DIGITAL WE DAYS 2023

EFFICIENT HF SIGNAL TRANSPORT OVER SMA CONNECTORS

WÜRTH ELEKTRONIK MORE THAN YOU EXPECT

TODAY'S SPEAKERS

PRESENTATION
Remco van de Griendt
Field Application Engineer

MODERATION
Silas Zorn
Marketing Department

INFORMATION ABOUT THE WEBINAR

You are muted during the webinar.
However, you can ask us questions using the chat function.

Duration of the presentation	30 Min
Q&A:	10 – 15 Min

Any questions?	
No problem! Email us	digital-we-days@we-online.com

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We are looking forward to your feedback.

On our channel	Würth Elektronik Group
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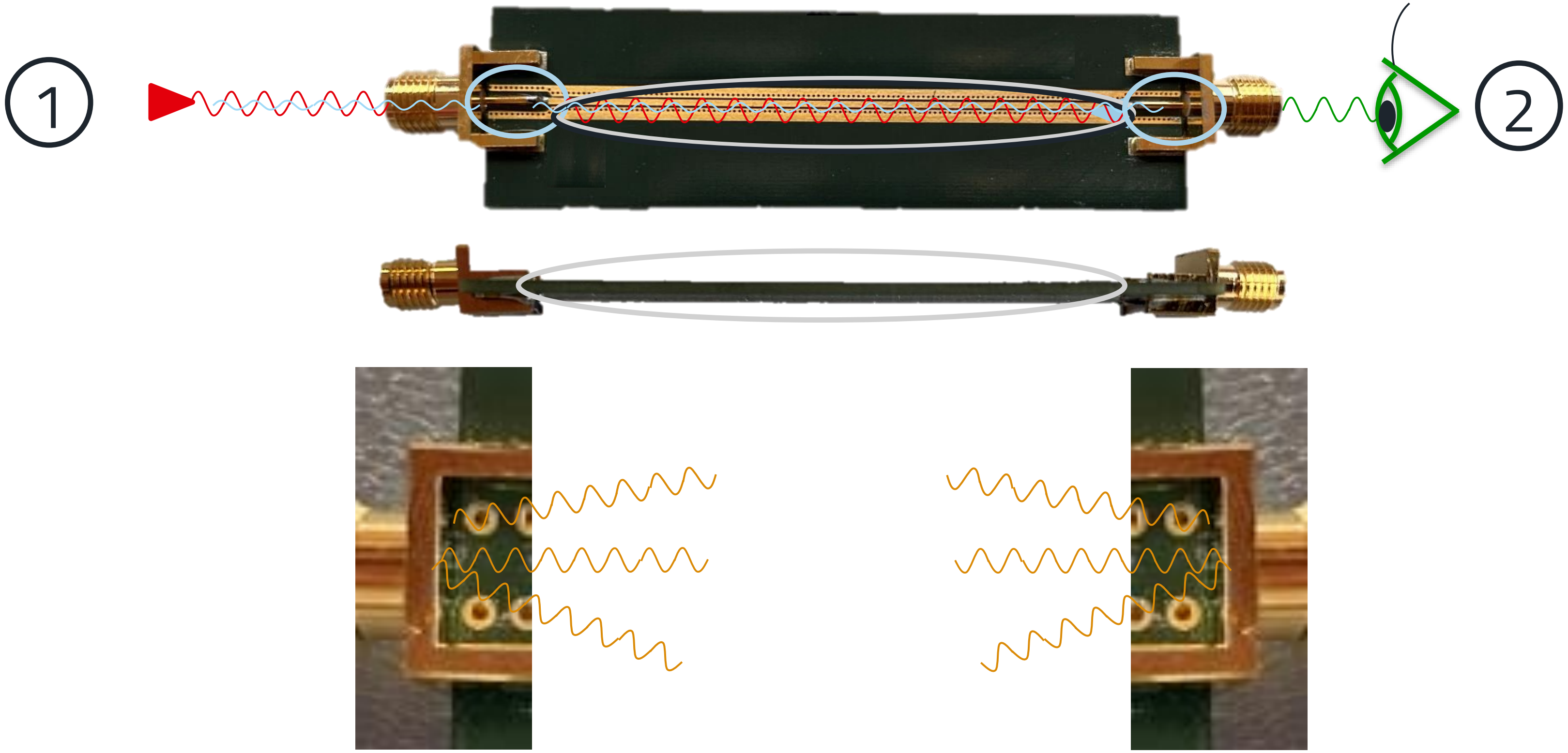
AGENDA

- EM Wave basic
- Trace impedance basic
- TDR
- Influences EM waves
- Real measurements

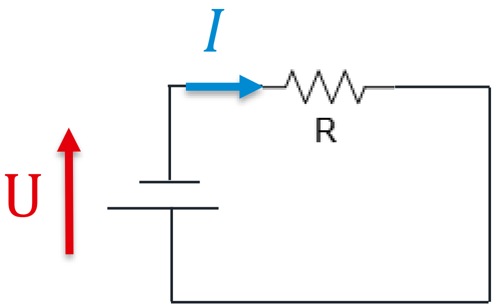
EM WAVES LOSSES

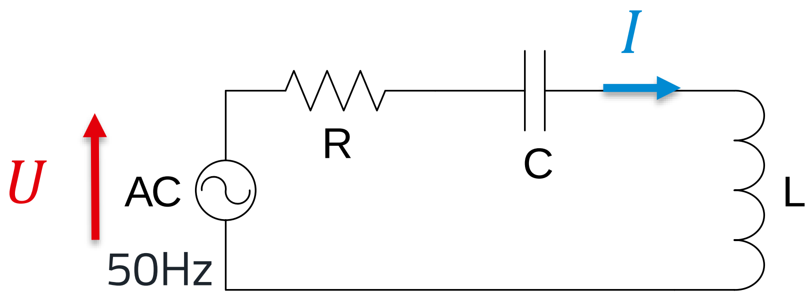
Insertion loss – S21:

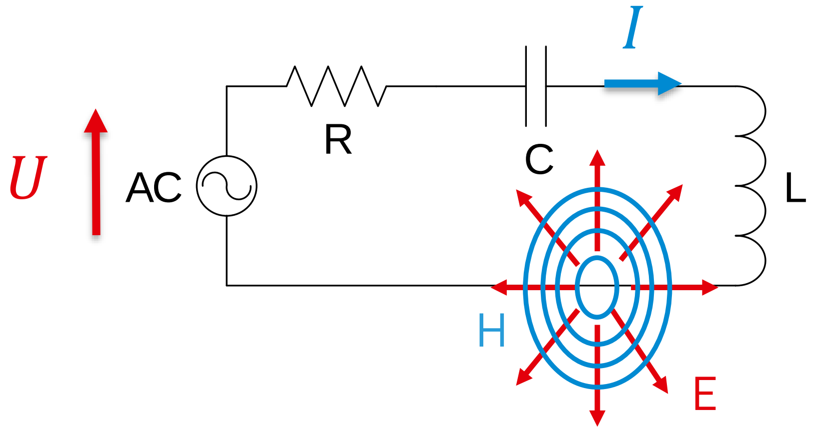
- radiation loss
- reflection loss
- absorption loss
- Joule loss (Ri²)



R – Z – ZC ?







$$\text{DC}: R = \frac{U}{I}$$

$$\text{AC}: Z = \frac{U}{I}$$

$$\text{High frequency}: Z_C = \frac{E}{H}$$

R: DC resistance (Ω)

Z: AC impedance (Ω)

Zc: characteristic impedance (Ω)

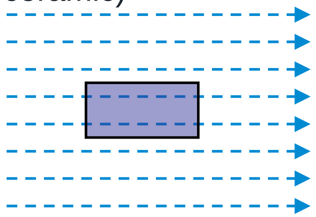
U: voltage (V)
I: curent (A)

E: electric field (Vm^{-1})
H: magnetic field (Am^{-1})

PERMEABILITY

Air

(or ceramic)

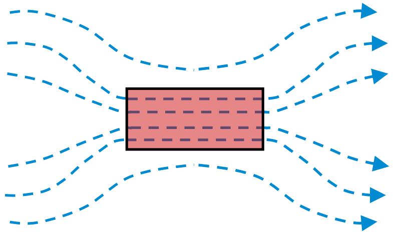


Magnetic field

$$Z_C = \frac{E}{H}$$

$$Z_c = \sqrt{\frac{\mu_0 \cdot \mu_r}{\varepsilon_0 \cdot \varepsilon_r}}$$

Rod core ferrite

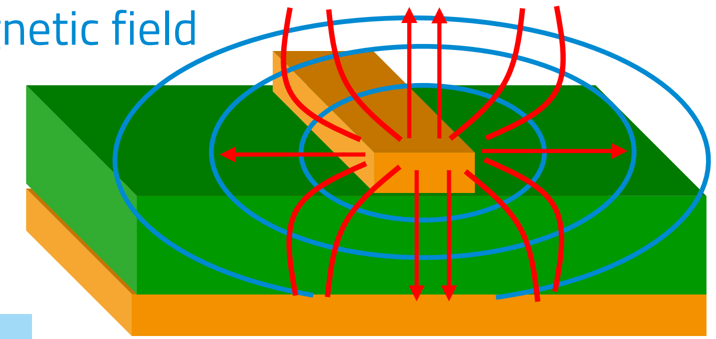


μ_0: vacuum permeability (**H·m^{-1}**)

μ_r: relative permeability

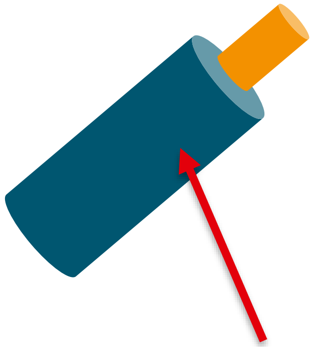
Material	Relative permeability μ_r
MnZn	300~20 000
Fe	~5 000
NiZn	40~1500
Iron powder	50~150
Al	~1
Air	~1
water	~1
Plastic	~1
Cu	~1
vacuum	1

PERMITTIVITY



$$Z_C = \frac{E}{H}$$

$$Z_c = \sqrt{\frac{\mu_0 \cdot \mu_r}{\varepsilon_0 \cdot \varepsilon_r}}$$

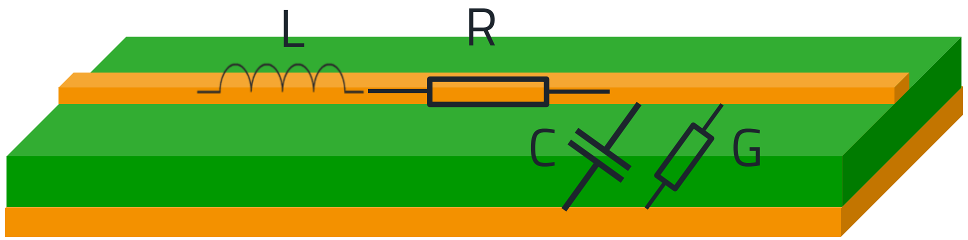


ε_0 : vacuum electrical permittivity (**Fm^{-1}**)

ε_r **:** dielectric relative permittivity

Material	Relative permittivity ε_r
Vacuum	1
Air	≈1
PTFE (Teflon)	2.1
PET	2.3
Roger (RO4003)	3.6
FR4	4.5
PVC	5
glass	≈5 to 7.5
water	≈80 (at 20°C)

TRACE IMPEDANCE



$$Z_c = \sqrt{\frac{R + j\omega L}{G + j\omega C}}$$

$$\omega = 2\pi f$$

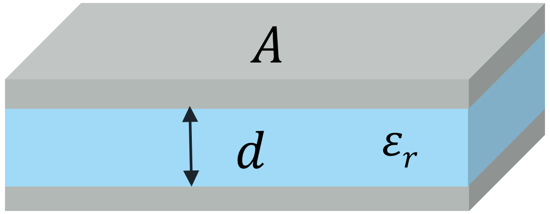
f → 0 Hz

$$Z_c = \sqrt{\frac{R}{G}} = R$$

f → ∞ Hz

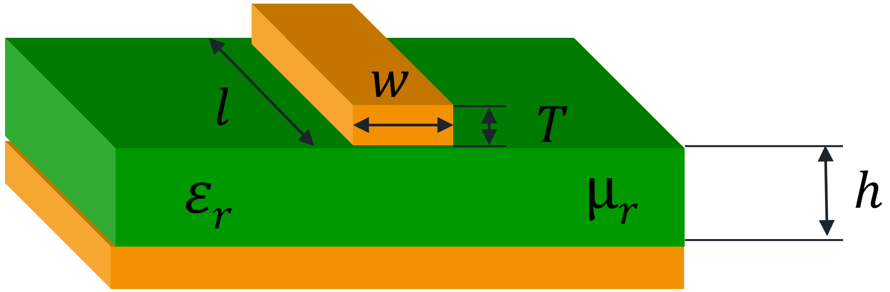
$$Z_c = \sqrt{\frac{L}{C}}$$

TRACE IMPEDANCE



$$C = \varepsilon_0 . \varepsilon_r . \frac{A}{d}$$

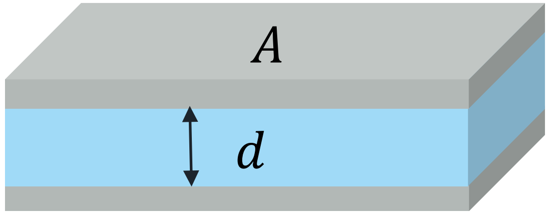
$$C = \varepsilon_0 . \varepsilon_r . \frac{w.l}{h}$$



$$Z_c = \sqrt{\frac{L}{C}}$$

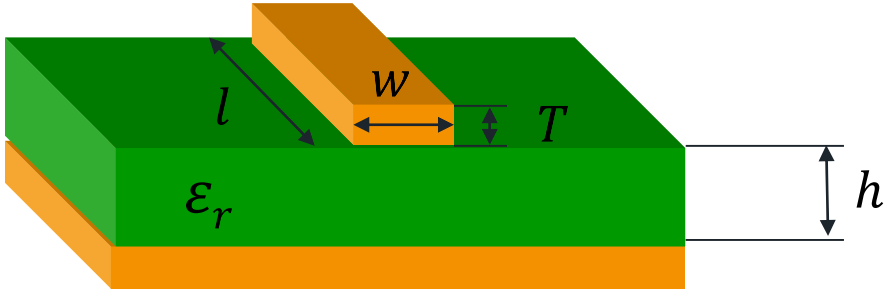
$$L \approx \frac{\mu_0 \mu_r . (h + \frac{T}{2}) . l}{w}$$

TRACE IMPEDANCE



$$C = \varepsilon_0 . \varepsilon_r . \frac{A}{d}$$

$$C = \varepsilon_0 . \varepsilon_r . \frac{w . l}{h}$$



$$Z_c = \sqrt{\frac{L}{C}}$$

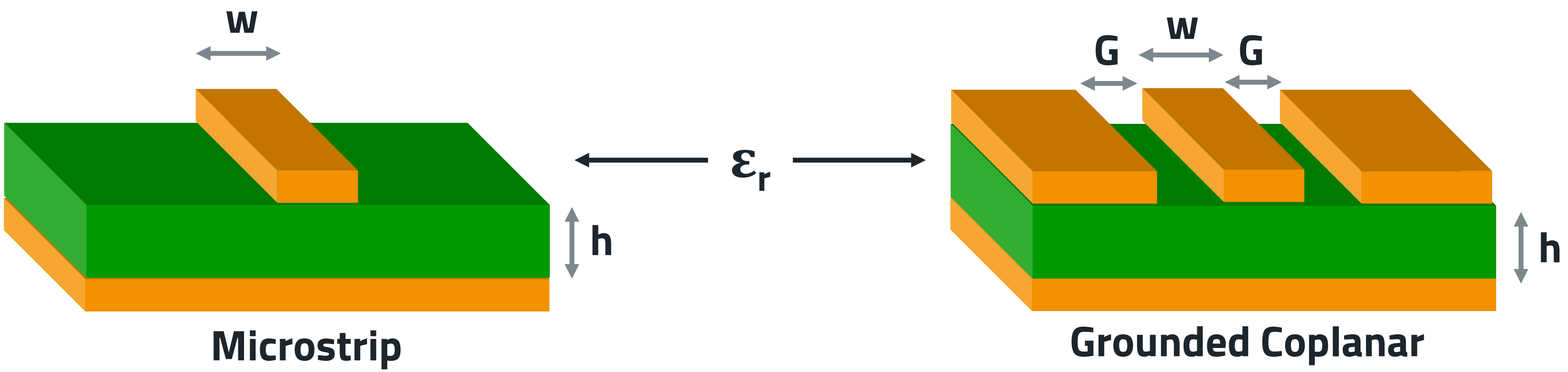
$$L \approx \frac{\mu_0 \mu_r . (h + \frac{T}{2}) . l}{w}$$

PLANAR TRANSMISSION LINES

$$Z_c = \sqrt{\frac{L}{C}}$$

$$C = \varepsilon_0 . \varepsilon_r . \frac{w.l}{h}$$

- **Line impedance depends on:**



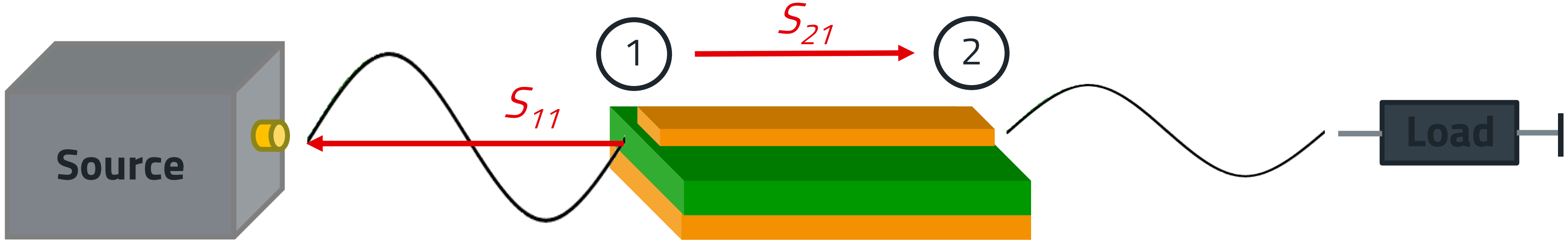
- **w** = Trace width
- **ε_r** = Dielectric constant of the core/prepreg
- **G** = Gap between trace and ground
- **h** = Height of the core/prepreg

↑ **w** ⇨ ↓Z_{Line}
↑ **ε_r** ⇨ ↓Z_{Line}
↑ **G** ⇨ ↑Z_{Line}
↑ **h** ⇨ ↑Z_{Line}

S PARAMETERS

$$S_{ji} = 10 \log \frac{power\ j}{power\ i}\ \text{(dB)}$$

- **Factor of reflection and throughput:**



- **S-Matrix:**
  - S_{ii}: Reflection at Port i
  - S_{ji}: Insertion losses from Port i to Port j
- **Power domain!**

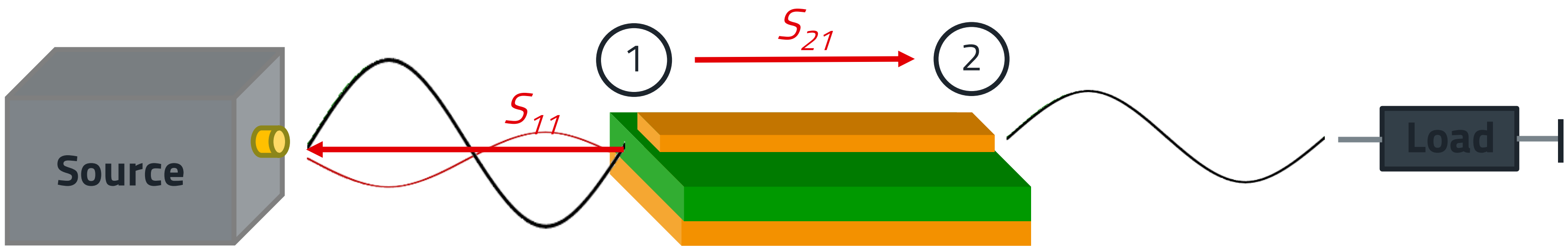
- **Mostly given in dB:**
  - $\text{e.g. } -3dB = 10 \times \log(0.5)$

Signal power-50%

- **Calculation from source:**
  - $1000\ mW \times 0.5 = 500mW$
  - $30dBm - 3dB = 27dBm$

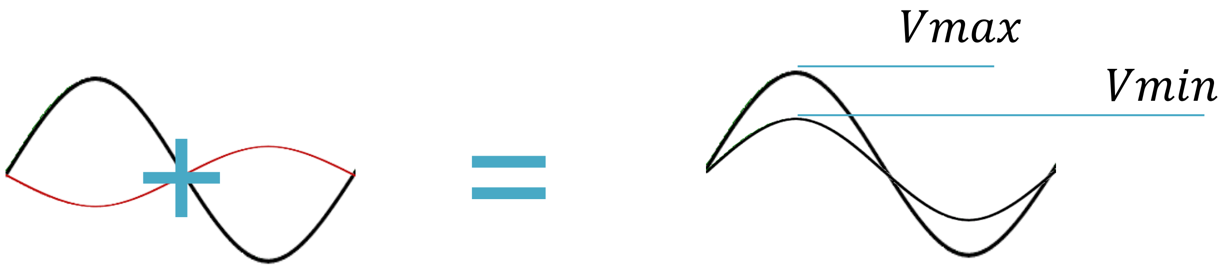
S PARAMETERS: VSWR

- **Voltage standing wave ratio (VSWR):**



- **Only reflection/return loss:**

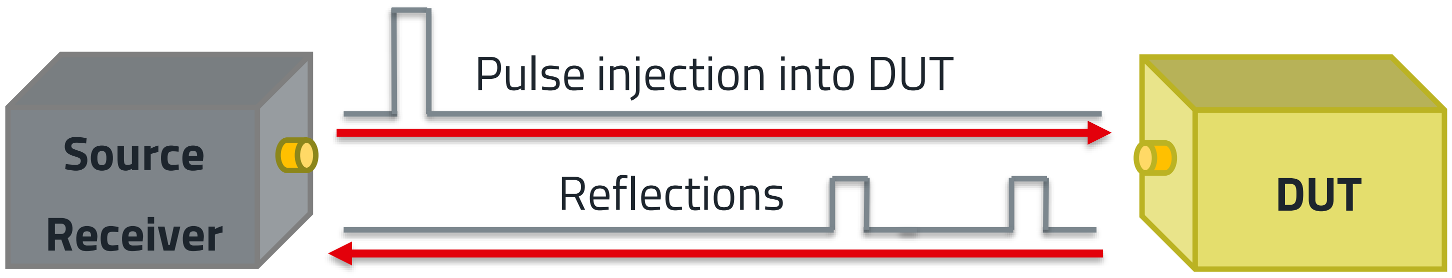
$$VSWR = \frac{Vmax}{Vmin} \; [dB]$$



- **Voltage domain!**

TIME DOMAIN REFLECTOMETRY

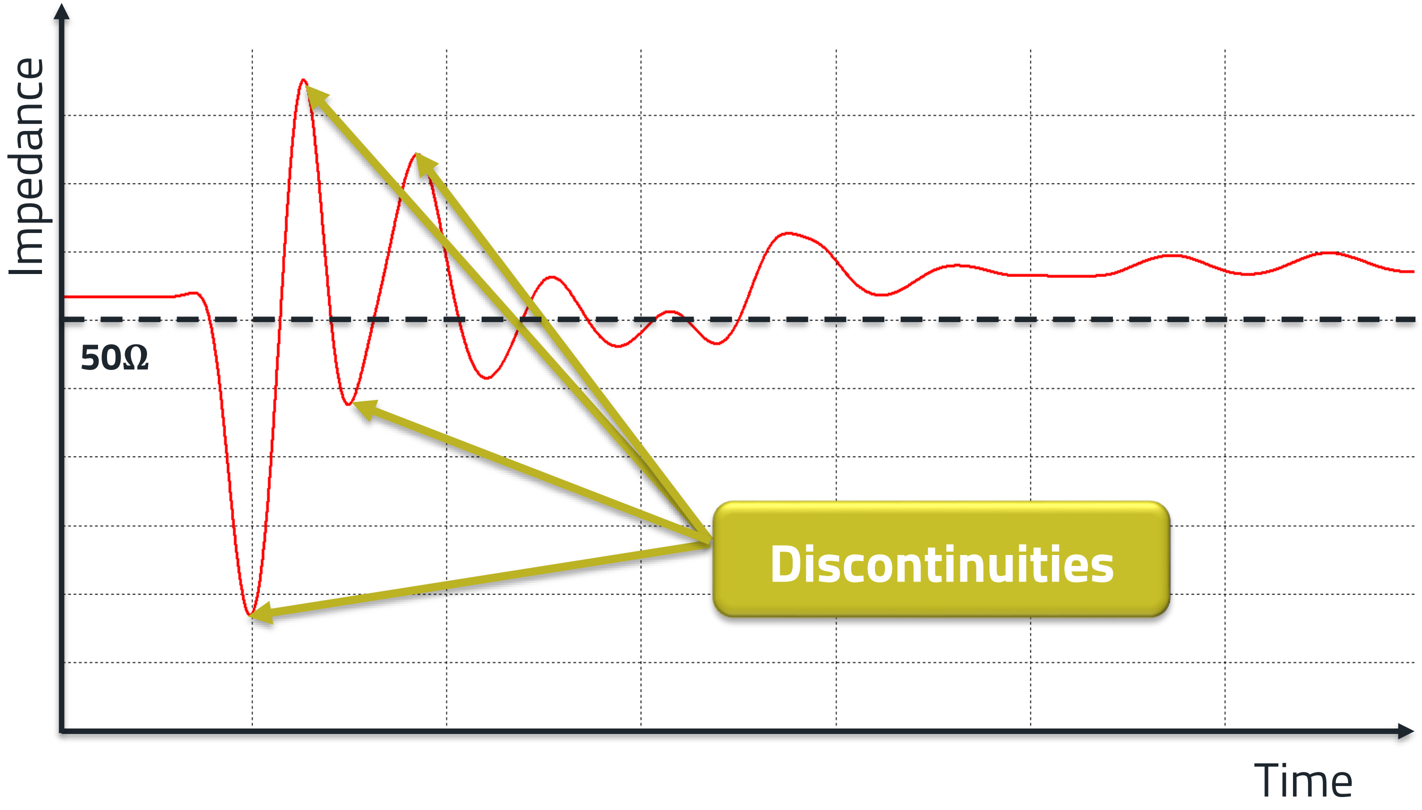
- **Wave impedance measurement through a system**



- **Measurement of reflections**
  - Amplitude
  - Time

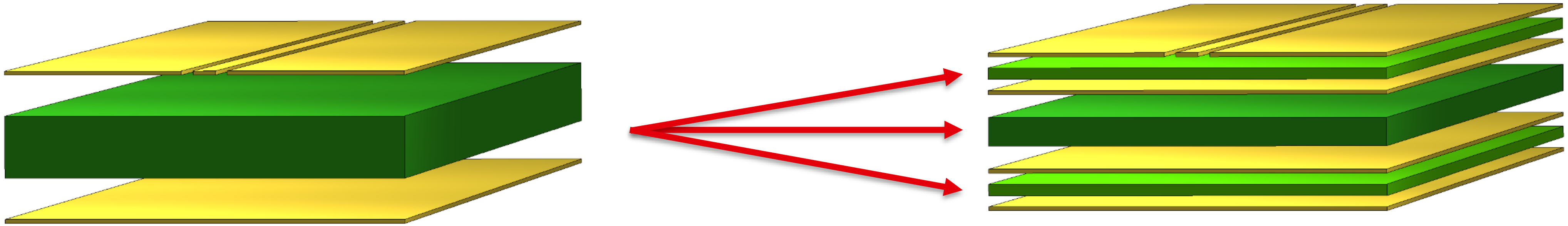
VNA calculation → **Characteristic impedance**

TIME DOMAIN REFLECTOMETRY



- **Time ~ Length :** $L = \frac{c}{\sqrt{\varepsilon_r \mu_r}} \times t$

TYPICAL LAYER SETUP

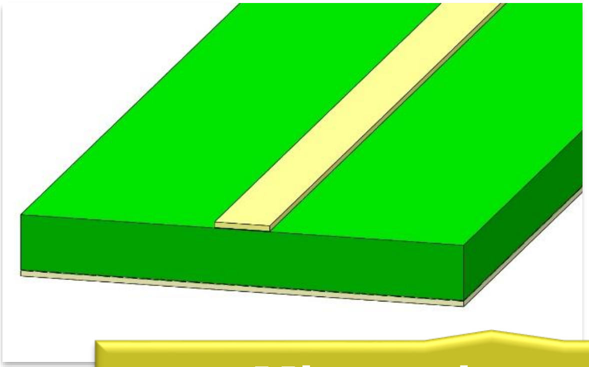


2-Layer	
Height	1.55 mm
Prepreg + core	FR4

4-Layer	
Height	1.55 mm
Prepreg + core	FR4

- **Low production cost**
  - Mostly no separate GND-Plane
- **Good for RF-Designs**
  - Separate GND-Plane
  - Dielectric differs

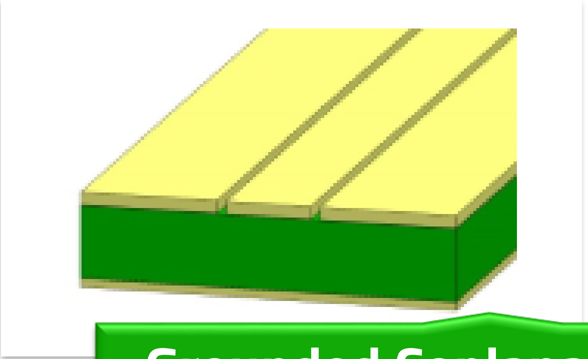
PLANAR TRANSMISSION LINES



Microstrip

- Wider line width
- Antenna fed-line
- No Ground on RF-Layer

- Line width depends on substrate height and εr

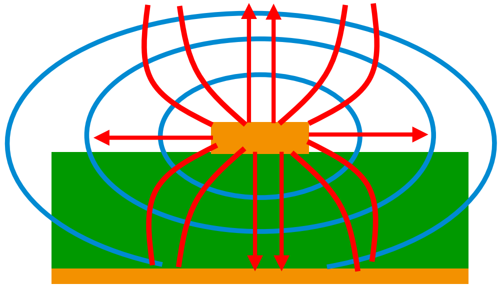


Grounded Coplanar

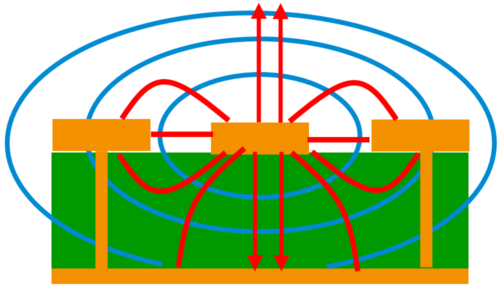
- Smaller line width
- Ground connection to components
- Various planar matching designs

- Line width depends on substrate height. εr and gap width

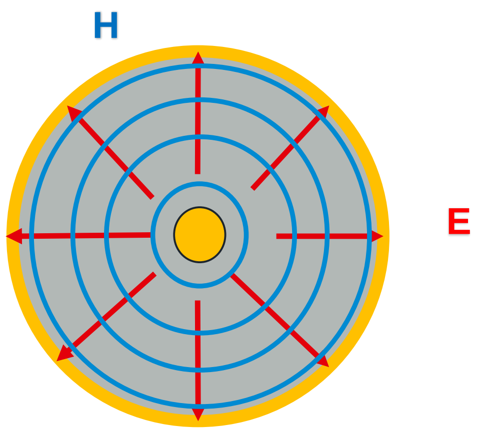
RADIATION - WAVE GUIDE LOSSES



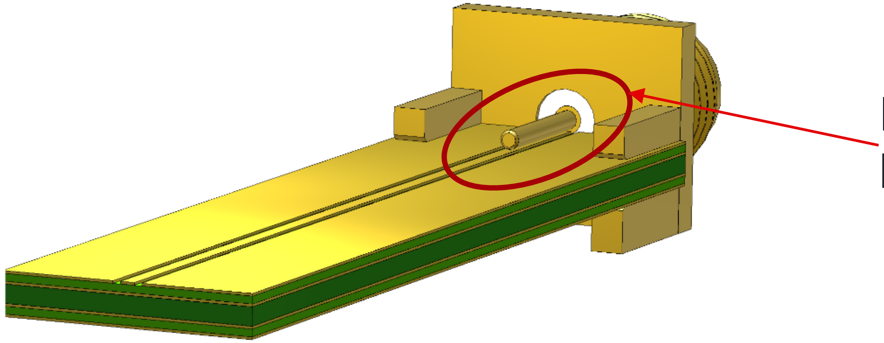
Microstrip : middle losses



Ground coplanar: low losses

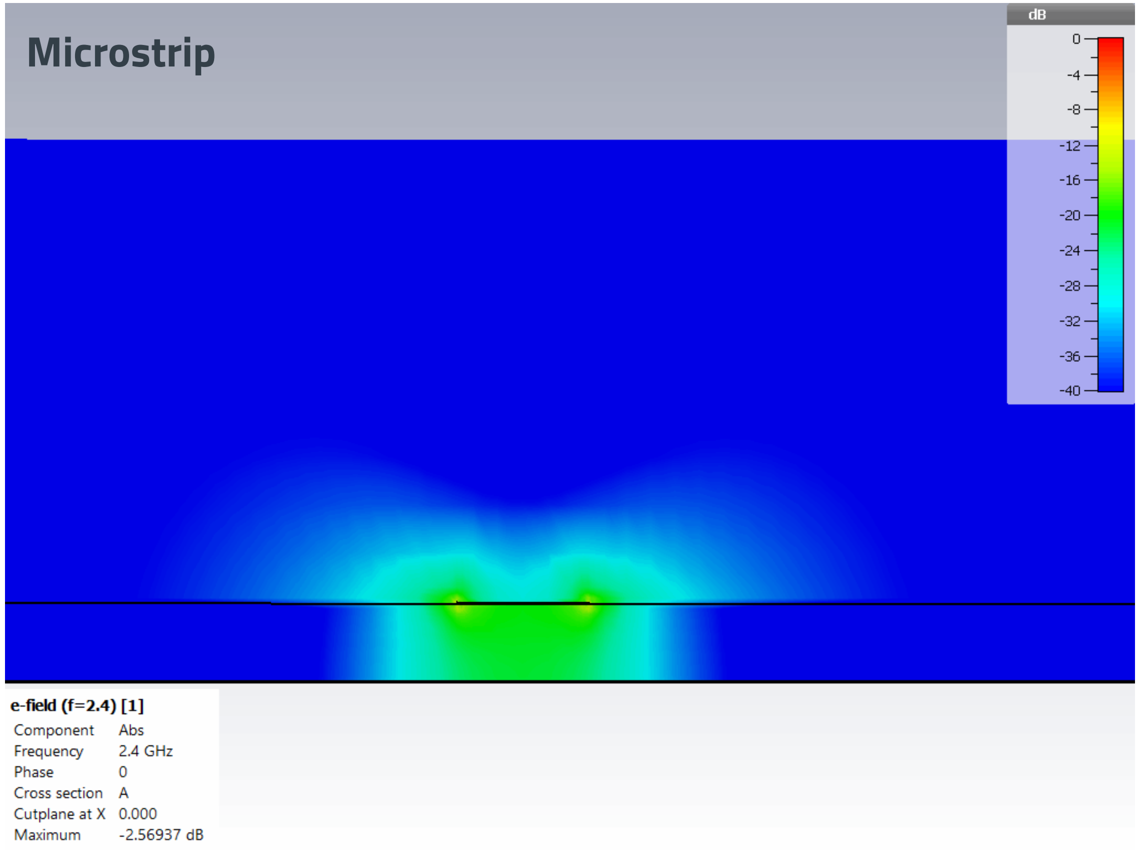


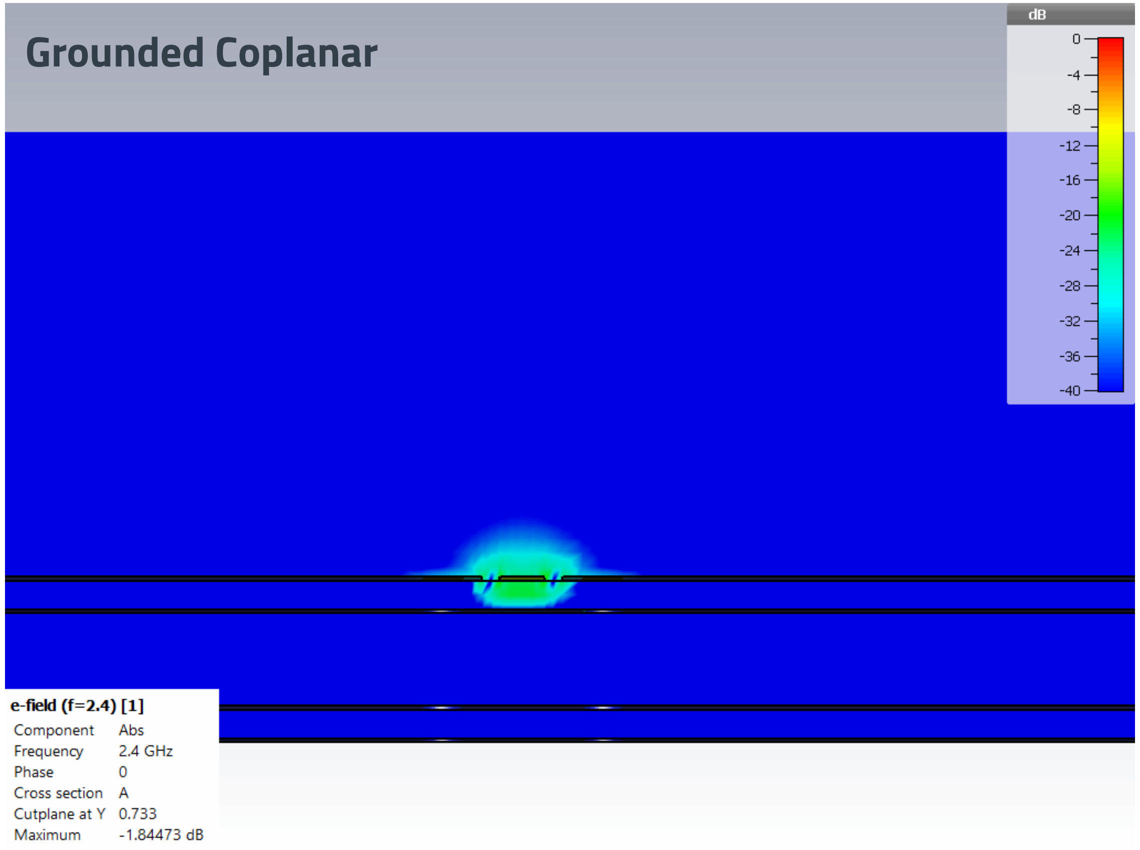
Coax: very low losses



Impedance change:
high or low losses ?

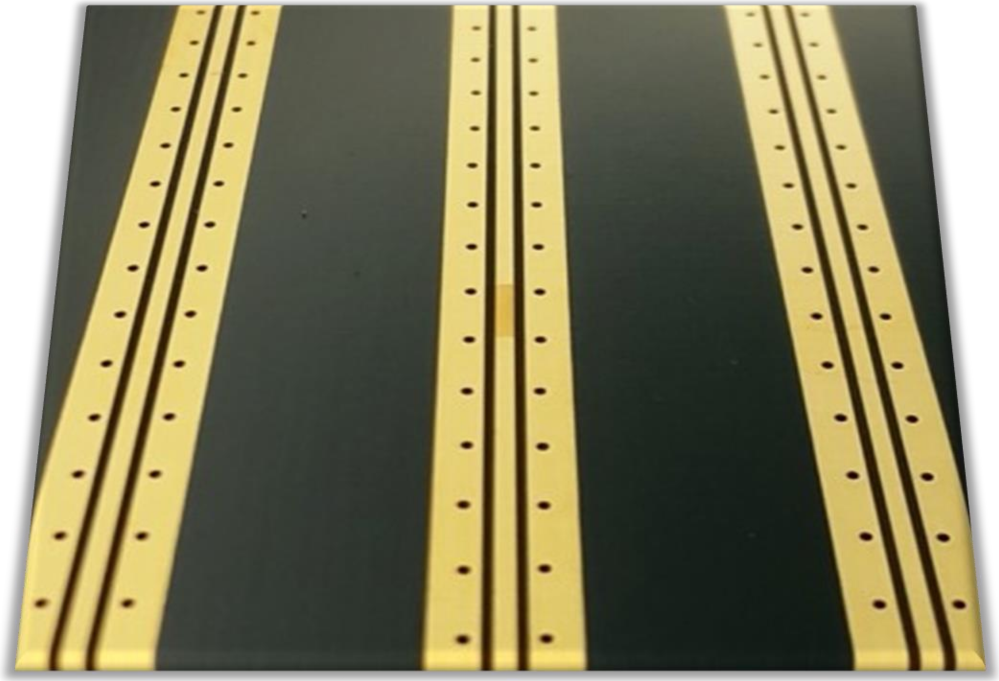
FIELD DISTRIBUTION





OVERVIEW PCB STRUCTURES: TIPS & TRICKS

Solder-Resist free



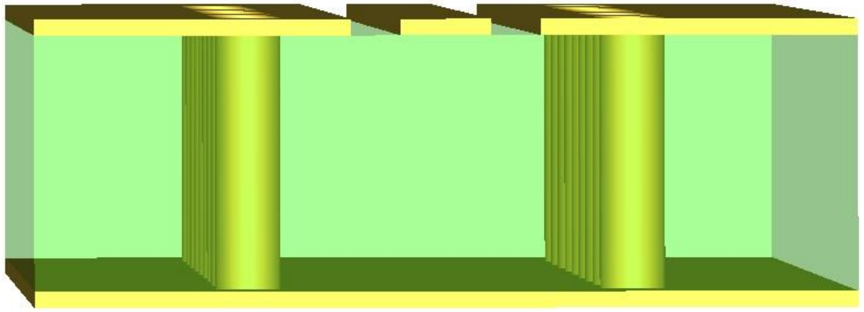
- **Solder resist:**
  - Increases loss
  - Adds dielectric

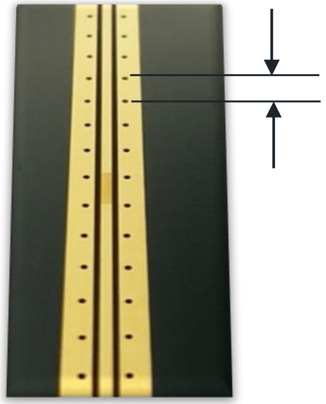
- **Remove solder resist from:**
  - RF-Line and
  - Near Ground-Plane

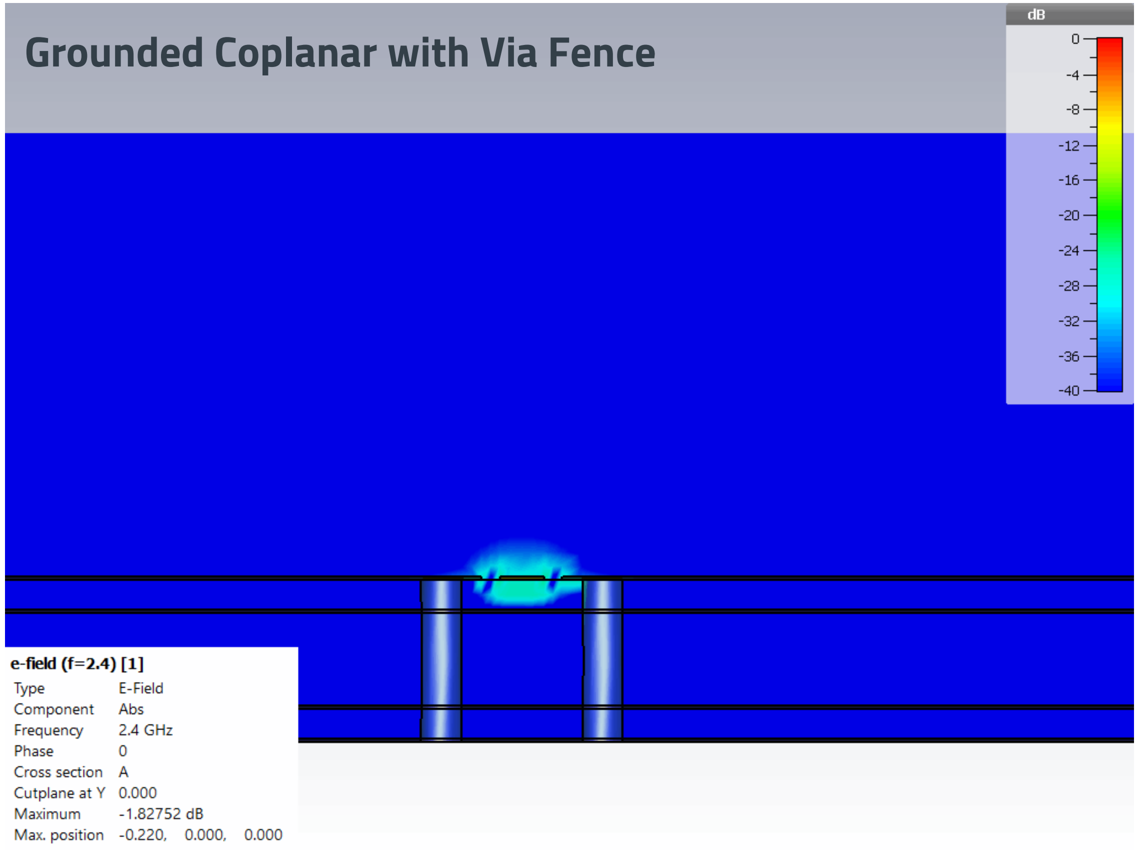
OVERVIEW PCB STRUCTURES: TIPS & TRICKS

Via Fence

Via center distance ~ λ/10





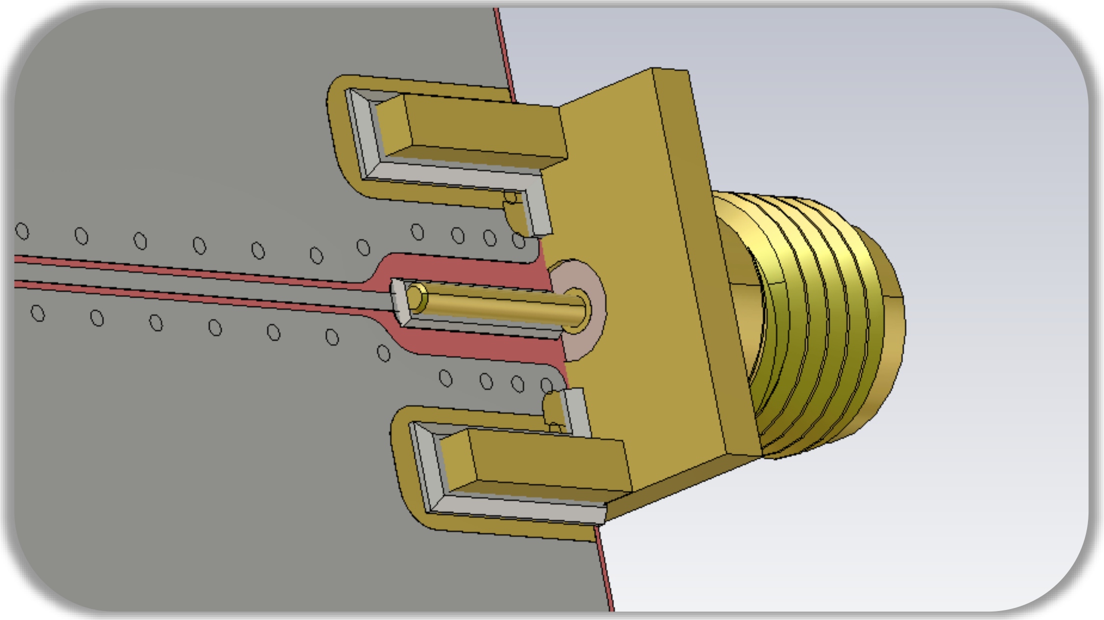


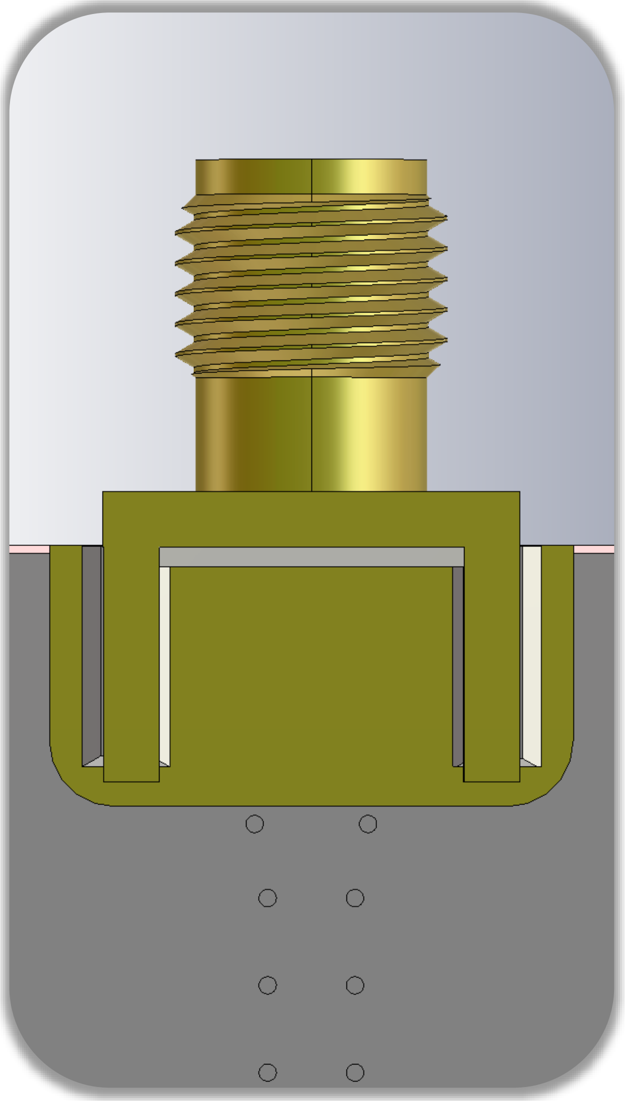
- **Field captured between GND**
  - Reduces coupling
  - Less loss
- **Stabilized ground planes**

COMBINATION CONNECTOR & PCB: EXAMPLES

CPWG - Round: Design

- Solder pads & several vias
- Very good GND connection
- Optimized RF-Line with tapers

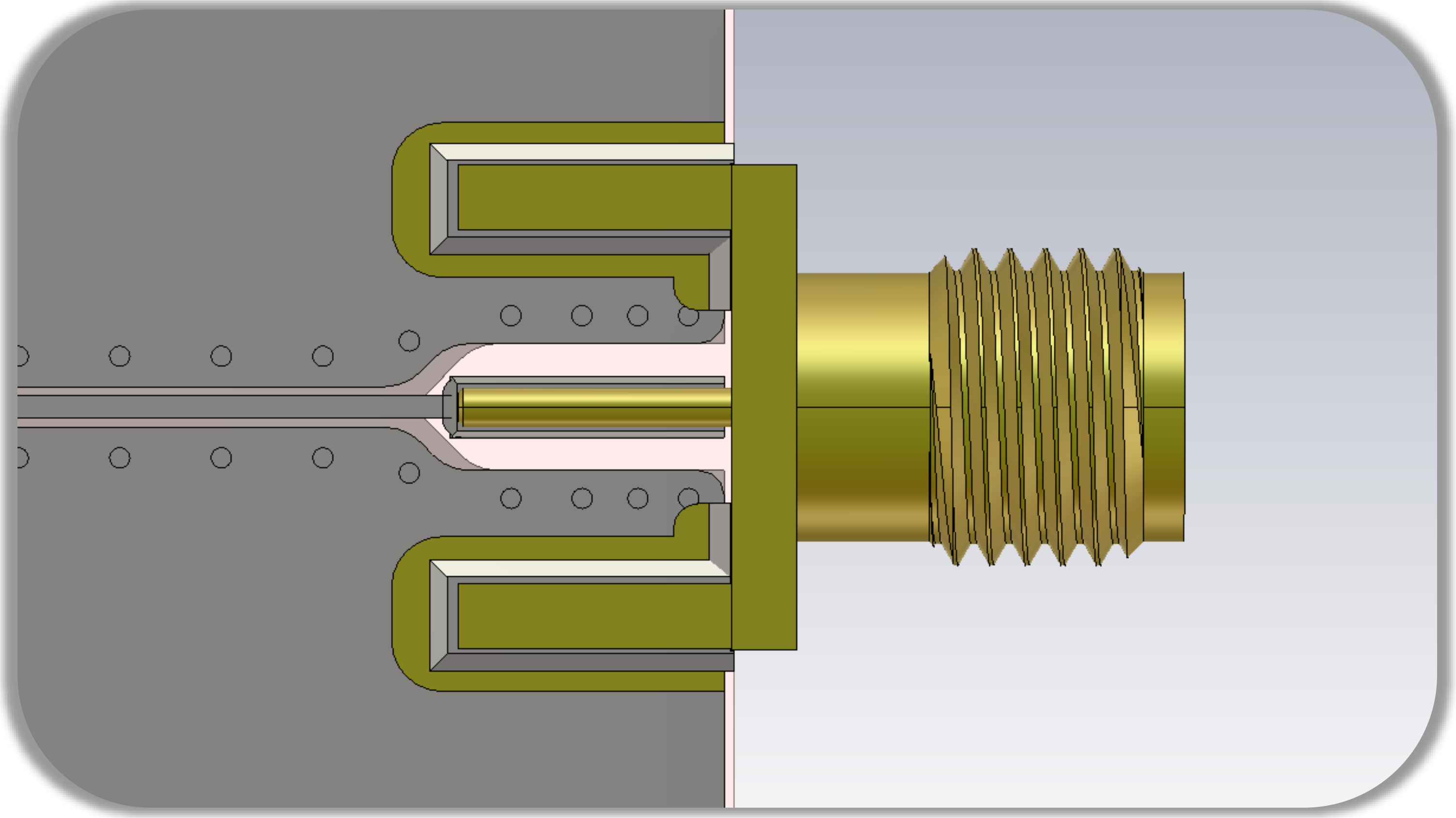




COMBINATION CONNECTOR & PCB: EXAMPLES

CPWG - Round: Design - DGS

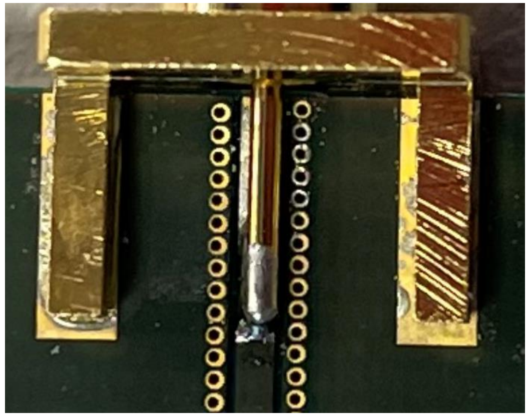
- **Defective Ground Structure: matching structure → decreases parasitic capacitance**



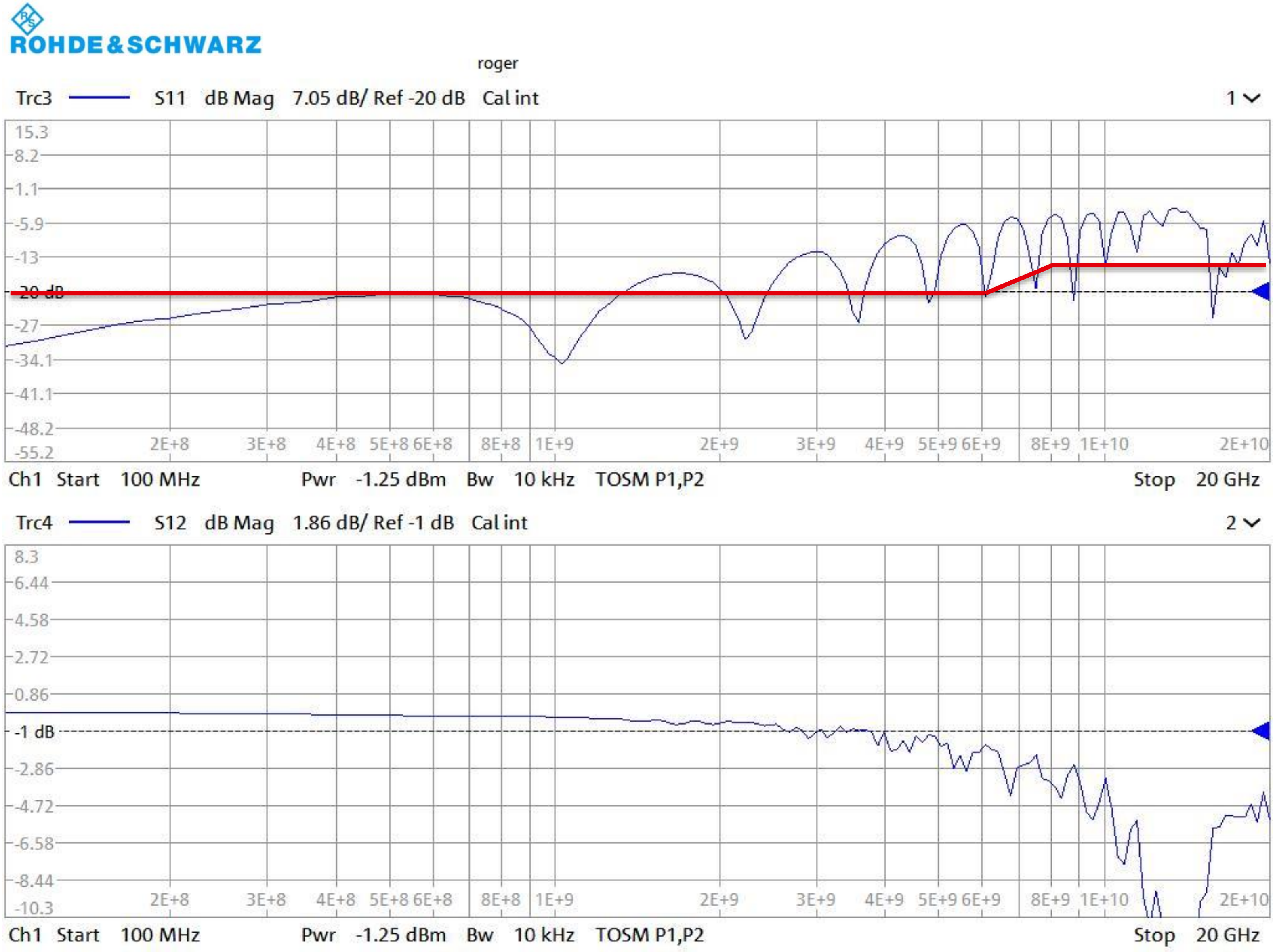
REAL MEASURMENTS

Initial without tin

Straight trace
No impedance adjustment



No tin



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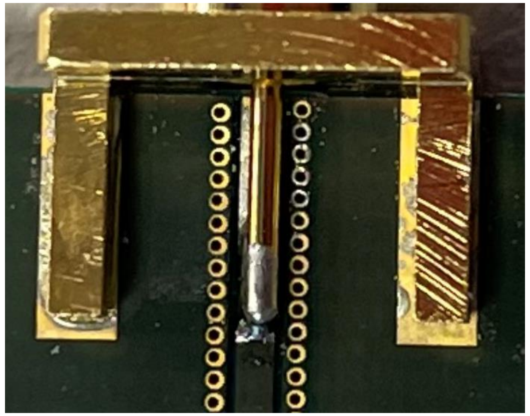
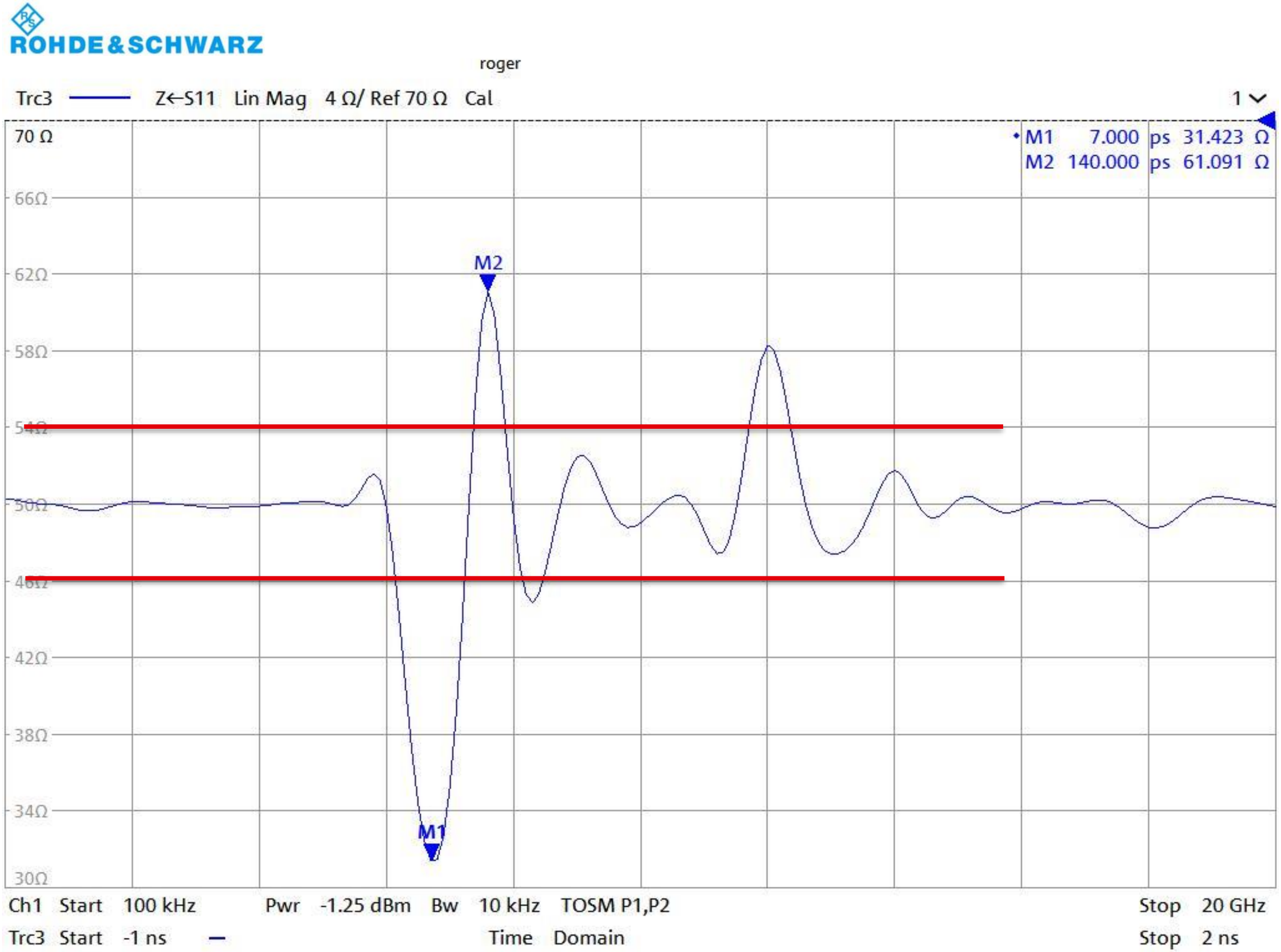


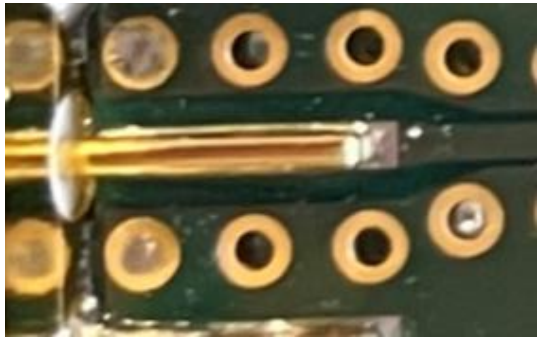
No tin



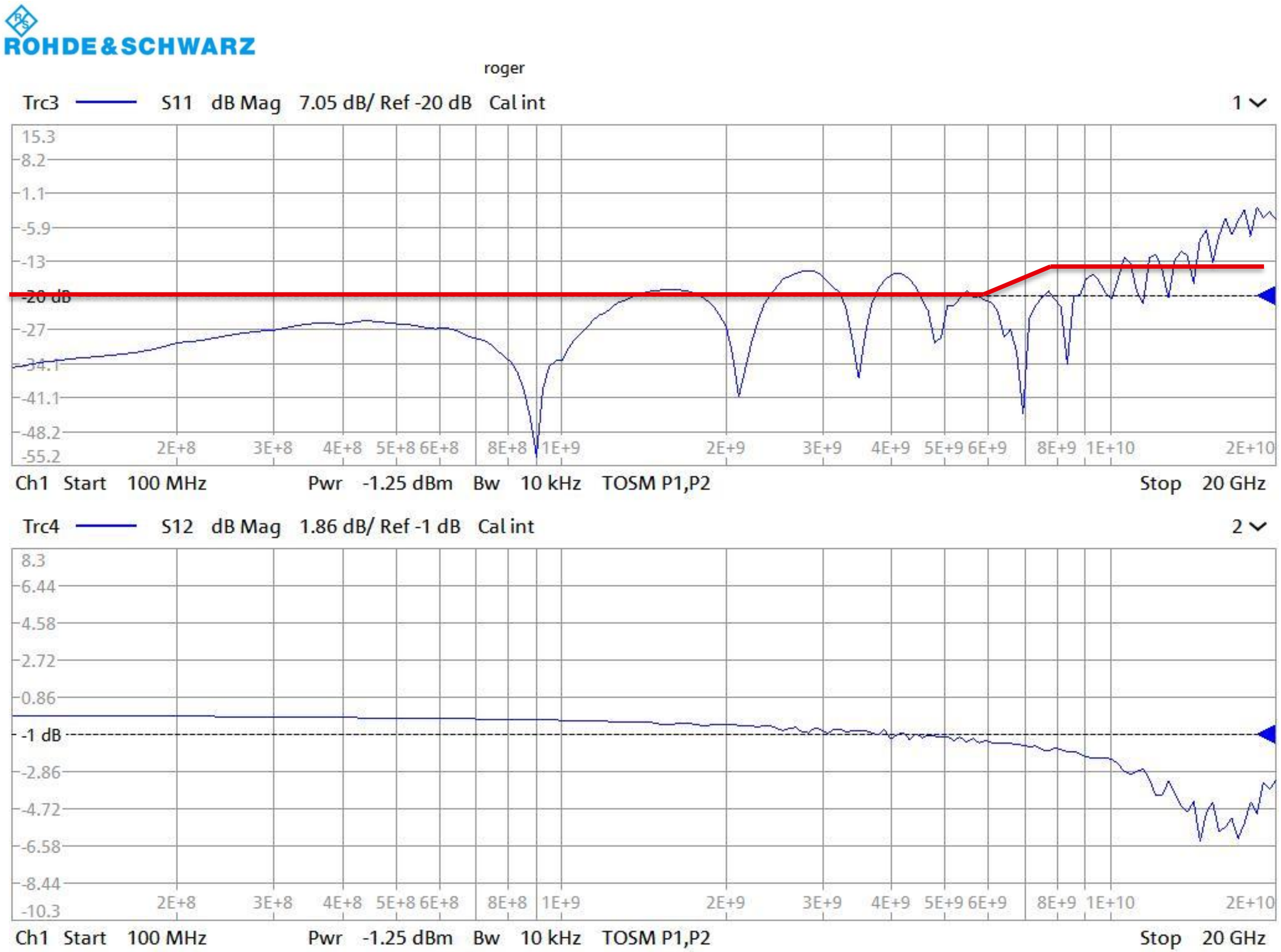
REAL MEASURMENTS

Round shape without DGS with tin

Ground layer adjustment
Round shape



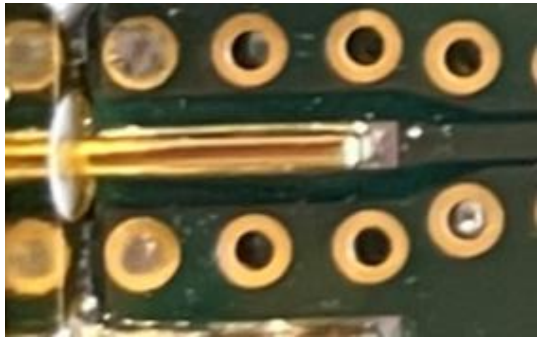
Tin



REAL MEASURMENTS

Round shape without DGS with tin

Ground layer adjustment
Round shape

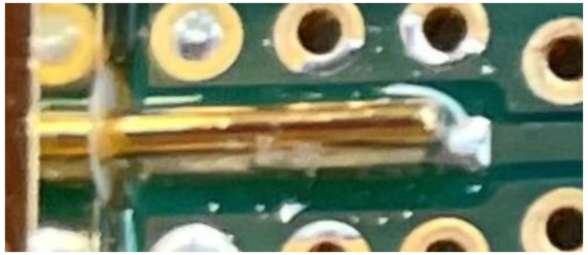


Tin

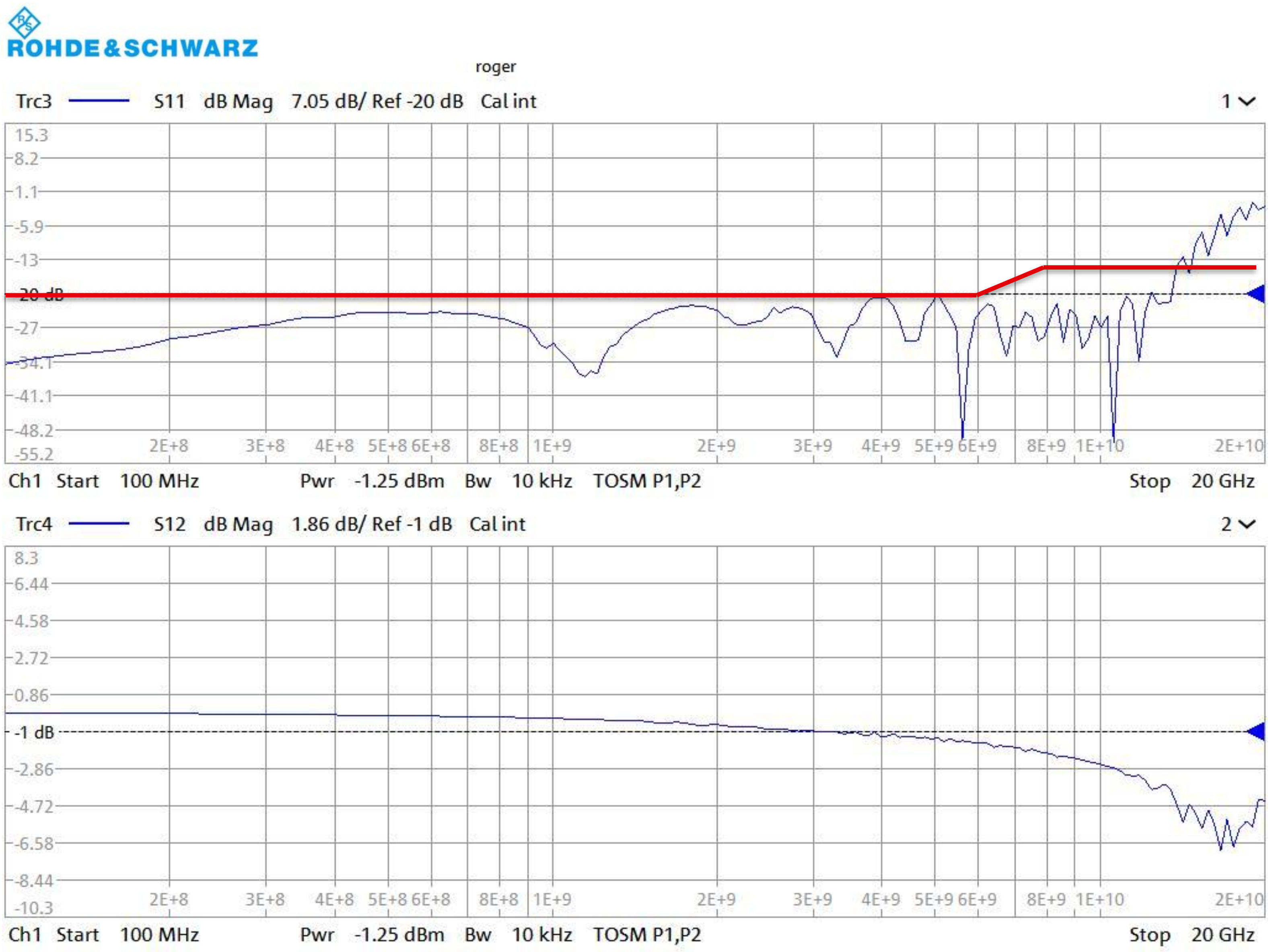
REAL MEASURMENTS

Adjusted shape without DGS with tin

Ground layer adjustment
Adjusted shape



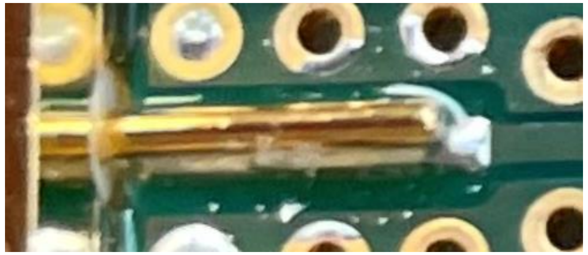
Tin



REAL MEASURMENTS

Adjusted shape without DGS with tin

Ground layer adjustment
Adjusted shape

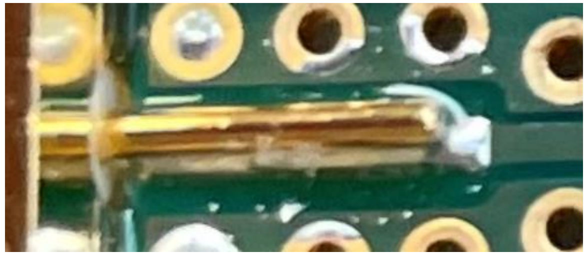


Tin

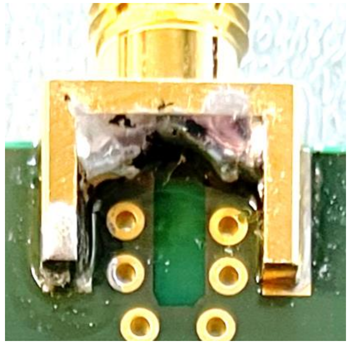
REAL MEASURMENTS

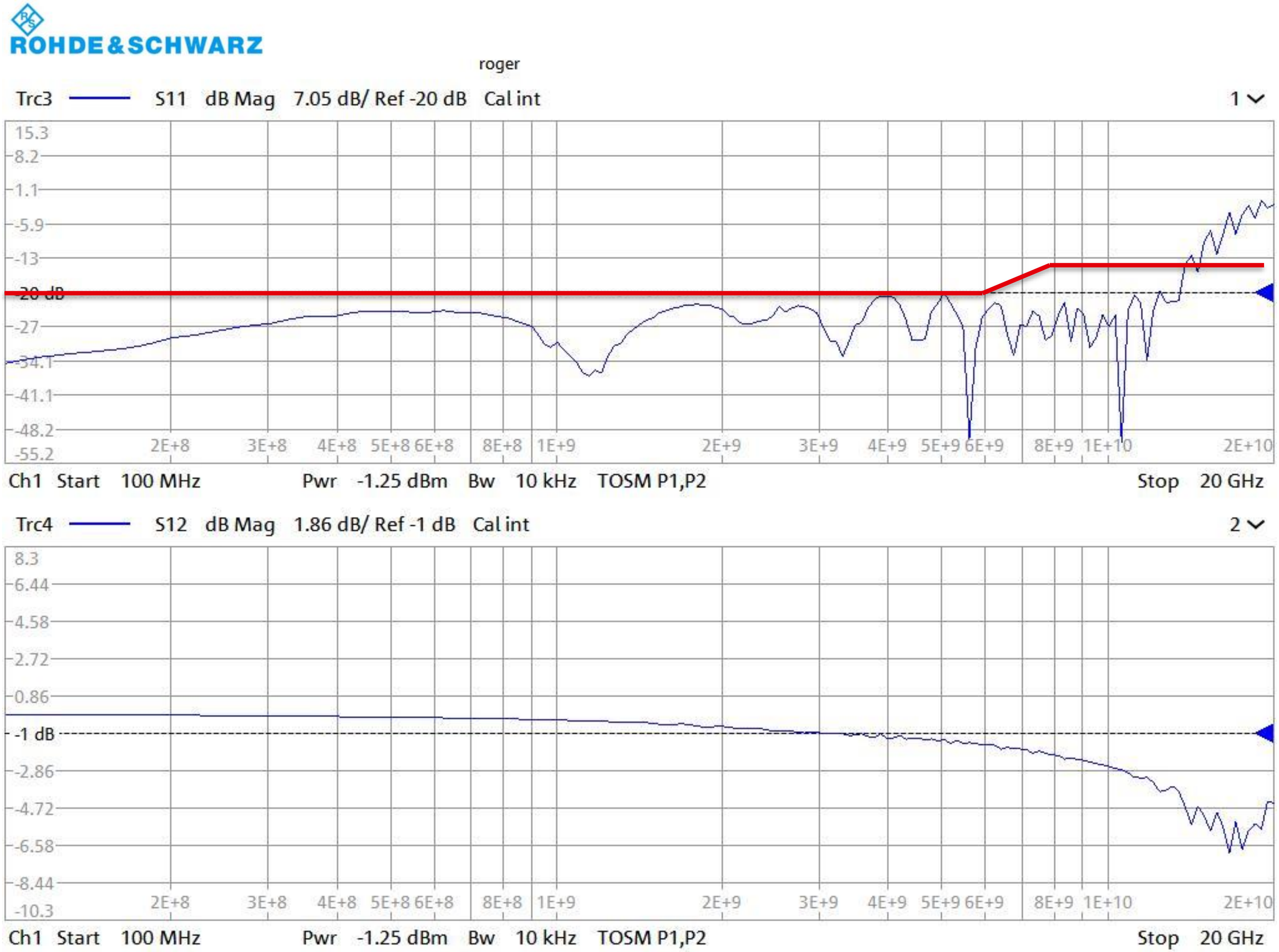
Adjusted shape with DGS with tin

Ground layer adjustment
Adjusted shape



Tin + DGS

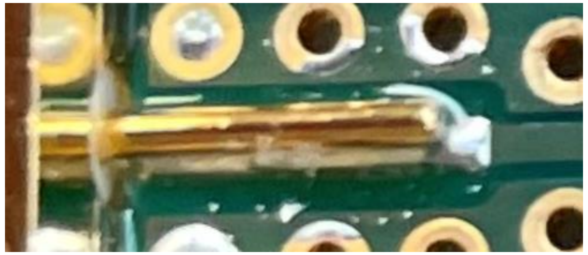




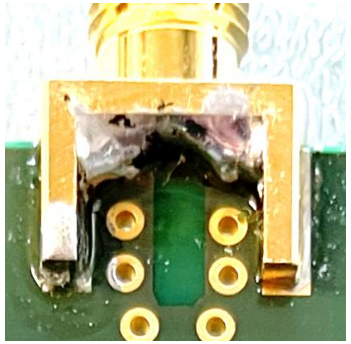
REAL MEASURMENTS

Adjusted shape with DGS with tin

Ground layer adjustment
Adjusted shape



Tin + DGS



Questions

& Answers

We are here for you now!
Ask us directly via our chat or via E-Mail.

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Remco.VandeGriendt@we-online.de