Accidental/Unintentional Antennas

By Dr. Min Zhang

MACHone

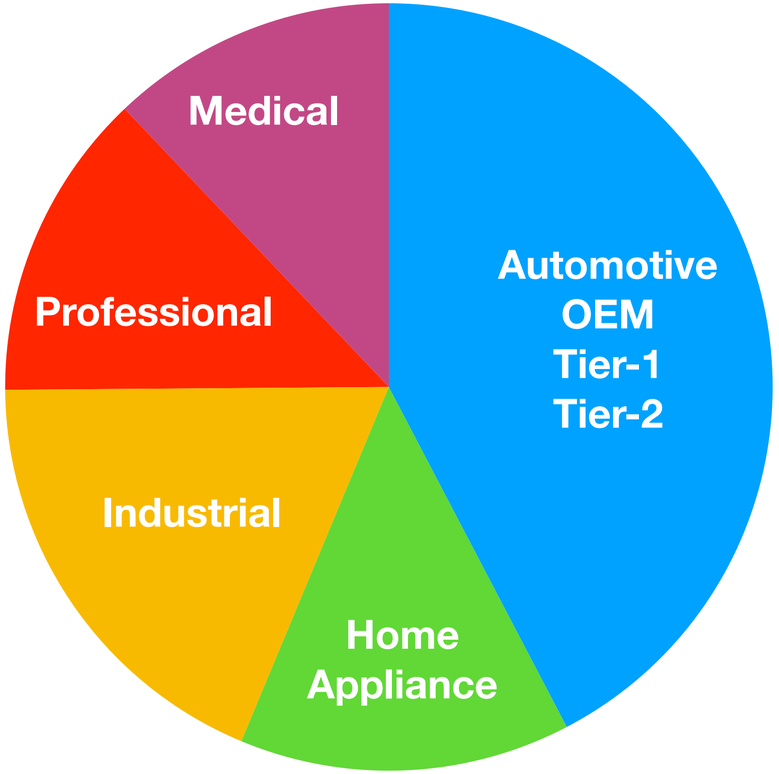
Expertise Propels Excellence

Seminar

About the presenter

Dr. Min Zhang

- EMC & SIPI expertise
- Specialised in automotive, home appliance, industrial, professional and medical sectors
- Advanced insight on product research and development
- Background in electronics design, motor control for high tech volume production business
- In-depth knowledge and experience in electromagnetic design



Outlines

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- Antenna 101 - half and quarter wavelength antennas
- Commonly seen unintentional antennas
- Techniques of preventing unintentional antennas
- Conclusions

Antennas 101- A half-wavelength dipole

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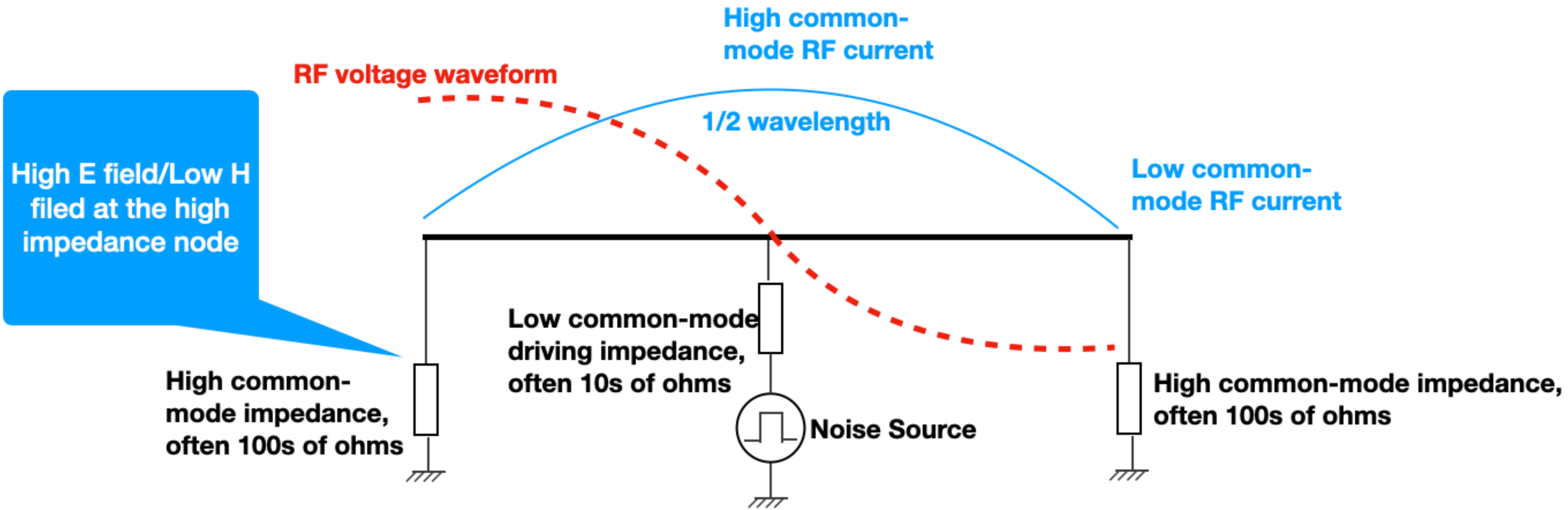
The RF current in the wire peaks at the frequency at which the wire acts as one half-wavelength dipole.



Antennas 101- A half-wavelength dipole

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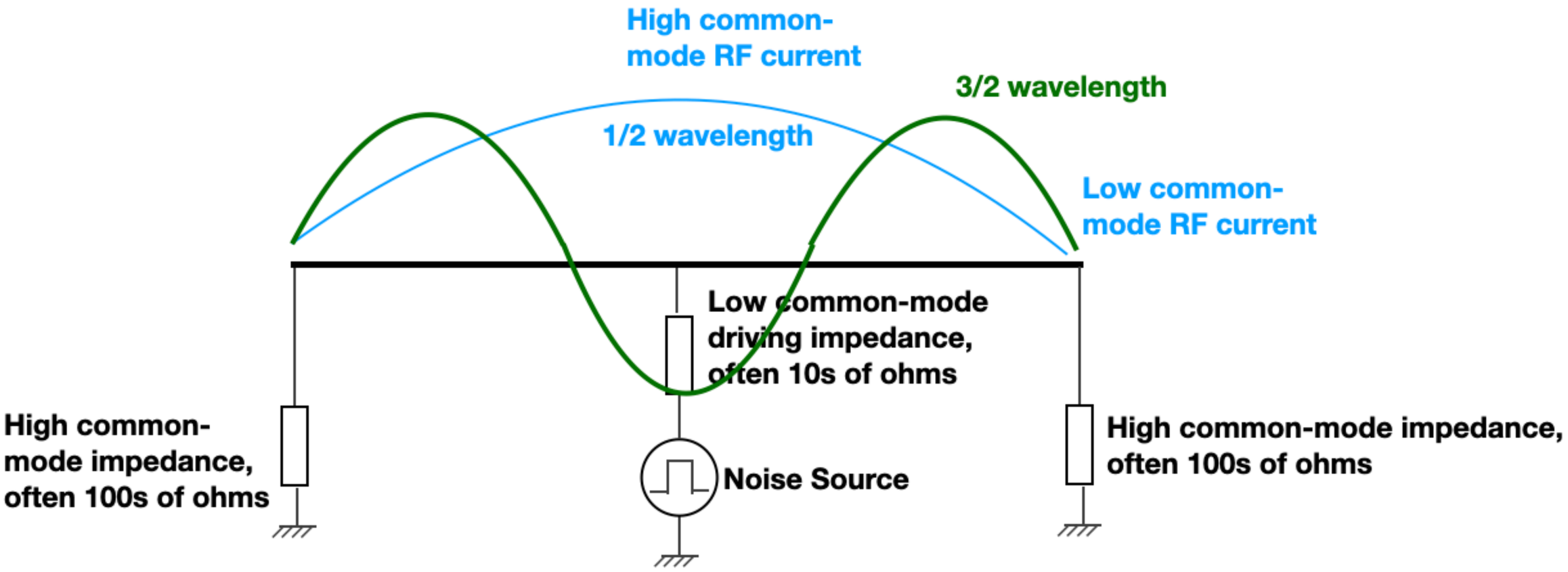

Antennas 101- A half-wavelength dipole

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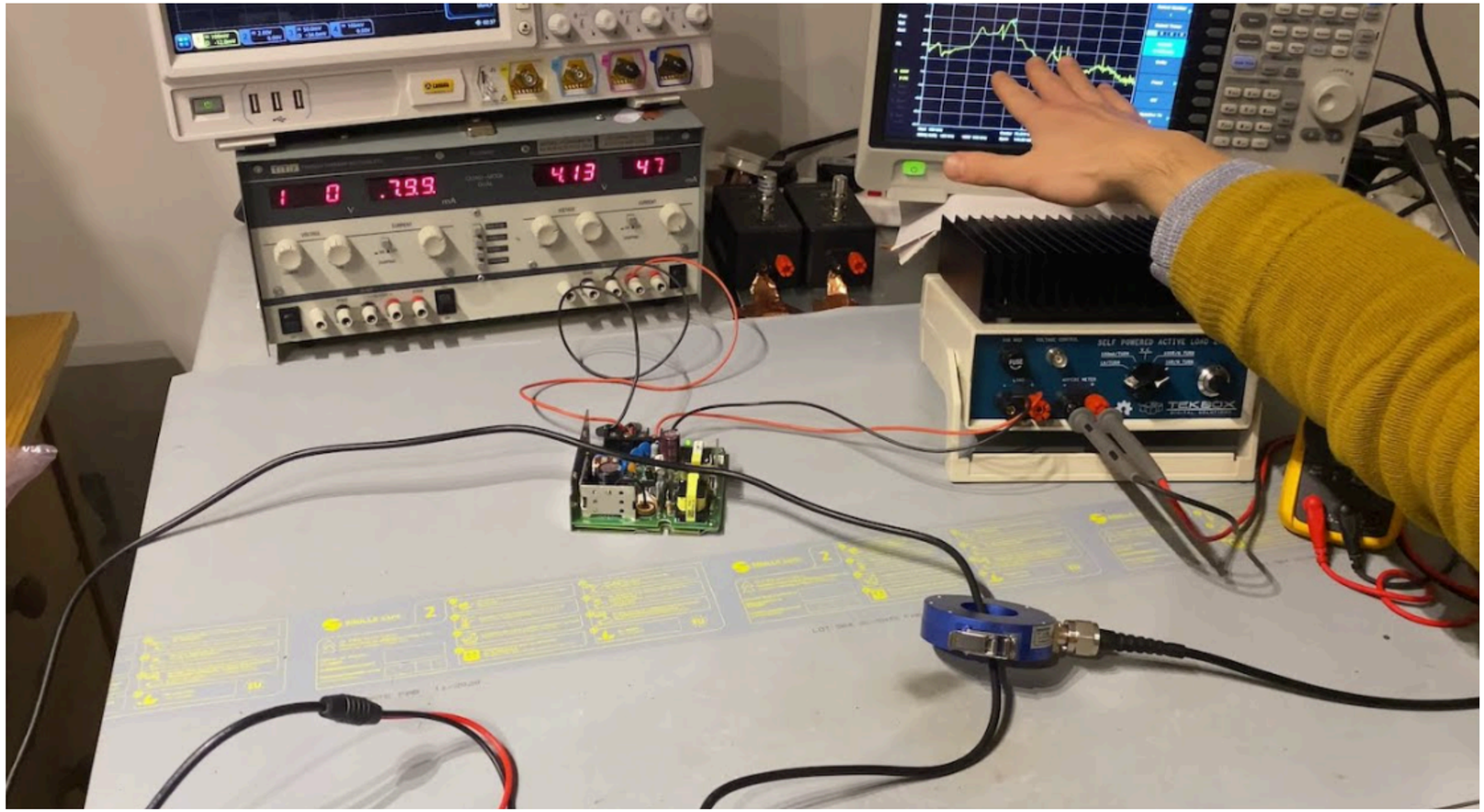
A video demonstration, source: https://youtu.be/gL2XCWO3SLU



Antennas 101- A quarter-wavelength dipole

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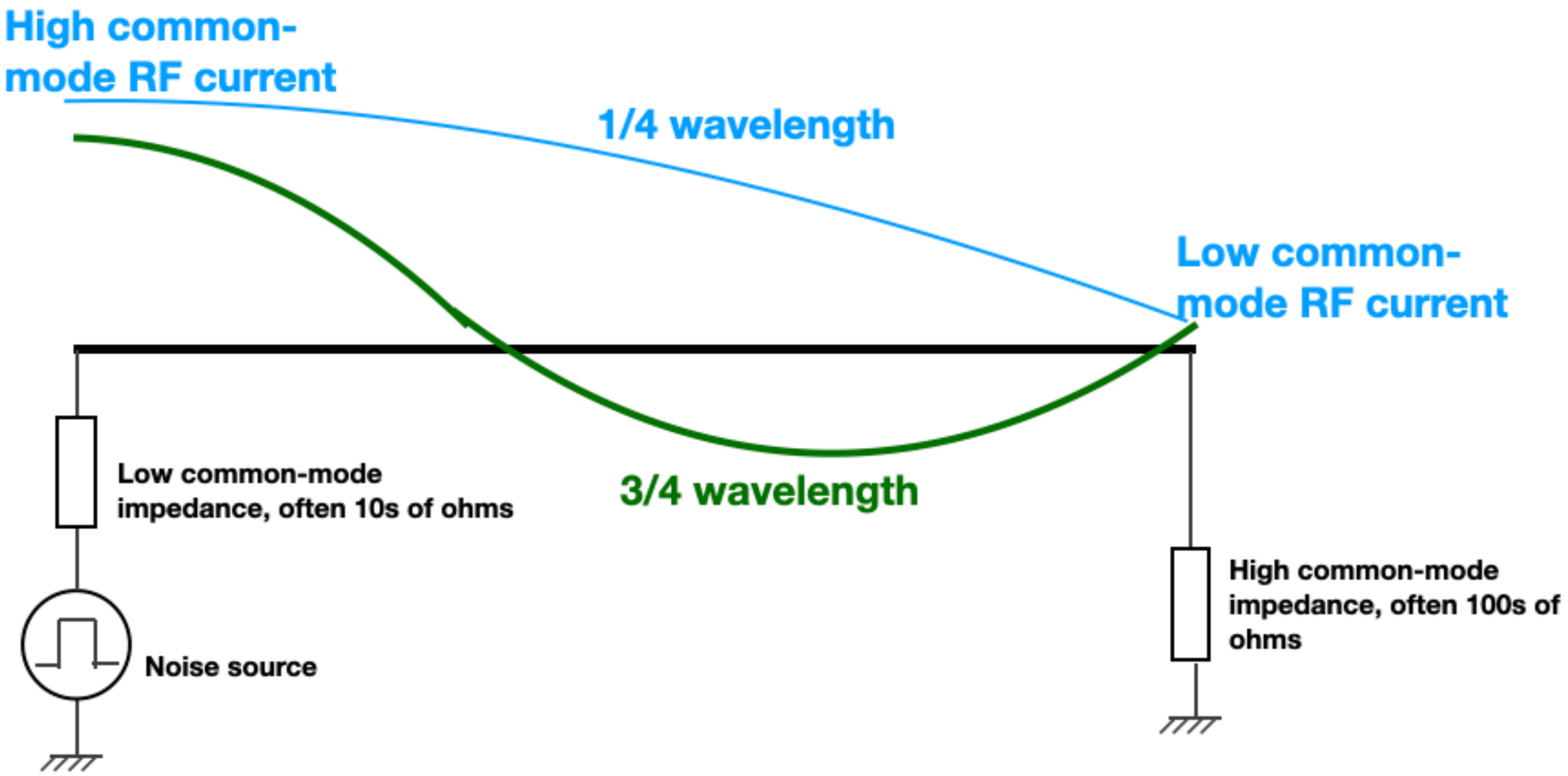
A quarter-wavelength wire translates a high impedance at one end to a low impedance at the other.



Antennas 101- A quarter-wavelength dipole

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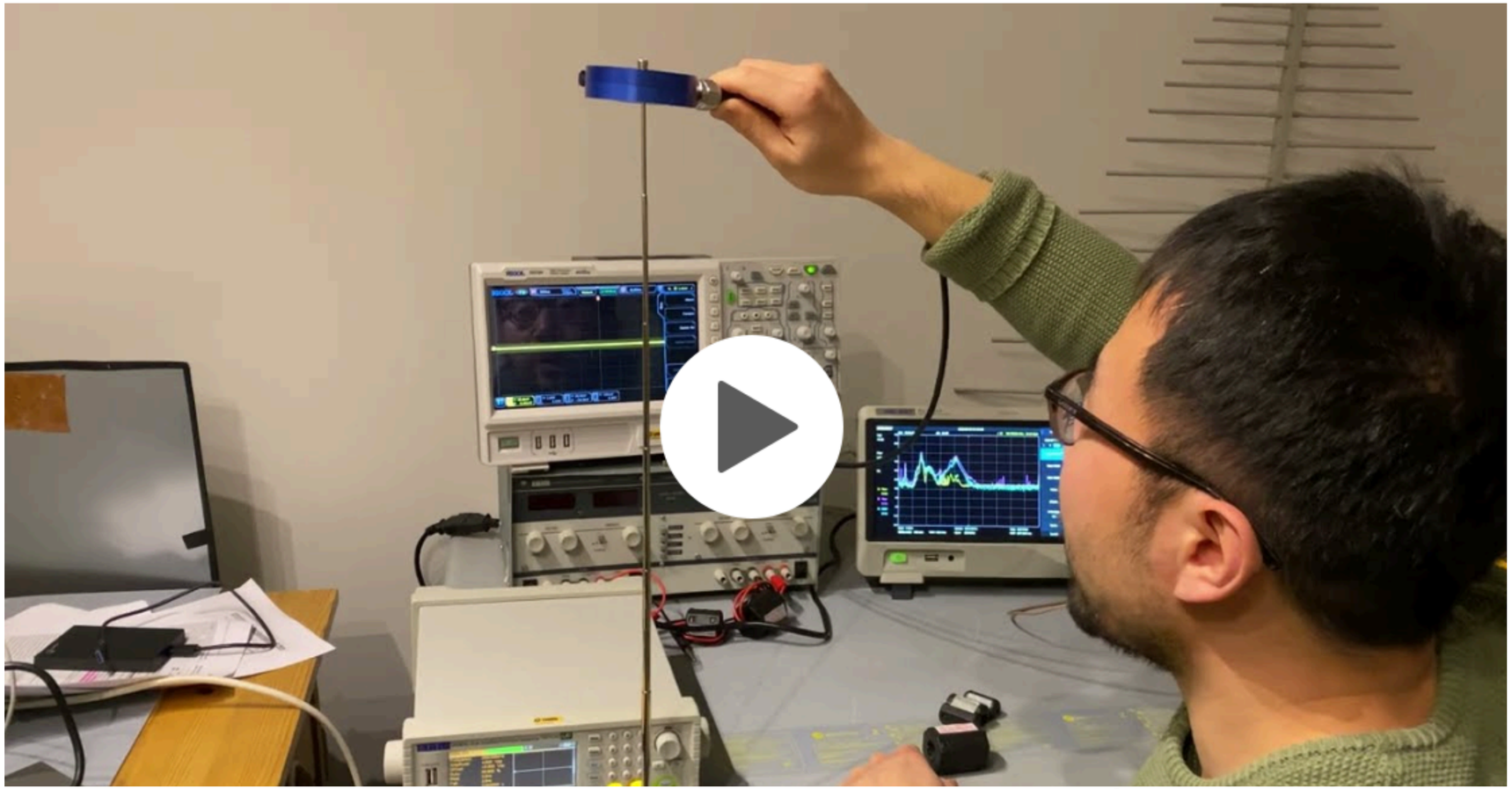
A quarter-wavelength wire, with its end in free space, present a low impedance at the equipment end, which allows RF currents to flow into the wire and radiate.



source: https://youtu.be/HMvpml48v4g

Commonly seen unintentional antennas - Messy wires

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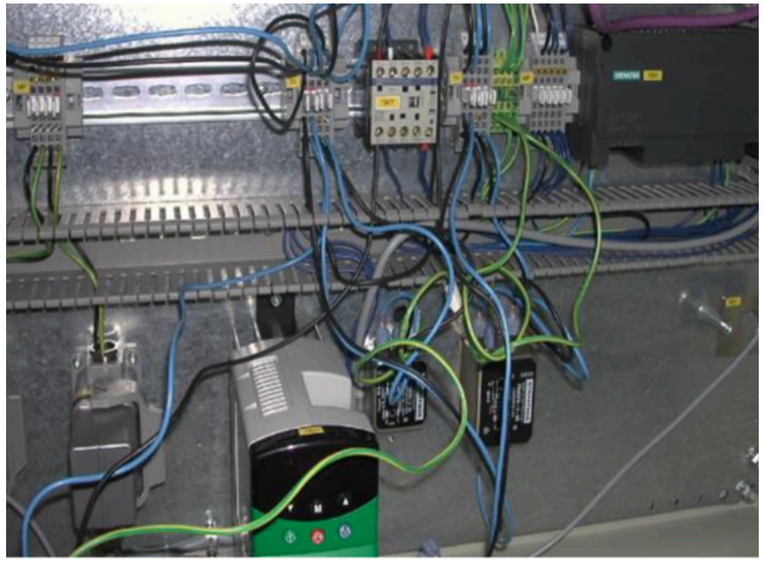
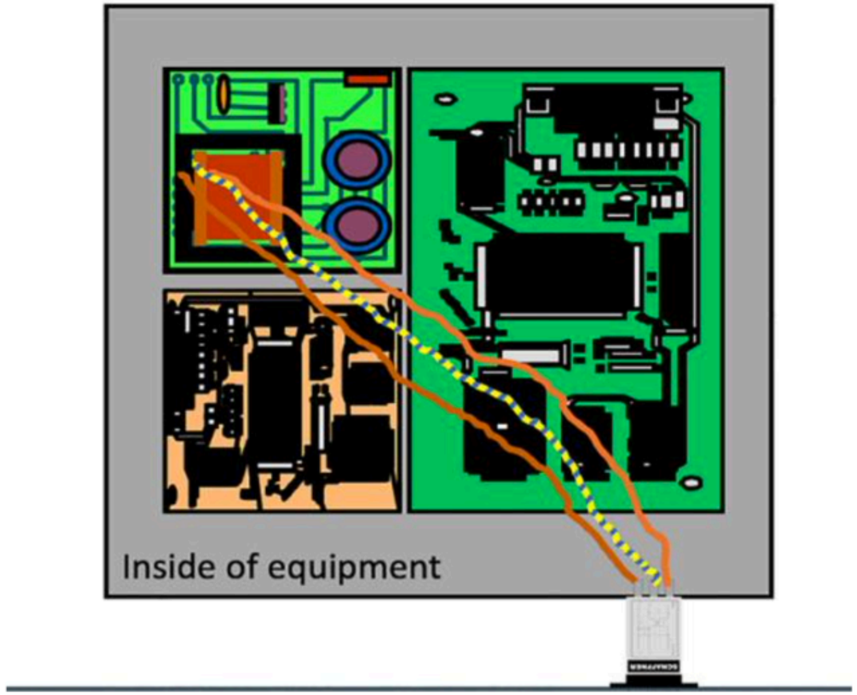
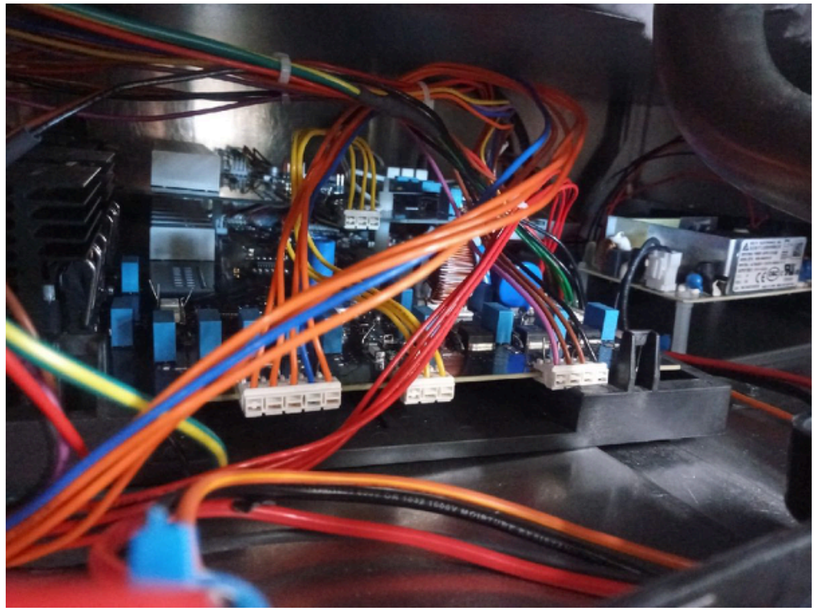
Messy wires ‘flying’ over the PCBs. Most of the time, the PCBs generate broadband noise, but the local field from the PCB is probably not physically large enough to radiate efficiently at a frequency range between 30 MHz and 300 MHz, but with RF current induced in the wire, the wire itself is long enough to be an efficient radiator.







Commonly seen unintentional antennas - bad shielding/‘pigtailed’ termination

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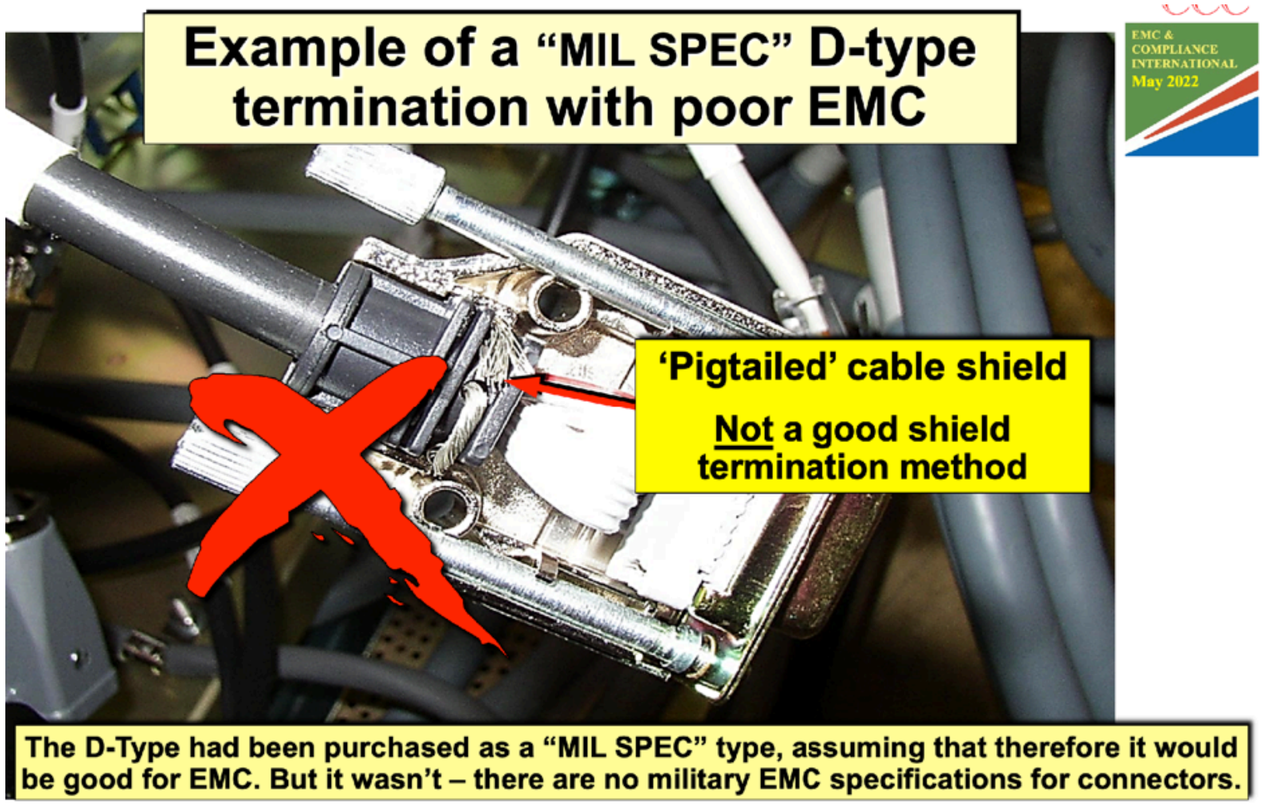
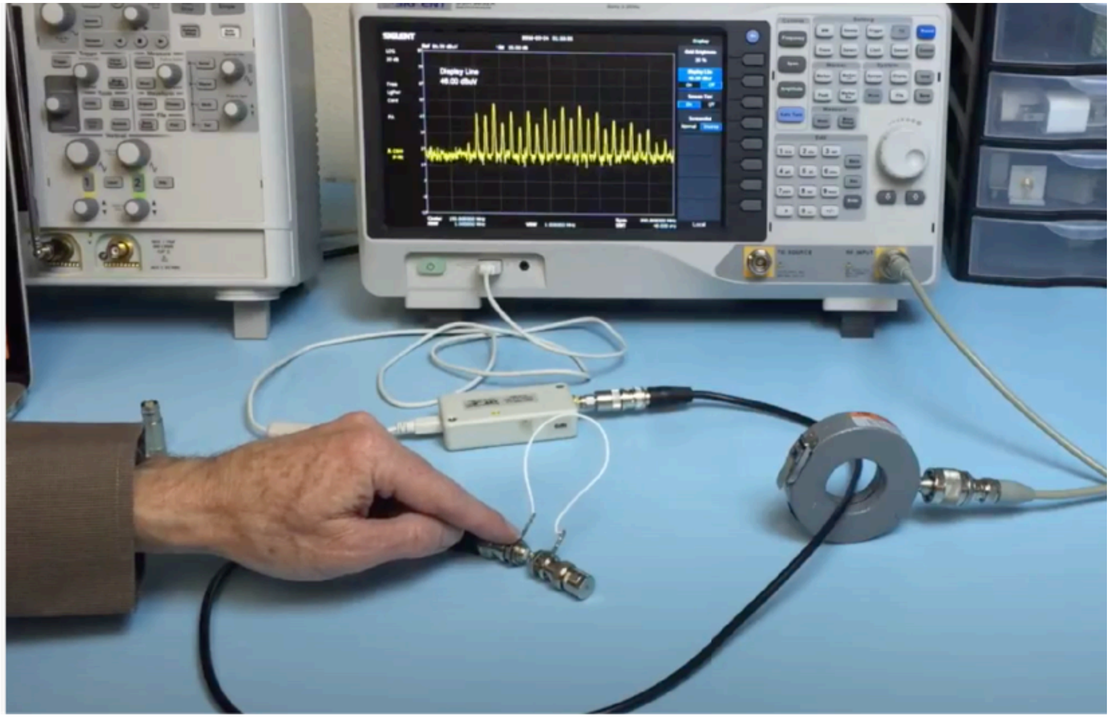
“My shield should work, right?”
“What? My shield causes radiation?”



Source: EMC+CI 2022 Training Workshop, Keith Armstrong, Cherry Clough Consultants



Source: Ken Wyatt, pigtail demo https://youtu.be/XoLBOuLH8t0

Commonly seen unintentional antennas - Green/yellow grounding wires

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Grounding wires organised in this way basically form a very efficient multi-turn loop antennas.

- **Green/yellow wires are OK for safety earthing (safety grounding) at power-line frequencies…**
  - **but *can't* provide a 'ground' at radio frequencies (RF) (i.e. can't provide an RF Reference, or RF-bond to one)**

see Module 1: 'The Physics of EMC'

2.3.4 Cherry Clough Consultants confidential training material 17 of 109

Source: Good EMC practices for cabinets, systems and installations, Keith Armstrong, Cherry Clough Consultants

Commonly seen unintentional antennas - resonance structures

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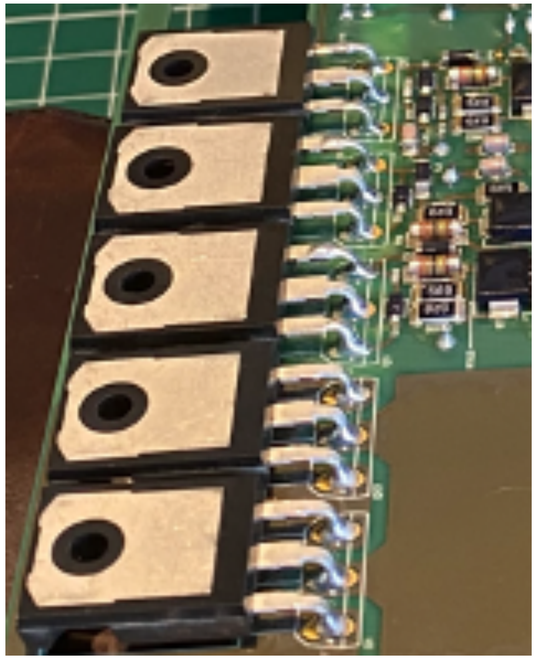

MOSFETs on the edge of the PCB where cut-out areas are designed to allow screws to mount the MOSFETs on heatsink (a) front view (b) back view

This unit failed radiated emission test at 250 & 360MHz. A visual inspection on the MOSFET layout shows that the PCB has a cut-out area the same size as the MOSFET cooling pad, so that the MOSFET can be mounted to a heatsink via the screw connection through the PCB cut-out areas (A mechanical team's dream, but an EMC nightmare).

Another "interesting" feature of this design is that the MOSFETs and the PCB cut-out areas are all located on the edge of the PCB, so they could radiate very efficiently. This structure could easily resonate as we expected.

Commonly seen unintentional antennas - resonance structures

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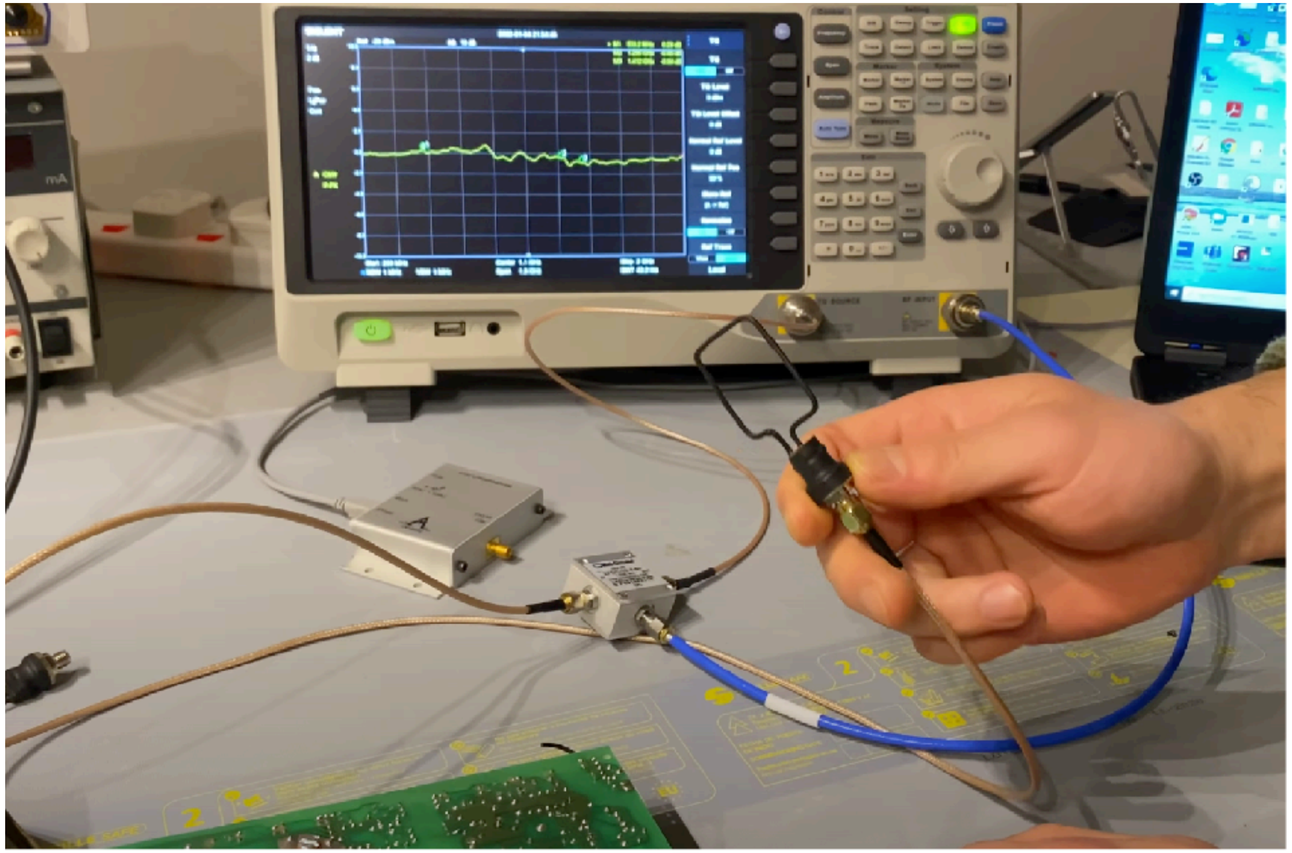
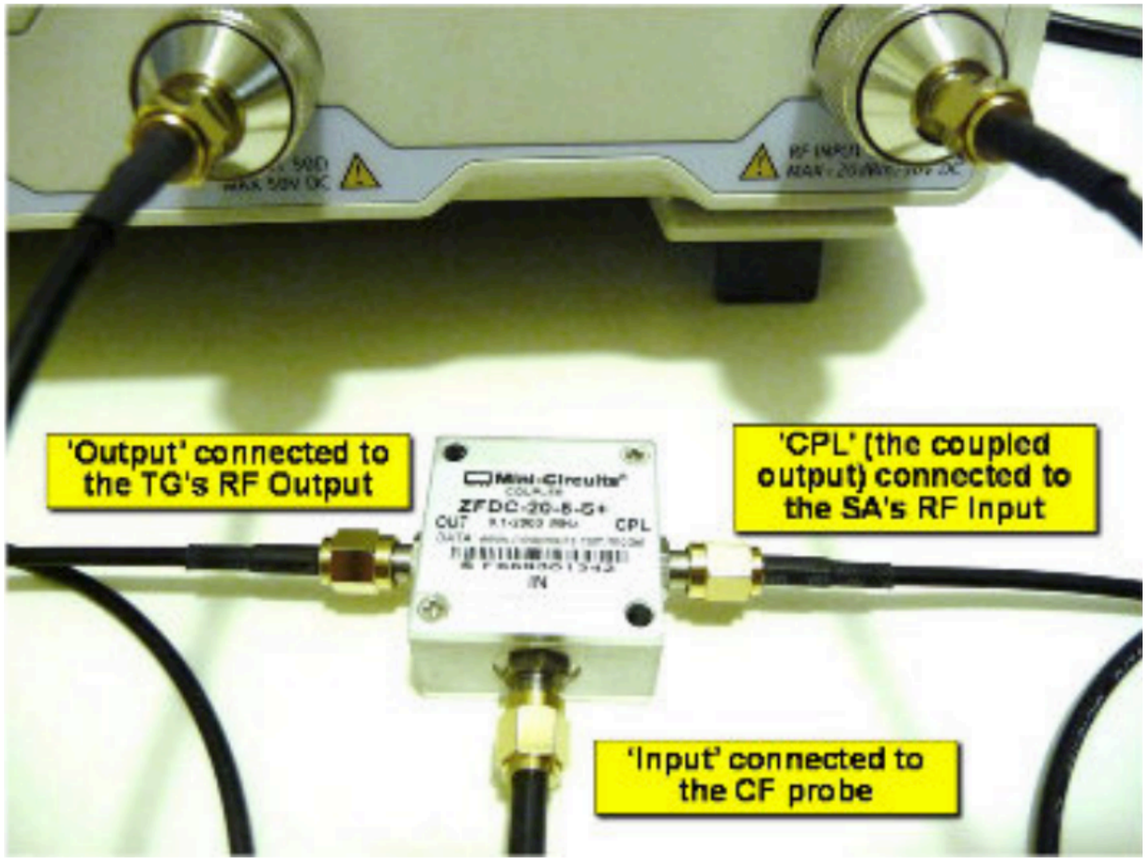
Ways to measure structure resonance, see https://youtu.be/-YMhuYstbCI for video demonstration.





Source: Keith Armstrong, Cherry Clough Consultants

Commonly seen unintentional antennas - resonance structures

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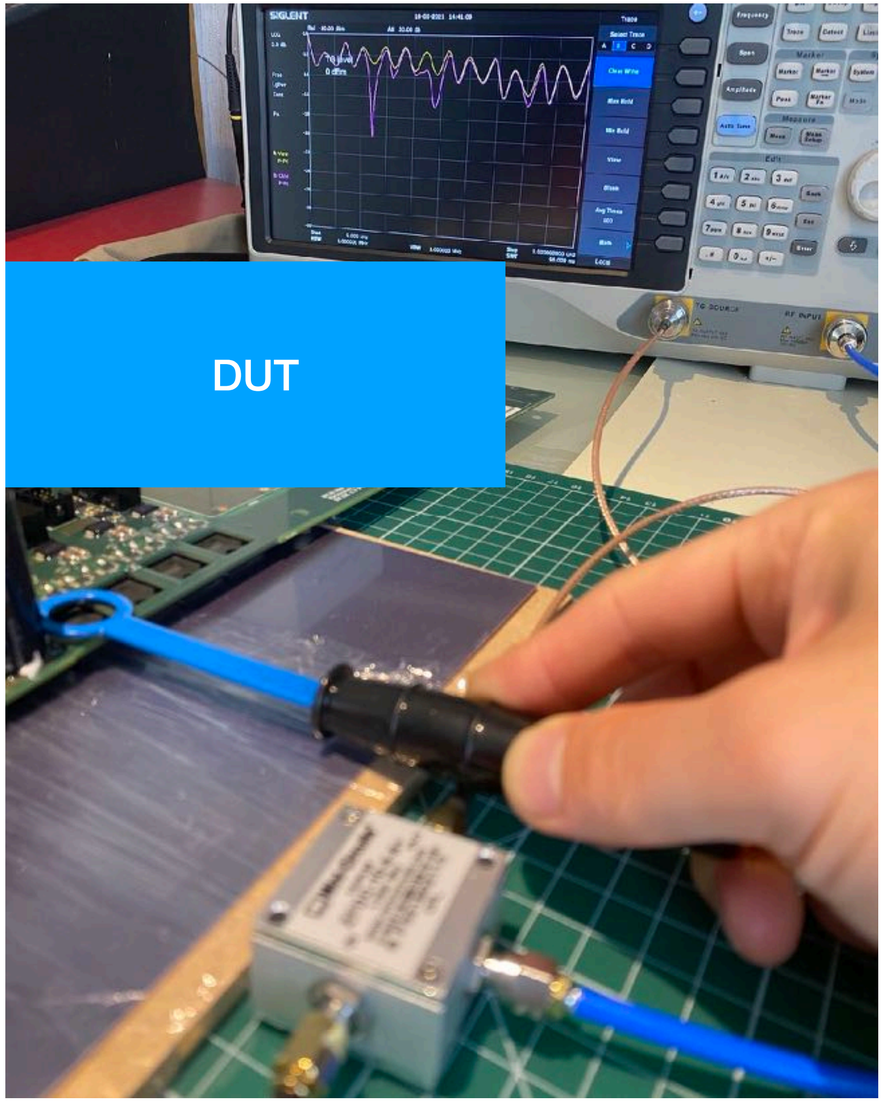

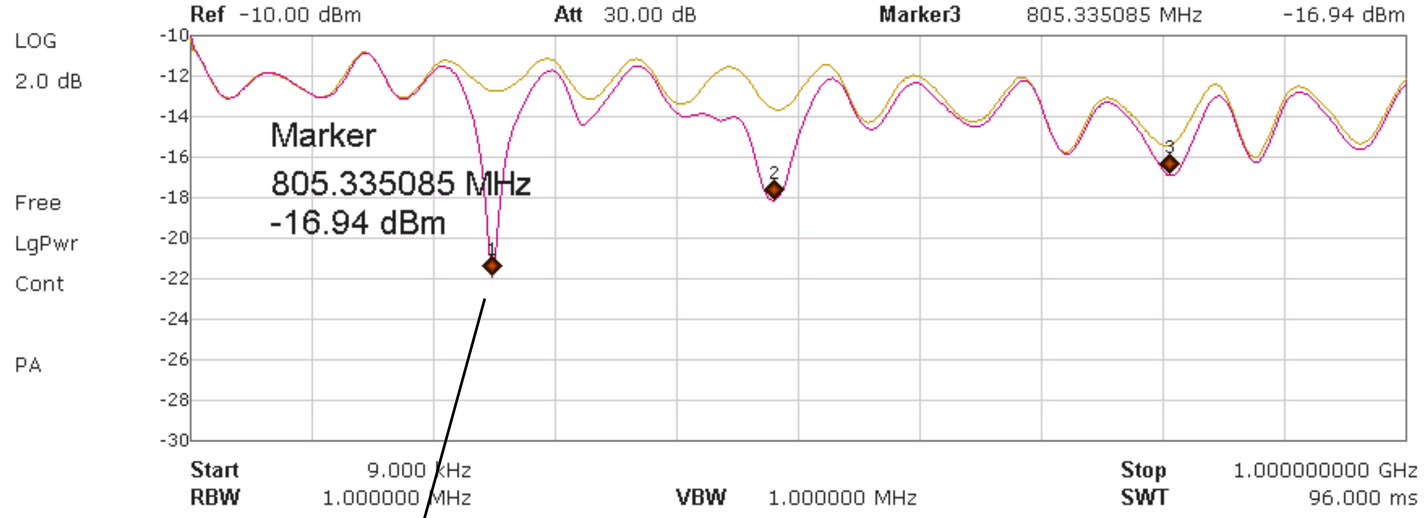

Marker Table

Marker	Trace	Readout	X Axis	Ampt
Marker1	B	Frequency	248.006768 MHz	-21.98 dBm
Marker2	B	Frequency	480.004680 MHz	-18.15 dBm
Marker3	B	Frequency	805.335085 MHz	-16.94 dBm

240 MHz Strong Resonance

Commonly seen unintentional antennas - Unconnected copper areas

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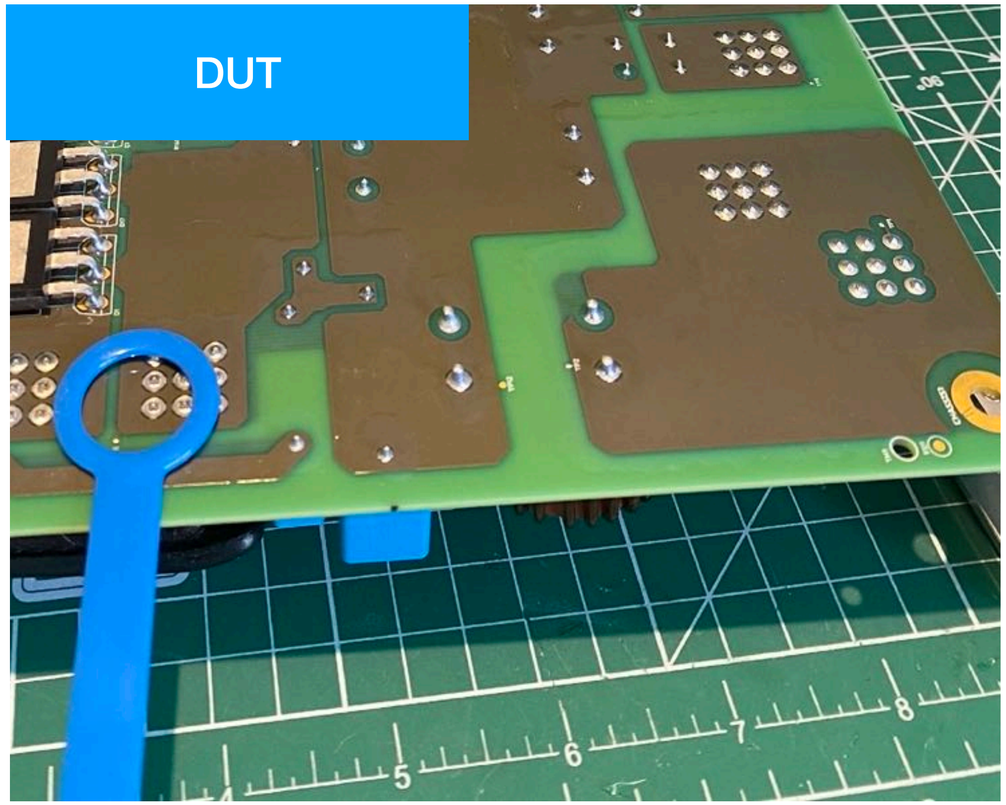
Ground/power planes/islanded copper areas, if not connected using vias or decoupling capacitors, could become patch antennas. The resonance frequency of the 'unwanted' patch antenna depends on the geometry of the structure.



Commonly seen unintentional antennas - Unconnected copper areas

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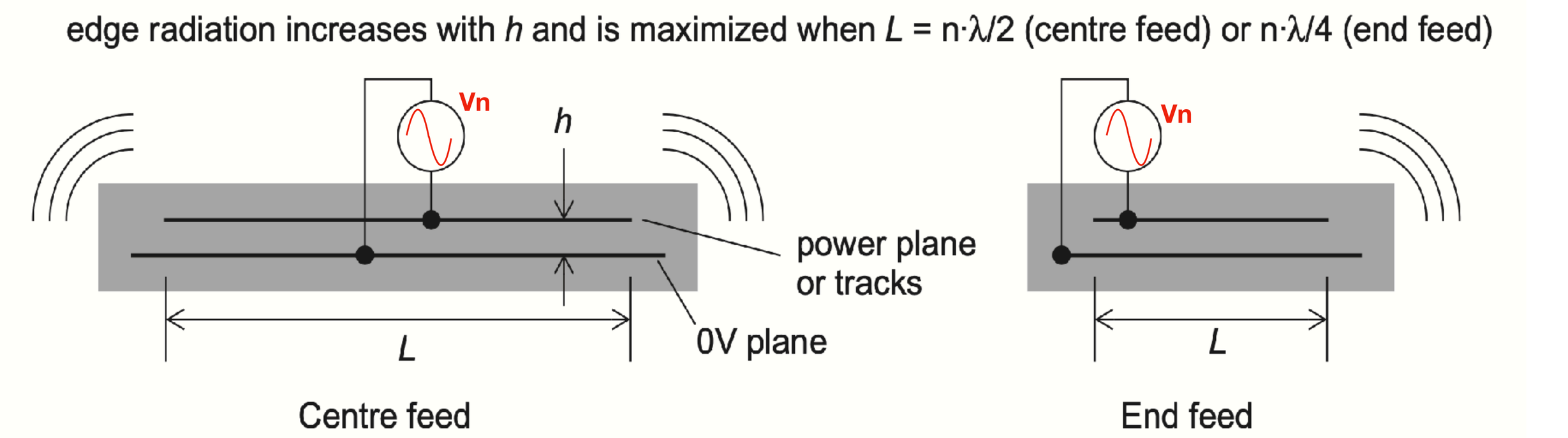
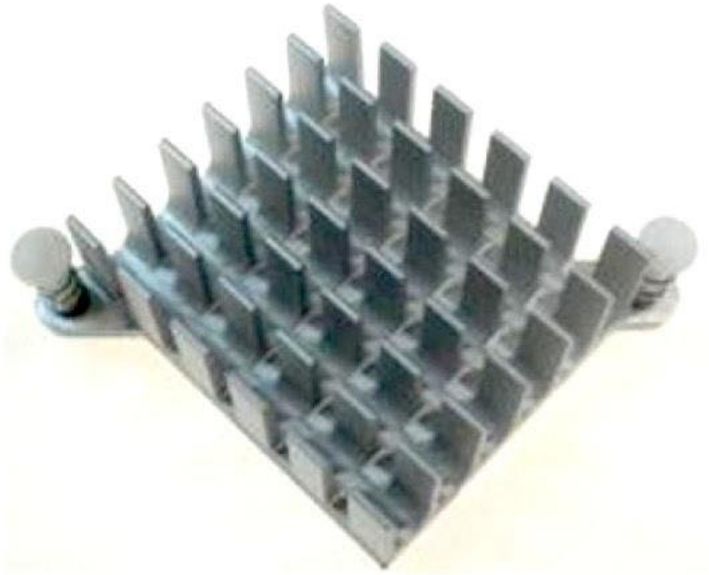


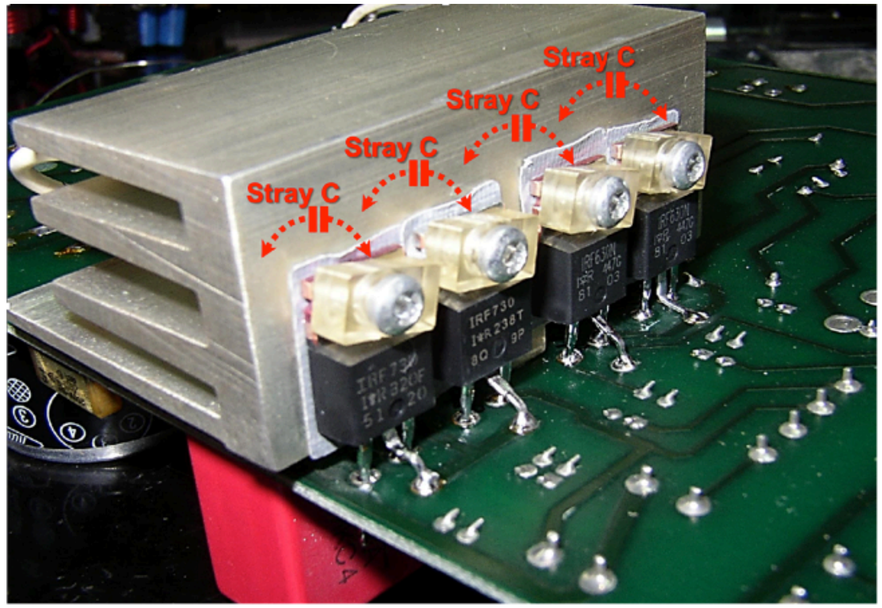
Figure 11.13 The patch antenna model

Source: Tim Williams, EMC for Product Designers

Commonly seen unintentional antennas - Heatsink

Heatsinks, such as the one shown below, when mounted on an IC, could serve as a small "antenna farm" (words from Doug Smith emcesd.com).

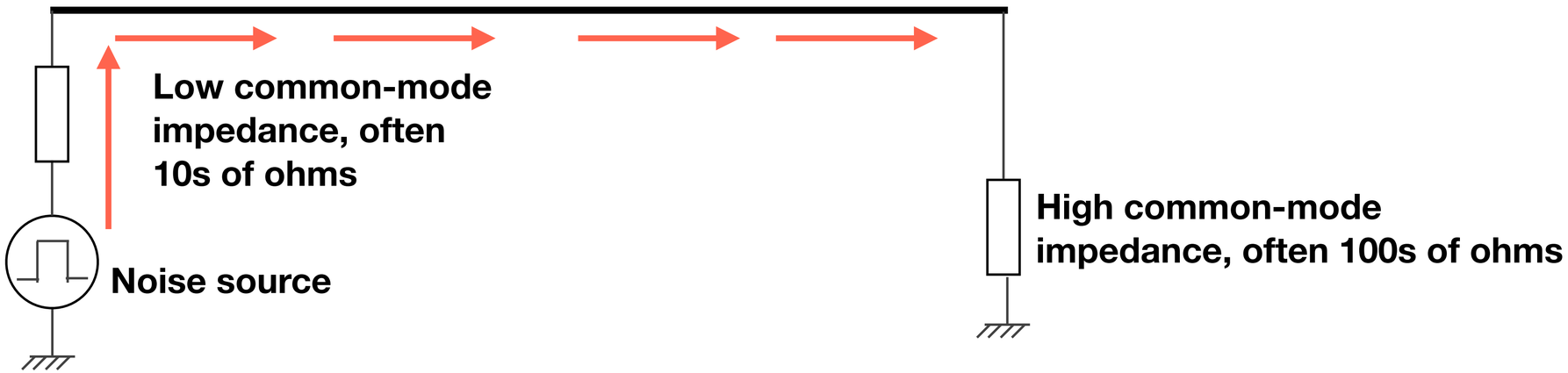




Source: Keith Armstrong, EMC Techniques for Heatsink, Cherry Clough Consultants

Techniques of preventing unintentional antennas - Cables

For wires that radiate, use ferrite cores to suppress noise, the trick is where to place the core and how. Ferrite cores are most effective when they are placed at the lower impedance end of the cable.



Source: Richard Marshall, " A cable can be an effective antenna, so you add a ferrite", https://www.emcstandards.co.uk/blog/4/6

Techniques of preventing unintentional antennas - Shielding

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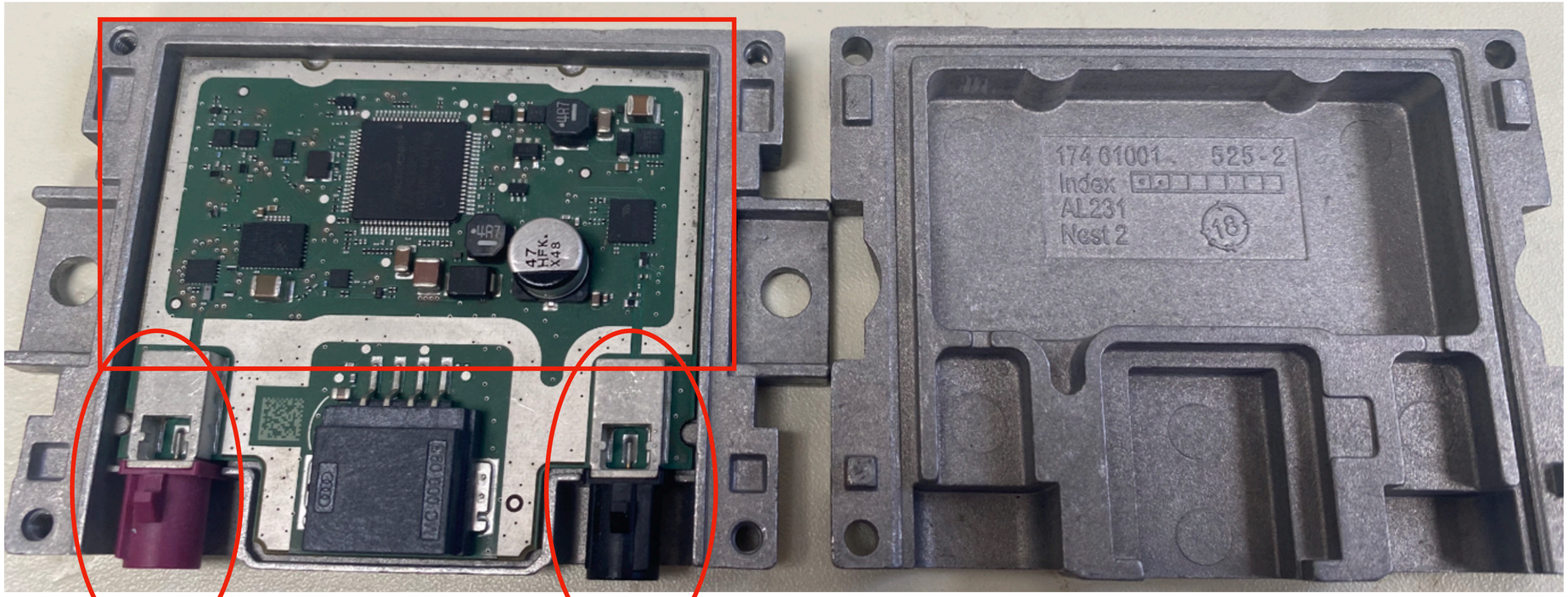
For shielding cables, avoid using ‘pigtails’, always use 360 degree bonding. Details can be found in Keith Armstrong’s “EMC in interconnections (good EMC design for cables and connectors)”.



Good shielding termination practices in an automotive product.

Techniques of preventing unintentional antennas - Grounding

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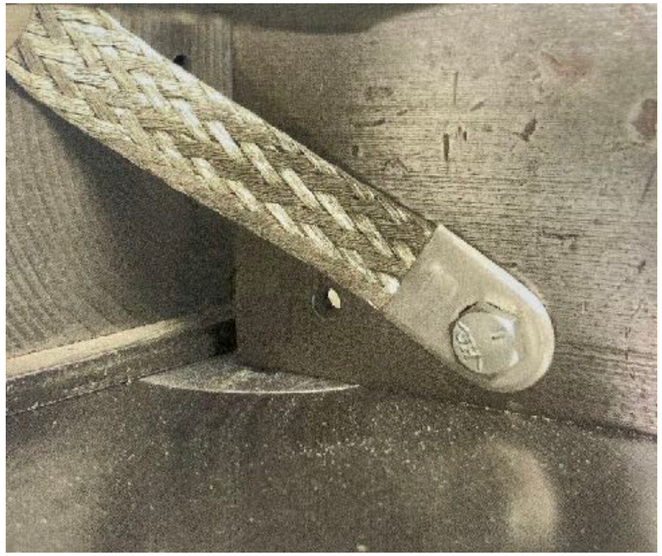
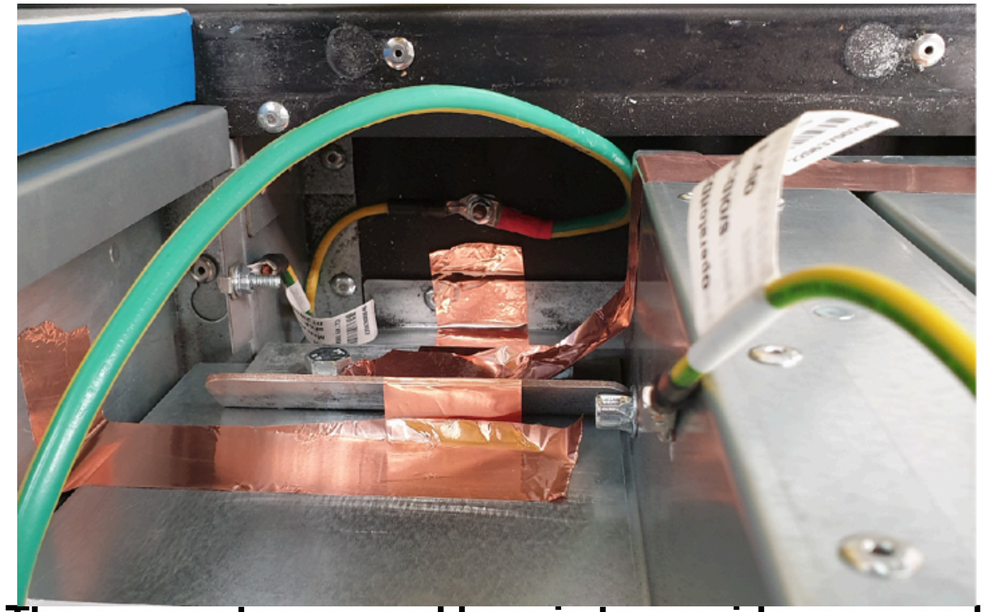
* For Grounding wires, always use short wires. Reducing the loop area is the key.
* Avoid single point grounding whenever you can, single point grounding creates problems of all sorts.
* Use a conductive gasket to prevent galvanic corrosion and ensure a good electrical bond between two dissimilar metals.



Use short, wide and braided wire



The copper tapes used here is to provide more and better bonding areas

Techniques of preventing unintentional antennas - PCB

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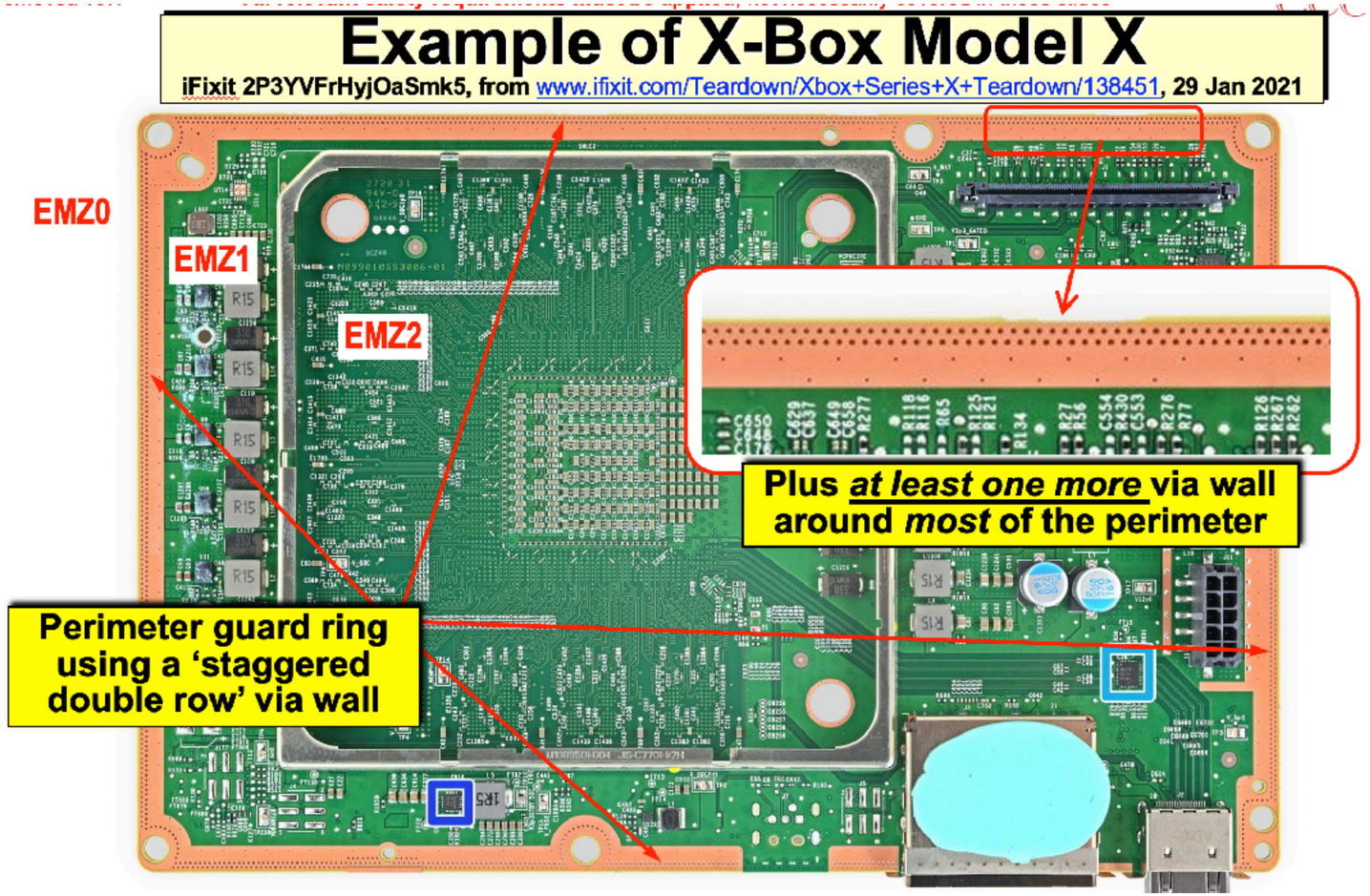
On PCB, design against resonance structures.



At least a single row of via holes linking copper areas together all around the board. These vias that are spaced apart by much less than one-twentieth of the wavelength in air of the highest frequency they want to control for EMC reasons. (One-twentieth, because the wavelength inside the FR4 is half what it would be in the air.)

Source: "Essential PCB design/layout techniques for cost-effective SI, PI and EMC", Keith Armstrong, Cherry Clough Consultants

Techniques of preventing unintentional antennas - PCB

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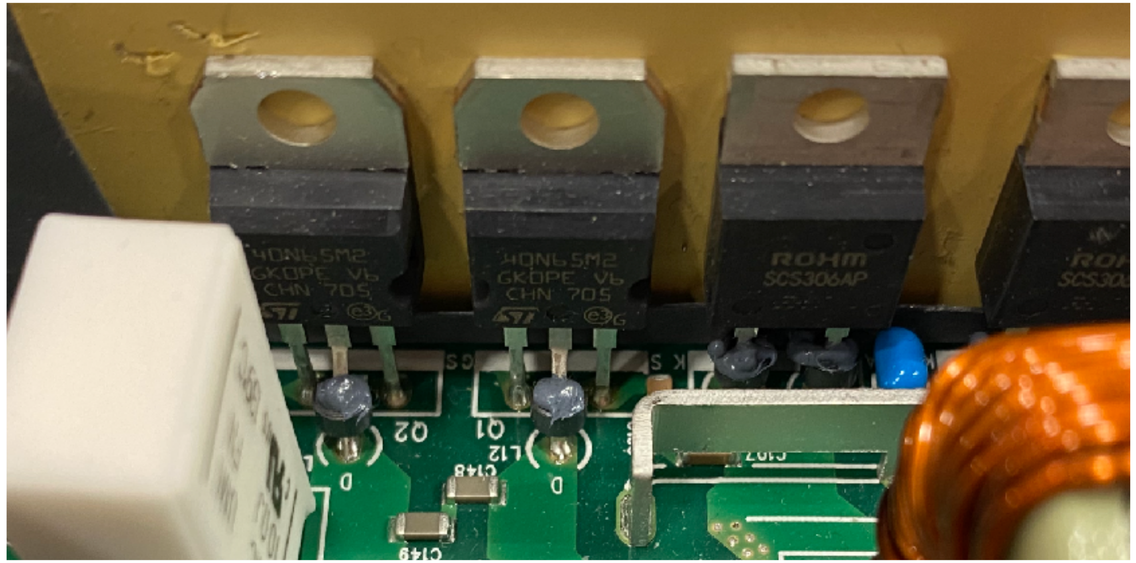
On PCB, design against resonance structures.



Putting a small lossy square-loop ring core on the transistor leg is often good for this sort of problem. A technology used in the 1990s, but still finds its way even in today's design The core increases inductance, but the ring is damped, so the frequency and amplitude of the resonance go down. Also, the square loop material delays the current rise, making the switching softer.

Insert an EMI flexible absorber sheet between the devices and the PCB. Modern absorber sheet has often a high permeability and can serve as a good thermal conduction material in the same time, perfect for this application.

Techniques of preventing unintentional antennas - heatsinks

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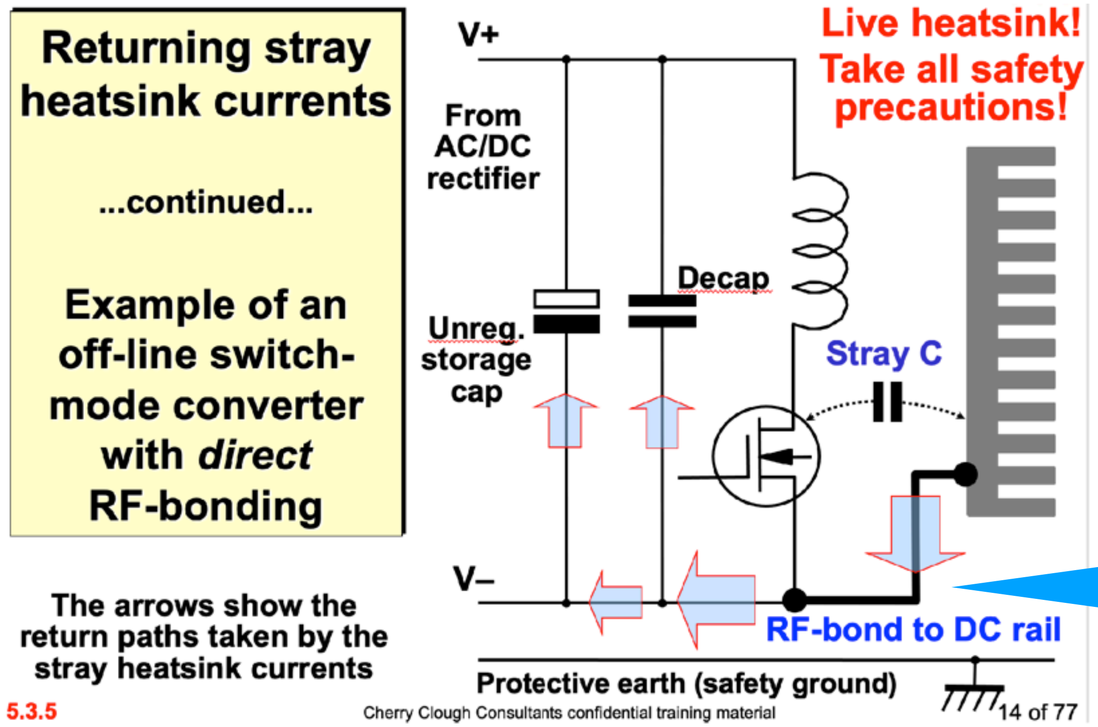
Heatsink shall never be left 'floating', it needs bonding points to the RF reference. Details can be found in Keith Armstrong's "EMC techniques for heatsinks".



But how many points do we need?
10 bonds per wavelength at the highest frequency for which resonances need to be prevented to suppress noise emissions.

For instance, here, we only need a single short RF bond (because the stray current loop was a lot less than half wavelength diameter.

Source: Keith Armstrong, EMC techniques for heatsink

Conclusions

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- Understanding the basics of antennas is important.
- In the design stage, EMC review should be carried out in parallel with other design reviews to avoid potential issues.
- Often, identifying and locating the unintentional antennas is the first step before fixing the problems.
- Radiation caused by unintentional antenna(s) can be suppressed effectively using the techniques introduced in this training session.