EMC Shielding – a practical guide

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Agenda

1. About us
2. Shielding basics
3. Shielding apertures
4. Shielding experiment – A lucid explanation
5. Practical examples and shielding tips

1. About us

~~resistance~~ is futile

impedance

1. About us

Victor Martinez
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- **First steps in EMC during an intership in Catedra EMC Würth Elektronik – University of Valencia.**
- **Responsible for EMC Shielding products:**
  - **EMC Gaskets.**
  - **Grounding Contacts**

1. About us

Adrian Stirn
EMC-Laboratory Engineer
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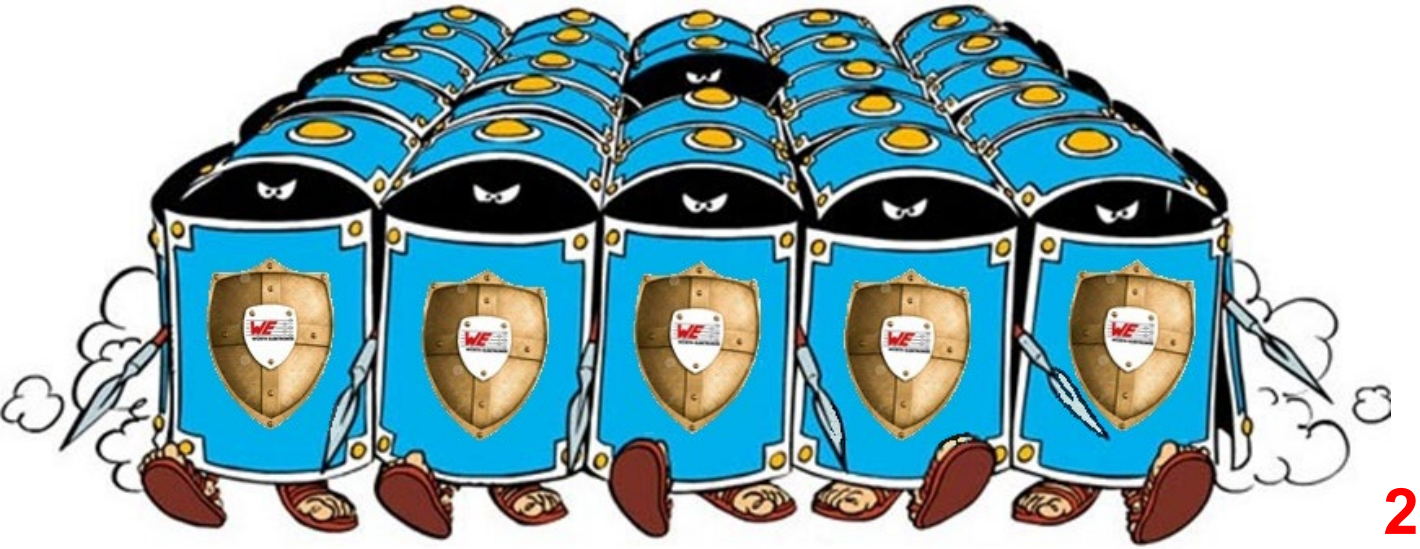
- **Get in contact with EMC during apprenticeship and studies on electrical engineering as a company student.**
- **Responsibility for the EMC-Lab in Waldenburg after receiving engineers degree in 2016):**
  - **Precompliance EMC measurements.**
  - **Customer support: measurements, EMC debugging, redesigns, optimizations…**

➢ **One big questions that is asked by customers: WHAT ABOUT CE?**

- **Since 2019 also working on product compliance topics and CE.**

➢ **Shielding and mechanical design is always an issue during EMC debugging!**



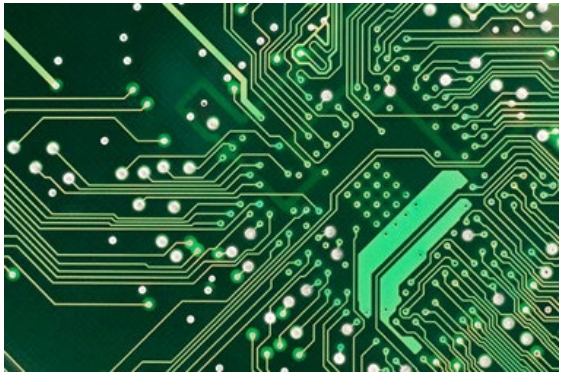
2. Shielding basics

Elementary dipoles
Characteristic wave impedance
Shielding effectiveness
Shielding of E-fields
Shielding of H-Fields

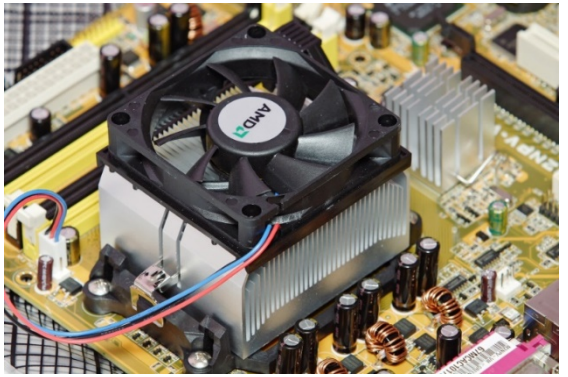
2. Shielding basics

- **Electromagnetic fields are radiated from and received by conductive structures.**
- **Possible antennas:**

Cables, interfaces, apertures



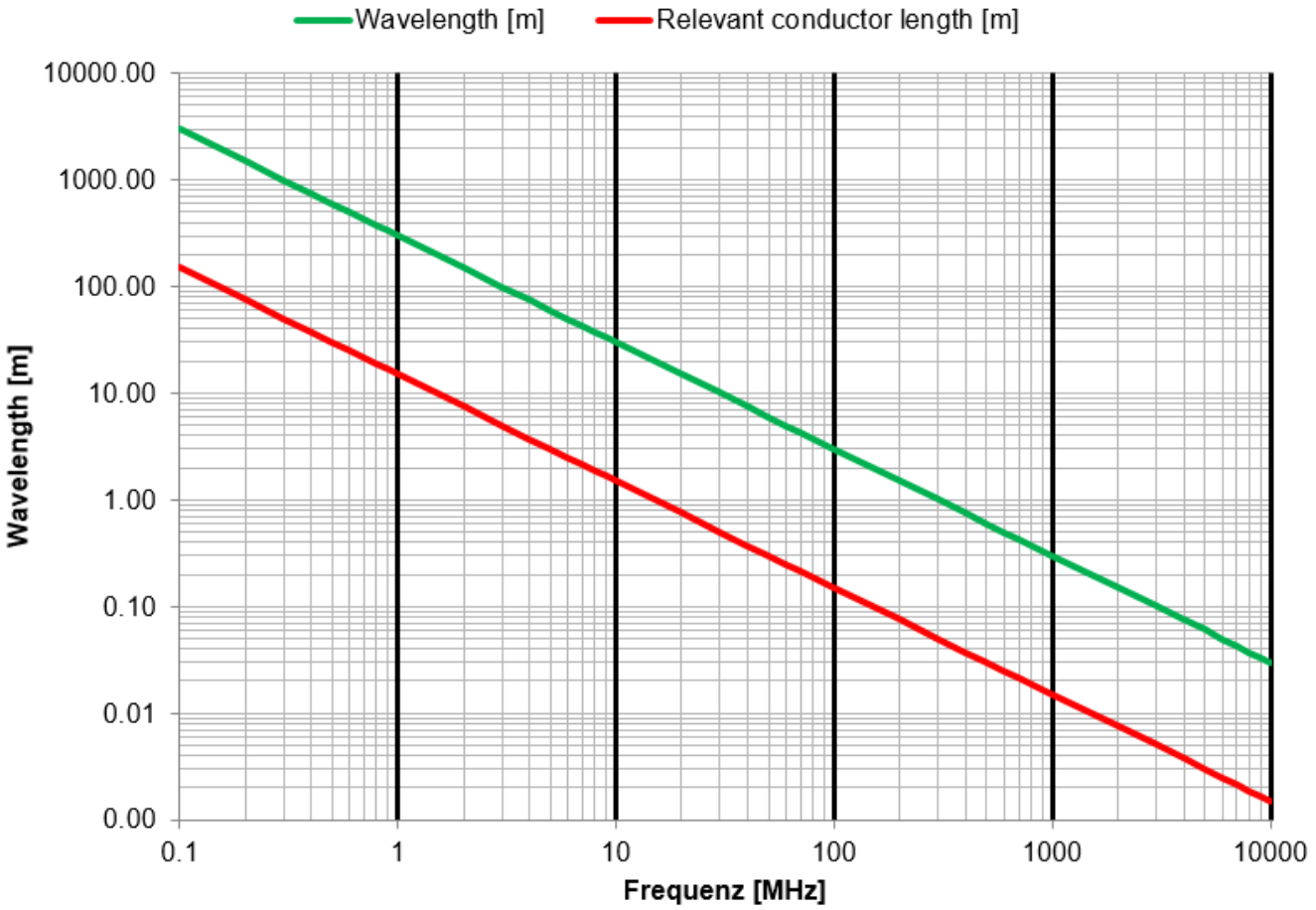
Traces, groundplanes, vias, slits



Components, heatsinks, integrated circuits

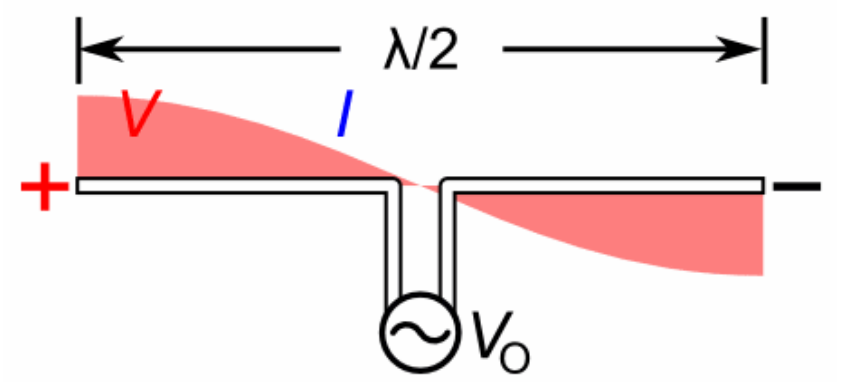
2. Shielding basics – Critical wavelength

- $\lambda = \frac{c}{f}$
- $\lambda_{[m]} = \frac{300}{f_{[MHz]}}$
- **Critical length:**
  - $\frac{\lambda_{[m]}}{10}$
- **Critical length to be sure:**
  - $\frac{\lambda_{[m]}}{20}$



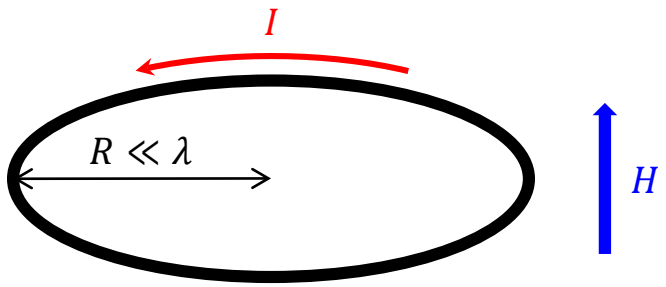
2. Shielding basics – Elementary dipole

- The most basic antenna is an electric (Hertzian) dipole. Its length ℓ is small compared to the wavelength considered.
- Along its dimension a locally constant, temporally changing current I is flowing. Charges are accumulated at the ends.
- The electric dipole generates an electric field.

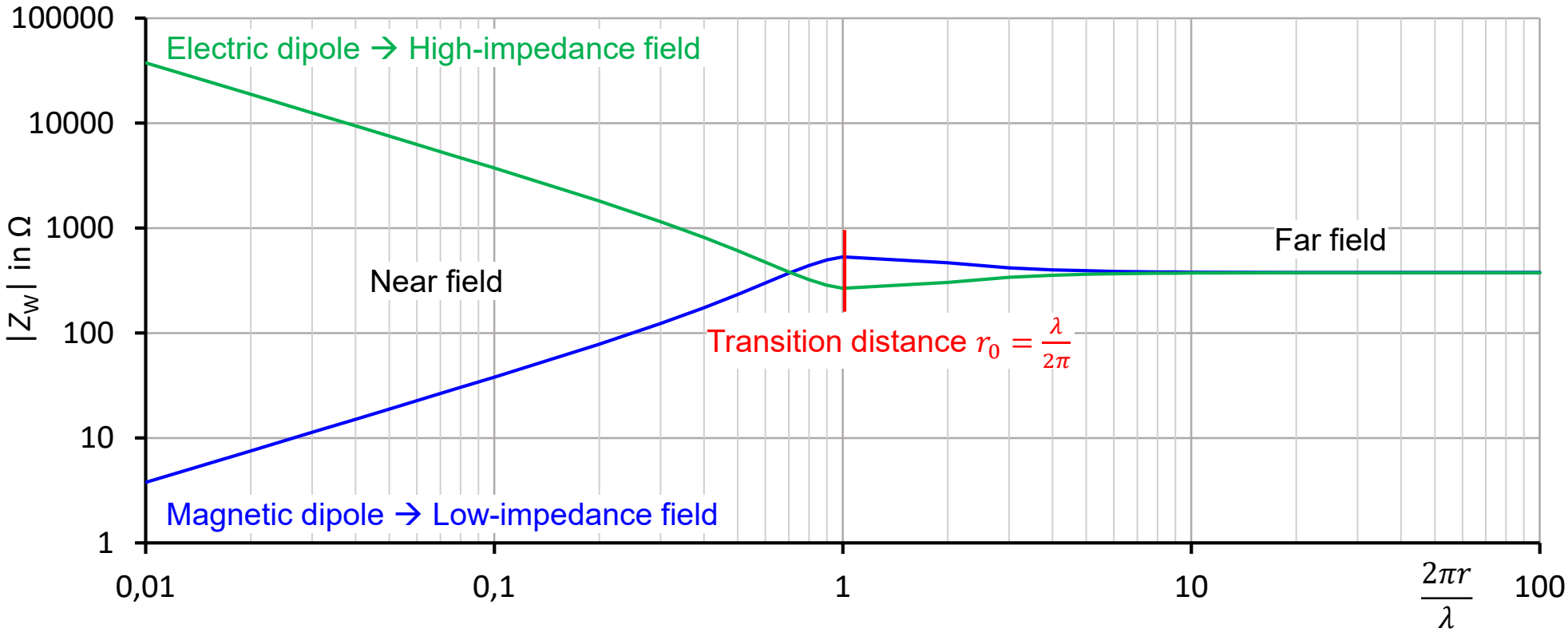


2. Shielding basics – Elementary dipole

- A second elementary antenna is created by a current loop or magnetic dipole. Its radius R is small compared to the wavelength considered.
- Along its circumference a locally constant, temporally changing current I is flowing.
- The magnetic dipole creates a magnetic field.



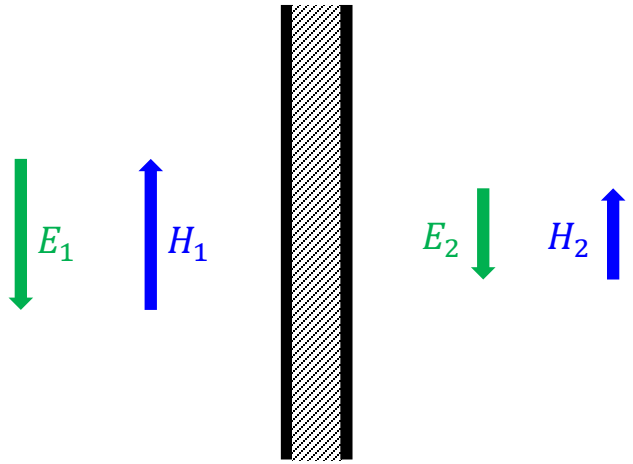
2. Shielding basics – Characteristic wave impedance



2. Shielding basics – Shielding effectiveness

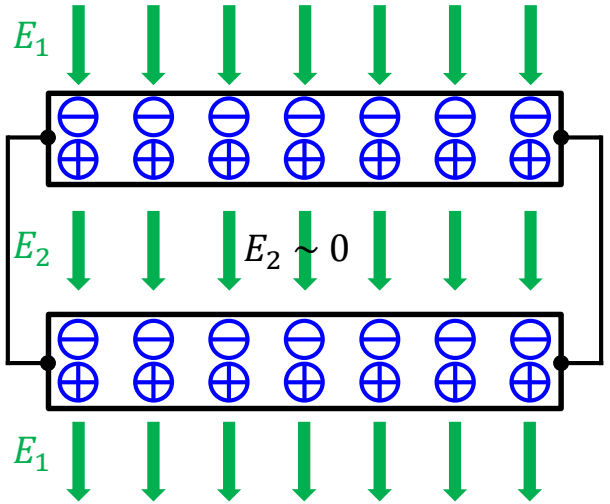
- **The shielding effectiveness A_S, given in decibel, characterises the quality of an electromagnetic shield.**
- **The field amplitudes E_1 and H_1 in front of the shield are compared with the field amplitudes E_2 and H_2 behind the shield.**

$$A_S = 20 \cdot \log\left(\frac{E_1}{E_2}\right) \mathrm{dB} = 20 \cdot \log\left(\frac{H_1}{H_2}\right) \mathrm{dB}$$



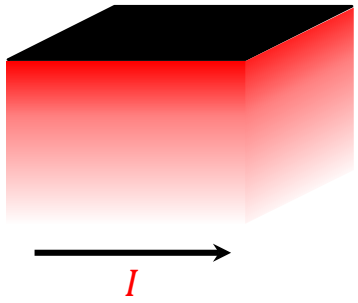
2. Shielding basics – Shielding of electric fields

- Electric fields can be shielded easily.
- Electric field lines start and end on charges.
- It has to be assured that free charges are able to be balanced.
- Shielding effect of electrically conducting and connected plates on a static electric field:



2. Shielding basics – Shielding of magnetic fields

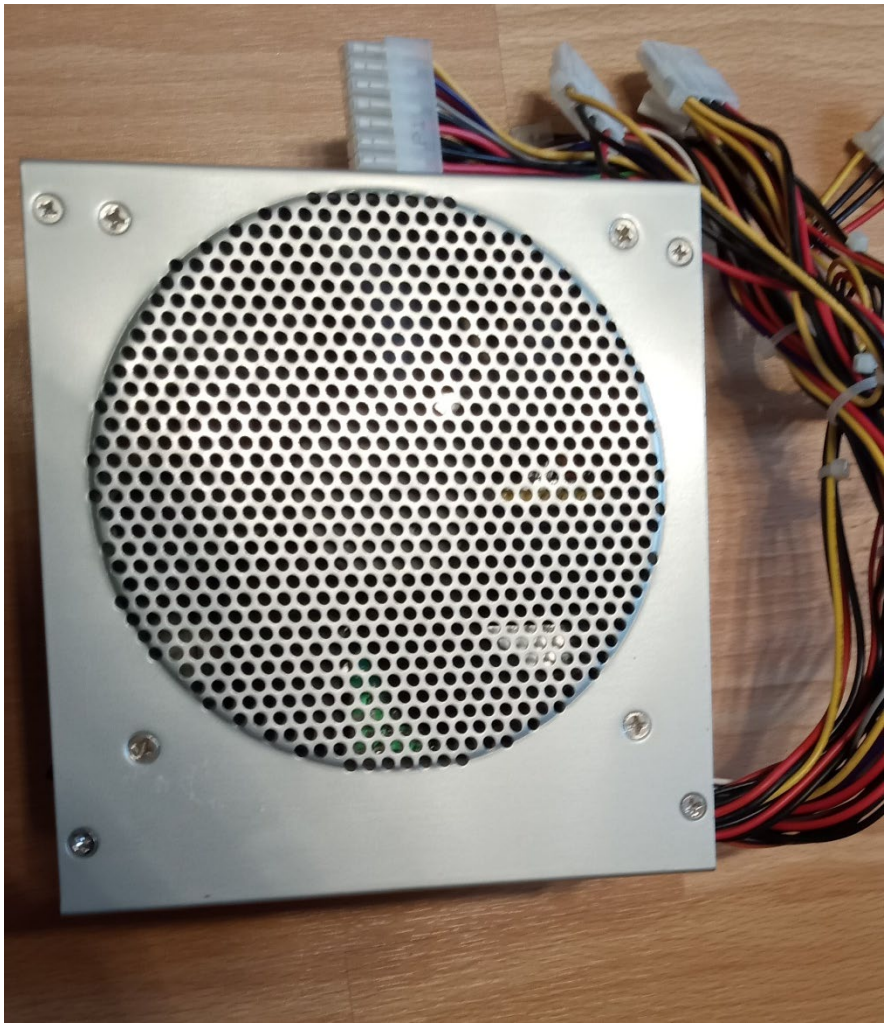
- **Shielding of magnetic fields is more difficult, particularly static and low-frequency fields (16⅔ Hz, 50 Hz).**
- **Categorization of shielding measures:**
  - **Against static and low-frequency fields → High-permeable materials**
  - **Against medium-frequency fields → Utilizing of the skin effect**
  - **Against high-frequency fields → Reflection and absorption**



2. Shielding basics – Summary

1. In order to maximise the field reflection in the proximity of the noise source (near field), we need a shield
   - with high electric conductivity (= low impedance) against electric fields,
   - with high magnetic conductivity (= high permeability) against magnetic fields.

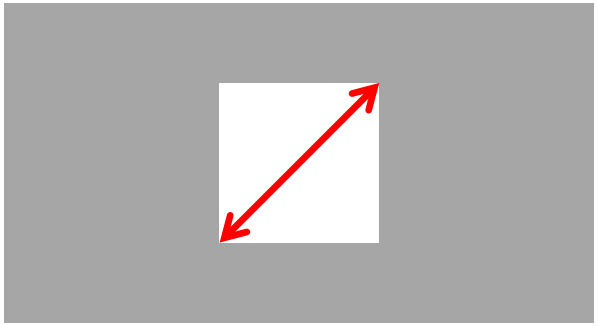
2. In order to maximise the field absorption inside the shield, the shield should
   - have a high electric and magnetic conductivity,
   - be as thick as possible.

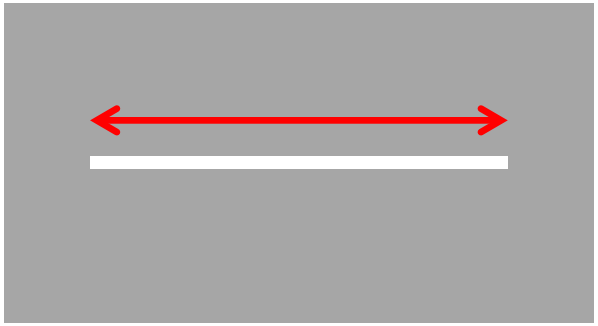


3. Shielding apertures

3. Shielding apertures

- There‘s no perfect shield, i.e. completely closed.
- There is a greater impact of apertures in the shield on the magnetic shielding attenuation than on the electric shielding attenuation.
- The maximum linear dimension of an aperture is crucial, not its area.

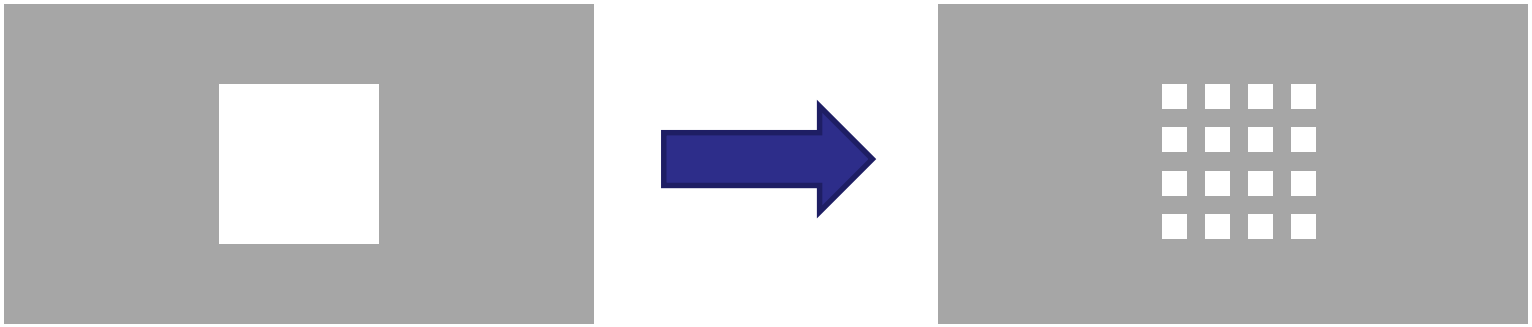




3. Shielding apertures

- An aperture with length $\ell = {}^{\lambda}/_{2}$ shows the same behavior as a half-wavelength dipole.
- When the electric field vector is oriented perpendicularly in relation to the slit, the shielding attenuation at the corresponding frequency is 0 dB.

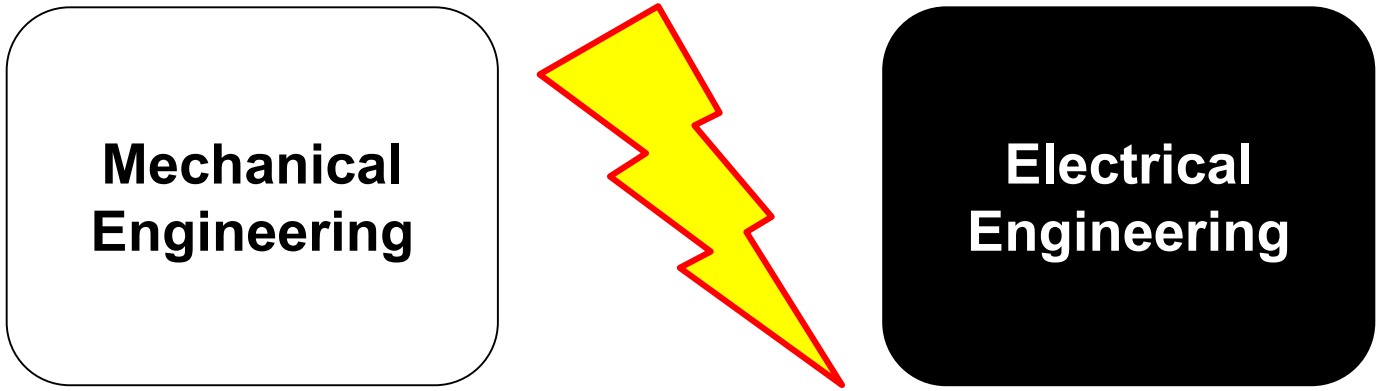
- If a larger aperture is required, e.g. for ventilation of the interior, the area should be devided into many smaller apertures.



4. Shielding experiment – A lucid explanation

4. Shielding experiment – A lucid explanation

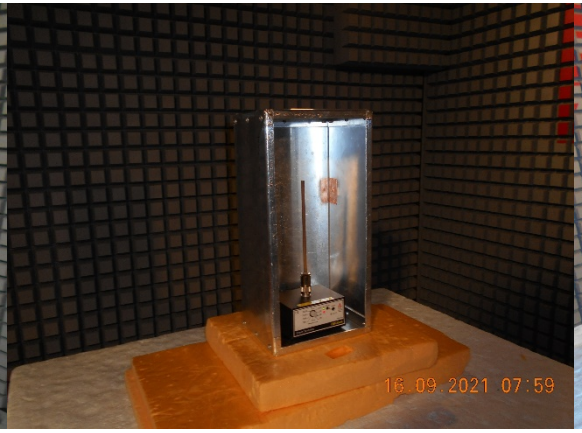
- **EMC and mechanical structures belong together!**
- **Electrical Engineers and mechanical engineers often don't understand each other – but they work together on the same project!**

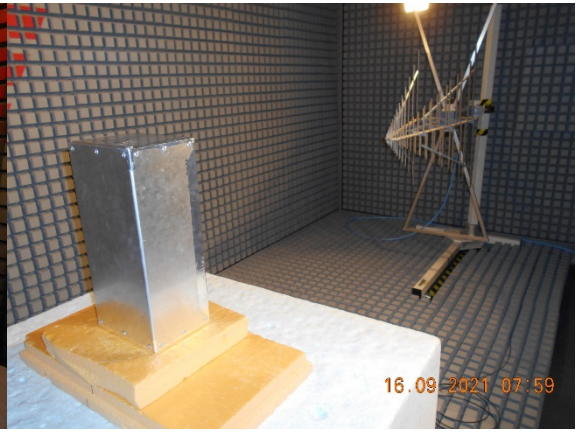


- **Make sure that you explain your colleagues from the mechanical engineering what you need from them to successfully fulfil the EMC requirements.**
- **Maybe the next easy slides can help you to explain this.**

4. Shielding experiment – Test setup

- Shielding example: Comb generator as a noisy electronic, that should be shielded.
- Comb generator in aluminium box, 20 MHz harmonics as noise source.
- Test setup:

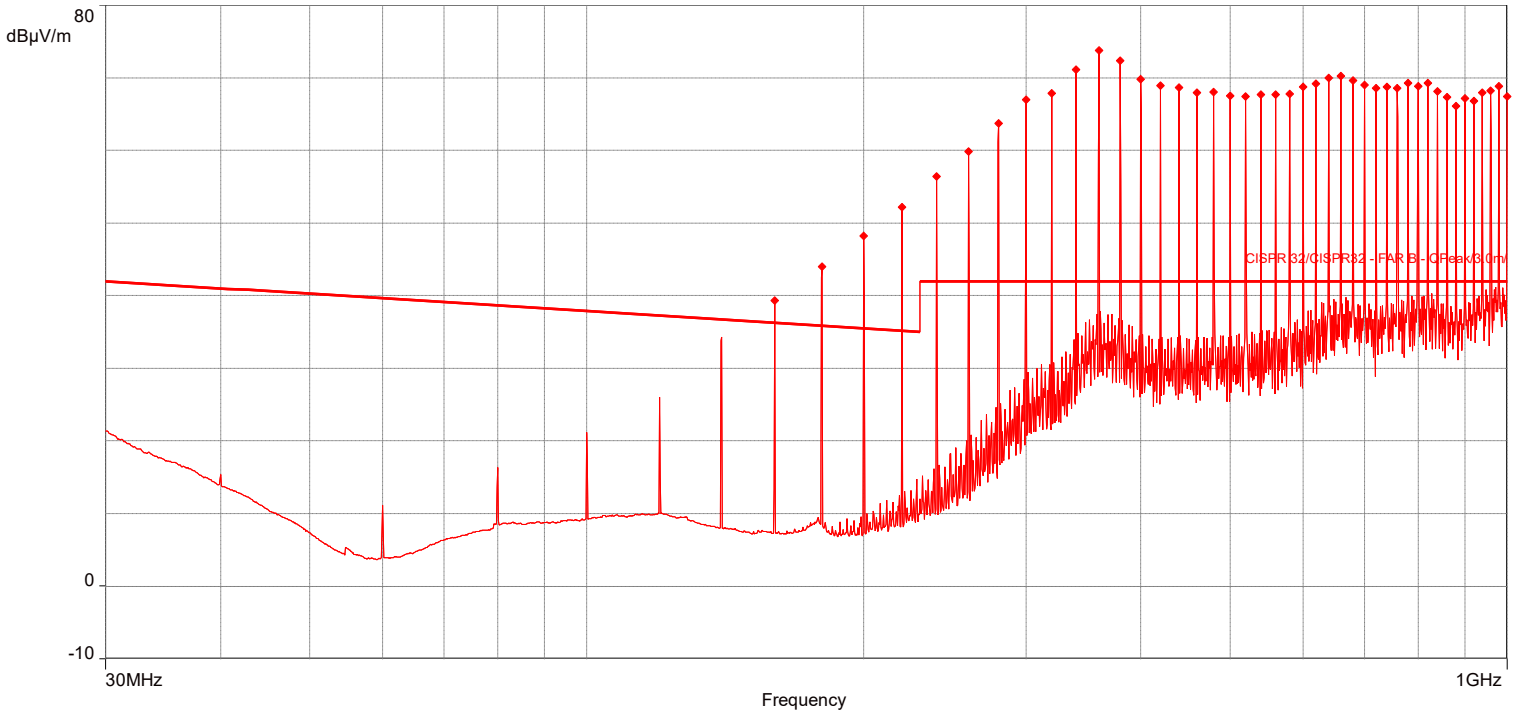




- All measurements are performed with vertical measurement antenna.
- Measurements in a fully anechoic chamber.

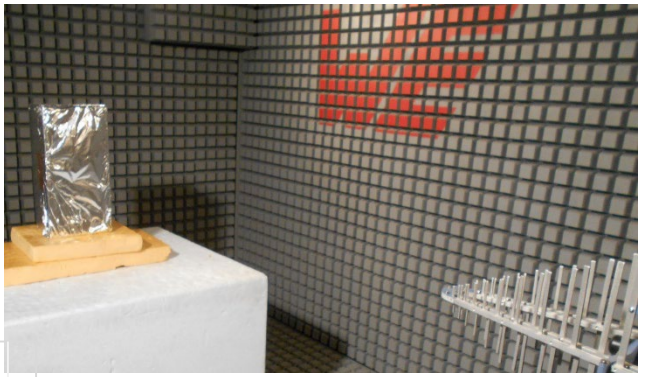
4. Shielding experiment – Reference measurement

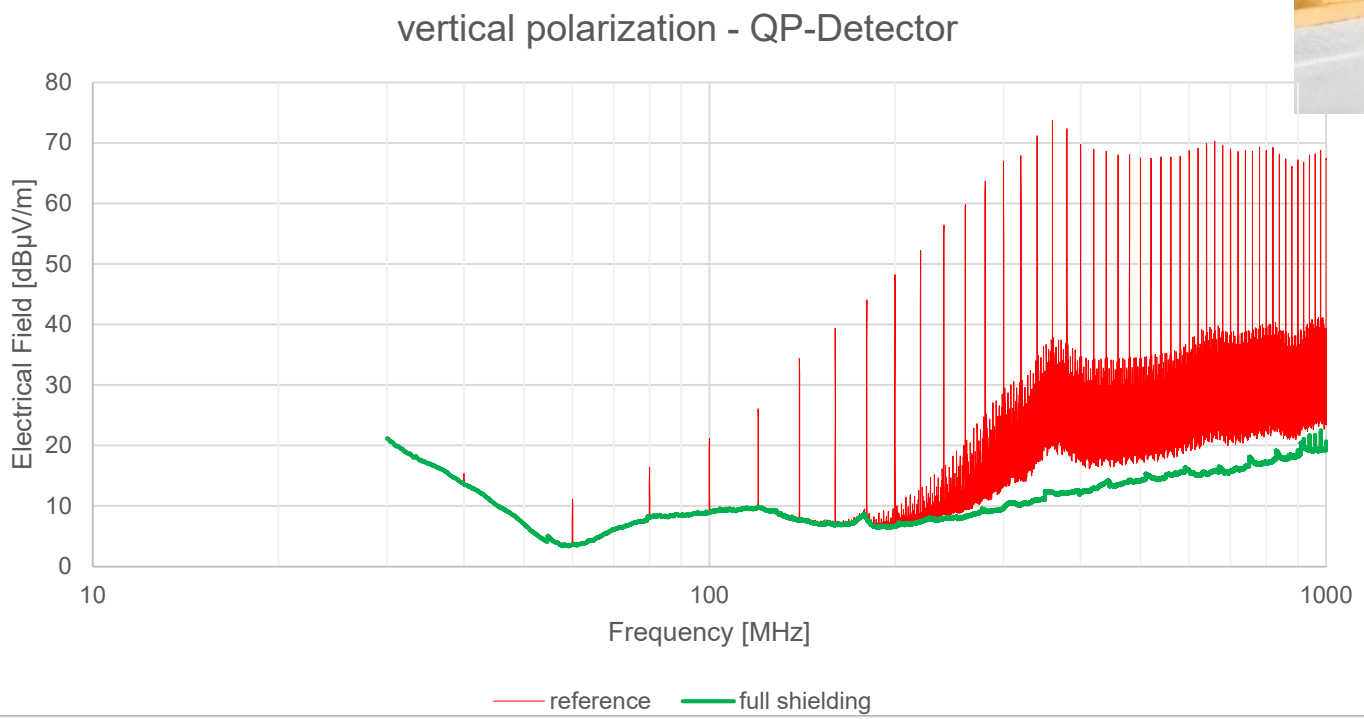
- Shielding example: Comb generator as a noisy electronic, that should be shielded.
- Comb generator in aluminium box, 20 MHz harmonics as noise source.
- 30 dB above the class B Limit.



4. Shielding experiment – Full shielding of the box

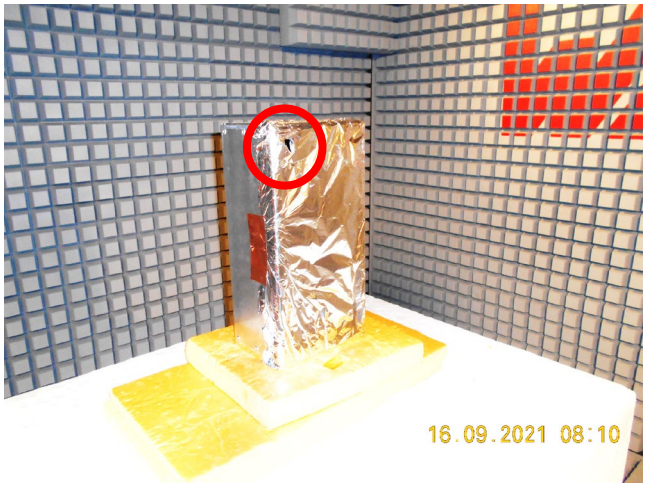
- **Electronic still in the box, adding aluminium foil and copper tape.**
- **60 dB attenuation at 360 MHz.**

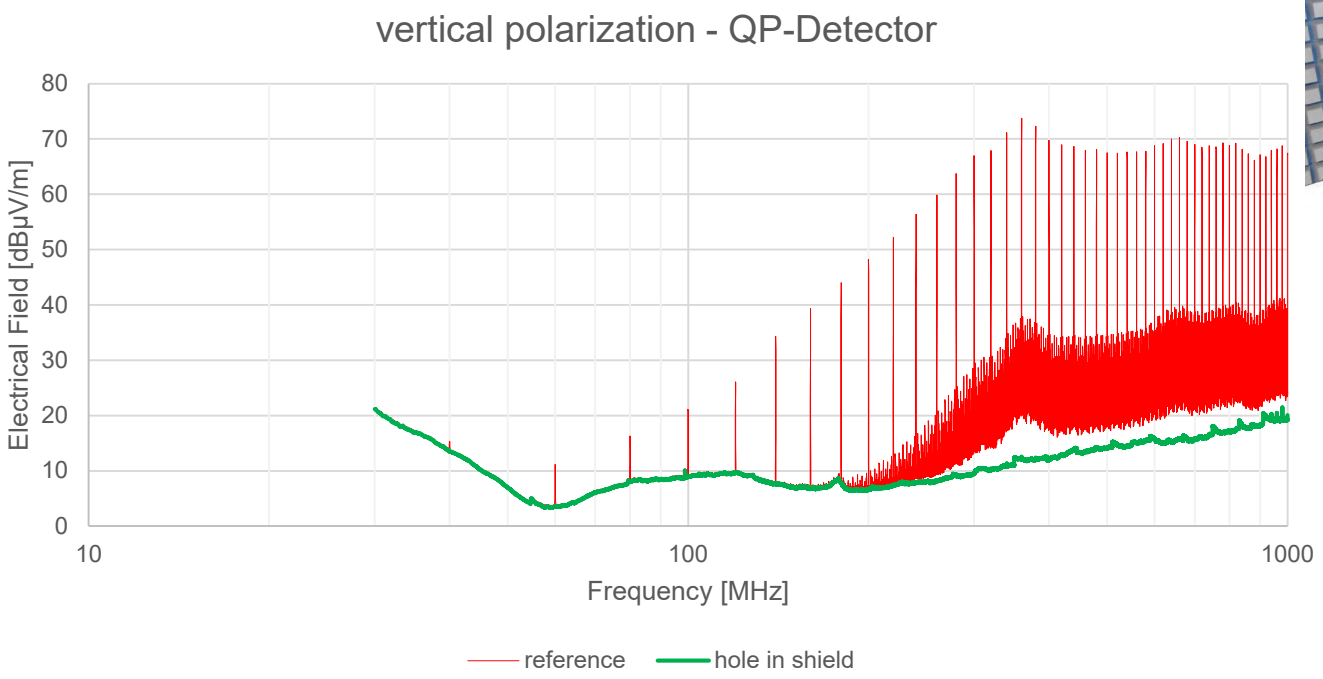




4. Shielding experiment – Shielding with one hole

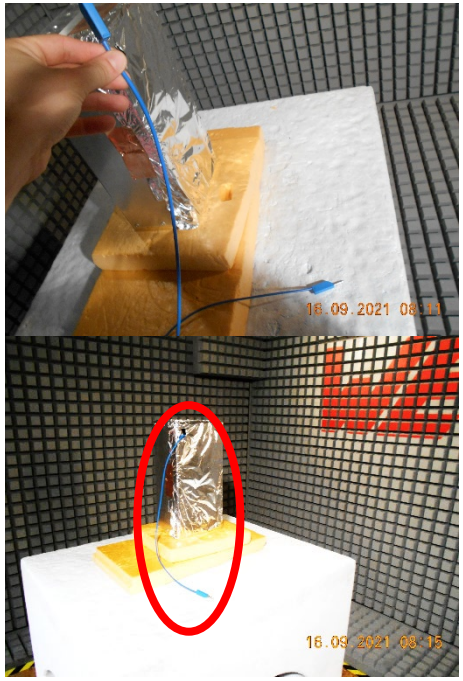
- **A full shield will not be suitable for electronics in reality.**
- **A small hole for connection e.g. a cable is added to the aluminium shield.**

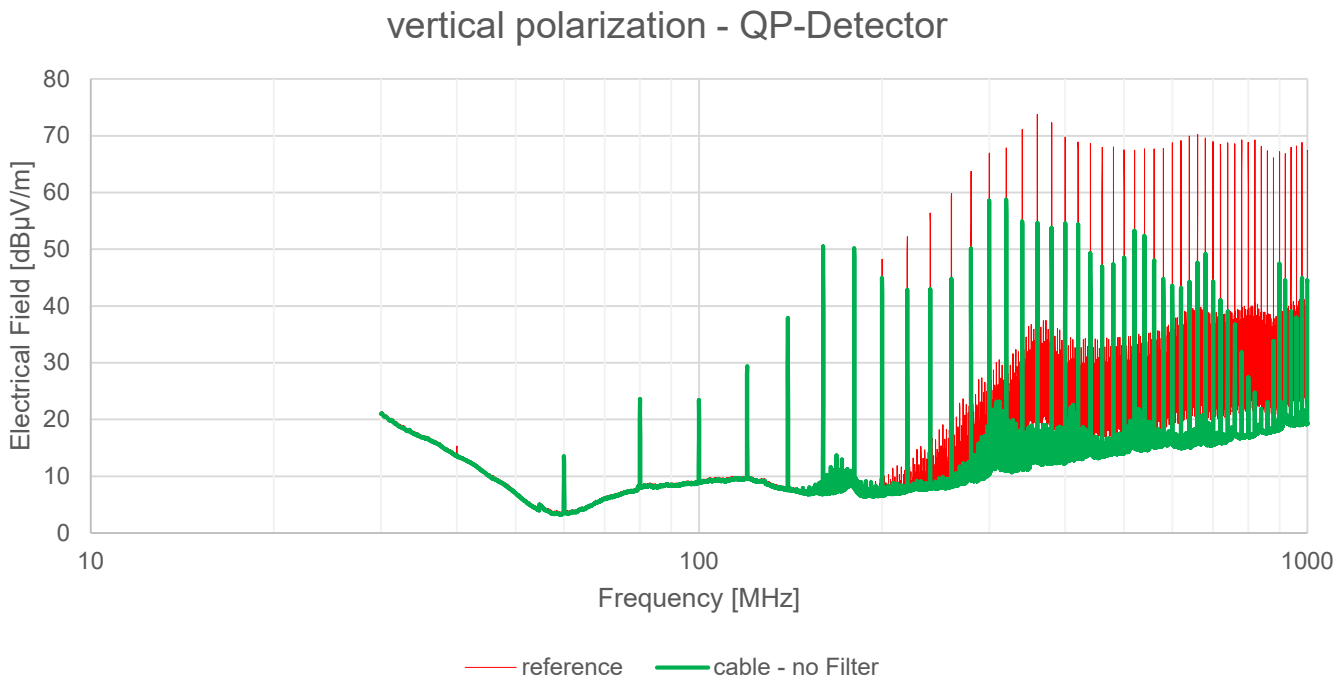




4. Shielding experiment – Shielding with one hole and a connected cable

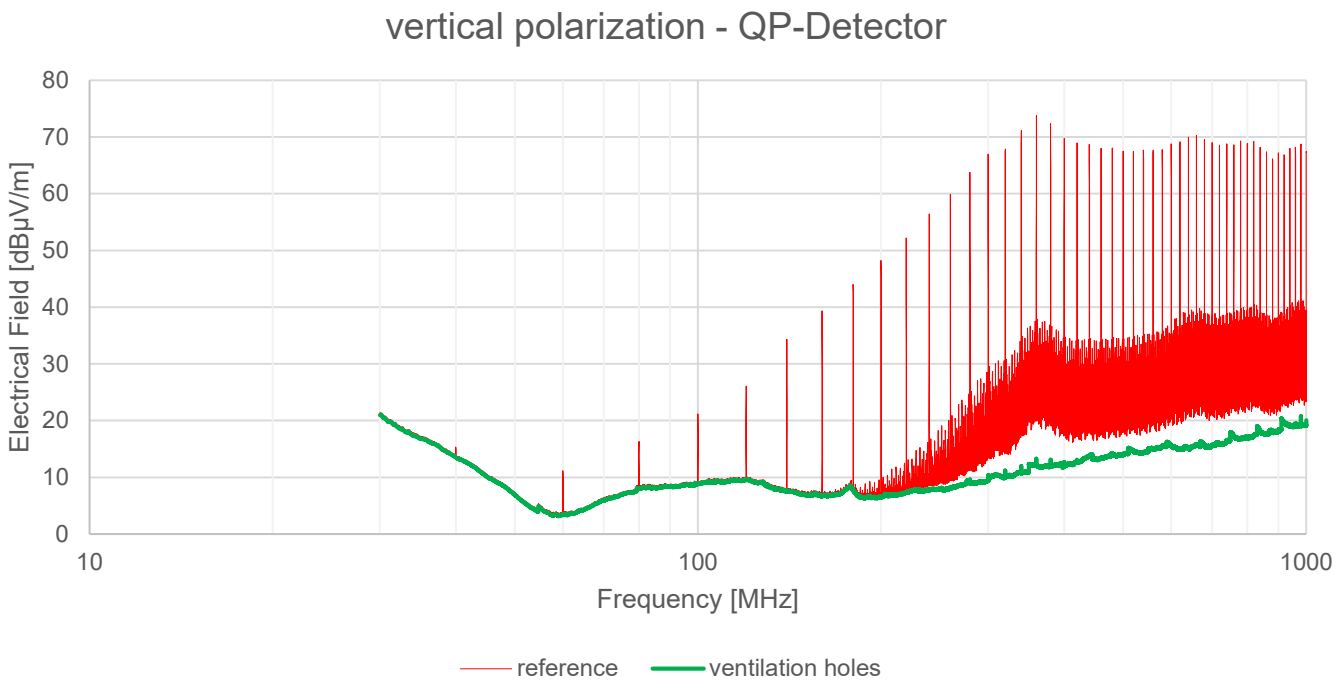
- A full shield will not be suitable for electronics in reality. Interfaces are needed.
- A cable without filter is added to the box and internally not connected to the noise generator.
- Massive reduction of shielding effect!





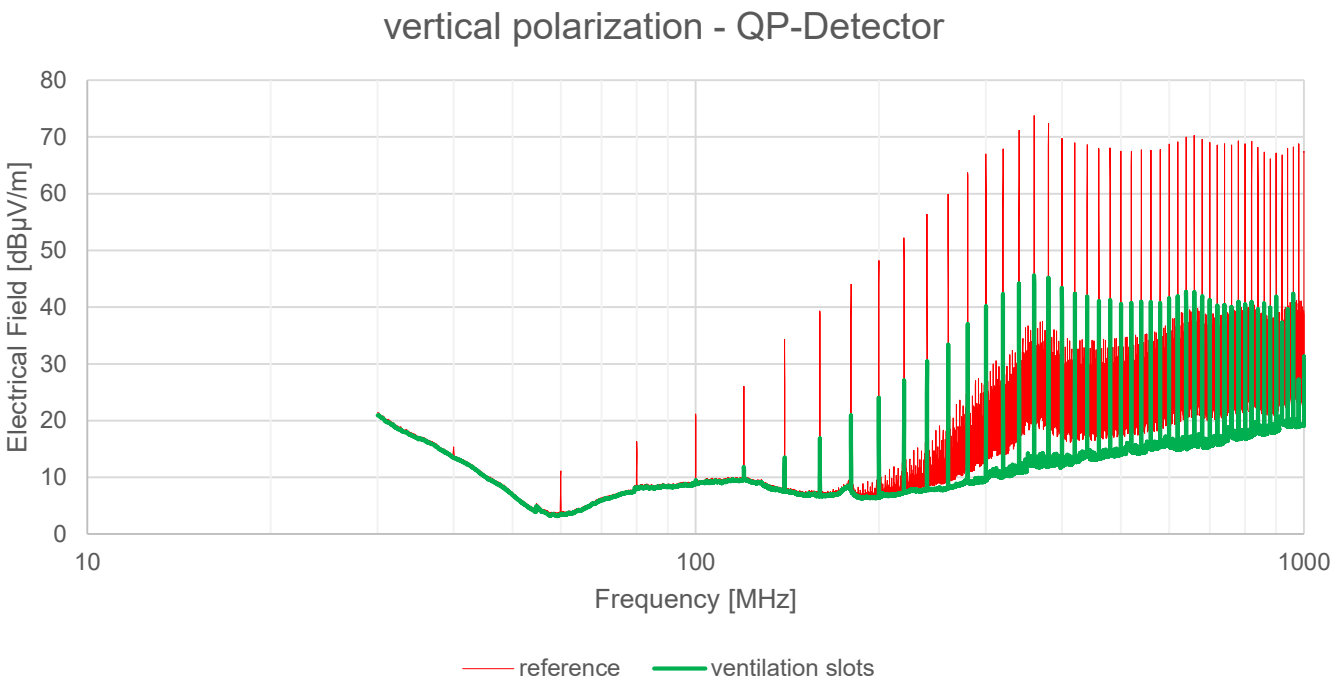
4. Shielding experiment – Ventilation holes

- **Electronics need often ventilation holes for cooling or holes for RF-communication like Bluetooth and WiFi.**
- **A grid of holes is added to the shield.**



4. Shielding experiment – Ventilation slots

- **Electronics need often ventilation holes for cooling or holes for RF-communication like Bluetooth and WiFi. Sometimes slots are used.**
- **Ventilation slots are added to the shield.**
- **It is recommended to use ventilation holes instead of slots!**



4. Shielding experiment – Conclusion

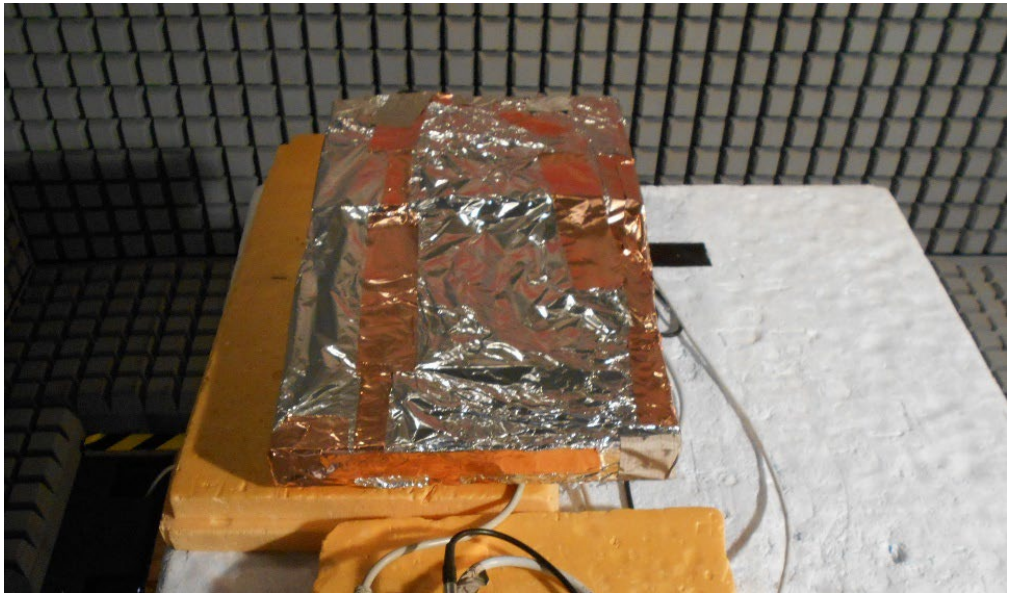
- Interfaces that leave the shielded electronic need to be:
  - Shielded - shield fully connected to the chassis (no pig tail).
  - Filtered in the relevant frequency range.

- Ventilation:
  - Avoid slots.
  - Remember $\frac{\lambda}{10}$ and $\frac{\lambda}{20}$ rule for holes.

- Avoid slots in the shield by badly connected or isolated metal plates:
  - Surfaces that are connected in the shielded box need to be conductive.
  - Use conductive gaskets to reduce slot length and increasing shielding effectiveness.

- Am I shielded? Sometimes it makes sense to put the DUT in aluminium foil during EMC testing or use copper tape to identify radiating slots.

5. Practical examples and shielding tips



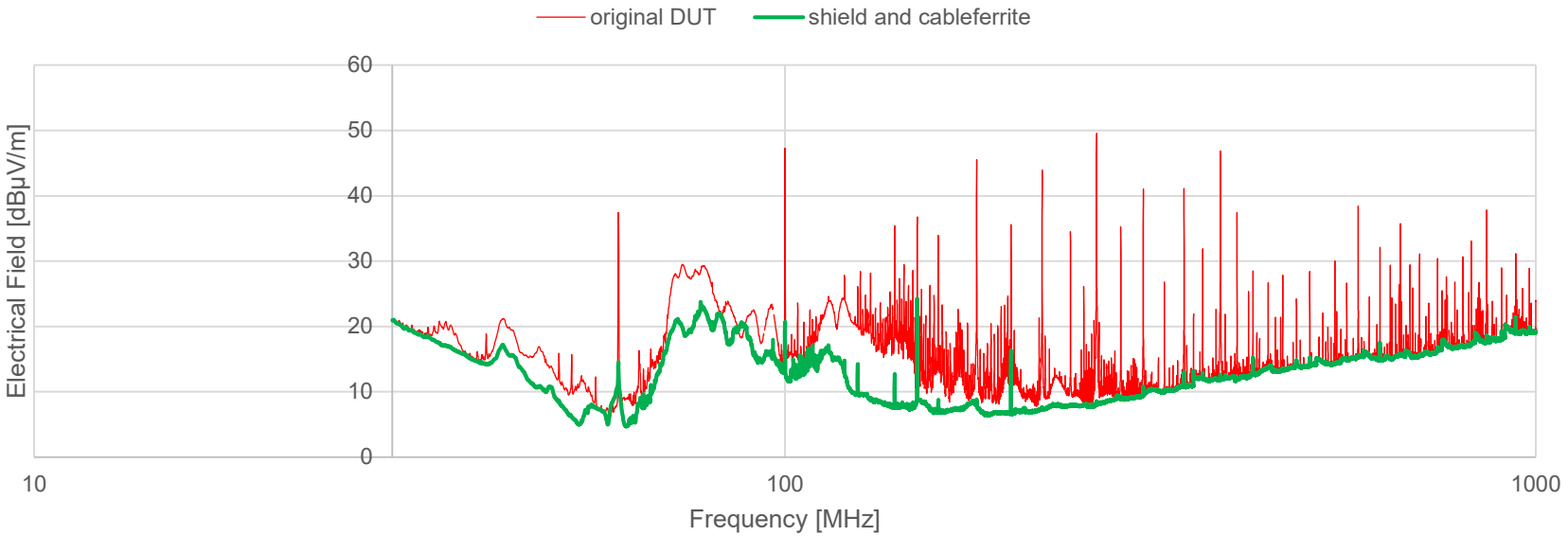
5. Practical examples – shielding issue
Debugging in the lab

- **Testing with aluminium foil:**

  - **Take care on interfaces leaving the shielding:**
    - **Use shielded cables, with good connected shield.**
    - **Use Filters.**
    - **Additional shielding not adequate shielded cables might be necessary.**
  - **Take care that the noise is not coming from auxiliary Equipment.**

5. Practical examples – shielding issue
Debugging in the Lab

- **Testing with aluminium foil will bring an improvement:**
  - **If all cables are shielded.**
  - **If all unshielded interfaces are filtered.**
  - **If the noise is coming from the DUT.**



- **With partly removing the EMC measures additional brought to the DUT, the optimized and relevant EMC measures can be identified.**

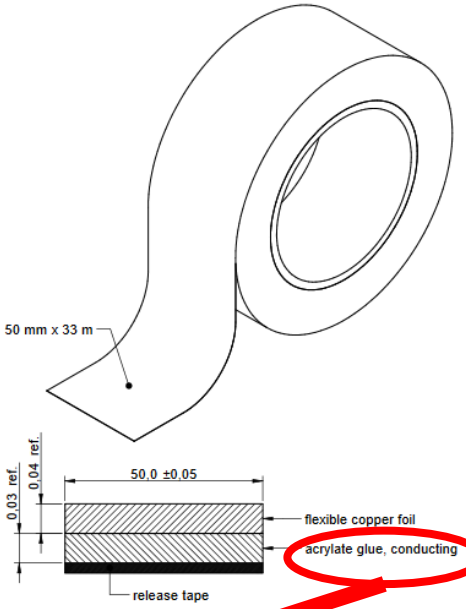
5. Practical examples – shielding issue

- **Why does barbecue foil and copper tape help to solve EMC issues?**

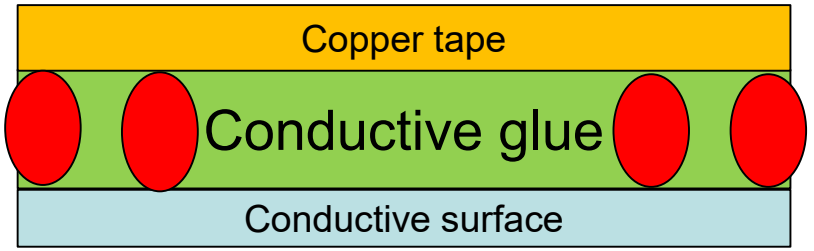
Sometimes you can even see the slot in the enclosure – this enclosure will not shield RF noise!

5. Shielding tip – Conductive Tapes

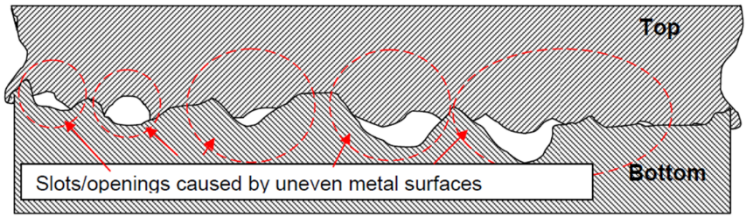
- The conductive glue is not fully conductive.
- There are conductive bubbles in the adhesive, which must be connected between the conductive part of the tape and the conductive surface, where it is glued to, by hard pressing.

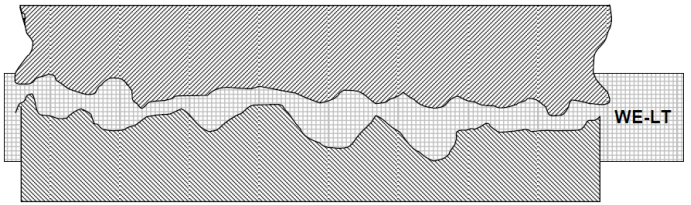


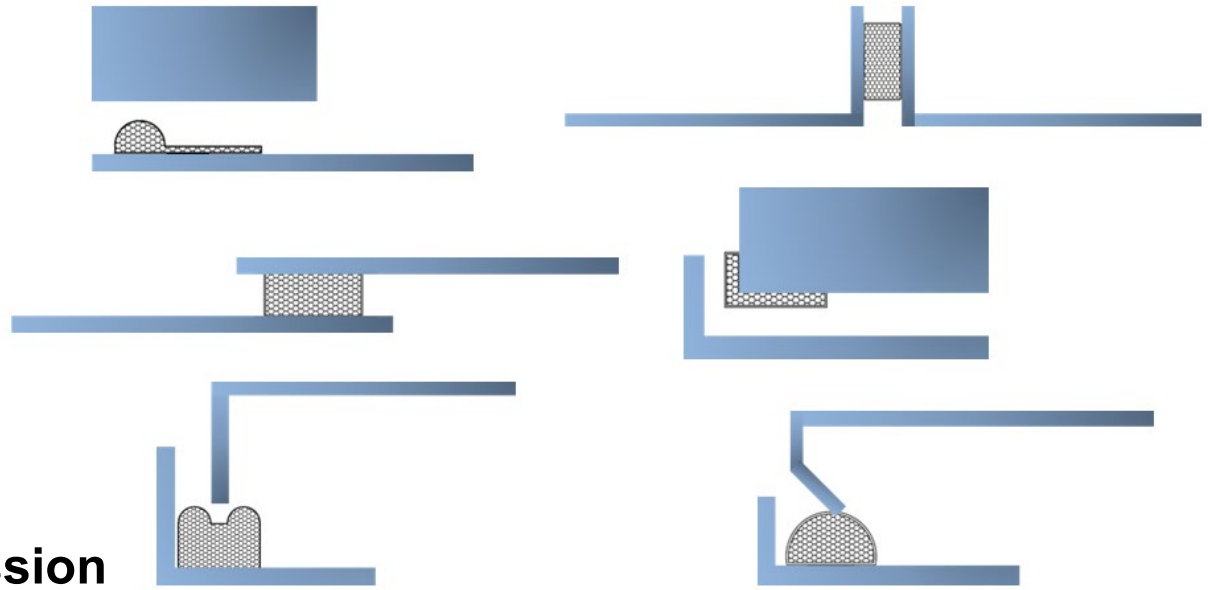
- Bubbles in glue (shown in red).
- Bubbles will connect the CU-Tape with the surface, when pressed.



5. Shielding tip – Reduce slots!





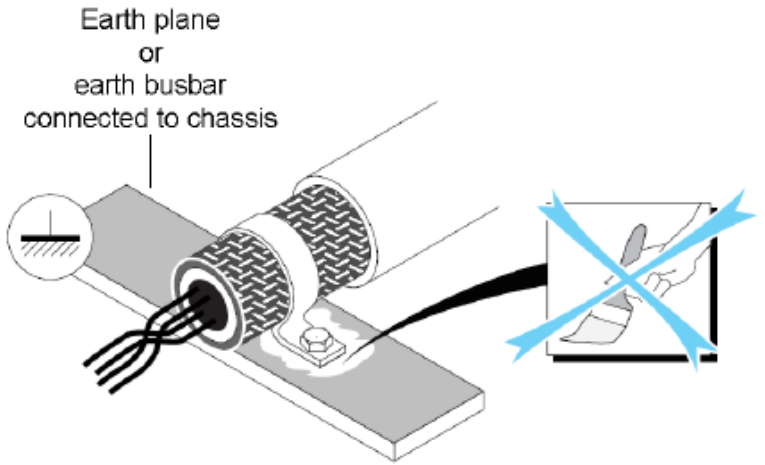


Thumb's rule:
20% Compression

5. Shielding tip – Take care of your surface

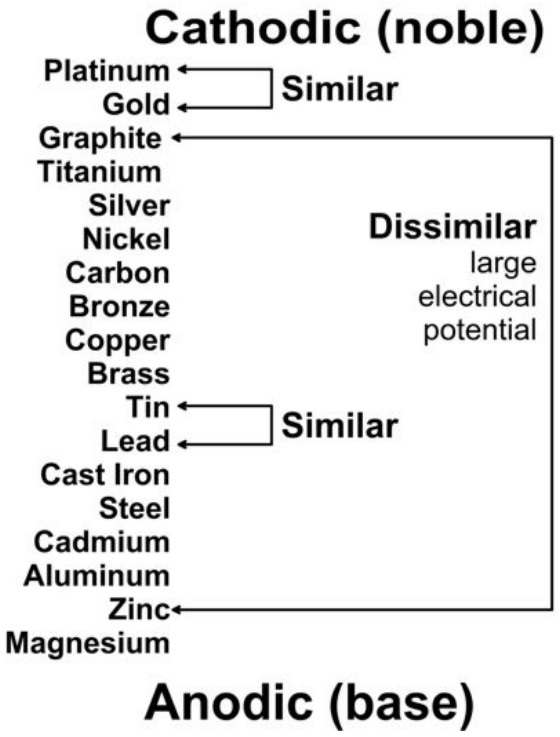
- **Application:**

  - **No paint on the connection of metallic enclosure parts.**
  - **No anodic treated aluminium on connections of metallic enclosure parts.**
  - **Take care for surface oxidation.**
  - **Take care for protection paint, when buying metal plates which may reduce surface conductivity.**



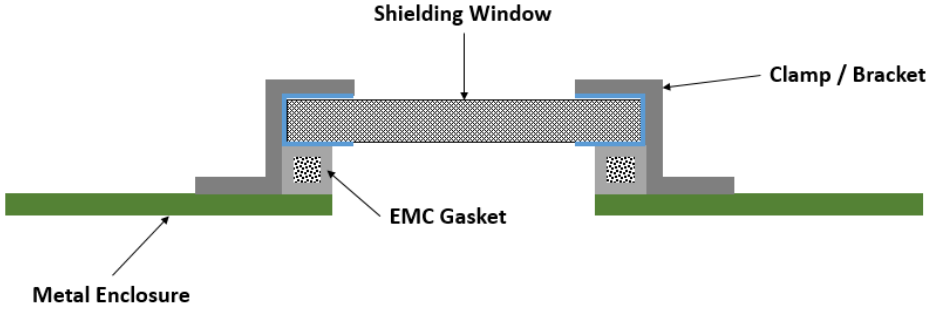
5. Shielding tip – Galvanic Corrosion

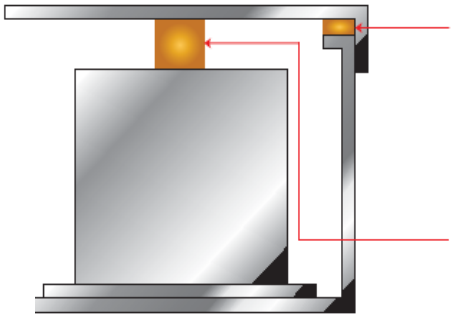
- **Selection of material pairing:**



5. Shielding tip – Connections between metallic plates

- **Take care at Displays:**
  - **Internal Shielding might be not sufficient (connection of different display layers).**
  - **Connection of backside shield of display to internal shield layer behind display glass might be not suitable.**
  - **Backside shield of display might be not conductive**
- **In this case, the Display can not be successfully included in a fully shielded device and should be changed!**



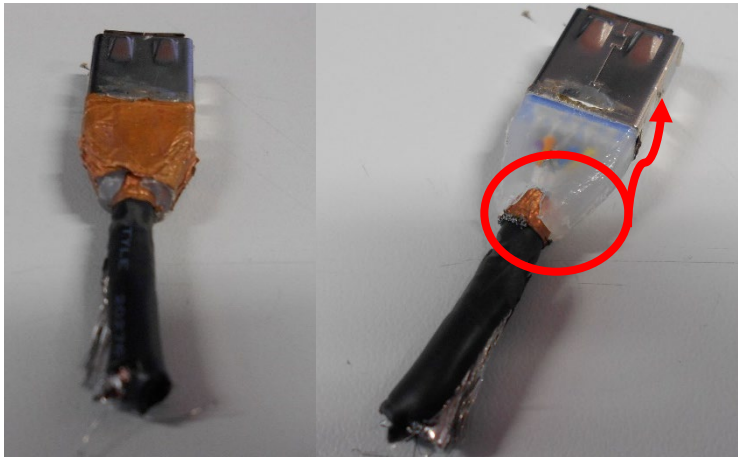


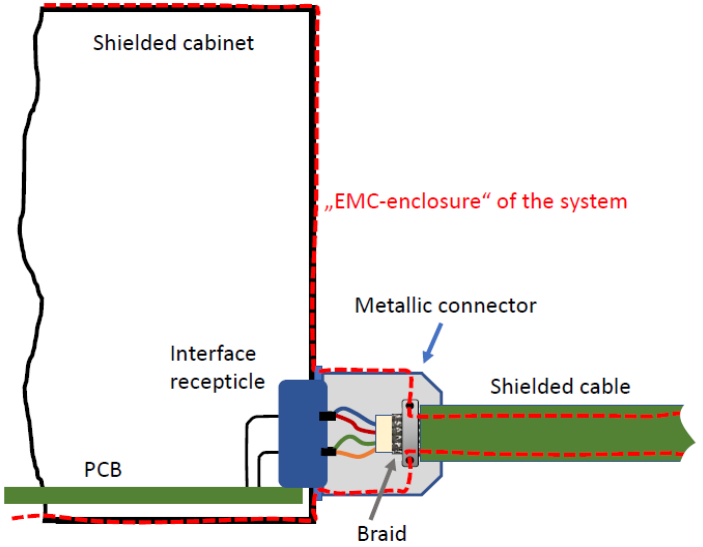
Shielding: Provides high electrical conductivity inside gaps

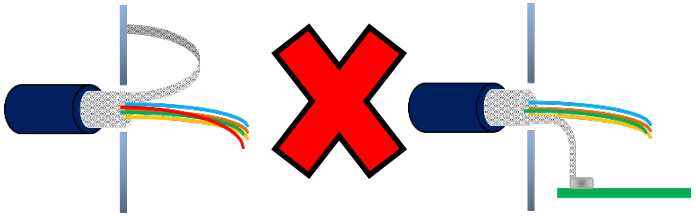
Grounding: Effective conduction path for low and high frequencies

5. Practical examples – shielding issue
Avoid Pigtails!

- **Bad Example – USB-Cable:**
  - **CU-Shield hides pig tail.**
  - **CU-Shield is not connecting on all sides.**
  - **Cable shield connected with pig tail only.**
  - **NOT a full connection.**
  - **Inductive coupling in pigtail loop.**







5. Shielding tip – 360º degrees shielding

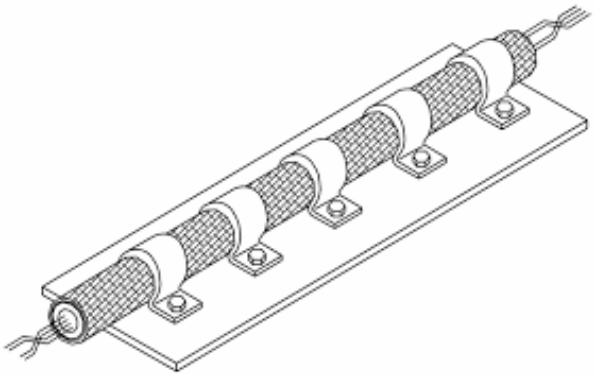
- **Avoid pig tails and connect shields fully an on all sides!**
- **Good Connection of an Coax-Cable – Shield connected on 360 ° to connector.**

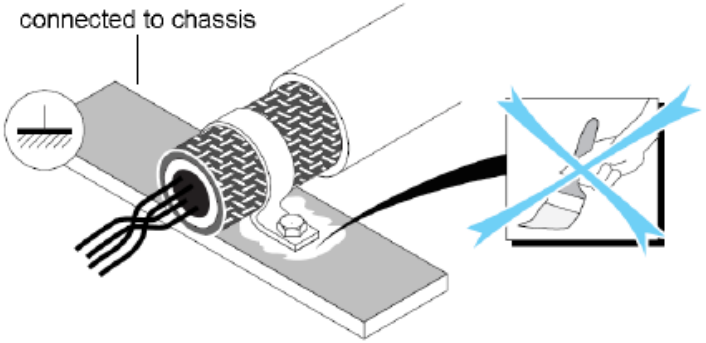
5. Shielding tip – Take care of you cable!

- **Shielding of cables and cable bundles:**

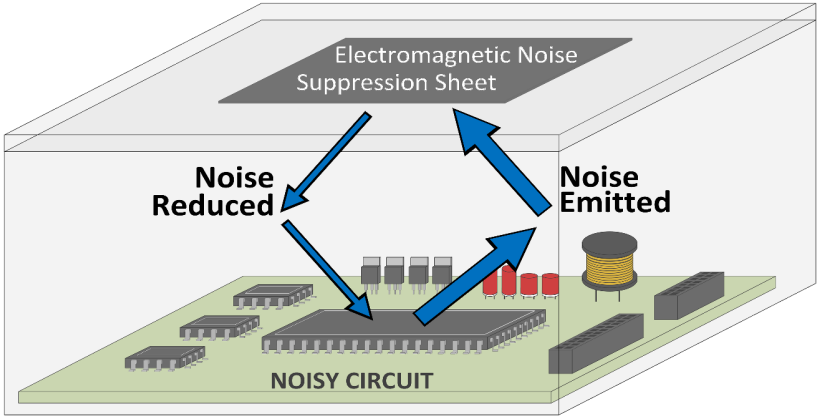
WE-ST

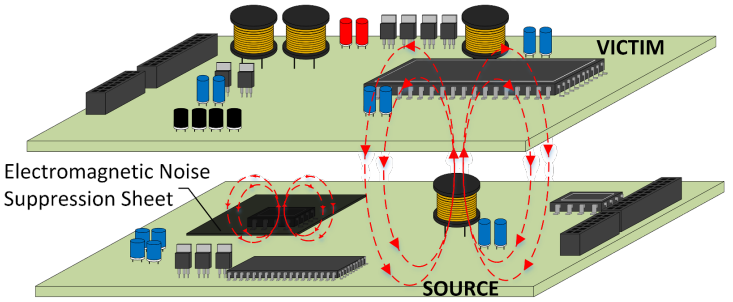
WE-EEL

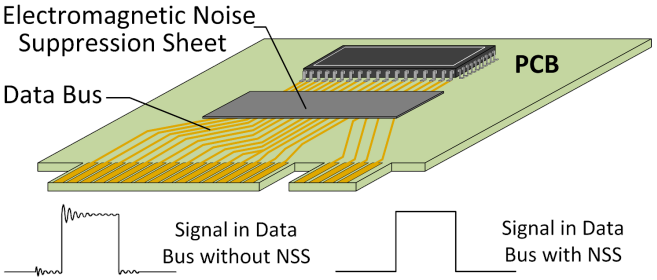




5. Shielding tip – Where to use a ferrite sheet

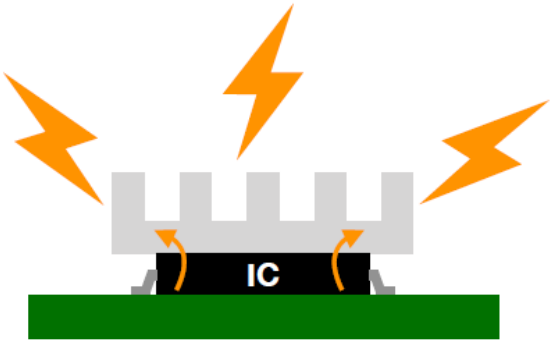




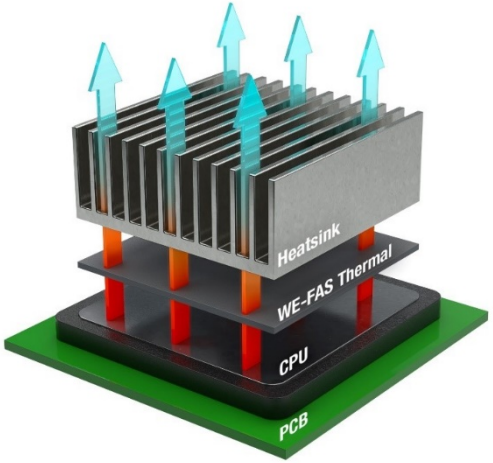


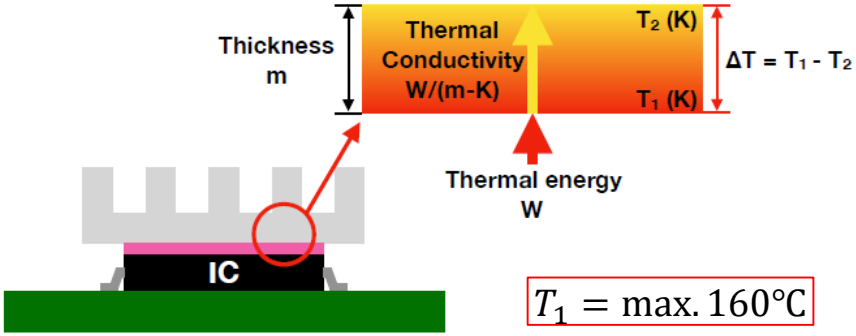
5. Shielding tip – Ferrite sheet + thermal solution

- **Applications for WE-FAS TC:**
  - **Shielding on hot surfaces like ICs, processors**



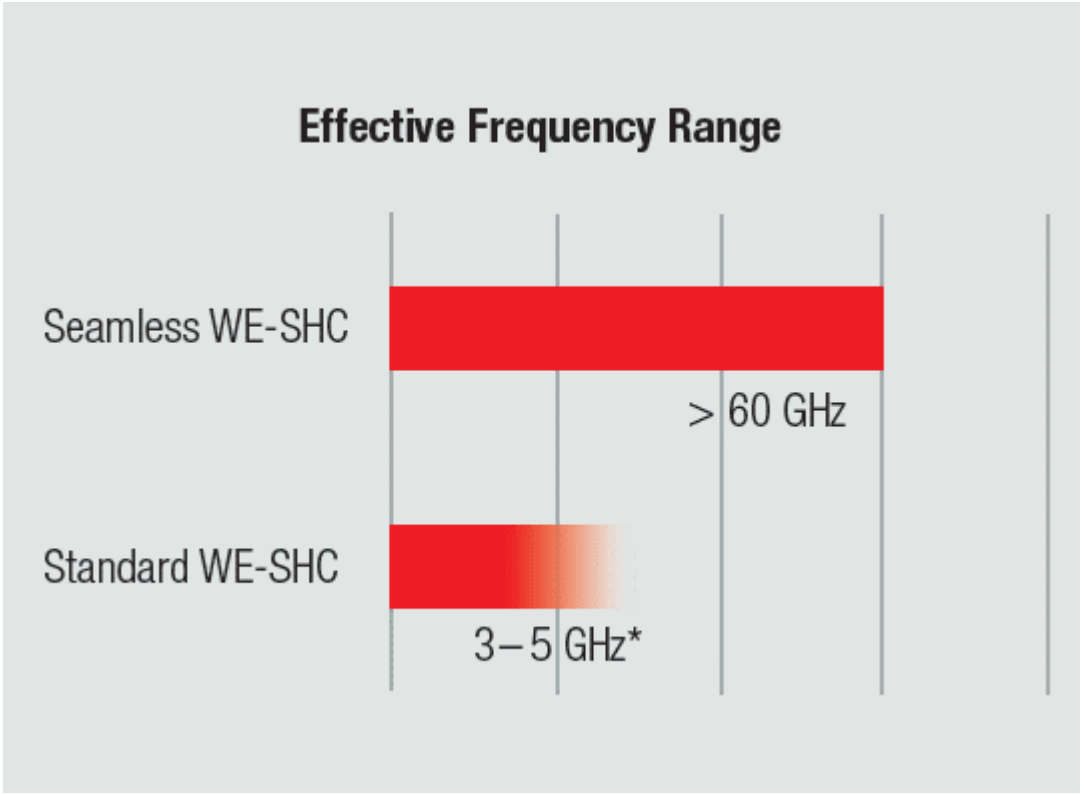
Heatsink acts as an antenna!





$T_1 = \max. 160°C$

5. Shielding tip – Cabinet for each frequency range

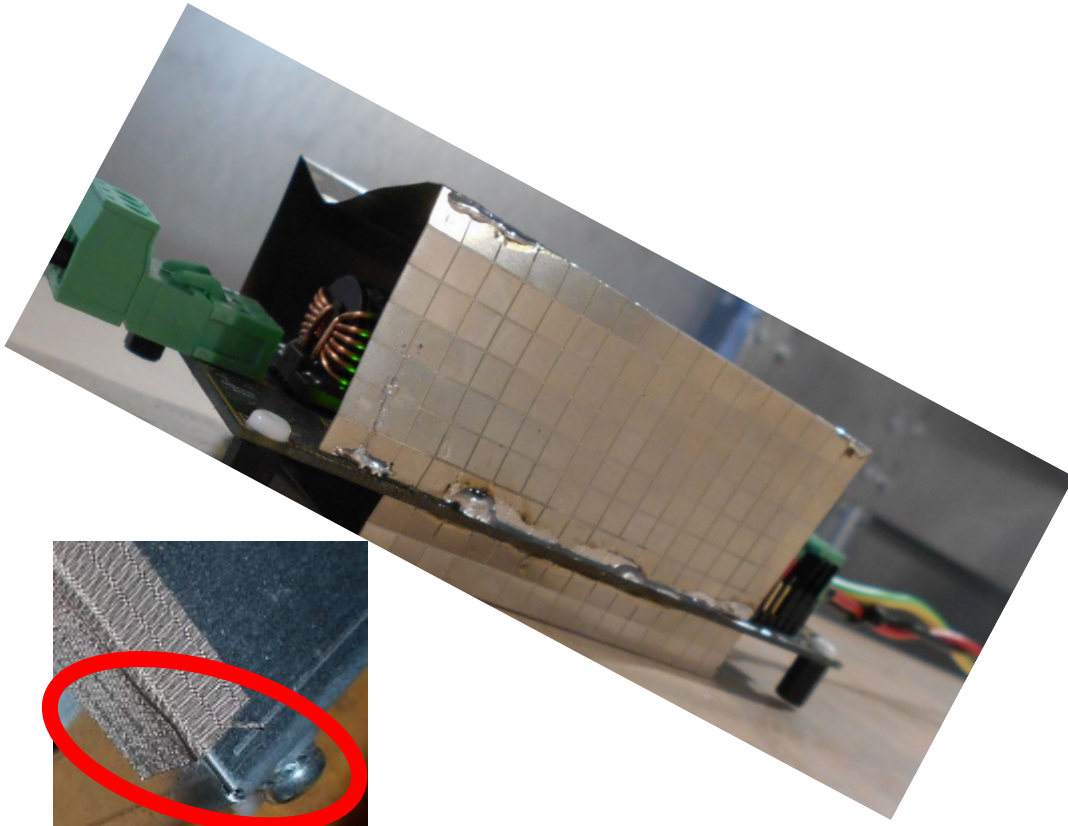


WE-SHC

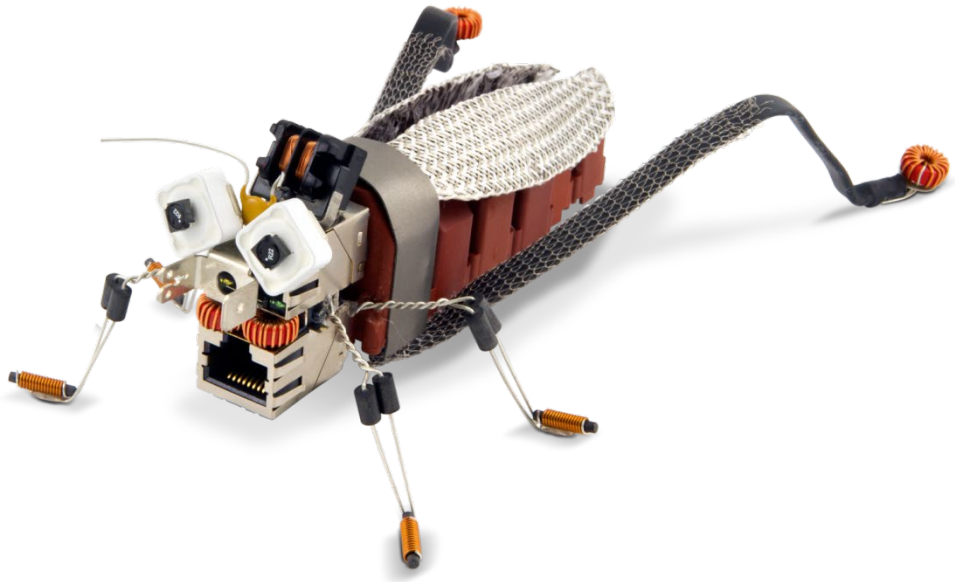
WE-SHC Seamless

5. Shielding tip – practical examples
How to implement the shielding measures?

- Aluminium foil is not an adequate measure for the mass production.
- Some ideas to implement the shielding materials in the series:
  - Gaskets.
  - Flexible tape.
  - PCB Shields.
  - Shielded enclosure.



Questions?



Thanks for your attention!

You can meet EMC and RF everywhere…