EMC WITH EMC

ELECTROMAGNETIC COMPATIBILITY WITH ELECTROMECHANICAL CONNECTIONS

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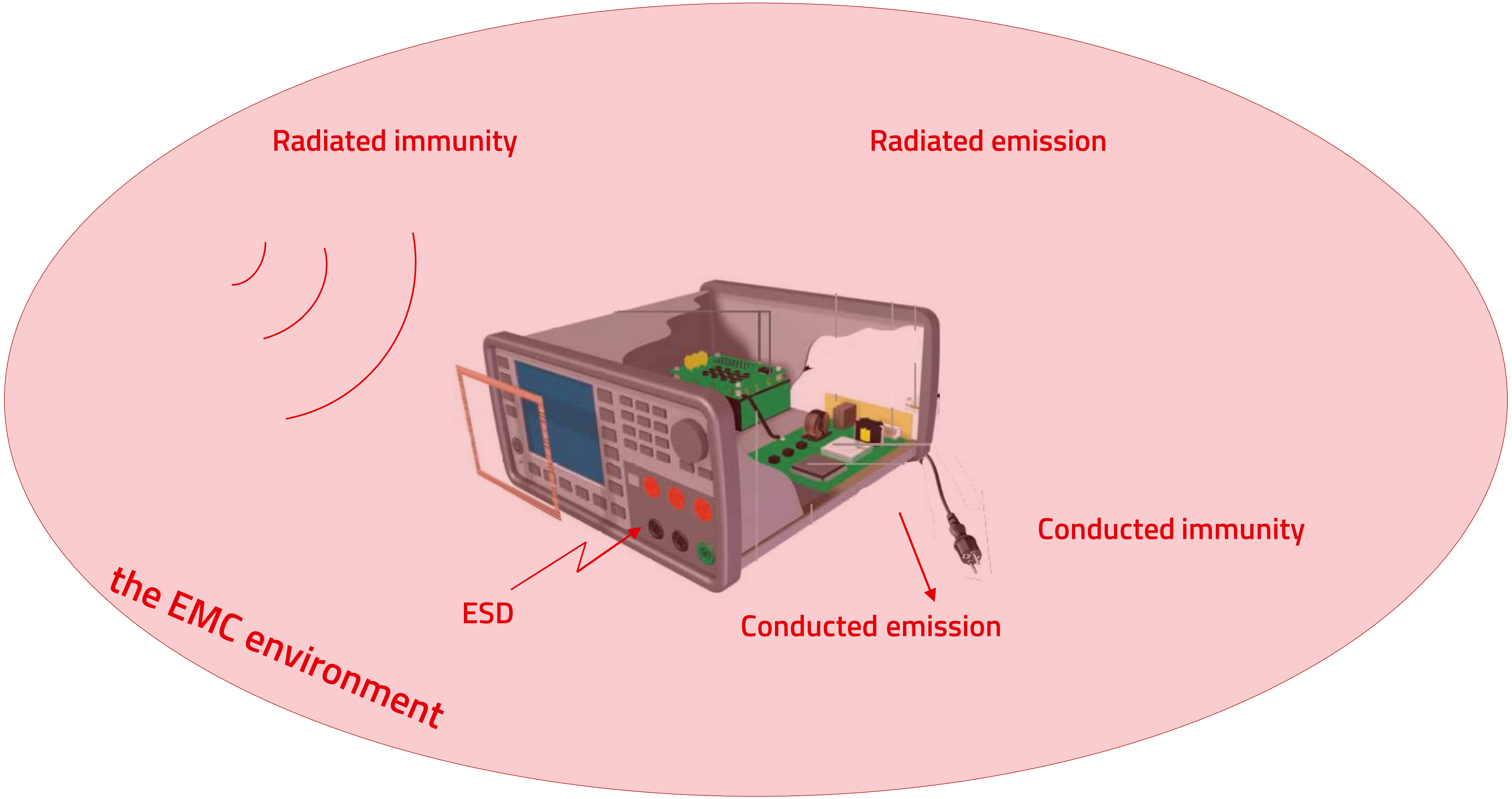
WÜRTH ELEKTRONIK MORE THAN YOU EXPECT

Agenda

- Introduction
- Coupling effects
- Layout concepts
- Signal integrity
- Shielding

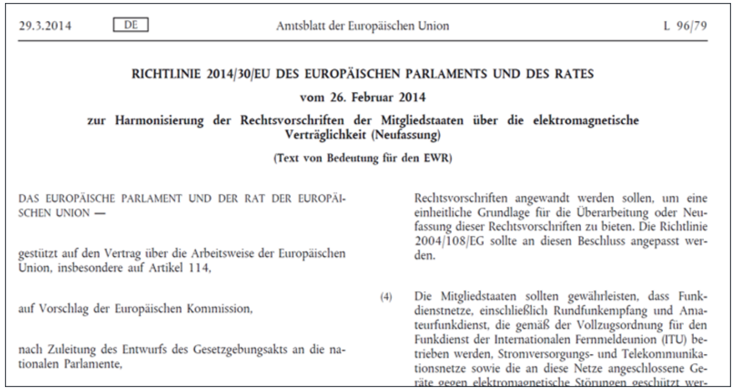
Introduction

Legal requirements



Introduction

In Austria: EMC-Guideline 2014/30/EU



29.3.2014 DE Amtsblatt der Europäischen Union L 96/79

RICHTLINIE 2014/30/EU DES EUROPÄISCHEN PARLAMENTS UND DES RATES

vom 26. Februar 2014

zur Harmonisierung der Rechtsvorschriften der Mitgliedstaaten über die elektromagnetische Verträglichkeit (Neufassung)

(Text von Bedeutung für den EWR)

DAS EUROPÄISCHE PARLAMENT UND DER RAT DER EUROPÄISCHEN UNION —

gestützt auf den Vertrag über die Arbeitsweise der Europäischen Union, insbesondere auf Artikel 114,

auf Vorschlag der Europäischen Kommission,

nach Zuleitung des Entwurfs des Gesetzgebungsakts an die nationalen Parlamente,

Rechtsvorschriften angewandt werden sollen, um eine einheitliche Grundlage für die Überarbeitung oder Neufassung dieser Rechtsvorschriften zu bieten. Die Richtlinie 2004/108/EG sollte an diesen Beschluss angepasst werden.

(4) Die Mitgliedstaaten sollten gewährleisten, dass Funkdienstnetze, einschließlich Rundfunkempfang und Amateurfunkdienst, die gemäß der Vollzugsordnung für den Funkdienst der Internationalen Fernmeldeunion (ITU) betrieben werden, Stromversorgungs- und Telekommunikationsnetze sowie die an diese Netze angeschlossene Geräte gegen elektromagnetische Störungen geschützt wer-

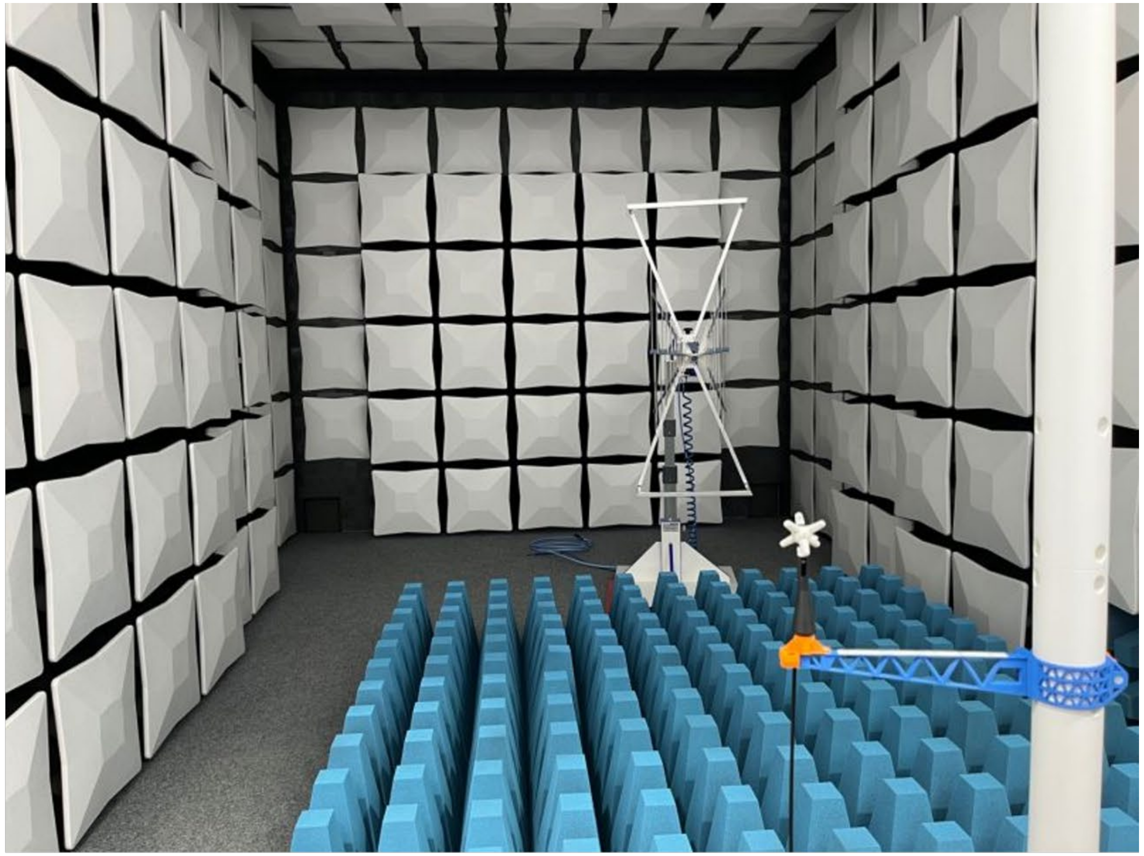
International:

- IEC 61000-1 - Allgemeines, Definitionen und Interpretation der EMV-Normen
- IEC 61000-2 - Umgebungsbedingungen
- IEC 61000-3 - Grenzwerte und Oberschwingungen
- IEC 61000-4 - Prüf- und Messverfahren
- IEC 61000-5 - Installationsrichtlinien und Abhilfemaßnahmen
- IEC 61000-6 - Fachgrundnormen Störaussendung/Störfestigkeit

Europäisch:	**Störaussendung**	**Störfestigkeit**
Informationstechnische Einrichtungen	EN 55022 (2011)	EN 55024 (2011)
Industrielle, wissenschaftliche und medizinische HF-Geräte		EN 55011 (2011) EN 61000-6-1 (2007)
Signalübertragung auf Niederspannungsnetzen	EN 50065-1 (2012)	EN 50065-2 (2006)
Rundfunkempfänger	EN 55013 (2006)	EN 55020 (2007)
Haushaltsgeräte	EN 55014-1 (2012)	EN 55014-2 (2009)

Introduction

The EMC lab



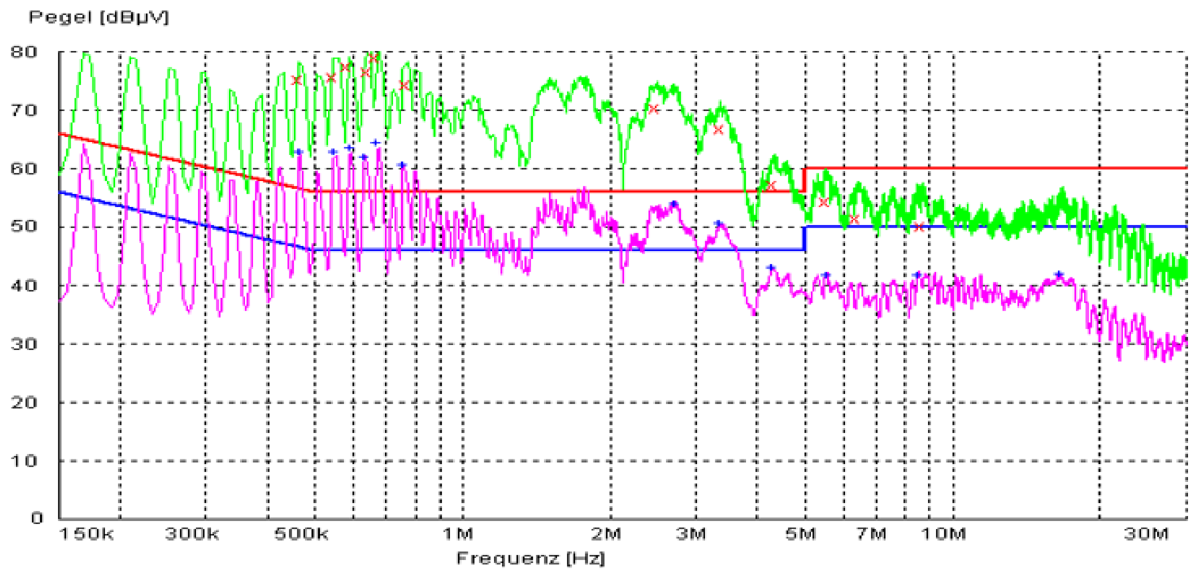
Würth Elektronik HIC Freiham

Introduction

Conducted emission

- Conducted emission over a broad frequency range
- Induced by ripple current on the input side (Common mode ; Differential mode)
- EMC requirements for

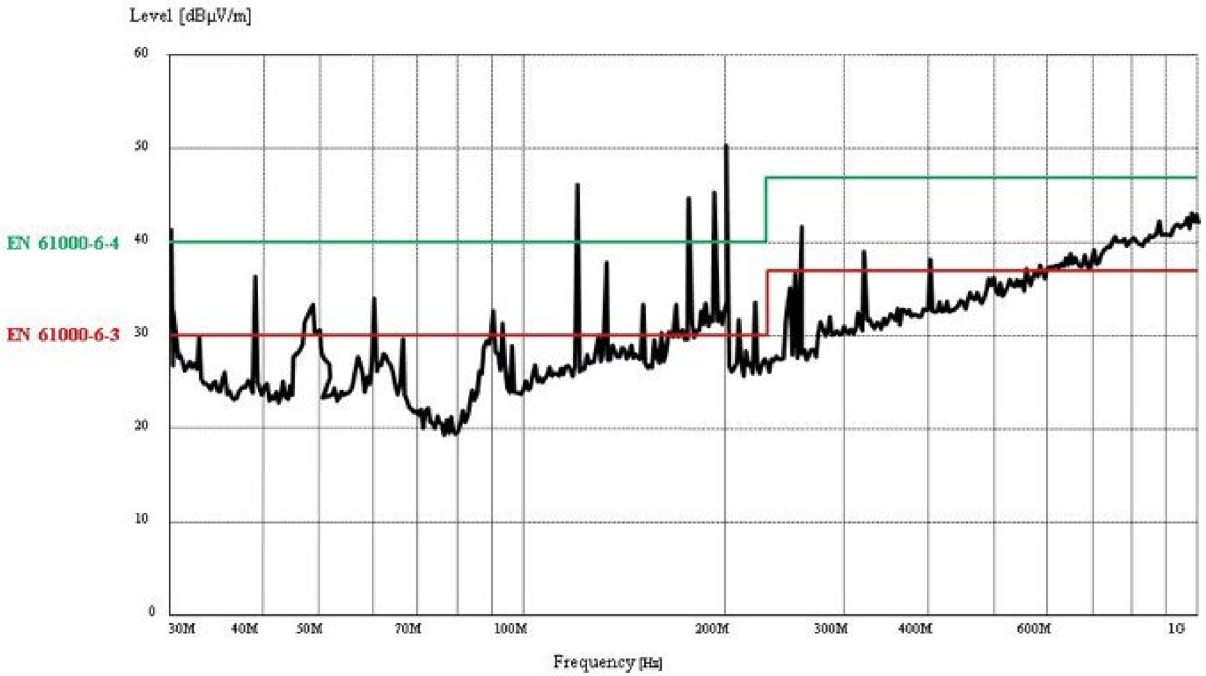
„Conducted Emission“
in accordance with
ETSI, CEN, CENELEC



Introduction

Radiated emission

- Radiated Emission over a broad frequency range caused by:
  - Power path on the circuit board
  - Inductors and DC/DC converter
  - other unintentional sources
- EMC requirements for „Radiated Emission“
  in accordance with ETSI, CEN, CENELEC
- e.g..: EN 61000-6-4 (Industry) QP
- e.g..: EN 61000-6-3 (Consumer) QP



Introduction

Flora and fauna – BBC David Attenborough

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Introduction

Flora and fauna – BBC David Attenborough

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Flora and fauna – BBC David Attenborough

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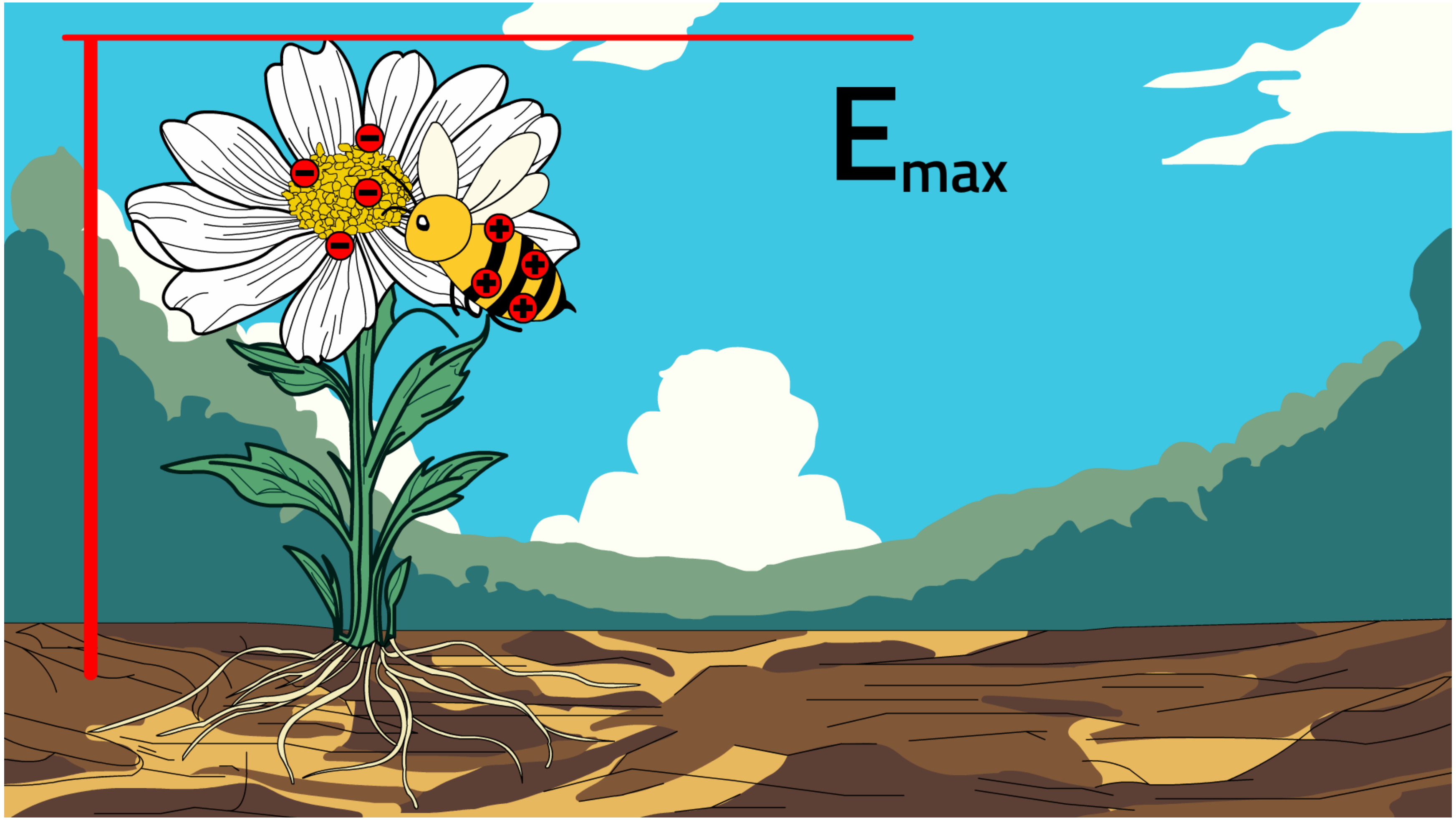
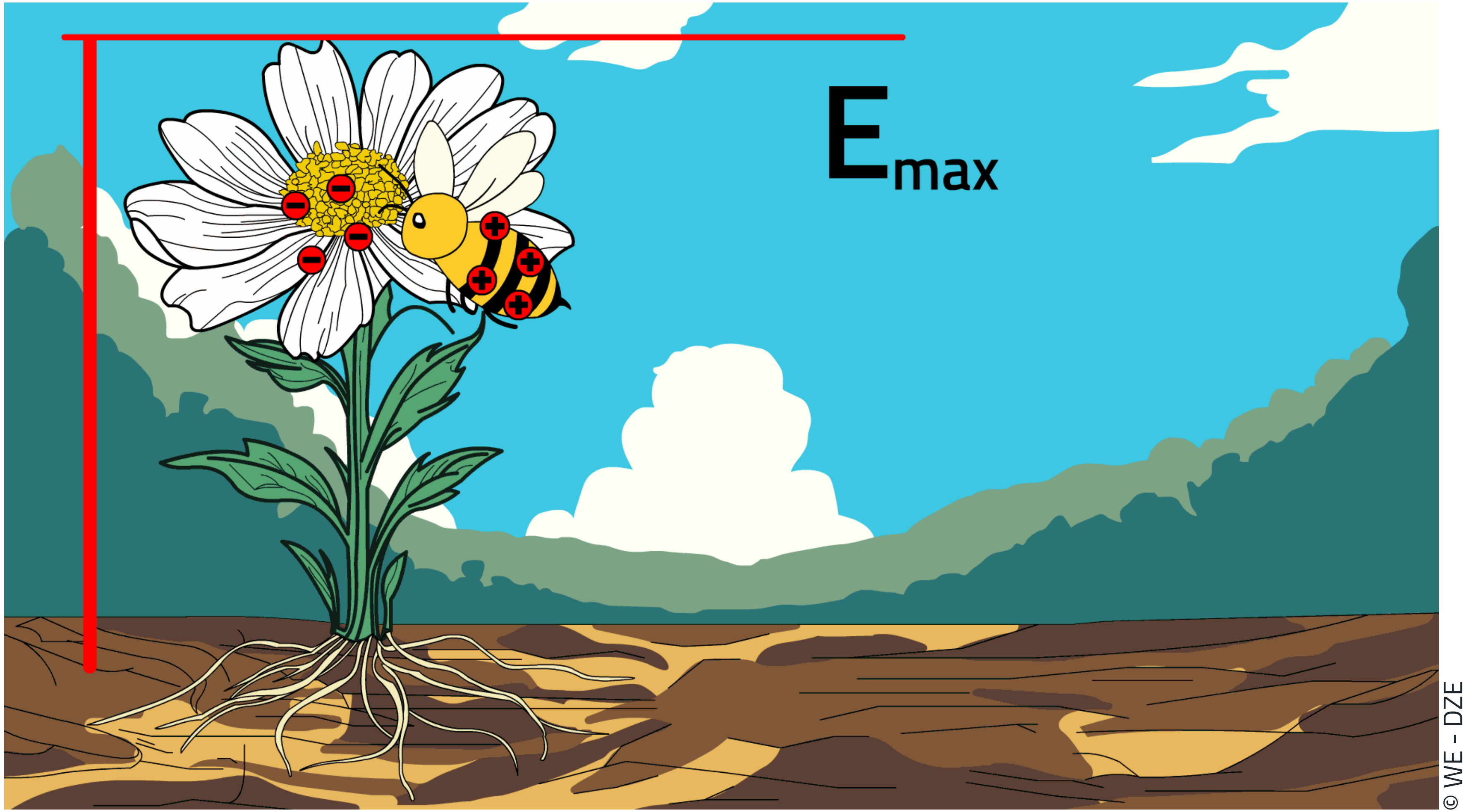


Introduction

Flora and fauna – BBC David Attenborough

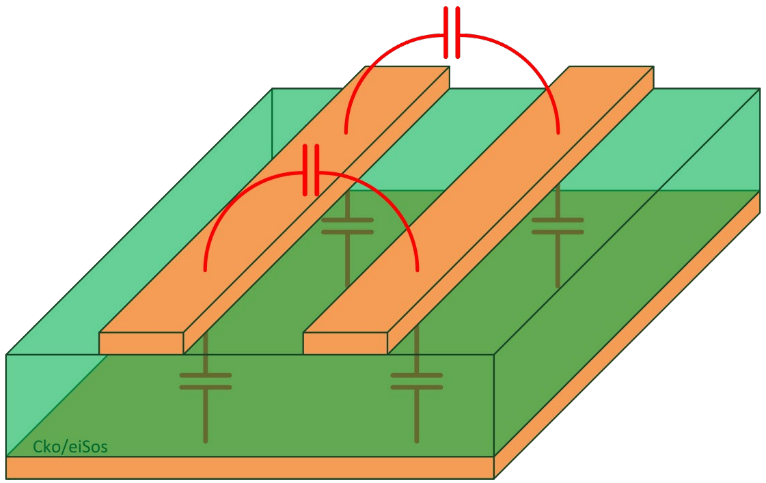


COUPLING EFFECTS

Coupling effects

Origin of capacitive coupling

- Originates from high dU/dt
- Parallel conductors form a parasitic capacitance
- Coupling capacitance is directly proportional to the length of the parallel trace run

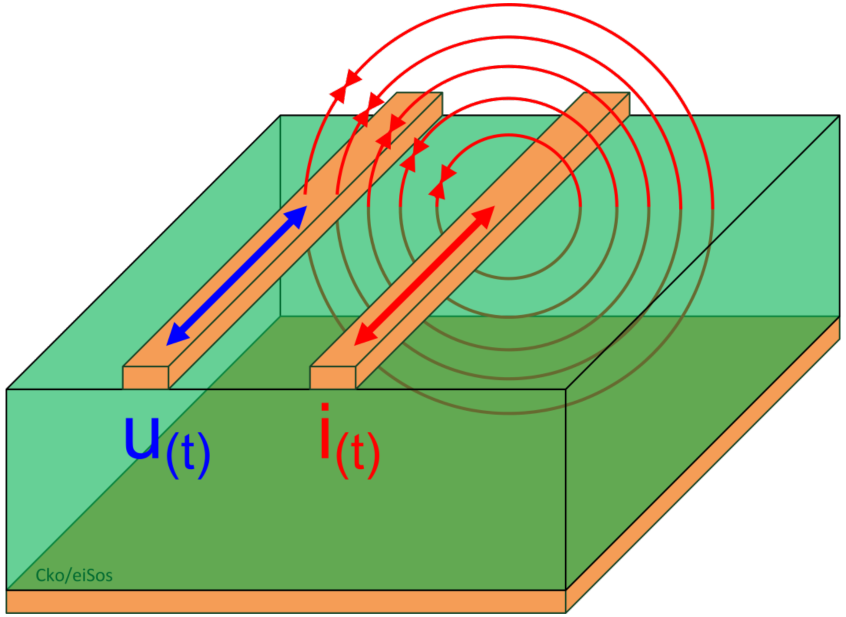


Isolating Components	typ. Coupling Capacitance
Optocoupler	1 ~ 5pF
Solid State Relay	5 ~ 10pF
Electromechanical Relay	10 ~ 100pF
Transformers in SMPS	Up to 1000 pF

Coupling effects

Origin of inductive coupling

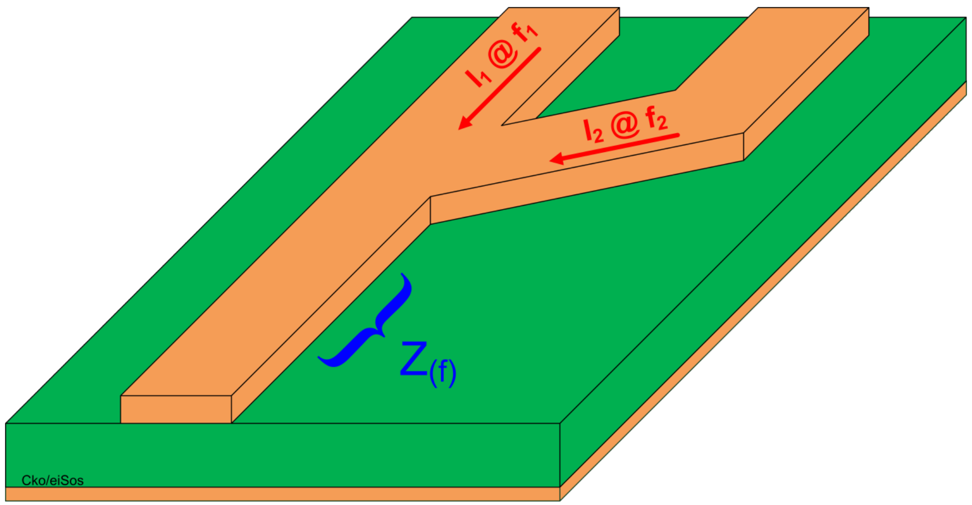
- Originates from high dI/dt
- Parallel traces form a parasitic transformer
- Mutual inductance increases with shorter distance



Coupling effects

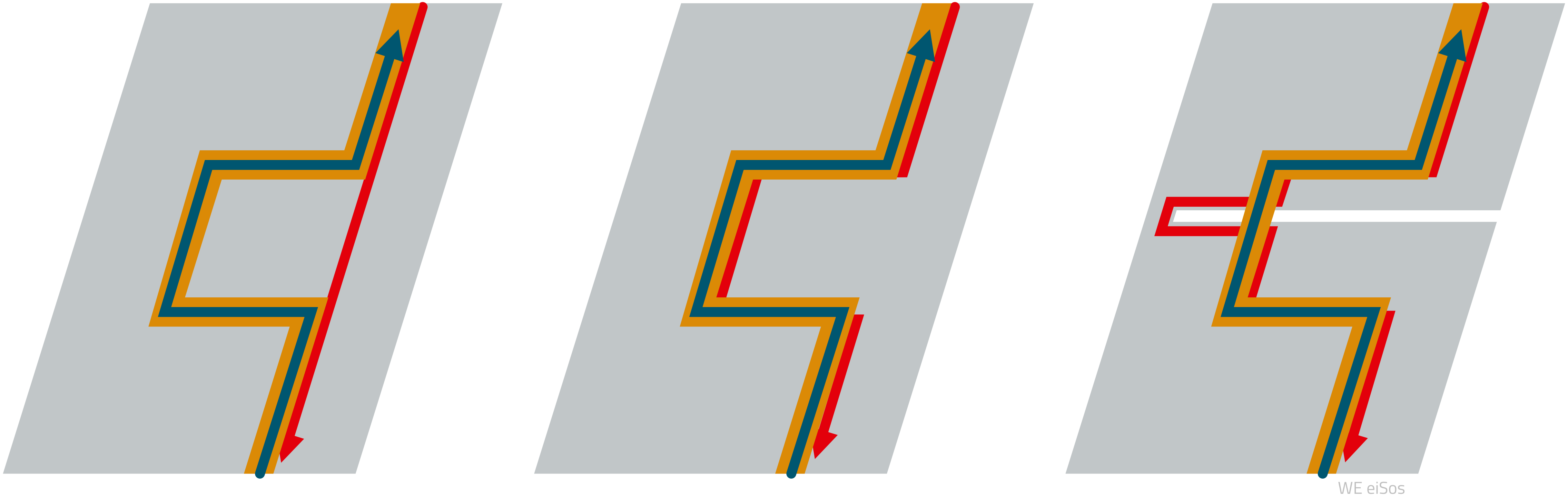
Origins of impedance/galvanic coupling

- Interference affects circuits with mutual traces
- Circuits share an impedance and therefore the voltage across that impedance
- Main cause for high mutual impedances is self-inductance across copper traces



Coupling effects

Path of least impedance



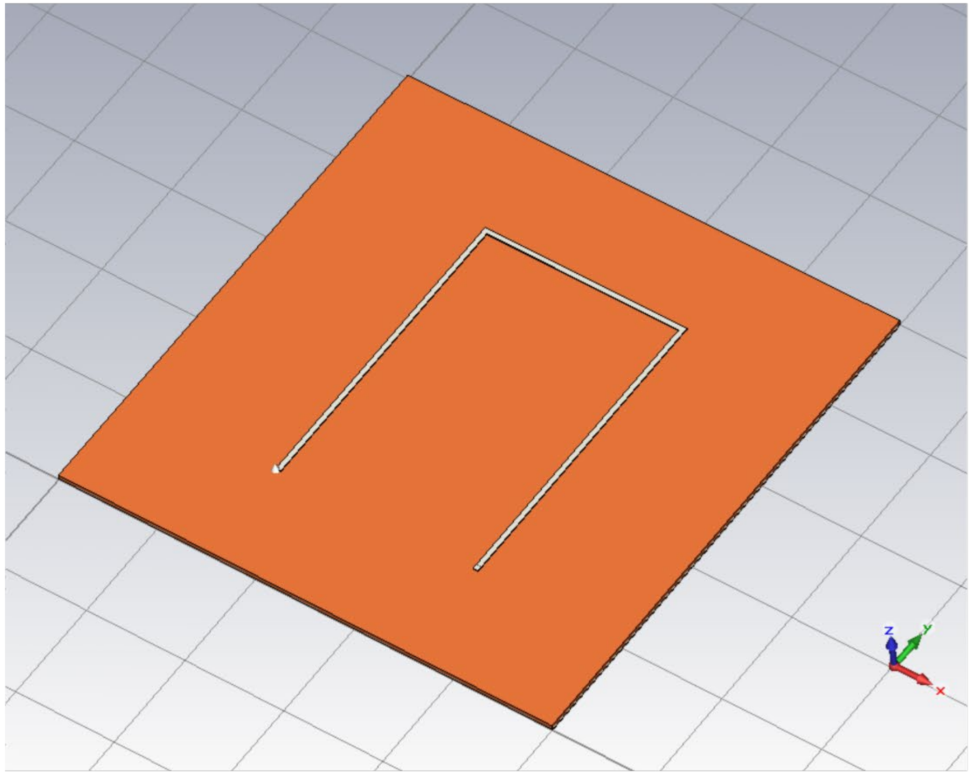
DC return path

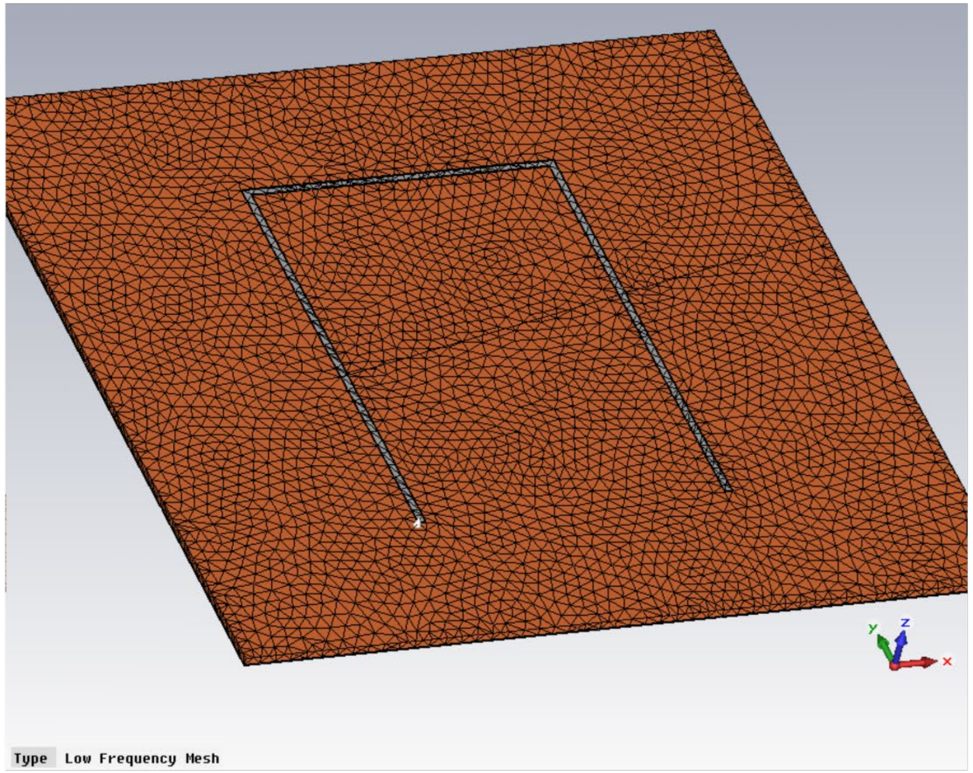
AC return path

Slotted AC return path

Coupling effects

Simulation in CST EMS



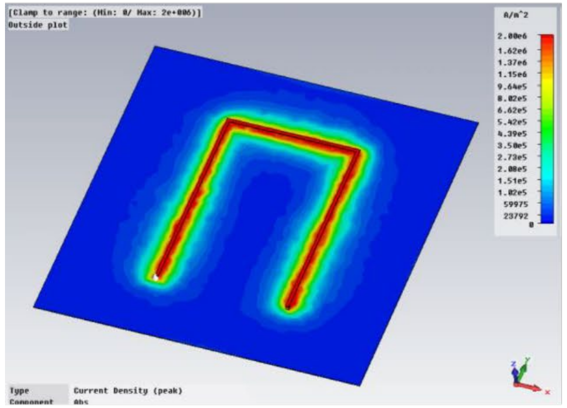


Coupling effects

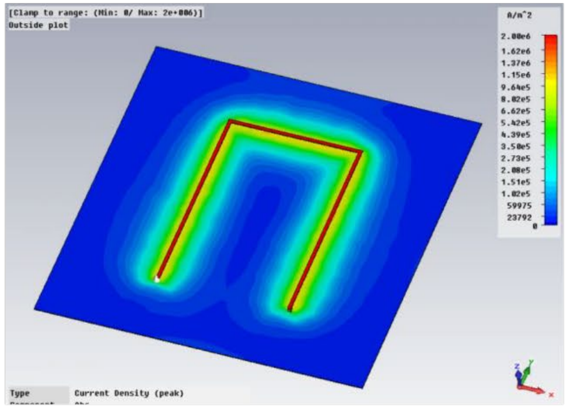
Current path with a u shaped conductor simulated in CST EMS

SEIBERSDORF LABORATORIES

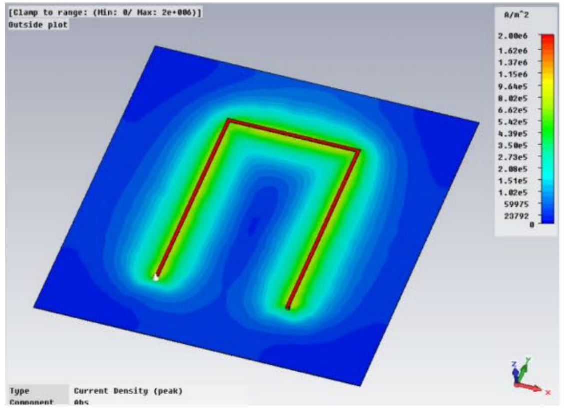
100kHz



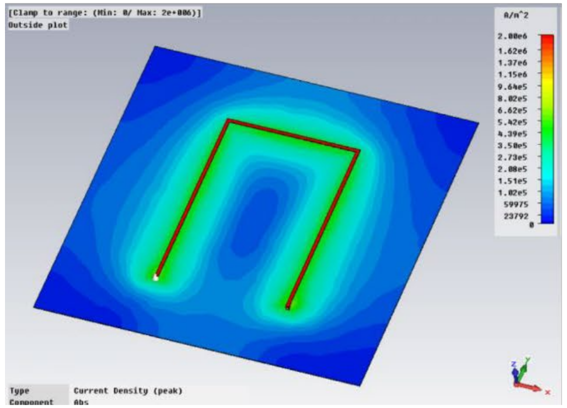
10kHz



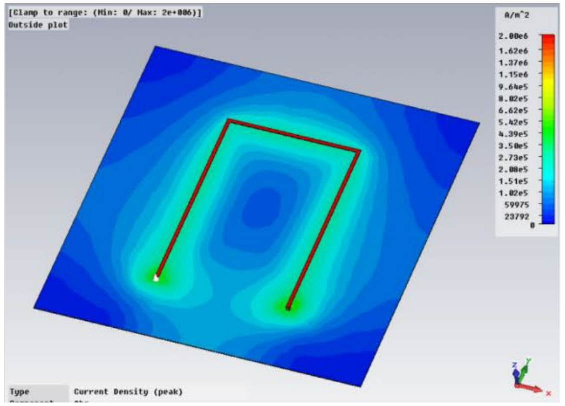
5kHz



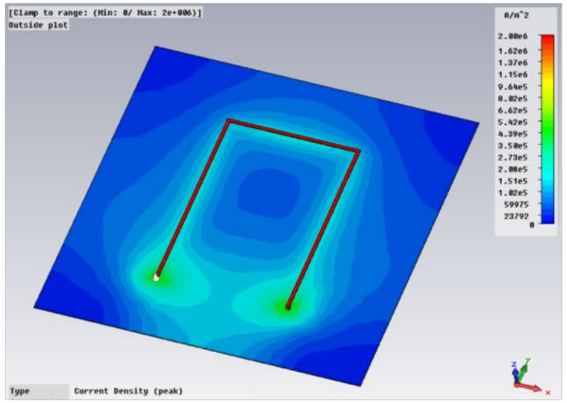
2kHz



1kHz



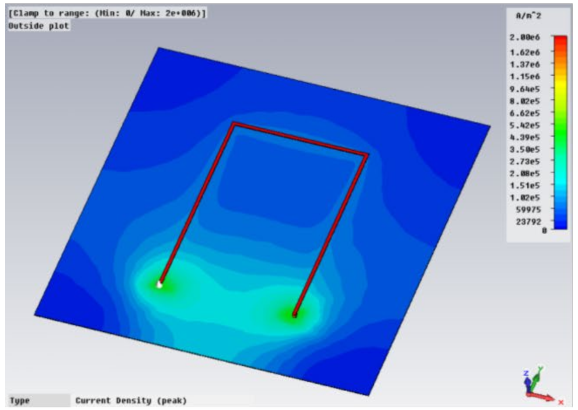
500Hz



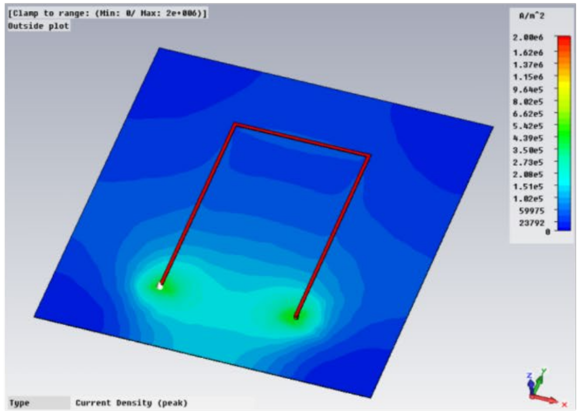
Coupling effects

Current path with a u shaped conductor simulated in CST EMS

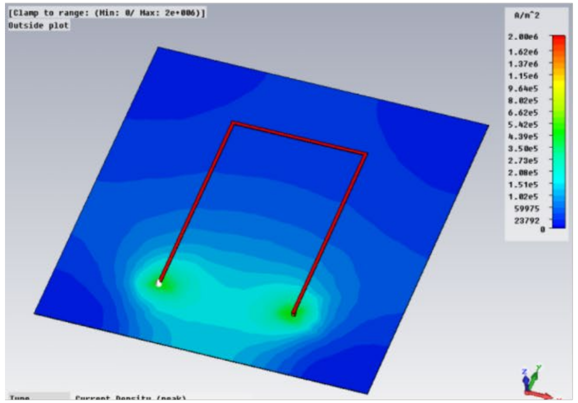
200Hz



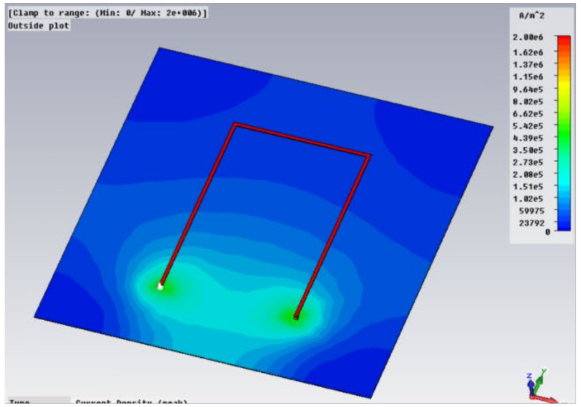
100Hz



50Hz

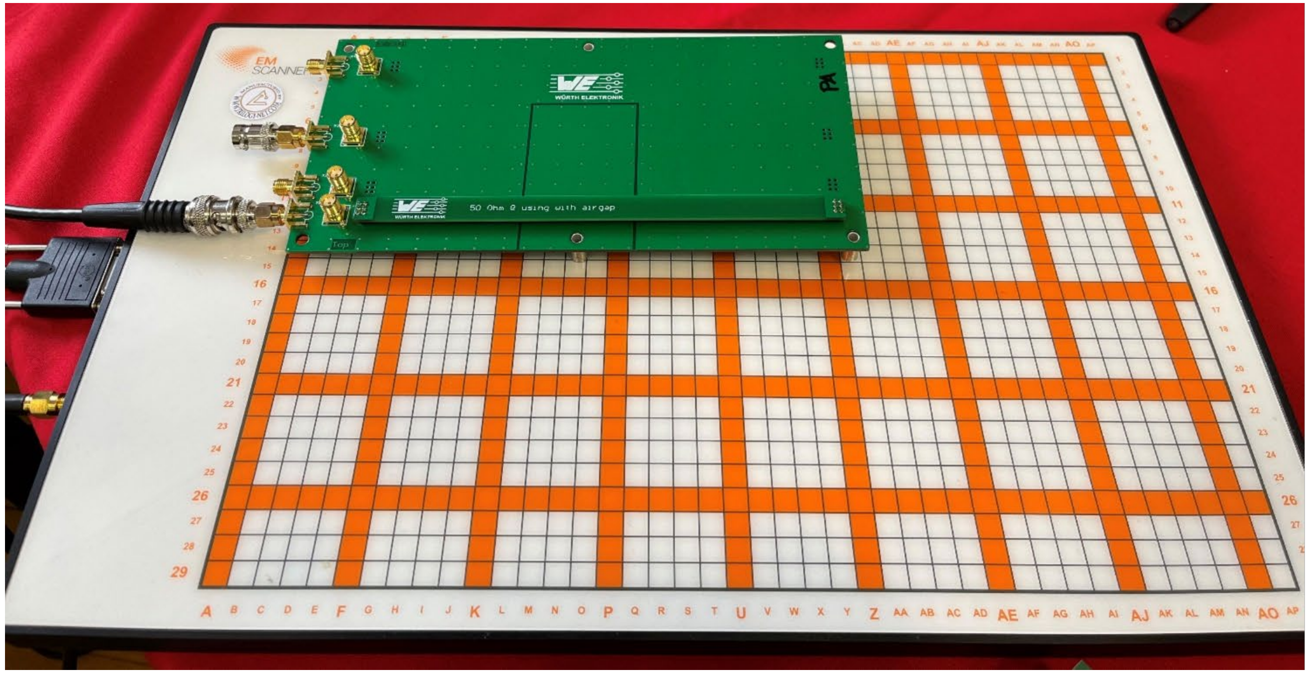


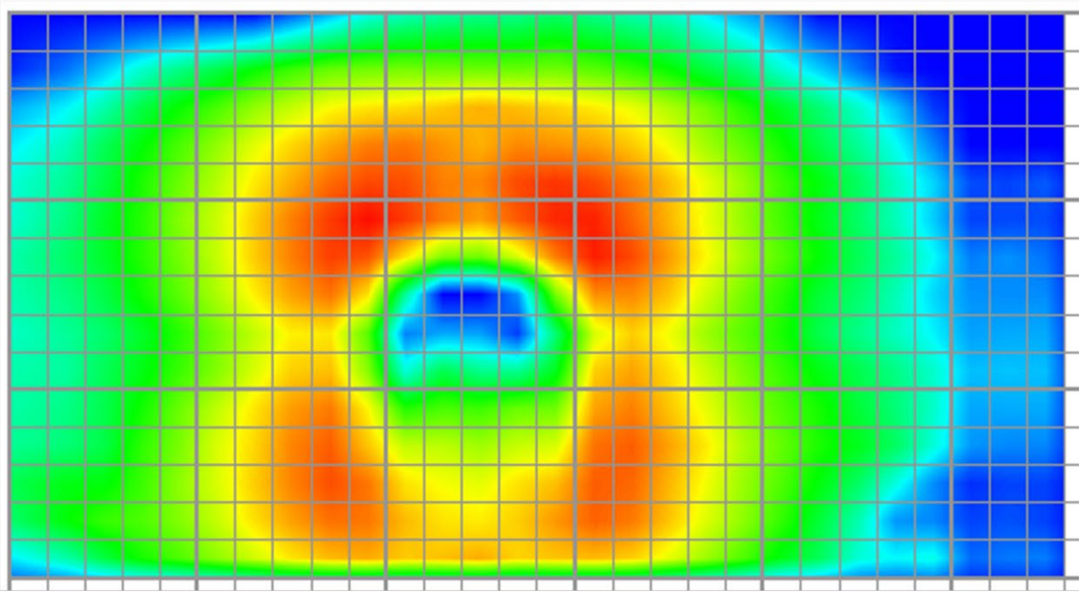
10Hz



Coupling effects

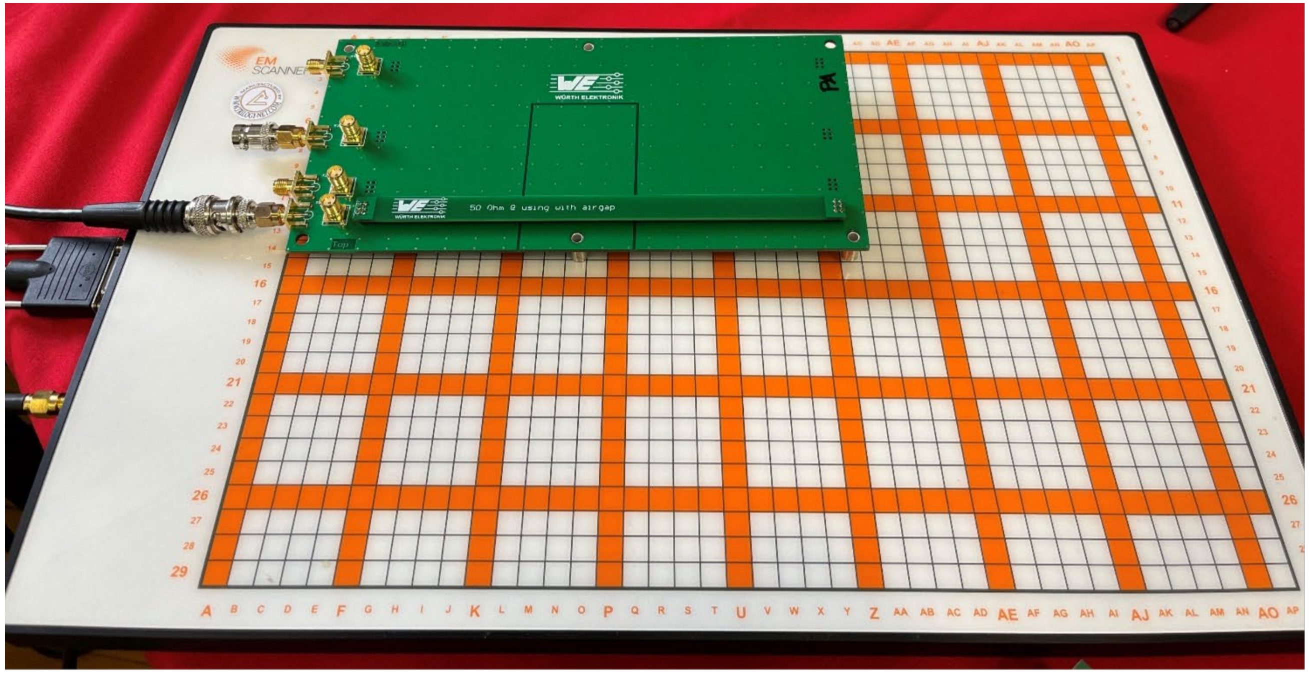
H - Near field measurement

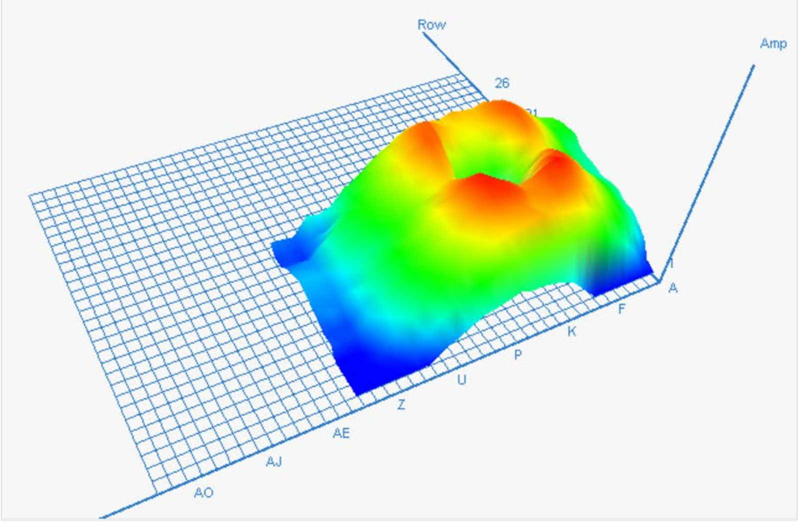


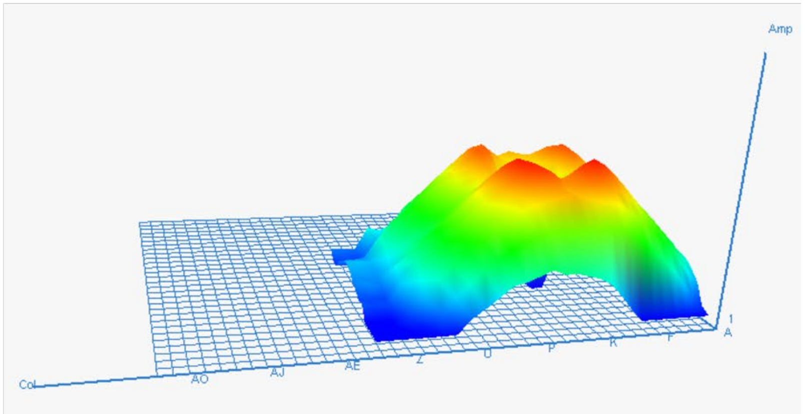


Coupling effects

H - Near field measurement

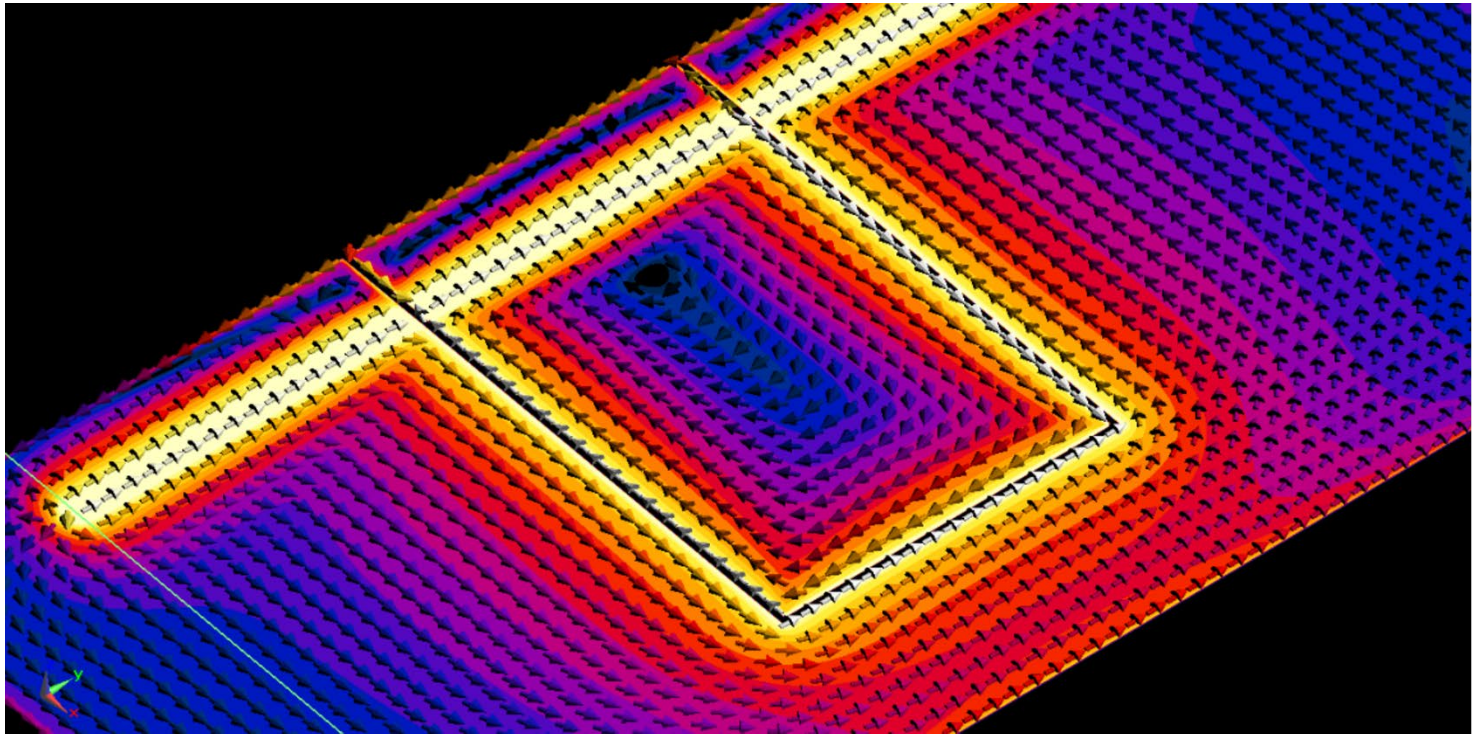






Coupling effects

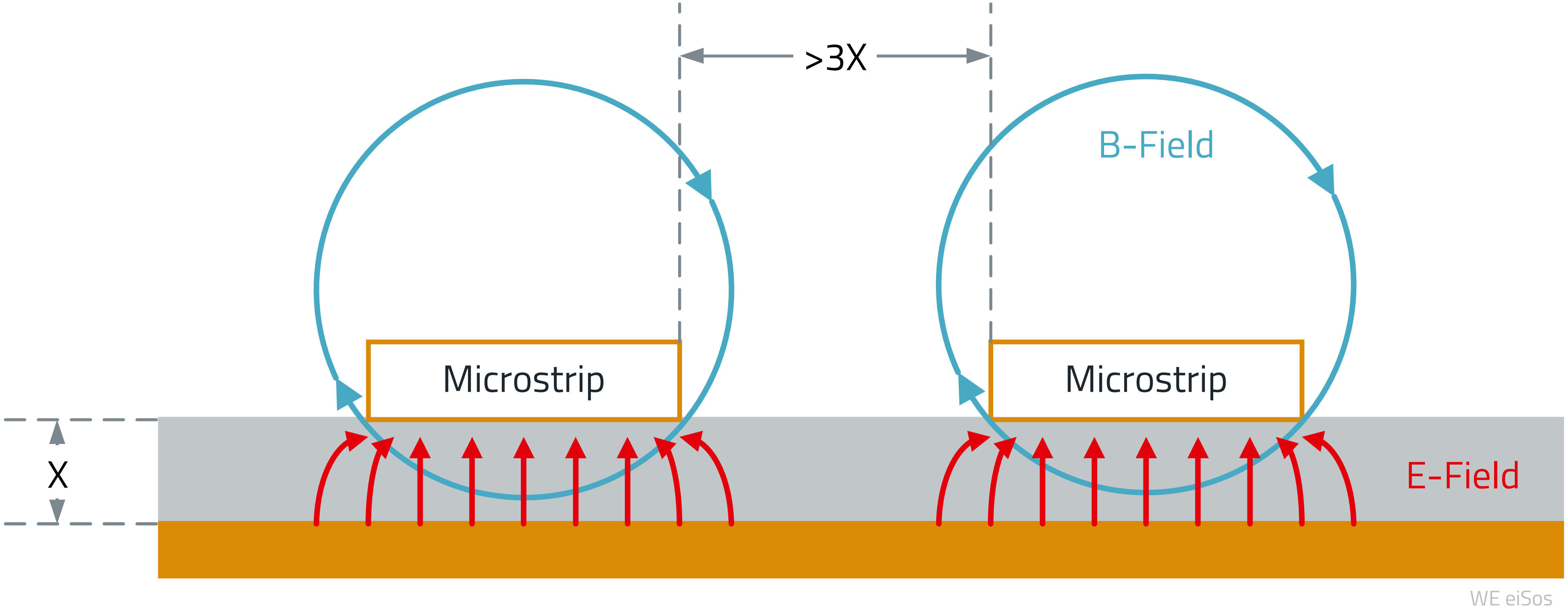
Current path on the GND layer



SEIBERSDORF LABORATORIES

Coupling effects

Minimizing Crosstalk - Increase distance between traces



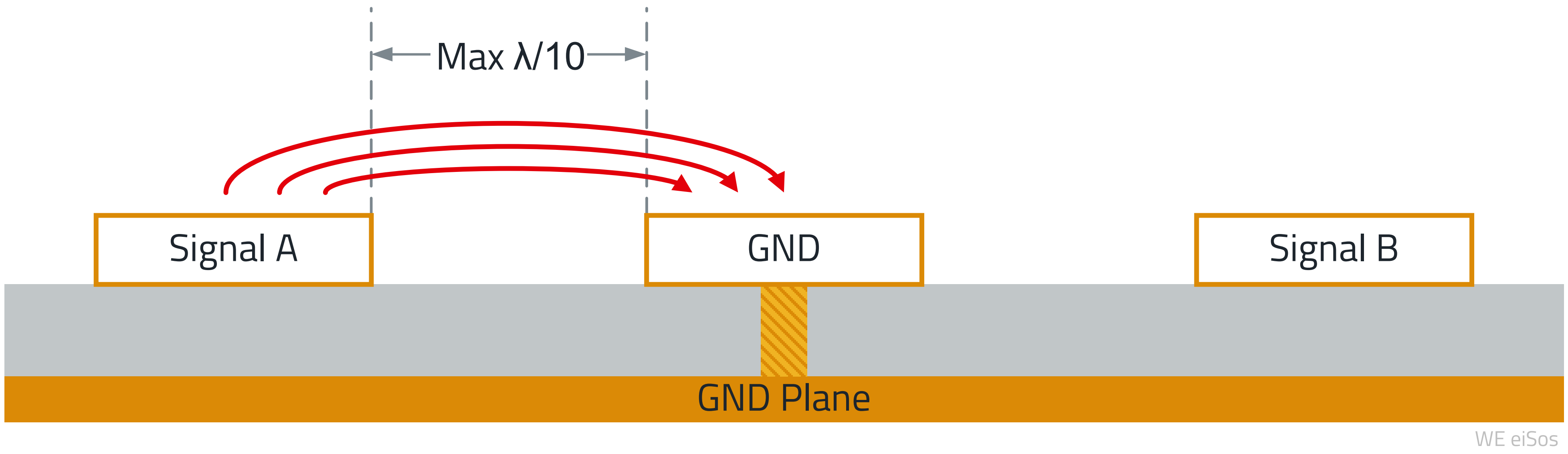
Crosstalk can be reduced to 1% by placing Strip Lines at 3 times the substrate thickness apart

Coupling effects

Minimizing Crosstalk - GND fence

- Inserting a copper area that is tightly bound to GND
  - Shielding the noise source

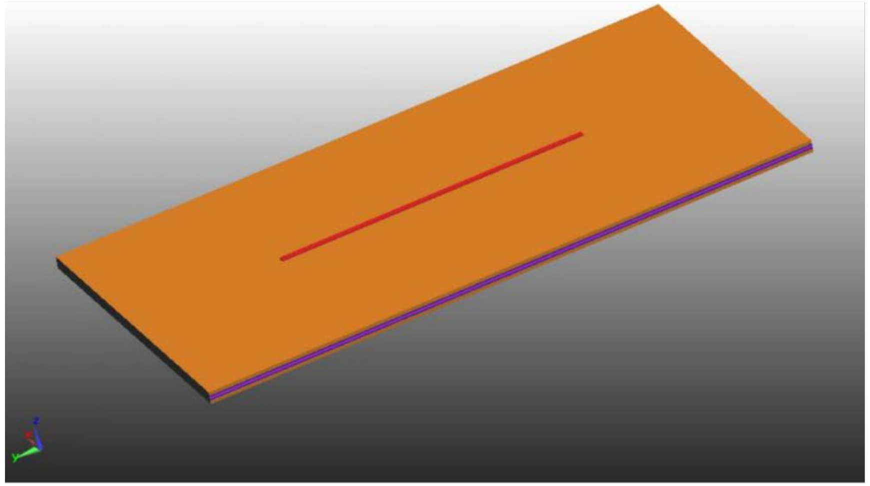
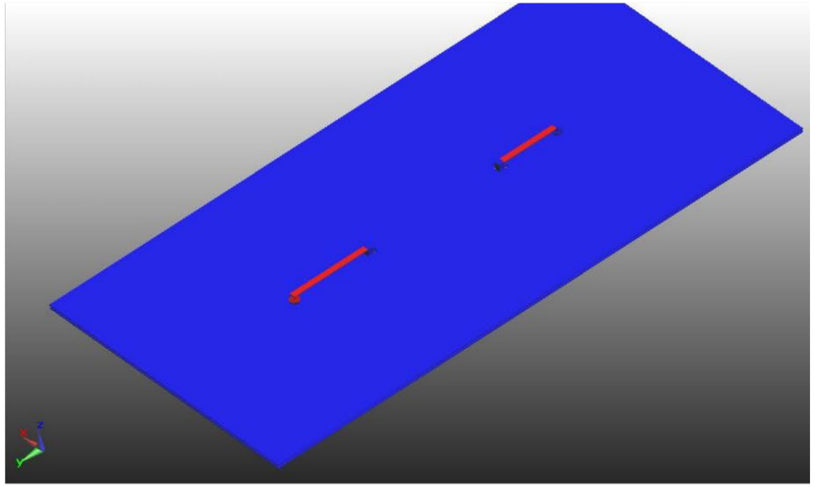
- Distance between Vias: Max. λ/10 of the highest noise frequency



Coupling effects

What happens if the current has to change layer?

- Print with 2 layers(Vcc, GND)
- Without and with a layer change of the signal line
- f=1GHz

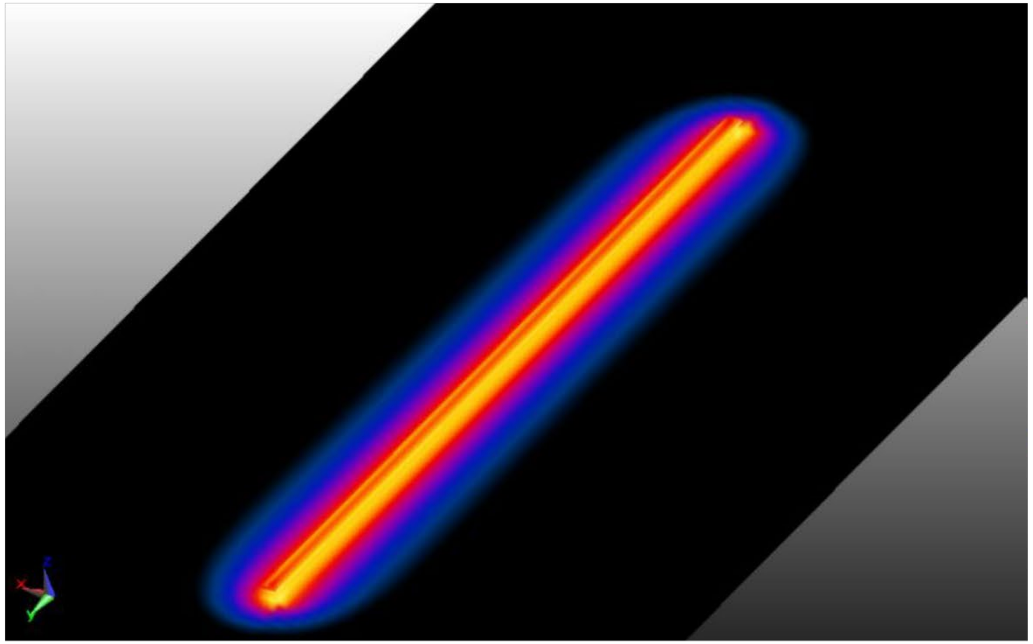
SEIBERSDORF LABORATORIES

Coupling effects

Path of the return current simulated in CST EMS

SEIBERSDORF LABORATORIES

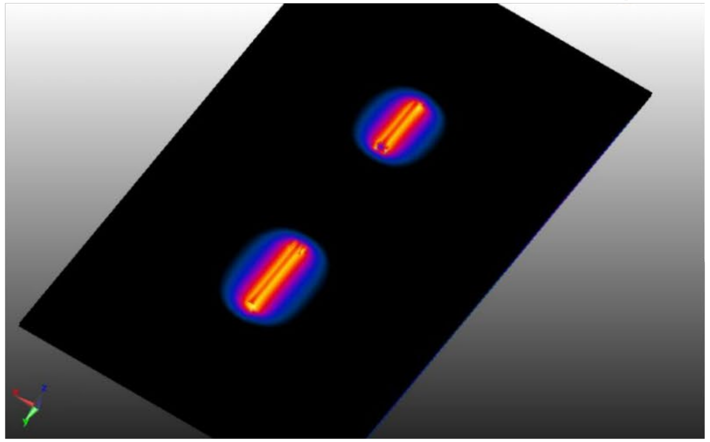
Return current without layer change



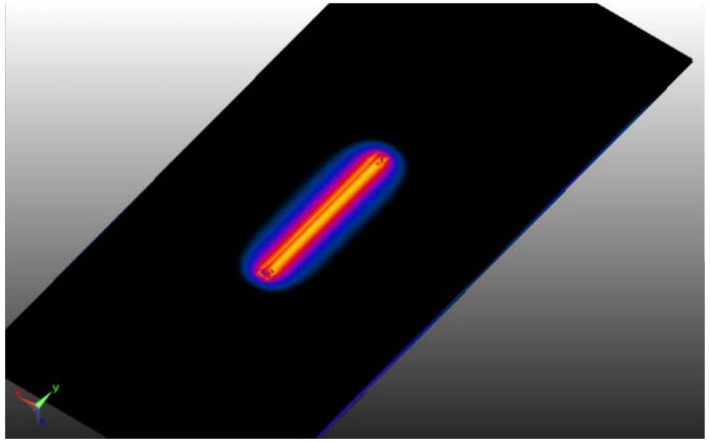
Ground plane

Reverse current also flows across the Vcc surface!

Return current with layer change



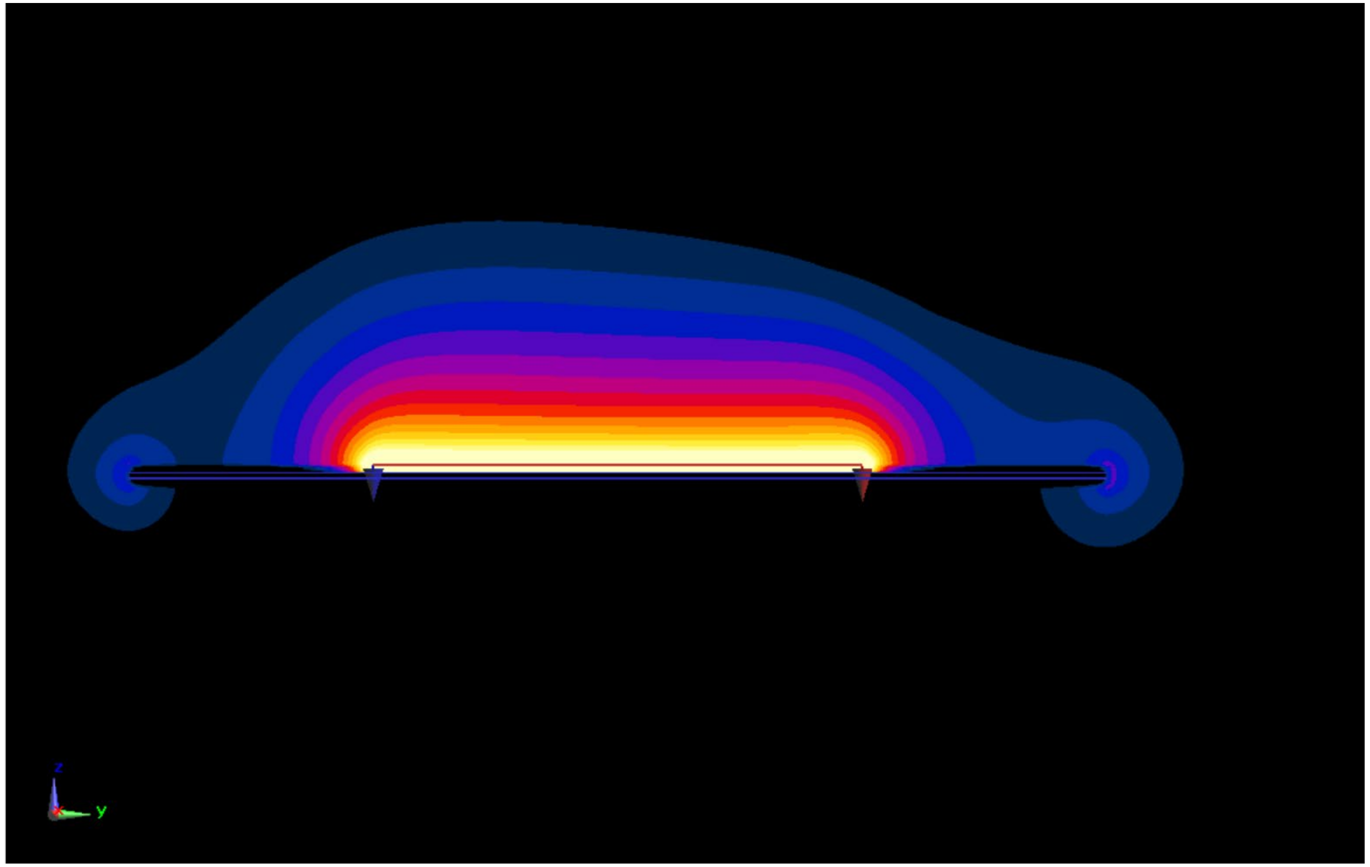
Ground plane



VCC plane

Coupling effects

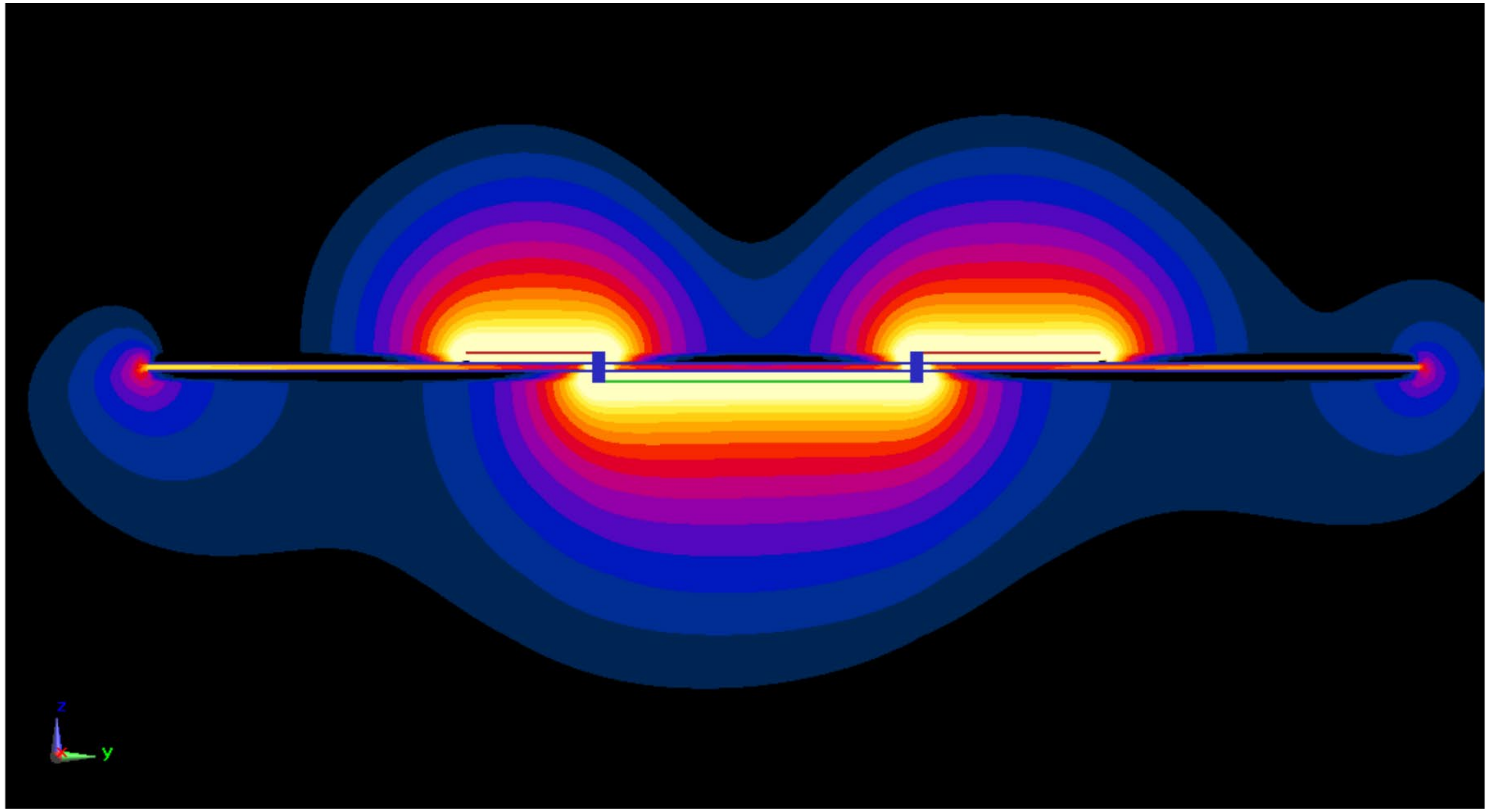
E-field without layer change



If the signal has to switch layers, the radiated power will doubled!

Coupling effects

E-field with layer change



An electromagnetic wave propagates between the ground plane and the Vcc layer!

LAYOUT CONCEPTS

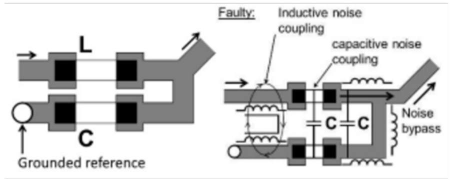
Layout concepts

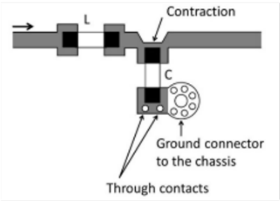
General countermeasures

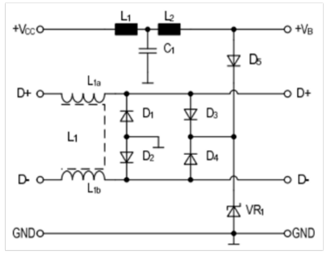
1. **Step** - Improving the layout
   One Problem many solutions

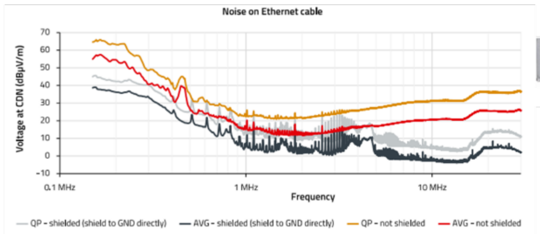
2. Step - Filtering

3. Step - Shielding



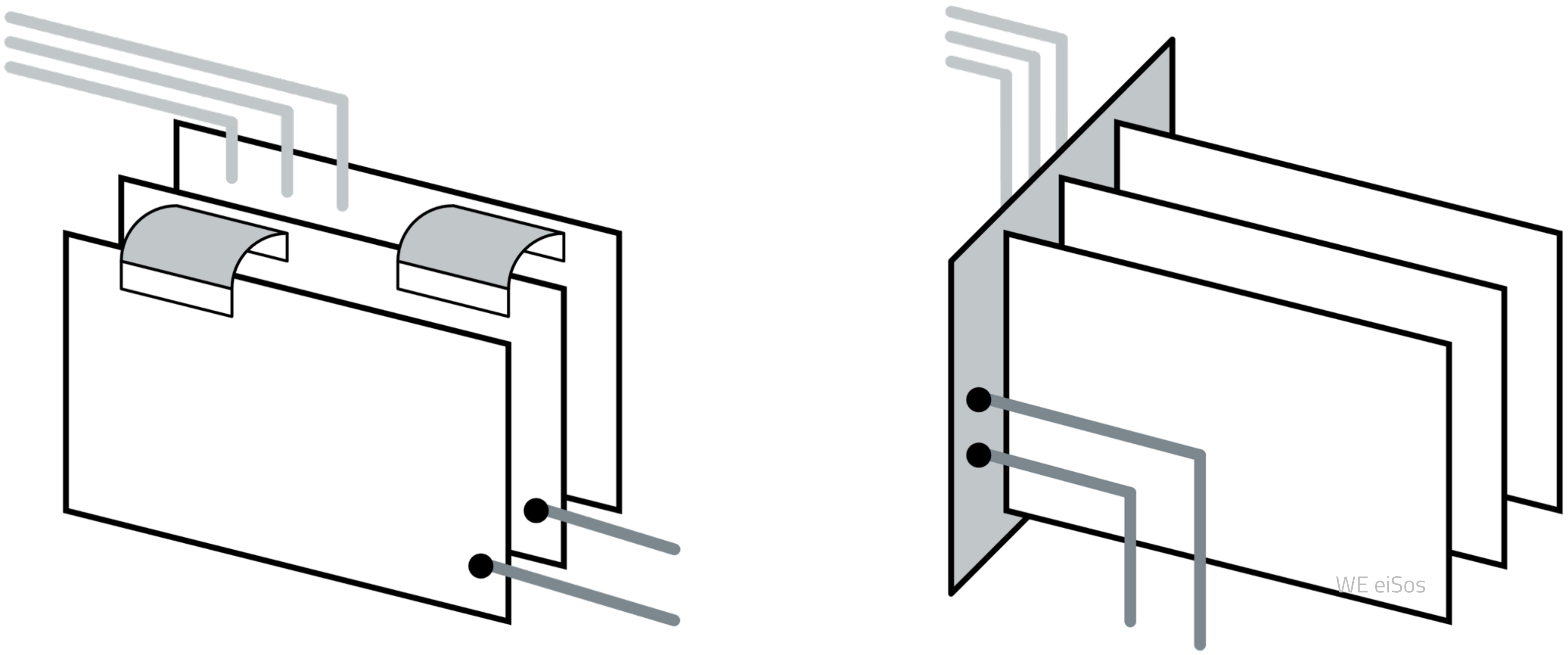






Layout concepts

Principle of a single point grounding/multipoint grounding on system level

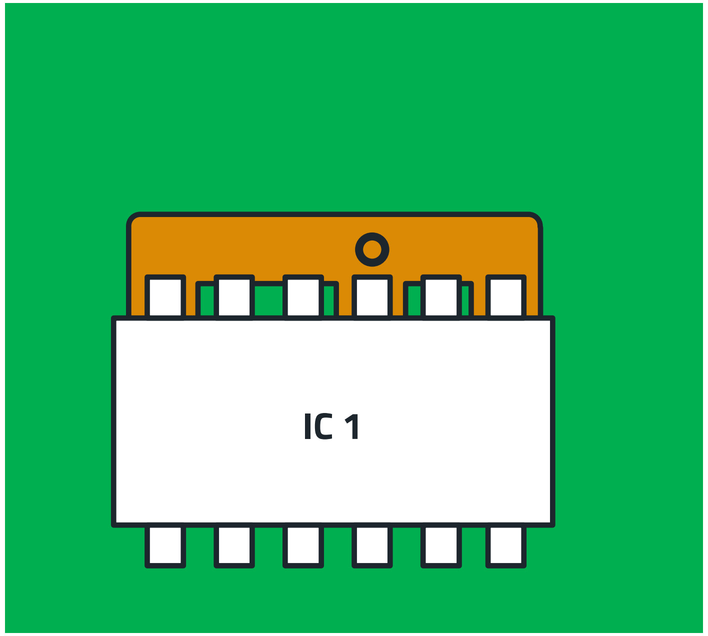


Susceptible to interferences (left) and a more fail-safe (right) construction of a device

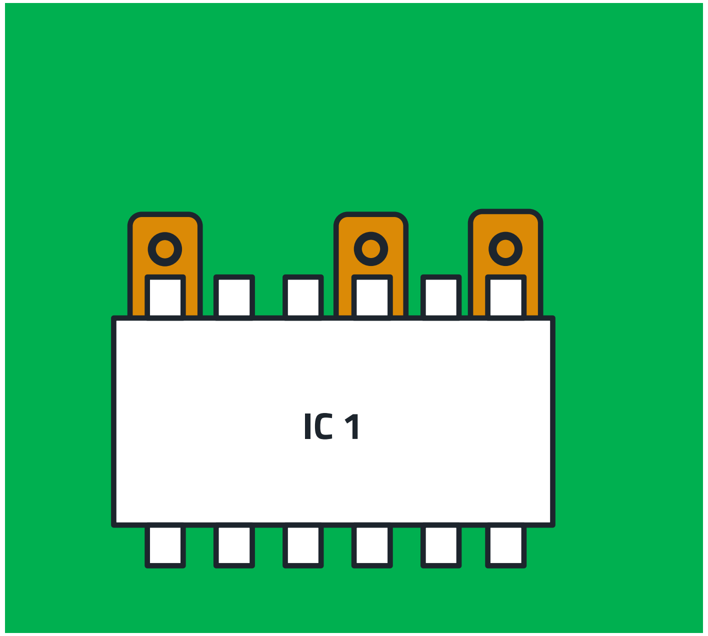
Layout concepts

Low impedance connections to the GND plane(s)

High impedance connection

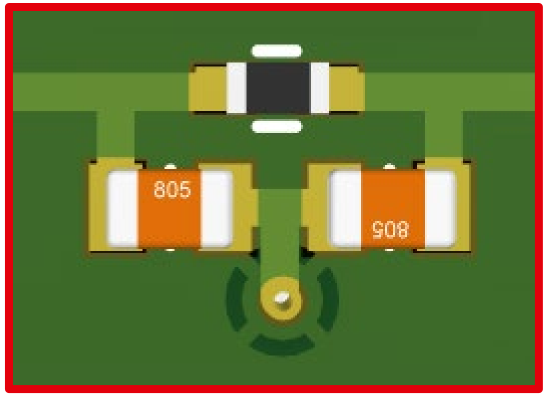


Low impedance connection

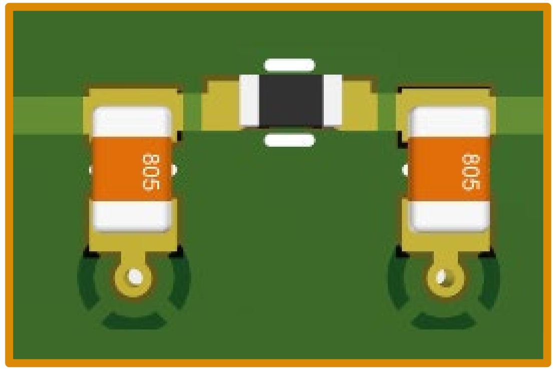


Layout concepts

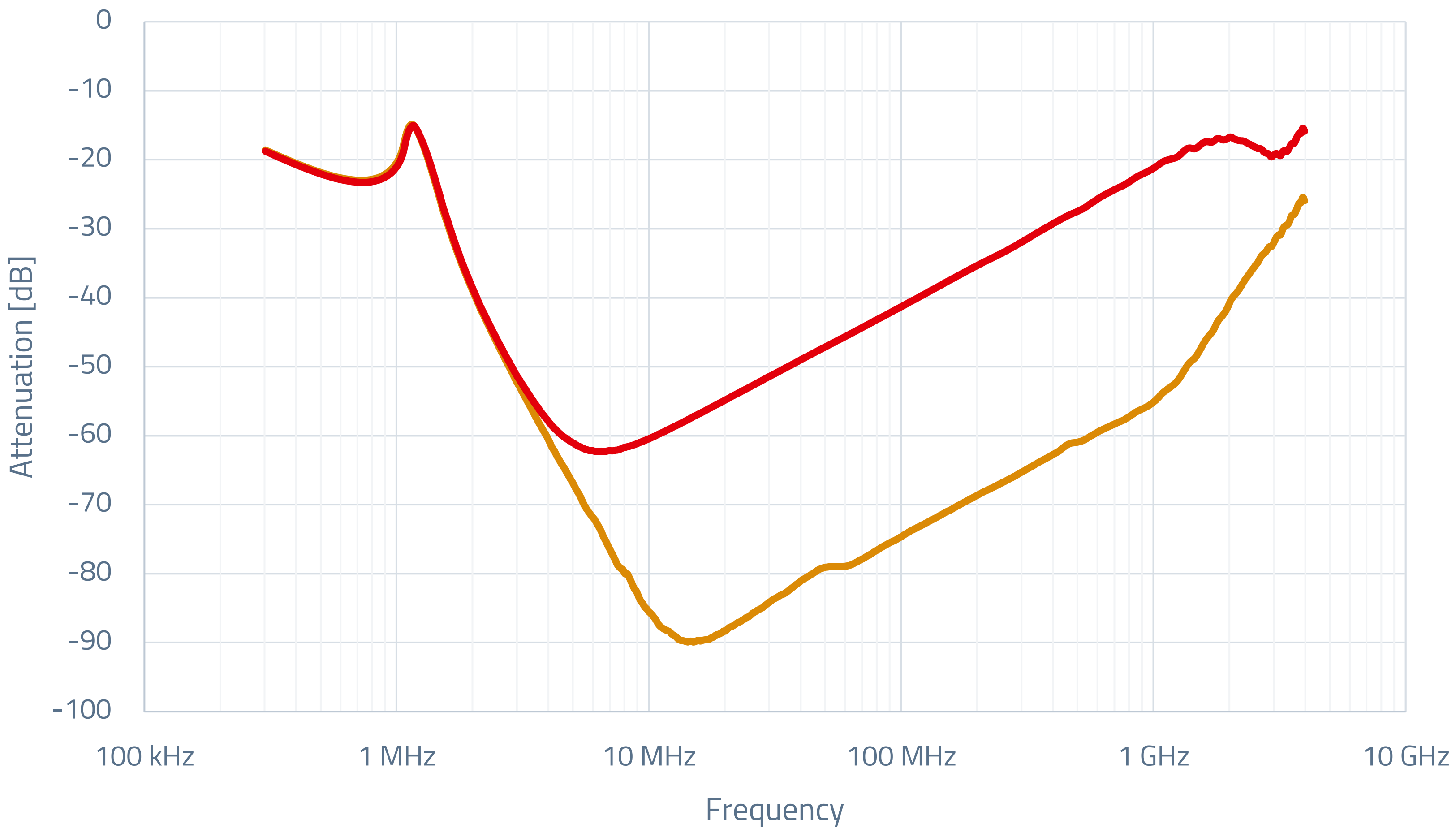
VNA measurement S21 300kHz – 3Ghz - Layout: Influence on the attenuation



0805, Bad layout



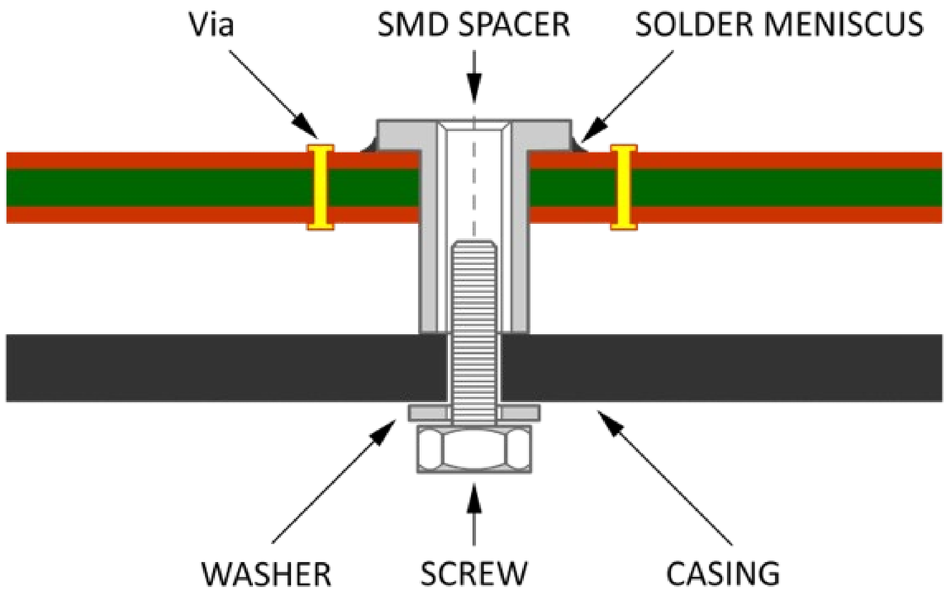
0805, Good layout



Layout concepts

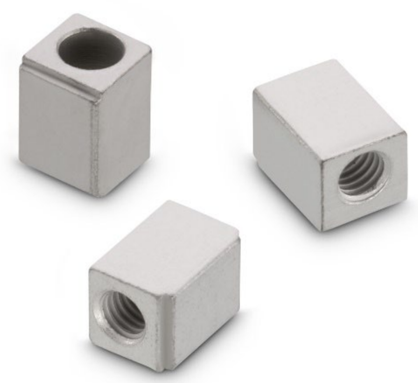
SMD Spacer for ground connections

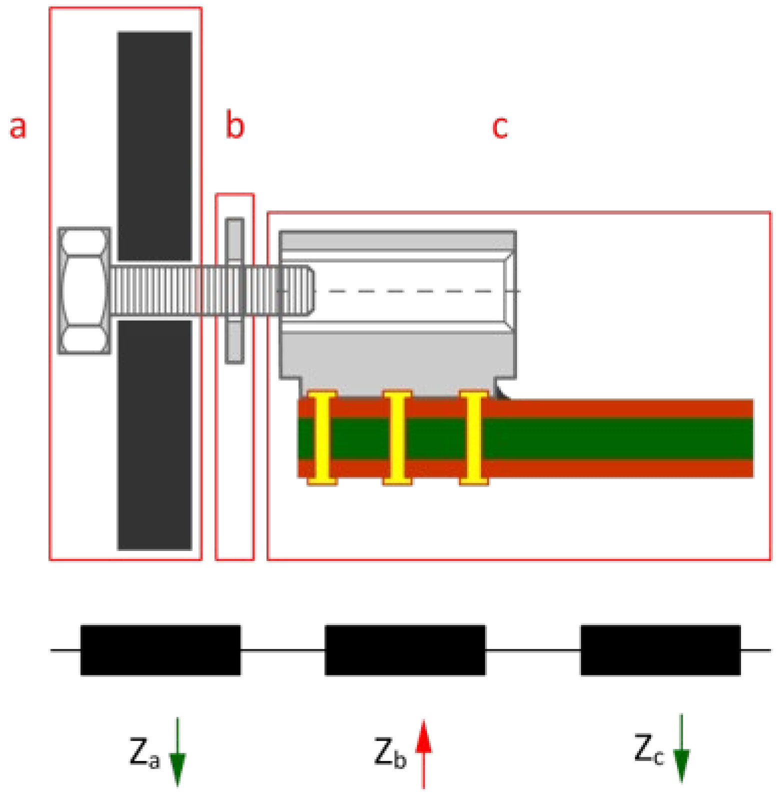
- Tin plated SMD spacers
- Solid solder pad and a big surface area
- Large contact transitions area



Layout concepts

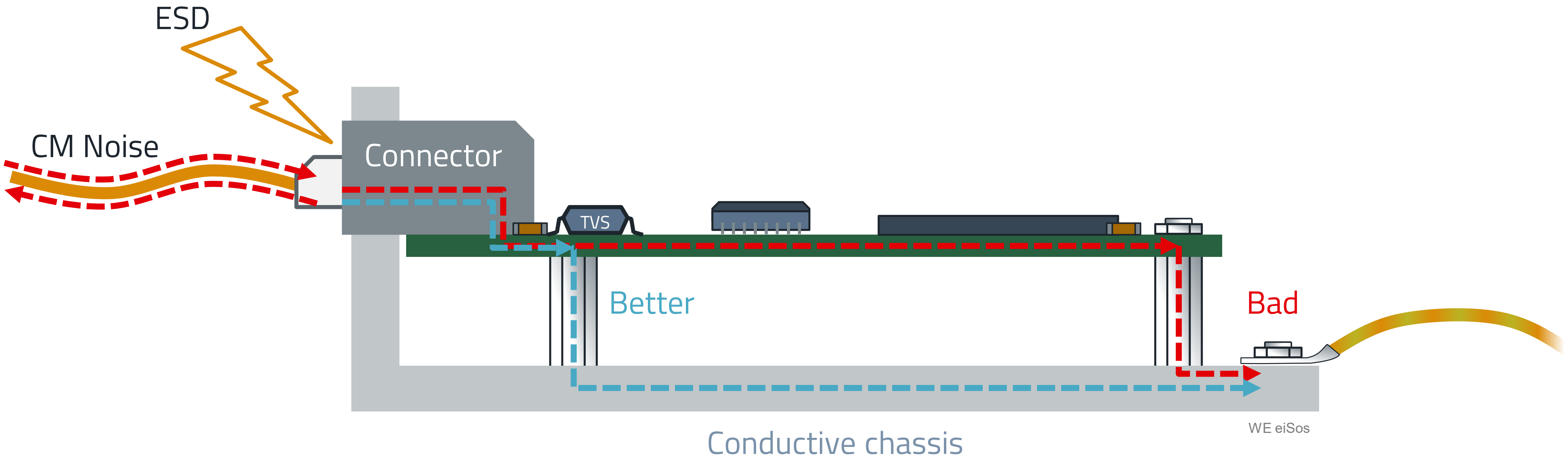
- Washer placement is important
- High impedance objects react as RF filter





Layout concepts

Diverting noise to earth

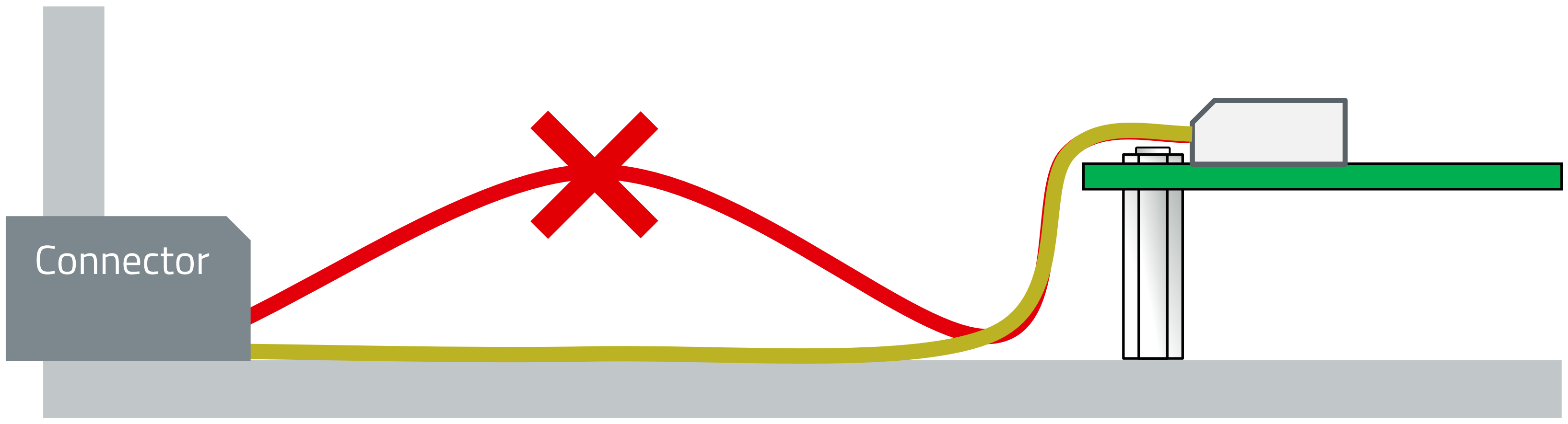


- Grounding studs have to be placed so that disturbances don‘t affect the electronic parts
- Reference ground for ESD (and common mode noise) is earth potential

Layout concepts

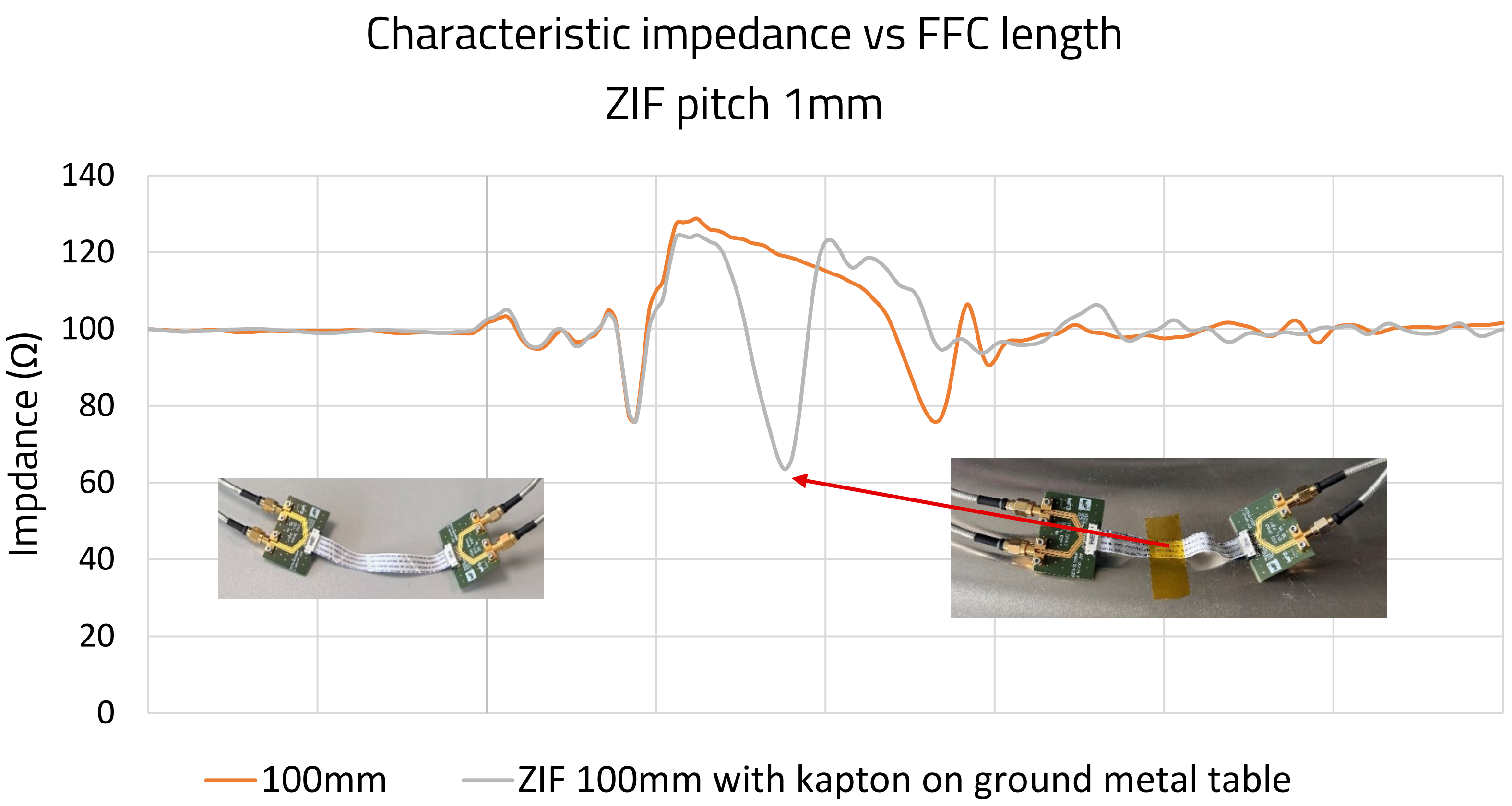
Reduce radiated emission

- Whenever possible, lay cables constantly along the chassis
- This keeps the electromagnetic field generated minimum



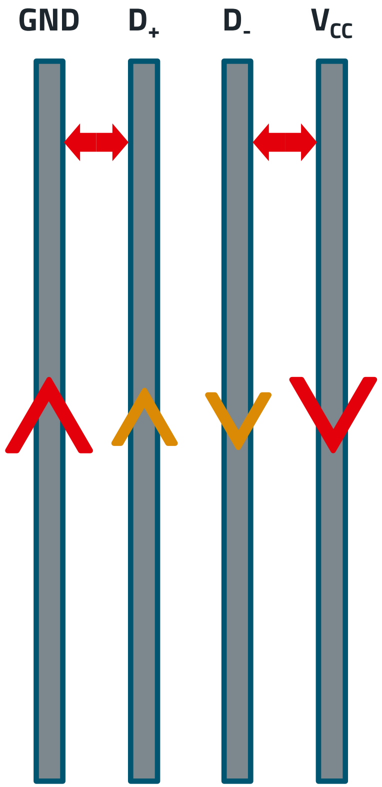
Layout concepts

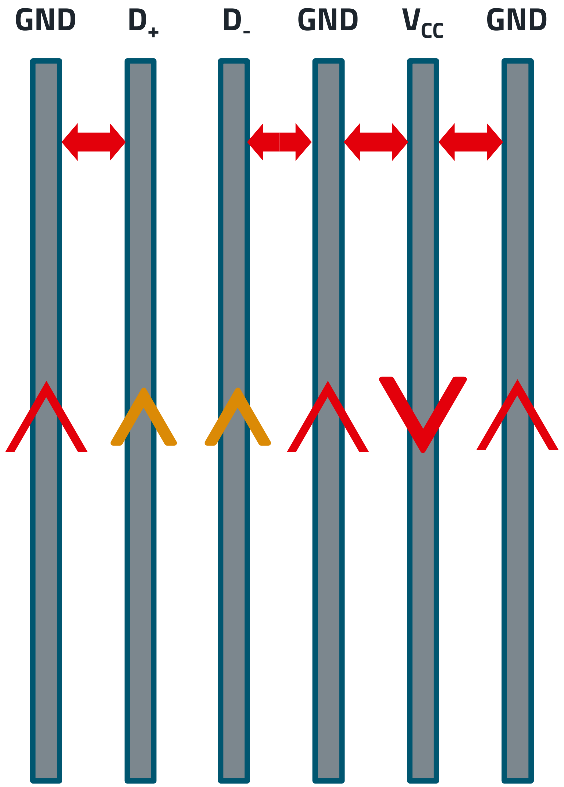
Kapton tape on ground metal plate

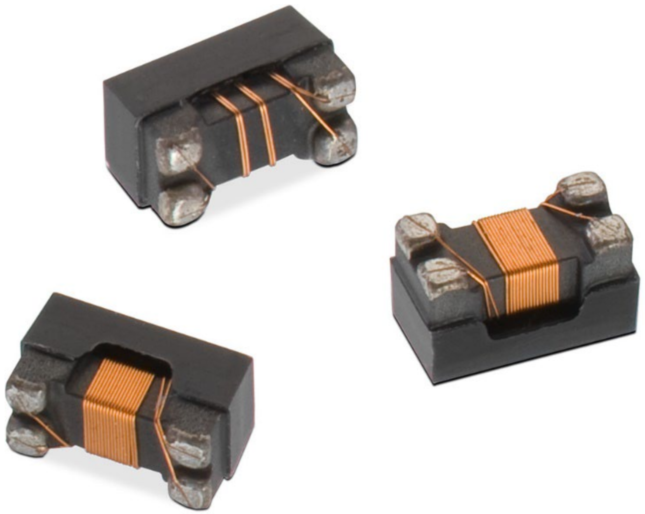


Layout concepts

From differential to common mode







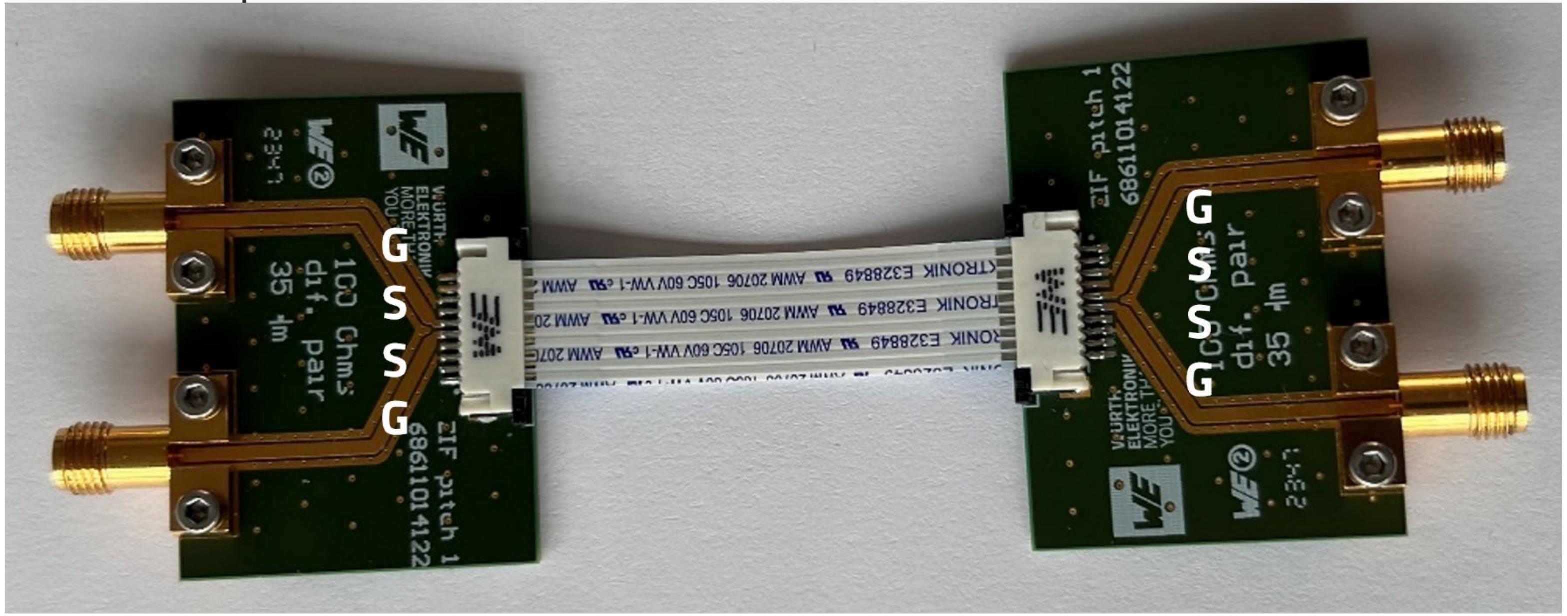
WE-CNSW SMT

SIGNAL INTEGRITY

Signal integrity

Measurement process

Differential pair PCB

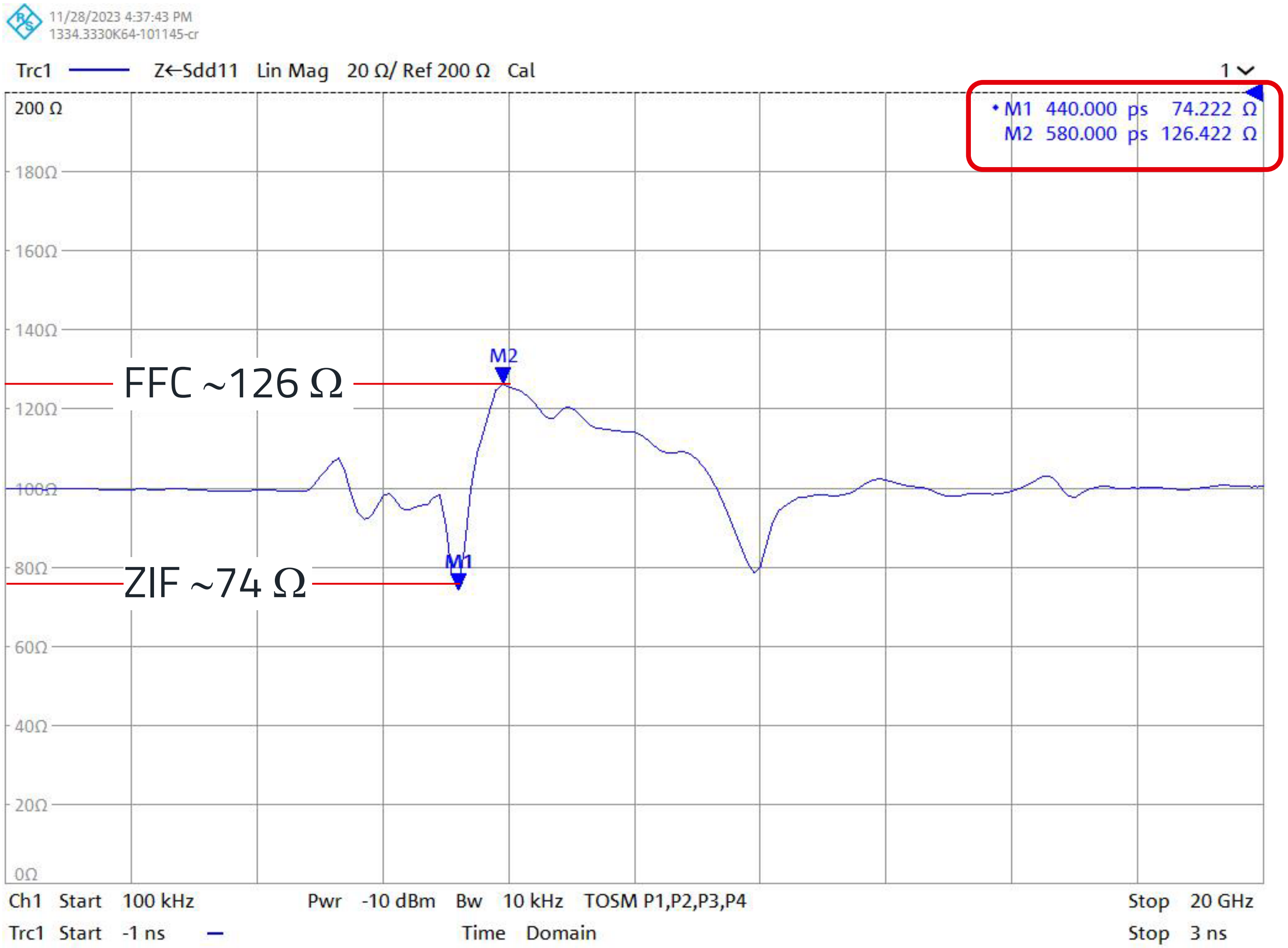


G: Ground
S: Signal

Signal integrity

ZIF FFC impedance

Pitch 0.5mm

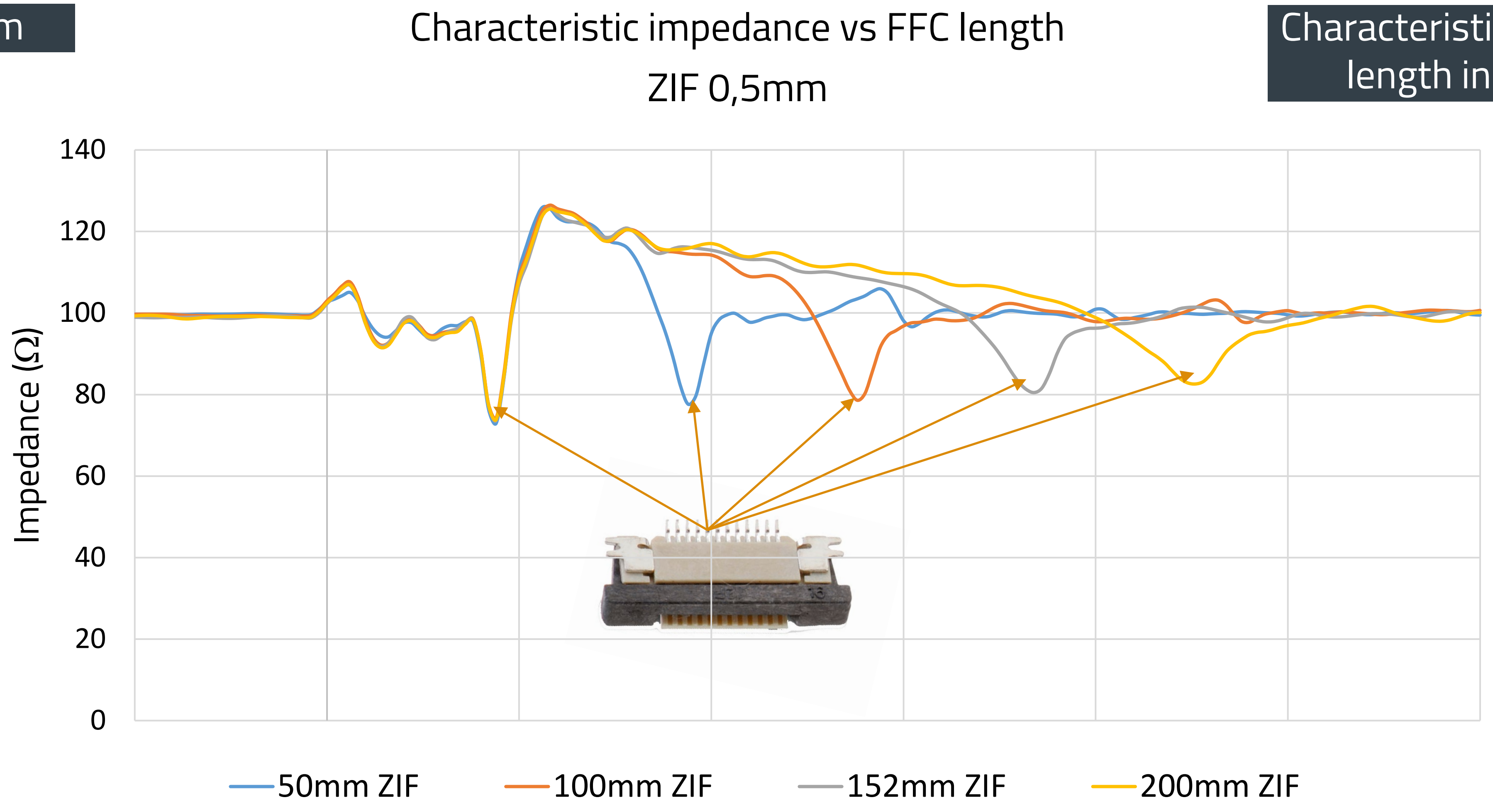


Signal integrity

ZIF FFC length impedance

Pitch 0.5mm

Characteristic impedance is length independent



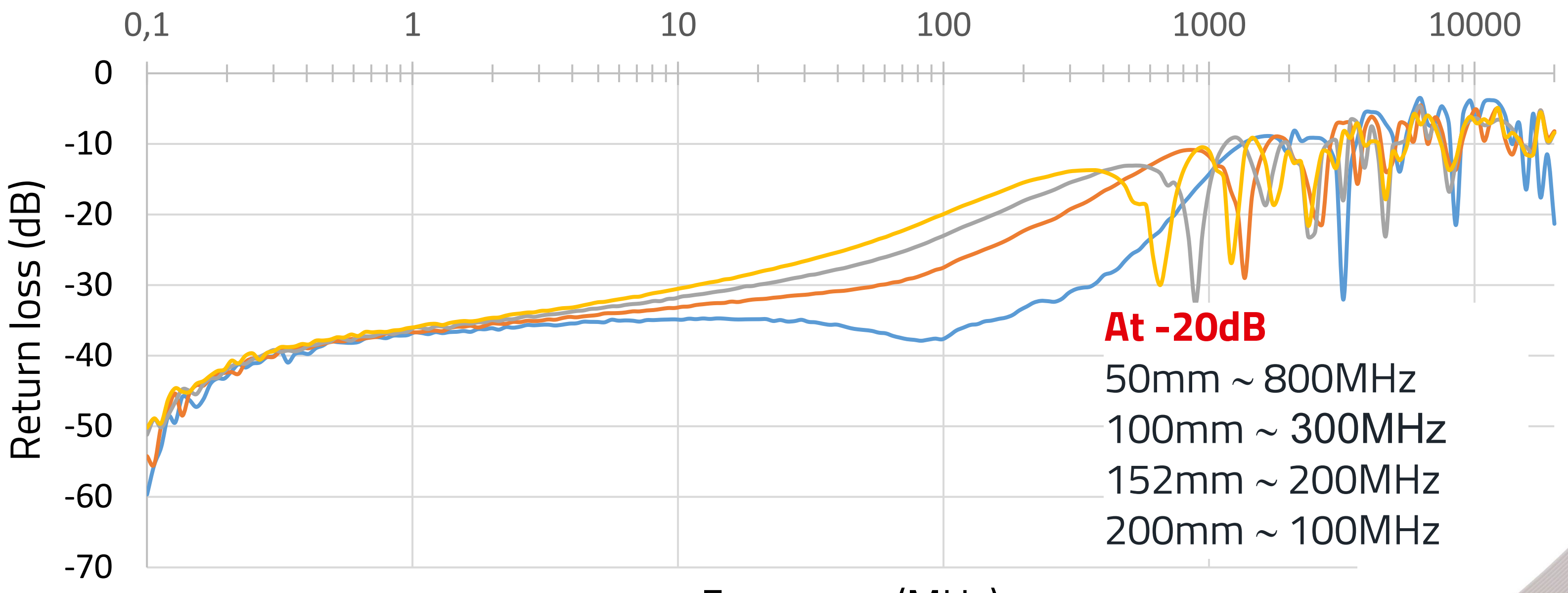
ZIF FFC insertion loss

Pitch 0.5mm

Increased FFC length increases return loss

Return loss vs FFC length

ZIF 0,5mm



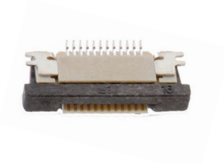
At -20dB

50mm ~ 800MHz

100mm ~ 300MHz

152mm ~ 200MHz

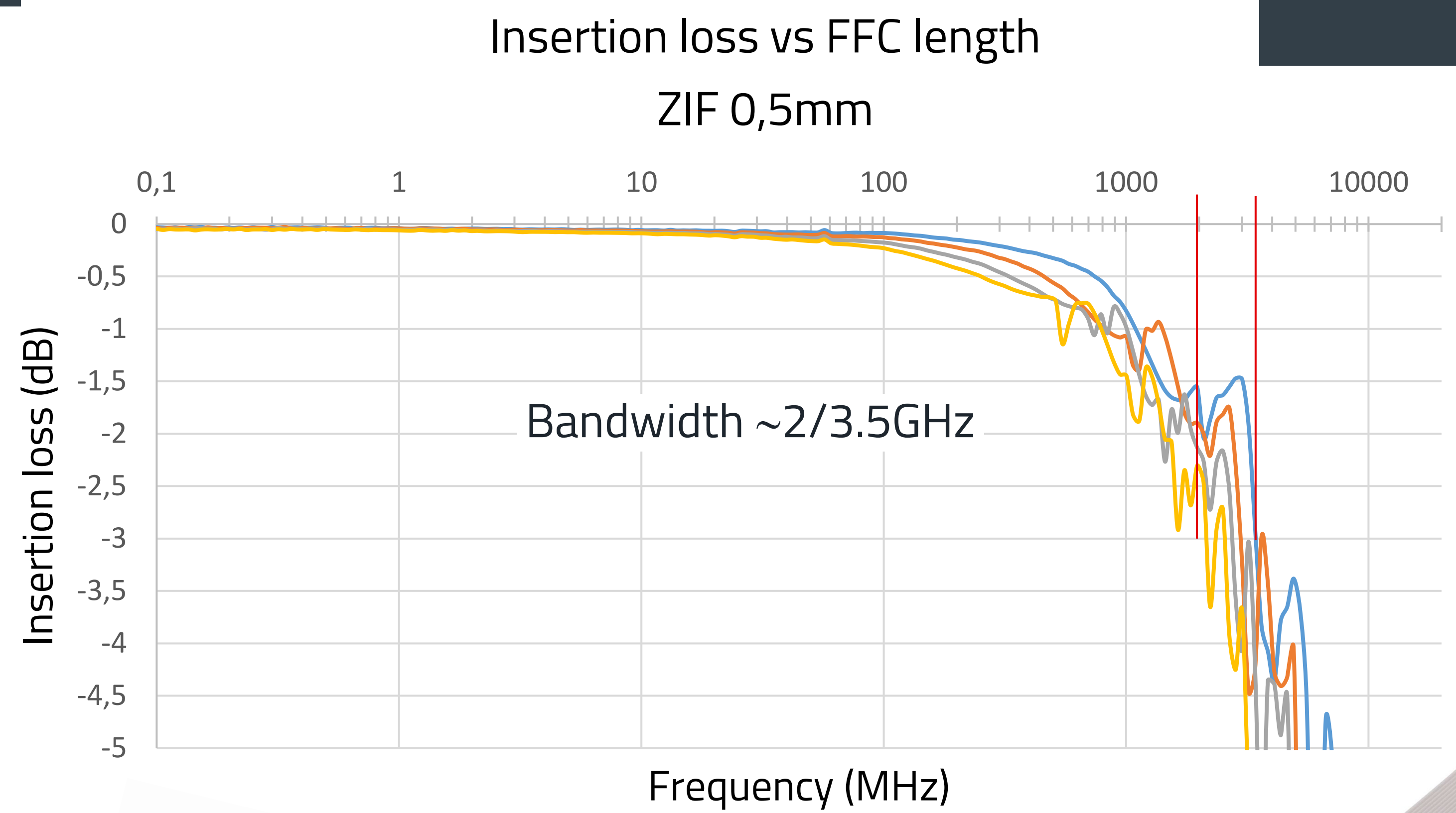
200mm ~ 100MHz

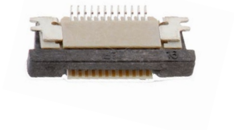


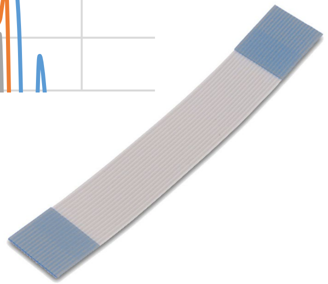
ZIF FFC insertion loss

Pitch 0.5mm

Increased FFC length increases insertion loss







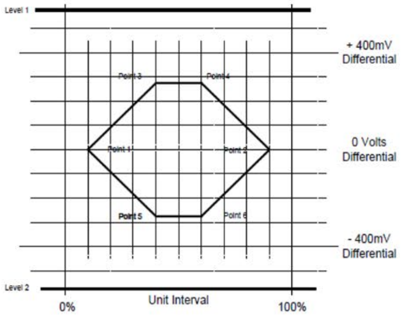
Eye diagram

USB standard eye diagram characteristics

Universal Serial Bus Specification Revision 2.0

Template 3

Figure 7-15 shows receiver sensitivity requirements for a device (with a captive cable) when a signal is applied at TP2.

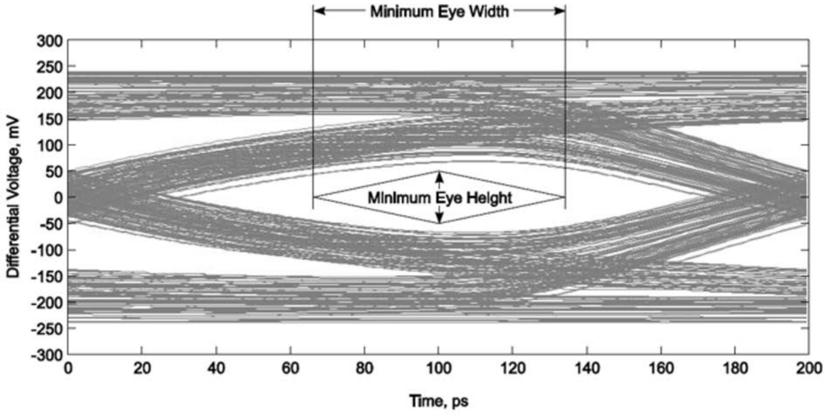


	Voltage Level (D+ - D-)	Time (% of Unit Interval)
Level 1	575 mV	N/A
Level 2	-575 mV	N/A
Point 1	0 V	10% UI
Point 2	0 V	90% UI
Point 3	275 mV	40% UI
Point 4	275 mV	60% UI
Point 5	-275 mV	40% UI
Point 6	-275 mV	60% UI

Figure 7-15. Template 3

Bit rising time 500ps

Figure 6-17. Eye Masks



Gen 1 eye mask

USB3.2 gen 1 standard

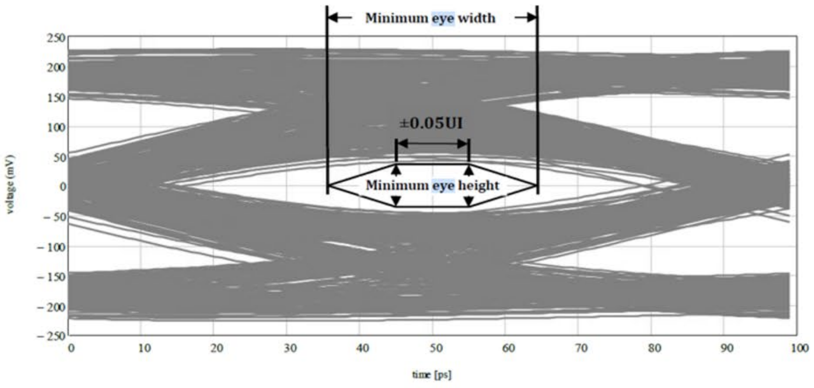
10Gb/s

Bit rising time 50ps

Revision 1.1
June 2022

- 80 -

Universal Serial Bus 3.2
Specification



USB3.2 gen 2 standard

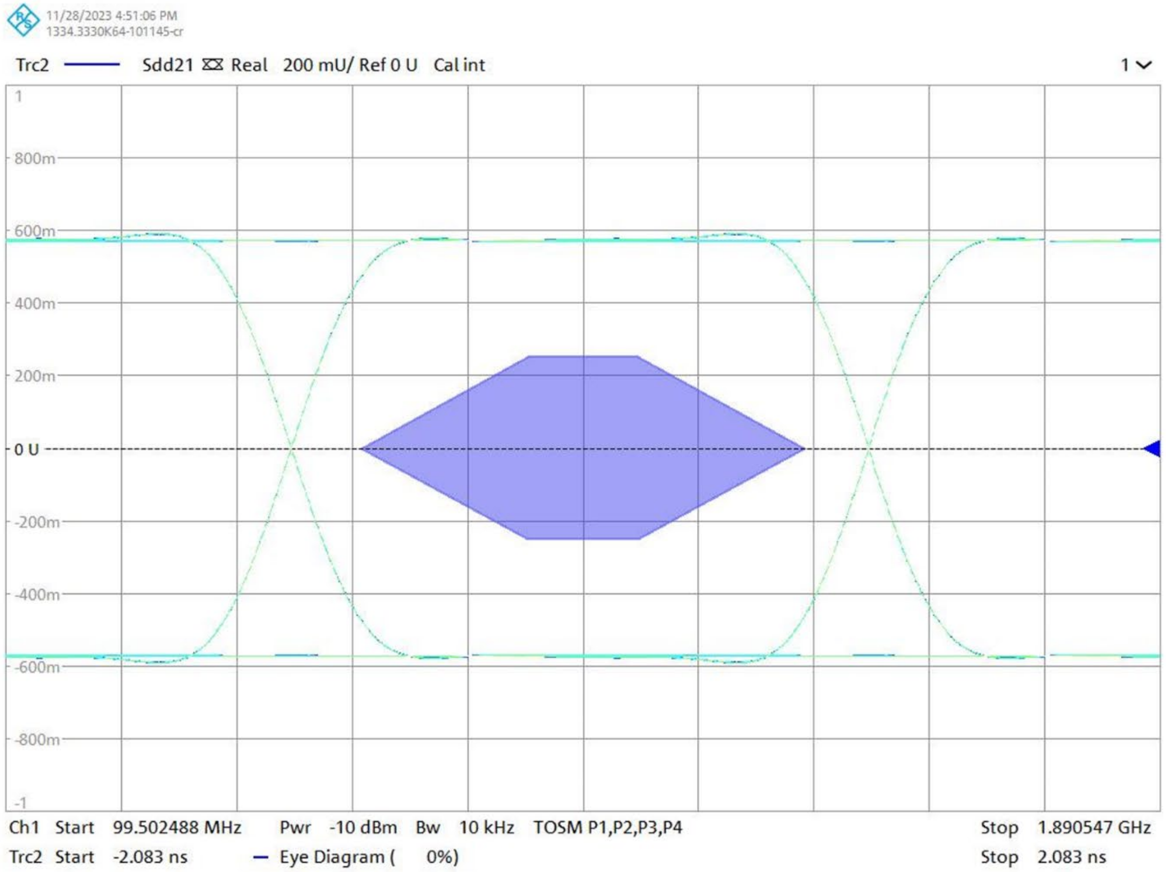
20Gb/s

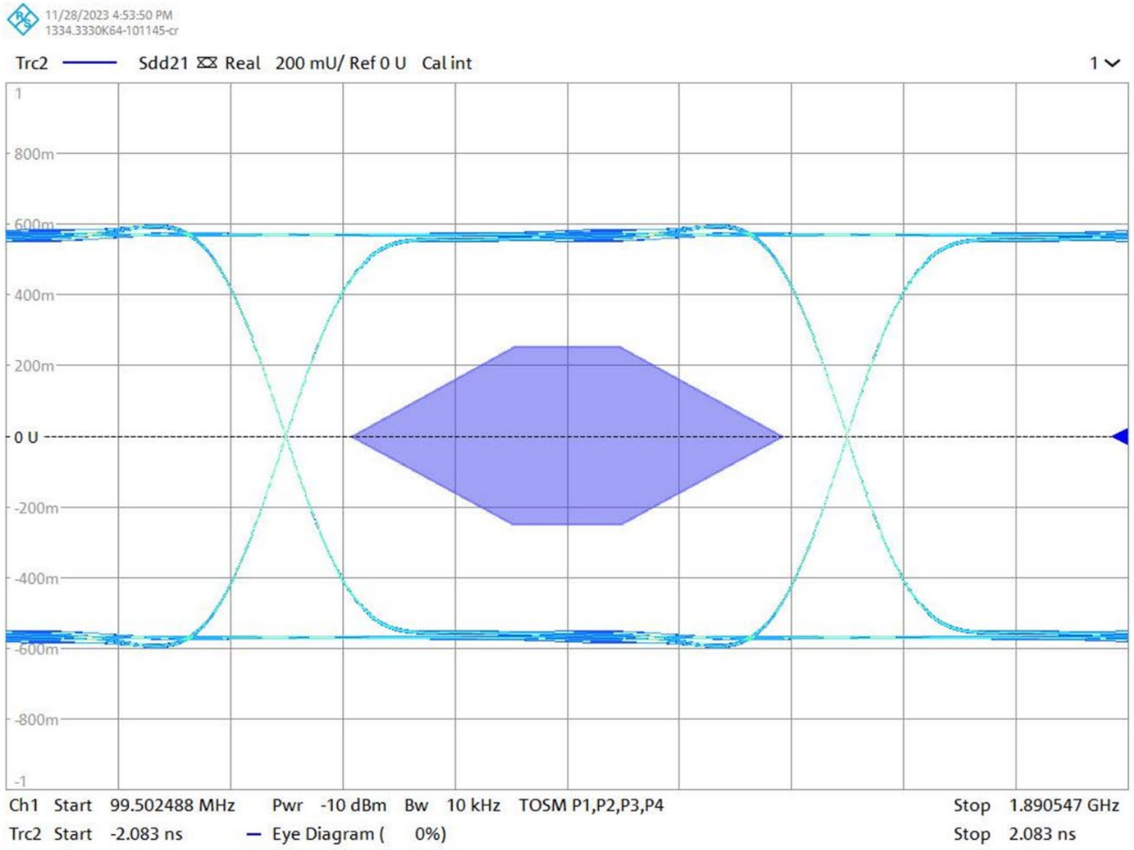
Bit rising time 50ps

Characteristics and masks given by usb.org - Public documents

Eye diagram

USB 2.0 – ZIF Pitch 0.5mm horizontal





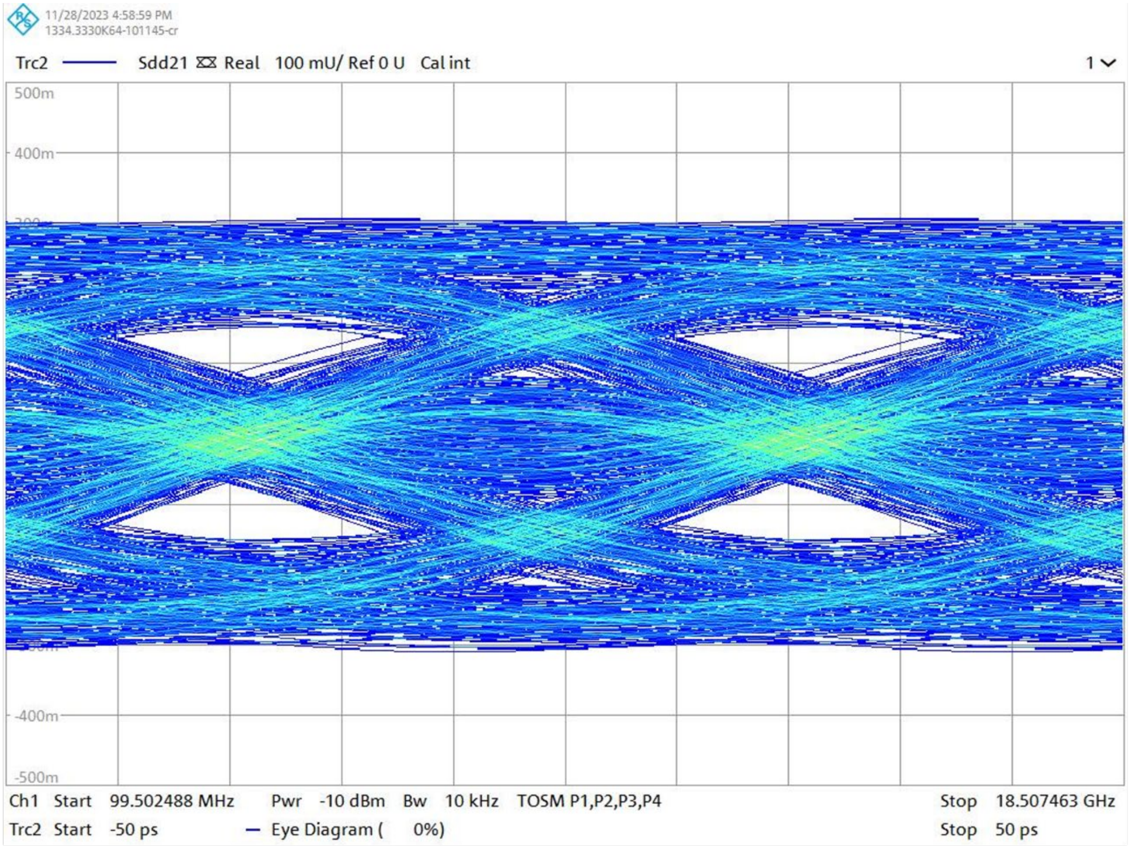
FFC 50mm

PASS

FFC 200mm

Eye diagram

USB 3.2 gen 2 10Gbps– ZIF Pitch 0.5mm horizontal



FFC 50mm

All length failed

SHIELDING

Shielding

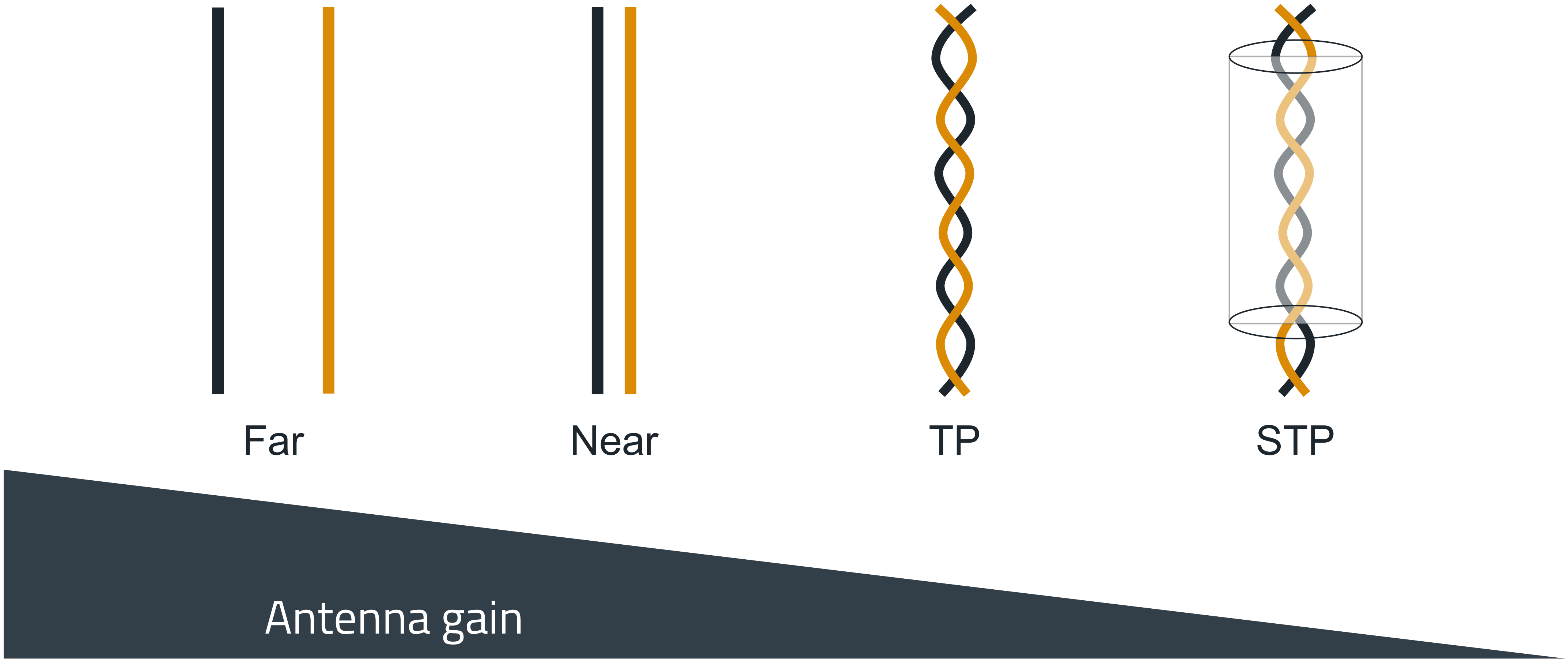
Reminder - Galvanic corrosion

Metal A / Metal B	Platine	Gold	St. steel	Silver	Nickel	Copper	Brass	Tin	Lead	Steel	Al.	Iron	Chrome	Zinc
Platine	0	0,13	0,25	0,35	0,43	0,57	0,65	0,8	0,84	1	1,09	1,11	1,2	1,4
Gold	0,13	0	0,11	0,22	0,3	0,44	0,52	0,67	0,71	0,87	0,96	0,98	1,07	1,27
St. steel	0,25	0,11	0	0,1	0,18	0,32	0,4	0,55	0,59	0,75	0,84	0,86	0,95	1,15
Silver	0,35	0,22	0,1	0	0,08	0,22	0,3	0,45	0,49	0,65	0,74	0,76	0,85	1,05
Nickel	0,43	0,3	0,18	0,08	0	0,14	0,22	0,37	0,41	0,57	0,66	0,67	0,77	0,97
Copper	0,57	0,44	0,32	0,22	0,14	0	0,08	0,23	0,27	0,43	0,52	0,54	0,63	0,83
Brass	0,65	0,52	0,4	0,3	0,22	0,08	0	0,15	0,19	0,35	0,44	0,47	0,55	0,75
Tin	0,8	0,67	0,55	0,45	0,37	0,23	0,15	0	0,04	0,2	0,29	0,31	0,4	0,6
Lead	0,84	0,71	0,59	0,49	0,41	0,27	0,19	0,04	0	0,16	0,25	0,27	0,36	0,56
Steel	1	0,87	0,75	0,65	0,57	0,43	0,35	0,2	0,16	0	0,09	0,11	0,2	0,4
Al	1,09	0,96	0,84	0,74	0,66	0,52	0,44	0,29	0,25	0,09	0	0,05	0,11	0,4
Iron	1,11	0,98	0,86	0,76	0,67	0,54	0,47	0,31	0,27	0,11	0,05	0	0,1	0,3
Chrome	1,2	1,07	0,95	0,85	0,77	0,63	0,55	0,4	0,36	0,2	0,11	0,1	0	0,2
Zinc	1,4	1,27	1,15	1,05	0,97	0,83	0,75	0,6	0,56	0,4	0,4	0,3	0,2	0

Metal A is attacked
Metal B is attacked
Risk of galvanic corrosion
No galvanic corrosion

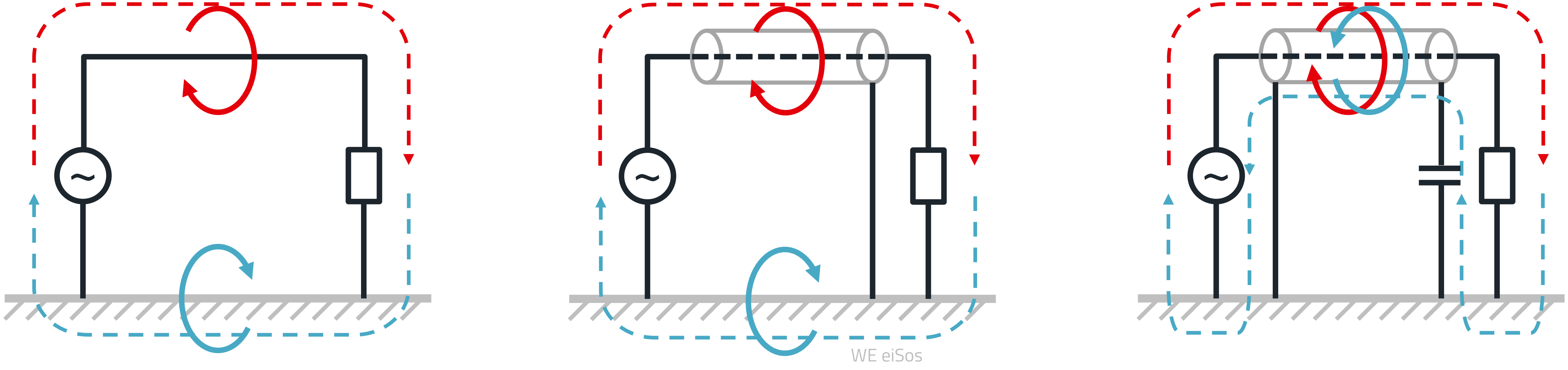
Shielding

Cable as antenna



Shielding

Attaching the cable shielding



Radiating Noise

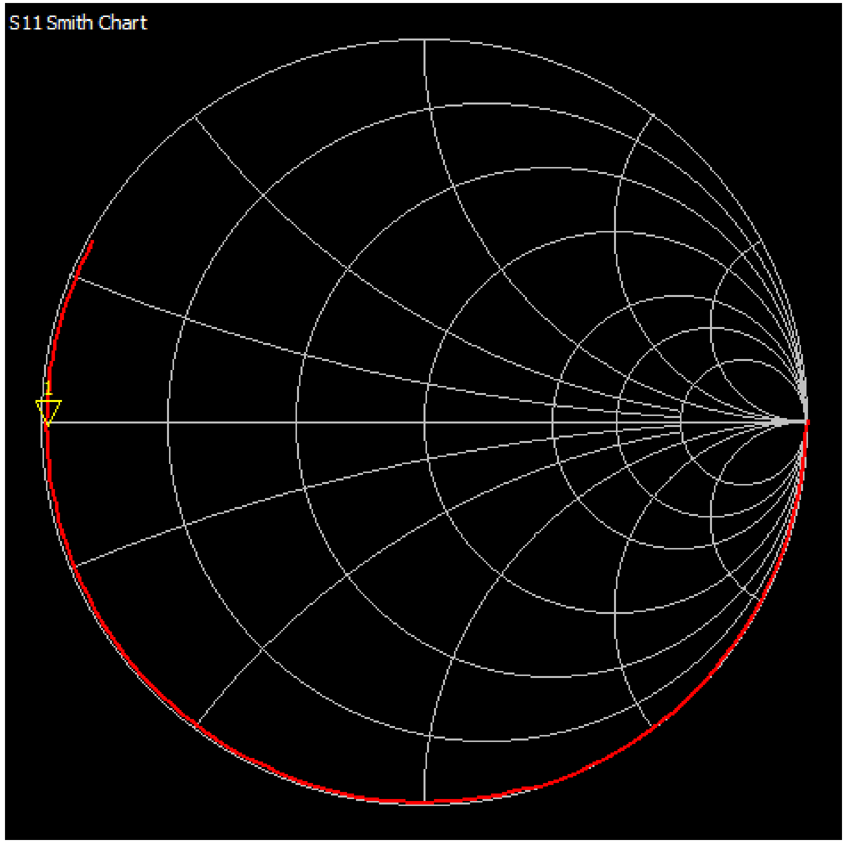
E-fields are shielded
H-fields radiating

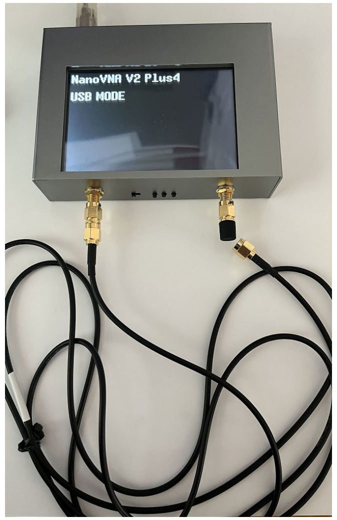
E-fields are shielded
H-fields are compensated

Shielding

How should you attach the shielding?

RG174 - 152mm
λ/4 - 344MHz





RG174 - 2000mm
λ/4 - 24MHz