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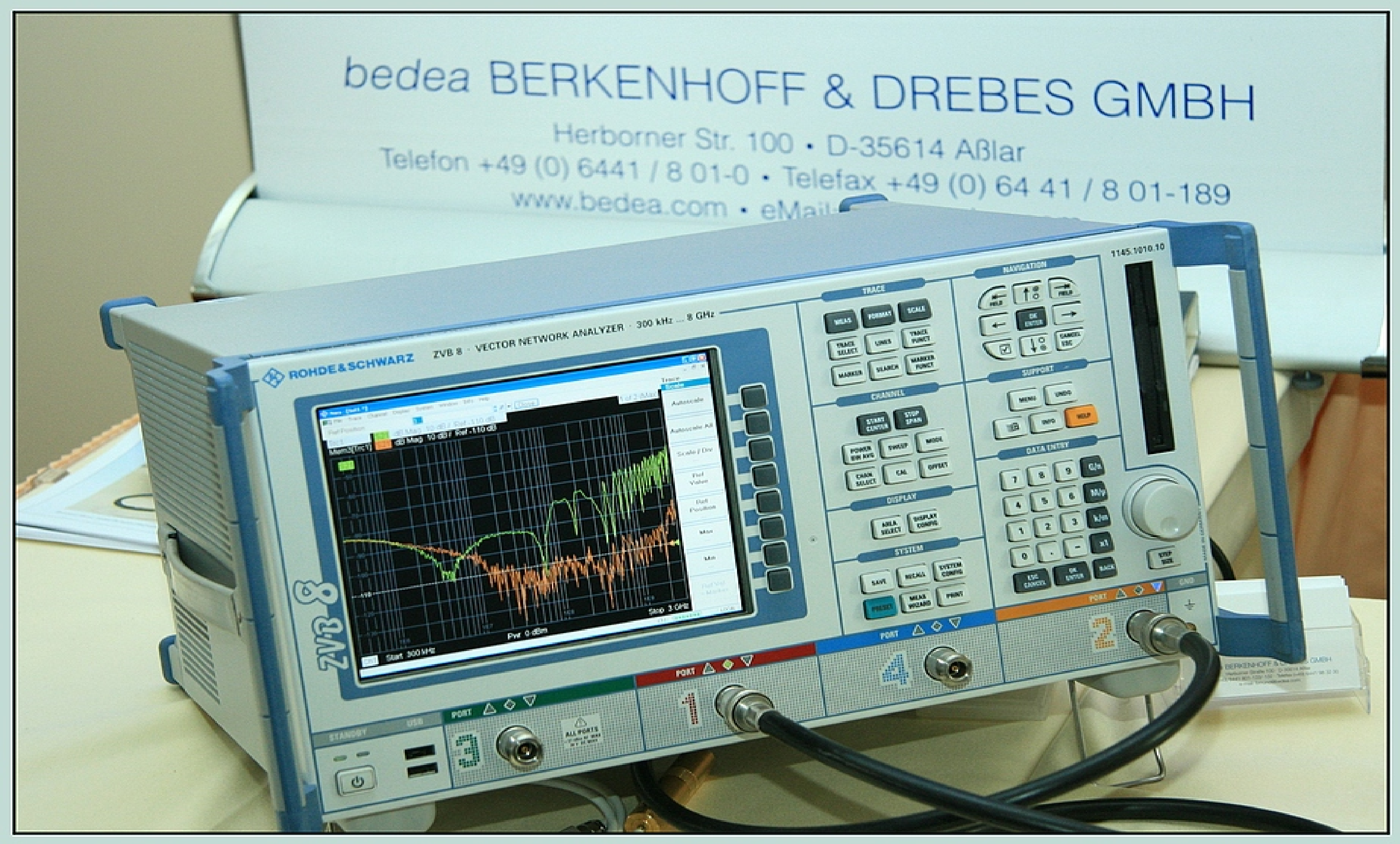
Coupling attenuation up to 2 GHz with virtual Balun



Multiport (four-port) respectively mixed-mode VNA

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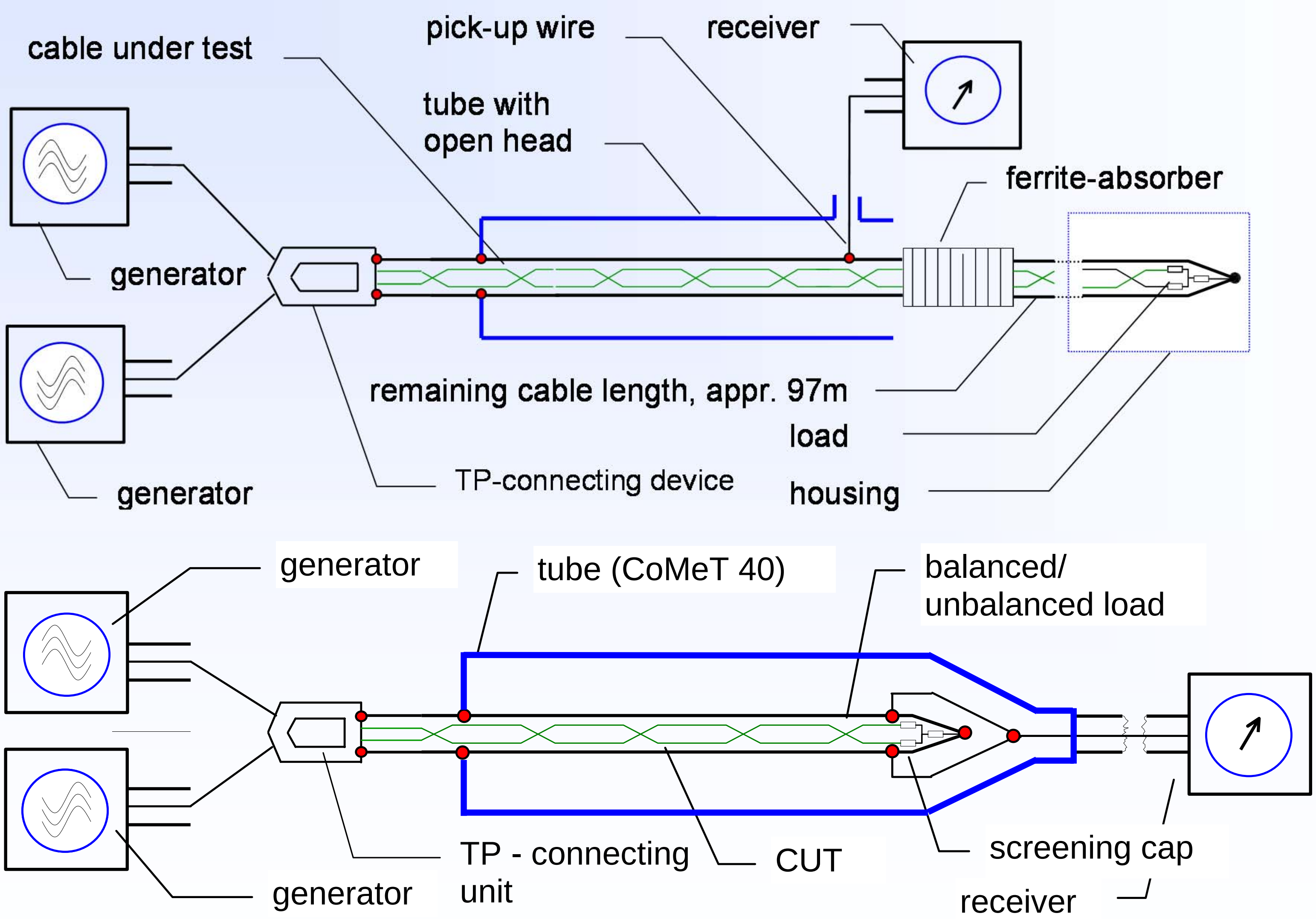


Overview

- Physical Basics of Screening
  - Transfer impedance,
  - Unbalance attenuation
  - Screening and Coupling attenuation
- Mixed mode S-Parameter (virtual Balun)
- Measuring of Coupling attenuation
  - Clamp proccedure, IEC 62153-4-5
  - Triaxial procedure, standard and open head, IEC 62153-4-9
  - Measurements
- Discussion

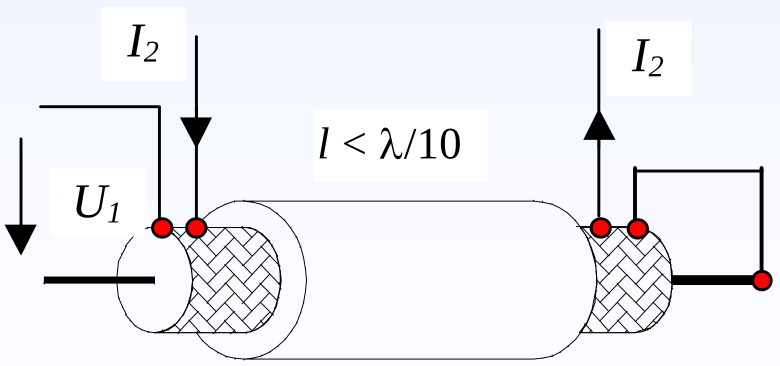
Transfer impedance & Screening attenuation

high frequencies: Screening attenuation

$$a_S = 10 \log (P_1/P_2) = 20\log_{10} (U_1/U_2) \text{ [dB]}$$

Ratio of two powers --> **length independent**

low frequencies: Transferimpedance



$$Z_T = \frac{U_1}{I_2 \cdot l} \quad \text{[m}\Omega\text{/m]}$$

Ratio of **U/I = R → length dependent, (Ohms law)**

Wave length

$\lambda = (c_0 \bullet v_k) / f$

electrical long:

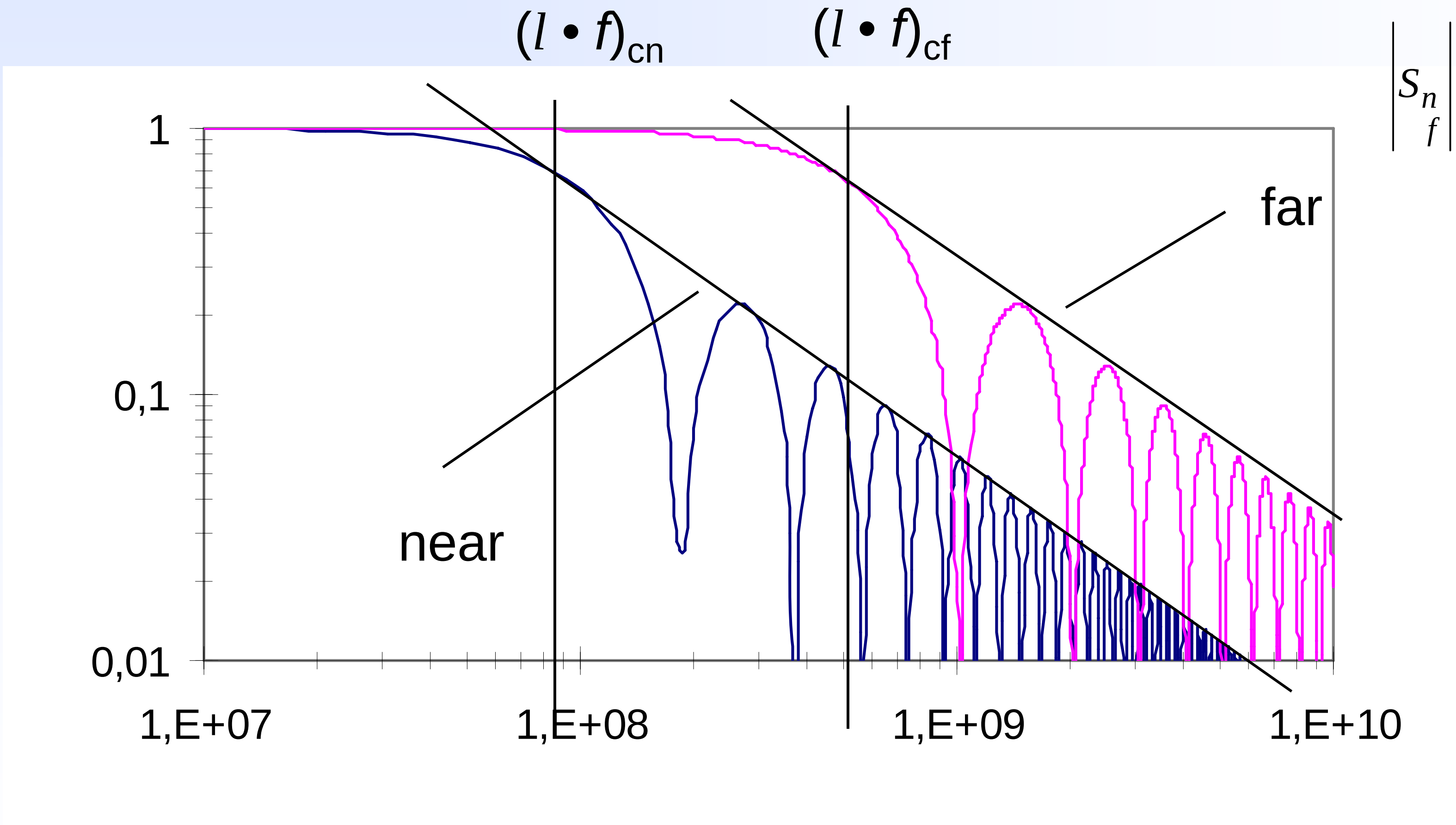
$$f > \frac{c_o}{2 \cdot l \cdot \left| \sqrt{\varepsilon_{r1}} - \sqrt{\varepsilon_{r2}} \right|}$$

electrical short:

$$f < \frac{c_o}{10 \cdot l \cdot \sqrt{\varepsilon_{r1}}}$$

(EN 50289-1-6)

Summing function S_{nf}



$$\left|S_{\frac{n}{f}}\right| = \frac{\left|2\sin\left(\frac{(\beta_1 \pm \beta_2).L_c}{2}\right)\right|}{(\beta_1 \pm \beta_2).L_c}$$

≈ sin x/x

low frequencies

$$\left|S_{\frac{n}{f}}\right| \to 1$$

high frequencies

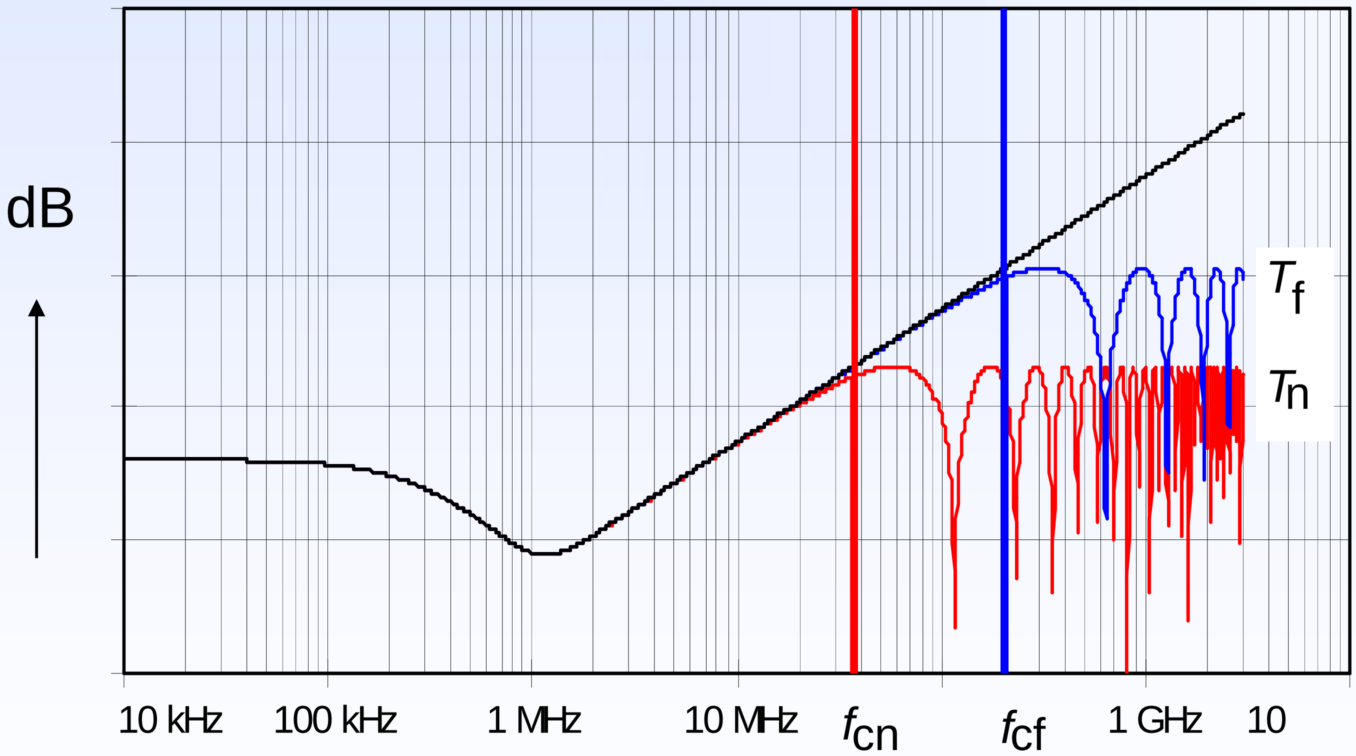
$$\left|S_{\frac{n}{f}}\right| \to \frac{2}{(\beta_1 \pm \beta_2) \cdot l}$$

introduced by Halme/Szentkuti 1988

Calculated Coupling Transfer Function T_{nf}

a_s and Z_T vs frequency

$$T_{\substack{s,n\\f}} = (Z_F \pm Z_T)\cdot\frac{1}{\sqrt{Z_1\cdot Z_2}}\cdot\frac{l}{2}\cdot S_{\substack{n\\f}}$$



n = near end
f = far end

L = 1 m
ε_{r1} = 2,3
ε_{r2} = 1,0
Z_F = 0

The Coupling Transfer function T_{nf} results from the multiplication of the equivalent Transfer impedance Z_{TE} and the Summing function S_{nf}

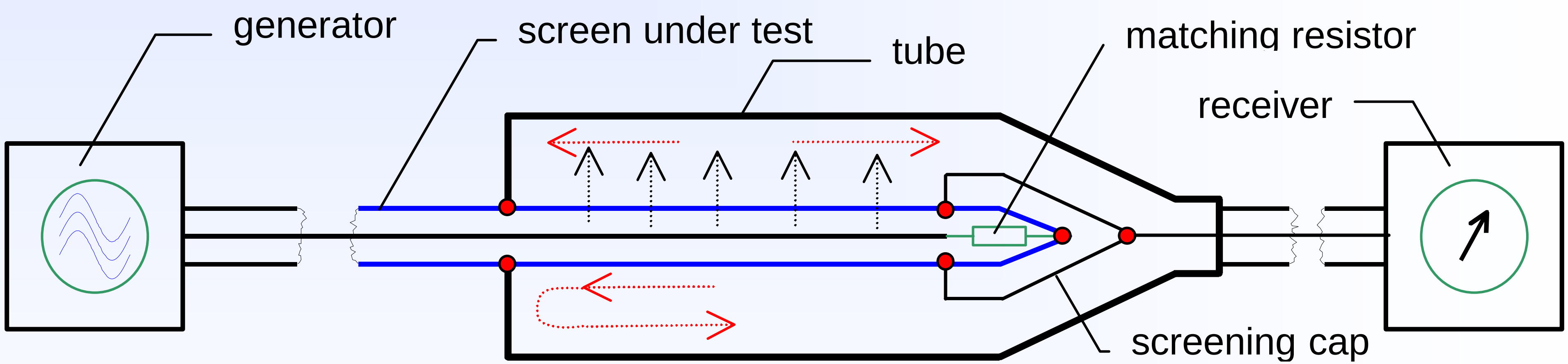
Transferimpedance ←

Screening attenuation
→
& Coupling attenuation

Triaxial test set-up CoMeT, principle

Transfer impedance & Screening (or Coupling) attenuation

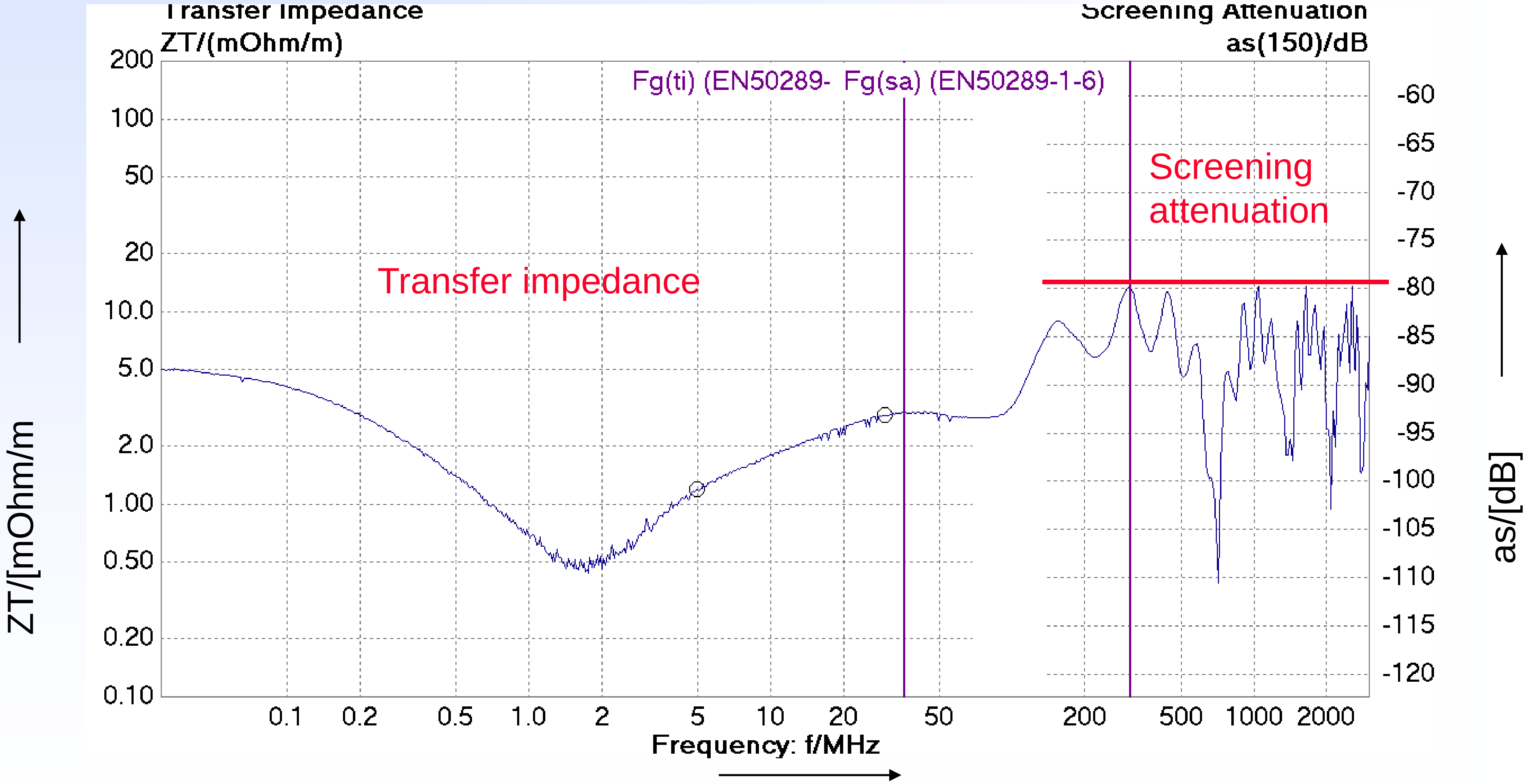
few kHz up to and above 8 (12) GHz with one test set-up



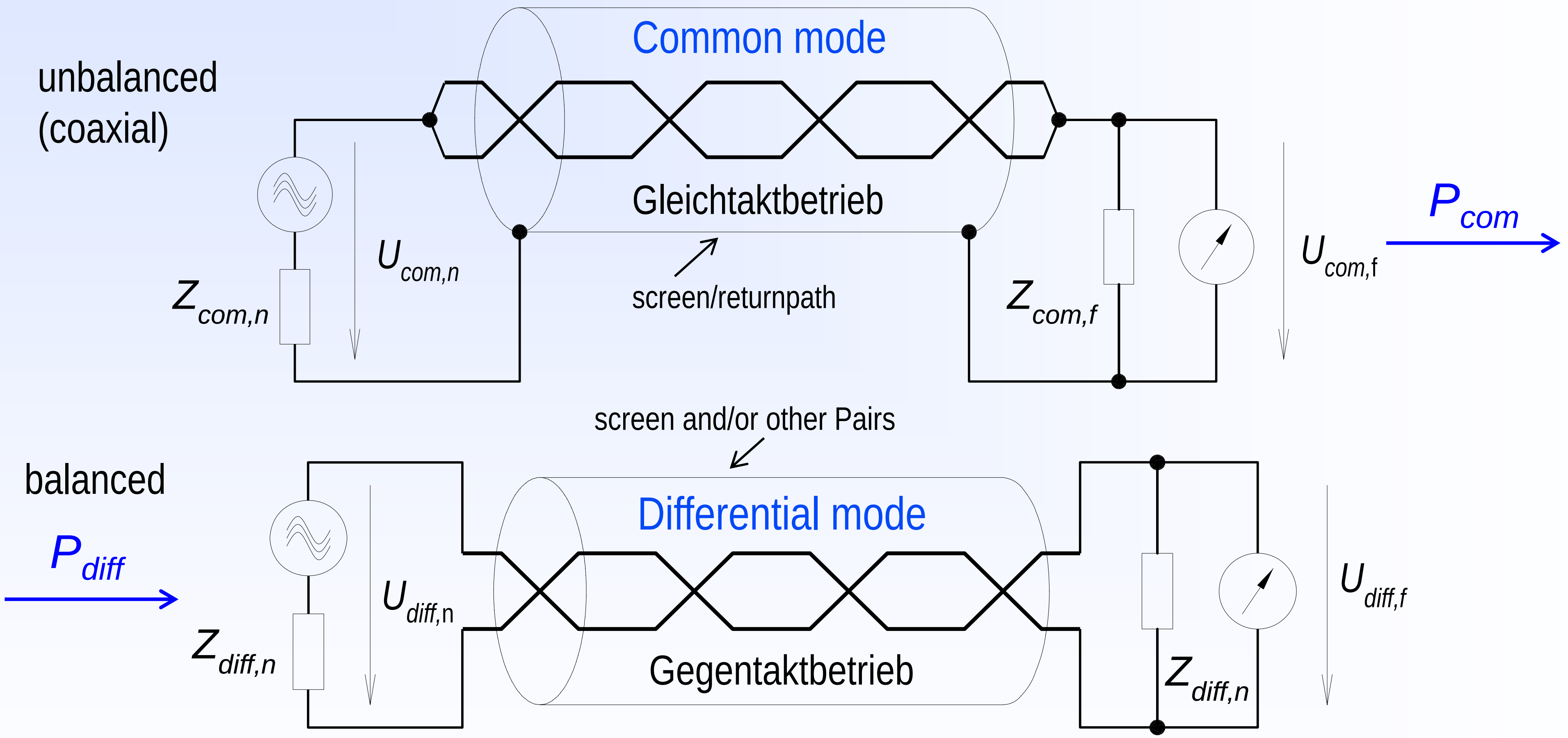
Generator and receiver are included in a modern network analyser

IEC 62153-4-3Ed2 Transfer impedance, IEC 62153-4-4Ed2 Screening attenuation
EN 50289-1-6 EMC on Communication cables

Coupling transfer function RG 214



Common mode & differential mode



The "Unbalance Attenuation" of a pair describes in logarithmic scale how much power couples from the differential mode to the common mode and vice versa. It is the logarithmic ratio of the input power in the differential mode P_{diff} to the power which couples to the common mode P_{com}: $a_u = 10 \cdot \log \left(P_{diff} \; / \; P_{com} \right)$

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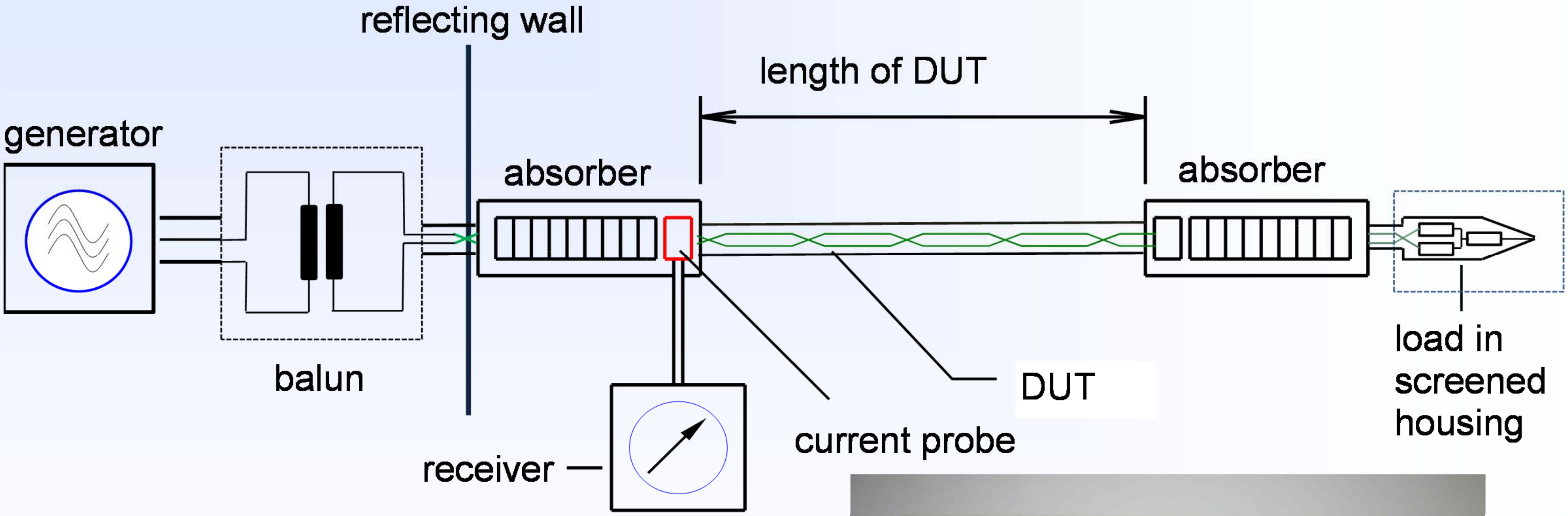
Screening- or Coupling attenuation with Absorbing clamps

Screening attenuation or Coupling attenuation
from 30 MHz to 1000 MHz MDS 21 or from 500 MHz to 2500 MHz MDS 22



IEC 62153-4-5 (EN 50289-1-6)

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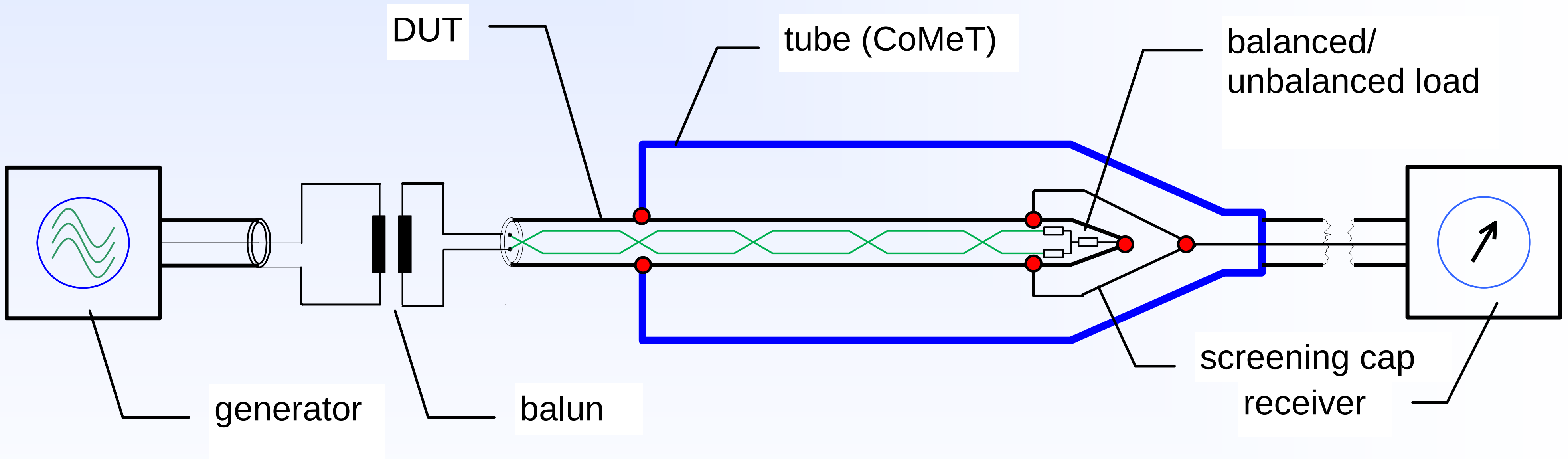
Coupling attenuation with balun & triaxial standard procedure

Coupling attenuation is the interaction of the Unbalance attenuation of the pair and the Screening attenuation of the screen



Screened balanced cables, (Cat-cables), multi core cables (and connectors)

IEC 62153-4-9, Coupling attenuation, triaxial method, (with standard head)

Four poles or two ports network

The transmission characteristics of Four Poles or Two ports, such as e.g. coaxial cables can be described by the Scattering Parameters or abbreviated “S-parameters”.

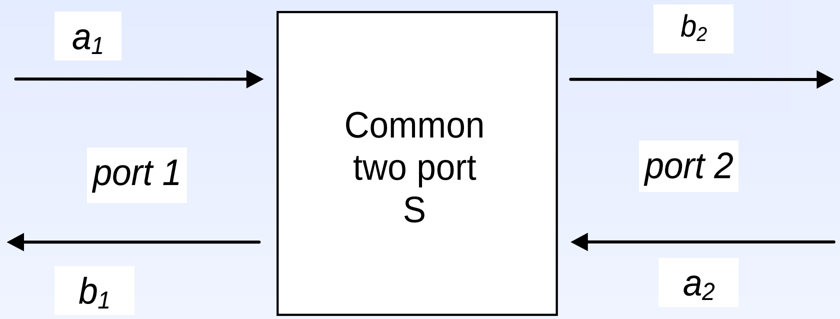
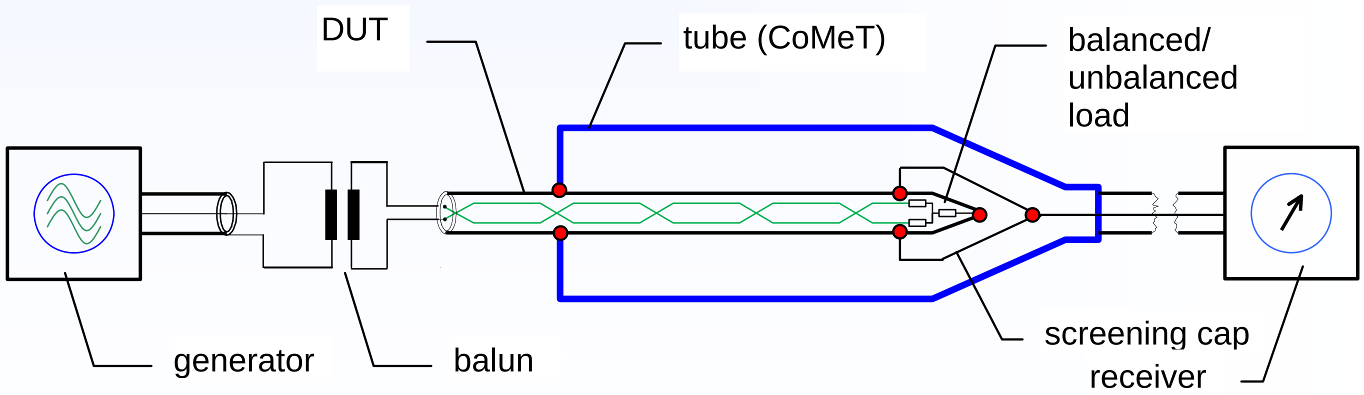


Figure 2 – Common two-port

in matrix notation it is written:

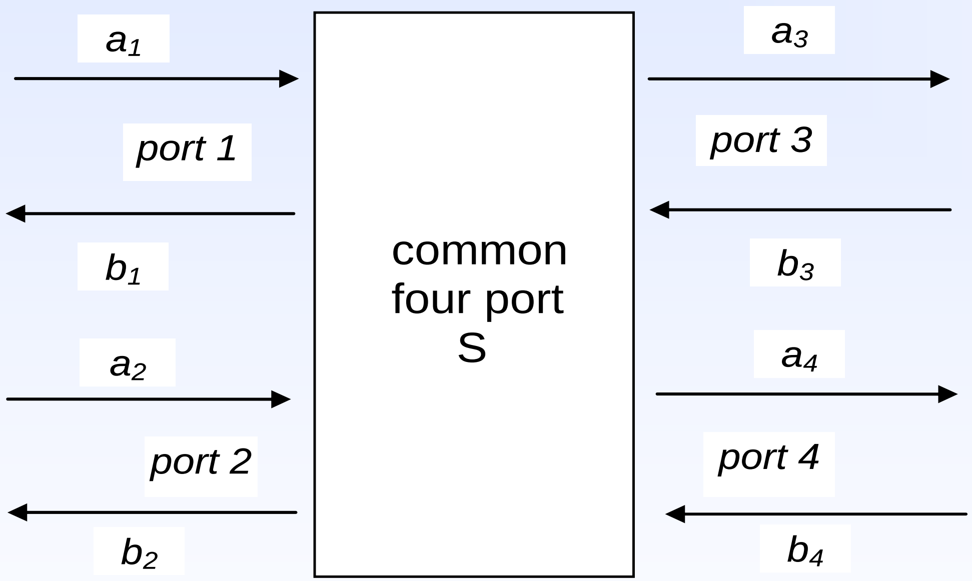
$$\begin{pmatrix} b_1 \\ b_2 \end{pmatrix} = (S) \cdot \begin{pmatrix} a_1 \\ a_2 \end{pmatrix} = \begin{pmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{pmatrix} \cdot \begin{pmatrix} a_1 \\ a_2 \end{pmatrix}$$

Coupling attenuation with balun $= S_{21}$ measurement



Four port network

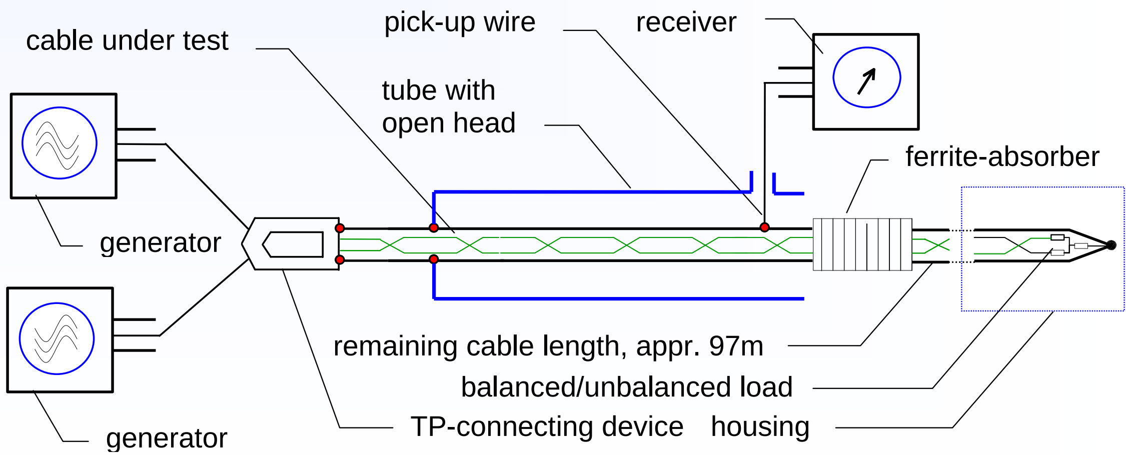
For the measurement of balanced two-ports the physical ports of the multi-port VNA are combined into logical ports. For a four-port, this results in:



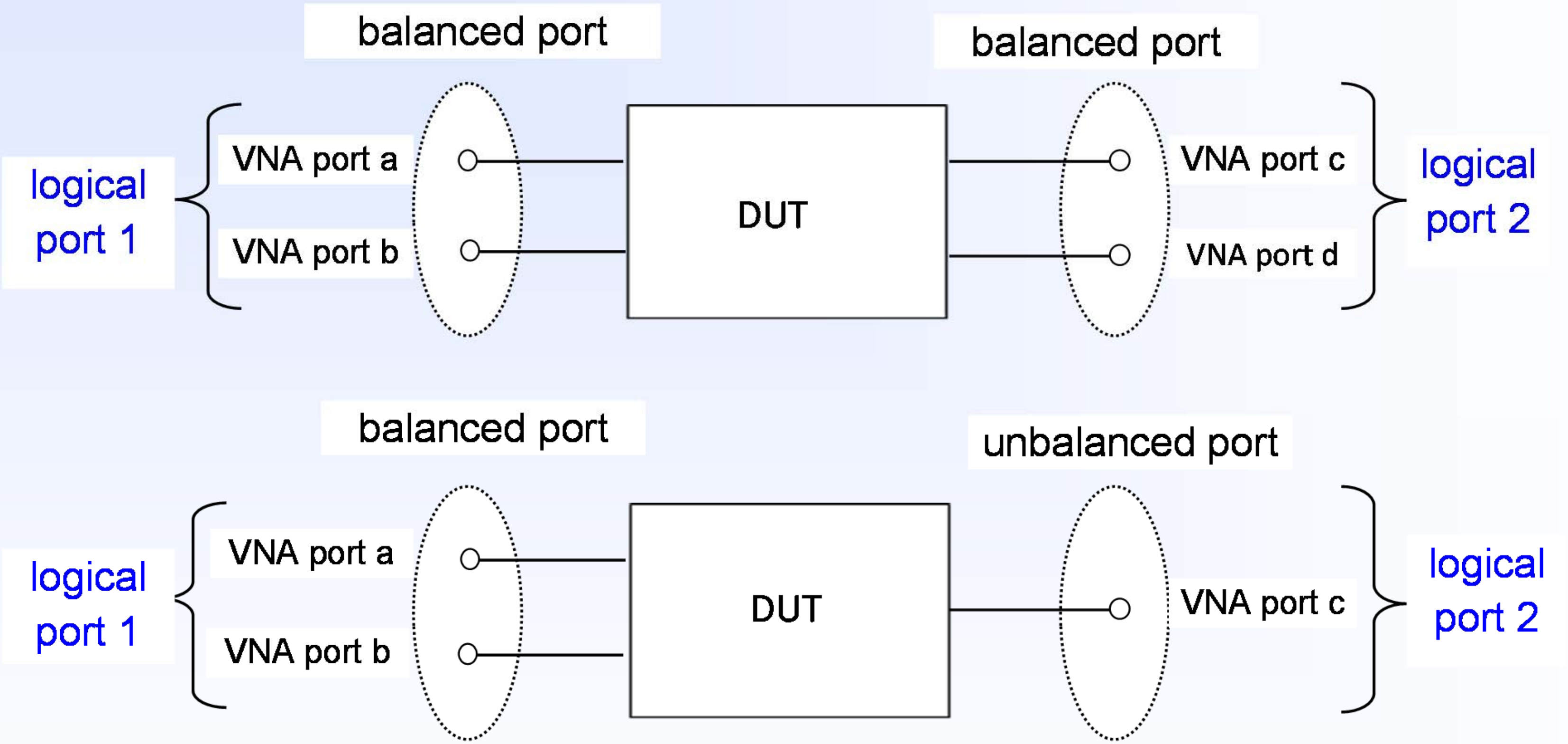
in matrix notation it is written

$$\begin{pmatrix} b_1 \\ b_2 \\ b_3 \\ b_4 \end{pmatrix} = \left(S^{std}\right) \begin{pmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \end{pmatrix} = \begin{pmatrix} S_{11} & S_{12} & S_{13} & S_{14} \\ S_{21} & S_{22} & S_{23} & S_{24} \\ S_{31} & S_{32} & S_{33} & S_{43} \\ S_{41} & S_{42} & S_{43} & S_{44} \end{pmatrix} x \begin{pmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \end{pmatrix}$$

to measure Coupling attenuation with “virtual balun“ resp. with “mixed mode“
the signal is fed into port 1 and port 2
and received at port 3, port 4 is not connected



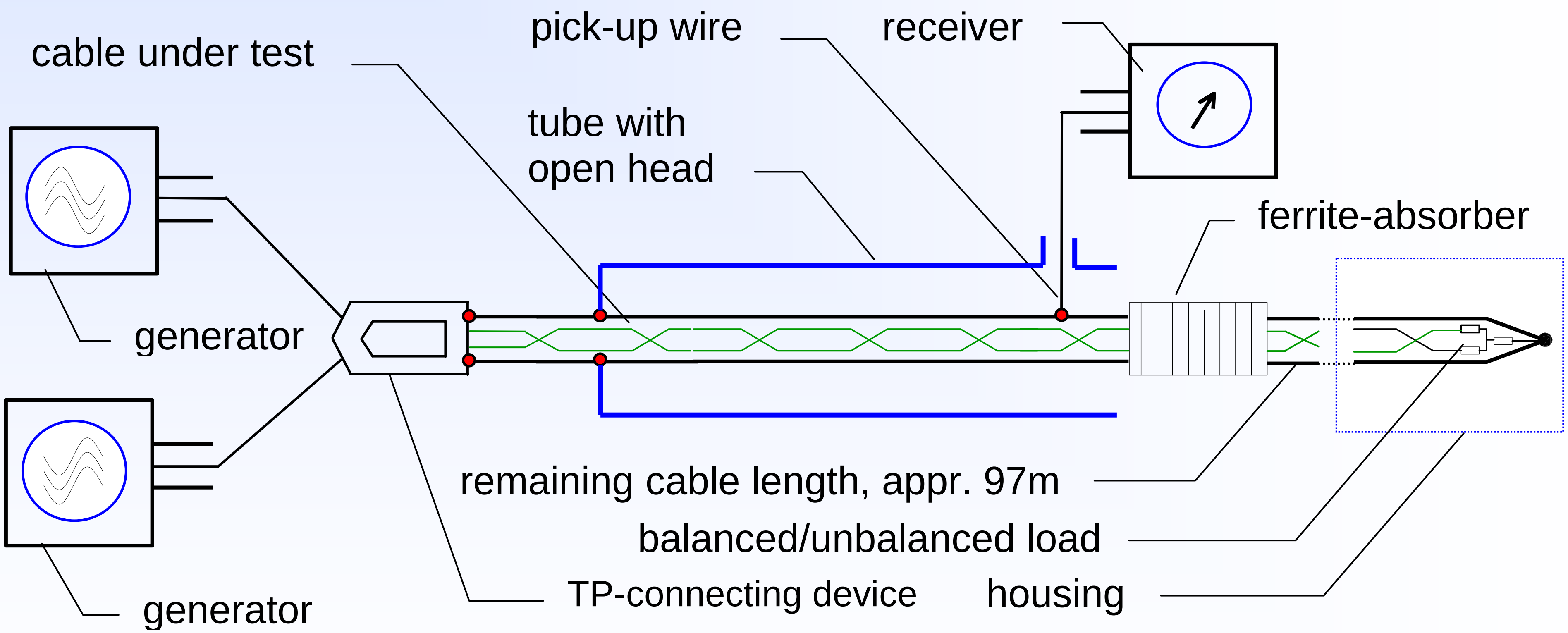
Physical und logical VNA-Ports



For the measurement of balanced two-ports
the physical ports of the multi-port VNA are combined into logical ports
To measure coupling attenuation, one balanced and one unbalanced port is used

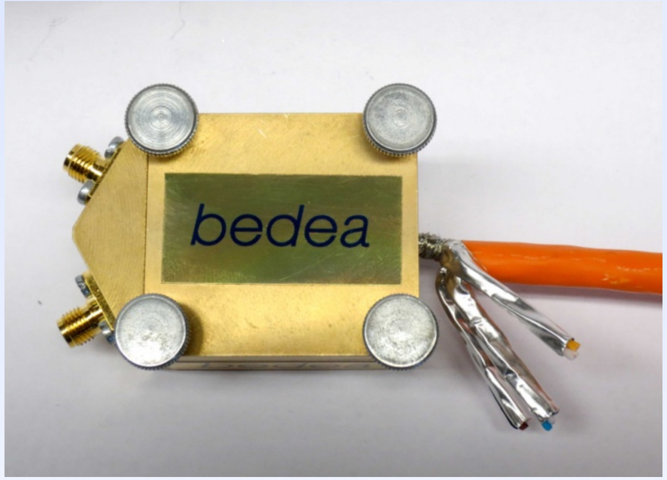
Coupling attenuation with “virtual balun“ and triaxial open head

IEC 62153-4-9, Coupling attenuation

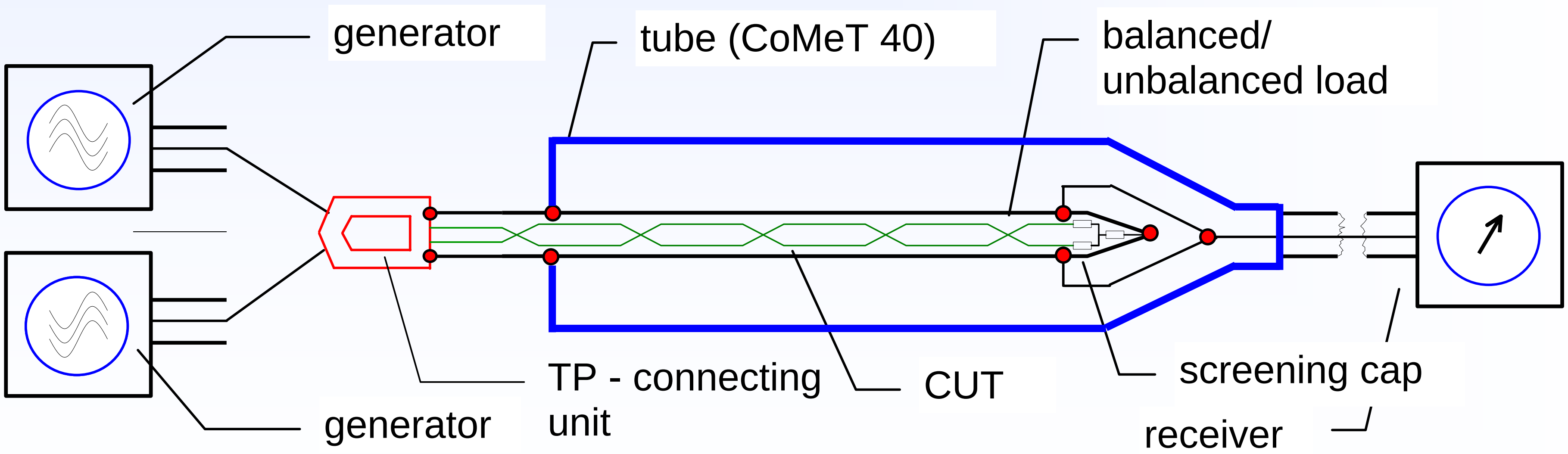


a balanced signal may be obtained with a network analyser having two generators with a phase shift of 180 °. Another alternative are multi-port VNAs (generators switched)

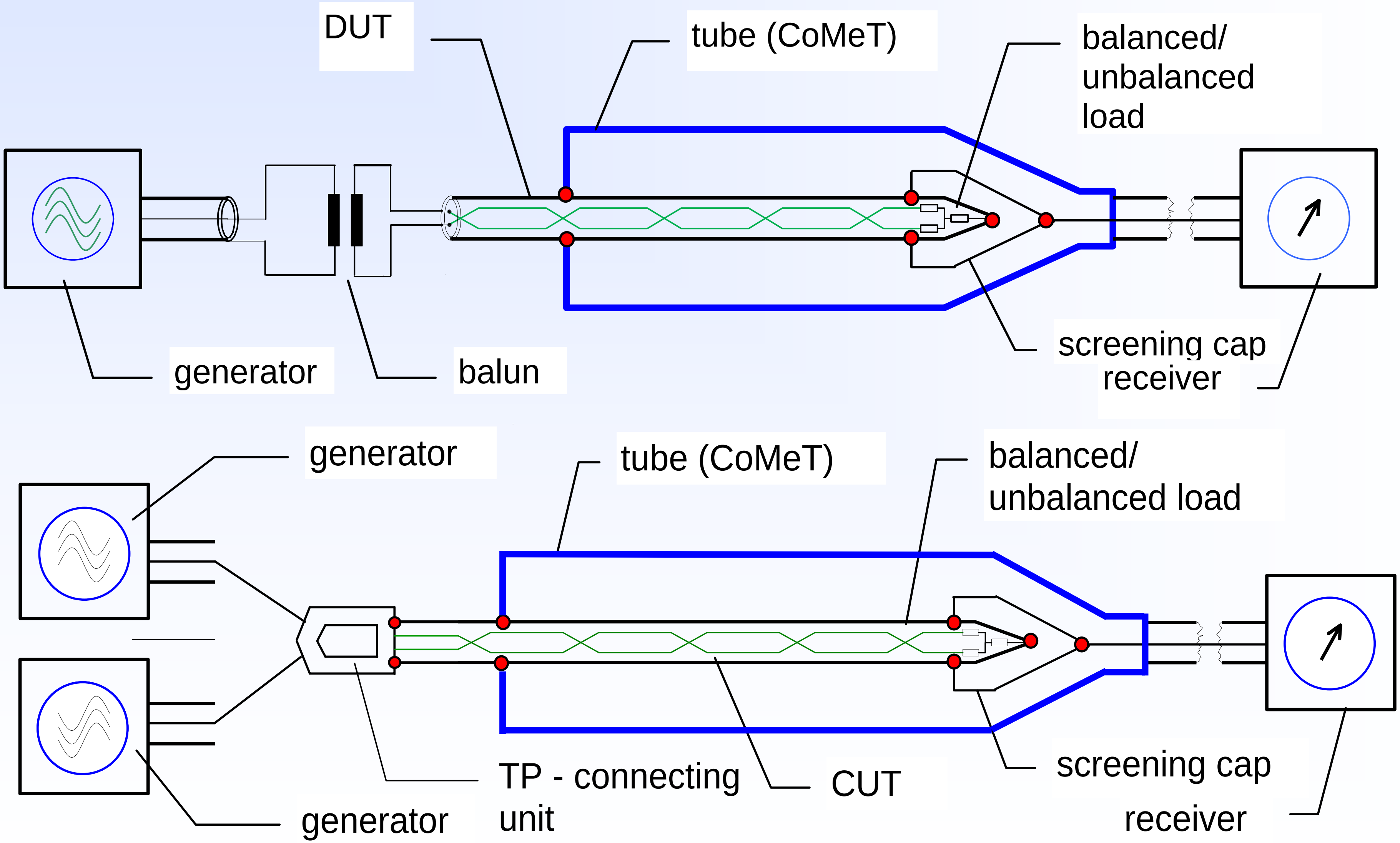
TP-connecting device for mixed mode



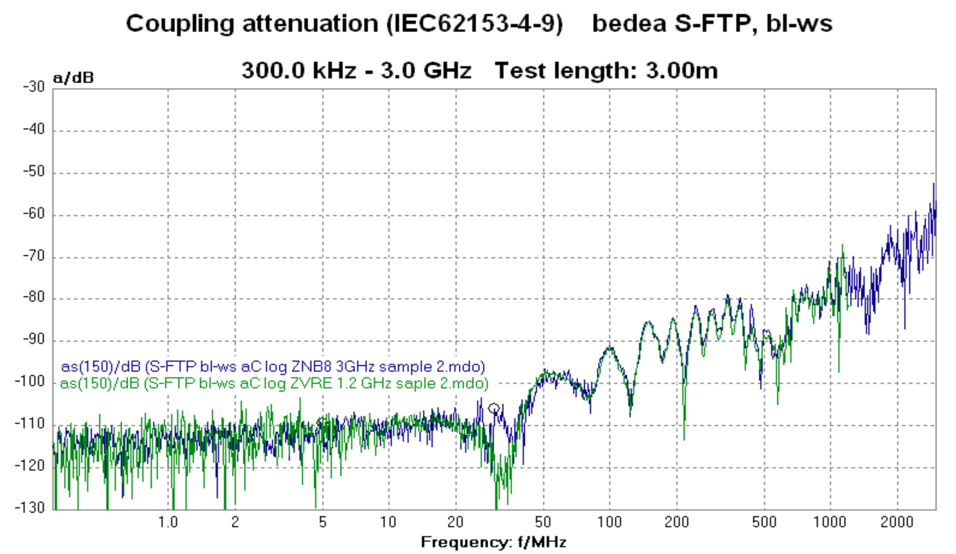
Characteristic impedance, primary side	2 x 50 Ohm
Characteristic impedance, secondary side	1 x 100 Ohm
Unbalance attenuation, secondary side (open)	> 40 dB
Unbalance attenuation, secondary side (matched)	> 40 dB
Attenuation, primary side (short circuit)	< 0,2 dB
Attenuation, secondary side (back to back)	< 0,8 dB

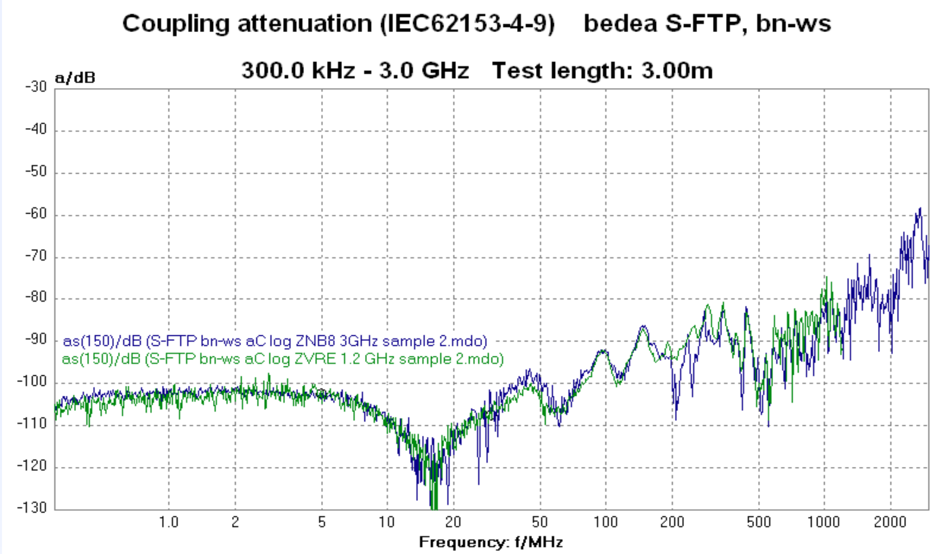


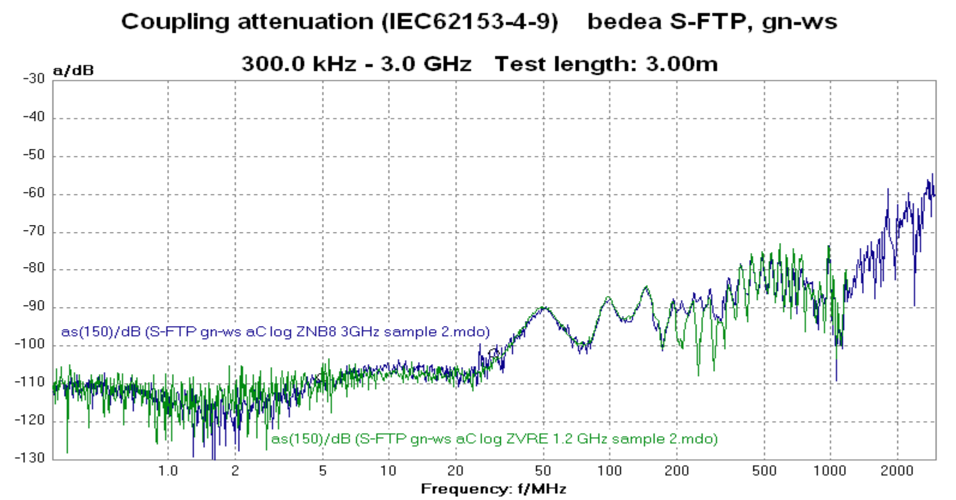
Comparison balun with virtual balun

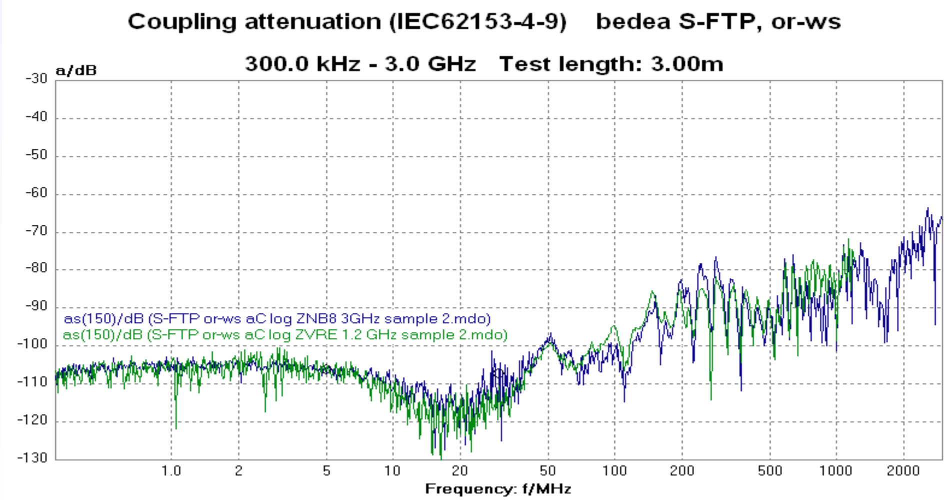


Balunless vs balun, S-FTP cable

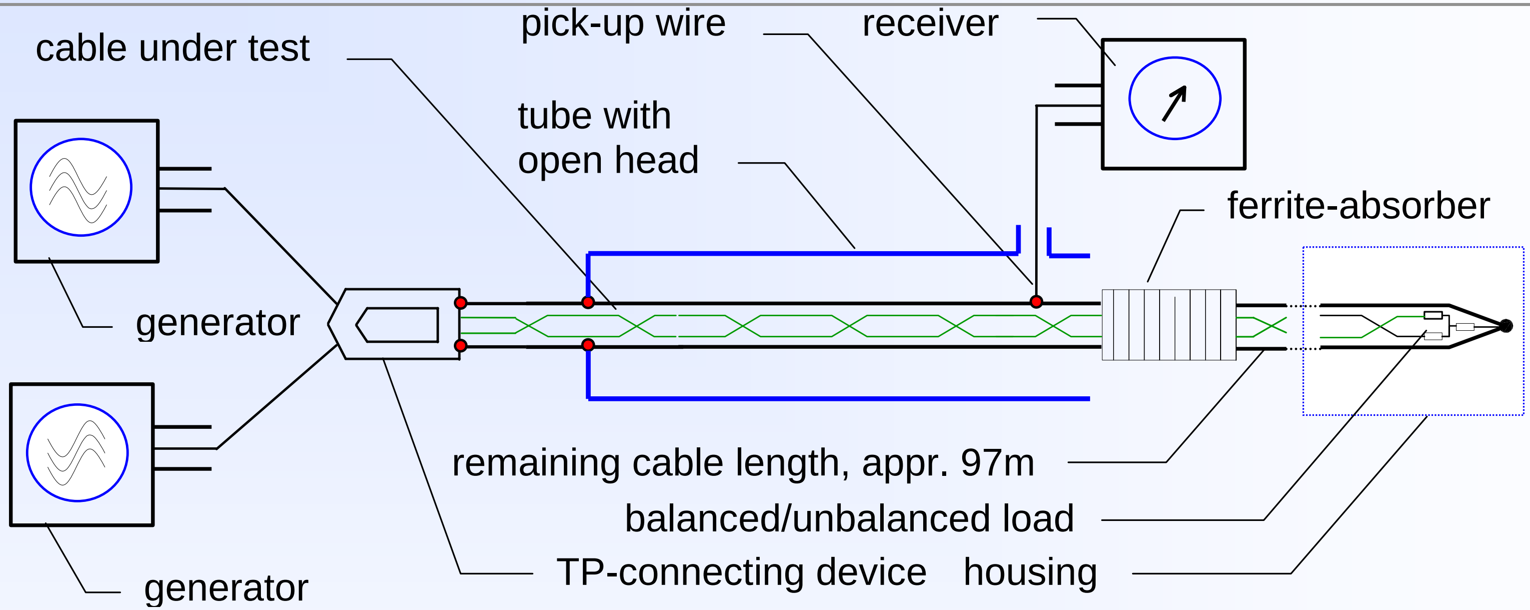


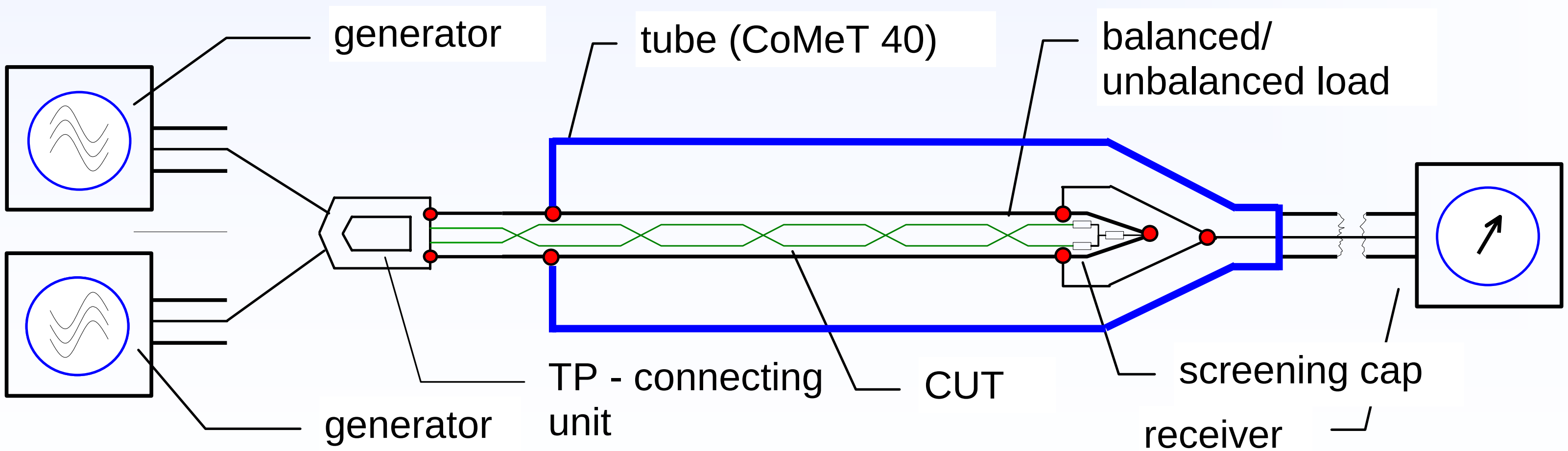




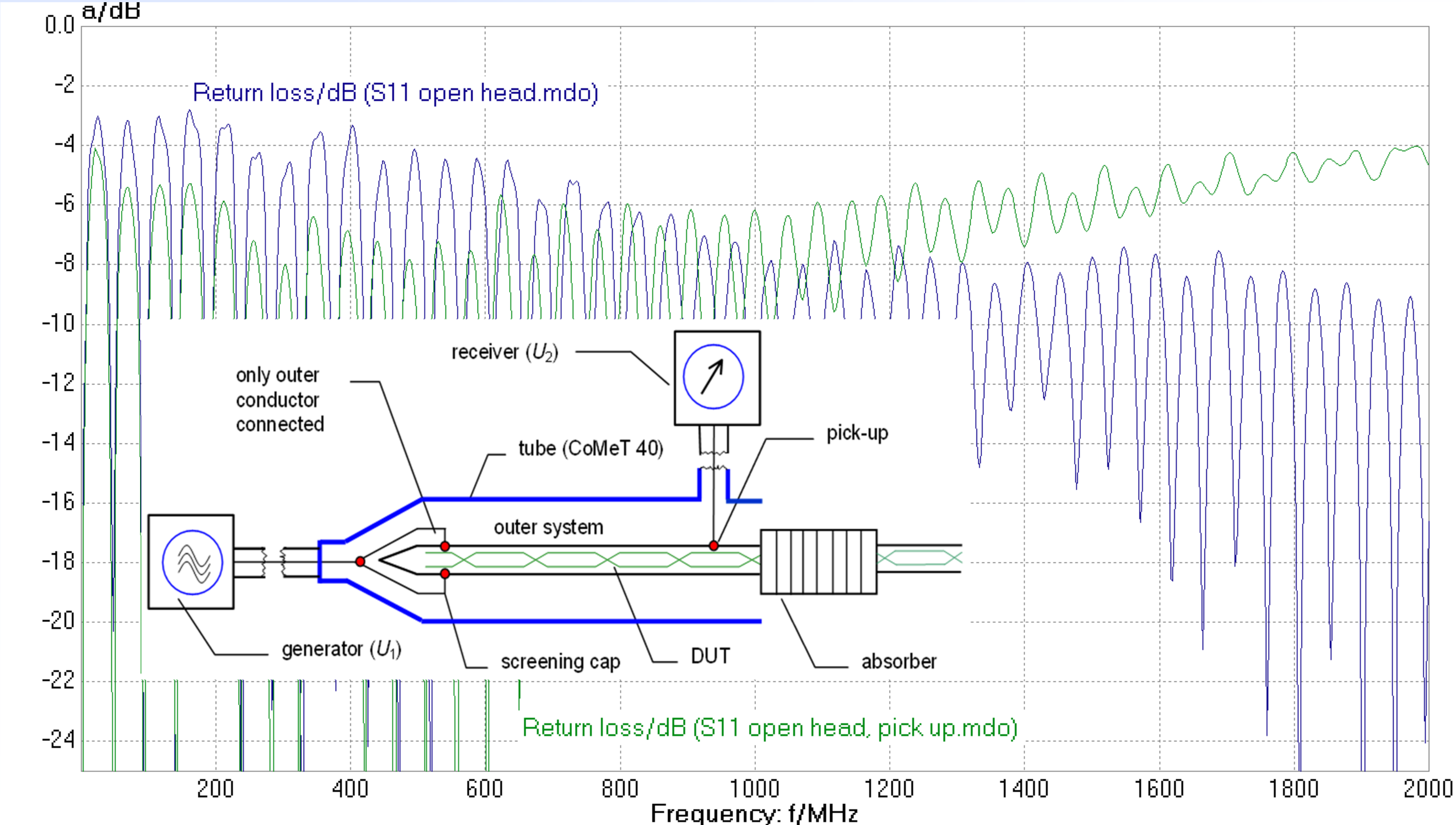


Open head vs. standard head





Return loss of open tube procedure



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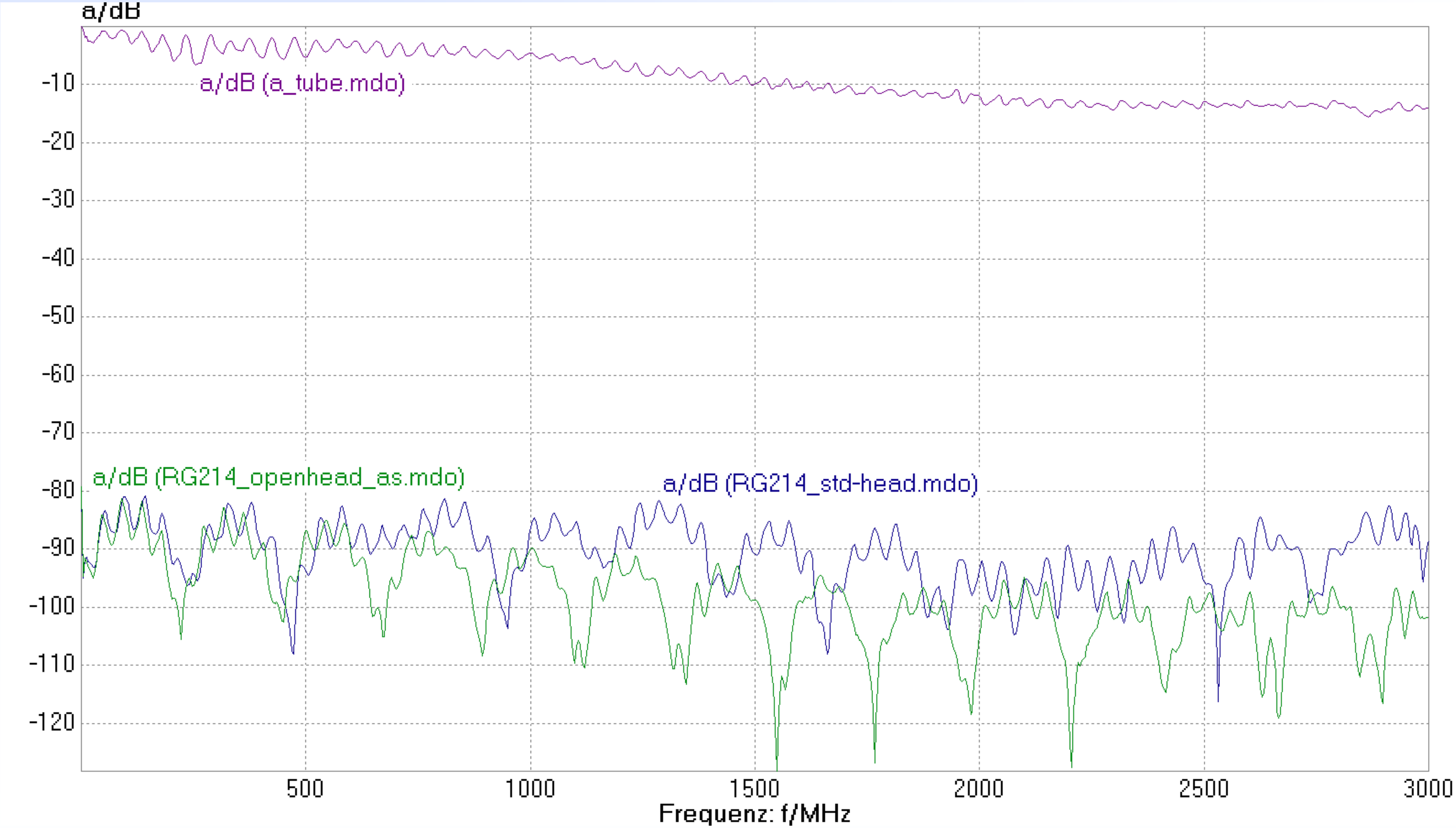
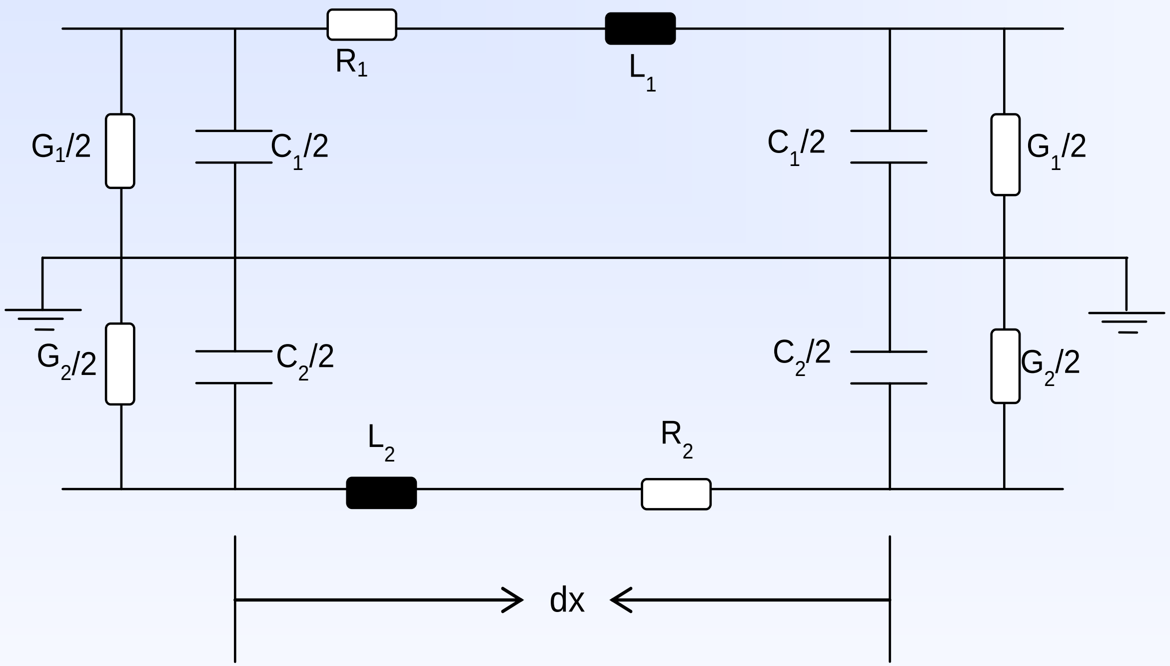
Screening attenuation RG 214, standard & open head



Calculation of unbalance attenuation of balanced pairs



longitudinal unbalance T_A

$$T_A = (G_2 + j\omega C_2) - (G_1 + j\omega C_1)$$

lateral unbalance L_A

$$L_A = (R_2 + j\omega L_2) - (R_1 + j\omega L_1)$$

unbalance coupling function

$$T_{\substack{u,n\\u,f}} = \left(T_A \cdot Z_{unbal.}^2 \pm L_A\right) \cdot \frac{1}{Z_{unbal.}} \cdot \frac{l}{4} \cdot S_{\substack{n\\f}}$$

summing function:

at high frequencies,
the asymptotic value approaches to: $\left|S_{\substack{n\\f}}\right| = \frac{2}{(\beta_{diff} \pm \beta_{com}) \cdot l}$

and at low frequencies
the summing function becomes: $\left|S_{\substack{n\\f}}\right| \Rightarrow 1$

if one sets the summming function into the equation for the unbalance coupling function,
the length *l* shortens at high frequencies from the equation of unbalance coupling attenuation.
at low frequencies *l* remains in the numerator; the result is a length dependency at low frequencies

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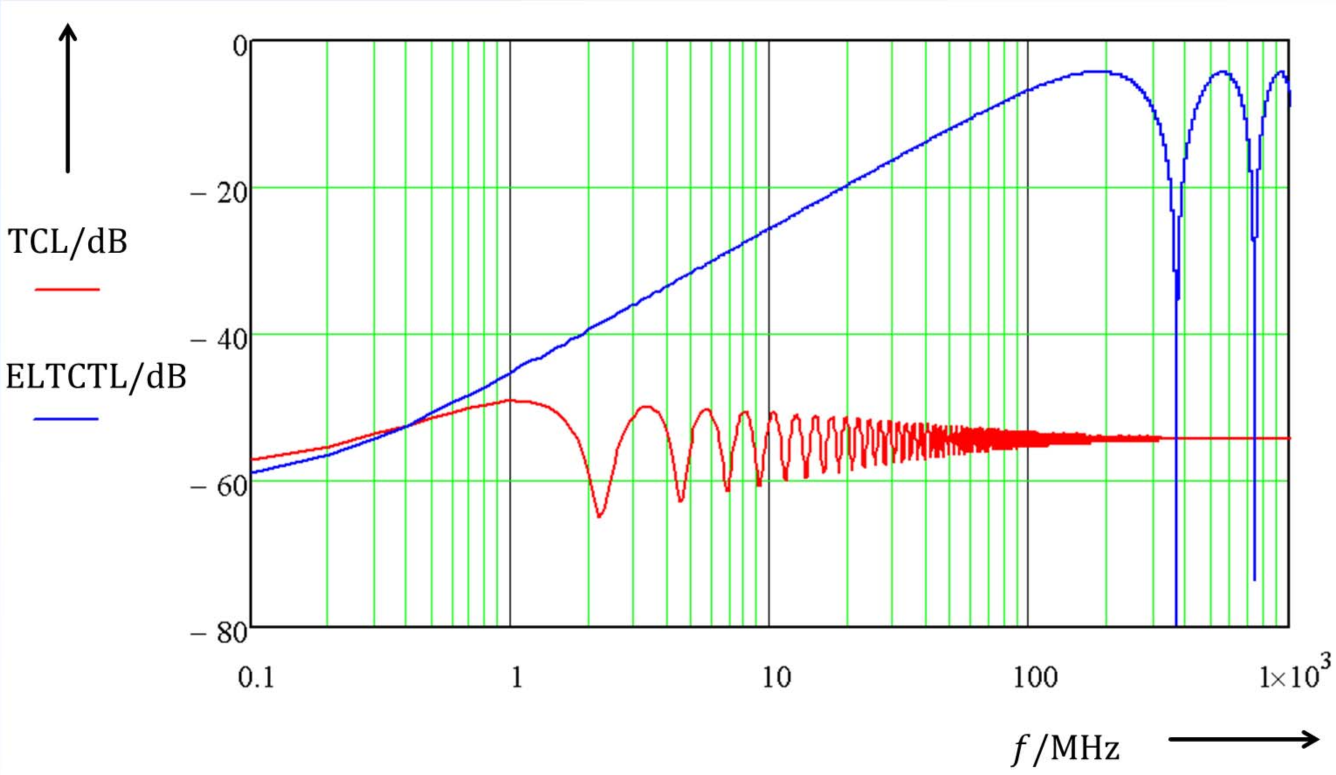
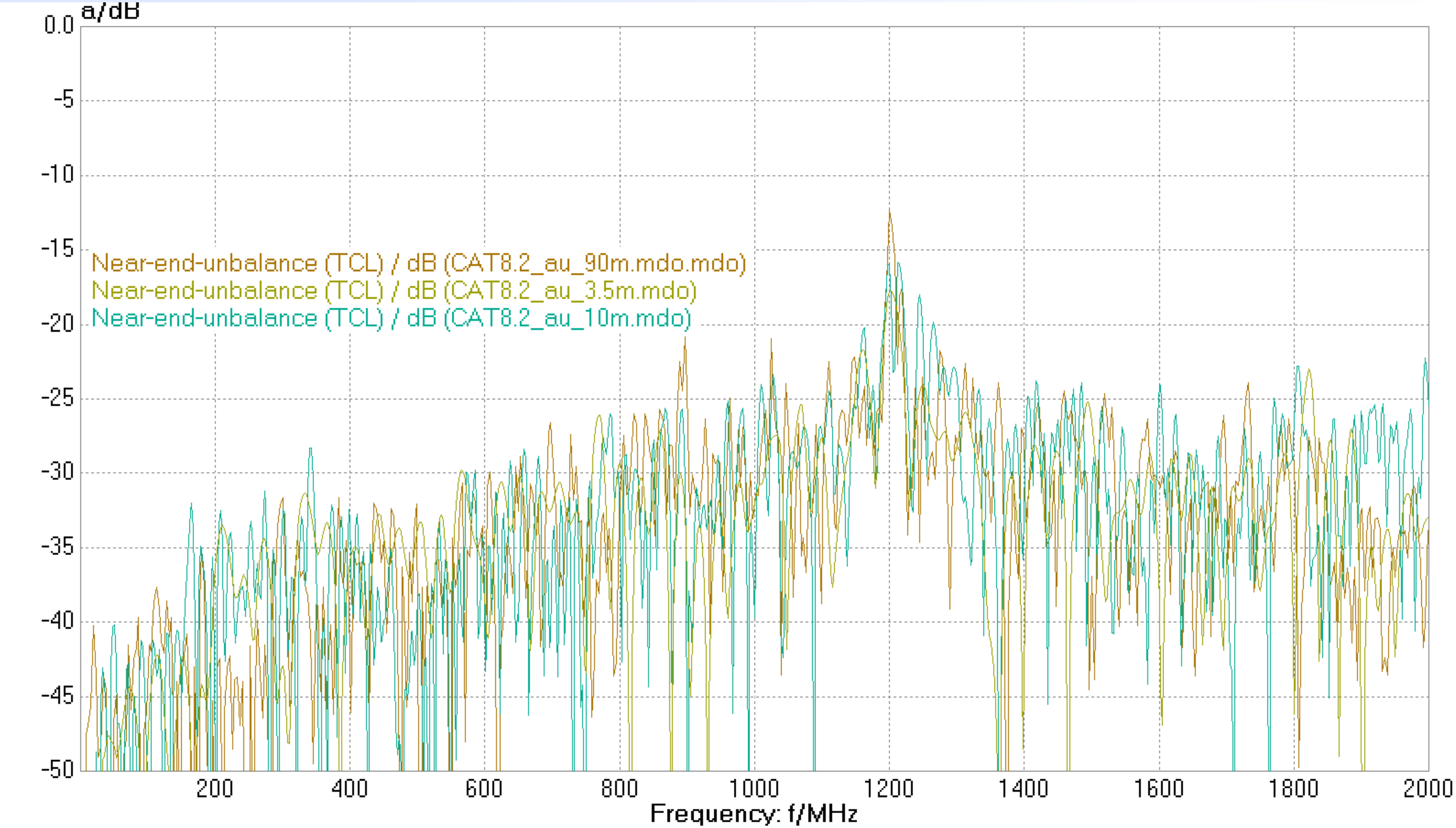
Calculation of TCL and ELTCTL

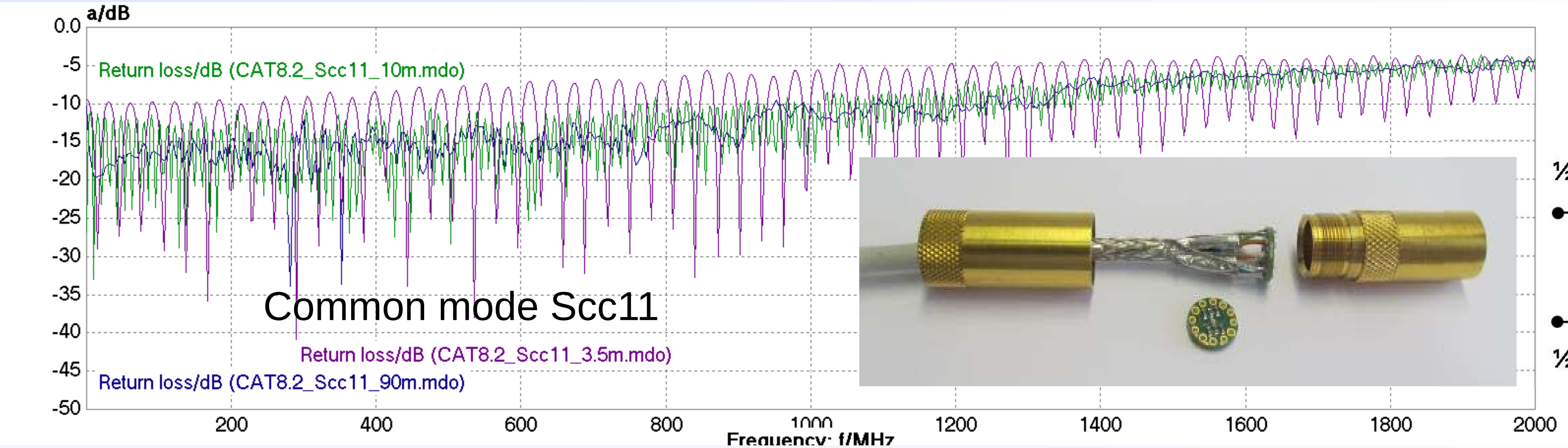


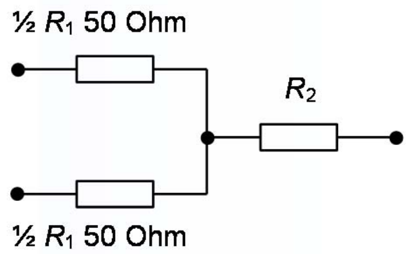
“summing function” x “unbalance coupling function” =
frequency independent value at high frequencies

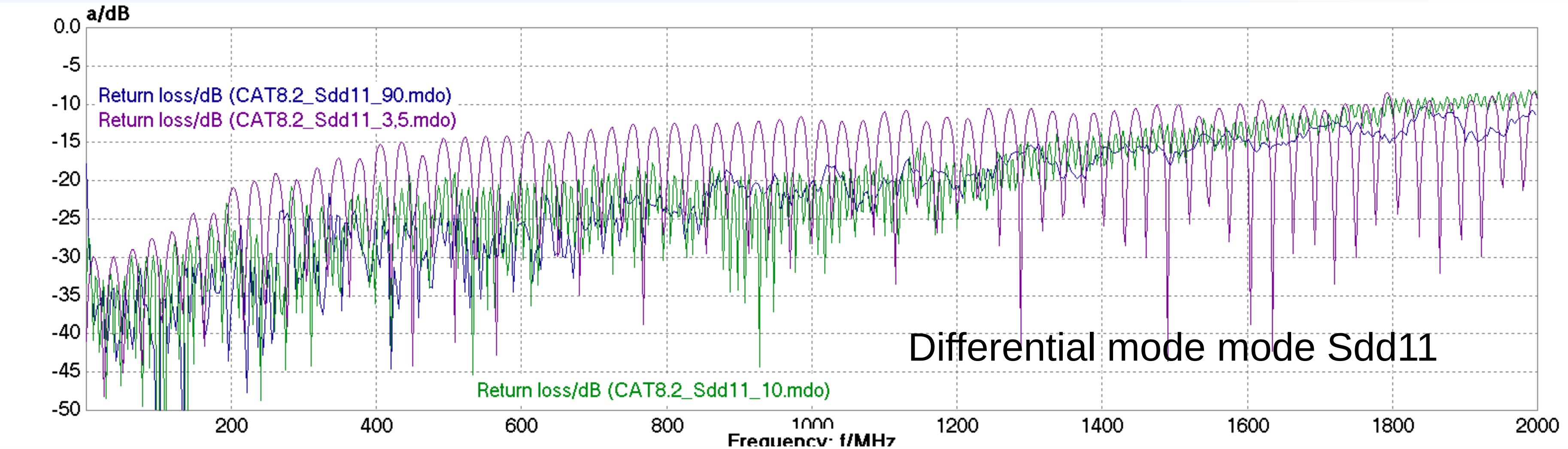
Near end unbalance a_U resp. TCL at different length



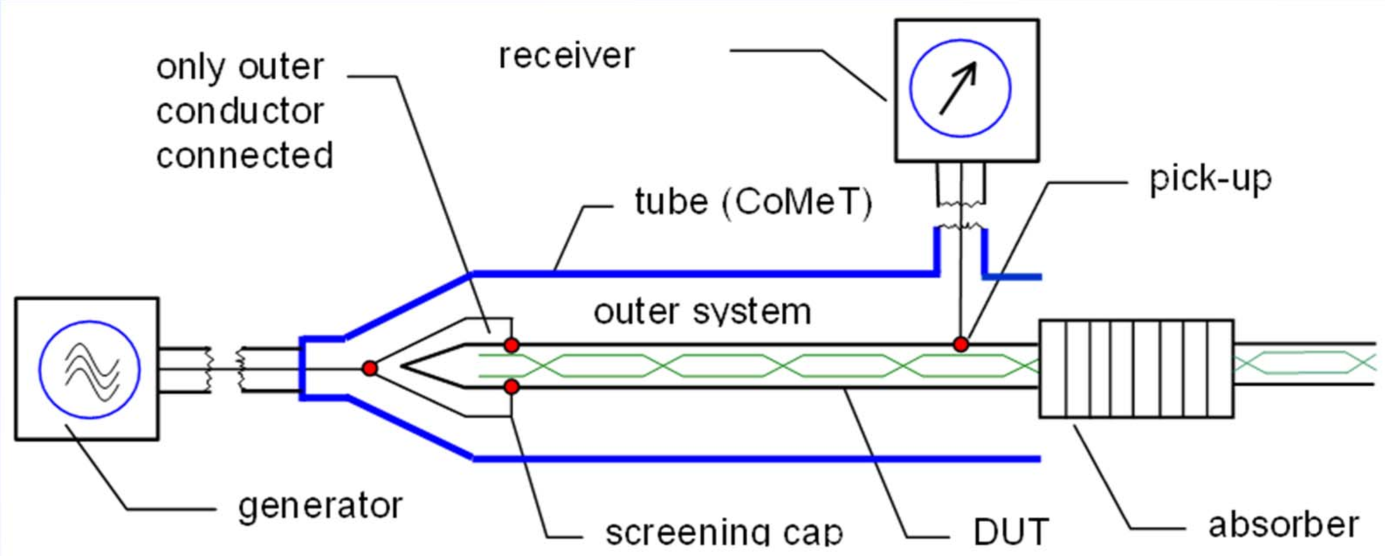
Scc11 and Sdd11 at different length with PCB 50/50/25







Expression of test results



Test set-up to measure a_{tube}

Proposal for the revision of IEC 62153-4-9

$$a_c = a_u + a_s$$

$$a_c = 10 \cdot \lg\left|\frac{P_{diff}}{P_{com}}\right| + 10 \cdot \lg\left|\frac{P_{com}}{P_{r,max}}\right|$$

$$a_c = 20 \cdot \lg\left|\frac{U_{diff}}{U_{com}}\right| + 10 \cdot \lg\left[\frac{Z_{com}}{Z_{diff}}\right]$$

$$+20 \cdot \lg\left|\frac{U_{com}}{U_{2,max}}\right| + 10 \cdot \lg\left[\frac{2 \cdot Z_S}{Z_{com}}\right]$$

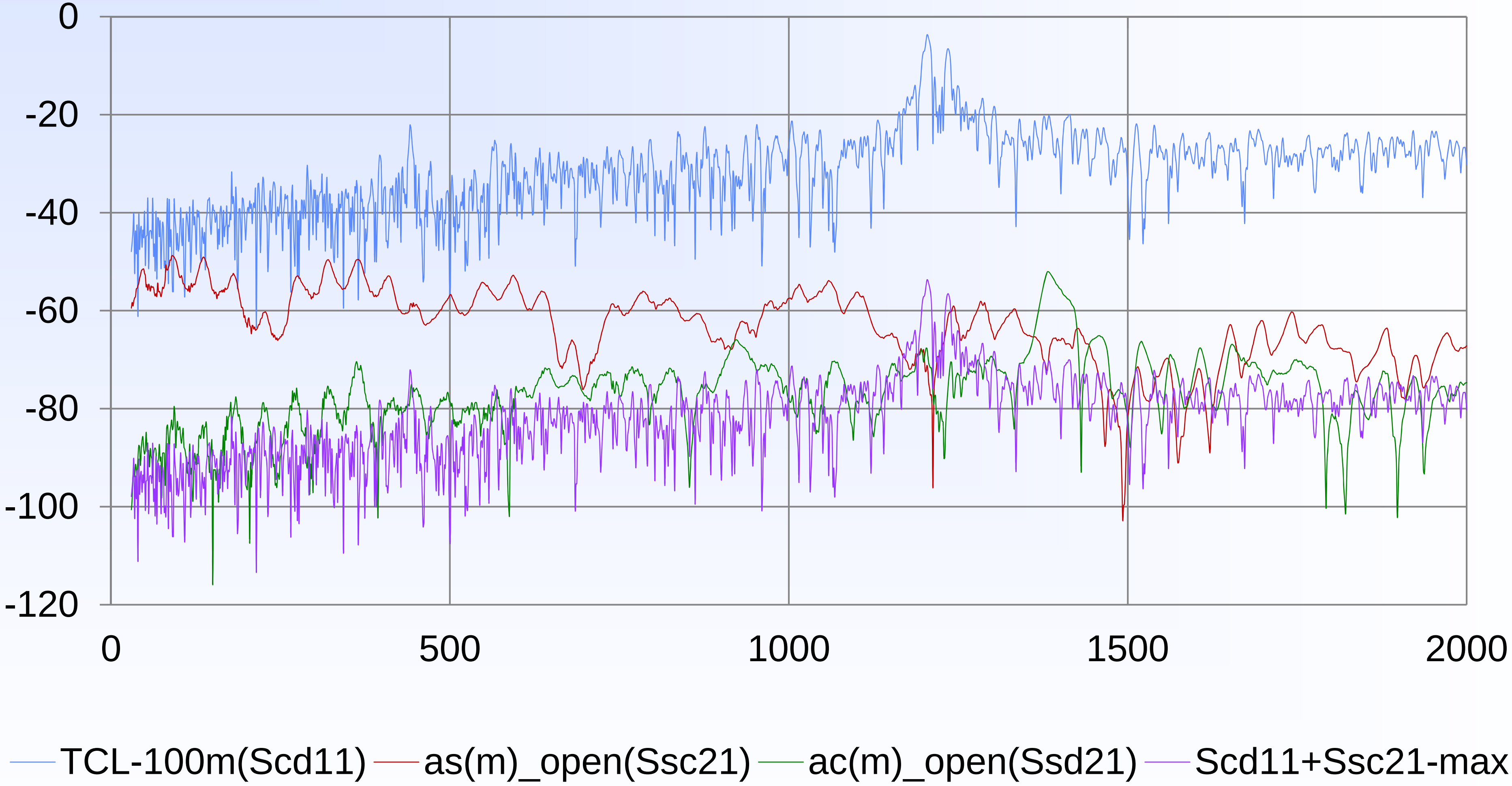
and with the operational attenuation a_{tube}

$$a_c = 20 \cdot \lg\left|\frac{U_{diff}}{U_{2,max}}\right| + 10 \cdot \lg\left[\frac{2 \cdot Z_S}{Z_{diff}}\right] - a_{tube}$$

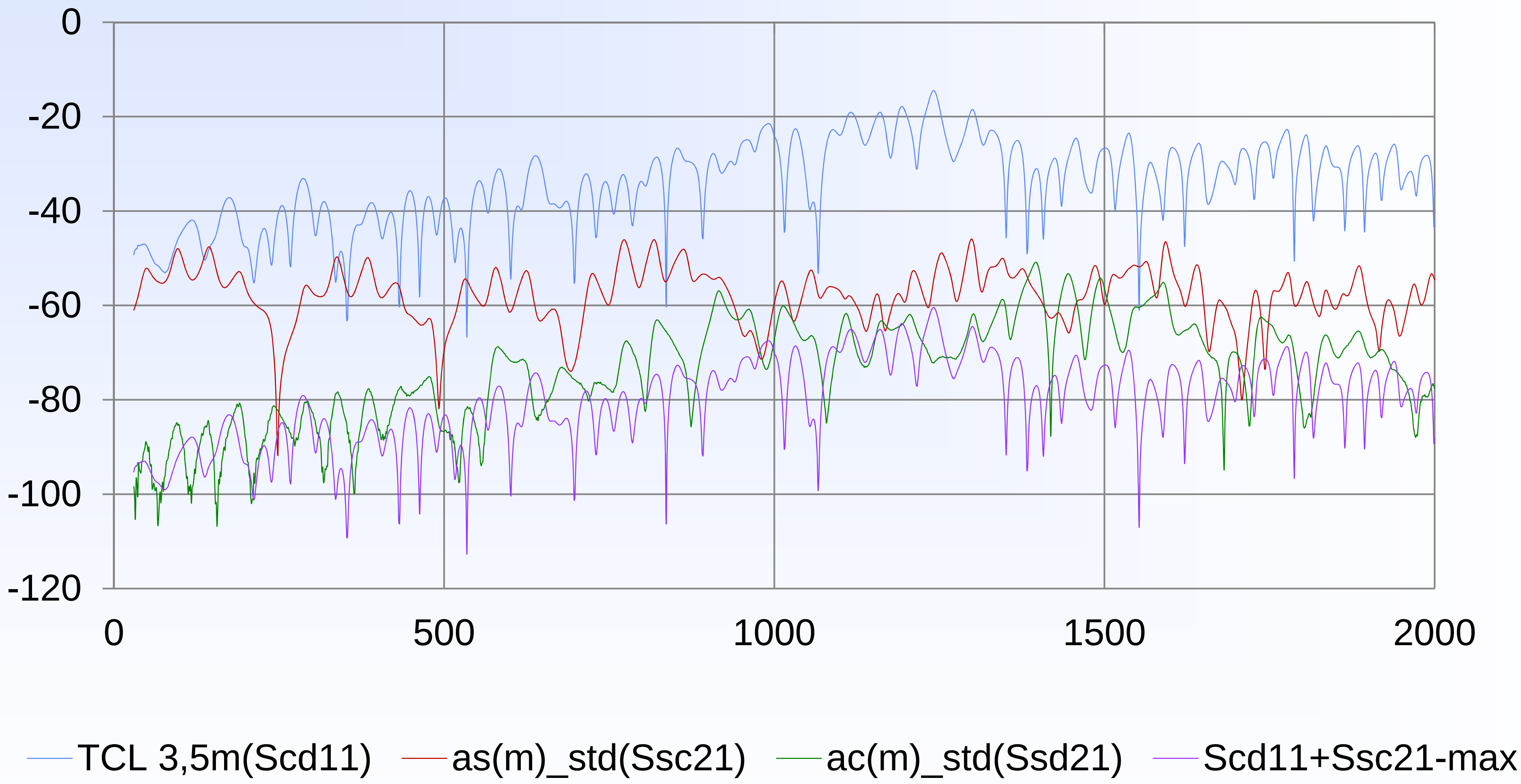
where $a_{tube} = 20 \cdot \lg[U_1 / U_2]$

The voltage ratio U_{diff}/U_{2max} shall be measured with calibrated devices. The operational attenuation $a_{tube} = 20 \cdot \lg(U_1/U_2)$ of the outer system of the test set-up shall be measured in case of open head procedure with the same absorber configuration as used during the coupling attenuation measurement. The coupling attenuation a_C which is comparable to the results of the absorbing clamp method shall be calculated with the arbitrary determined normalized value Z_S = 150 Ω

Measurements Twinax 105, triax open head



Measurements Twinax 105, triax standard head



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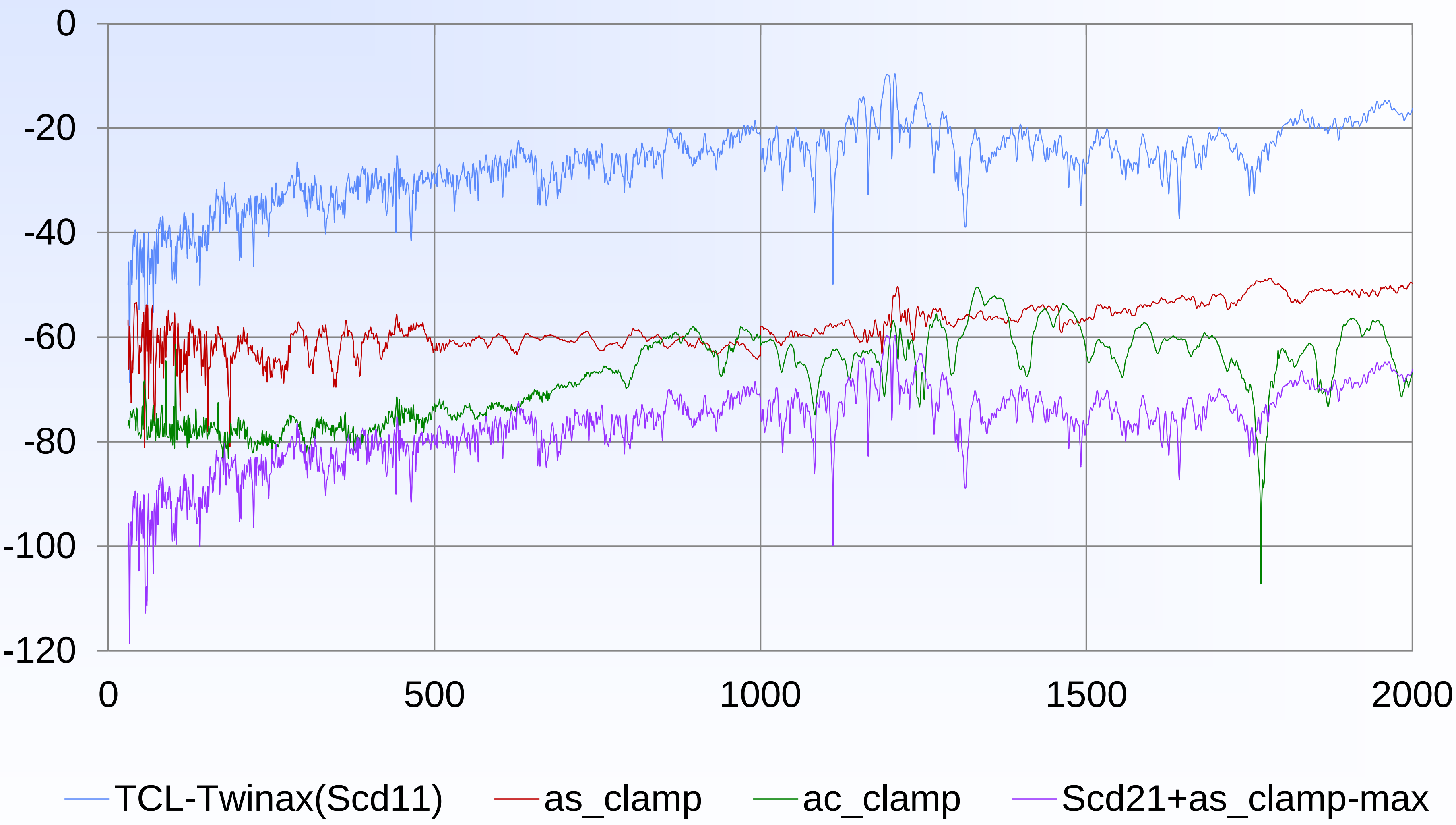
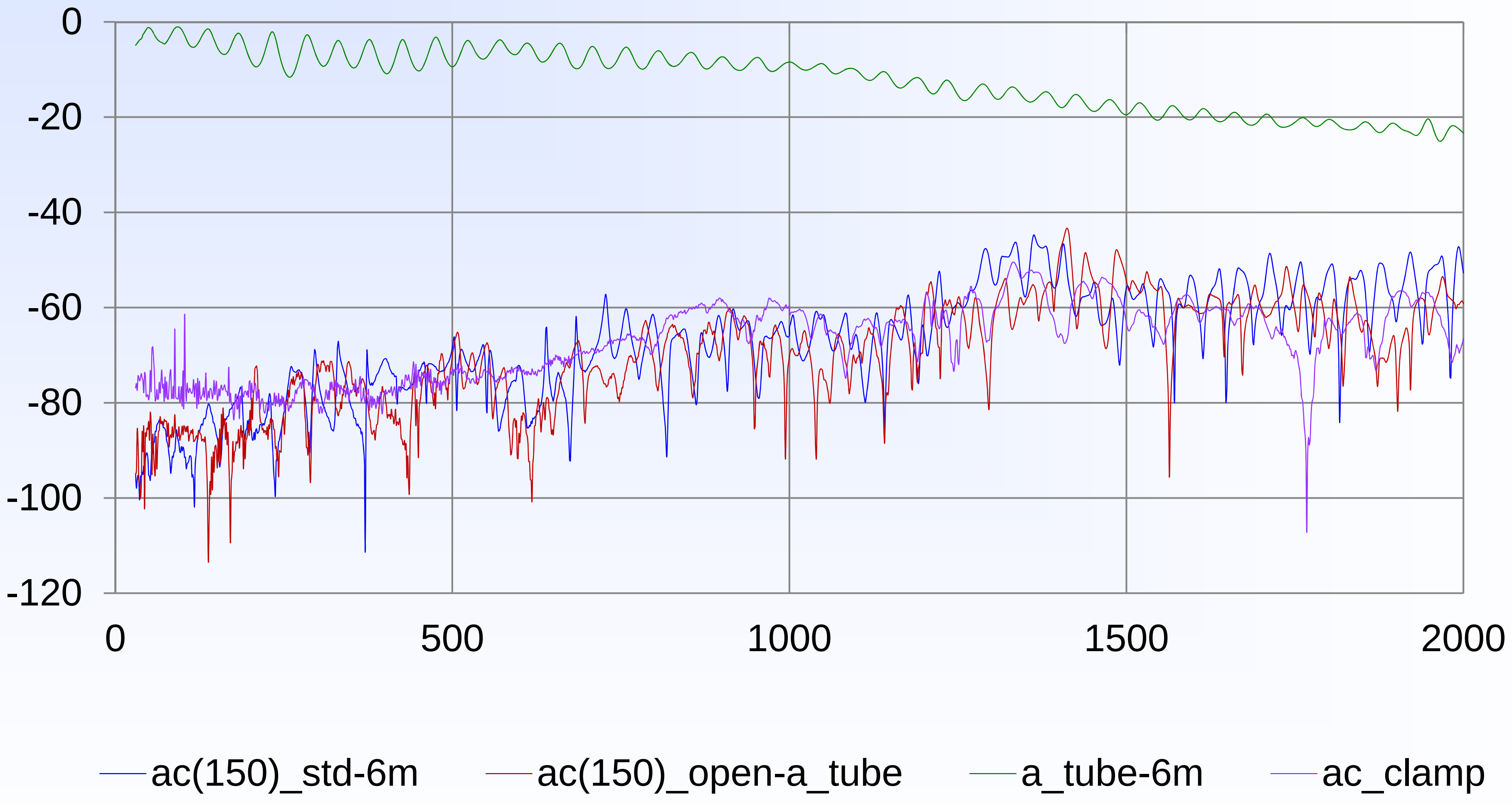
Measurements Twinax 105, absorbing clamps



Absorbing clamp MDS 22, 500 MHz to 2000 MHz

Compilation Twinax 105 (6m tube)



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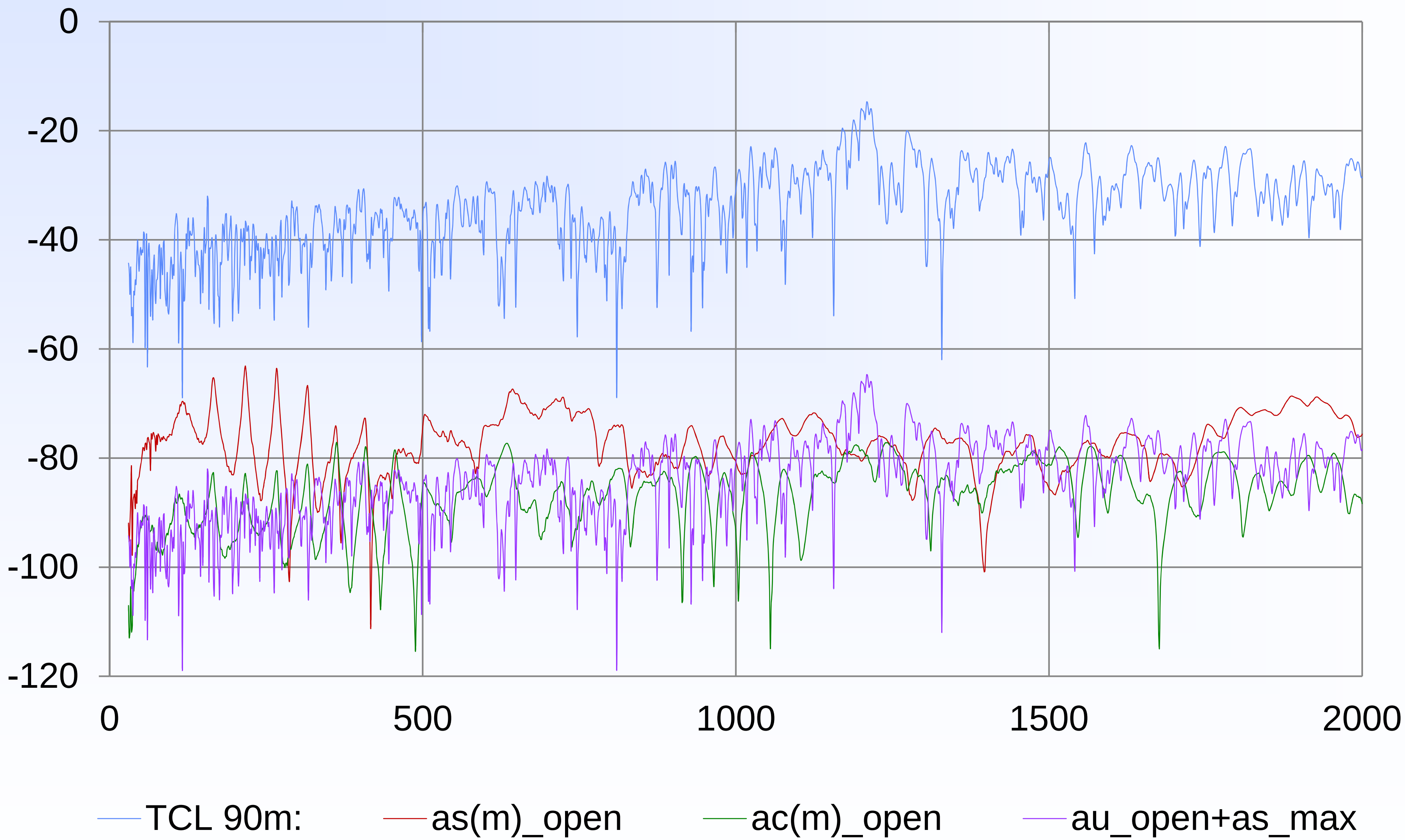
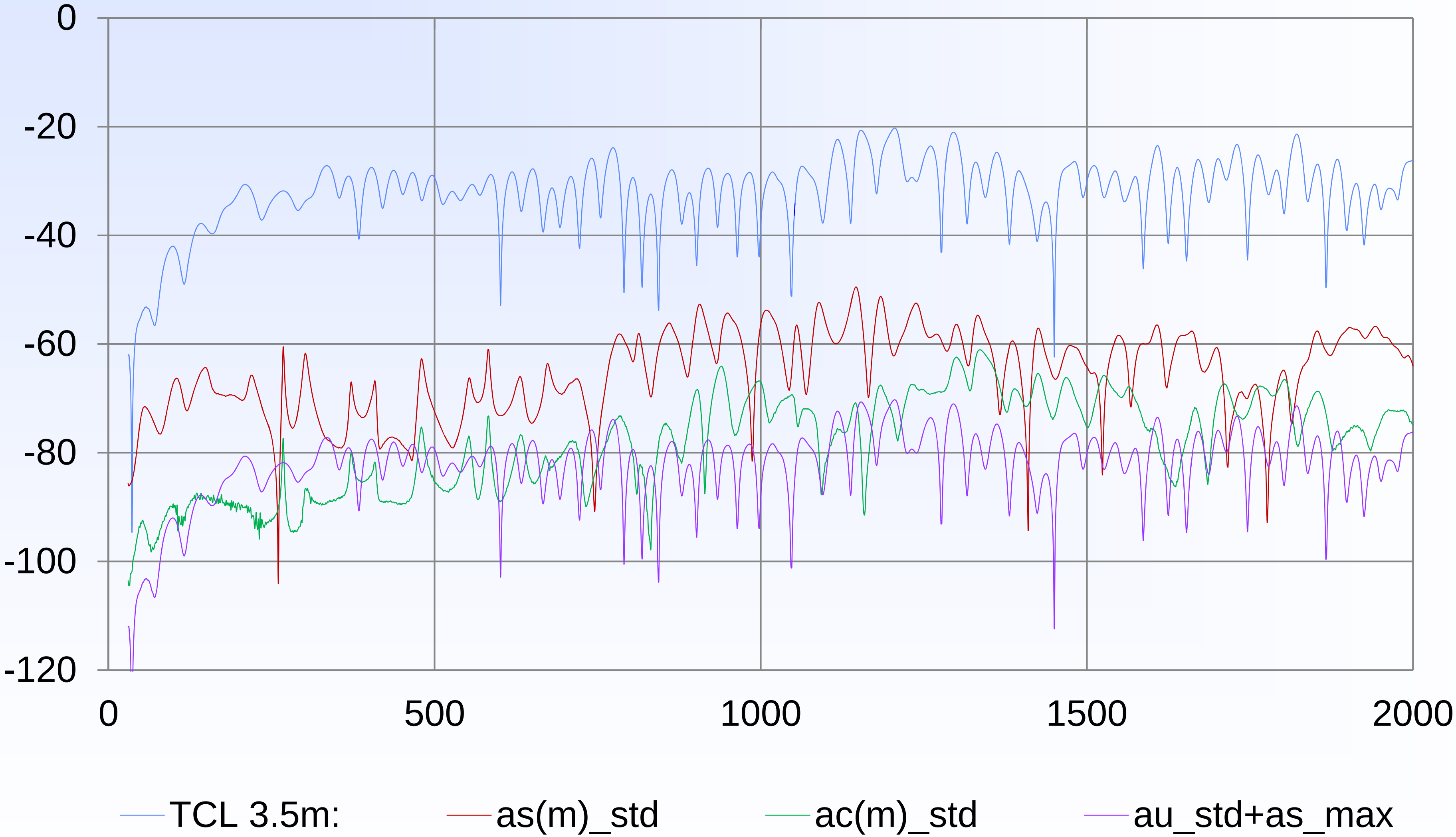
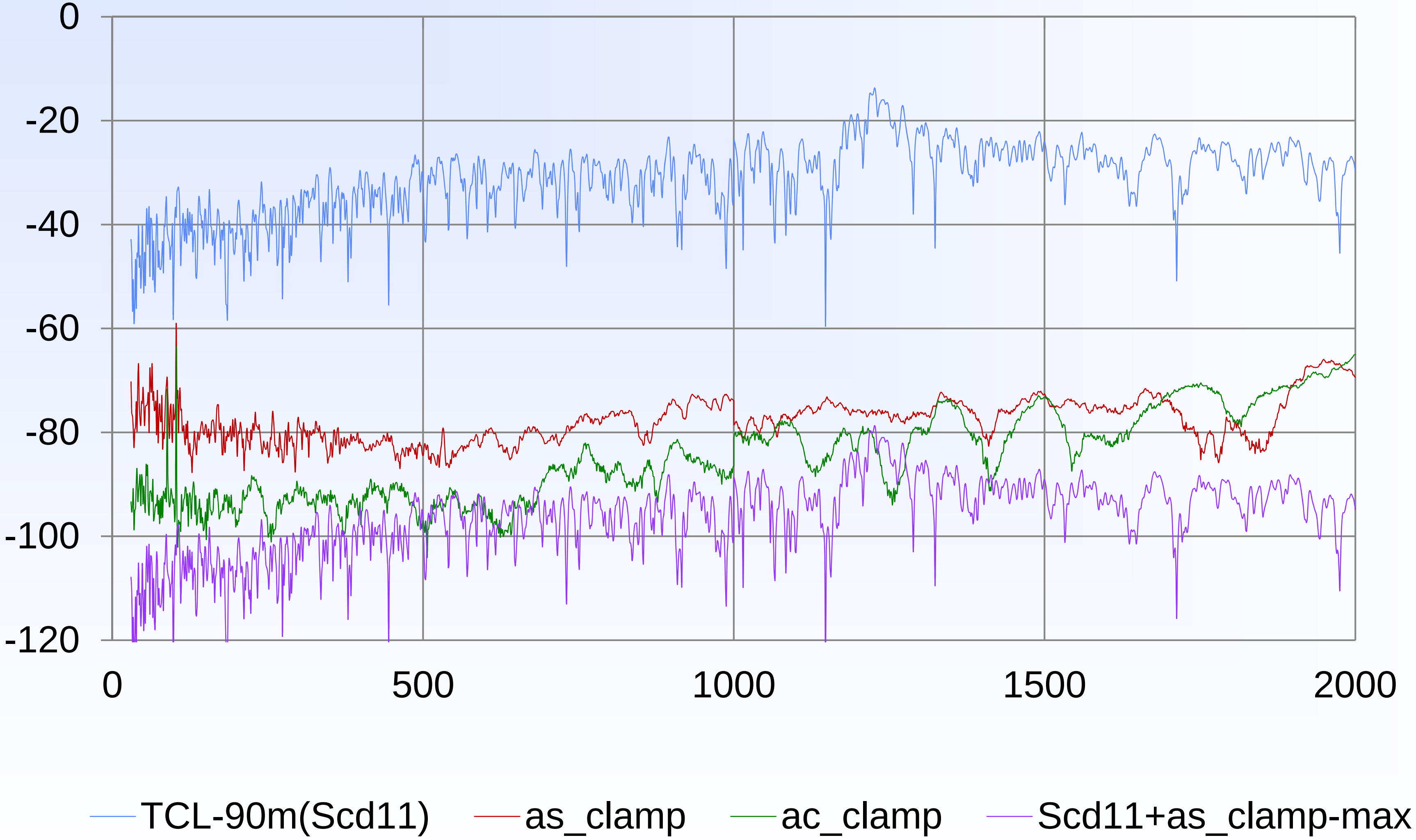
Cat 8.2 – open head, 3m



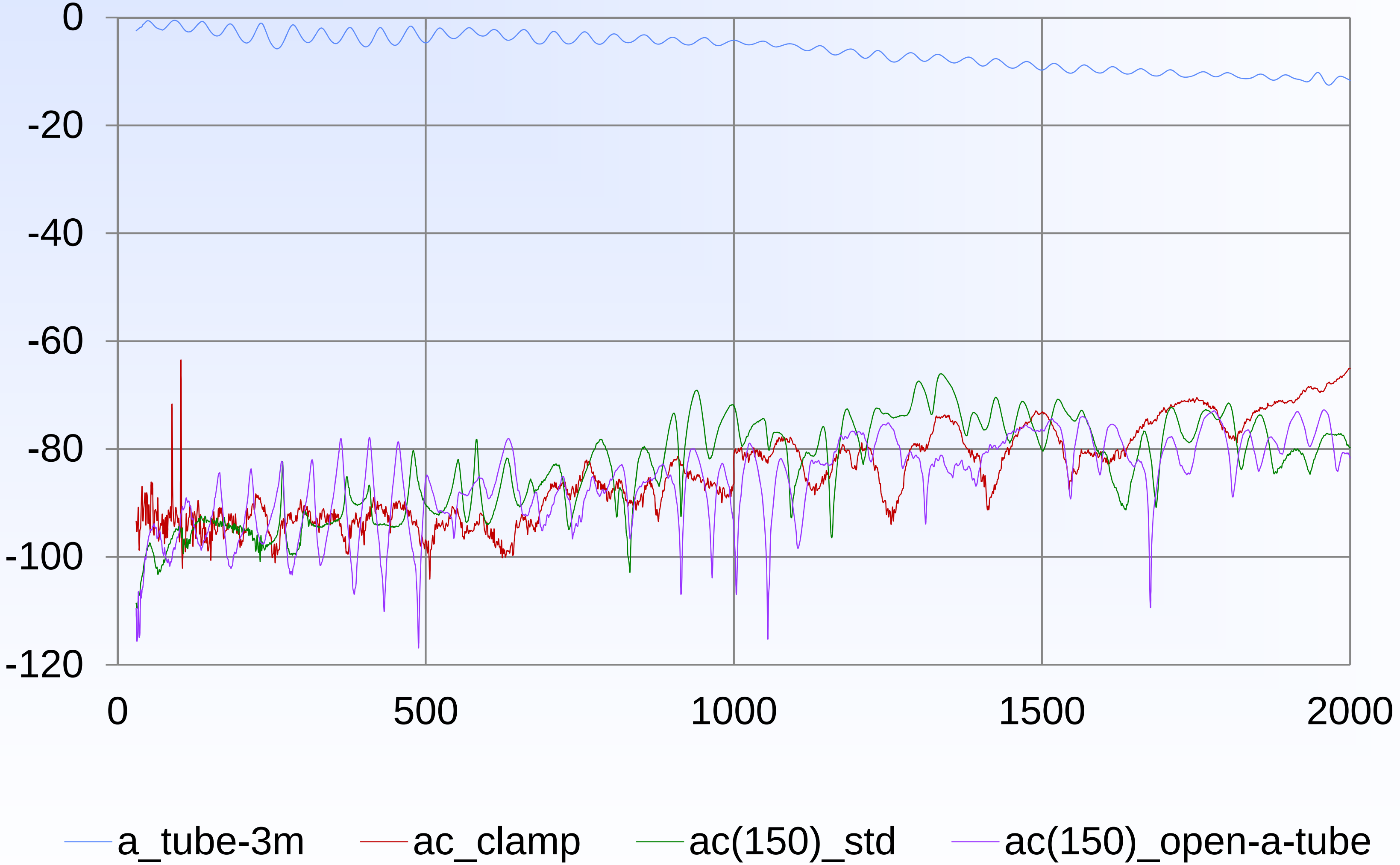
Cat 8.2 – standard head, 3m



Cat 8.2 – absorbing clamps, 6m



Cat 8.2 – Compilation



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Conclusion

- **Mixed mode** procedure can be used to measure **Coupling attenuation** on screened balanced pairs up to and above 2 GHz.
- Length dependence of the **Unbalance attenuation** is so small, that basically the same results can be expected using the open test head with a test length of 100m and the standard test head of the triaxial tube with a length of 3m
- However, the impact of the **Return loss** shall be considered, when measuring short lengths.
- The measurements presented show, that taking into account the boundary conditions, similar results can be expected from the **triaxial method** with open test head and with the standard head, as well as from the clamp method.
- **IEC 62153-4-9** will be revised accordingly

- Further questions: *christian.pfeiler@prysmiangroup.com, bmund@bedea.com*

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Progress of International Standards for Triaxial Procedure

TS 62153-4-1 Ed2	Introduction to electromagnetic (EMC) screening measurements	**2014-01**	**published**
62153-4-3Ed2	Surface transfer impedance - Triaxial method	**2013-10**	**published**
62153-4-4Ed2	Shielded screening attenuation, test method for measuring of the screening attenuation a_S up to and above 3 GHz	**2015-04**	**published**
62153-4-7Ed2	Shielded screening attenuation test method for measuring the Transfer impedance Z_T and the screening attenuation a_S or the coupling attenuation a_C of RF-Connectors and assemblies up to and above 3 GHz, Tube in tube method	**2015-09**	**46/572/FDIS**
62153-4-9Ed2	Electromagnetic Compatibility (EMC) – Coupling attenuation, triaxial method	**2008-03**	**in preparation**
62153-4-10Ed2	Shielded screening attenuation test method for measuring the Screening Effectiveness of Feedtroughs and Electromagnetic Gaskets	**2015-08**	**46/563/FDIS**
62153-4-15	Test method for measuring transfer impedance and screening attenuation - or coupling attenuation with Triaxial Cell	**2015-09**	**46/573/FDIS**
62153-4-16	Relationship between surface transfer impedance and screening attenuation, Conversion a_S and Z_T	**2014-06**	**46/511/DTR**

Standards

[1] 46C/1009/CDV - IEC 61156-9 Ed. 1.0: Multicore and symmetrical pair/quad cables for digital communications - Part 9: Cables for horizontal floor wiring with transmission characteristics up to 2 GHz - Sectional specification

[2] 46C/1010/CDV - IEC 61156-10 Ed. 1.0: Multicore and symmetrical pair/quad cables for digital communications - Part 10: Cables for work area wiring with transmission characteristics up to 2

[3] ISO/IEC TR 11801-99-1 Ed. 1.0: INFORMATION TECHNOLOGY - Guidance for balanced cabling in support of at least 40 Gbit/s data transmission

[4] IEC/TR 61156-1-2 Ed 1.0 Amdt 1: Multicore and symmetrical pair/quad cables for digital communications - Part 1-2: Electrical transmission characteristics and test methods of symmetrical pair/quad cables

[5] IEC 62153-4-4: Metallic communication cable test methods - Part 4-4: Electromagnetic compatibility (EMC) Shielded screening attenuation, test method for measuring of the screening attenuation as up to and above 3 GHz - Triaxial method

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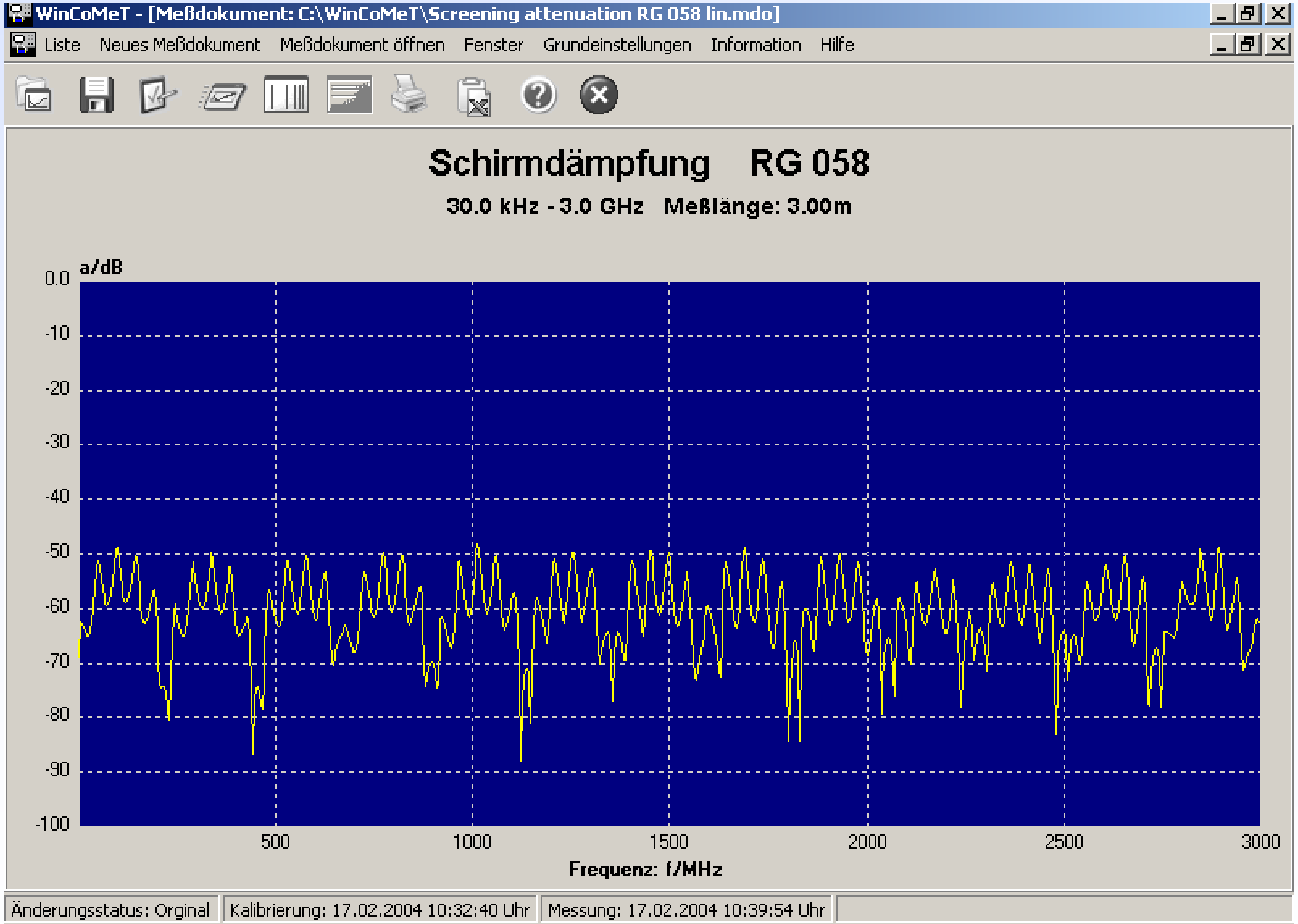
Control- and Evaluation - Software WinCoMeT



- Control of the VNA
- evaluation of test results
- documentation
- Data export to MS-Excel
- printing
- full version with transmission Parameters of Communication cabes including
- FFT and gating
- **ready for mixed mode measurements**

Thank you
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