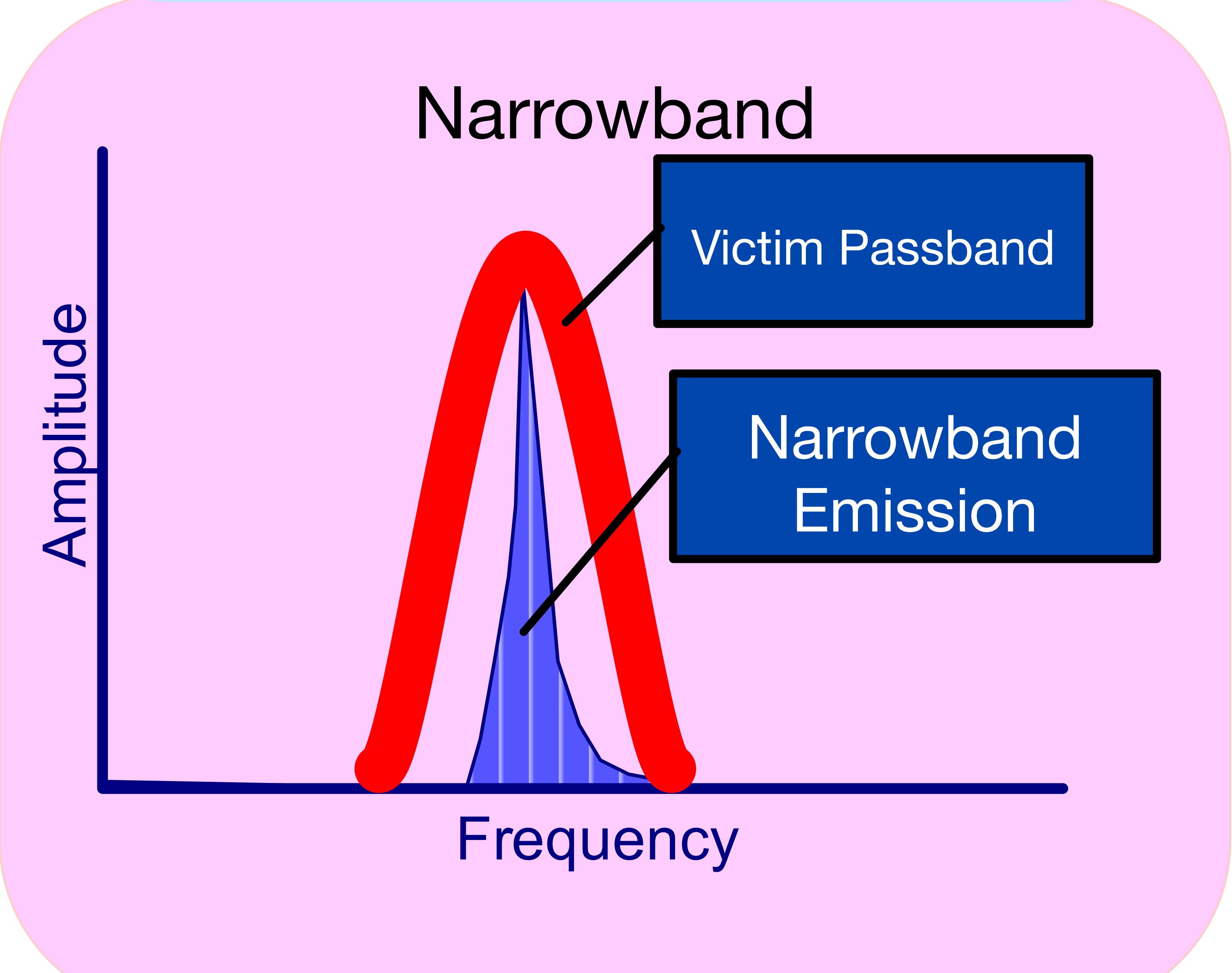
Demonstration of Radiated Emissions

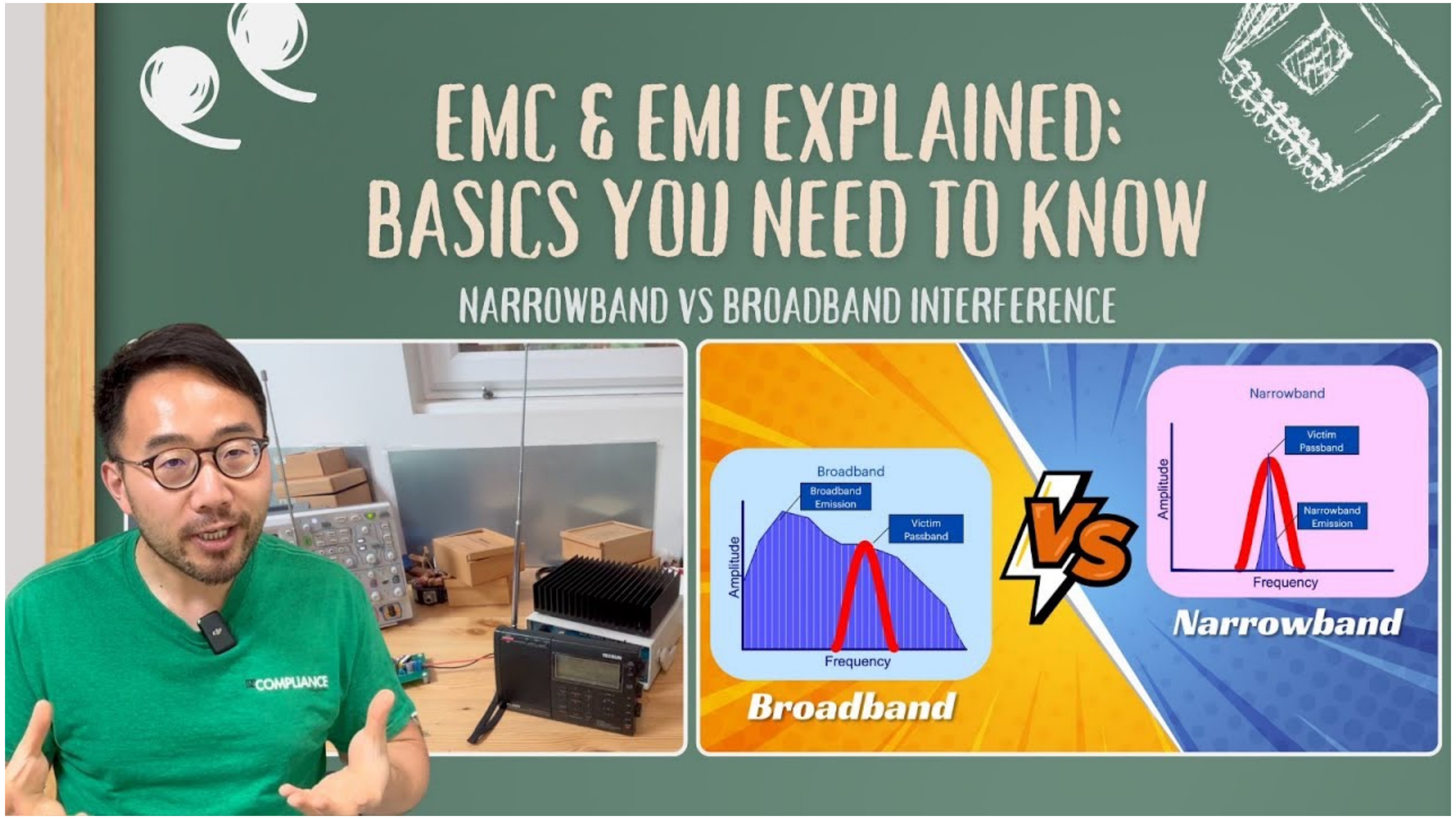
https://youtu.be/vT5BLphkc40?si=fcGmqgx4FFA5waMU

Radiated Emissions

Types of Continuous Interference - Narrowband and Broadband







https://youtu.be/MB8RRcWqbns?si=vzYvp-varwzoAuZ

Broadband Noise

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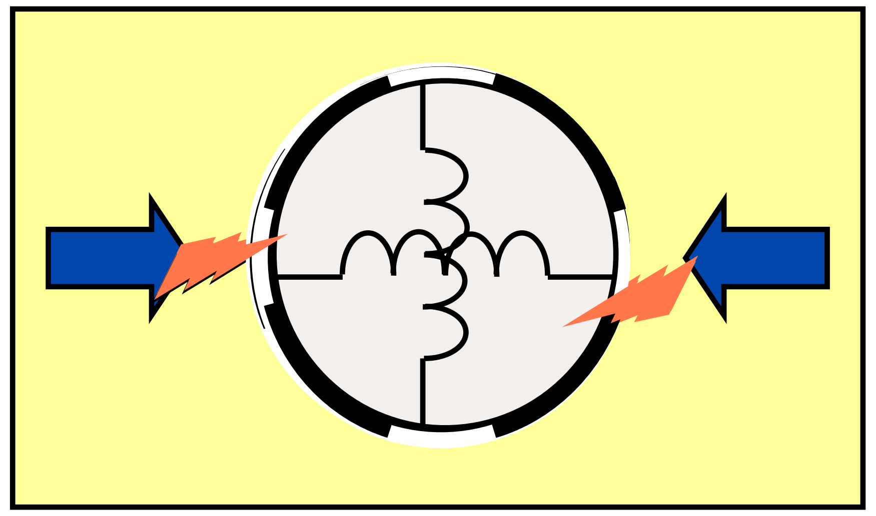
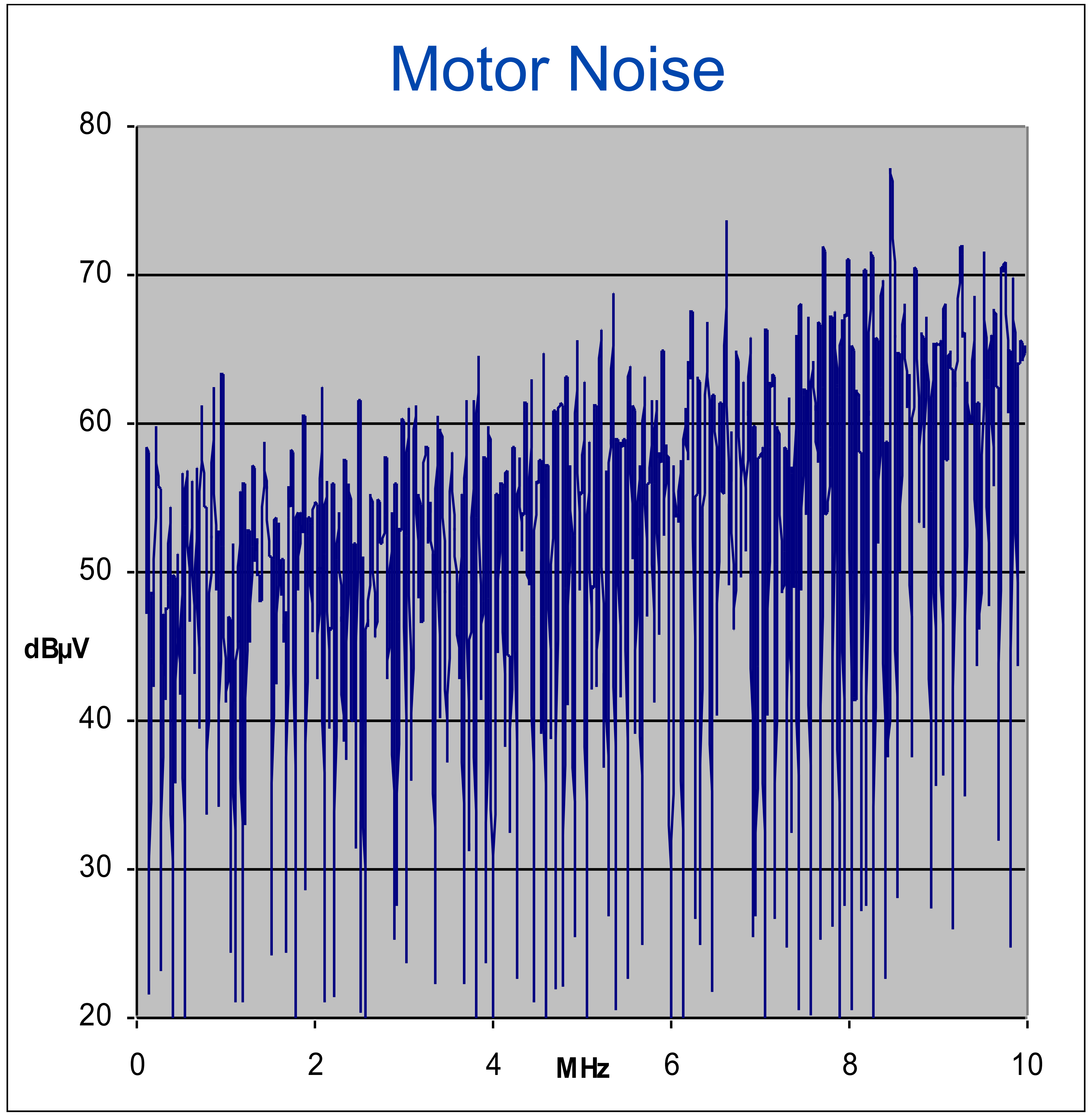
Pseudo-random bit sequence data

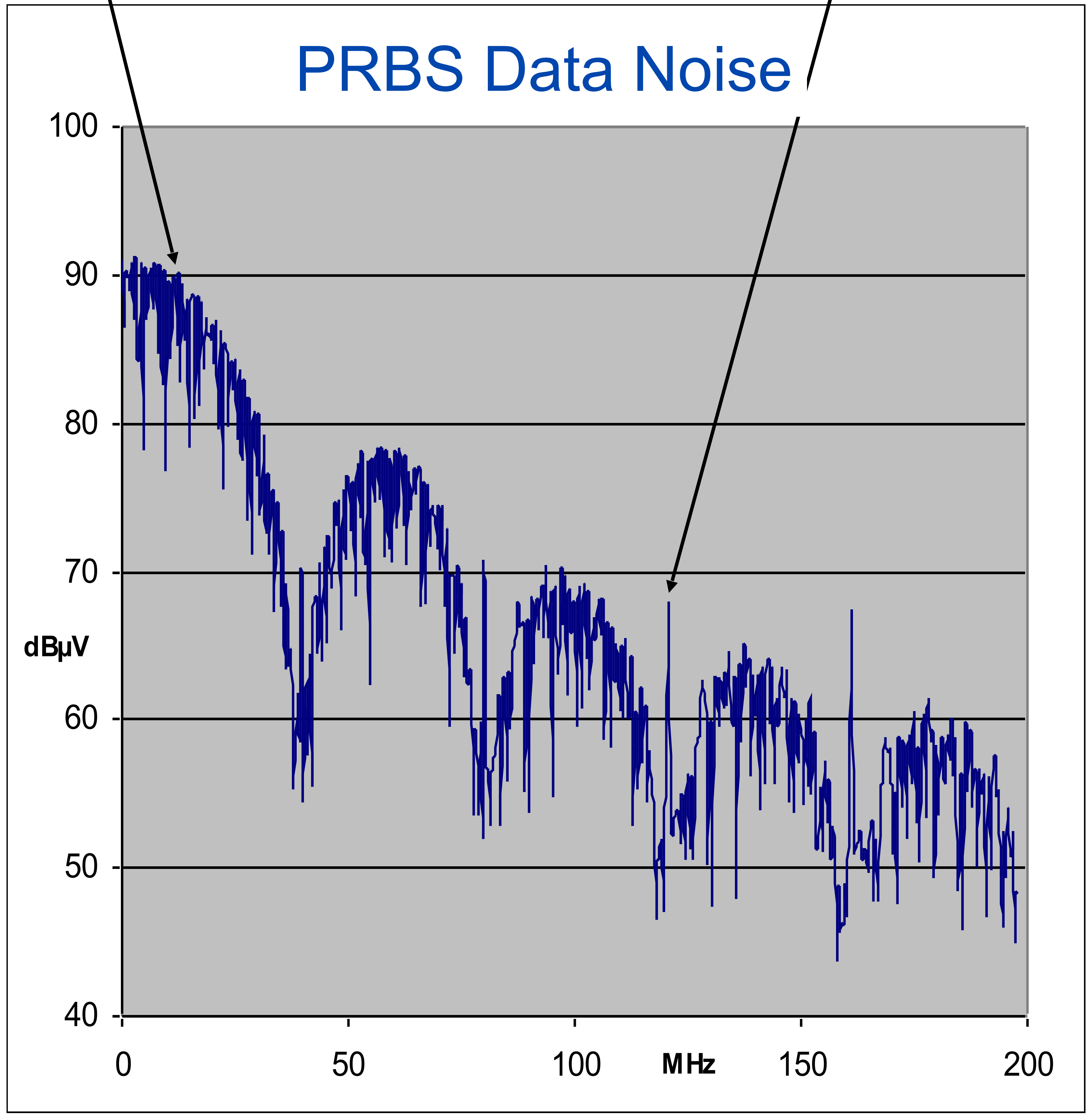
Data clock harmonics

Motor commutator

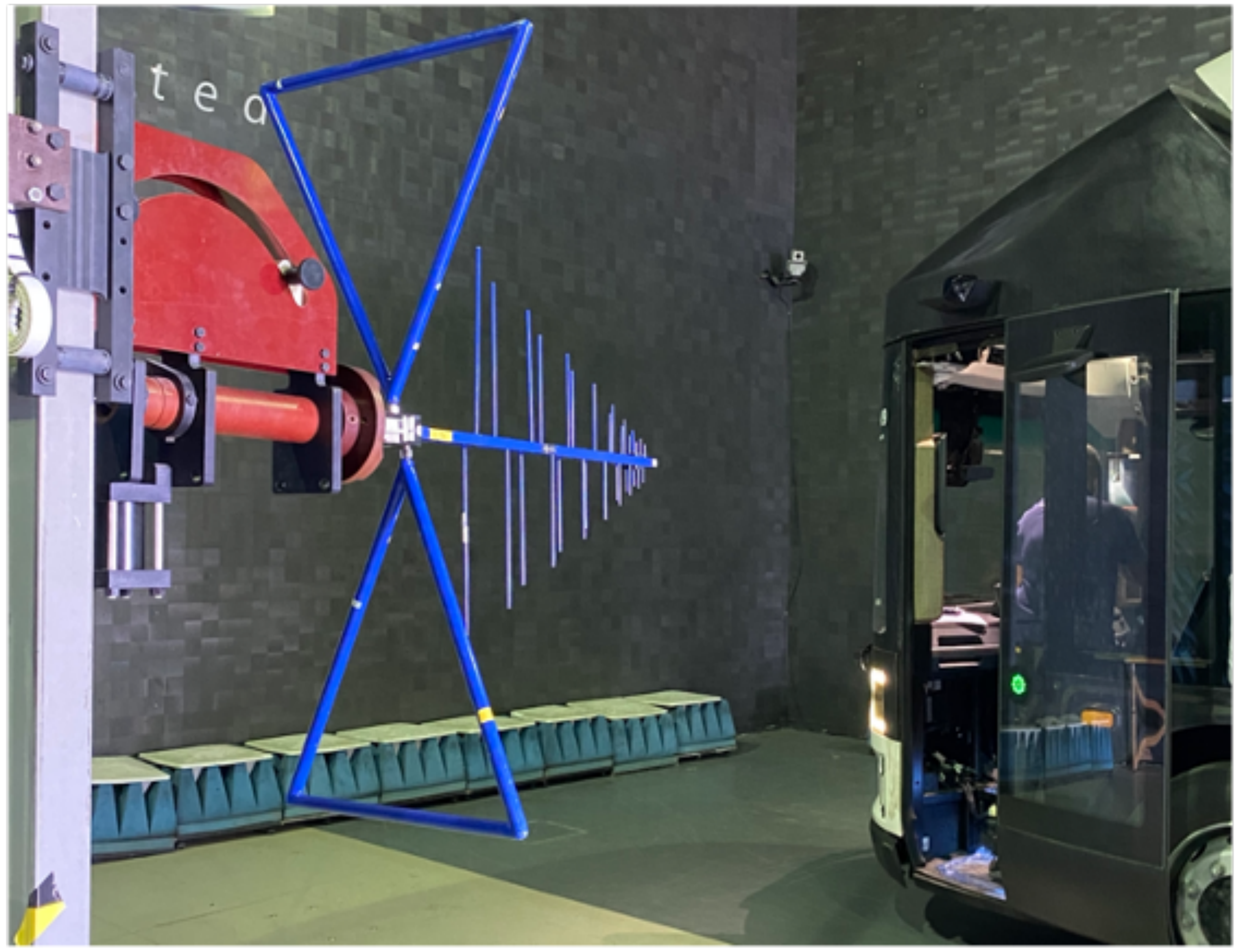


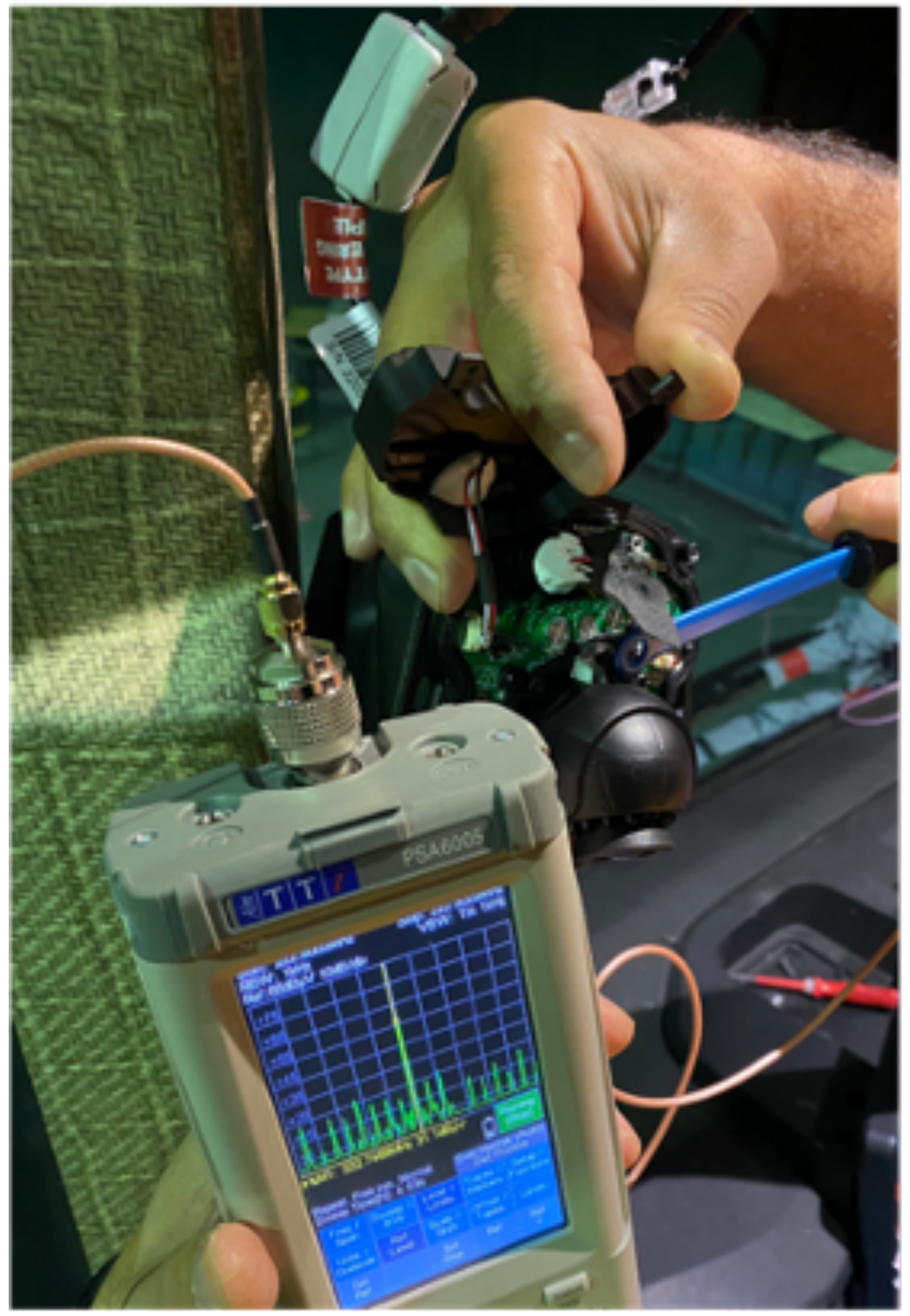
Each "spike" is actually a short-duration transient with a broadband envelope

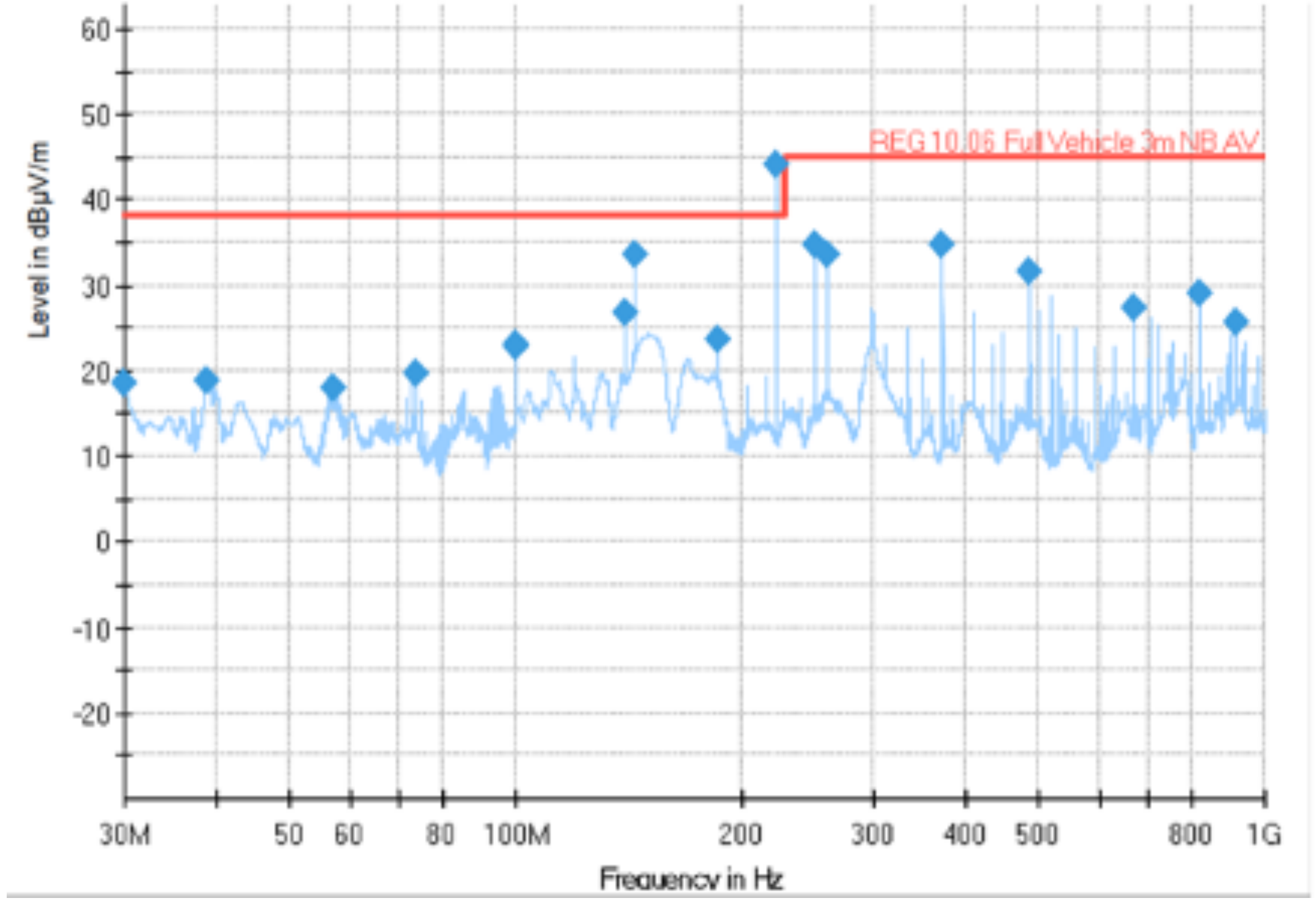




Narrowband Noise







Designing a Good PDN

Note: This is an excerpt from the full training material.
For the complete version, please feel free to contact us.

Power Distribution Network

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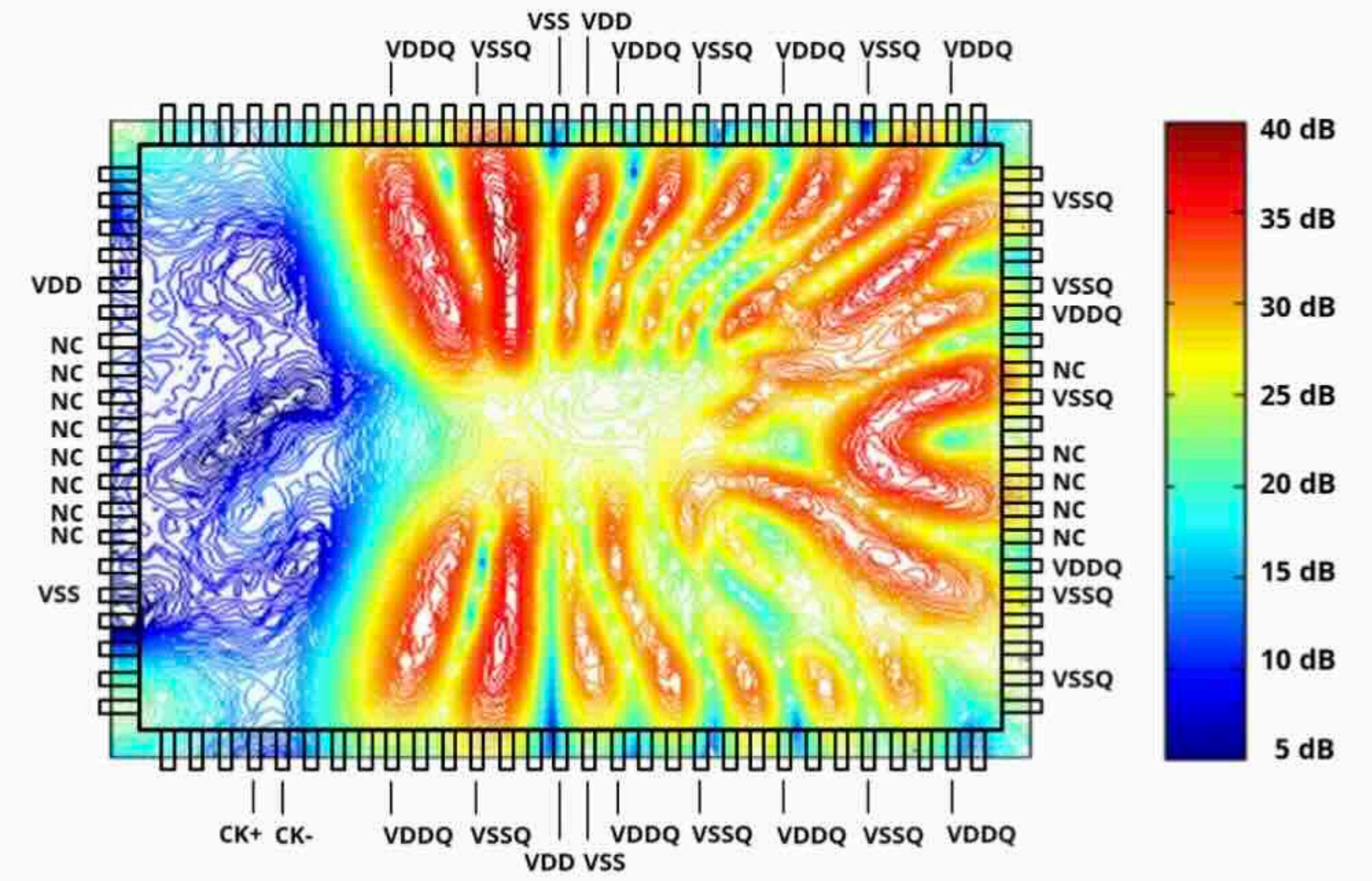
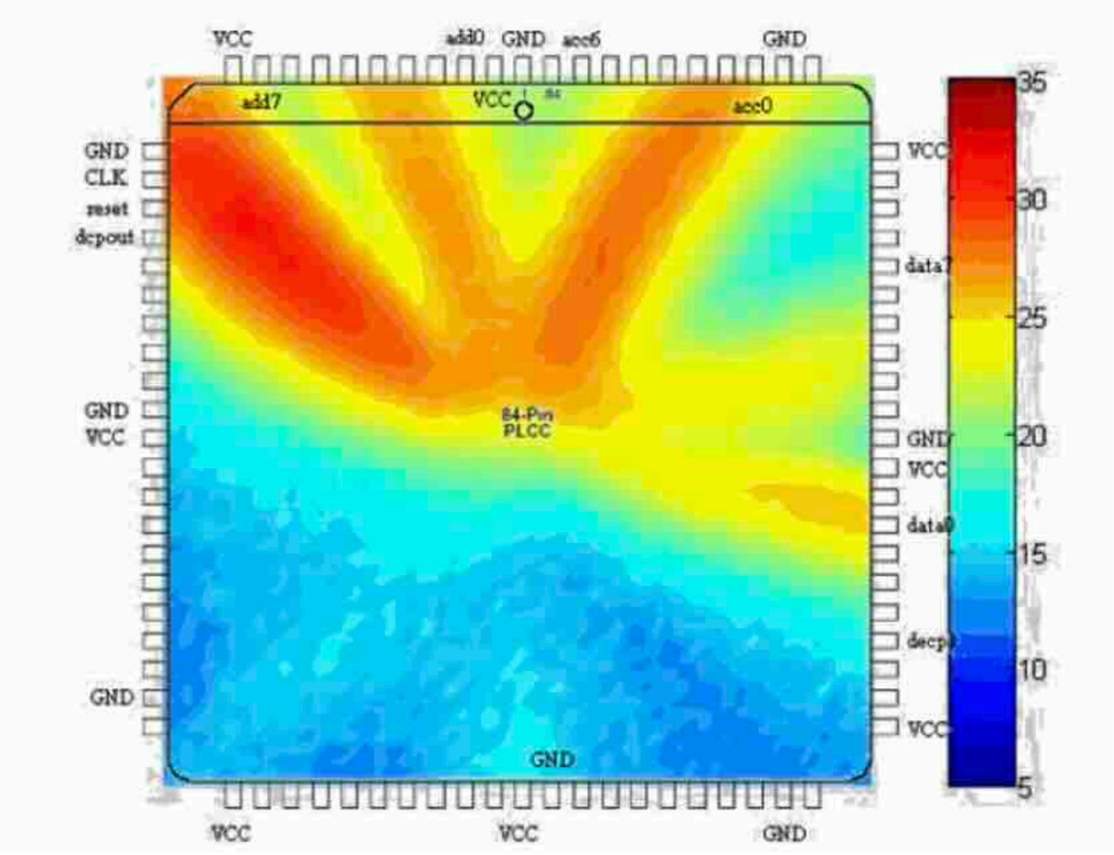
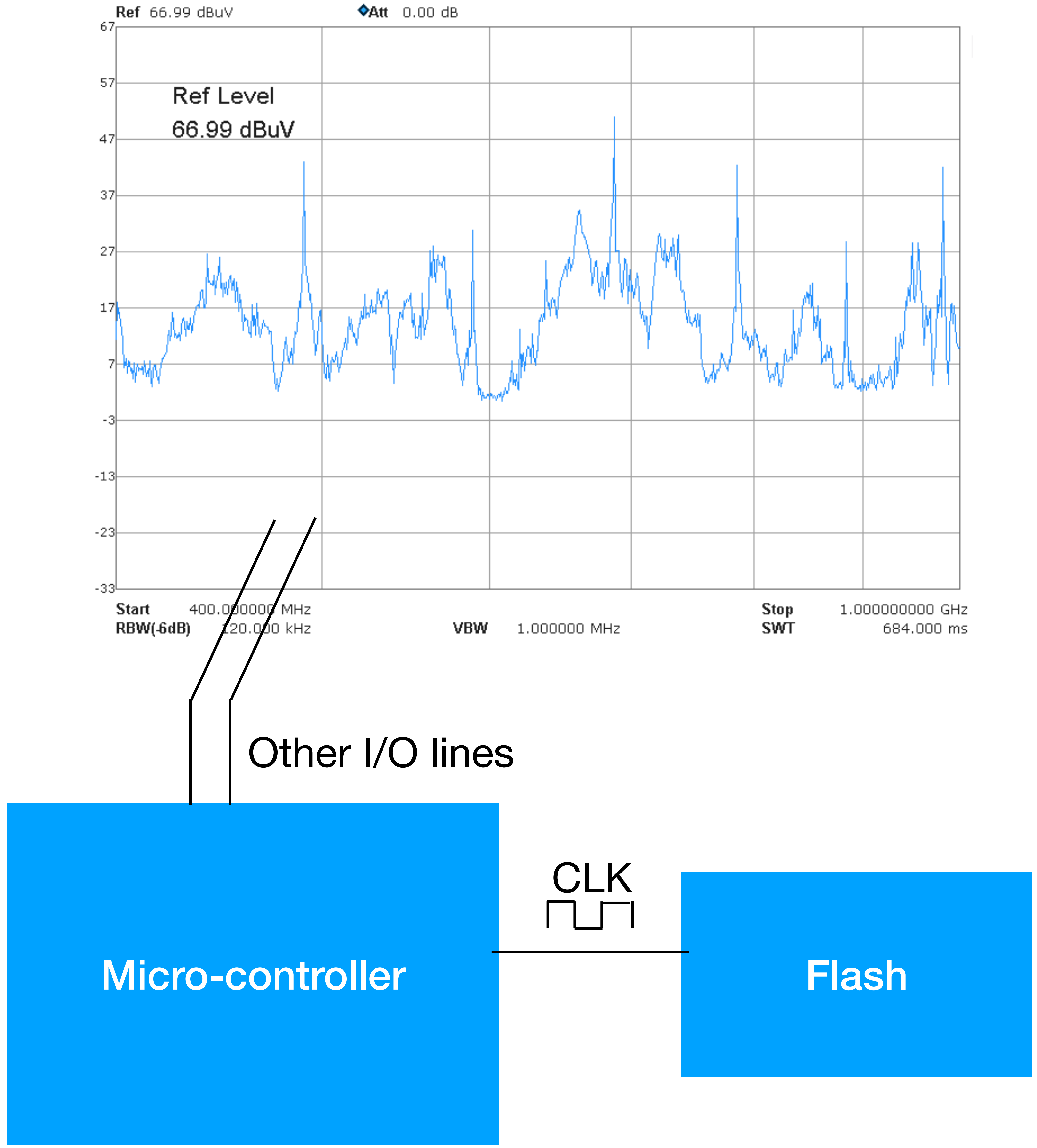


Near magnetic field above a packaged integrated circuit



Significant high-frequency currents appear on low-speed I/O including outputs that never change state during normal operation!



Source: Todd Hubing

Emissions due to Common-Mode Cable Noise

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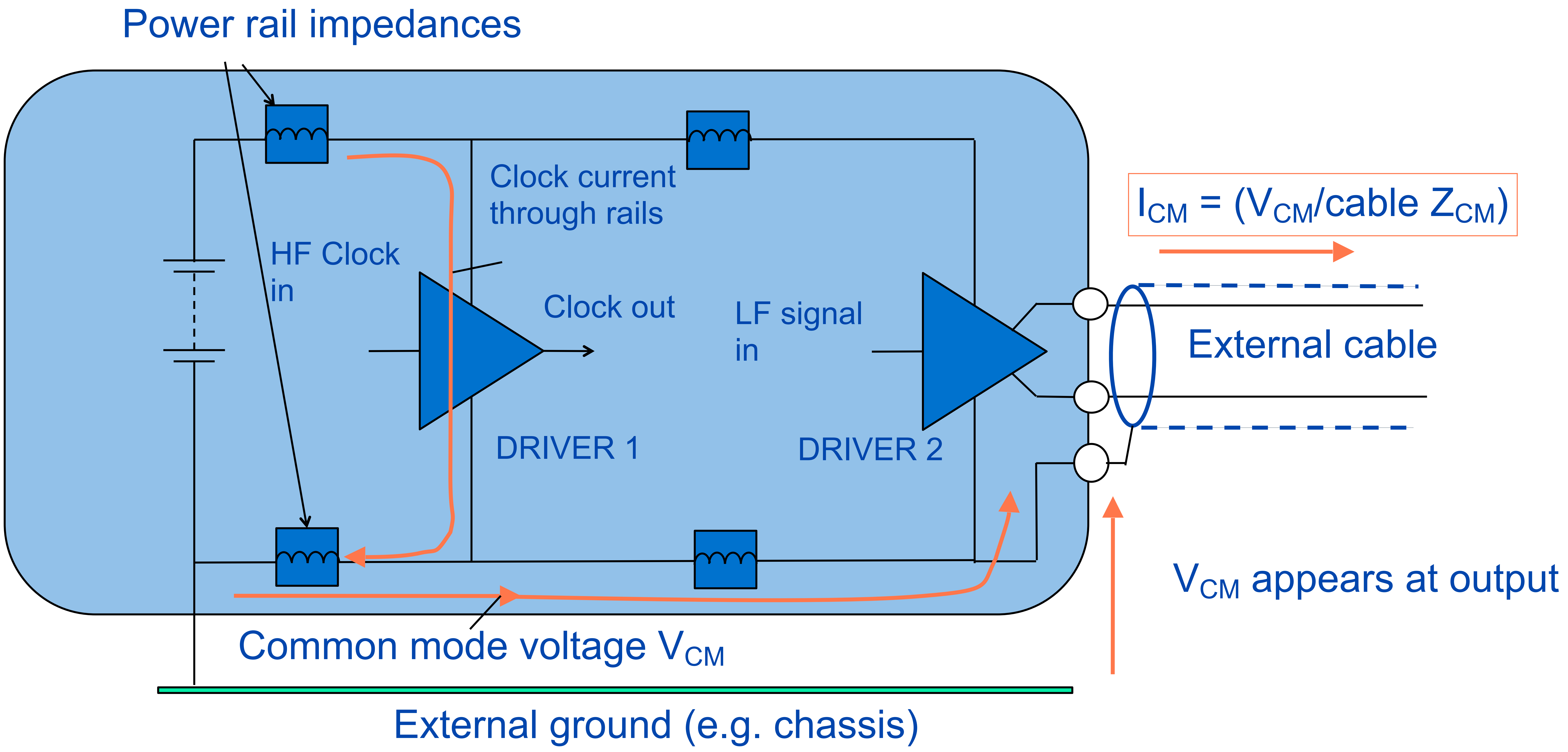
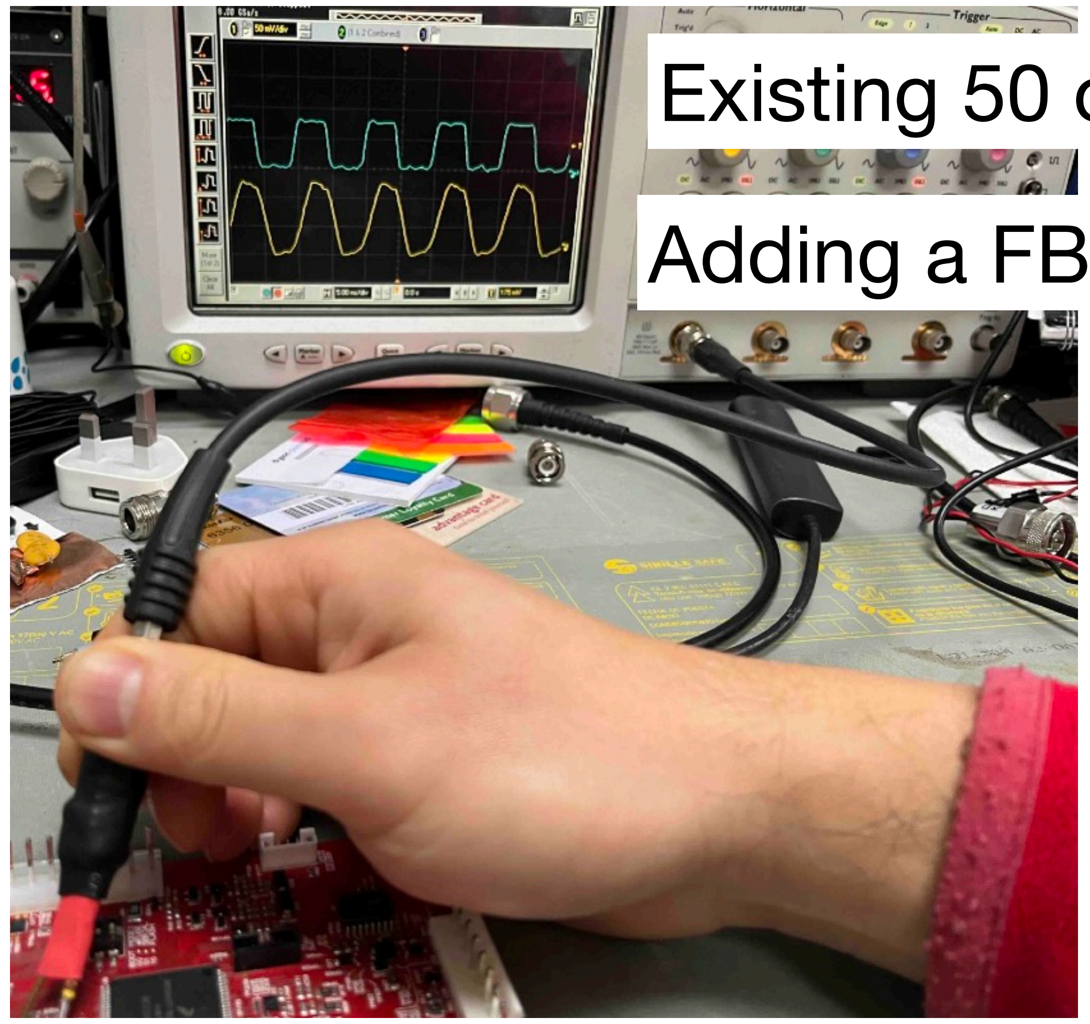


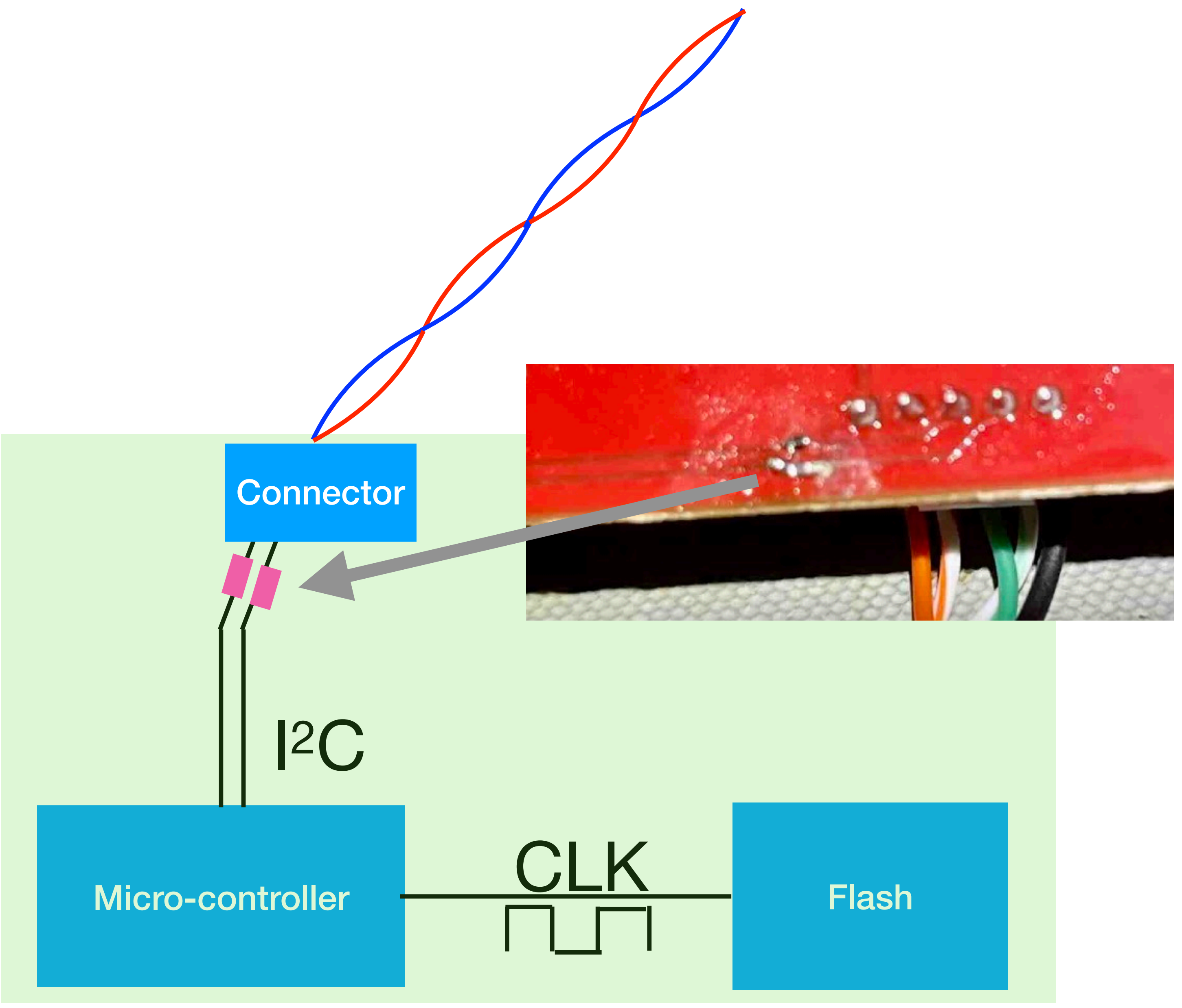
Troubleshooting the Issue

- Reduce the drive strength of the clock - Software change in the IC, preferred
- Adding a ferrite bead to the clock line
- Adding an on-board-shield over the chips
- Adding ferrite beads to ALL I/O lines

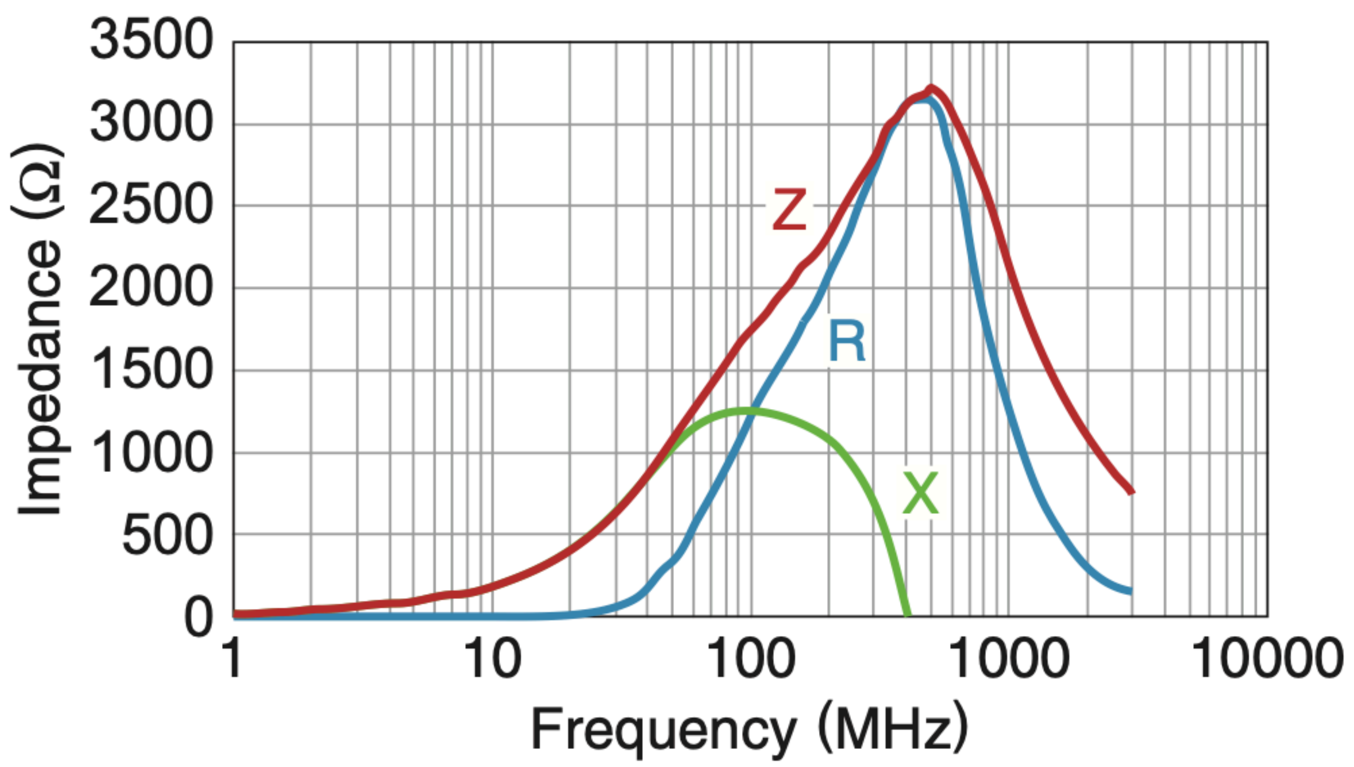


Existing 50 ohm terminating resistor

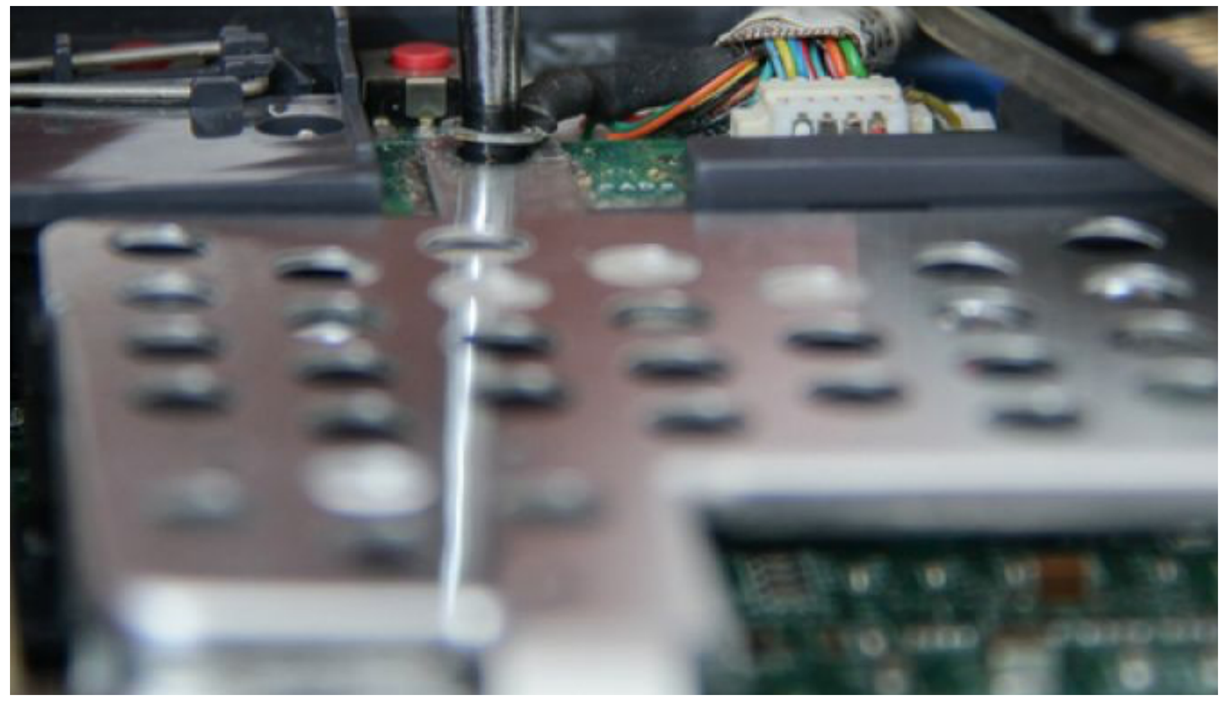
Adding a FB on the clock line



Using two ferrite beads on the I2C lines, close to the connector

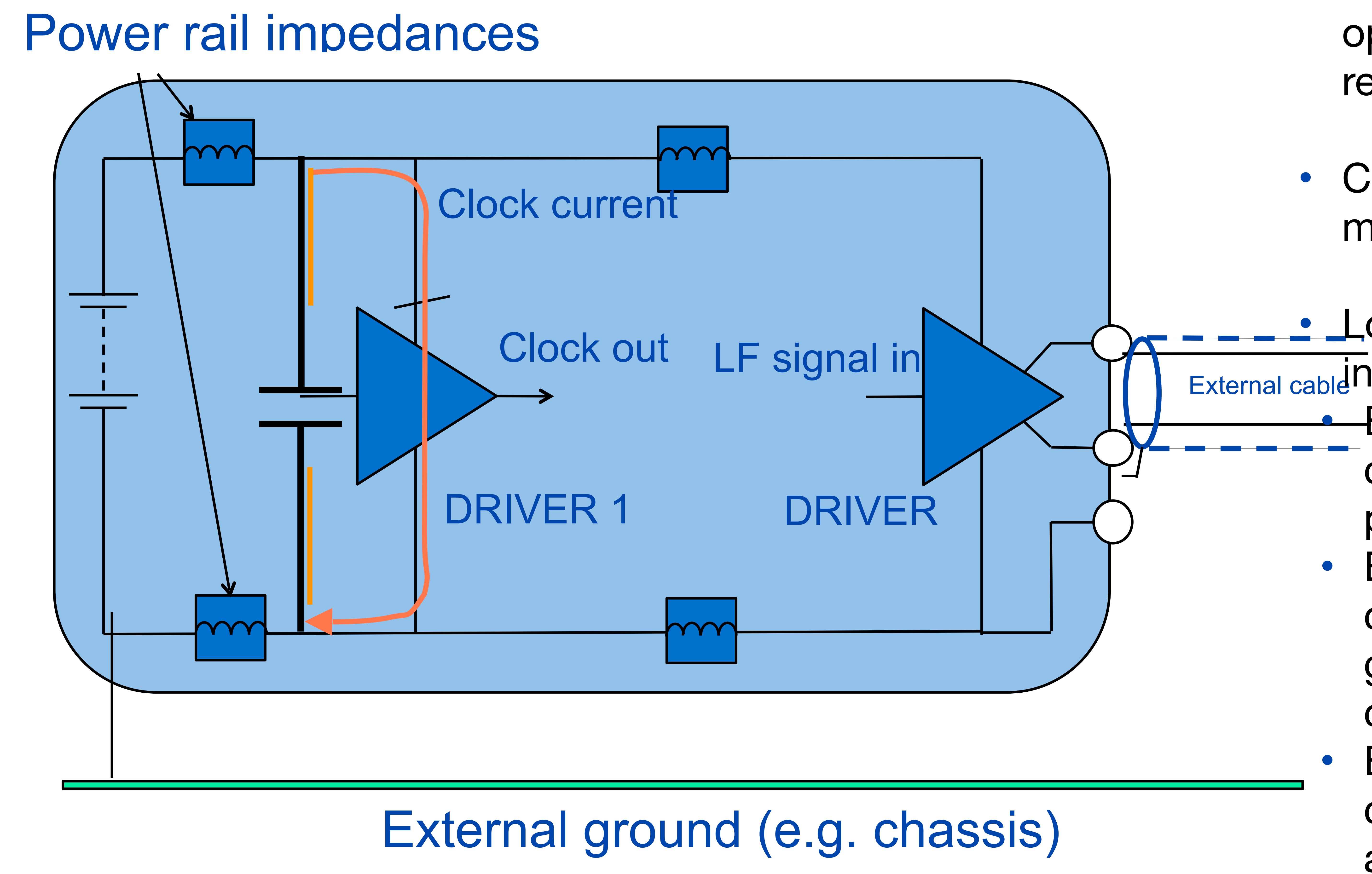


The ferrite bead has very low impedance below 10 MHz and reaches its maximum impedance around 500 MHz



On board shielding suppresses noise of clock frequency

Decoupling Capacitors



$$\lambda = \frac{c}{\sqrt{\epsilon_r} f}$$

Assuming FR4, for 900 MHz, a wavelength is 16 cm

Using a rule of them, λ/20 rule, the capacitor must be placed 8 mm away!

- Decoupling capacitors are inductors over most of their operating frequency range (they are used above self resonance)

- Choose the capacitor first for low inductance, then for maximum capacitance

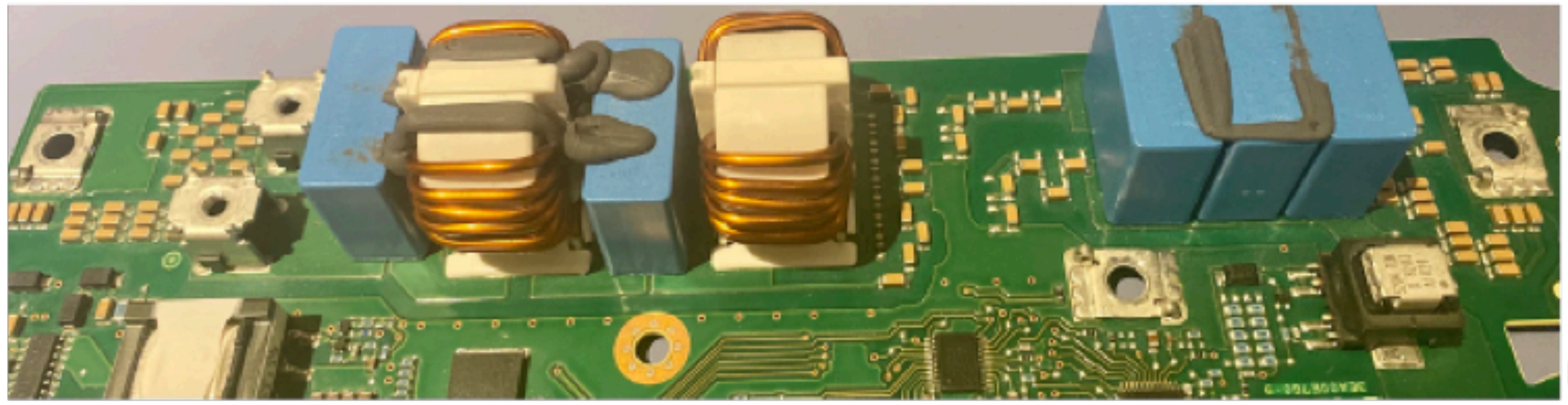
- Locate the capacitor to minimise the effect of total loop inductance:
  - Boards without power planes: – one local decoupling capacitor per active device, connected between the power and ground pins of the active device
  - Boards with power planes spaced > 0.5 mm: – location of capacitors is critical, locate them next to the power/ground pins of each device and use the largest capacitance available in a small package size
  - Boards with closely spaced power planes: – location of capacitors is not critical, use the largest capacitance available in a small package size, and use as many as possible distributed around the board

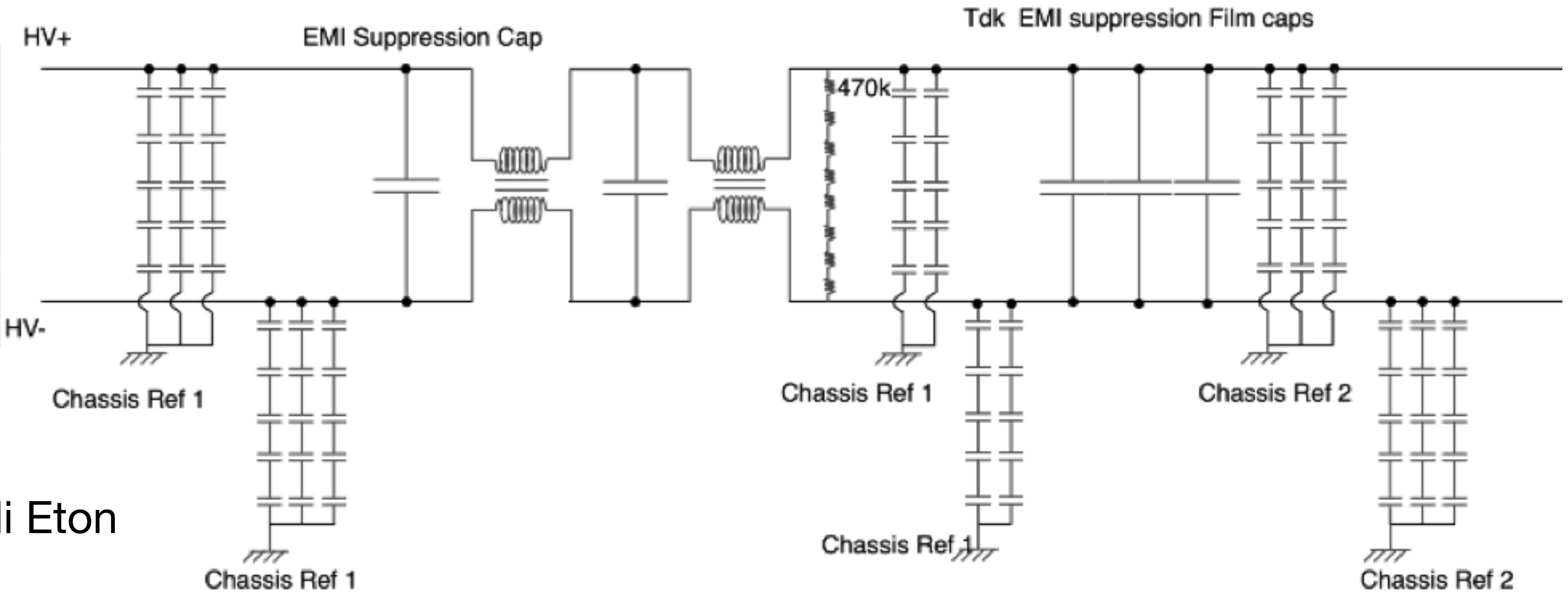
- Have at least one larger “bulk” decoupling capacitor per board

Designing a Good Filter

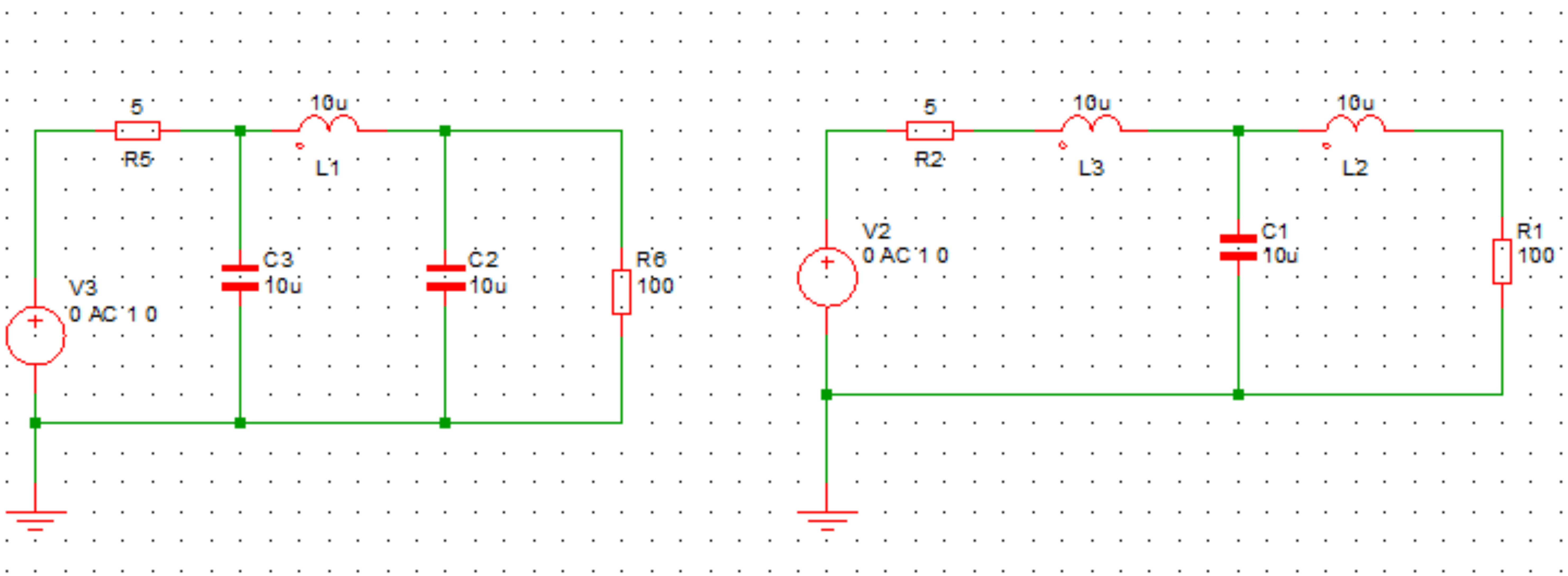
Note: This is an excerpt from the full training material.
For the complete version, please feel free to contact us.

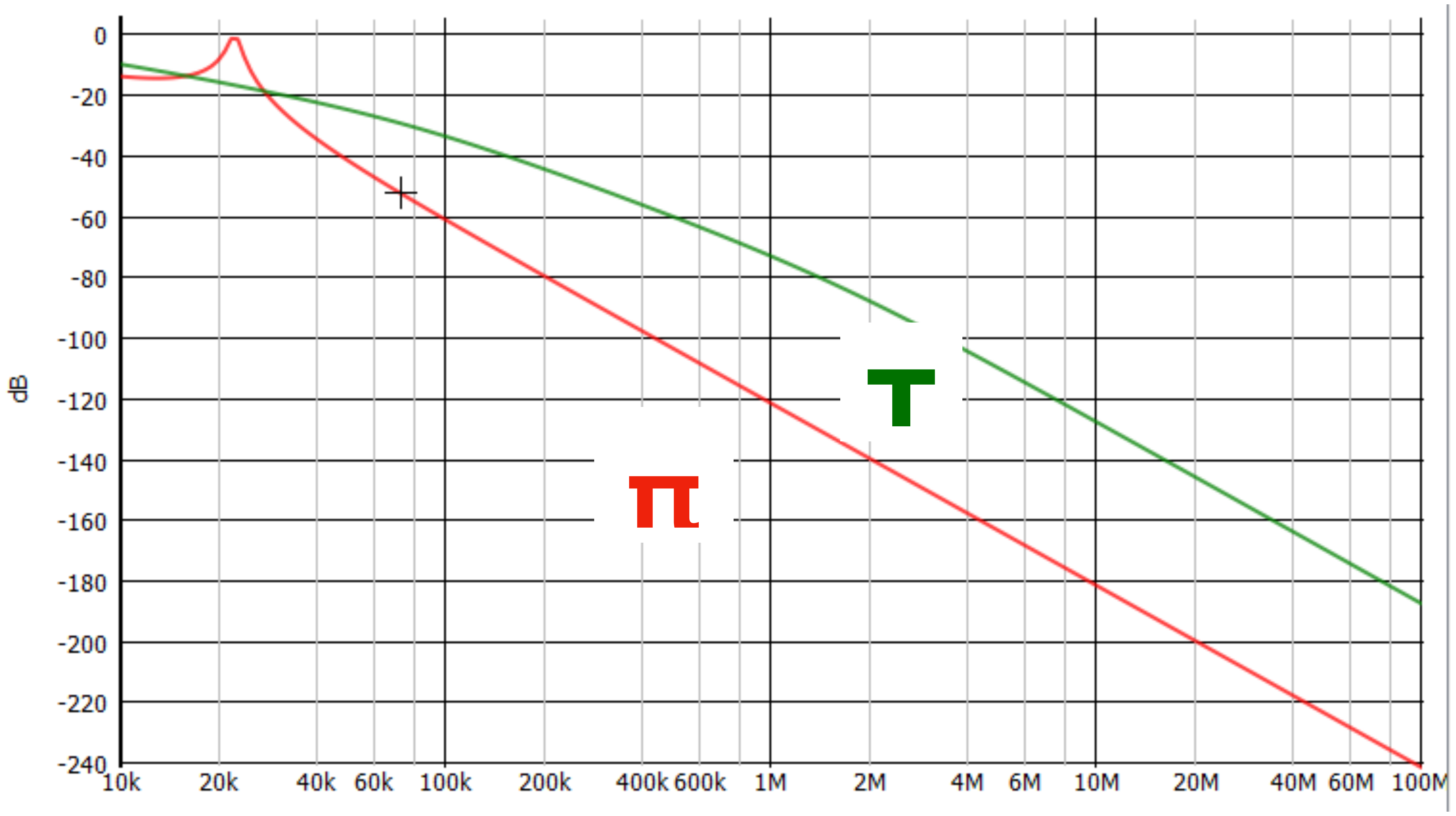
Basics





The input filter configuration in a DC-DC module used in Audi Eton





Filter Board Demonstration

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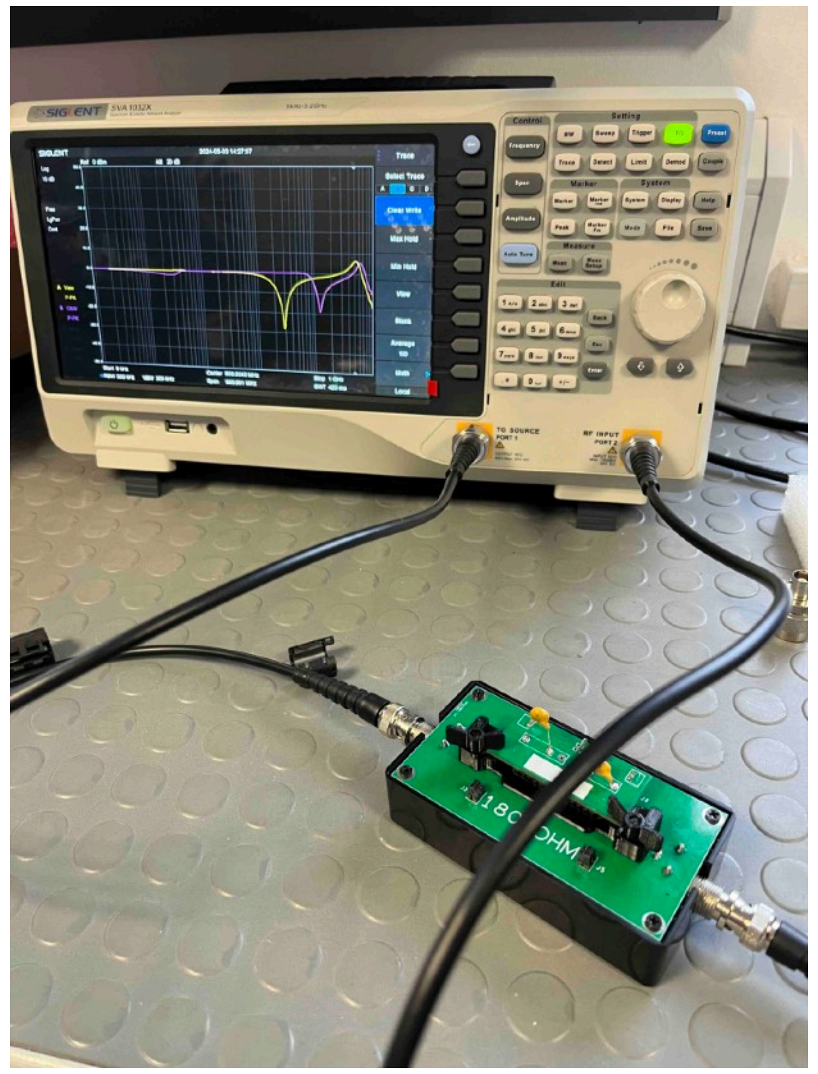
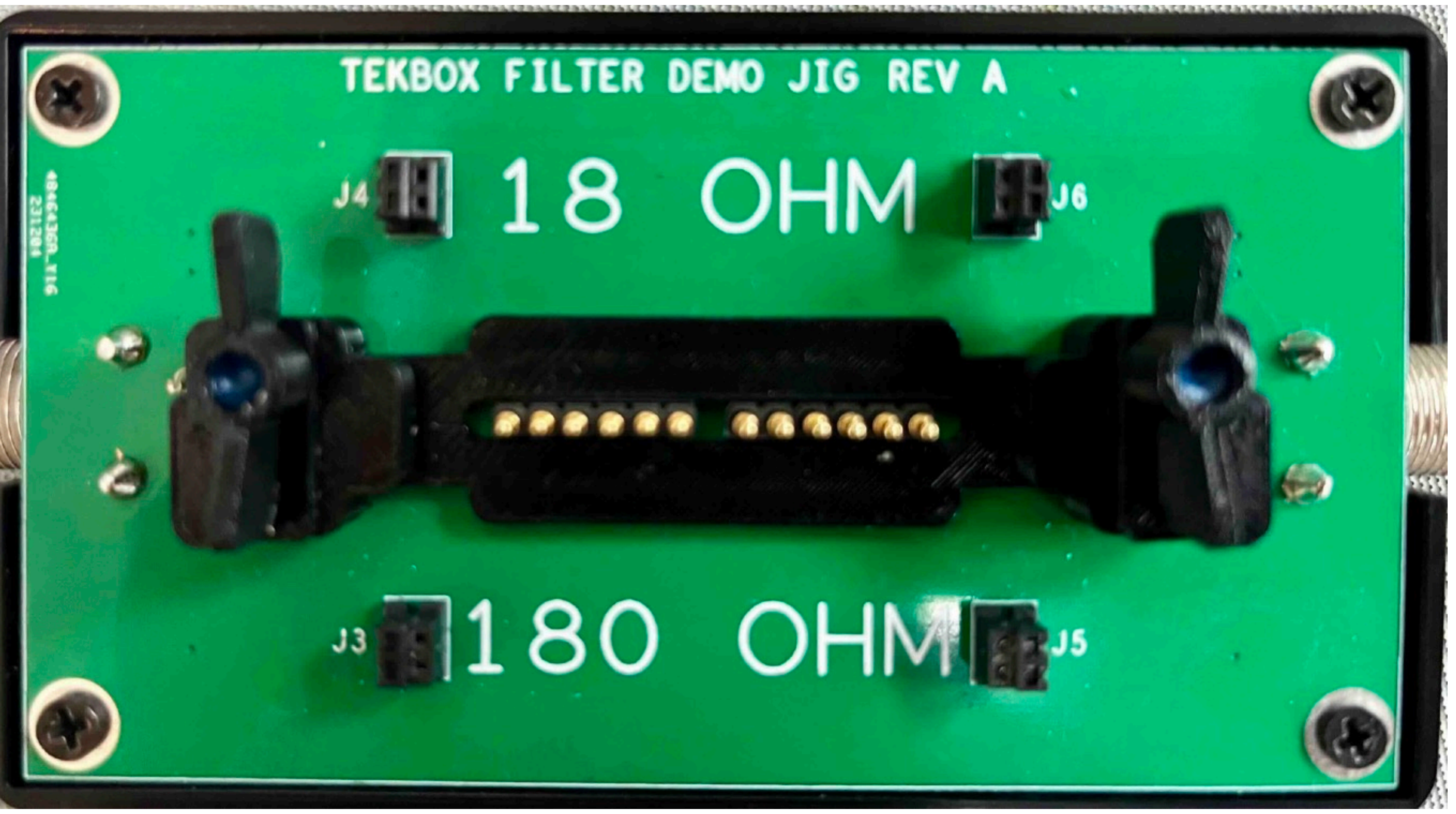
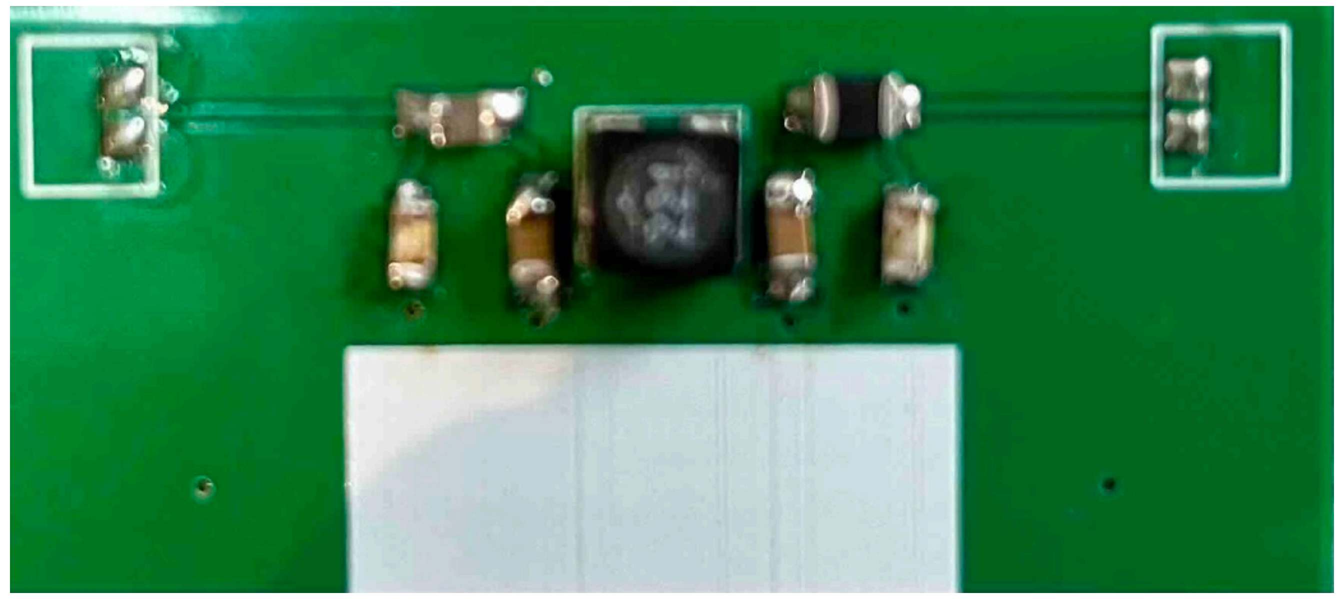
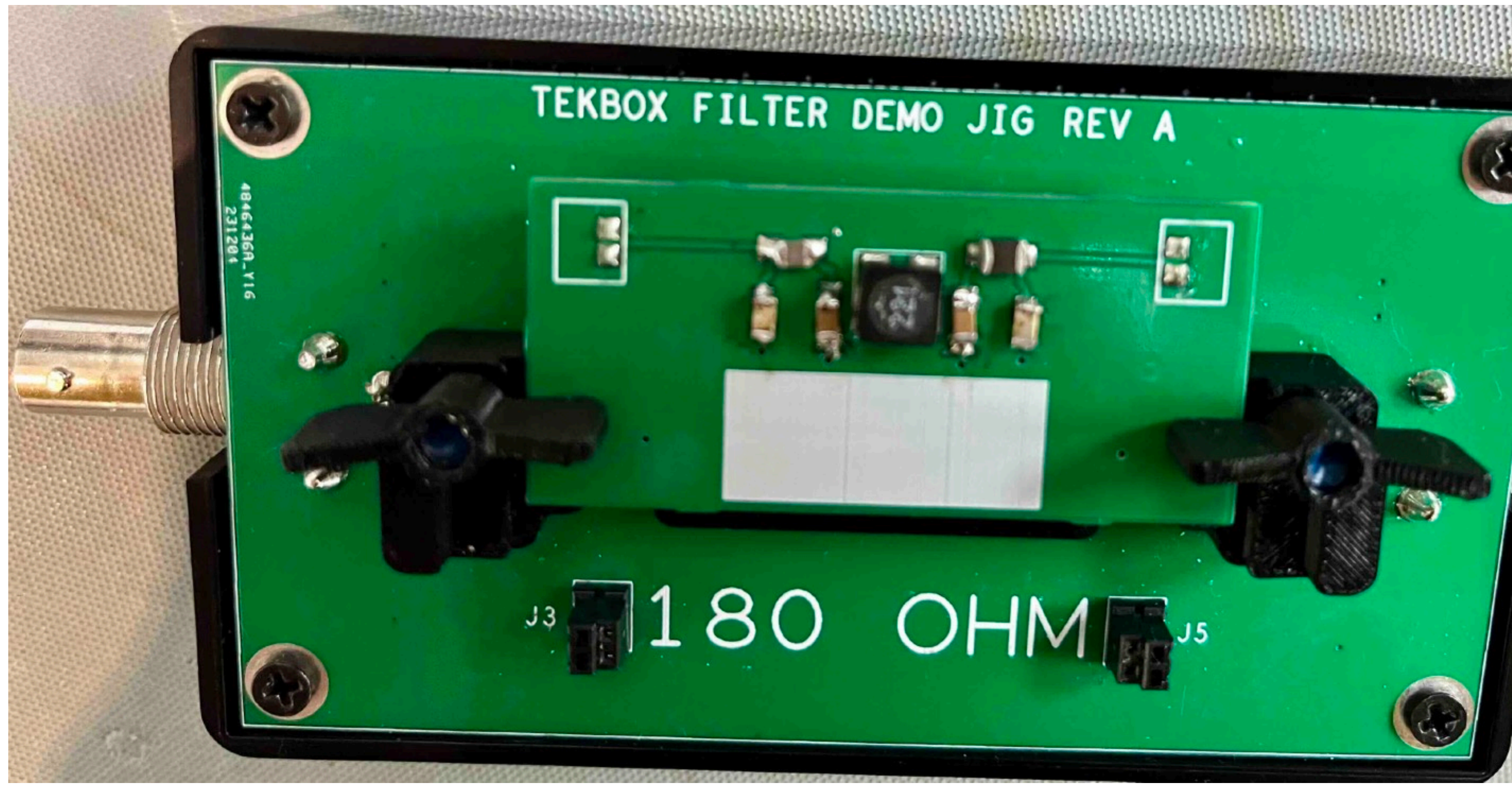


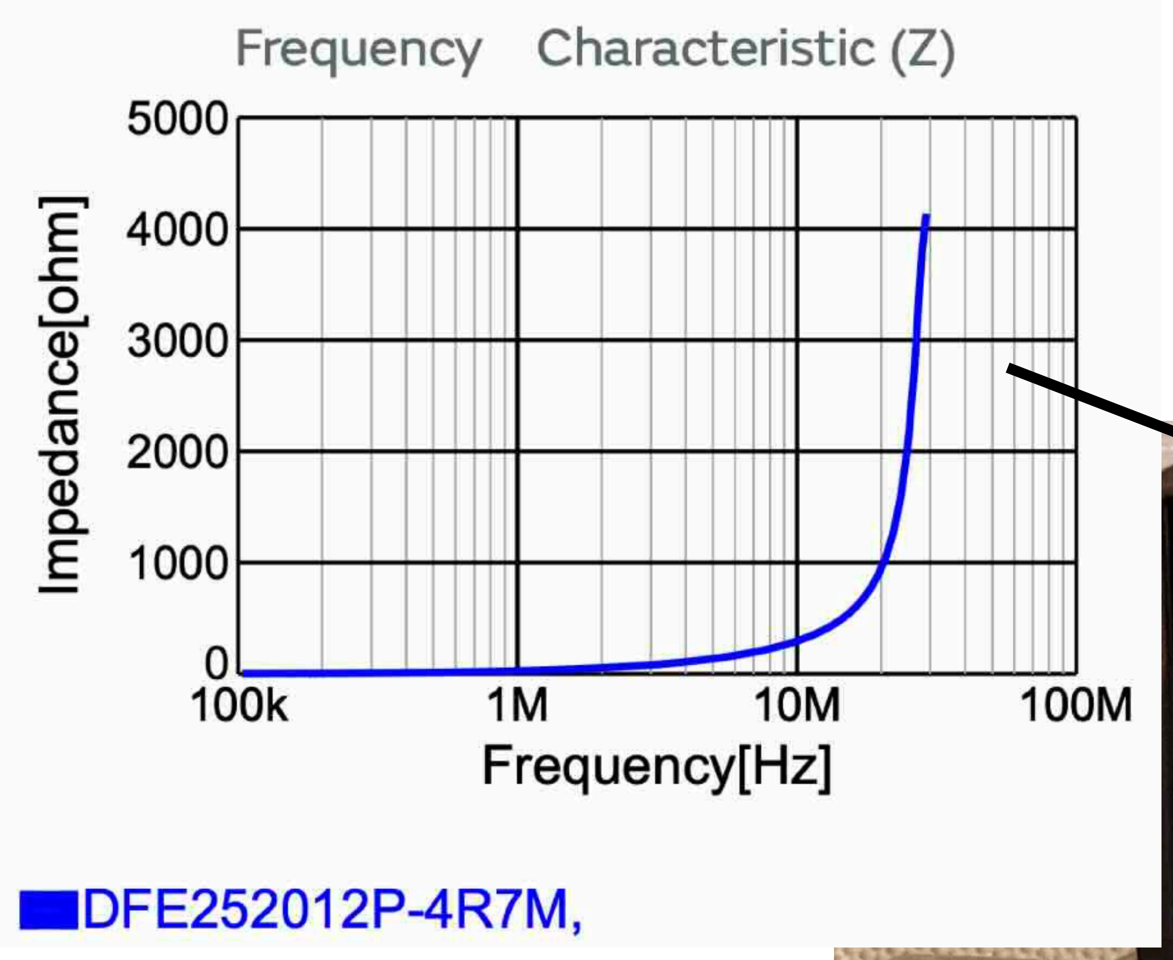


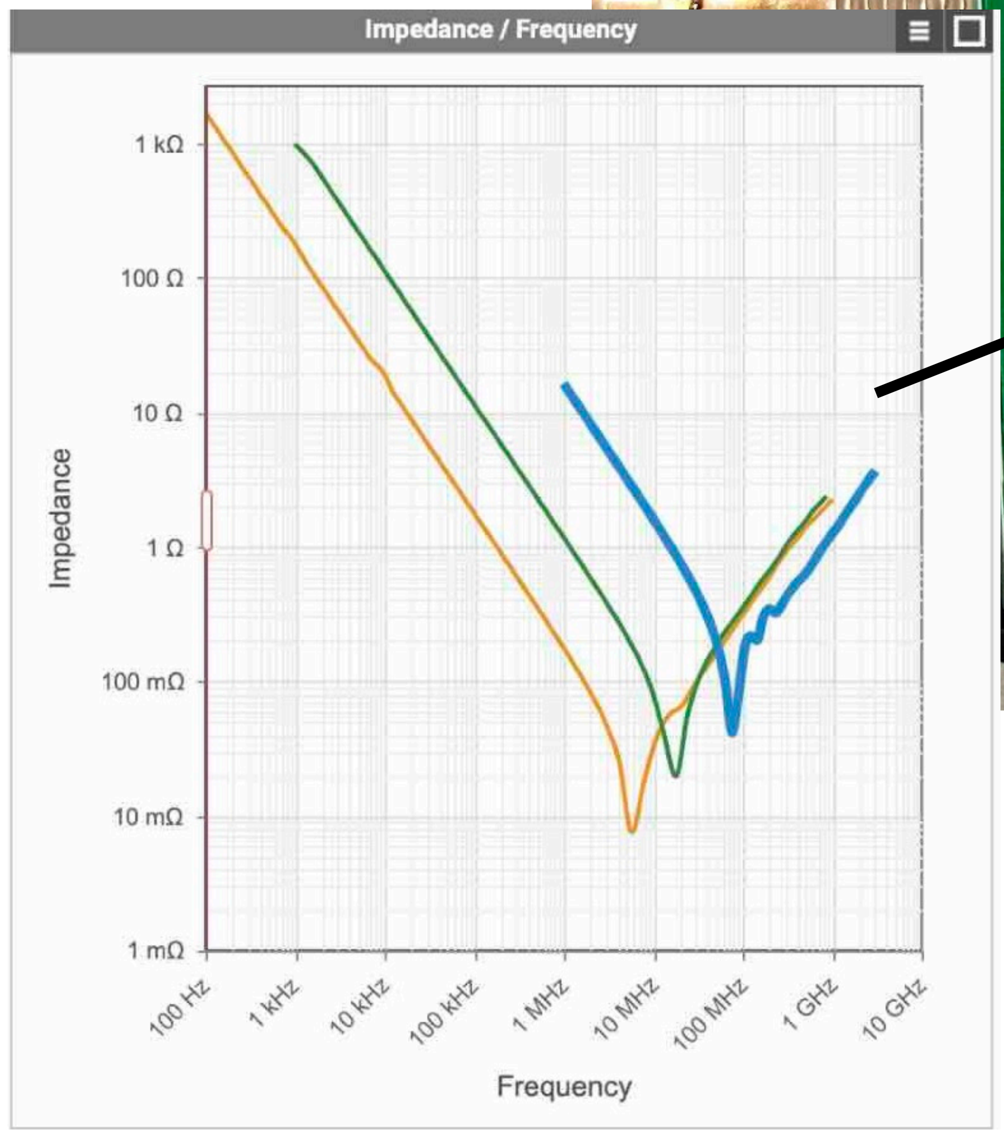


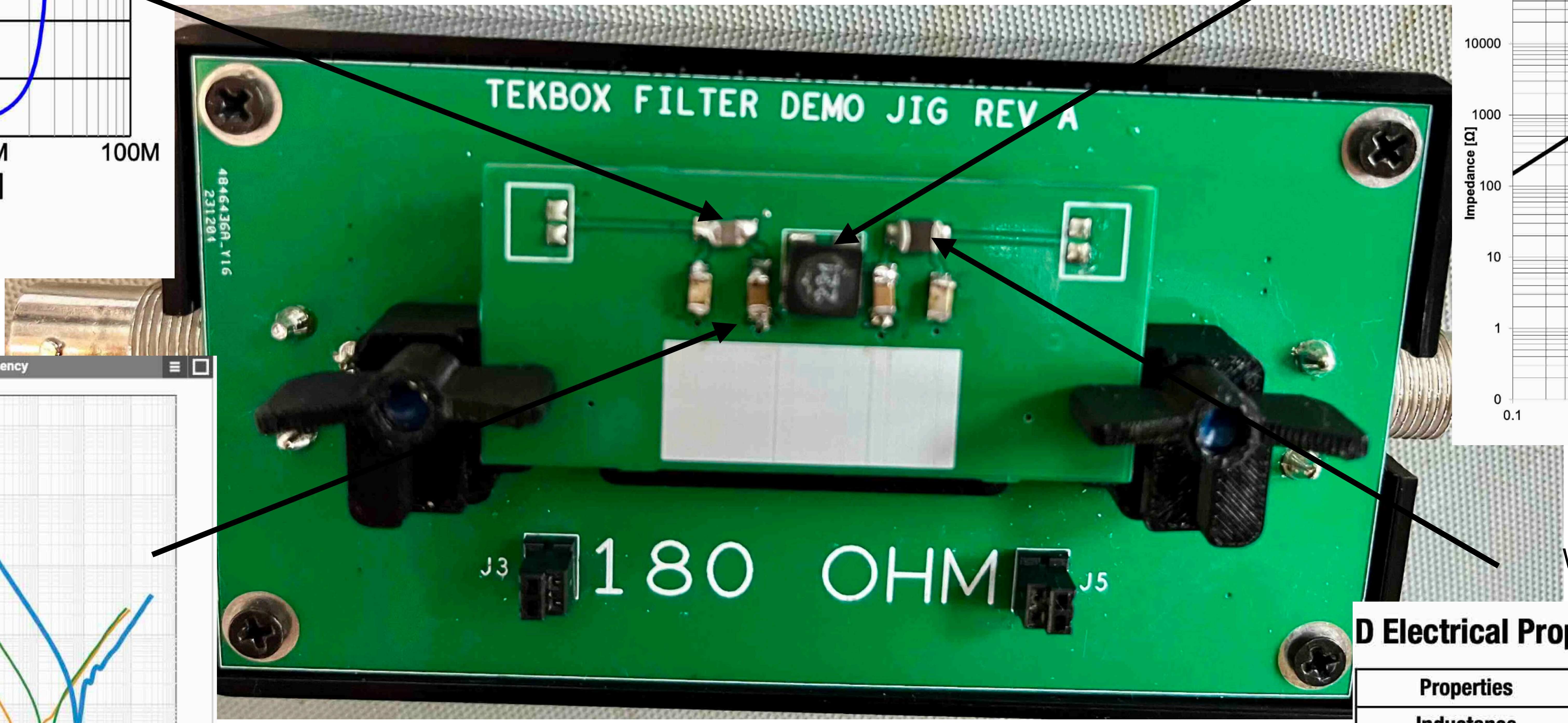


Component Impedance Imperfection

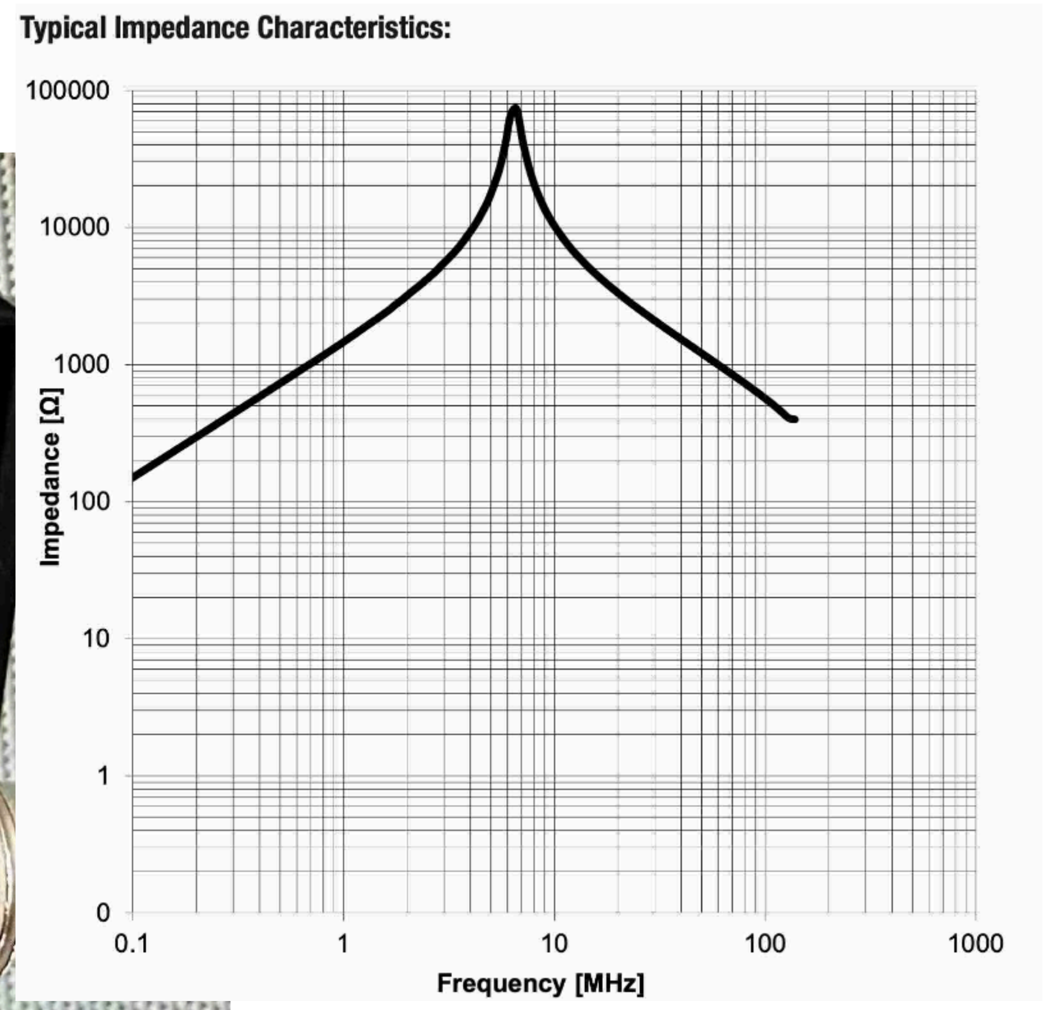
Murata, shielded metal alloy 4.7µH







220 µH Shielded Drum Core,

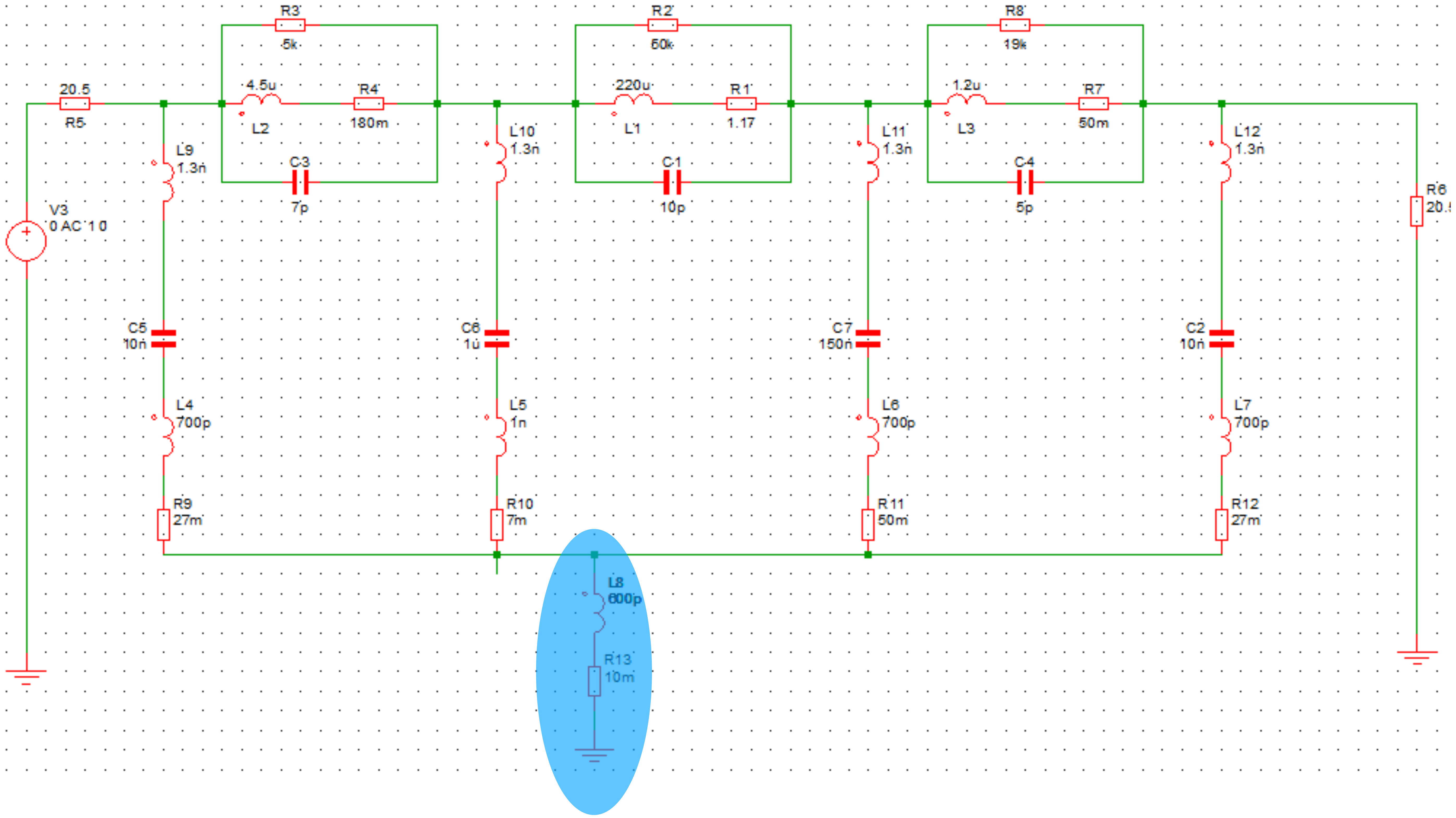


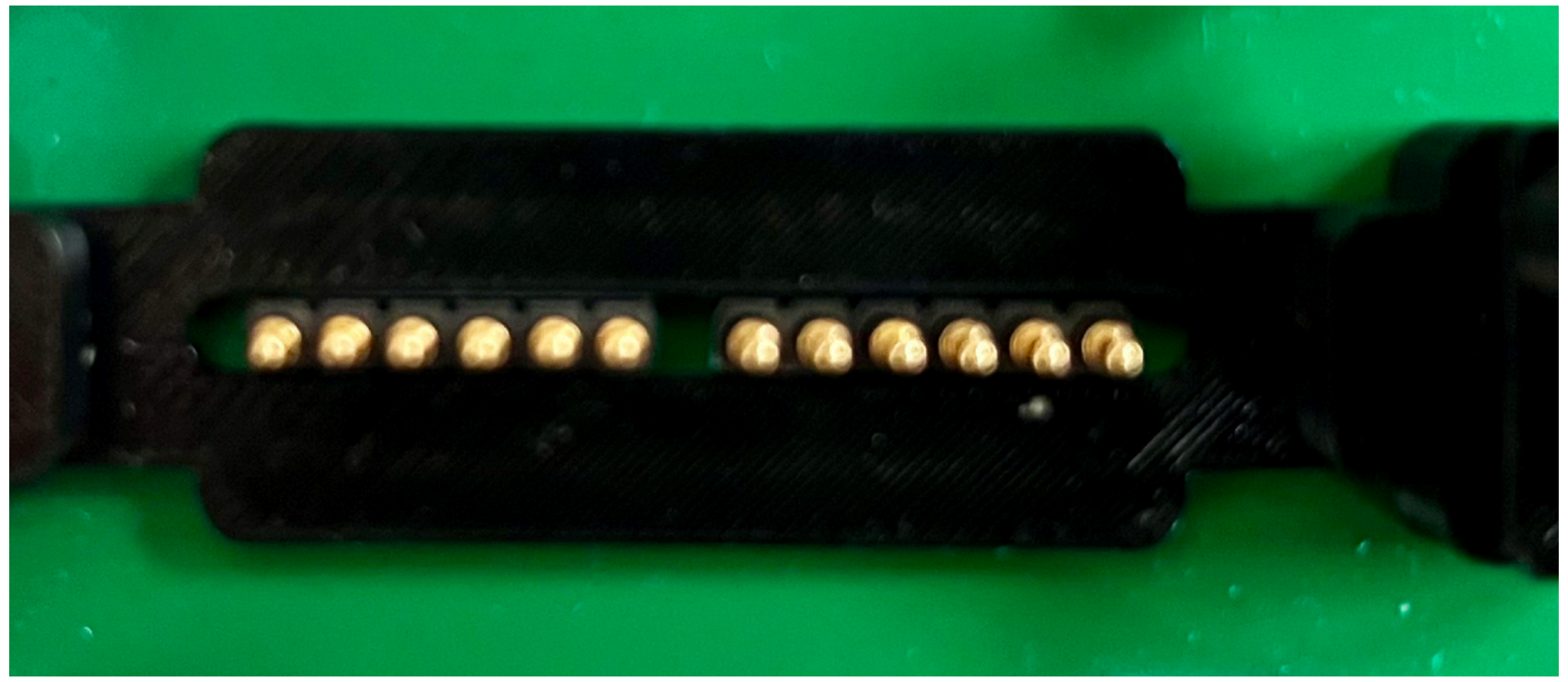
Würth, 1µH, shielded

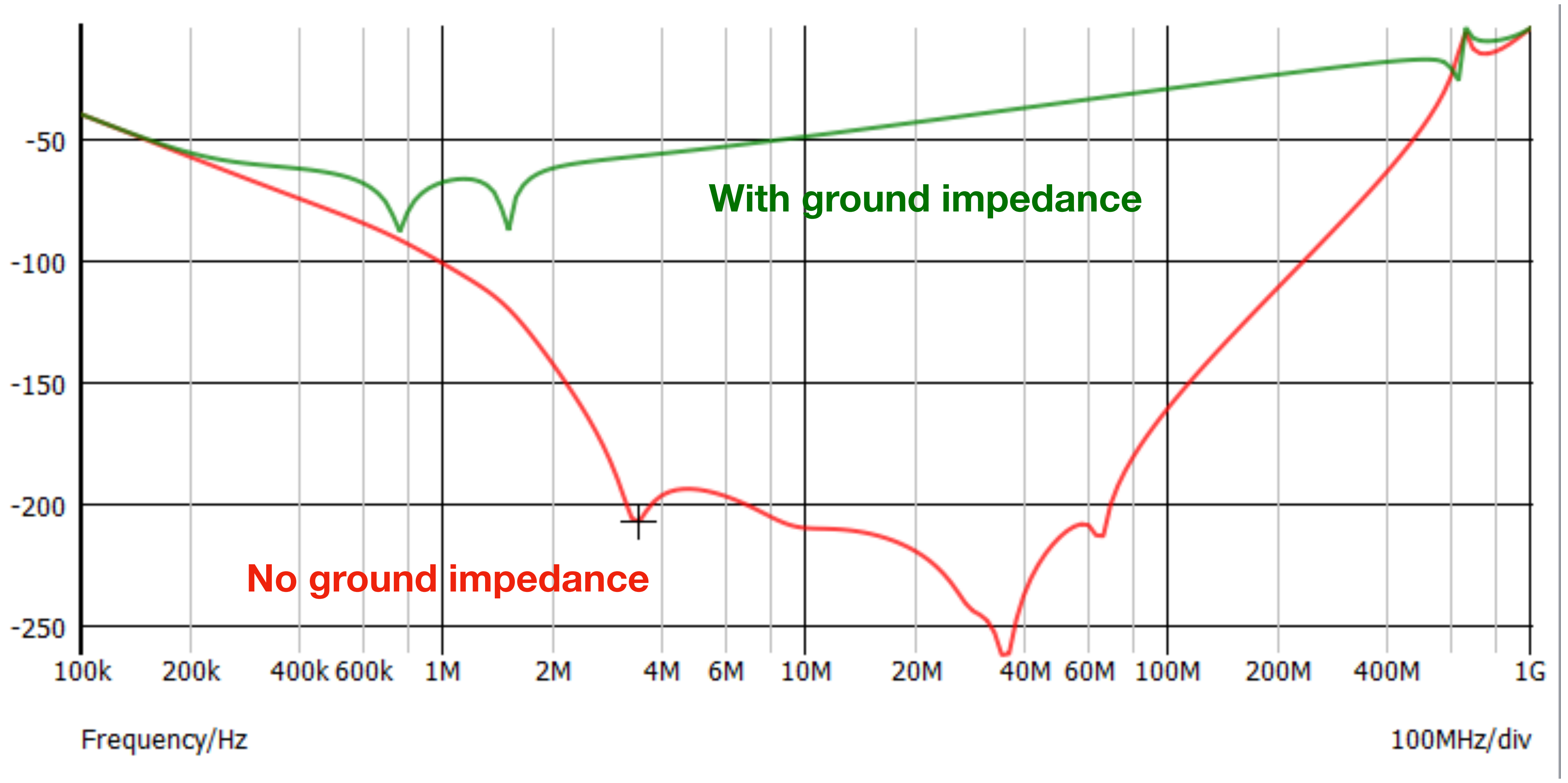
D Electrical Properties:

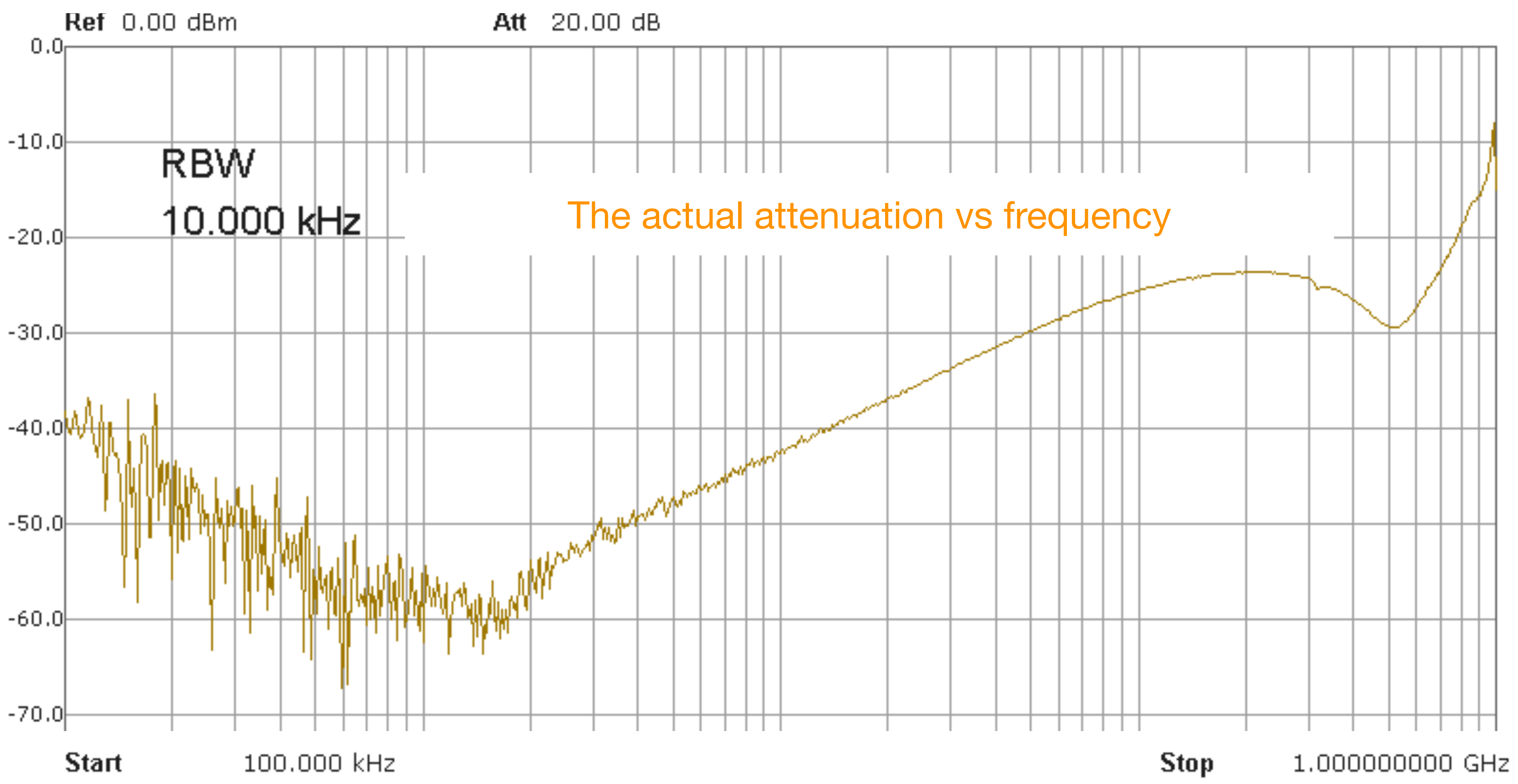
Properties	Test conditions		Value	Unit	Tol.
Inductance	1 MHz/ 5 mA	L	1.0	µH	±20%
Rated current	ΔT = 20 K	I_R	1600	mA	typ.
Rated current	ΔT = 40 K	I_R	2300	mA	typ.
Saturation current	|ΔL/L| = 30%	I_{sat}	2500	mA	typ.
DC Resistance	@ 20°C	R_{DC}	50	mΩ	±25%
Self resonant frequency		f_{res}	75	MHz	min.
Q-factor	1 MHz/ 5 mA	Q	18		min.

Respecting the Ground Impedance

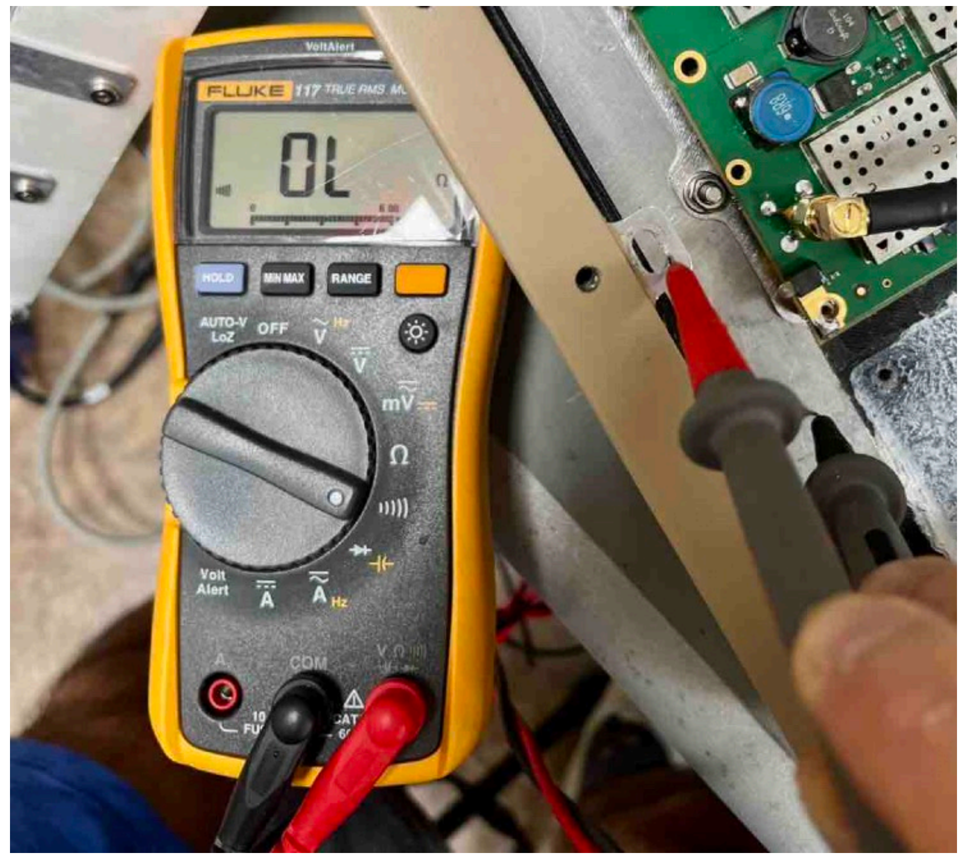




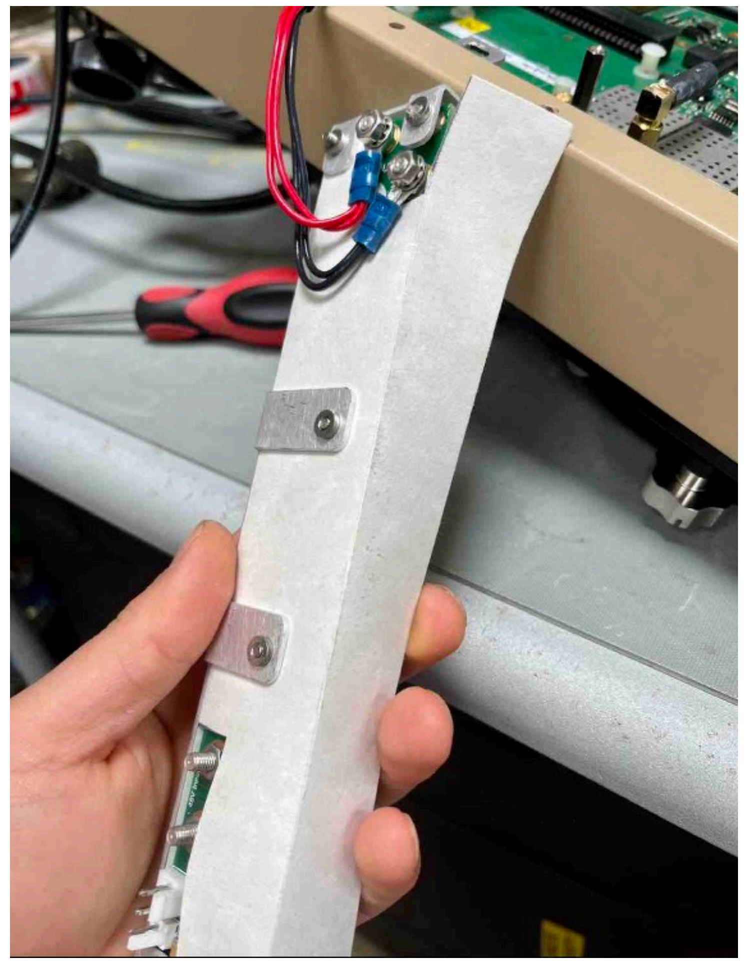




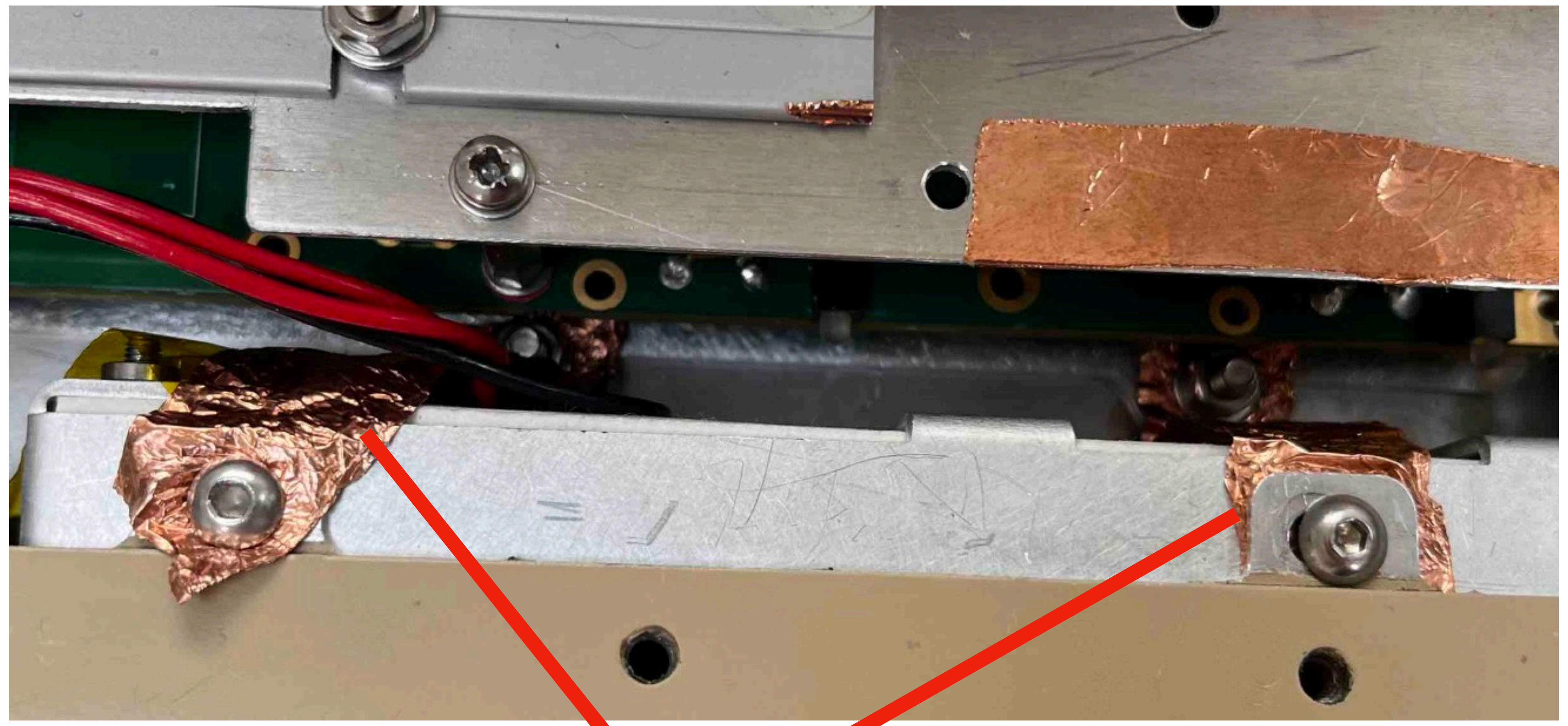
A Case Study



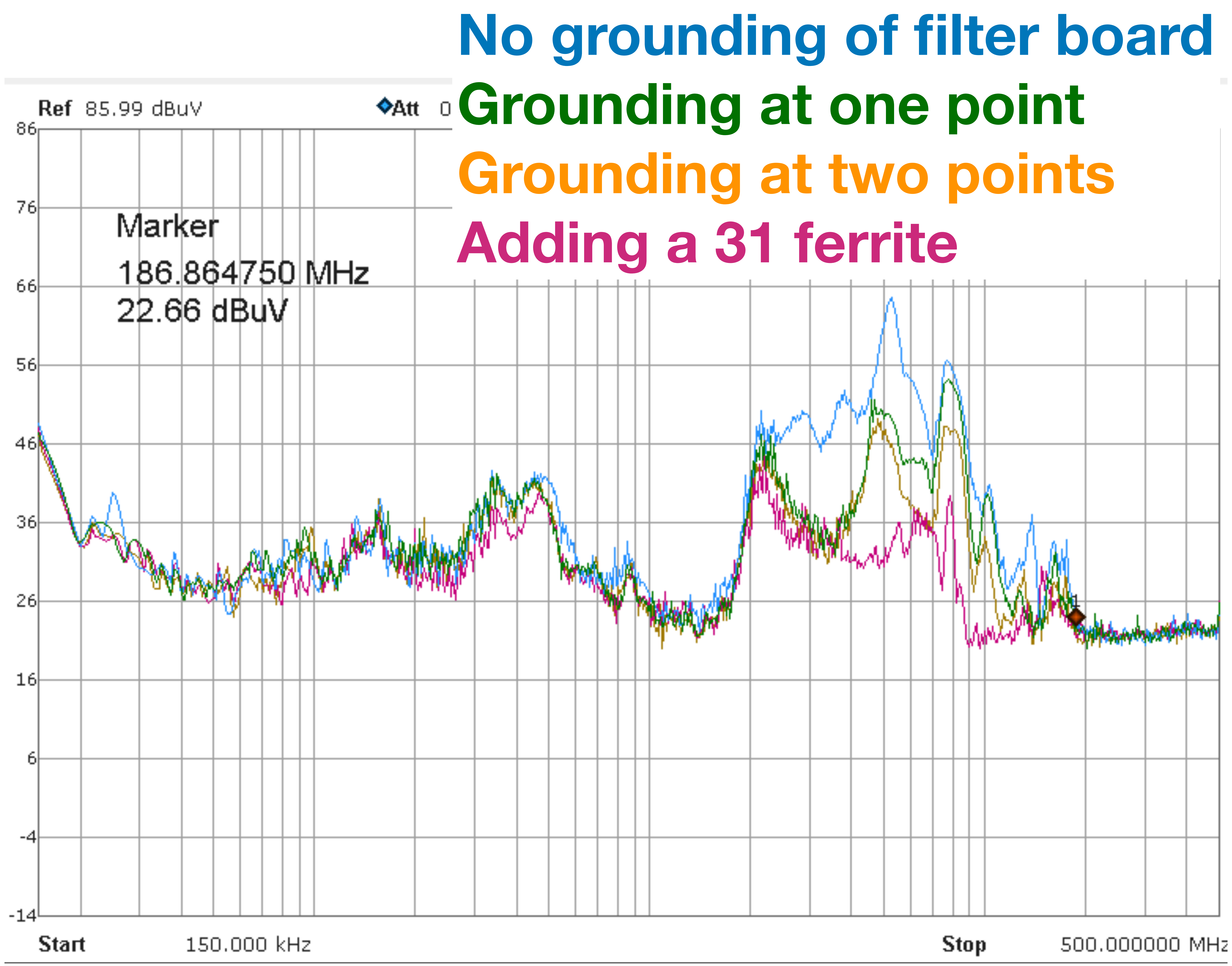
The filter case was not “Grounded” initially.



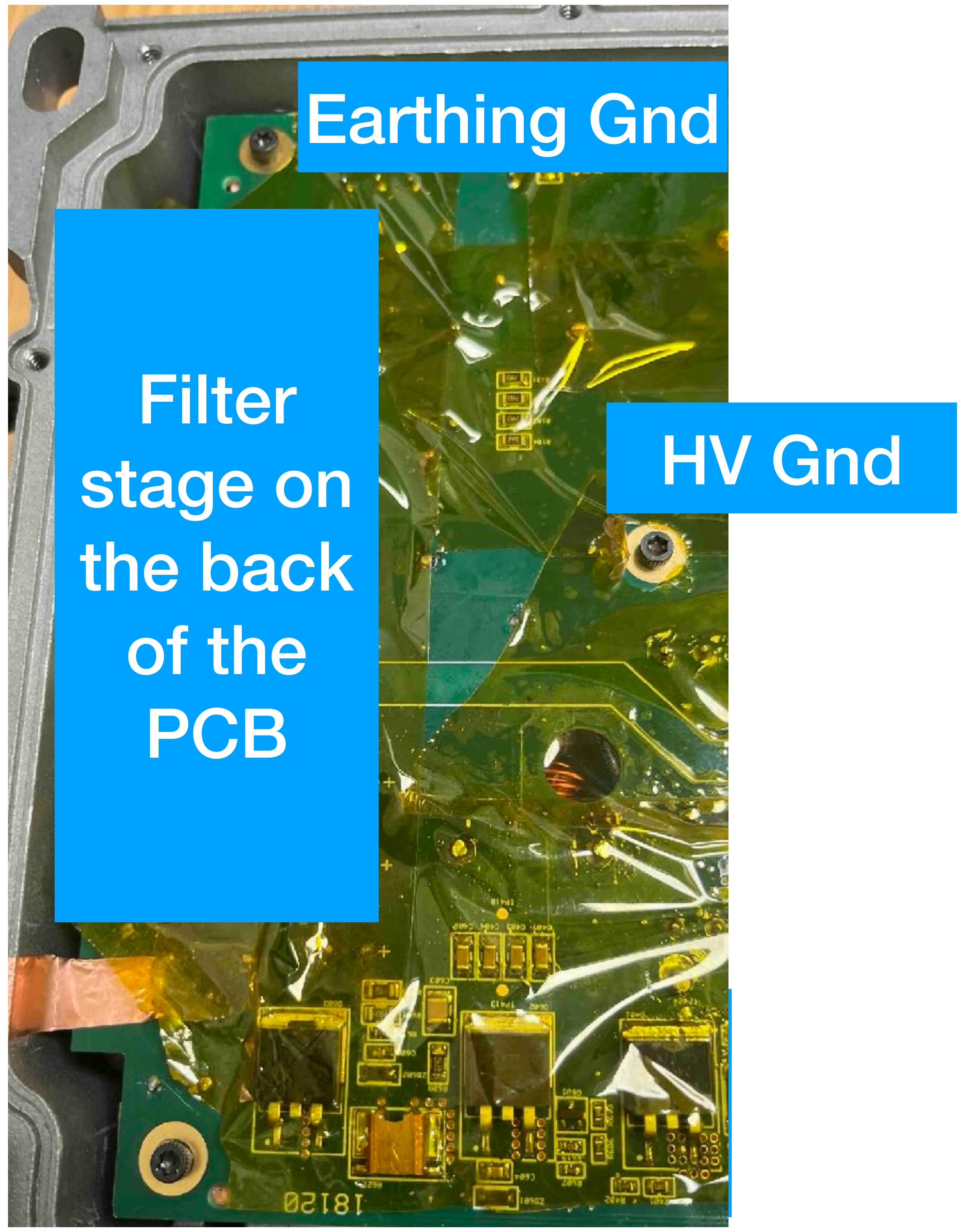
Not a fully enclosed case, “grounding” is tricky.



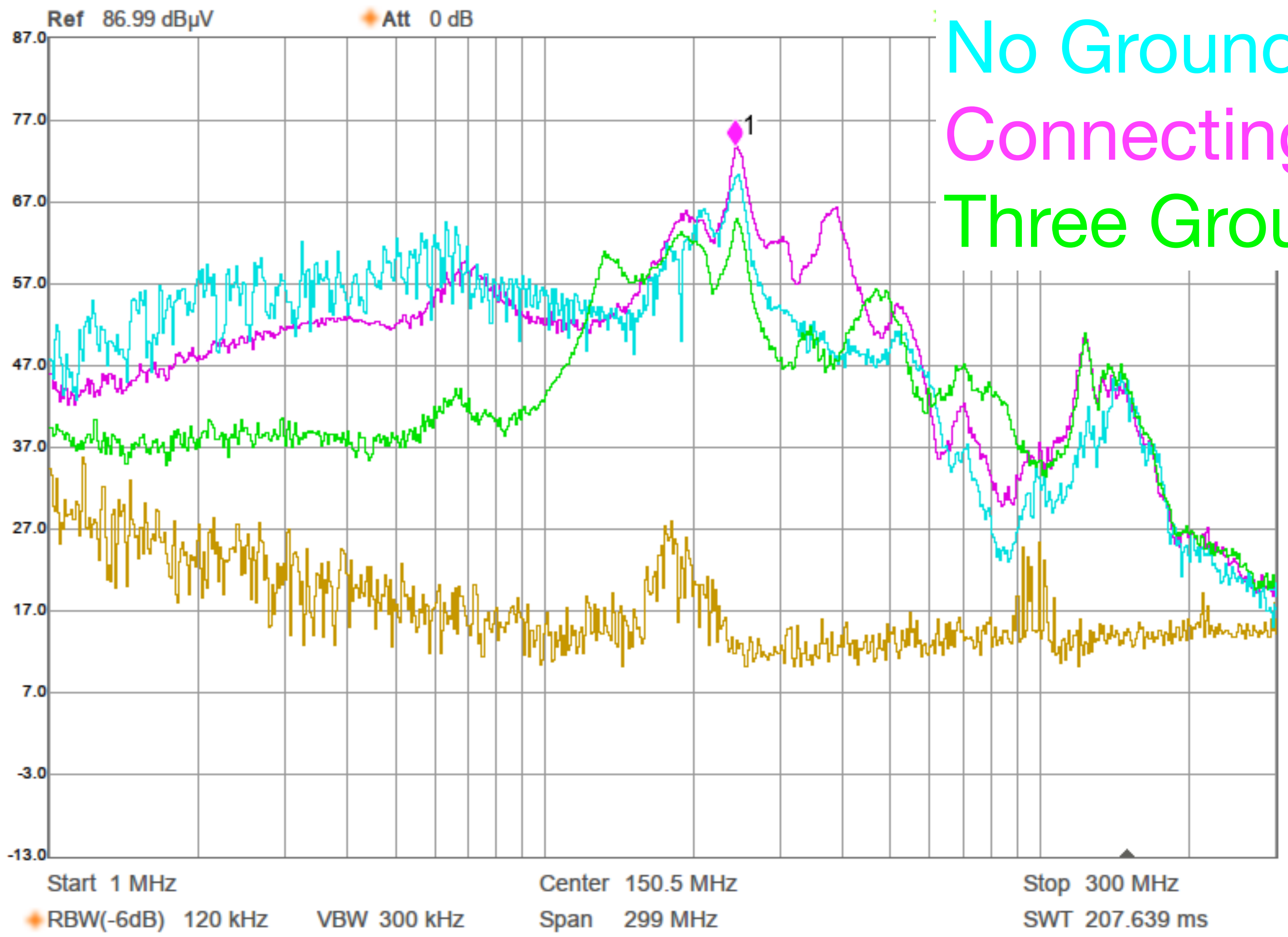
Short connection to the “ground”, this may be replaced by a wire connection, but the wire needs to be short and wide.

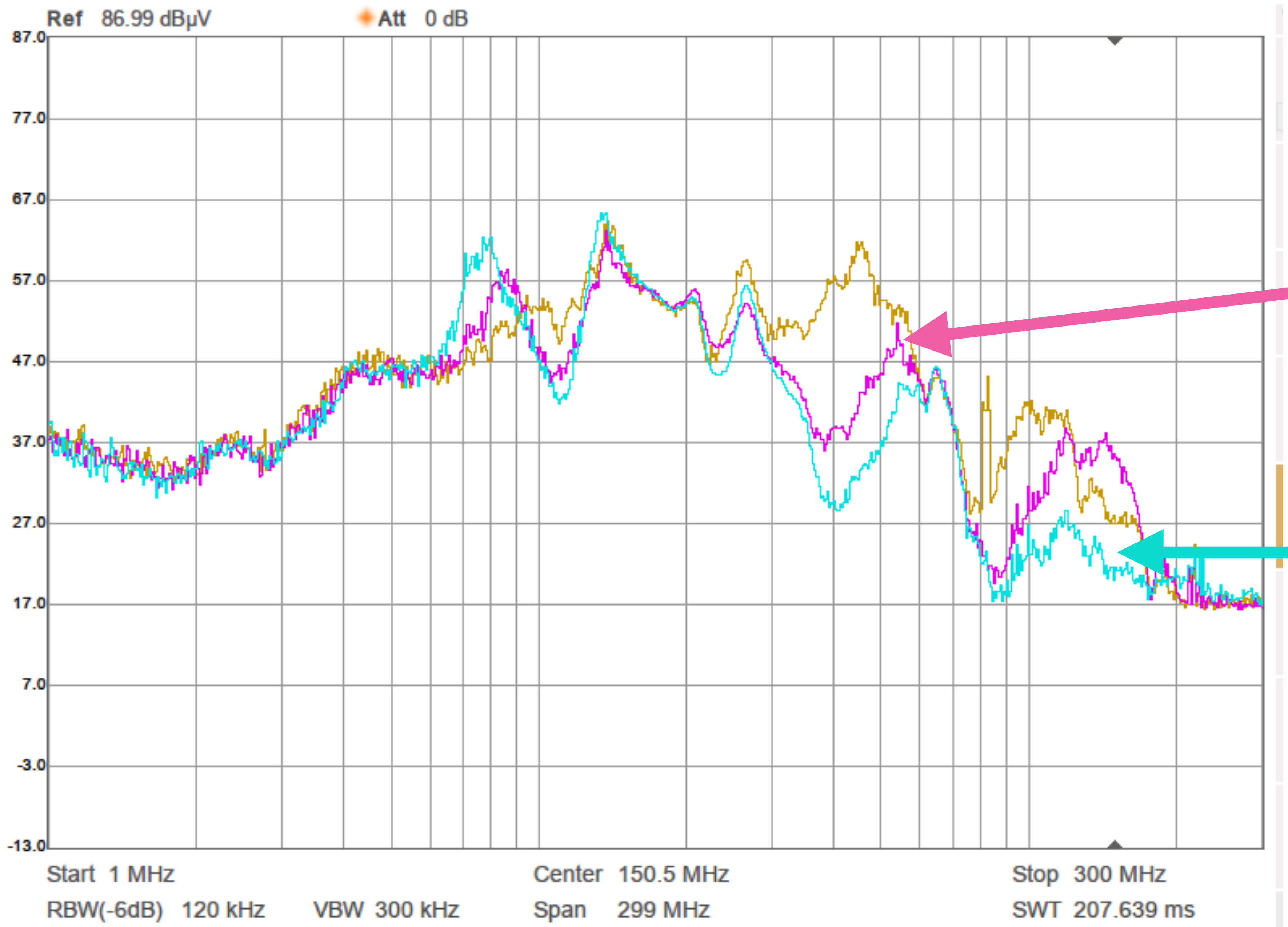


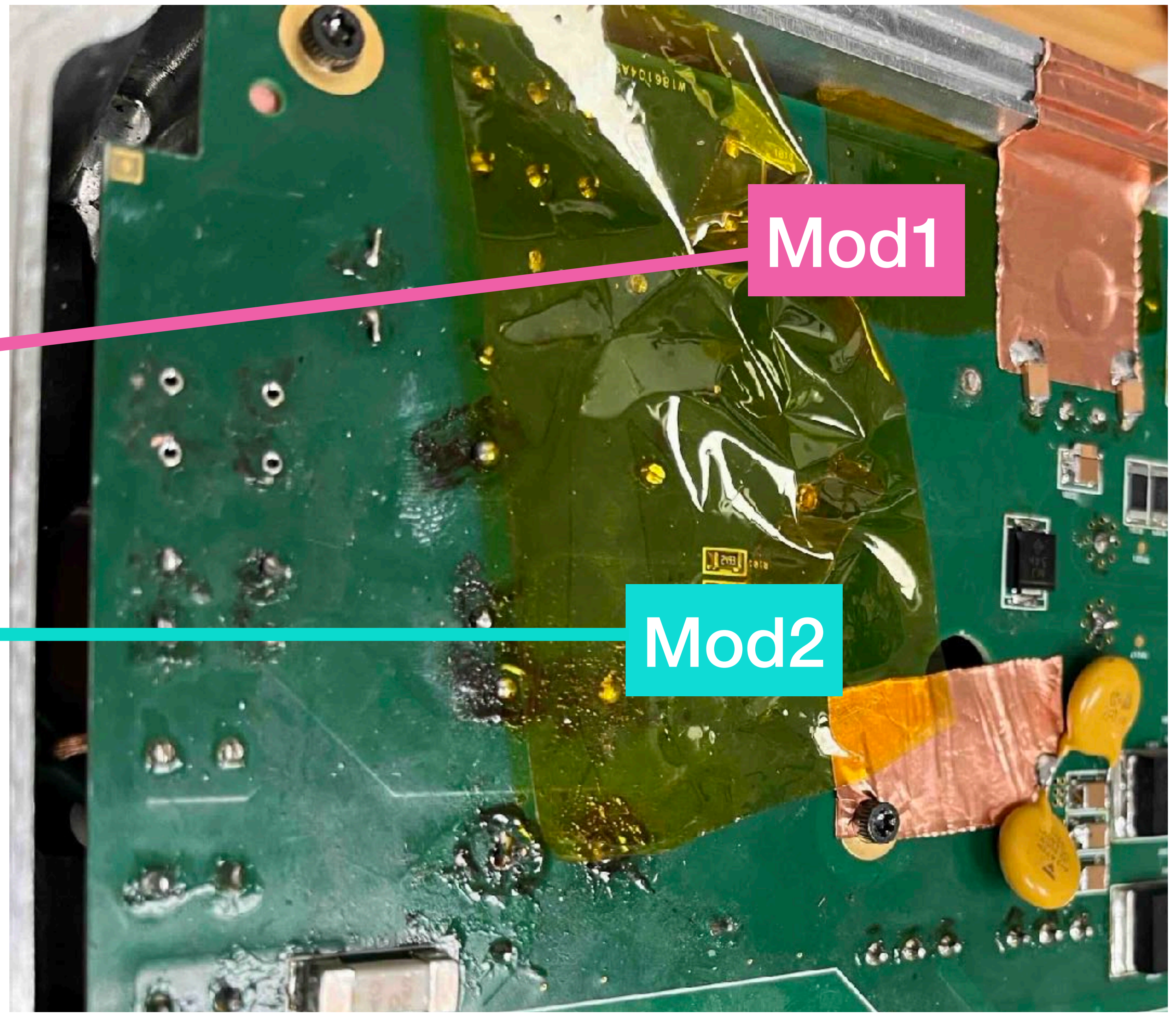
Grounding Strategy



Ambient
No Ground connection to chassis
Connecting earth and HV grounds to chassis
Three Grounds all connected to chassis







References & Recommended Materials

- Step-by-step guidance on how to solve conducted emissions of a power supply https://www.youtube.com/watch?v=Lf51sx6sC0I&t=1s

- Step-by-step guidance on how to solve radiated emissions of a power supply https://www.youtube.com/watch?v=fkNa-FejWsQ&t=28s

- Links to download pdfs https://mach1design.co.uk/resources

- https://www.emcstandards.co.uk/free-guide-the-engineers-practical-guide-to-emi