ELECTROMAGNETIC SHIELDING

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FAE & BDM

AGENDA

- Basics
- Apertures
- Shielding solutions
- Design tipps

BASICS

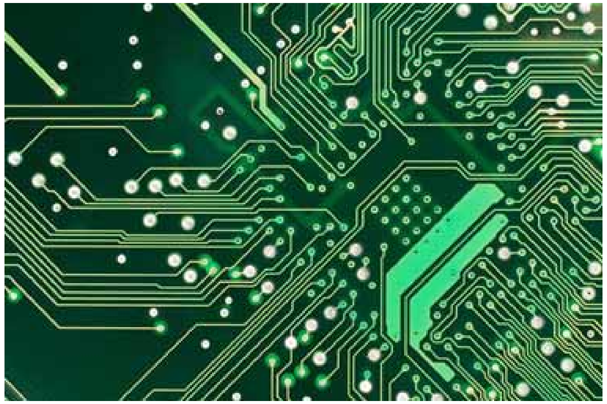
BASICS

What does “electromagnetic shielding” mean?

BASICS

- Electromagnetic fields are emitted or absorbed by electrically conductive structures.
- Antennas can be:

Cables, interfaces, housing openings

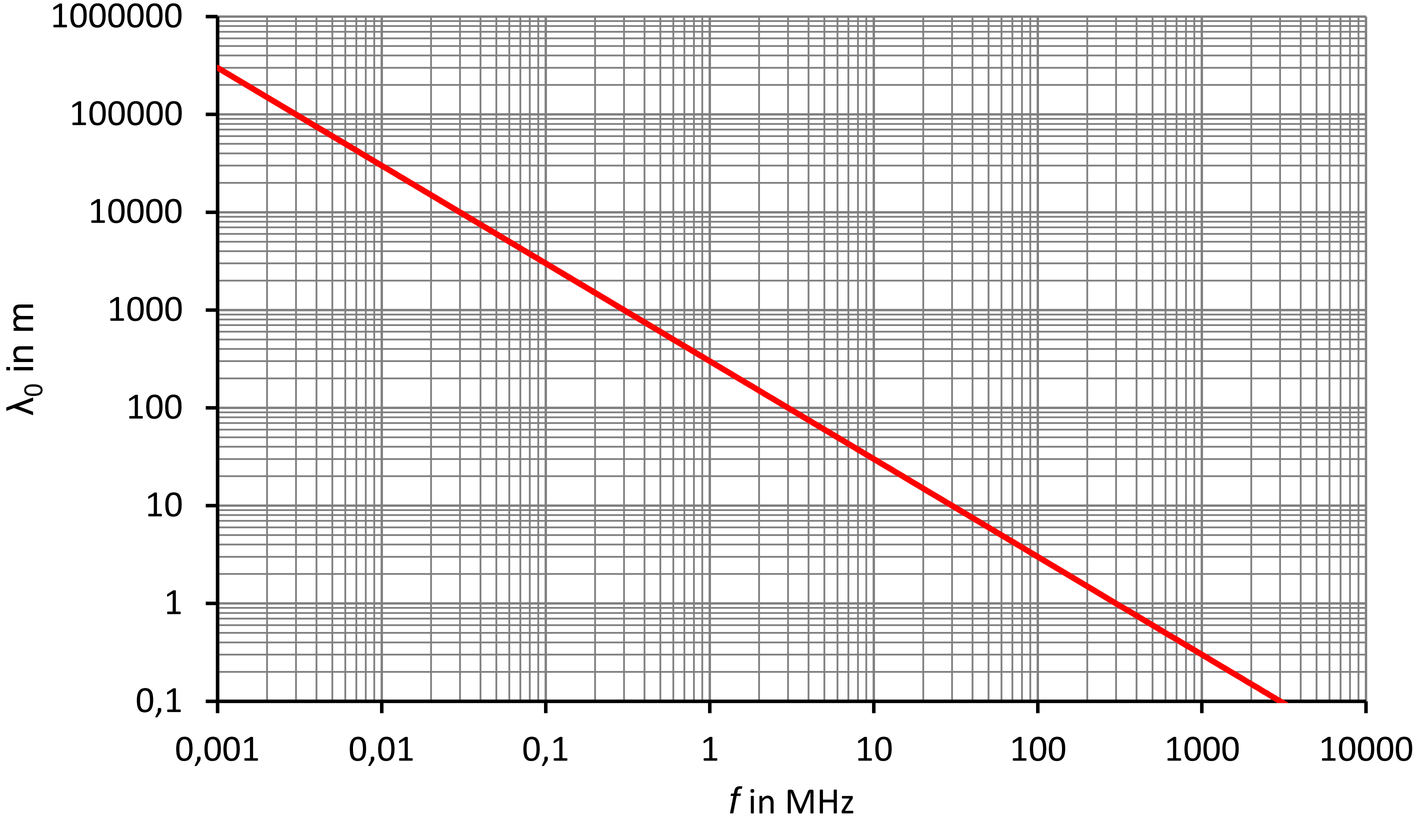


Conductor tracks, ground planes, vias, slots

Components, heat sinks, integrated circuits

BASICS

Wavelength



- Relationship between frequency and wavelength

$$\lambda_0 = \frac{c_0}{f}$$

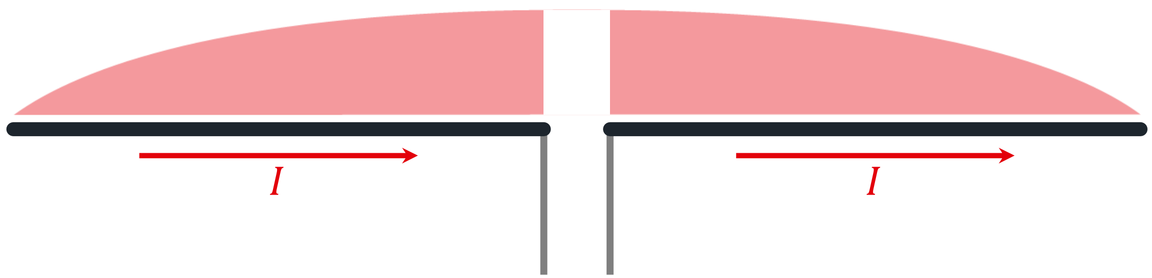
- Examples:

$$f = 500\text{kHz} \rightarrow \lambda_0 = 600\text{m}$$
$$f = 8\text{MHz} \rightarrow \lambda_0 = 37{,}5\text{m}$$
$$f = 100\text{MHz} \rightarrow \lambda_0 = 3\text{m}$$
$$f = 2{,}45\text{GHz} \rightarrow \lambda_0 = 12{,}5\text{cm}$$

BASICS

Half-wavelength dipole

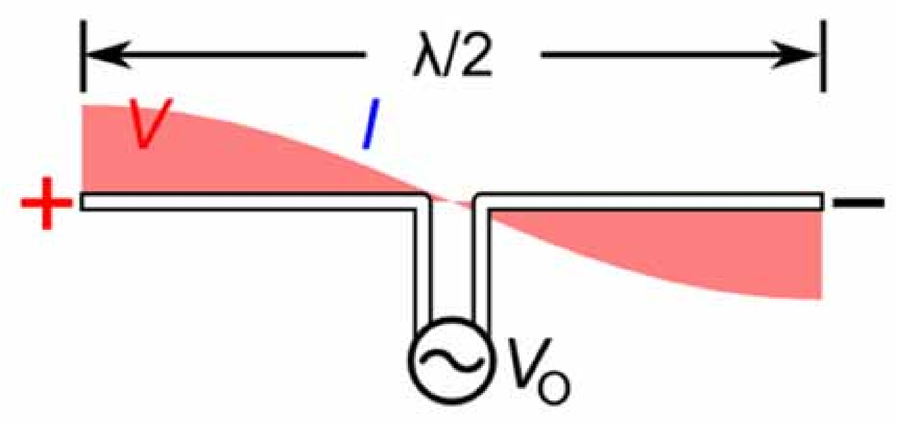
- A conductive structure is not a **proper antenna** for each frequency.
- The **relation** between the structure dimension and the wavelength is crucial.
- The relation is optimal if the structure length is equal to **half of the wavelength** (half-wavelength dipole).
- A significant antenna effect is observable for a length up **one twentieth** of the wavelength.



BASICS

Elementary dipole

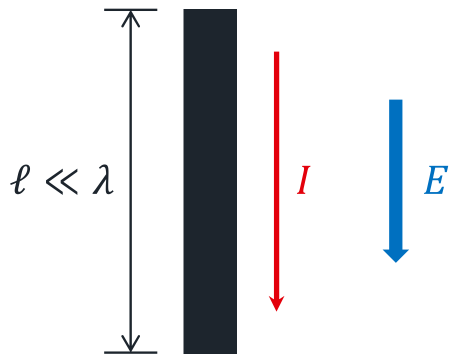
- The most basic antenna is an **electric** (Hertzian) **dipole**. Its length ℓ is small compared to the **wavelength** considered.
- Along its dimension a locally constant, temporally changing current I is flowing. Charges are accumulated at the ends.
- The electric dipole generates an **electric field**.



BASICS

Elementary dipole

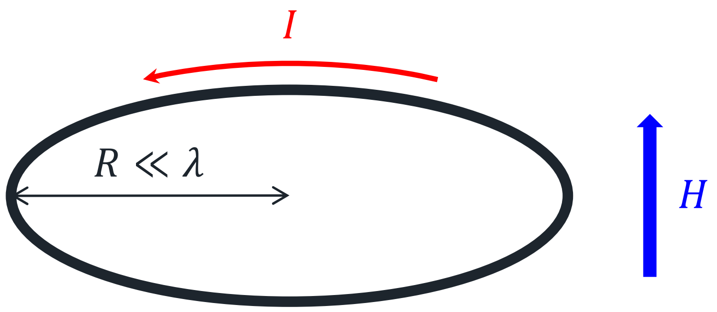
- The simplest antenna is an **electric** (Hertzian) **dipole**. Its length ℓ is small compared to the wavelength under consideration.
- A locally constant, time-varying current I flows along its length.
- Charges collect at the ends. The electric dipole creates an electric field.



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**.



BASICS

Characteristic wave impedance

- The **characteristic wave impedance $\boldsymbol{Z_{\mathrm{W}}}$** is equal to the relation of the electric field strength to the magnetic field strength at a distance r from the antenna.

$$Z_{\mathrm{W}} = \frac{E}{H}$$

- Characteristic wave impedance of the electric dipole in the **near field**:

$$|Z_{\mathrm{W,e}}| = Z_{\mathrm{W0}} \cdot \frac{\lambda}{2\pi r}$$

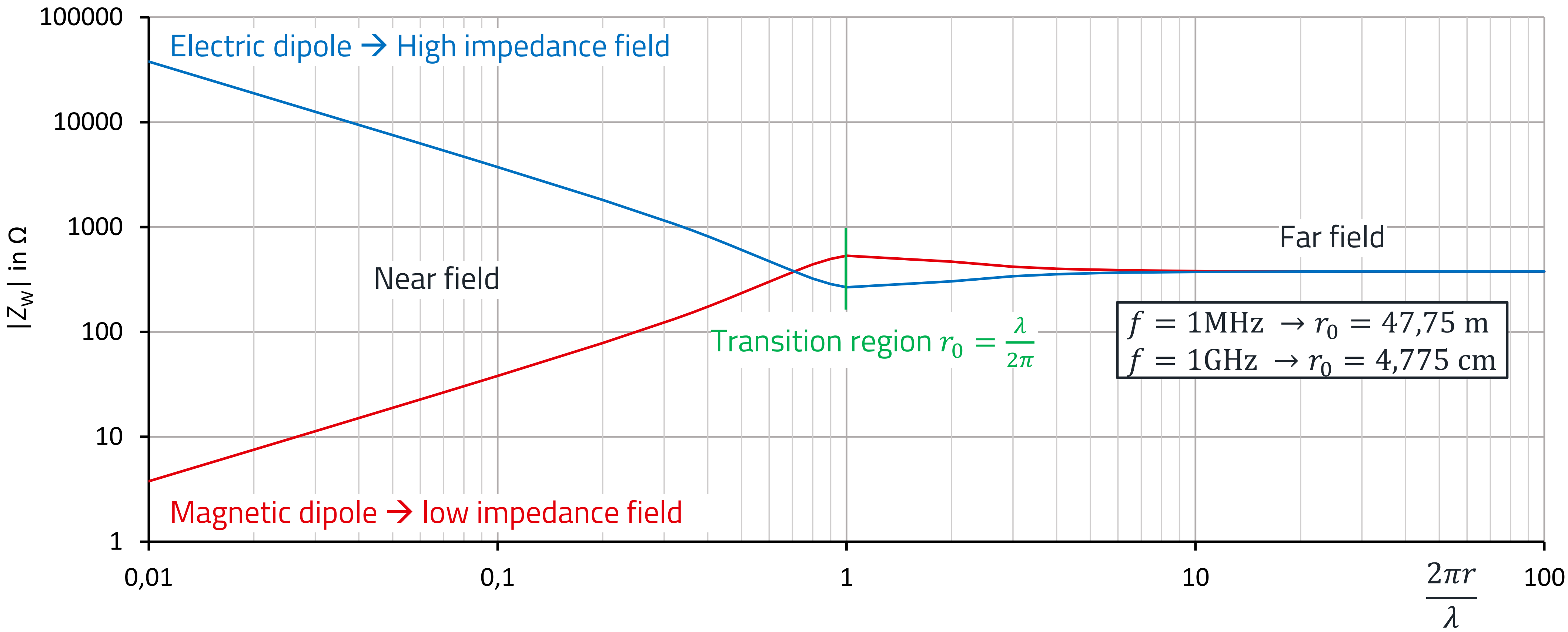
- Characteristic wave impedance of the magnetic dipole in the **near field**:

$$|Z_{\mathrm{W,m}}| = Z_{\mathrm{W0}} \cdot \frac{2\pi r}{\lambda}$$

- The factor $\boldsymbol{Z_{\mathrm{W0}} = \sqrt{\mu_0 / \varepsilon_0} = 377\Omega}$ is named the free-space characteristic wave impedance (**far field**).
- From an EMC perspective most of the relevant noise sources can be described by one of the elementary dipoles.

BASICS

Characteristic wave impedance



BASICS

Shielding of magnetic fields

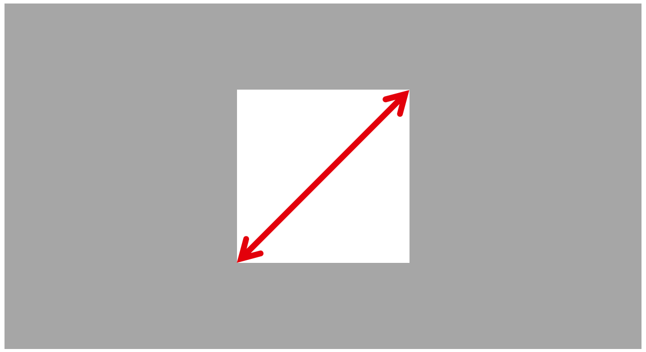
- Shielding of magnetic fields is more difficult, particularly static and low-frequency fields.

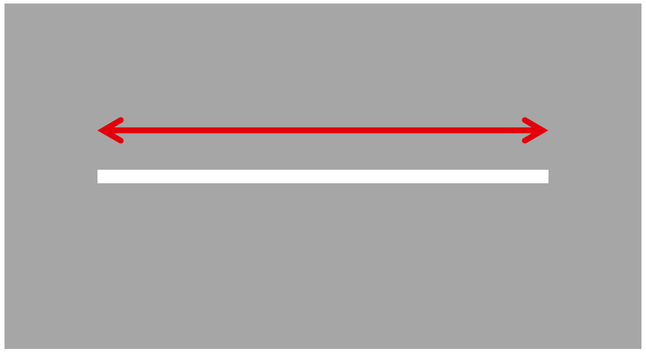
- Categorization of shielding solution types:
  - Against static and low-frequency fields → **High-permeable** materials
  - Against medium-frequency fields → Using of **skin effect**
  - Against high-frequency fields → **Reflection** and **absorption**

APERTURES

SHIELDING APERTURES

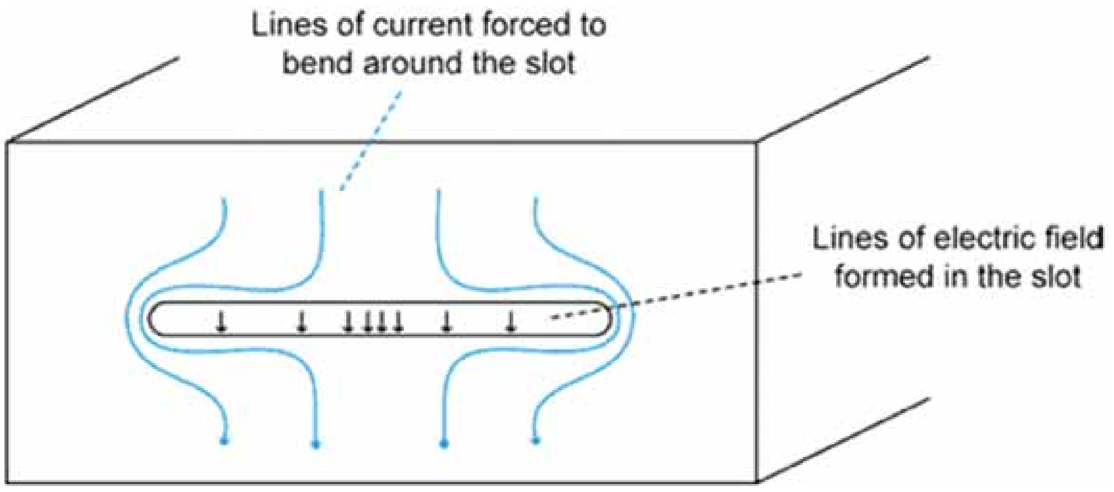
- The limit for determining the shielding attenuation by **measurement** lies at 120 dB.
- There's no perfect shield, i.e. completely closed.
- There is a greater impact of **apertures** in the shield on the magnetic shielding attenuation than on the electric shielding attenuation.
- For higher frequencies the **decrease** in shielding effectiveness due to leakage is more significant than the **theoretical** shielding attenuation of a material.
- The **maximum linear dimension** of an aperture is crucial, not its area.





SHIELDING APERTURES

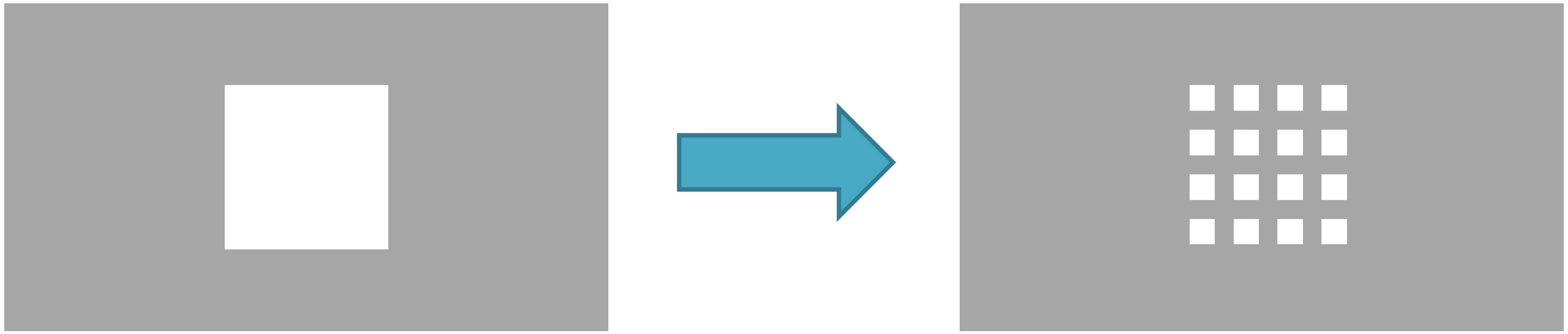
- A term used with enclosures and apertures is “Slot antenna”



- Horizontal slot = Vertical Electric field
- Vertical slot = Horizontal Electric field

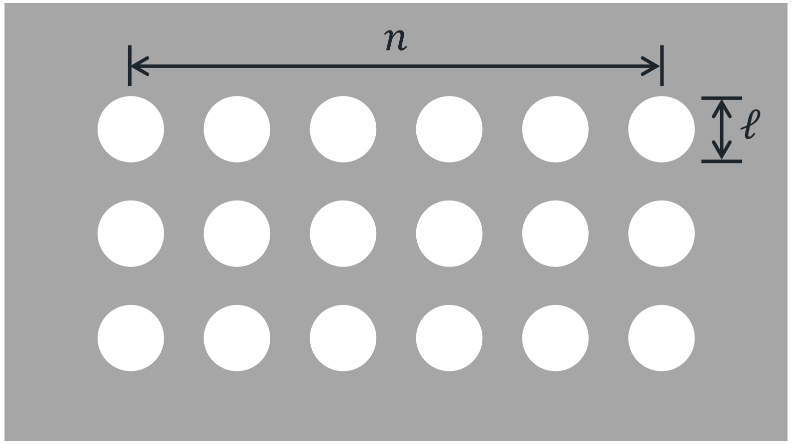
SHIELDING APERTURES

- 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**.



SHIELDING APERTURES

- For a two-dimensional **breadboard** the maximum number of holes lying **in a single row** is crucial for the reduction in shielding effectiveness.



- Shielding attenuation with apertures:

$$A_{\mathrm{S,Ap}} = 20 \cdot \log\left(\frac{\lambda}{2 \cdot \ell \cdot \sqrt{n}}\right) \mathrm{dB}$$

SHIELDING APERTURES

- Maximum slit length for 20 dB attenuation:

Frequency in MHz	Length in cm
30	50
50	30
100	15
300	5
500	3
1000	1,5
3000	0,5
5000	0,3

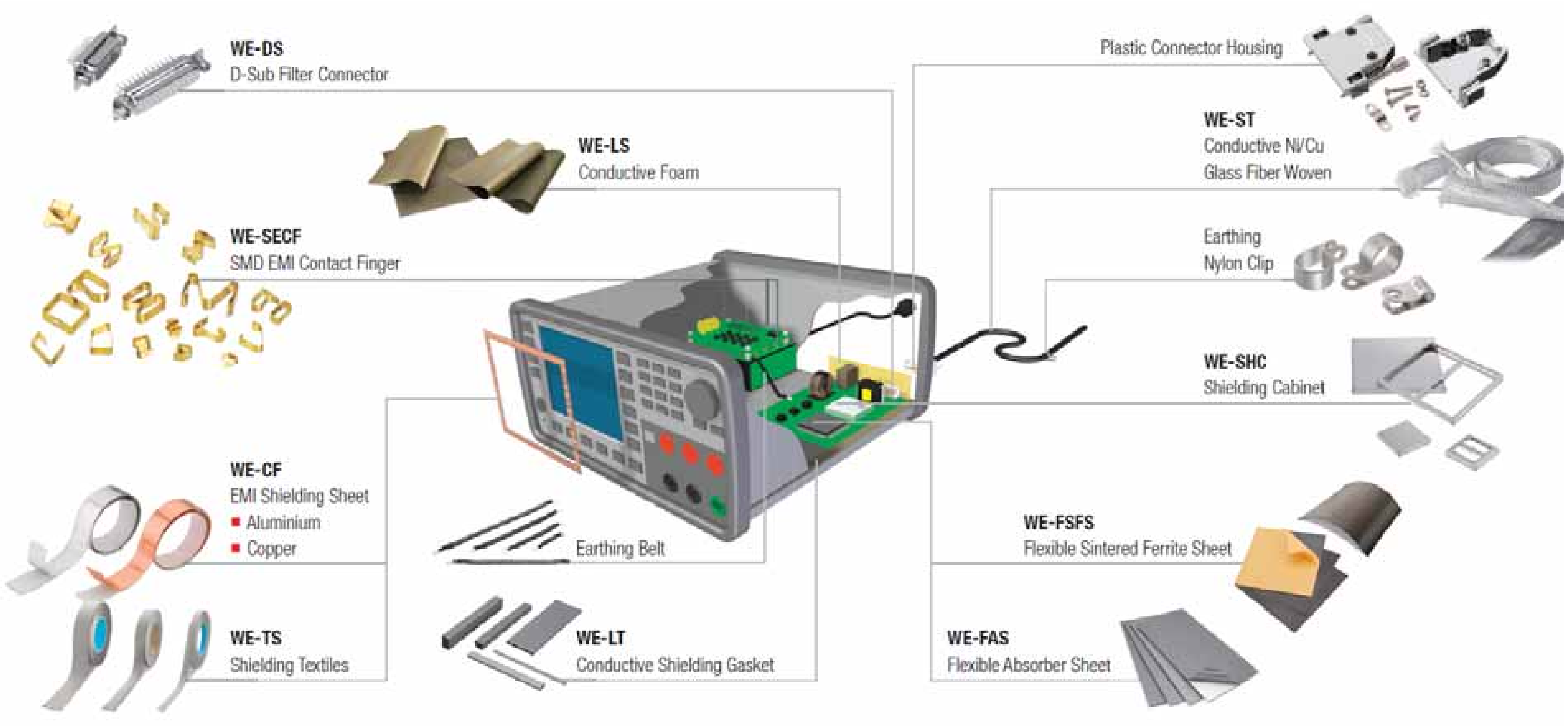
- Decrease in shielding attenuation for $n > 1$:

n	ΔA_S in dB
2	-3
4	-6
6	-8
10	-10
20	-13
40	-16
80	-19
100	-20

SHIELDING SOLUTIONS

SHIELDING SOLUTIONS

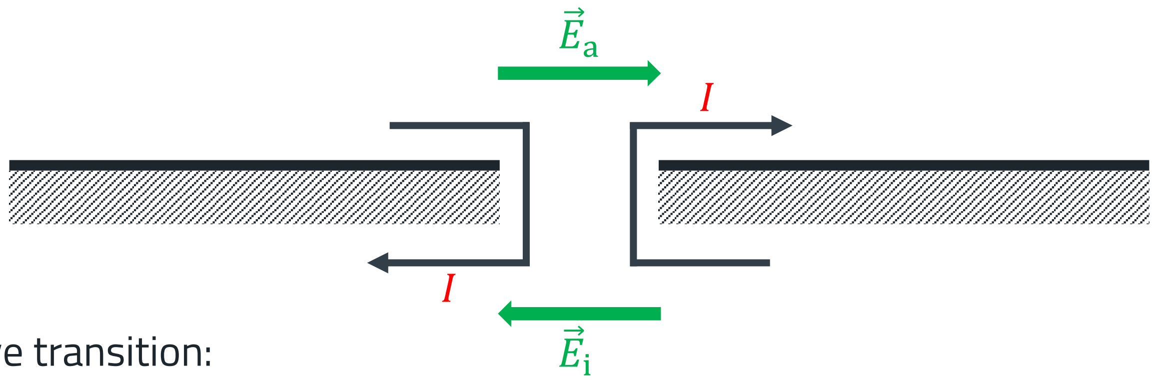
Overview



SHIELDING SOLUTIONS

Casing joints

- It is important to ensure a **large-scale conductive transition** at joints of a casing (edges, covers, doors).
- Joint without a conductive transition:

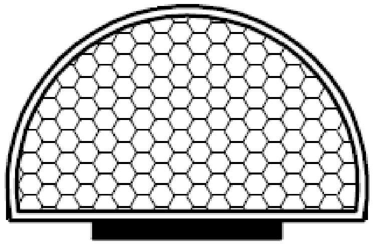


- Establishing a conductive transition:
  - Conductive fabric gasket
  - Spring contact strip

SHIELDING SOLUTIONS

Casing joints

- Conductive fabric gasket consists of **foam material**, surrounded by **nickel-copper fabric**. Adhesive tape is attached on one side.
- Maximum degree of protection: IP54
- Fire protection in railway applications → EN 45545-2:2013+A1:2015 → R22/R23



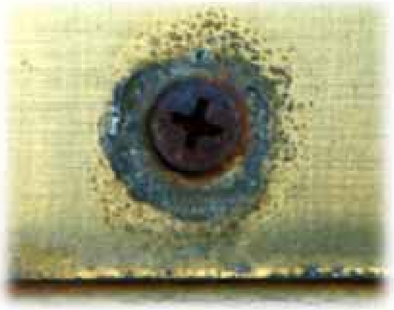
- Application examples:

SHIELDING SOLUTIONS

Casing joints: Beware of galvanic corrosion!

- Suitability of material pairings:

Base material	Nickel-copper	Aluminum
Zinc	––	++
Aluminum	––	++
Copper	+	–
Tin	+	–
Nickel-silver	+	–
Lead	+	–
Nickel	++	––
Silver	++	––
Nickel-copper	++	––
Gold	++	––



EMC GASKETS

- **How we can choose the proper EMC gasket?**
- Types of EMC Gaskets

  - Elastomer Gaskets (WE-EGS)→ Conductive filler mixed with rubber material

  - Conductive Fabric over Foam Gasket (WE-LT)→ Conductive textile wrapped over a PU sponge core

  - Contact Stripe Gasket (WE-CSGS) → Made of elastic metallic material

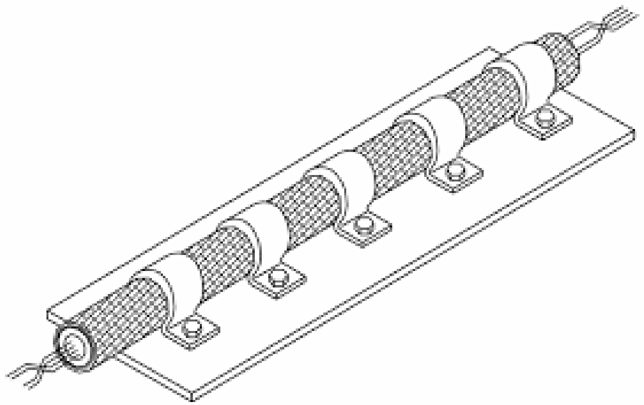
  - Knitted wire mesh gaskets (WE-GS)→ Composed mainly by a metallic wire mesh

SHIELDING SOLUTIONS

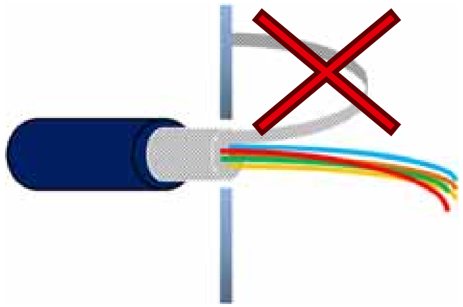
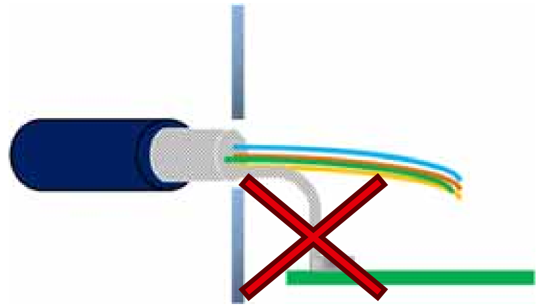
Cable

- Shielding of cables and cable bundles:





- Avoiding the following types of connection:

SHIELDING SOLUTIONS

Cable

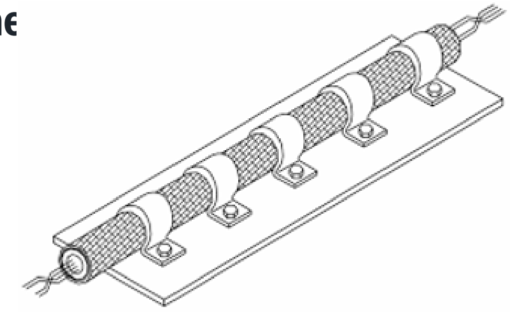
- Shielding of **flat wire cables** with conductive textile or metallic adhesive tape:

WE-FAS doesn’t require grounding. We will see it soon…

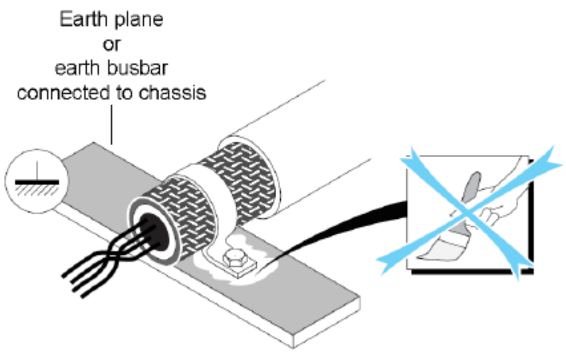
- Electric contact at both ends is necessary.

SHIELDING CABLES TIPS

- **Shield connected on 360° to the**



- **Don't use any type of painting on the connection metal clip- ground plane**



SHIELDING SOLUTIONS

CUSTOMIZABLE PRODUCT SERIES

Interface

- Filtered **D-SUB interface** for RS-232, RS-485 or power supply (max. 5 A @ 100 V_{DC}):

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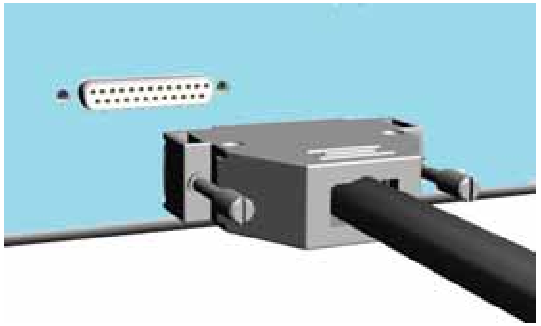
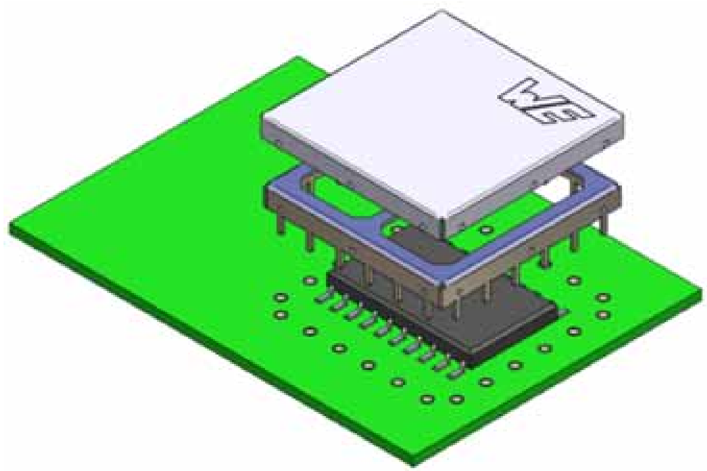


- D-SUB filter adapter:

SHIELDING SOLUTIONS

Circuit board

- **Copper ground planes** act as electrical shielding.
- Interfering or sensitive components/circuit parts can be **locally** electrically shielded.

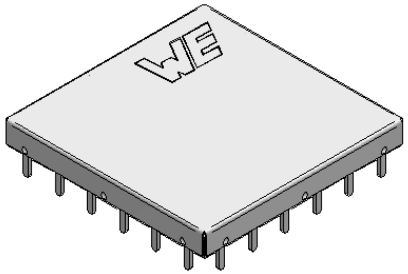
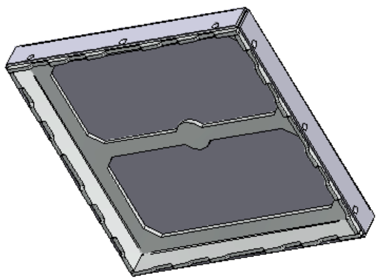


- Important: Low impedance connection to the local circuit ground

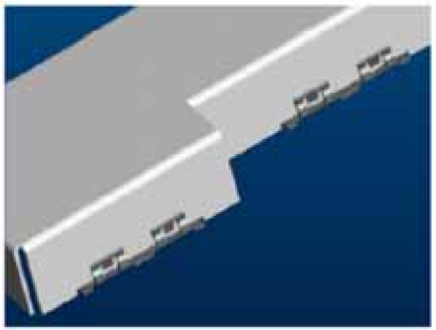
SHIELDING SOLUTIONS

Circuit board

- One or two-piece housing:

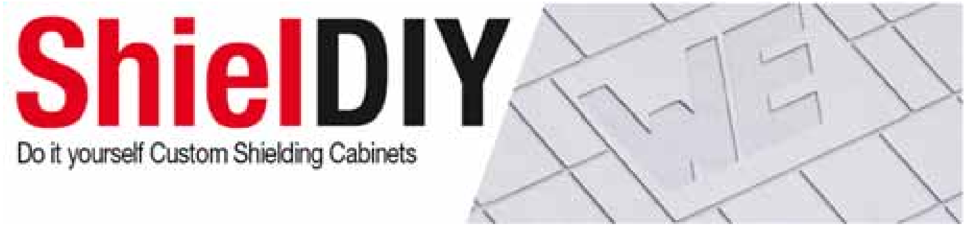
- SMT brackets:

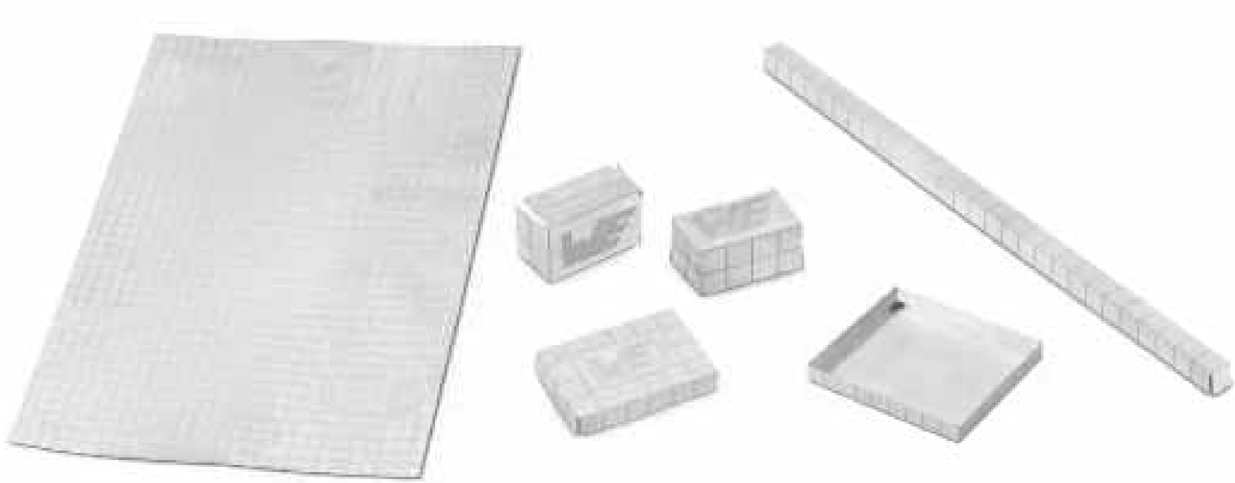



SHIELDING SOLUTIONS

Circuit board

- Do-it-yourself shield housing:
  - Tinned steel plate (0.2mm)
  - Square grid (5mm)





DESIGN KITS: BOARD LEVEL SHIELDING (CABINETS)

- **PCB Grounding Contacts: 367001**

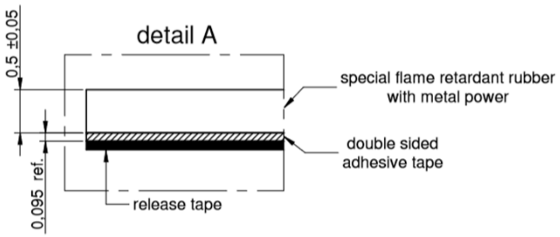
- **PCB Grounding Contacts: 367001**

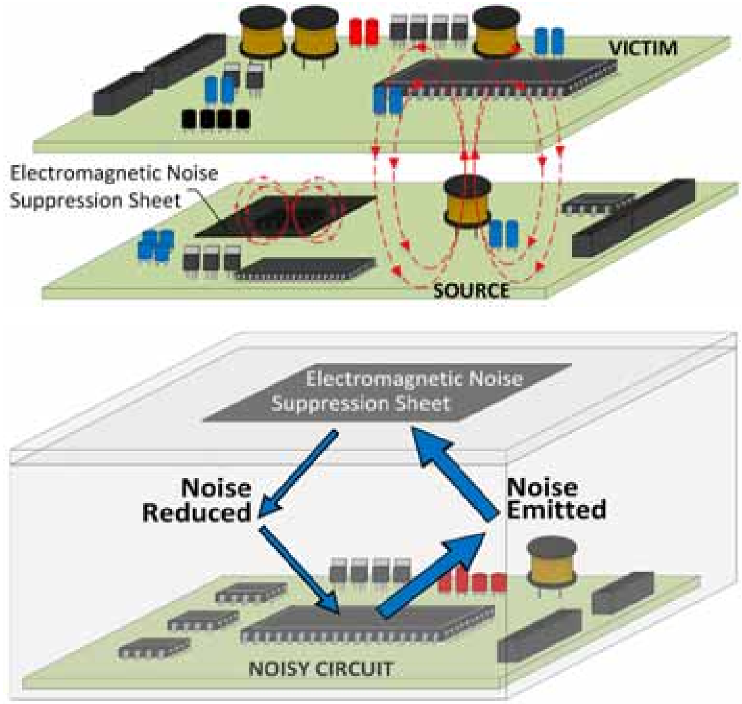
- **ShielDIY Custom Shielding Cabinets: 360002**

SHIELDING SOLUTIONS

Circuit board/housing

- **Flexible absorber** film **WE-FAS** with adhesive surface for attachment to the circuit board or housing
- Mode of action → **Reflection** and **absorption** in the near and far field

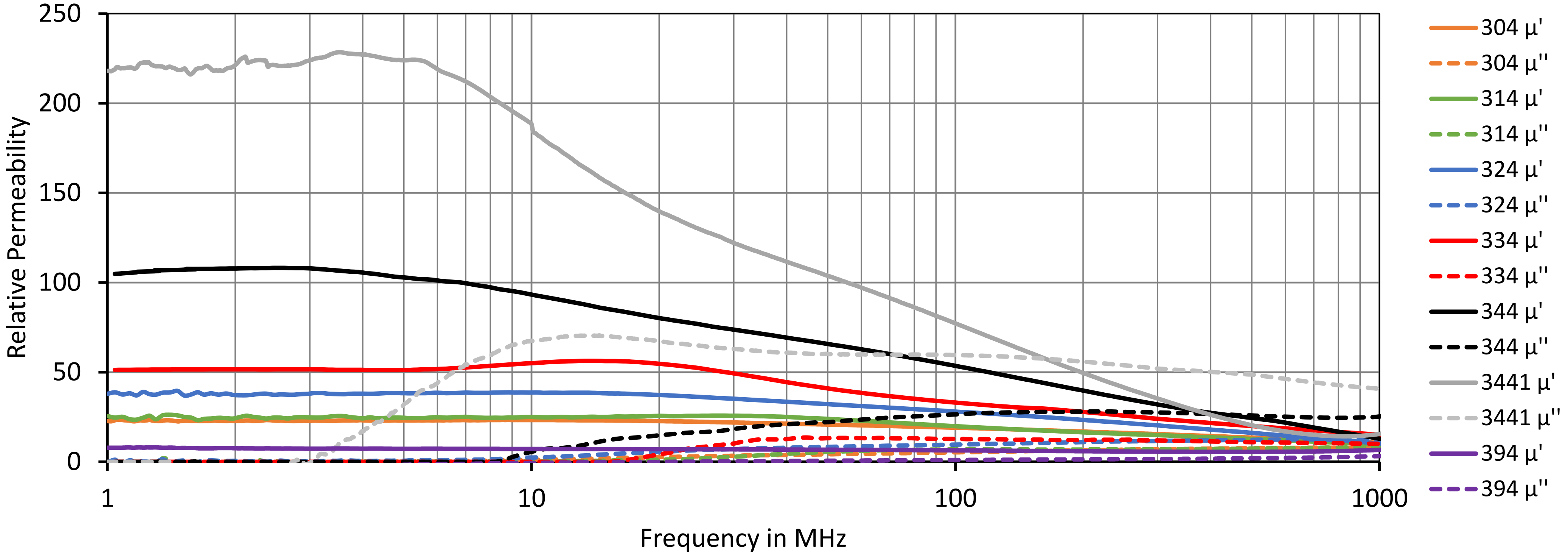




SHIELDING SOLUTIONS

Circuit board/housing

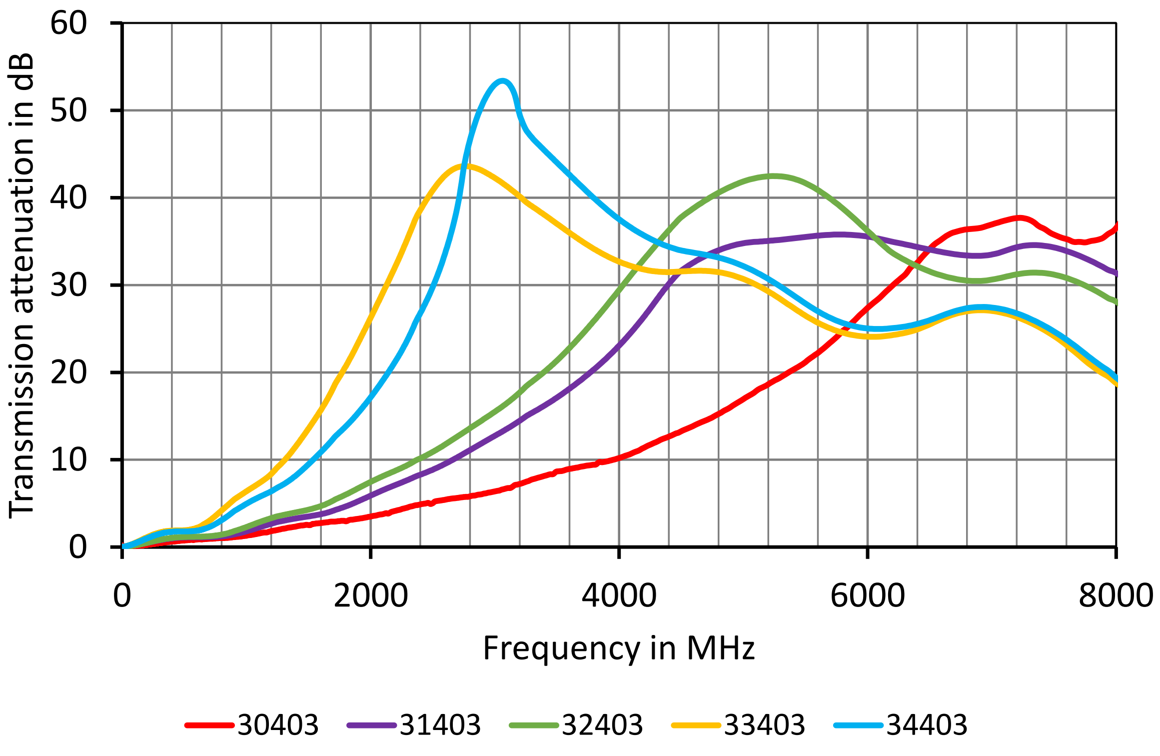
- Complex relative permeability of **WE-FAS** materials:

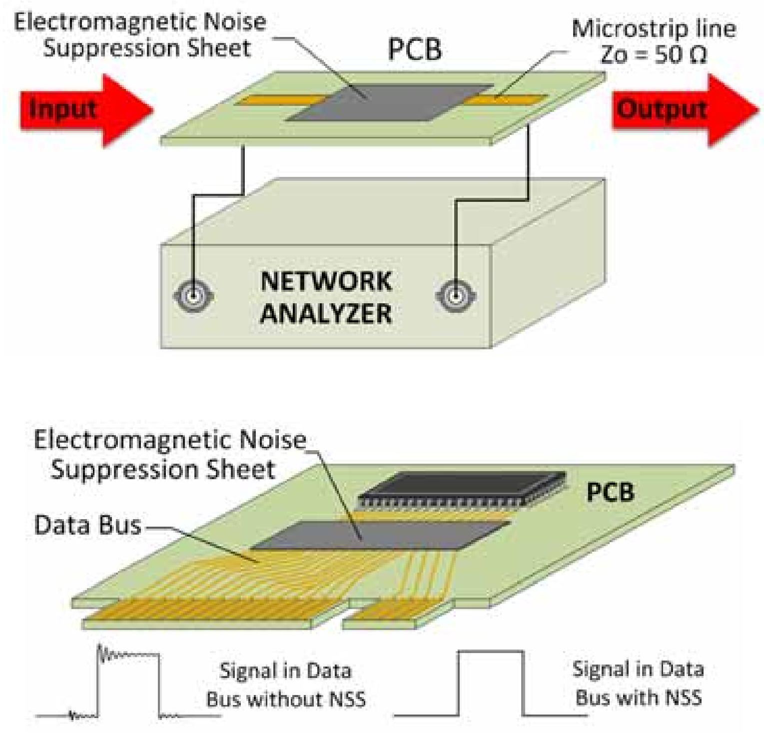


SHIELDING SOLUTIONS

Board Level Shielding/Housing

- Transmission attenuation dependent on the material (thickness: 0,3 mm):

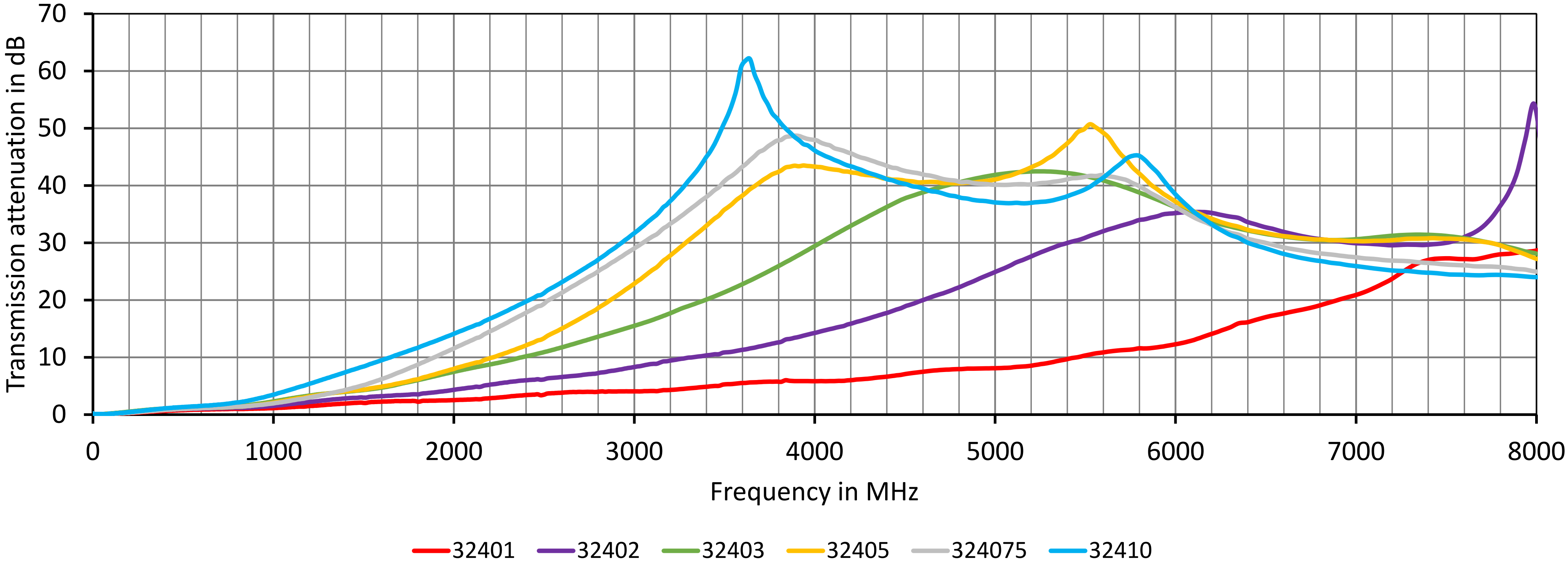




SHIELDING SOLUTIONS

Board/housing

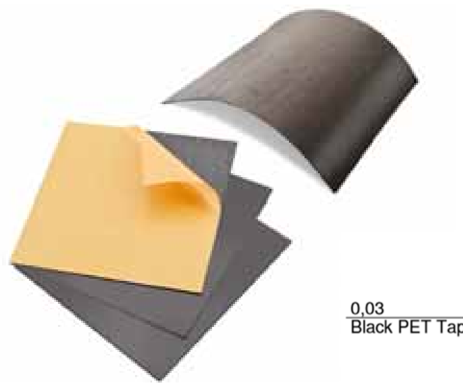
- Transmission attenuation dependent on the material thickness (material 324; 0,1…1 mm):

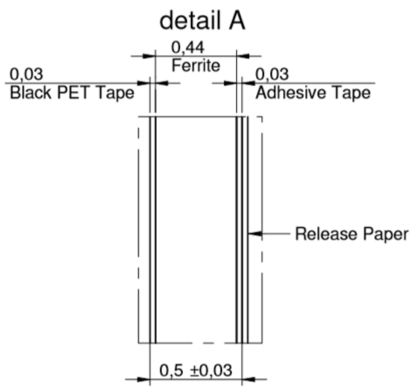


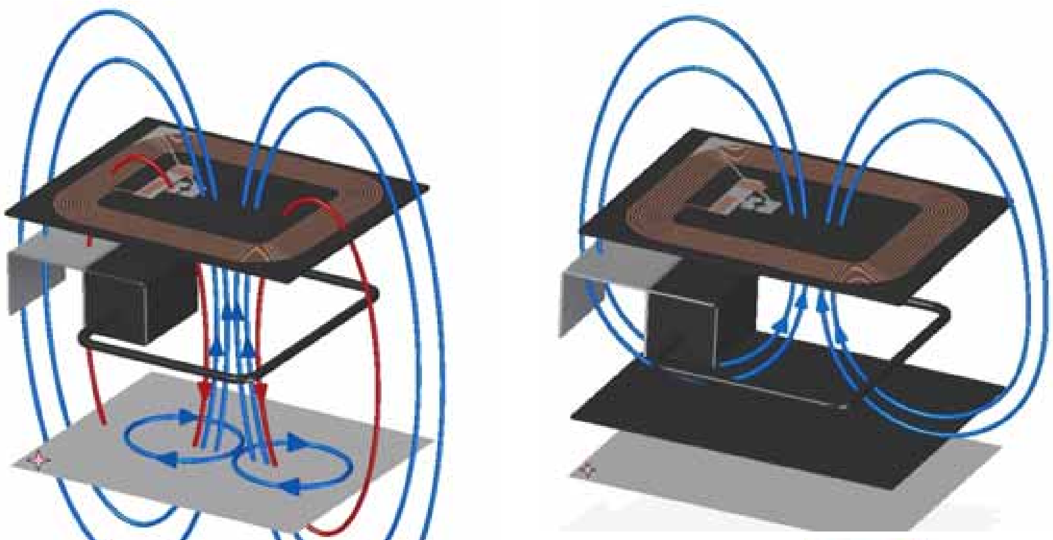
SHIELDING SOLUTIONS

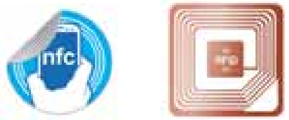
Board/Housing

- Flexible ferrite plate WE-FSFS with adhesive surface for attachment to the circuit board or housing
- How it works → **reflection** in the near field, **deflection** of the magnetic field lines
- Application → NFC, RFID, wireless charging technology





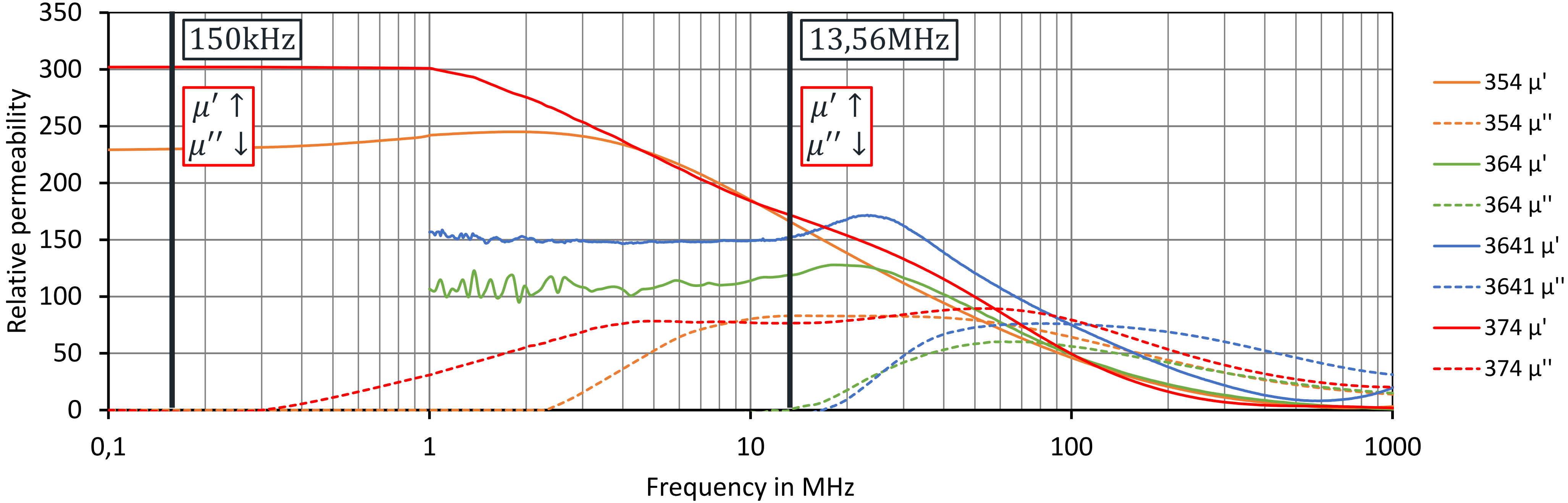




WE-FSFS

Circuit board/housing

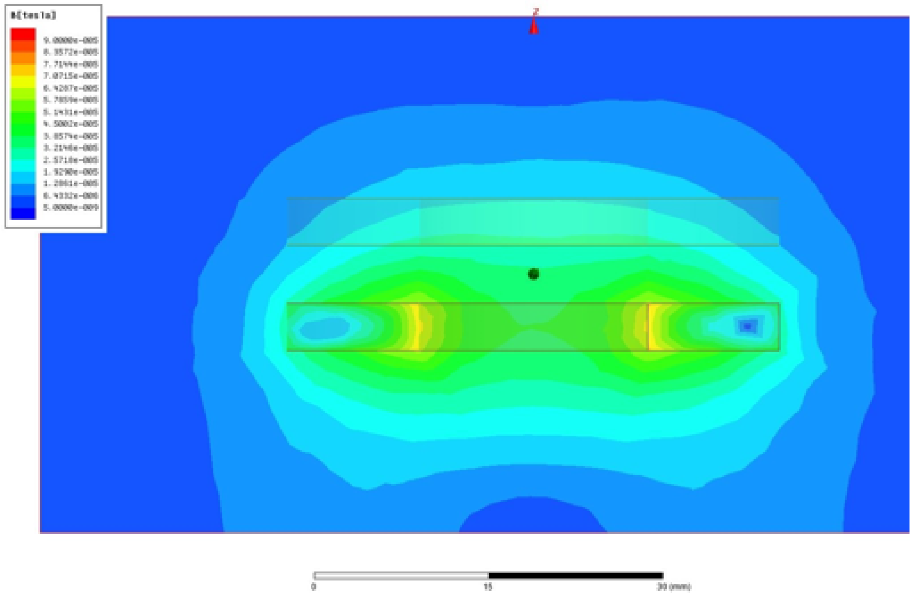
- A shielding effect is caused by reflection **(μ')** and absorption **(μ'')**.
- Complex permeability comparison of materials: **WE-FSFS**



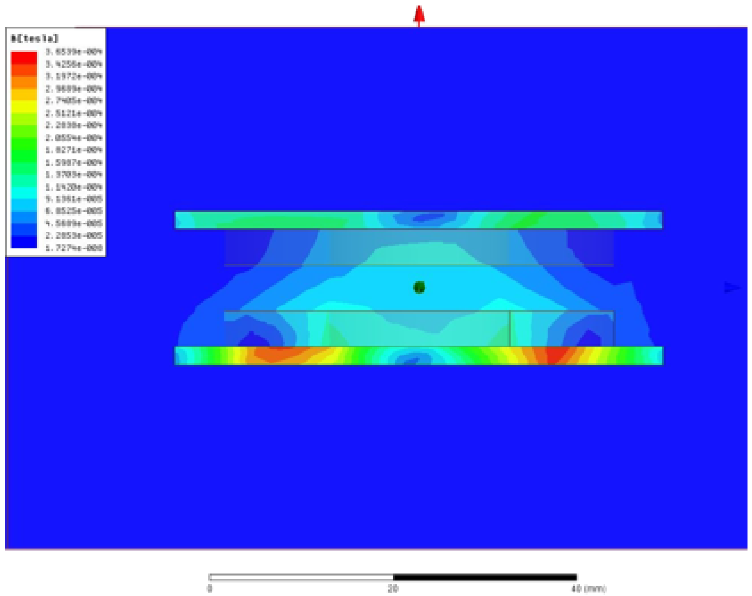
SHIELDING SOLUTIONS

Board/Housing

- Increasing the efficiency of wireless charging coils



Without additional ferrite foil

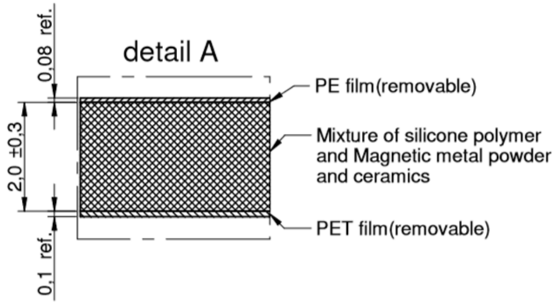


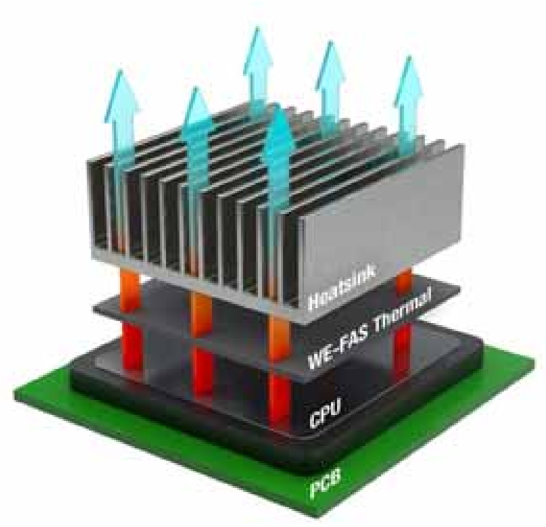
With additional ferrite foil

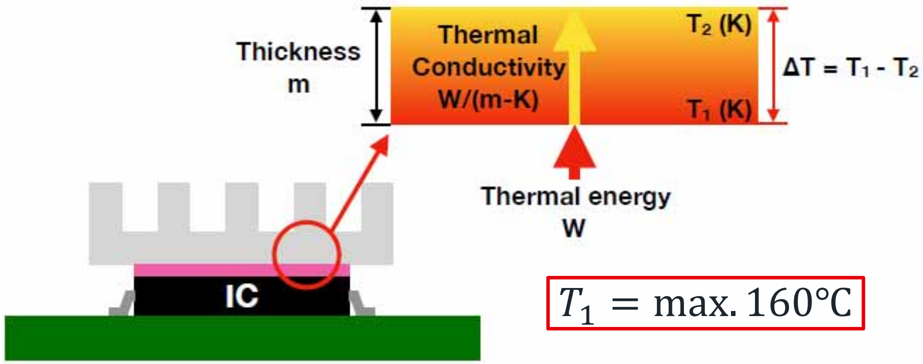
SHIELDING SOLUTIONS

Heat sink

- Flexible ferrite foil with ceramic particles for **heat conduction** ($\kappa = 1{,}4 \mathrm{W} \cdot \mathrm{m}^{-1} \cdot \mathrm{K}^{-1}$)





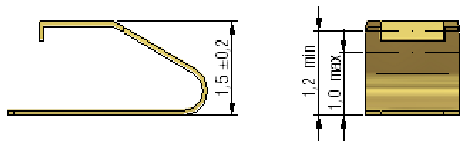


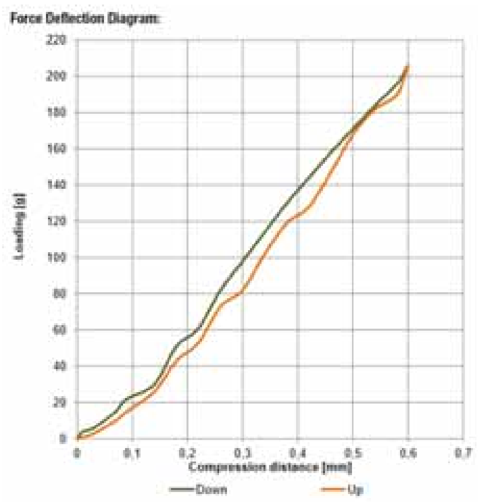
$T_1 = \max.160°\mathrm{C}$

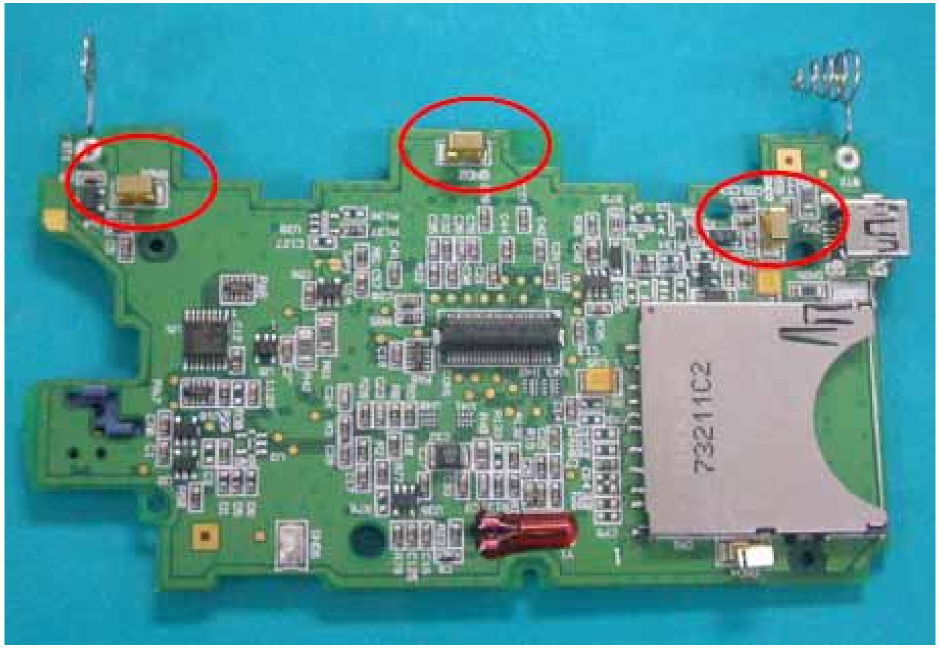
SHIELDING SOLUTIONS

Ground connection

- Surface-solderable **contact springs** made of copper-beryllium or phosphor-bronze
- Coating :
  - Au: 38nm
  - Sn: 1,5µm



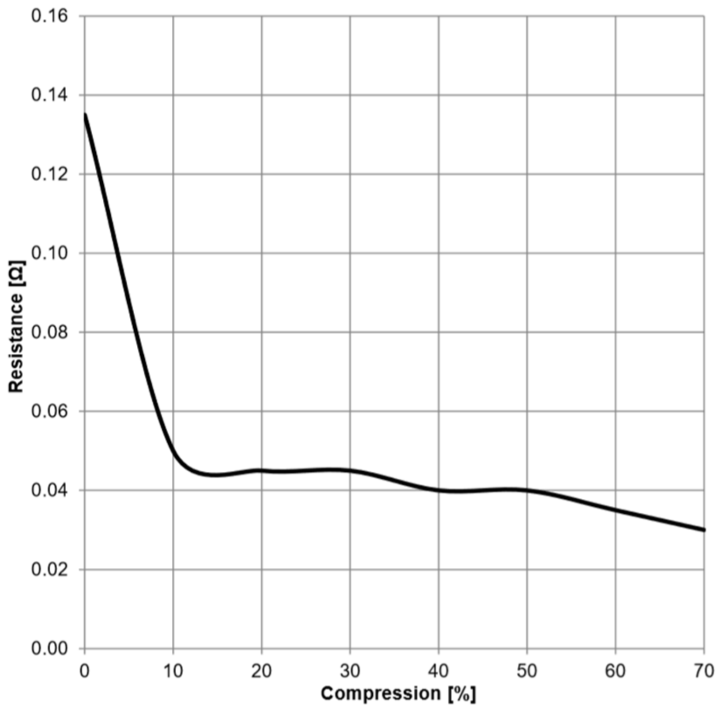




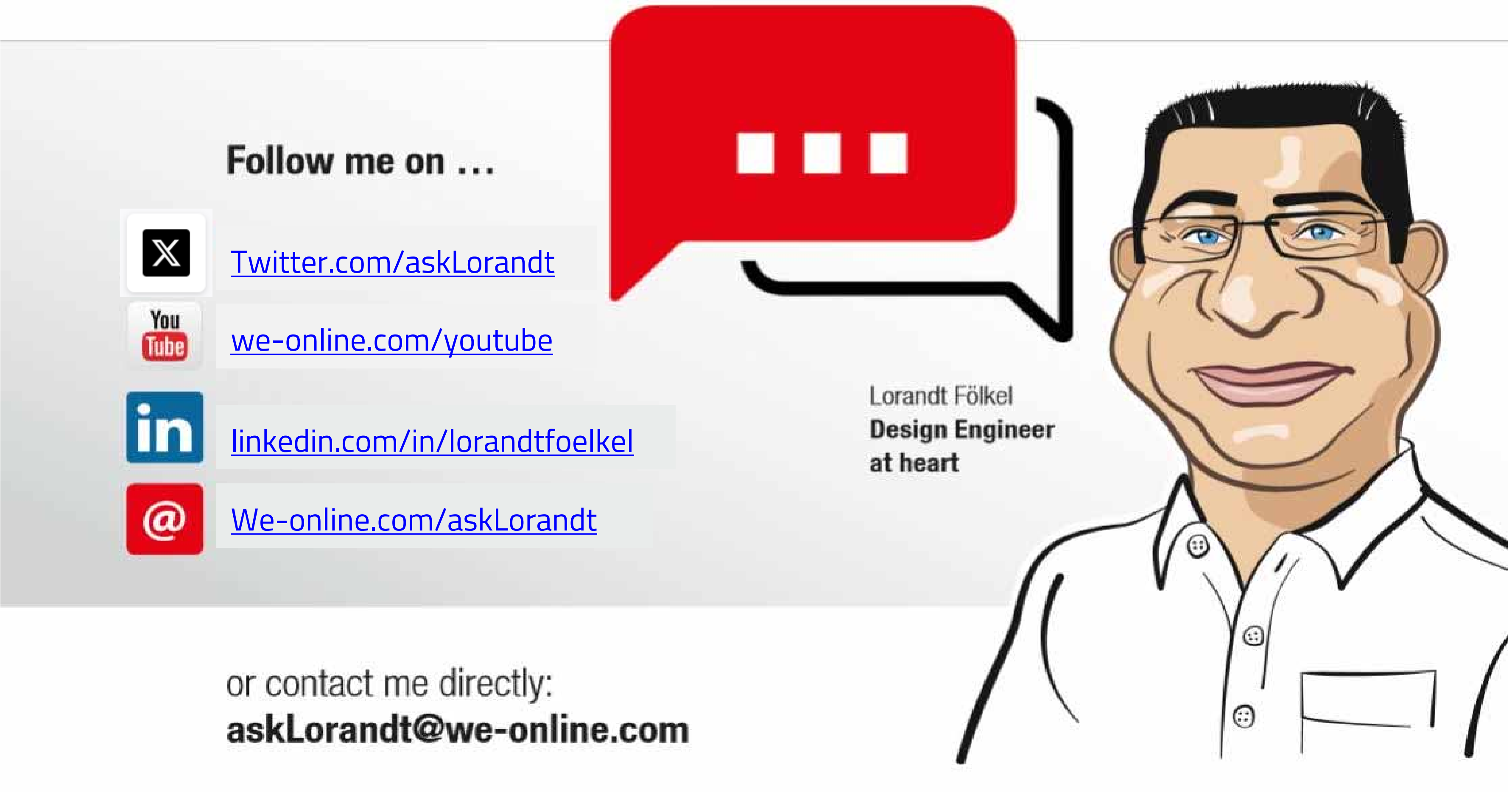
SHIELDING SOLUTIONS

Ground connection

- Surface solderable **foam block** with tin coating
- Optimale compression: 20…70%



TECHNICAL SUPPORT NEEDED?
use: #askLorandt



SHIELDING SOLUTIONS – CASING JOINTS DEMO

https://youtu.be/8vrrwR4KkOg