KOPPLUNG HOCHFREQUENTER SIGNALE AUF DER LEITERPLATTE

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Field Application Engineers

WÜRTH ELEKTRONIK MORE THAN YOU EXPECT

- Kopplung zwischen Stromkreisen
  - Kopplungsarten
  - Messungen mit Nahfeldsonden

- Schirmanbindung
  - Pfade hochfrequenter Ströme
  - Impedanz des Rückstrompfades
  - Messung des Magnetfeldes der Leiterschleife

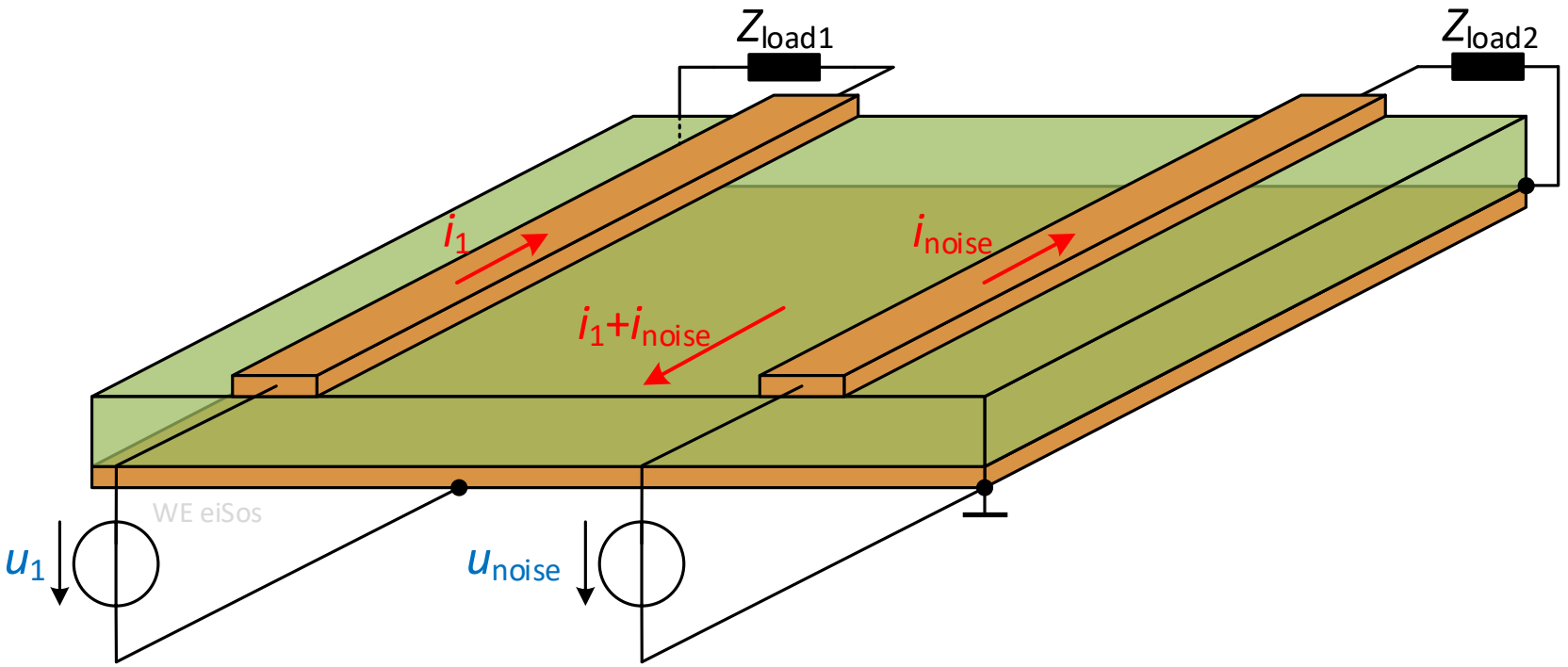
Kopplung zwischen Stromkreisen

Kopplungsarten

Messungen mit Nahfeldsonden

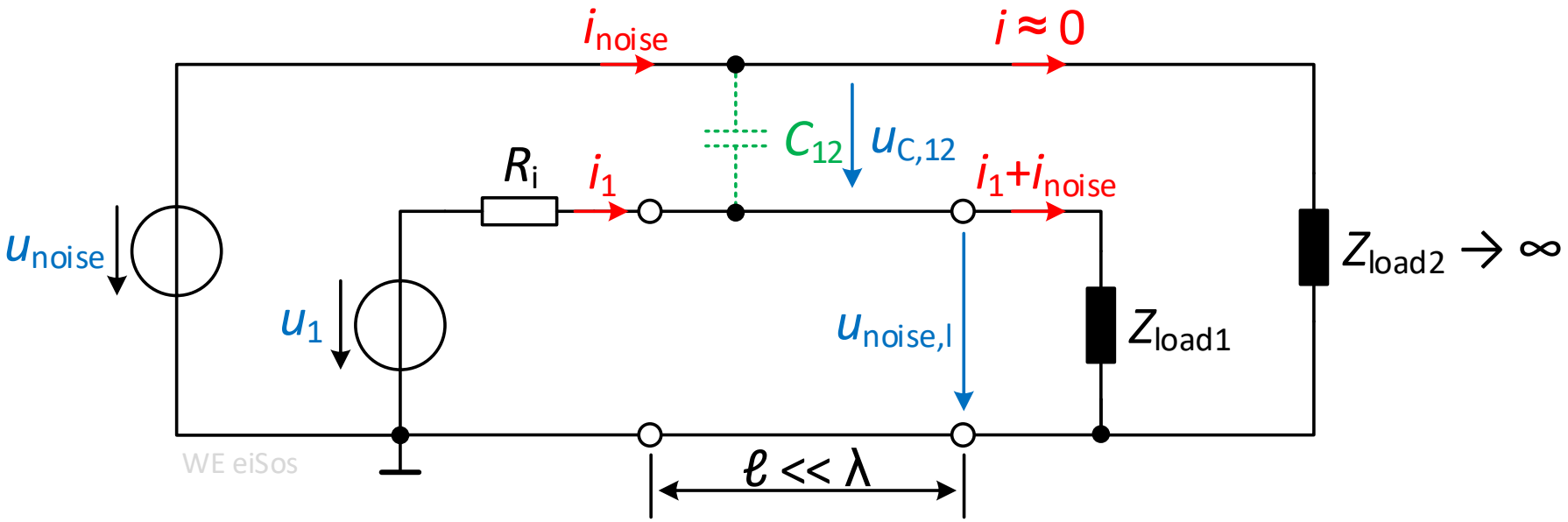
Coupling effects

Overview



- Dominant **capacitive** coupling when $Z_{\mathrm{load},2} \to \infty$
- Dominant **inductive** coupling when $Z_{\mathrm{load},2} \to 0$
- **Impedance coupling** when they have the same common return (Ground plane)

Kapazitive Kopplung



- Annahme und Vereinfachung: $X_{C_{12}} \gg R_i \| Z_{load,1} \Rightarrow u_{C_{12}} \gg u_{noise,l} \Rightarrow u_{C_{12}} \sim u_{noise}$
- Störspannung an der Last:

$$u_{noise,l} = i_{noise} \cdot \frac{R_i \cdot Z_{load,1}}{R_i + Z_{load,1}} = C_{12} \cdot \frac{du_{noise}}{dt} \cdot \frac{R_i \cdot Z_{load,1}}{R_i + Z_{load,1}}$$

Kapazitive Kopplung

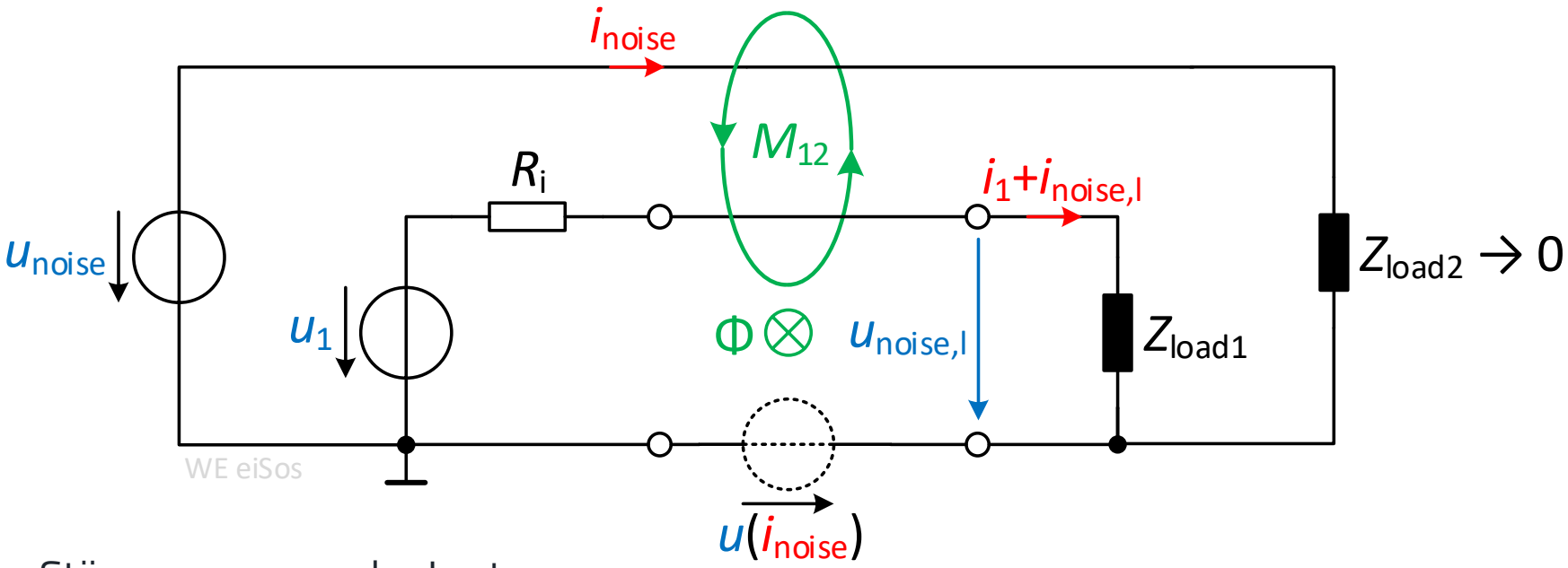
- Beispiel:
  - 2 parallele Mikrostreifenleitungen mit 2mm Breite, 50mm Länge und einem Abstand von 2mm ($\varepsilon_r = 2{,}4$) → $C_{12} = 1{,}7\text{pF}$
  - Schaltflanke eines MOSFET:
  - $R_i = 10\text{m}\Omega$, $Z_{load,1} = 5\Omega$
  - $U_1 = 5\text{V}$ → $U_{load,1} = 4{,}99\text{V}$
  - Störspannung:

  - Signal-Rausch-Abstand:

$$u_{noise,l} = C_{12} \cdot \frac{du_{noise}}{dt} \cdot \frac{R_i \cdot Z_{load,1}}{R_i + Z_{load,1}} = 17\mu\text{V}$$

$$\text{SNR} = 20 \cdot \log\left(\frac{4{,}99\text{V}}{17\mu\text{V}}\right) = 109{,}4\text{dB}$$

Induktive Kopplung



- Störspannung an der Last:

$$u_{\mathrm{noise,l}} = u(i_{\mathrm{noise}}) \cdot \frac{Z_{\mathrm{load,1}}}{R_{\mathrm{i}} + Z_{\mathrm{load,1}}} = M_{12} \cdot \frac{\mathrm{d}i_{\mathrm{noise}}}{\mathrm{d}t} \cdot \frac{Z_{\mathrm{load,1}}}{R_{\mathrm{i}} + Z_{\mathrm{load,1}}}$$

Induktive Kopplung

- Beispiel:
  - 2 parallele Kabel (Ø 5mm), 10cm über einer leitfähigen Ebene, mit einem Abstand von 10cm über eine Länge von 10m → $M_{12} = 1{,}61\mu\mathrm{H}$
  - Änderungsrate des Stromes durch die induktive Last $Z_{\mathrm{load},2}$:
  - $R_\mathrm{i} = 10\mathrm{m}\Omega$, $Z_{\mathrm{load},1} = 1\Omega$
  - $U_1 = 24\mathrm{V}$ → $U_{\mathrm{load},1} = 23{,}76\mathrm{V}$
  - Störspannung:

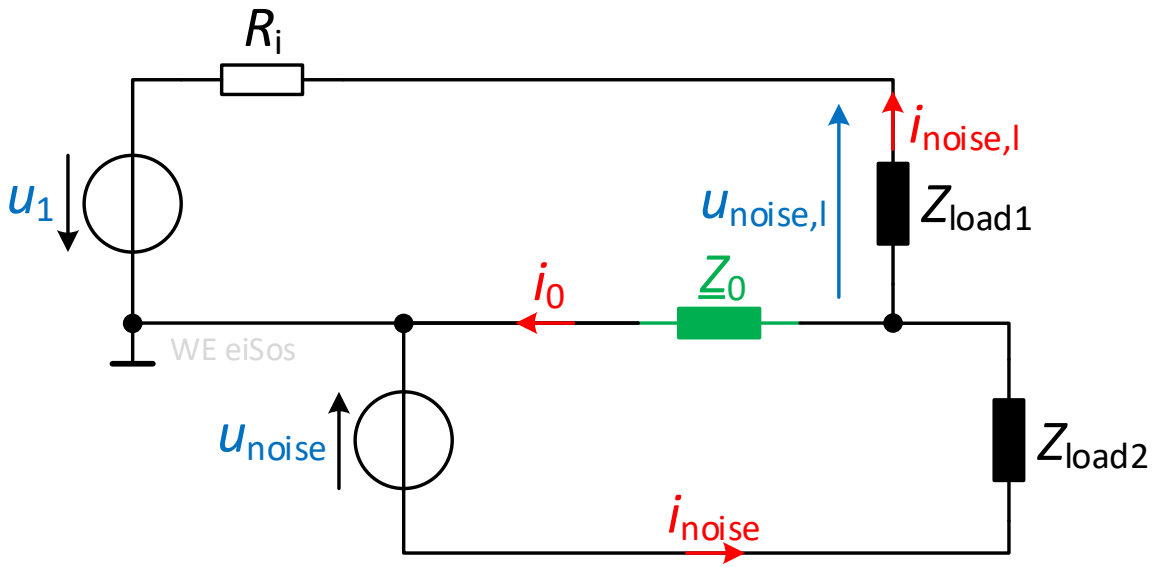
$$\frac{\mathrm{d}i_\mathrm{noise}}{\mathrm{d}t} = 2\frac{\mathrm{A}}{\mu\mathrm{s}}$$

  - Signal-Rausch-Abstand:

$$u_{\mathrm{noise,l}} = M_{12} \cdot \frac{\mathrm{d}i_\mathrm{noise}}{\mathrm{d}t} \cdot \frac{Z_{\mathrm{load},1}}{R_\mathrm{i} + Z_{\mathrm{load},1}} = 3{,}19\mathrm{V}$$

$$\mathrm{SNR} = 20 \cdot \log\left(\frac{23{,}76\mathrm{V}}{3{,}19\mathrm{V}}\right) = 17{,}45\mathrm{dB}$$

Impedanzkopplung



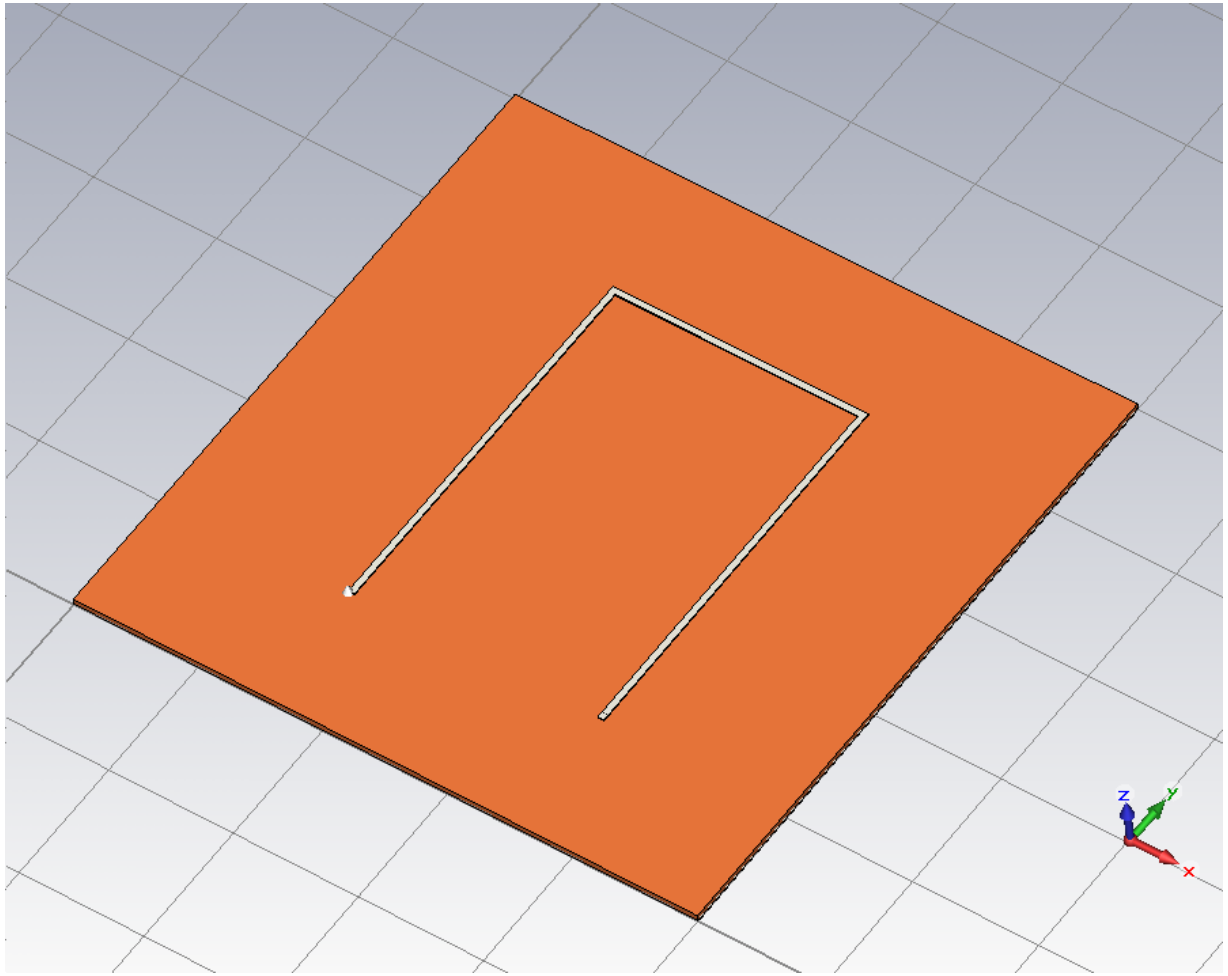
- Koppelimpedanz: $\underline{Z}_0 = R_0 + \mathrm{j}\omega L_0$
- Störspannung an der Last:

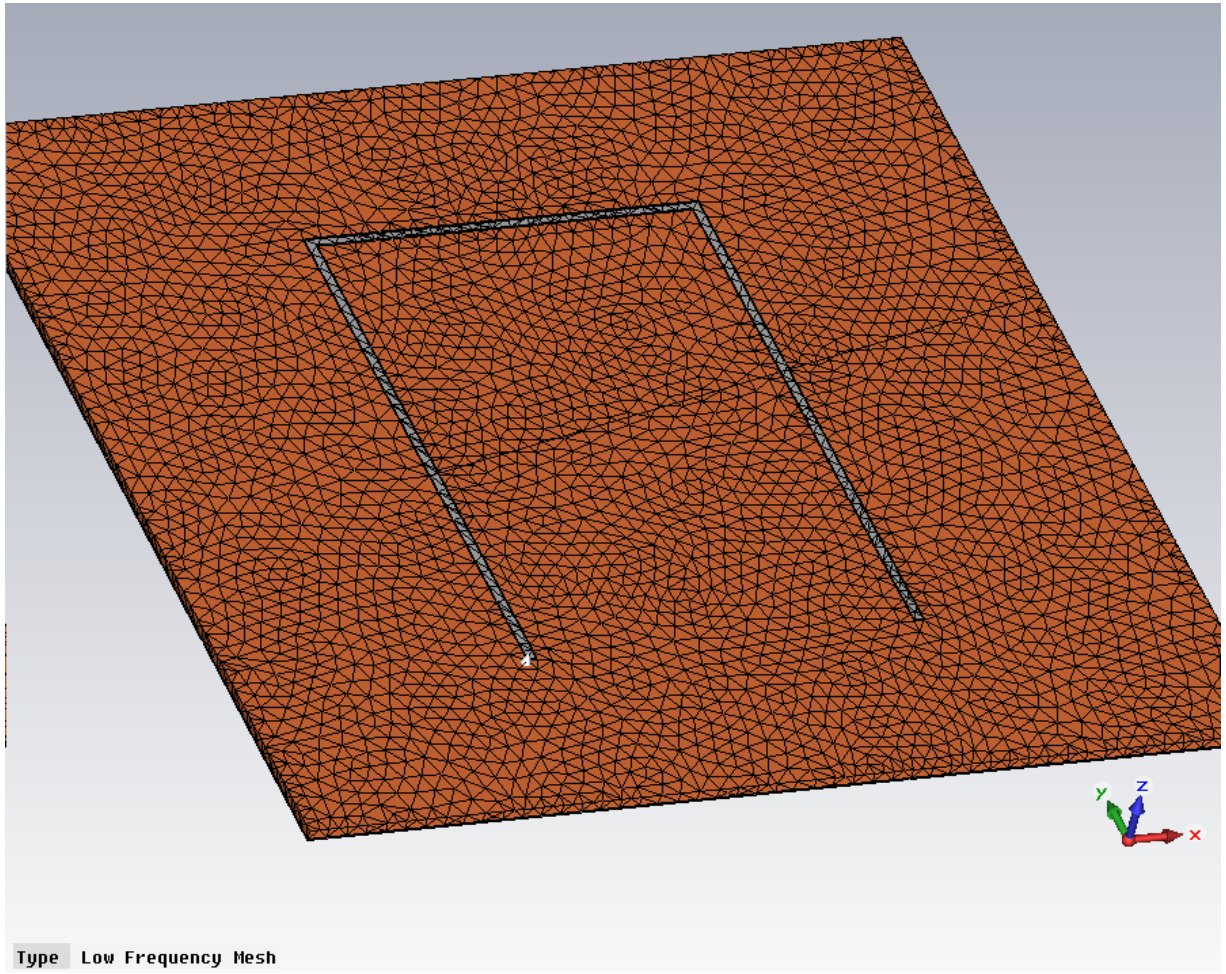
$$u_{\mathrm{noise,l}} = \frac{u_{\mathrm{noise}}}{Z_{\mathrm{load,2}} + \left(R_{\mathrm{i}} + Z_{\mathrm{load,1}}\right) \| Z_0} \cdot \frac{Z_{\mathrm{load,1}} \cdot Z_0}{R_{\mathrm{i}} + Z_{\mathrm{load,1}} + Z_0}$$

Coupling effects

Simulation in CST EMS

SEIBERSDORF LABORATORIES

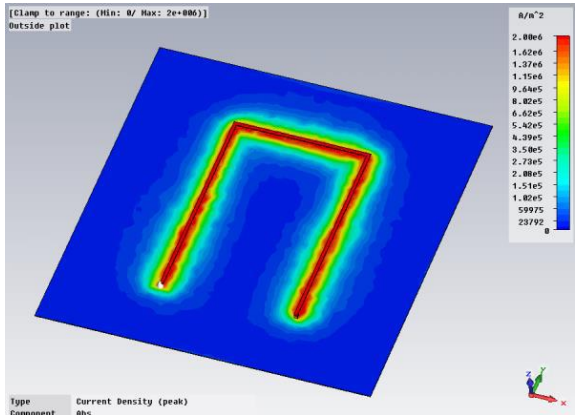




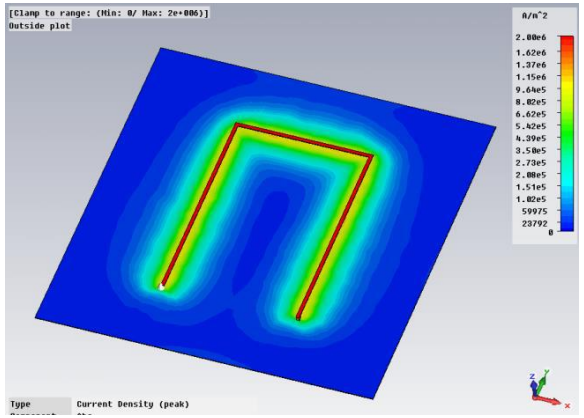
Coupling effects

Current path with a u shaped conductor simulated in CST EMS

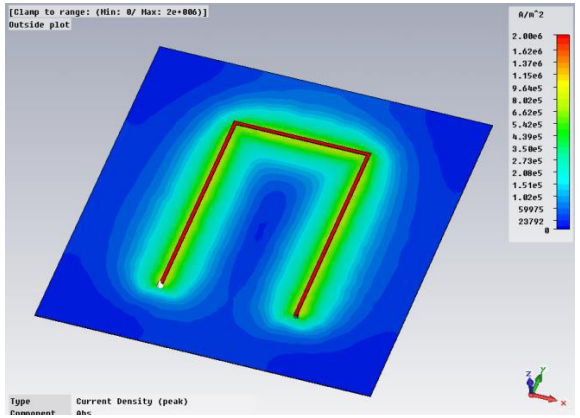
100kHz



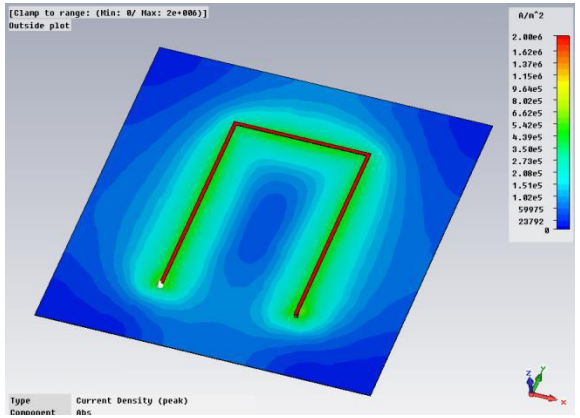
10kHz



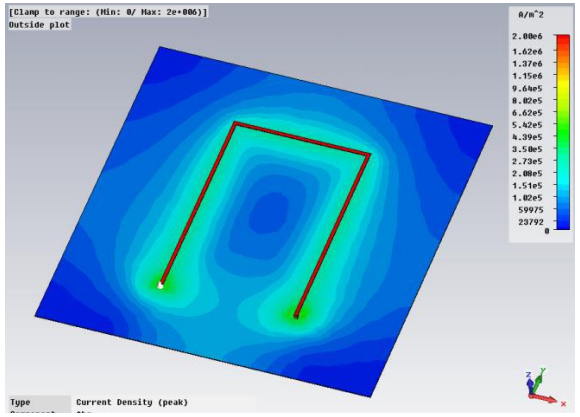
5kHz



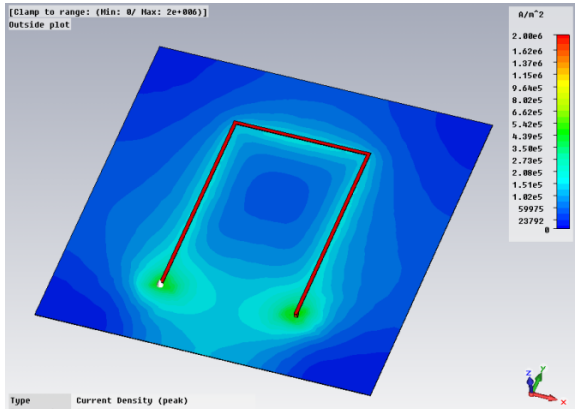
2kHz



1kHz



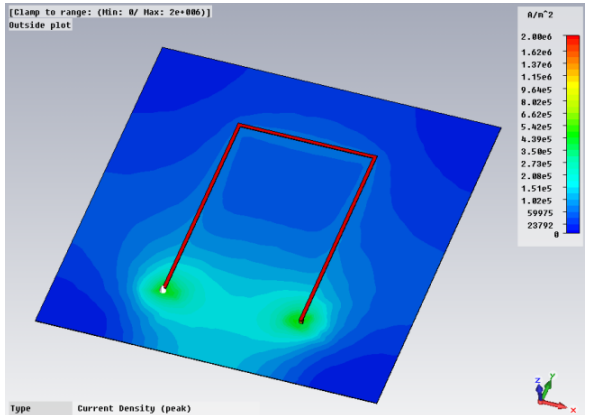
500Hz



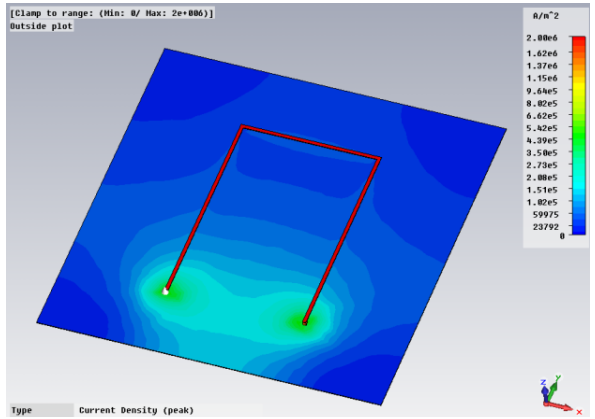
Coupling effects

Current path with a u shaped conductor simulated in CST EMS

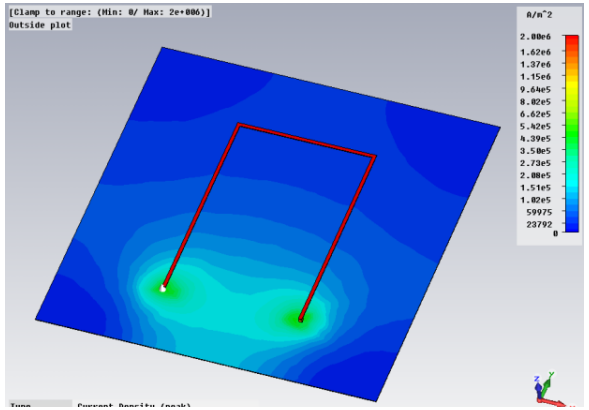
200Hz



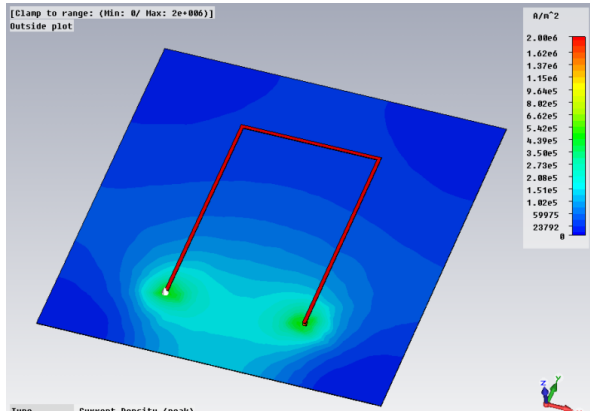
100Hz



50Hz

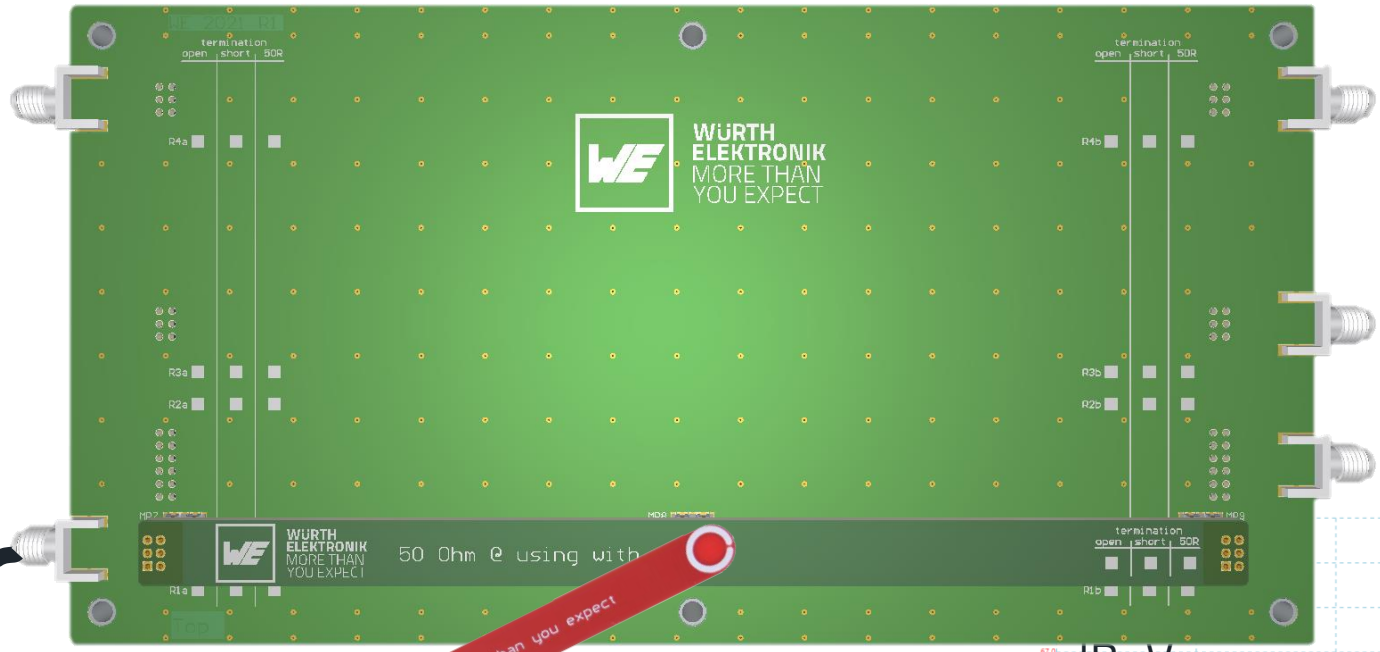


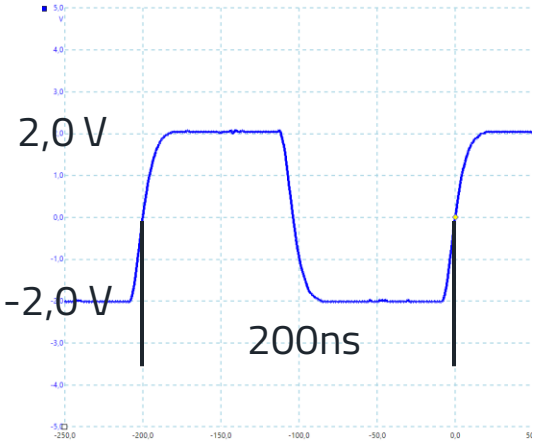
10Hz

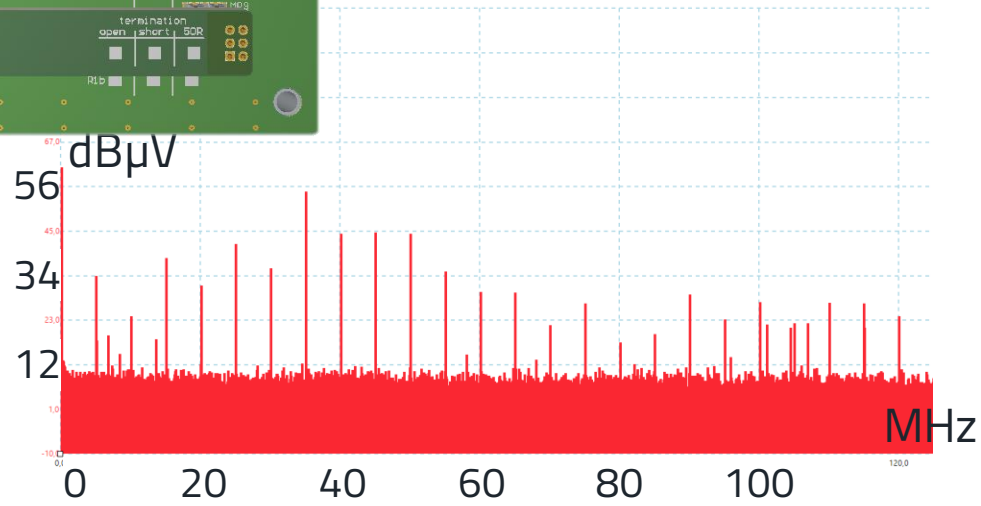


Coupling effects

Return path of high frequency current

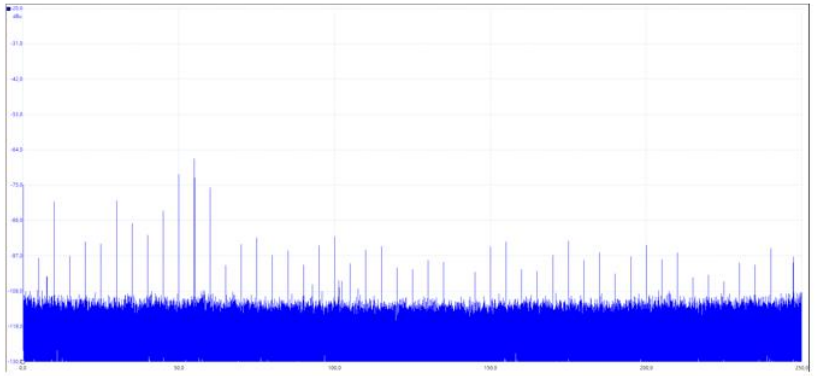




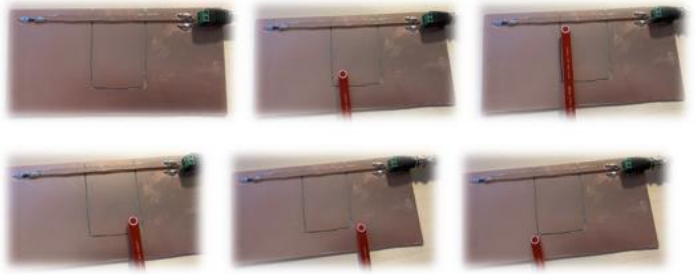


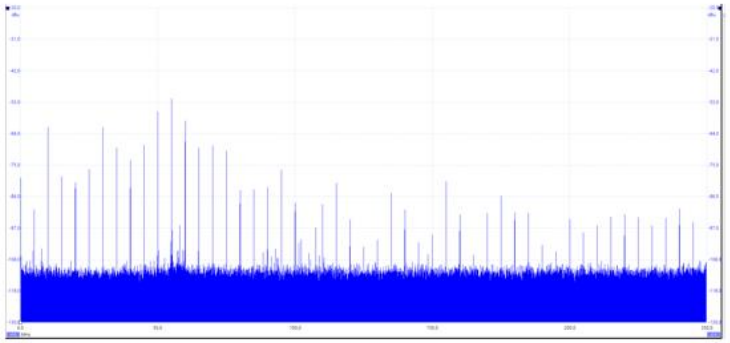
Coupling effects

Return path of high frequency current



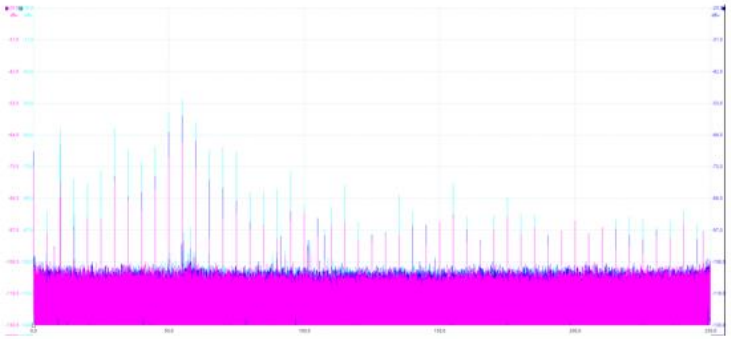
... ca. -67dB





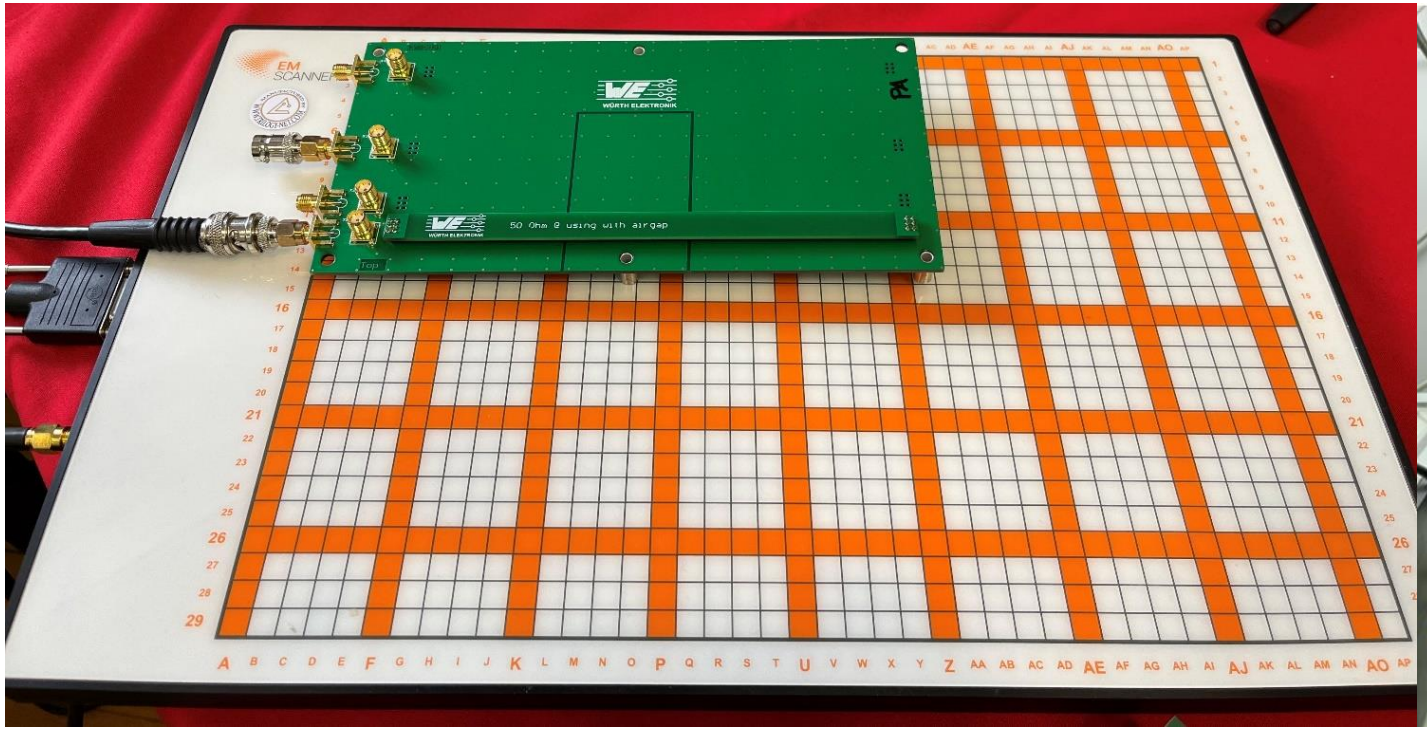
Ca. 52dB. ... Verschlechterung um ca. 15dB, im gesamten Bereich der Freistellung

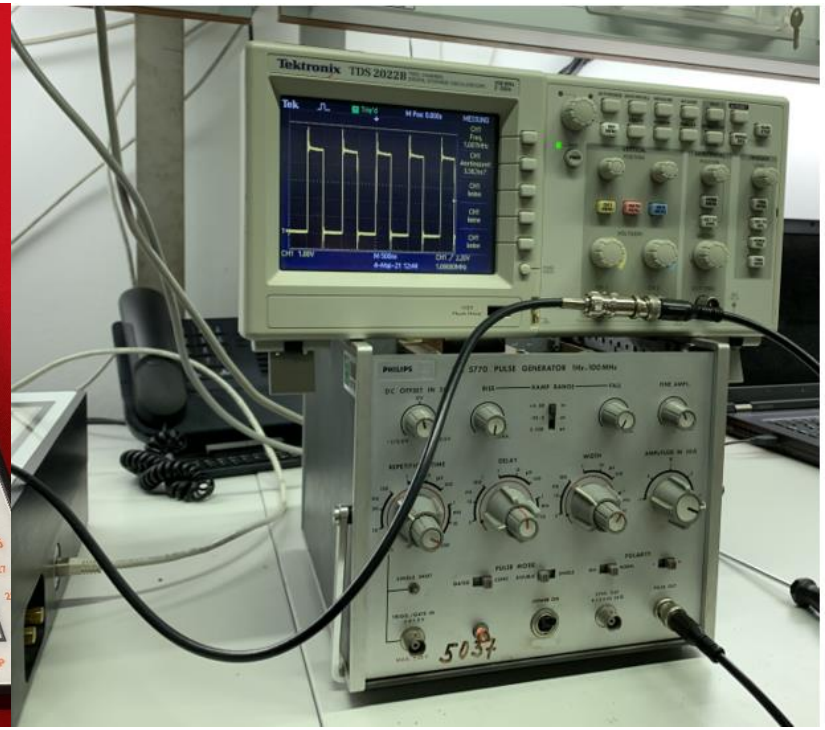
Vergleich



Coupling effects

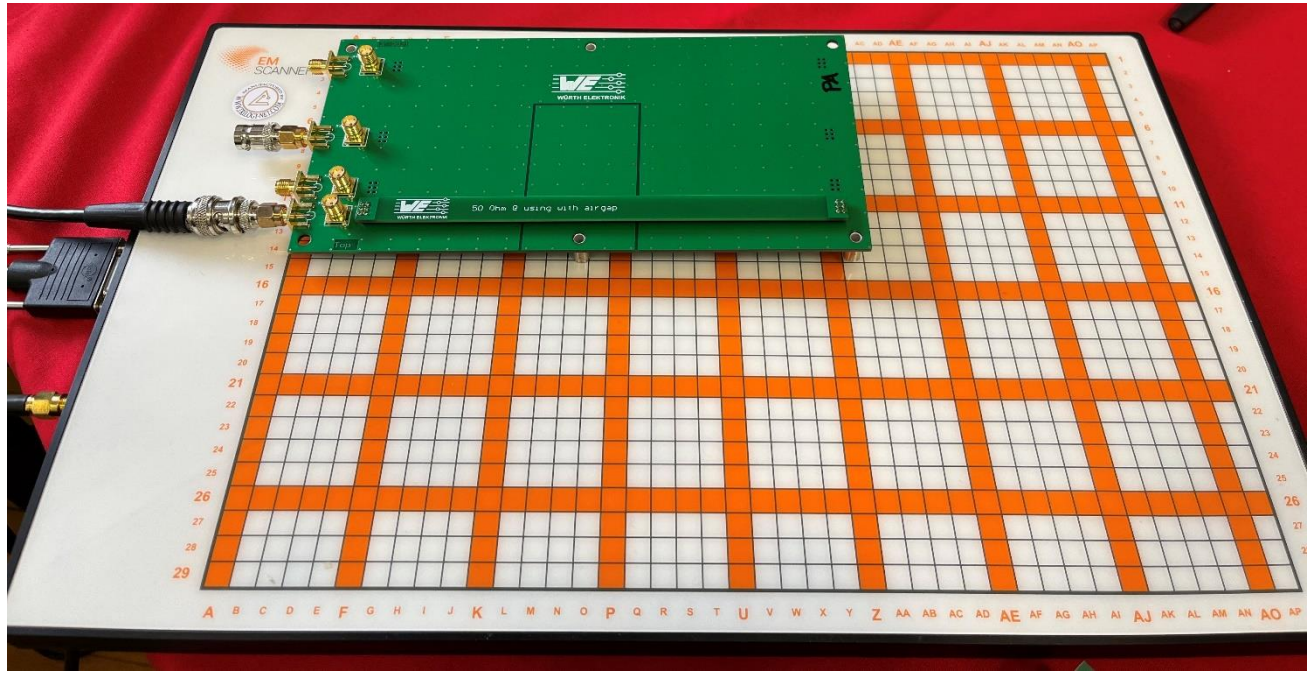
Return path of high frequency current

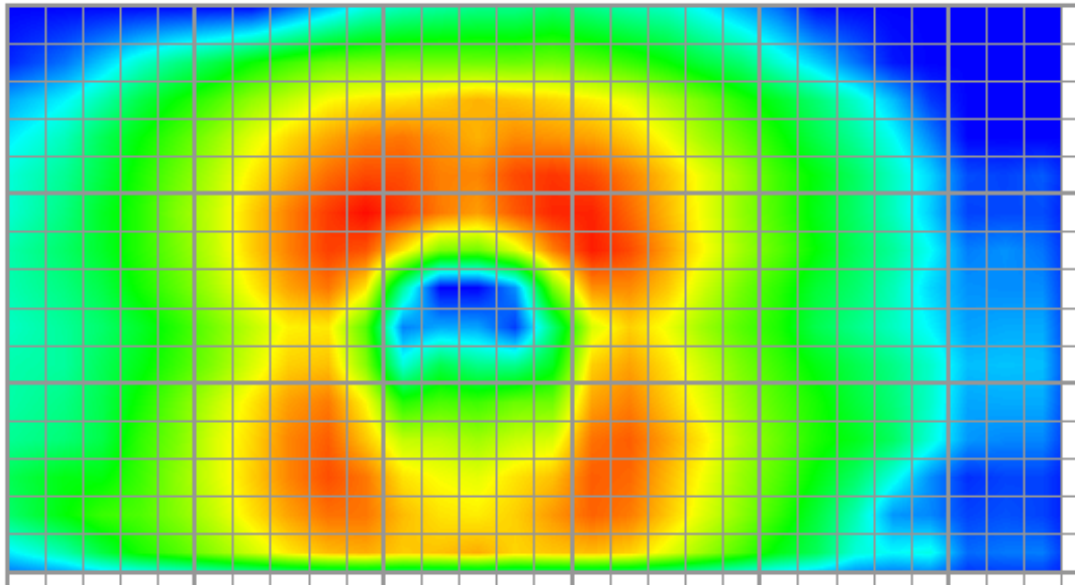




Coupling effects

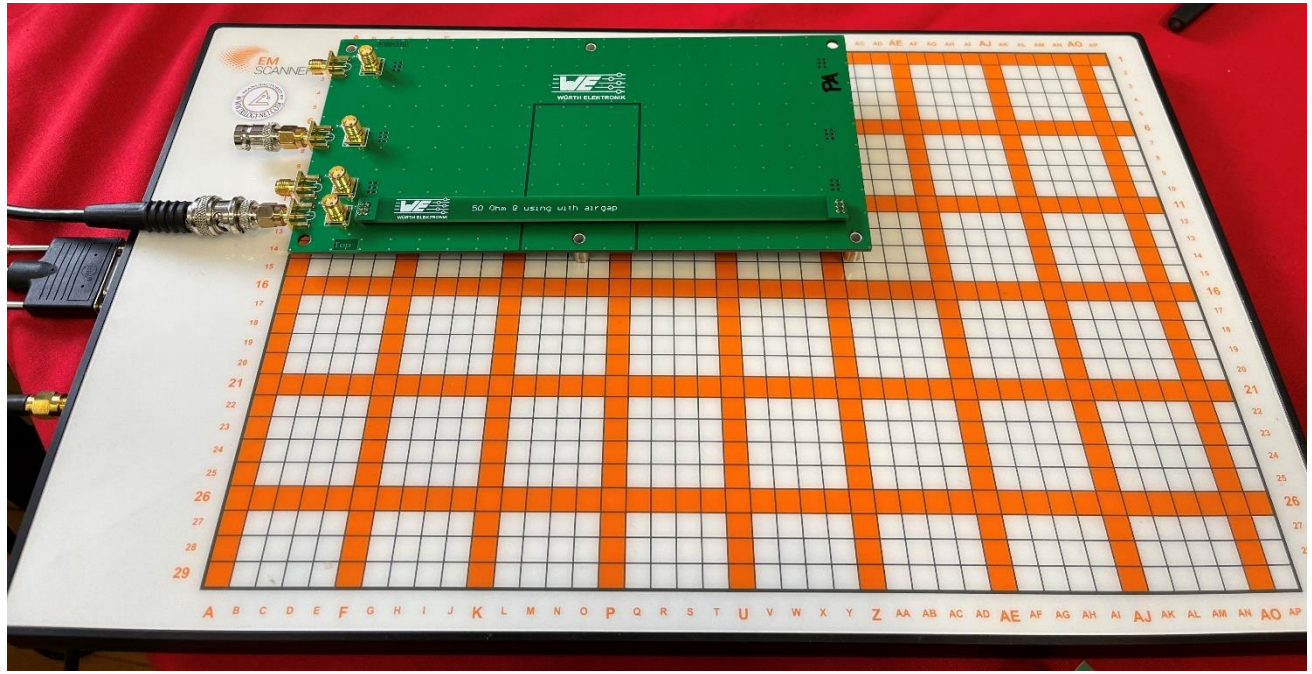
Near field measurement

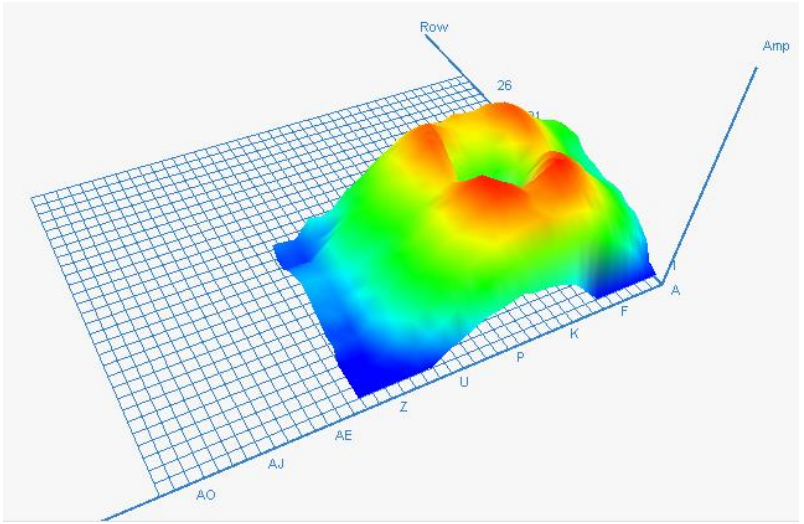


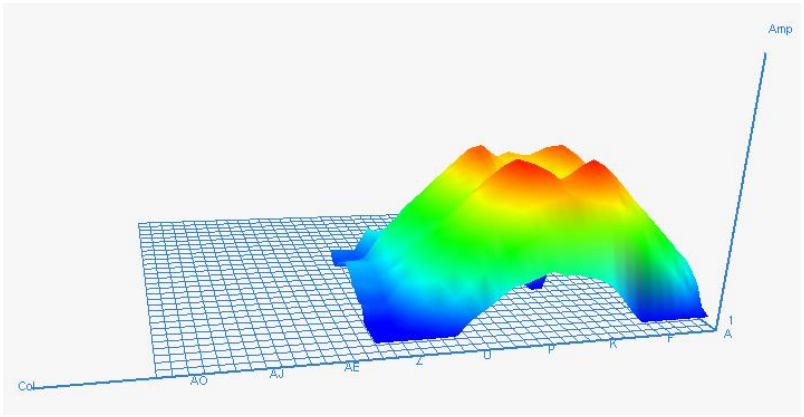


Coupling effects

Near field measurement

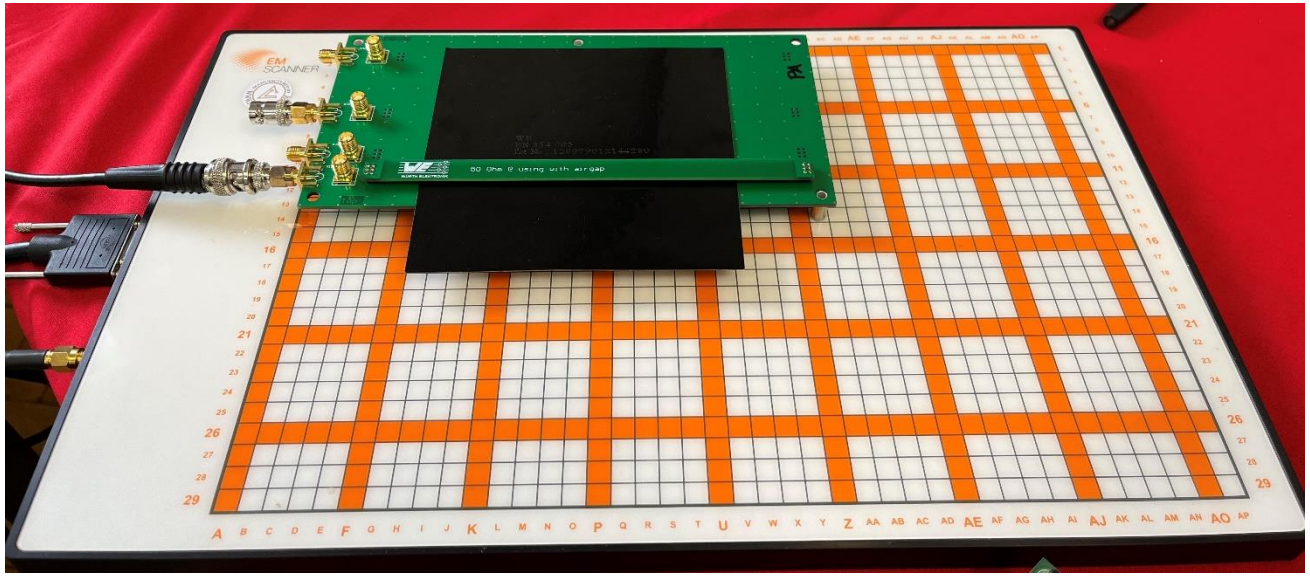


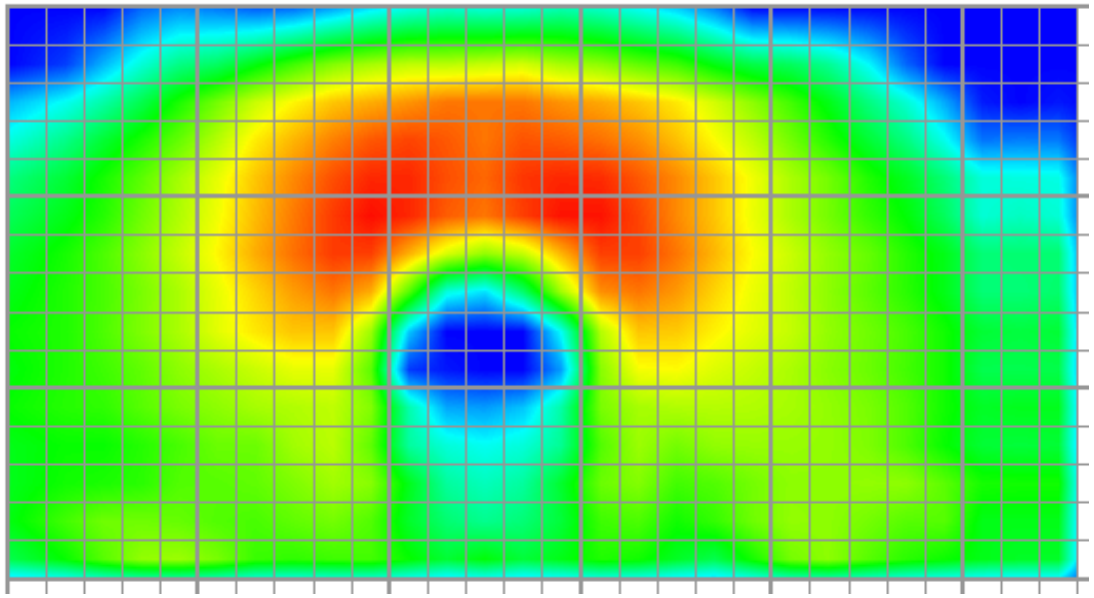




Coupling effects

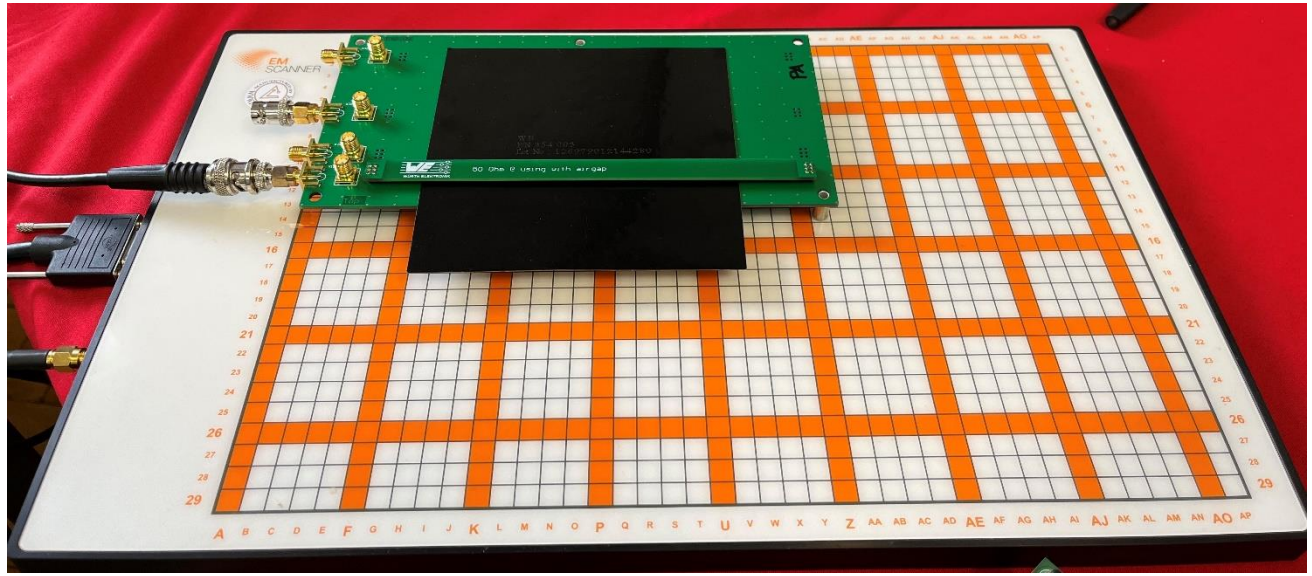
Near field measurement with ferrite shielding between signal and GND

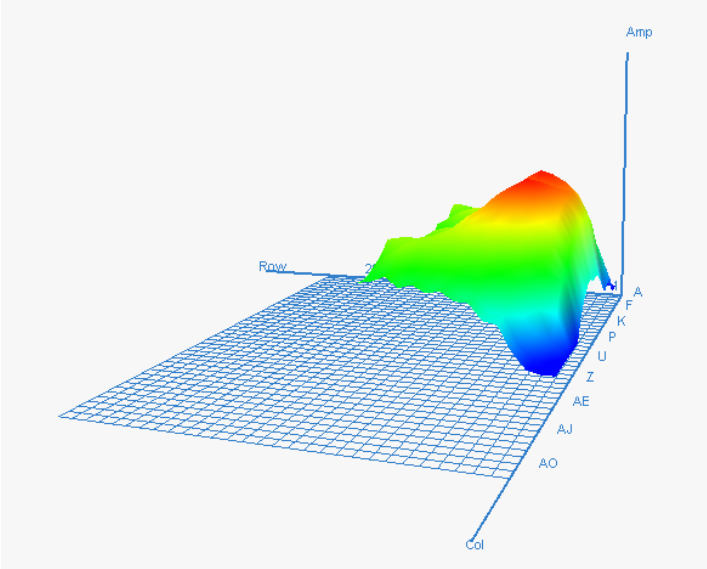




Coupling effects

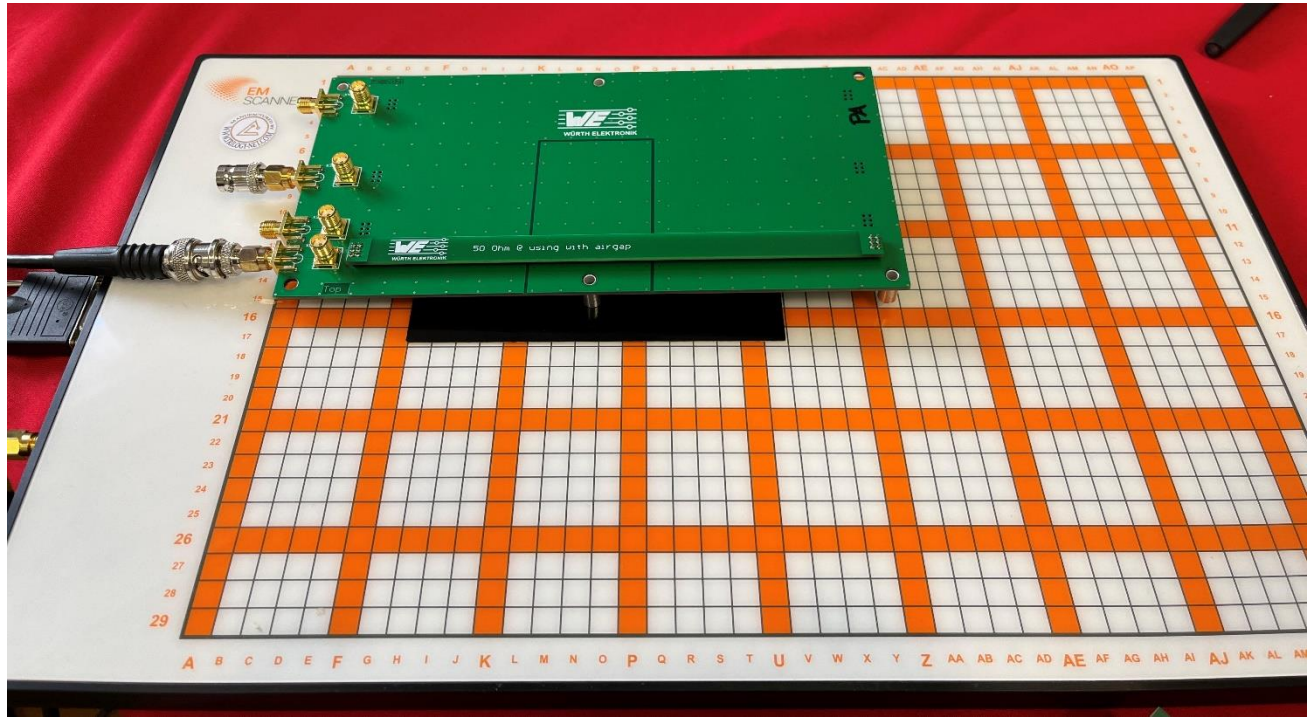
Near field measurement

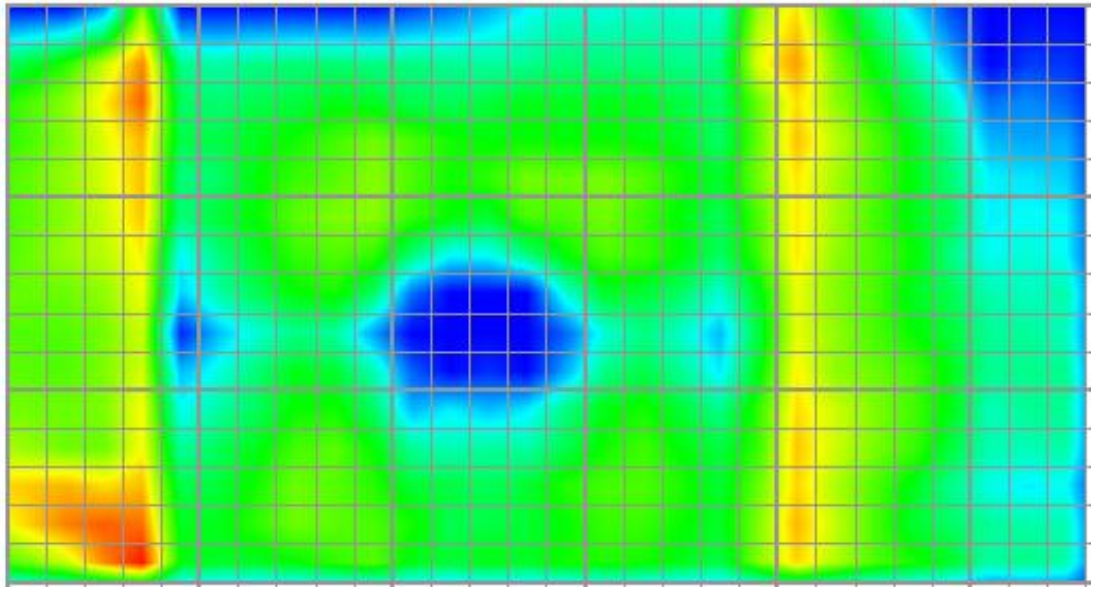




Coupling effects

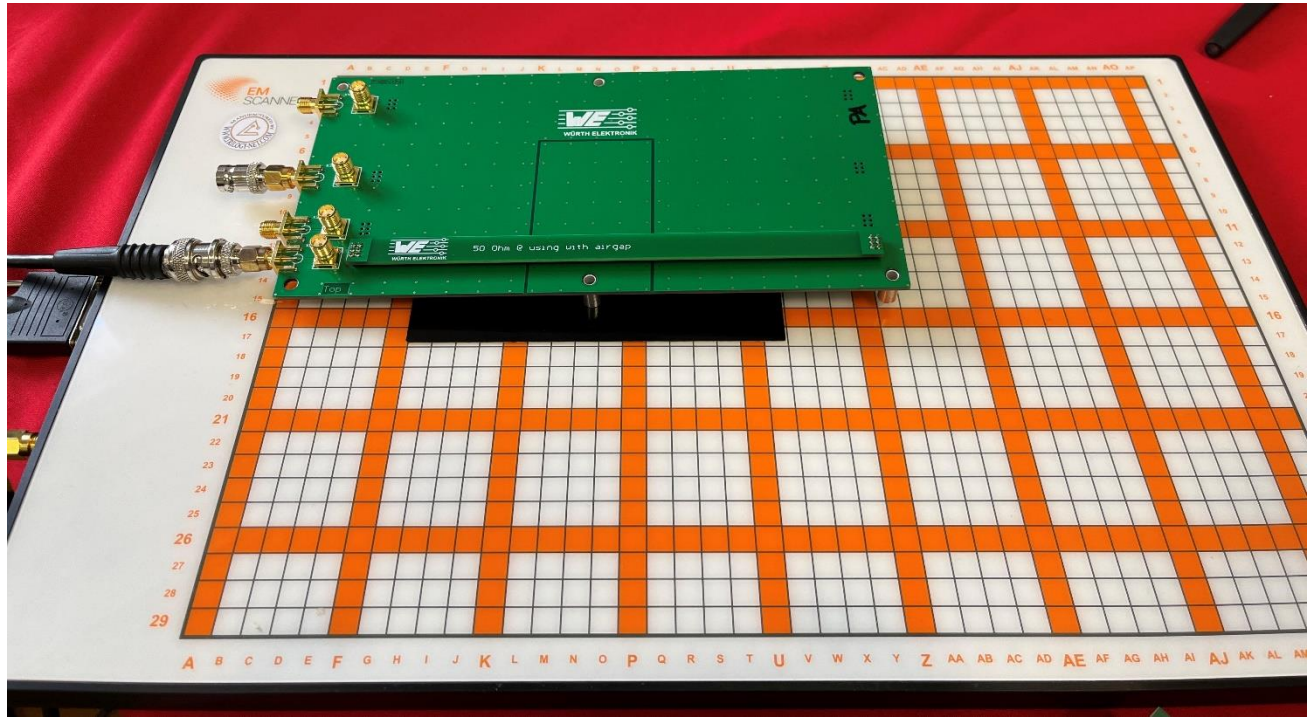
Near field measurement with ferrite shielding between GND and the near field probe

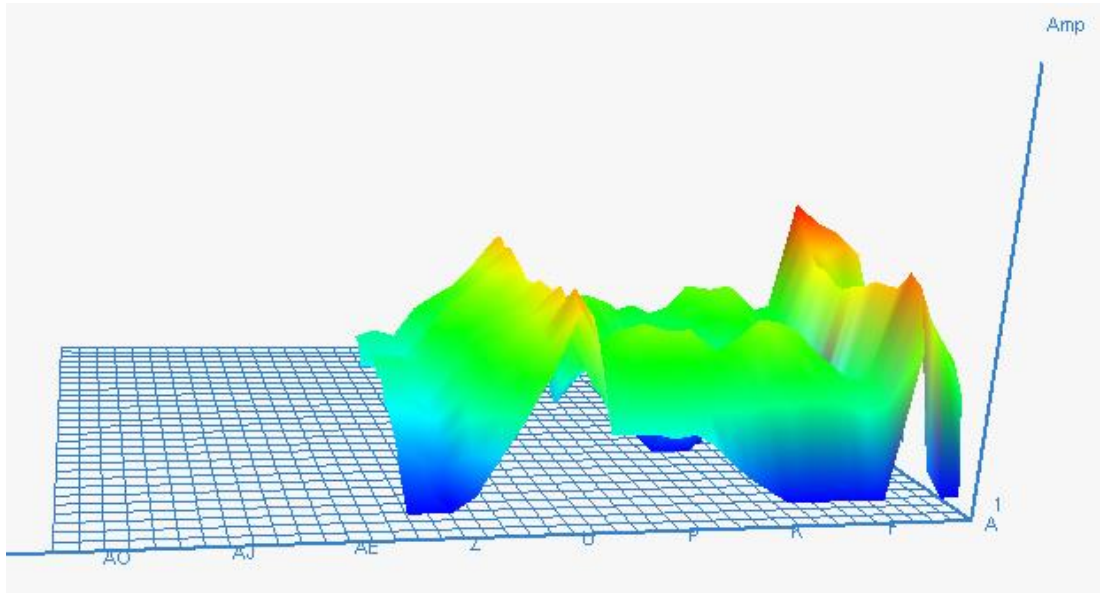




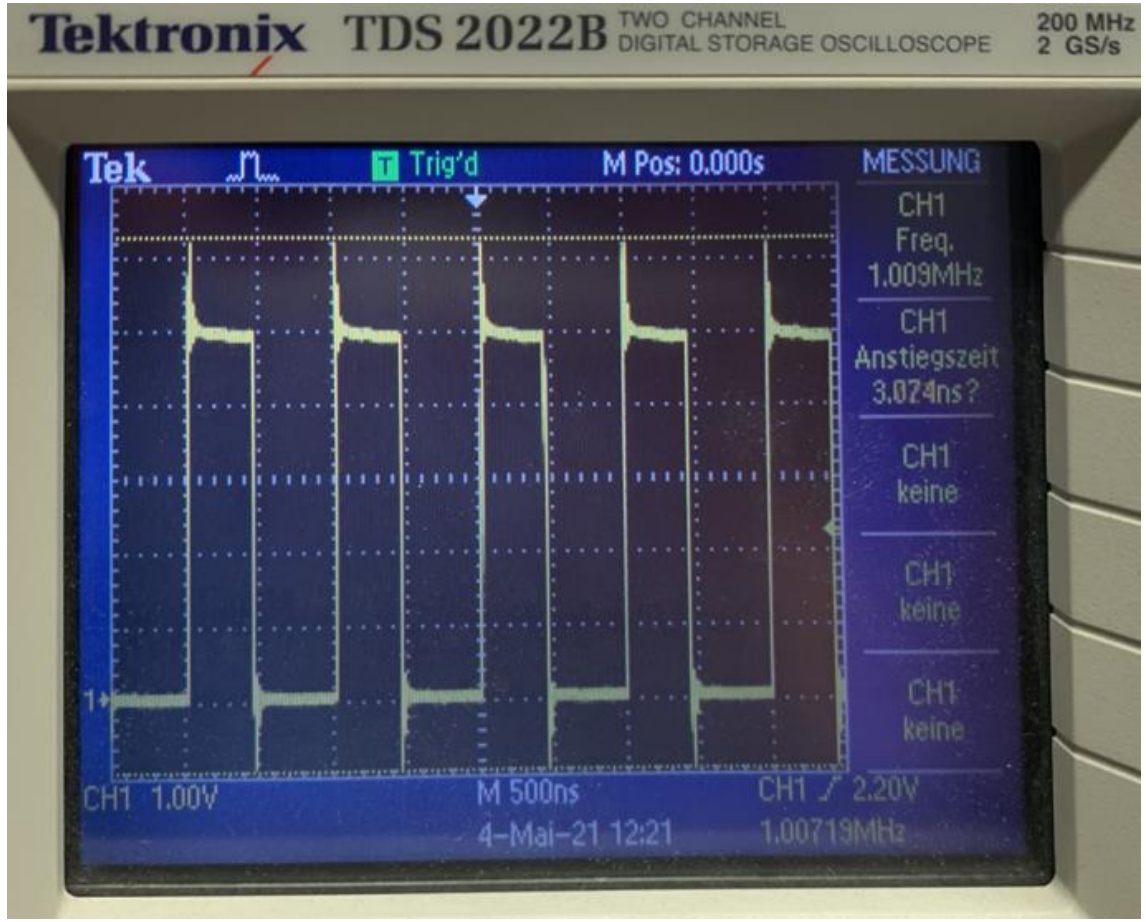
Coupling effects

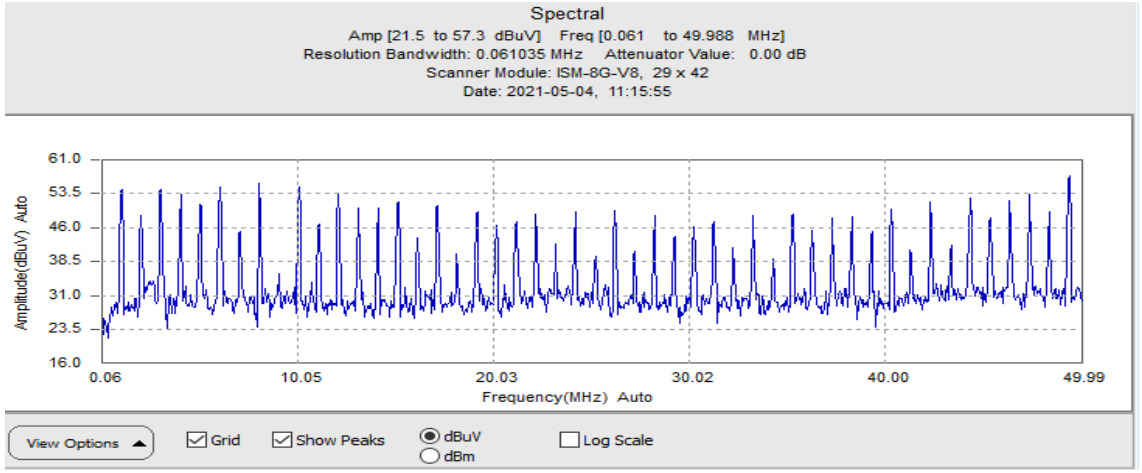
Near field measurement with ferrite shielding between GND and the near field probe

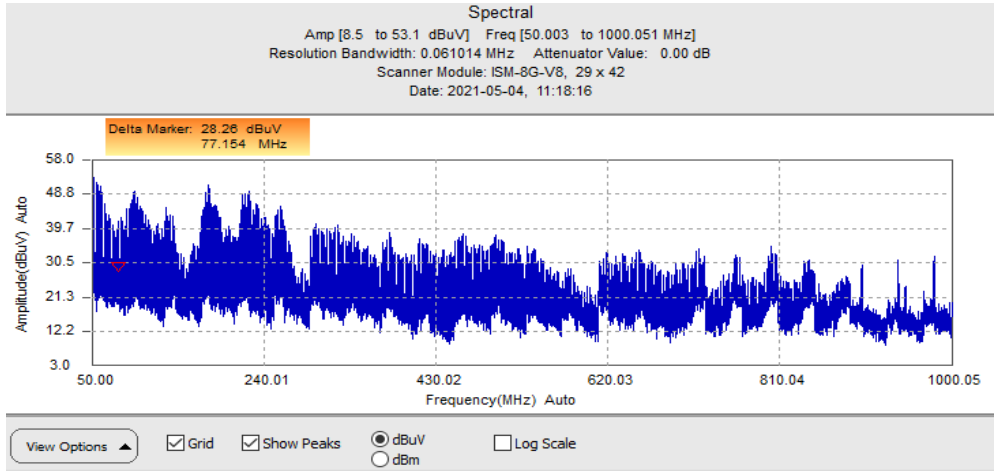




Messung mit dem EMScan





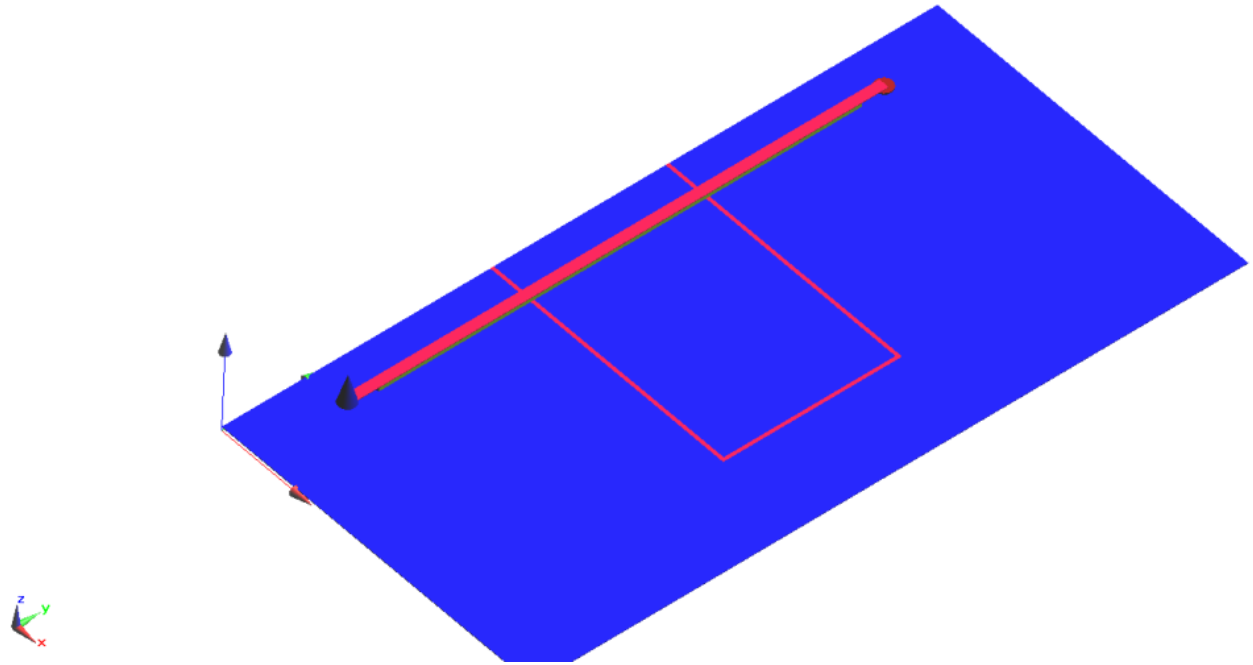


Coupling effects

Simulation

Simulationsoftware:
Sim4Life = FDTD-Simulationstool (FDTD=Finite Differences in Time Domain)
Swiss company ZMT (= Zurich Med tech)

Model:

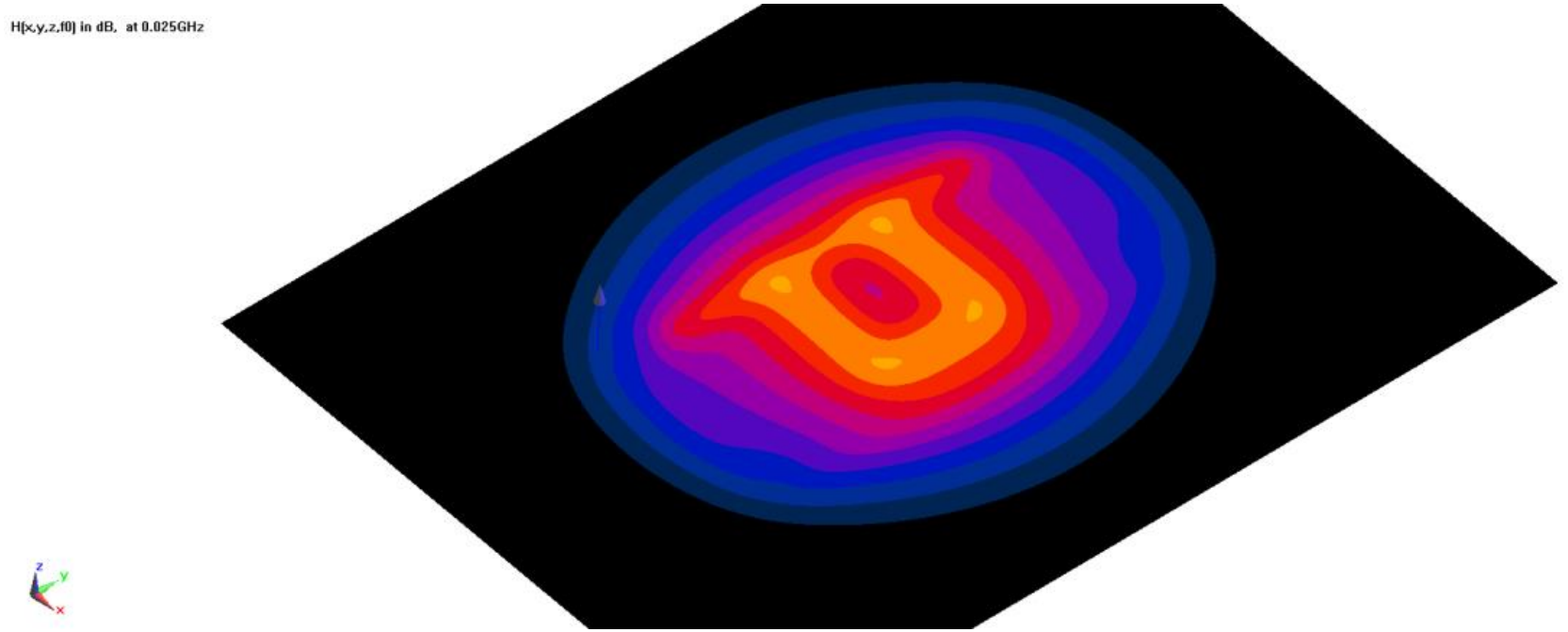


Coupling effects

Simulation

Magnetic-field simulation:

1cm under the prin (identical to the near field measurement with the EMScan)

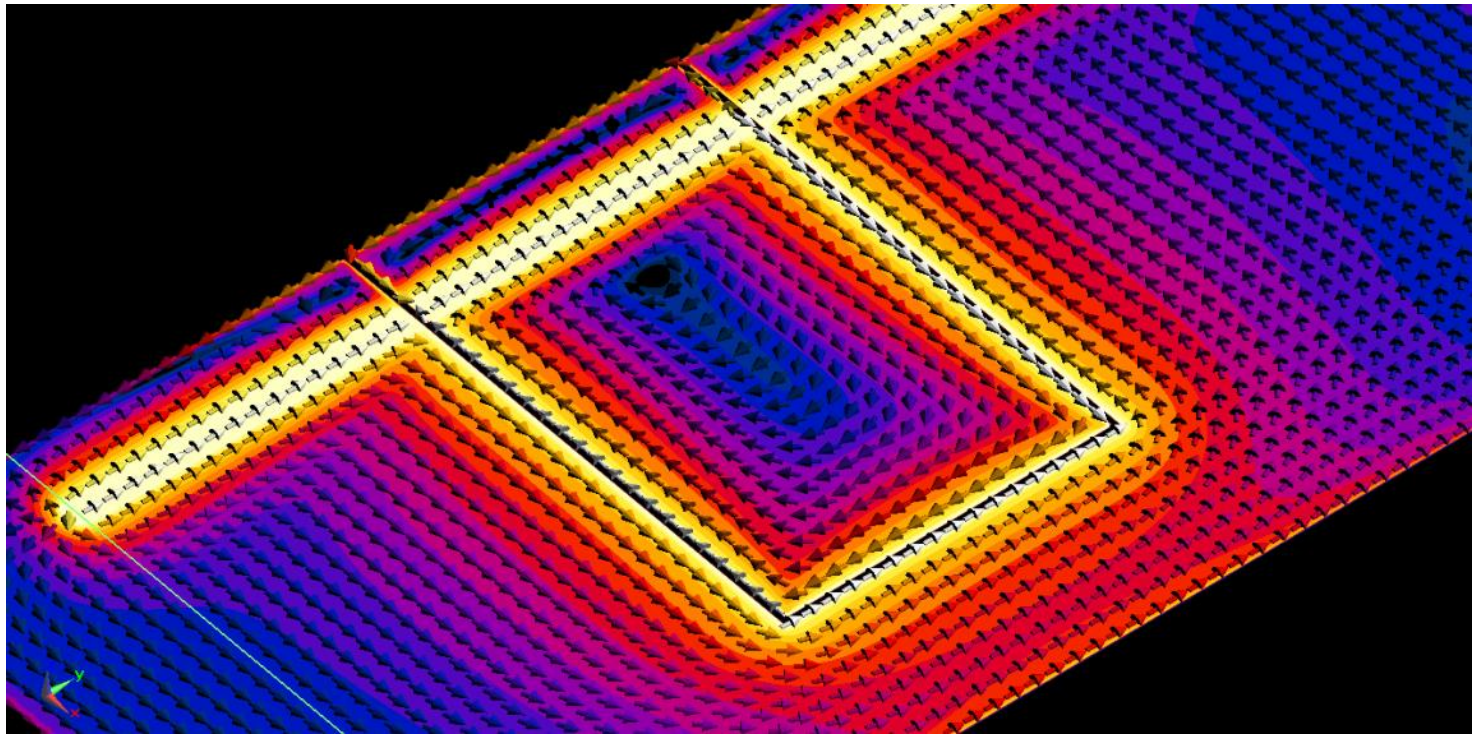


Coupling effects

Simulation

Current path:

On the GND layer



Schirmanbindung

Pfade hochfrequenter Ströme

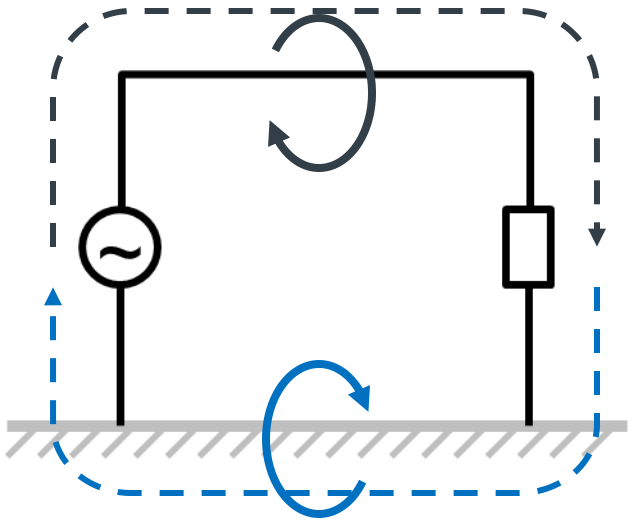
Impedanz des Rückstrompfades

Messungen des Magnetfeldes der Leiterschleife

Shielding

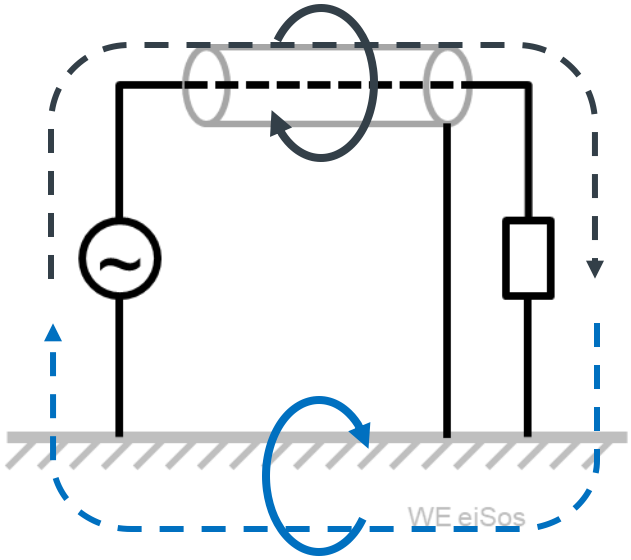
Cable shielding

RADIATED NOISE



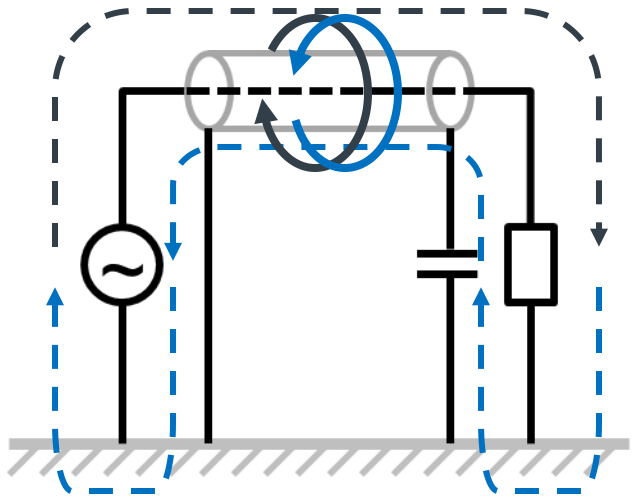
Without shielding, big enclosed current loop surface

Shielded E-field
uncompensated H-field



Added shielding, **one** end grounded,
big current loop surface

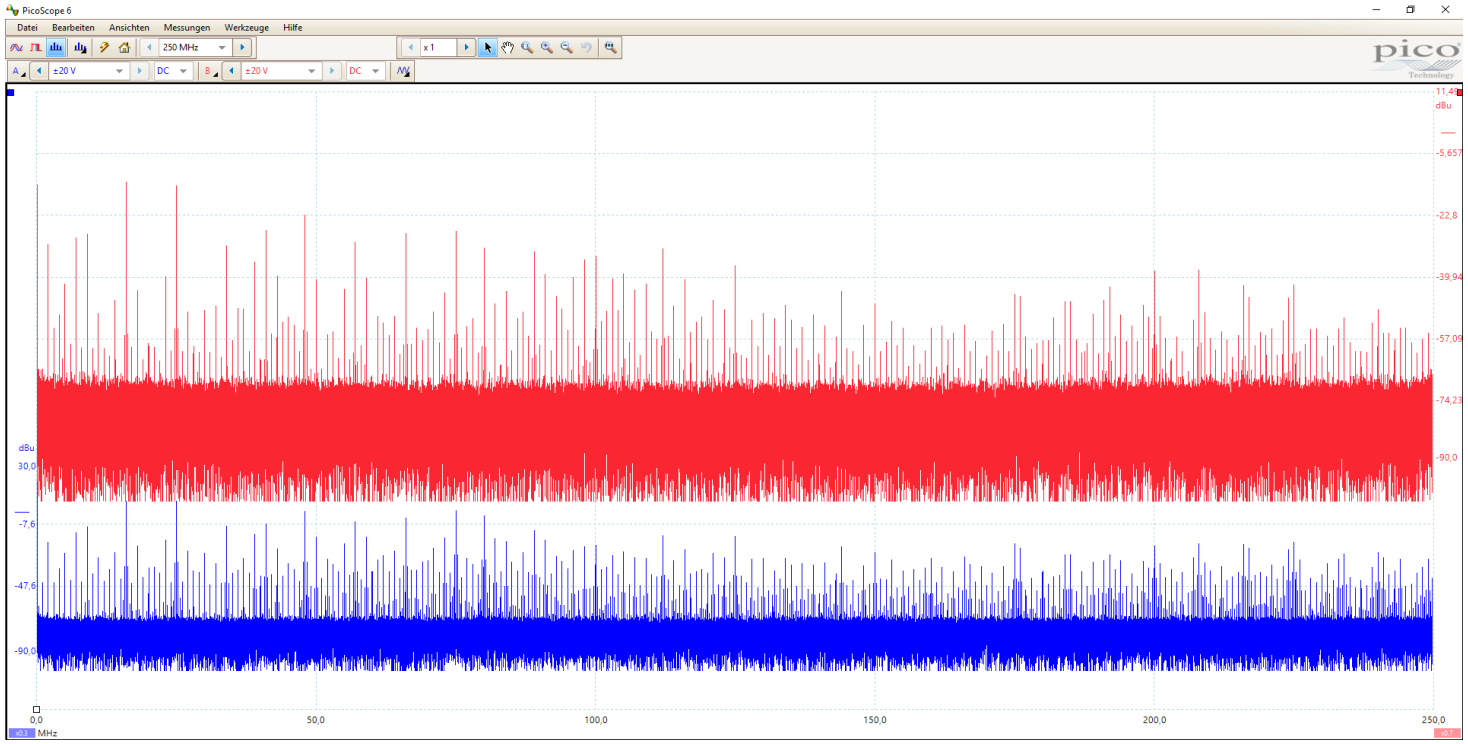
Shielded E-field
compensated H-field



Added shielding, **both** ends grounded,
reduced current loop surface

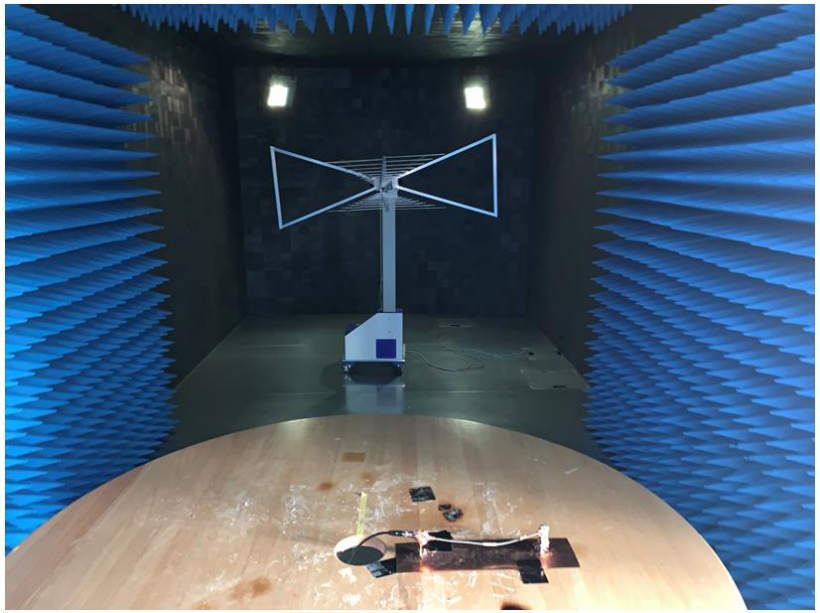
Shielding

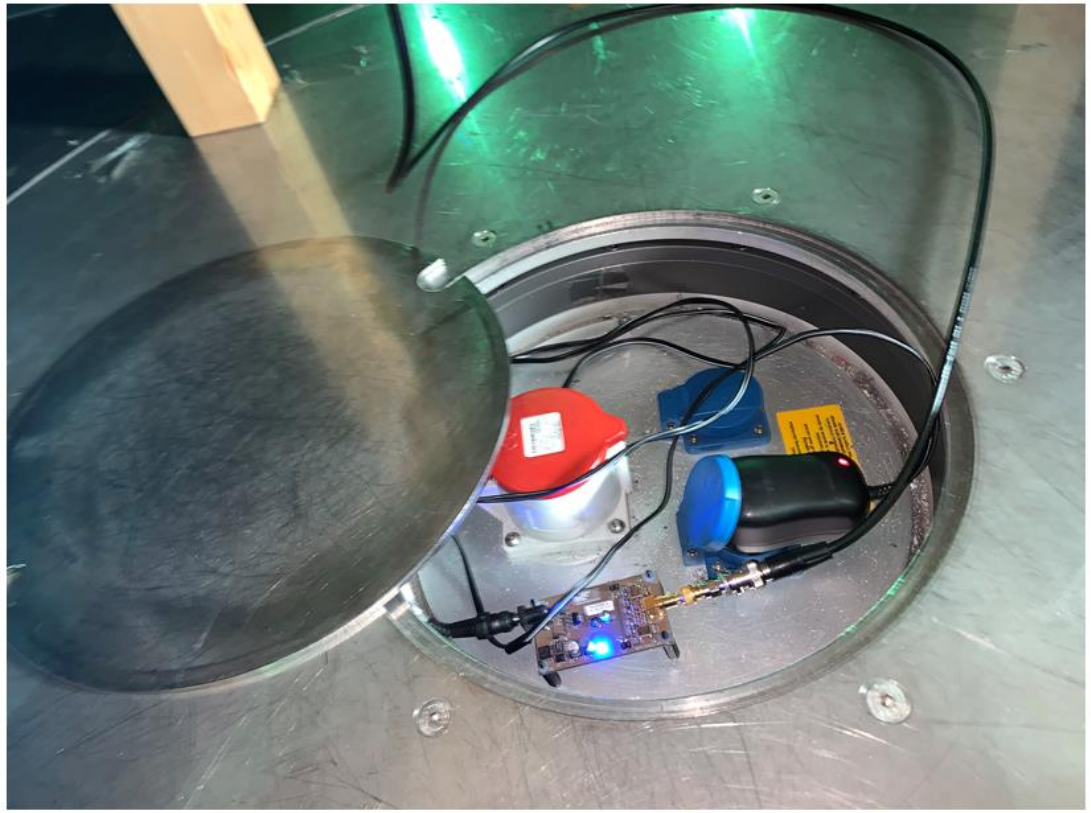
How should you attach the shielding?



Shielding

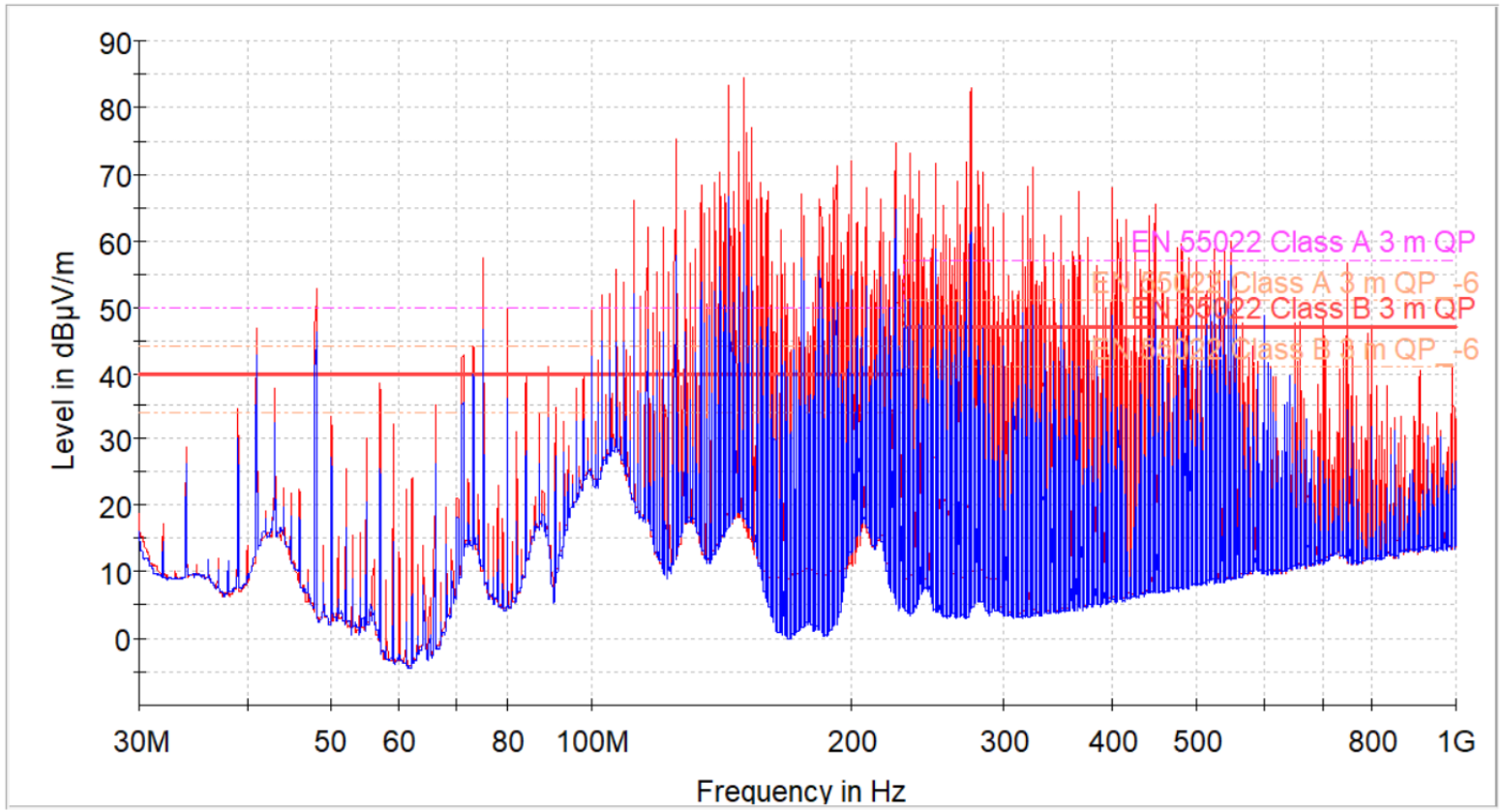
E – field measurements in the emc chamber





Shielding

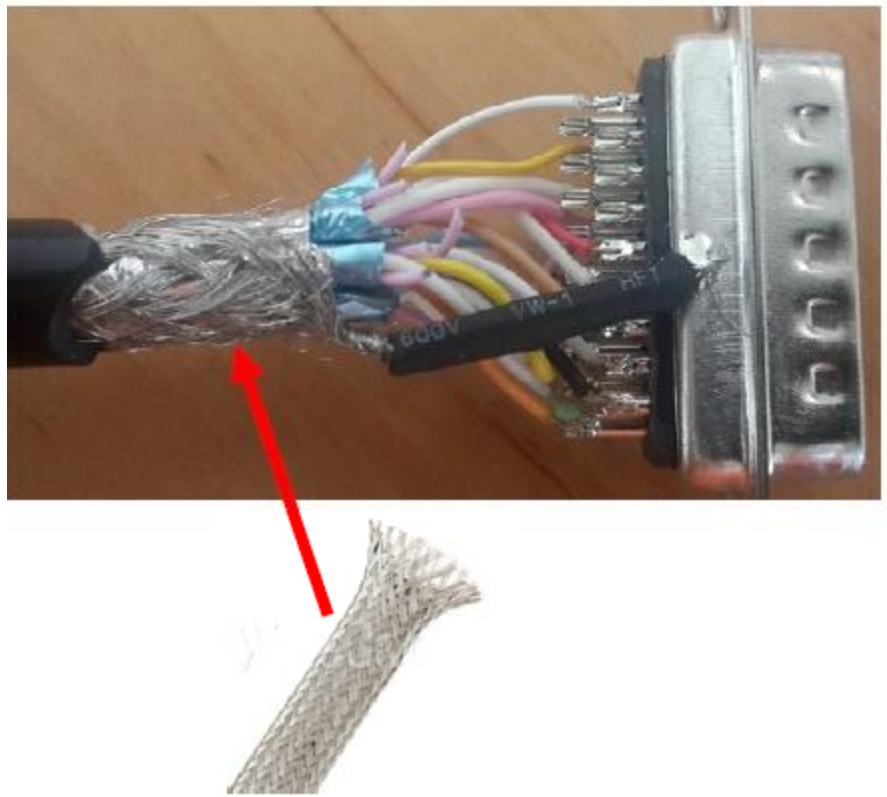
E – field measurements in the emc chamber



Shielding

Cable shielding examples

Area coverage of the braided shielding > 85%



Every twisted pair should be shielded seperatly