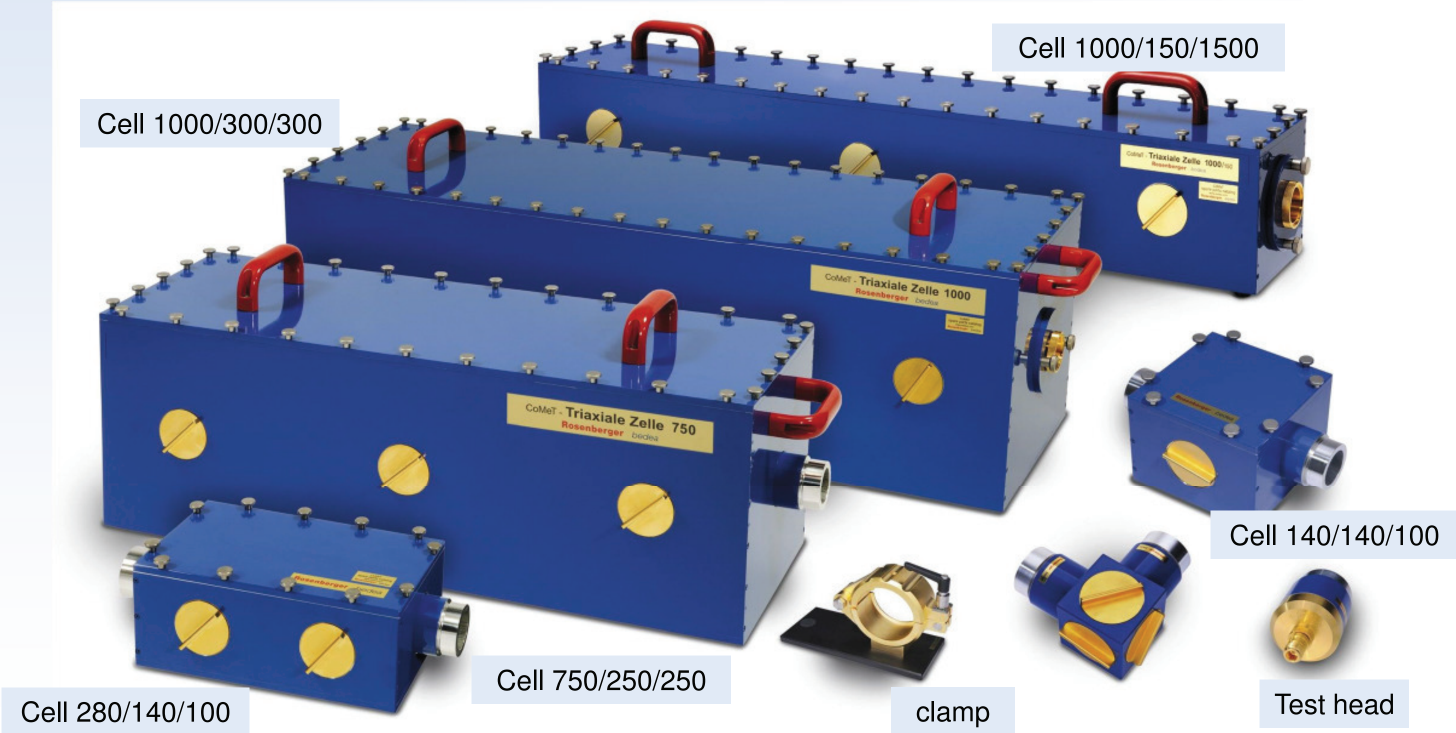
EMC of cables & connectors with Triaxial test procedure



Different designs of Triaxial Cells

Outline

- Physical Basics of Cable Screening
  - Definitions, electrical length, Coupling Transfer Function
- Triaxial test procedures
  - Transferimpedance & Screening attenuation, Tube in tube proc.
- Revised standards for Triaxial procedure
  - IEC 62153-4-3Ed2, Transfer impedance
  - IEC 62153-4-4Ed2, Screening attenuation
  - IEC 62153-4-7Ed2, Tube in tube
  - IEC 62153-4-9Ed2, Coupling attenuation with multiport VNA
  - IEC 62153-4-15(Ed2), Triaxial (“Absorber“) Cell
- Screening effectiveness of unscreened balanced pairs
- Conclusion & Discussion

First triaxial EMC concepts

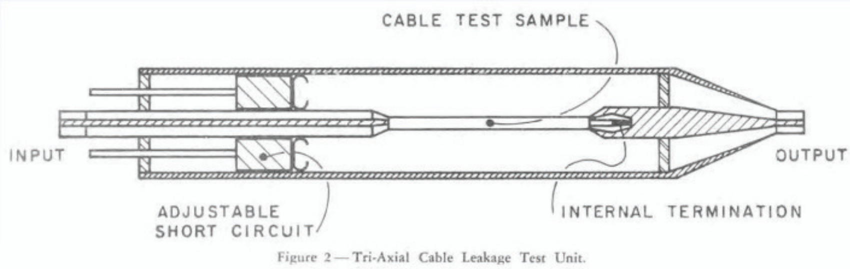
The Triaxial test procedure to has a long tradition and history.
Schelkunoff, (probably) first mention the concept of Transfer impedance Z_T for cable screens 1934

Further early description of Transfer impedance Z_T of different cable screen constructions including a triaxial test procedure is given 1936 by the German engineer Heinz Ochem.

A complete description of screening phenomena was given by Heinrich Kaden, in "The book of Kaden" 1950 respectively 1959 as 2nd edition.

There are numerous further articles describing the Triaxial procedure in the period from1950 to 1975

Vance (1974), Tyni (1976) & Kley (1991) among others described models for the calculation of coupling phenomena of braided screens. These models are still the basis for simulation software.



Triaxial test set-up 1961 by John Zorzy & R.F. Mühlenberger

Although analytical models of Z_T are useful for shielding analysis,
measurements are still the most reliable method of determining the Z_T due to the complex structure of braided shields.

The "ready for cable TV" room antenna

Neighbours leaky cable

Due to **leaky** cable networks, Cable TV could be received with a room antenna.
The "ready for cable TV" room antenna causes the German Telecom (Deutsche Post) to tighten their cable networks. At first 75 dB screening attenuation up to 1 GHz was required.
In 2000, screening classes acc. to EN 50117 were introduced, e.g. Class A with 85 dB up to 1 GHz

Progress of International Standards for Triaxial Procedure

TS 62153-4-1	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	2015-12	**published**
62153-4-9Ed2	Electromagnetic Compatibility (EMC) – Coupling attenuation, triaxial method	2018-04	**published**
62153-4-10Ed2	Shielded screening attenuation test method for measuring the Screening Effectiveness of Feedtroughs and Electromagnetic Gaskets	2015-11	**published**
62153-4-15 (Ed2)	Test method for measuring transfer impedance and screening attenuation - or coupling attenuation with Triaxial Cell	2015-12	46/712/CD
62153-4-16	Relationship between surface transfer impedance and screening attenuation, Conversion a_S and Z_T	2016-10	**published**

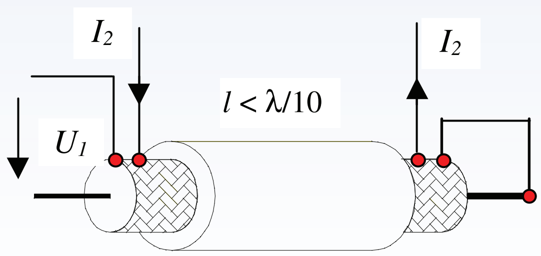
Definitions, electrical length

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: Transfer impedance



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

Ratio of **U/I = R** --> **length dependent (Ohms law)**

Wave length
$\lambda = (c_0 \cdot v_k) / f$

electrical long:

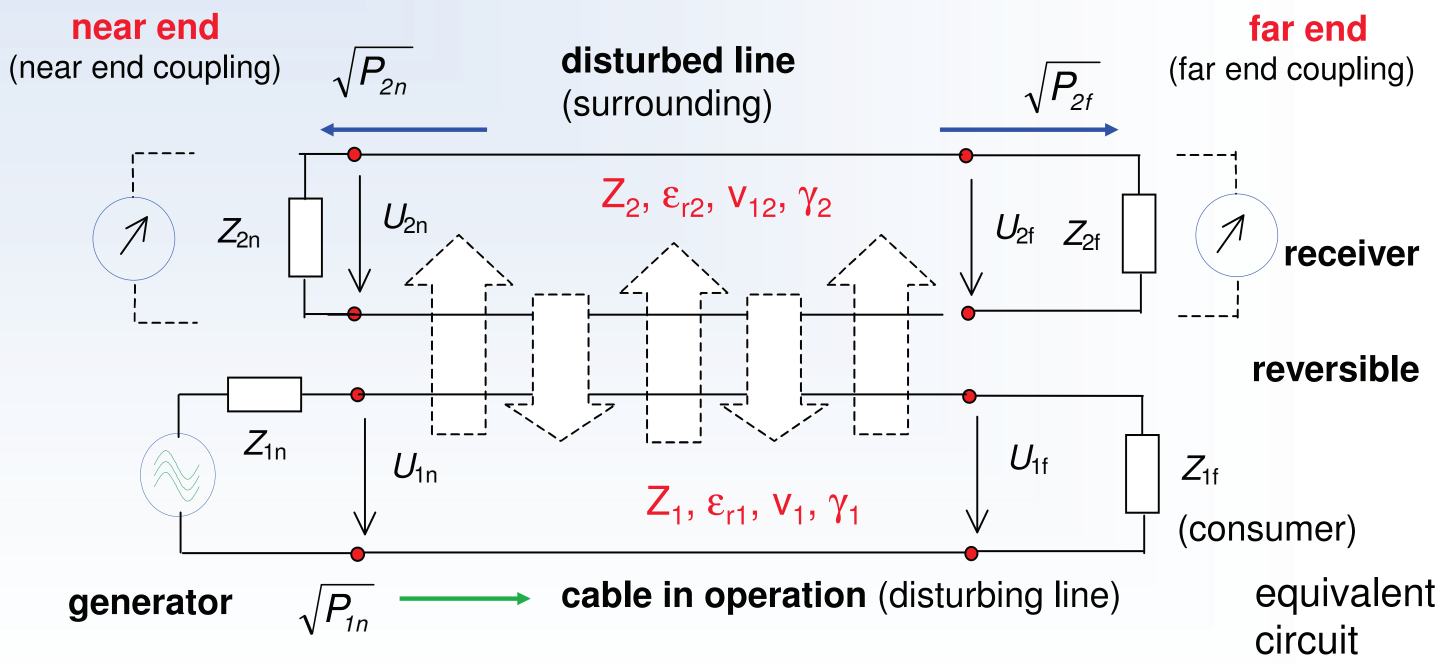
$$f > \frac{c_o}{2 \cdot l \cdot \left| \sqrt{\varepsilon_{r1}} - \sqrt{\varepsilon_{r2}} \right|}$$

electrical short:

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

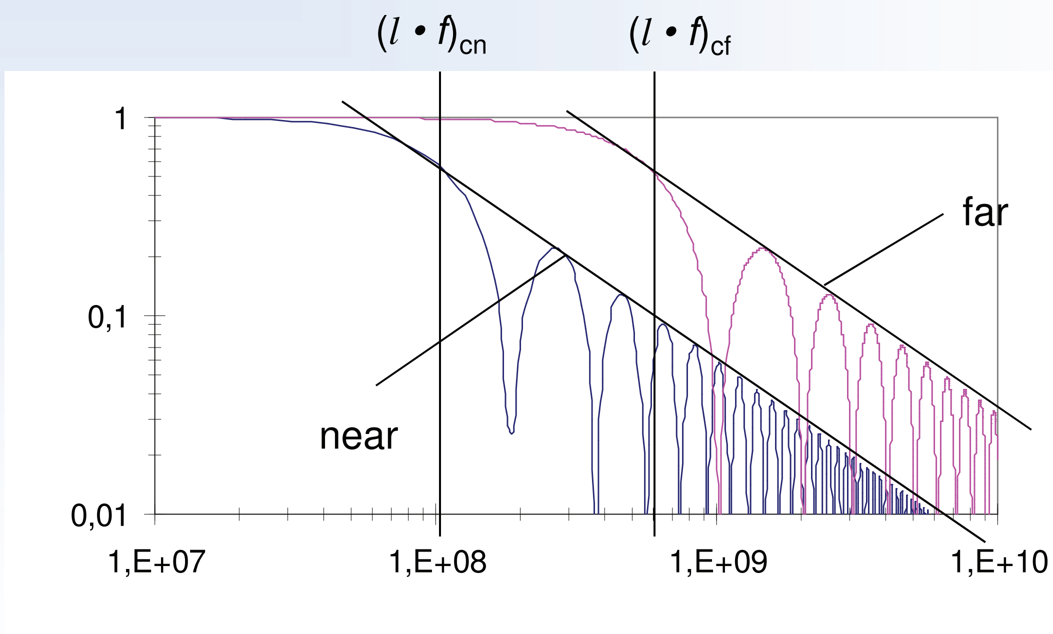
(IEC 62153-4-1)

Coupling between two lines (equivalent circuit)



Char. impedance Z, dielectric constant ε_r, velocity of propagation v, propagation constant $\gamma = \alpha + j\beta$

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

β includes the phase relation of the inner and the outer circuit

low frequencies

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

high frequencies

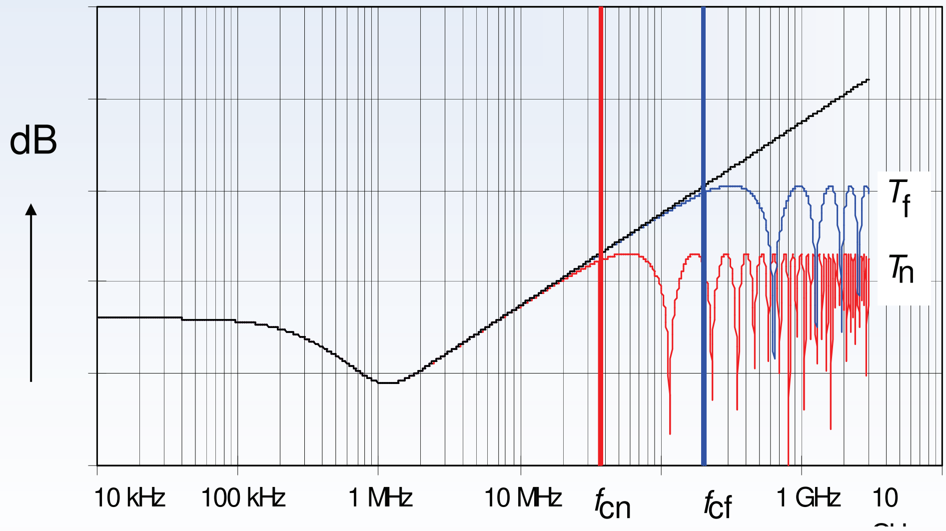
$$\left|S_{\frac{n}{f}}\right| \rightarrow \frac{2}{(\beta_1 \pm \beta_2)\cdot l}$$

introduced from Halme/Szentkuti 1988

Calculated Coupling Transfer Function T_{nf} (RG 058)

a_s and Z_T vs frequency

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



Transferimpedance

Screening attenuation

frequency

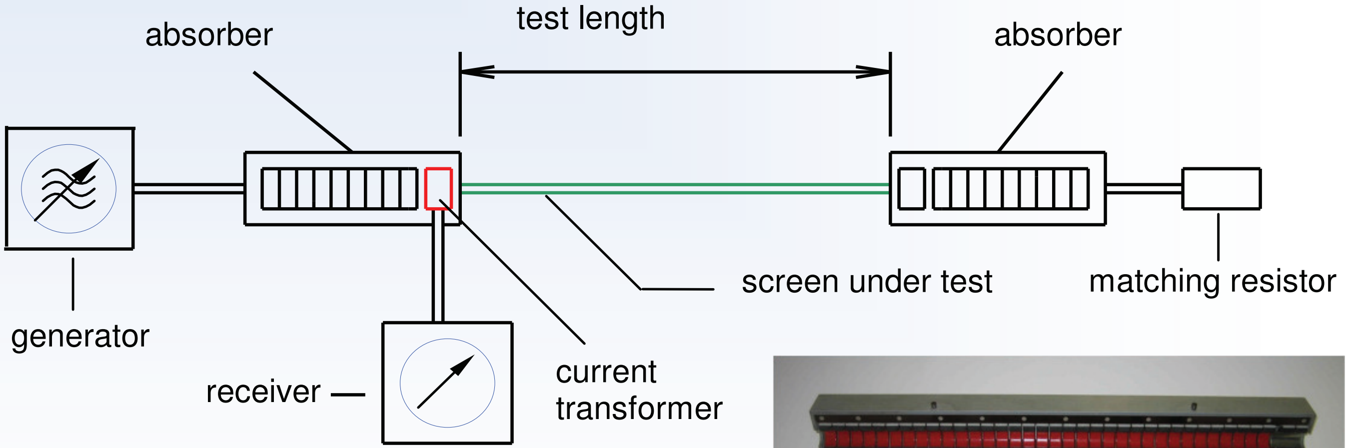
n = near end
f = far end

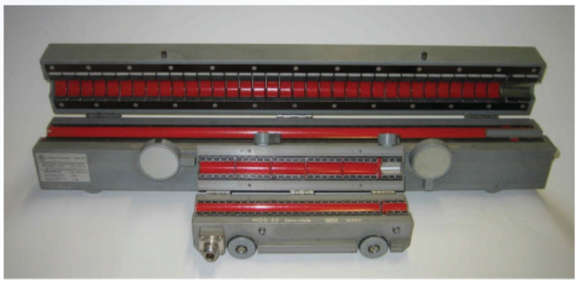
L = 1 m
ε_{r1} = 2,3
ε_{r2} = 1,0
Z_F = 0

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

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
(revision in preparation) by IEC TC 46/WG5

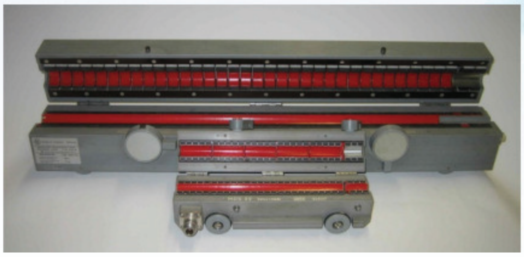
1985 – first computer controlled EMC-test station with VNA

my first task at bedea in **1985** was to establish a test station to measure screening attenuation (in dB)

It was realized with a Computer controlled Vector Network Analyser (VNA) ZVB from R&S and with absorbing clamps MDS 21

(the ZVB could work with narrow RF bandwith)

absorbing clamps
MDS 21, 30 MHz - 1 GHz
& MDS 22, 500 MHz - 2400 MHz

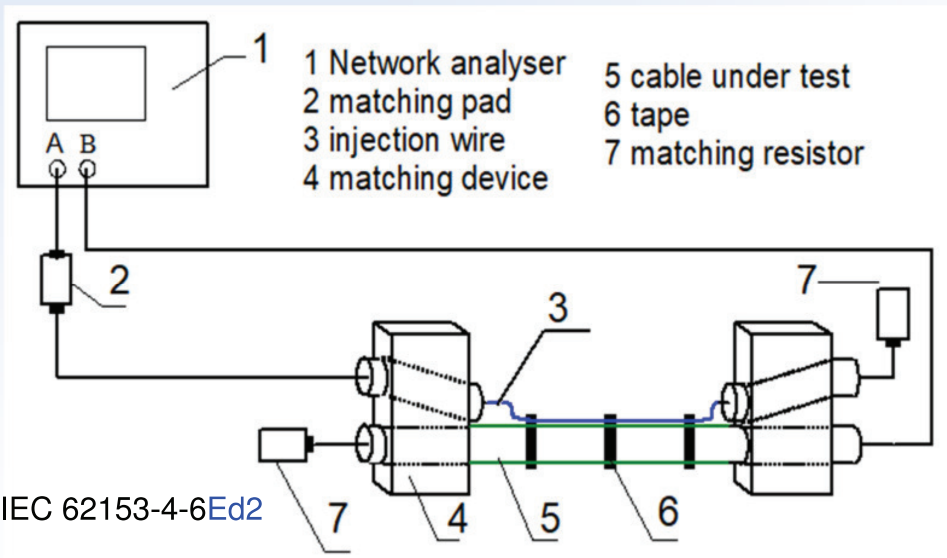


R&S ZPV
with GPIB Interface

up to the this time, screening effectiveness was measured only with measuring receivers

Line injection method

Transfer impedance up to ≈ 1 GHz, matching of injection wire 20 dB min !



IEC 62153-4-6Ed2

With the dielectric constants ε_{r1}, ε_{r2} of outer and inner circuit respectively, the propagation velocities v_1, v_2 and the test length L_c, the cut off frequency f_c is given by:

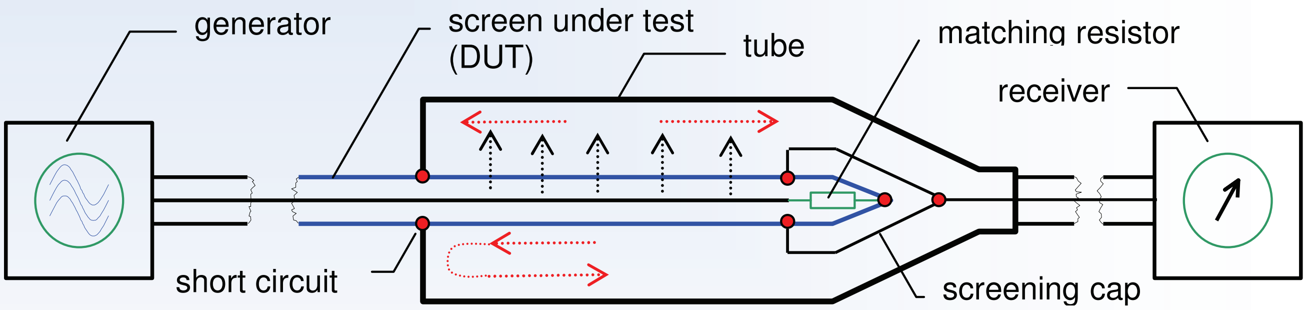
$$f_c = \frac{c}{\pi \cdot L_c \cdot \left|\sqrt{\varepsilon_{r1}} - \sqrt{\varepsilon_{r2}}\right|}$$

$$= \frac{1}{\pi \cdot L_c \cdot \left|\frac{1}{v_1} - \frac{1}{v_2}\right|}$$

Depending on the propagation velocities of inner and outer circuit,
Transfer impedance can be measured in the range of 50 MHz to about 1 GHz.

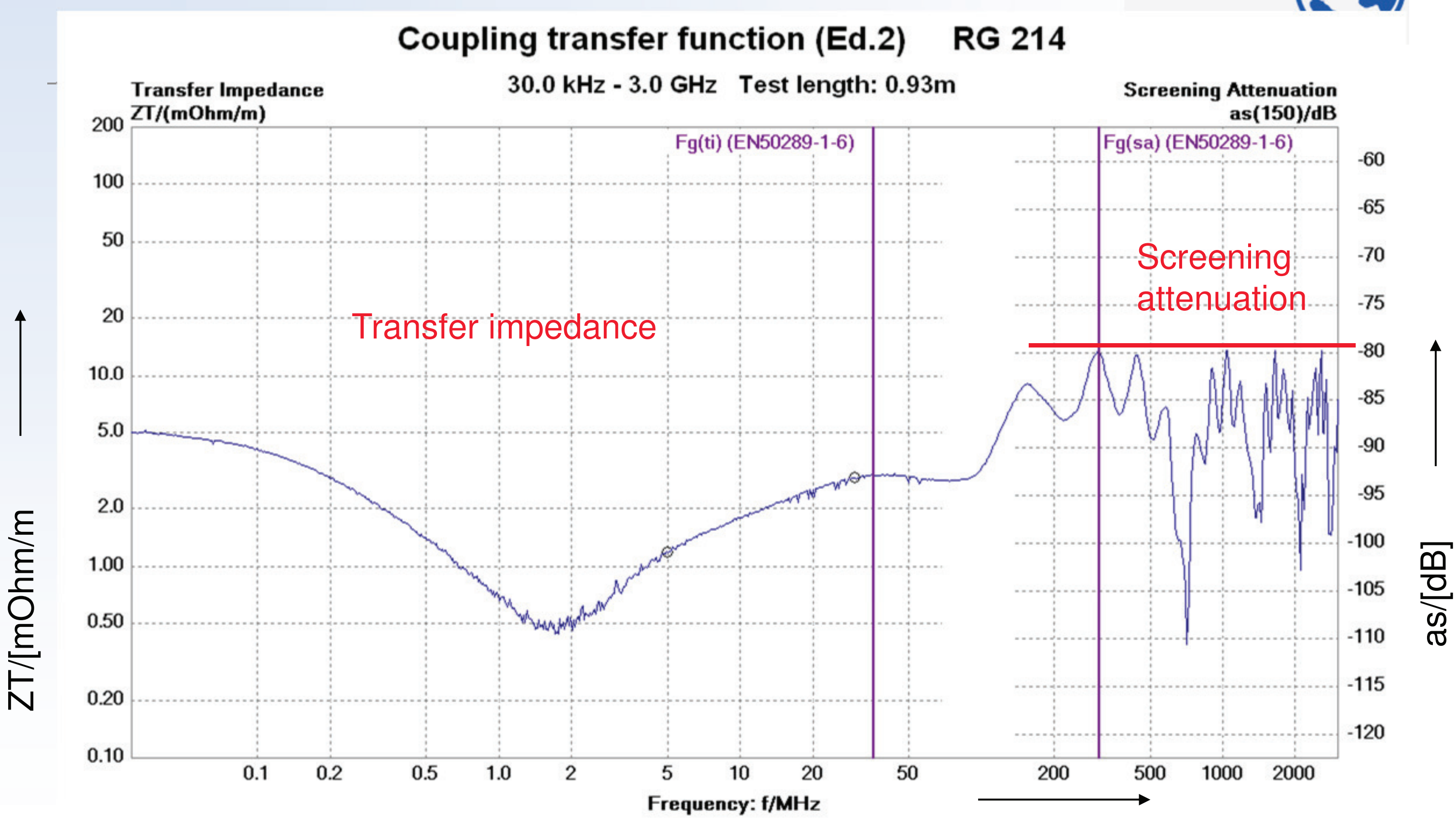
Principle of the Triaxial test set-up

Transfer impedance & Screening attenuation from DC up to and above 9 GHz with one test set-up



The set-up consists of the DUT in the middle of the tube, the generator and the receiver included in a modern VNA, the matching resistor at far end and the short circuit at near end.
The DUT is fed by the generator. Due to the weak screen of the DUT, energy is coupling into the outer system respectively into the tube and a wave is travelling in both directions first.
The short circuit at near end causes a total reflection; and the complete energy which couples into the outer system is travelling to the receiver and is measured there.
The logarithmic ratio of the received power to the input power is the Screening attenuation.

IEC 62153-4-3Ed2, Transfer impedance, IEC 62153-4-4Ed2, Screening attenuation

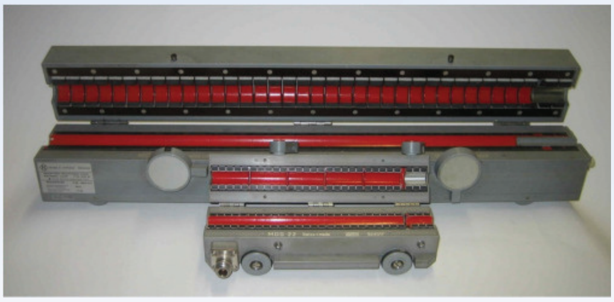


Compilation of screening test procedures

- Absorbing clamp procedure:
  - Screening attenuation 30 MHz to 1 GHz (2,5 GHz),
  - 2 test set-ups, 2 measurements (near and far end)
  - Screened room for higher a_S values required.
- Injection wire procedure:
  - Transfer impedance up to 1 GHz max. (depending on v_1/v_2)
  - At least 2 x 3 measurements (near and far end & turns)
- Triaxial procedure
  - Transfer impedance & Screening attenuation
  - DC up to 8 (12) GHz with one test set-up !
  - No screened room required
  - High sensitivity

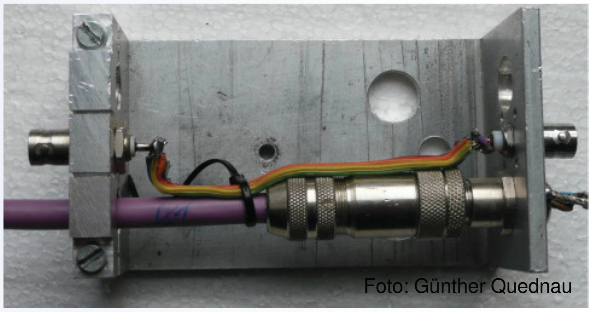
Compilation of screening test procedures

Absorbing clamp procedure

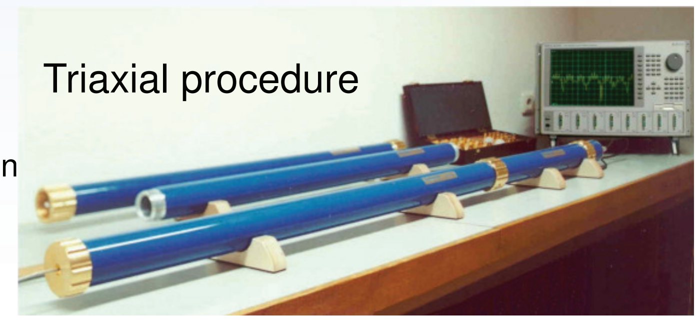


Screening attenuation
30 MHz to 1 (2,5) GHz

Wire injection

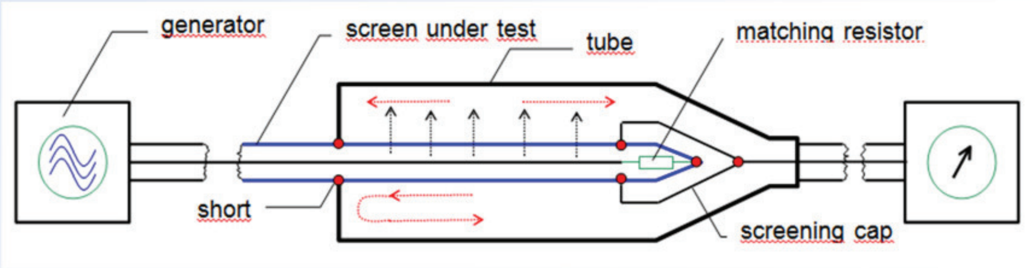


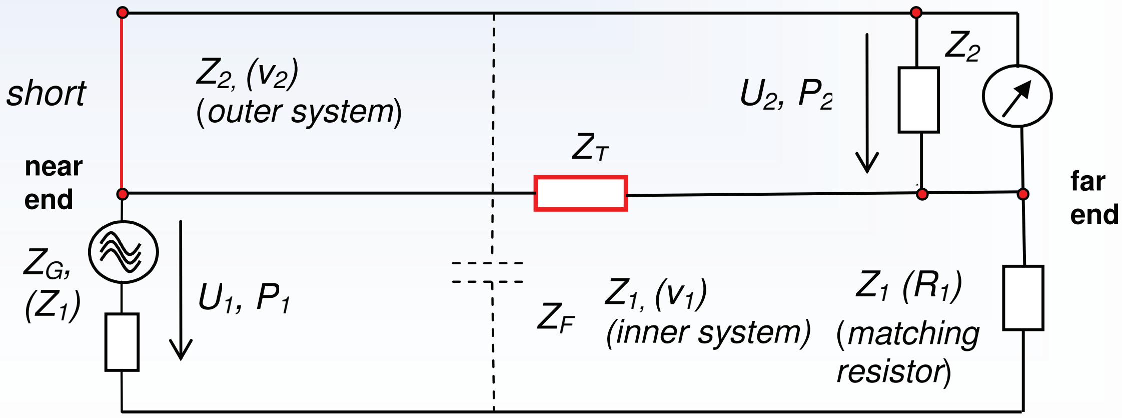
Transfer impedance up to 1 GHz



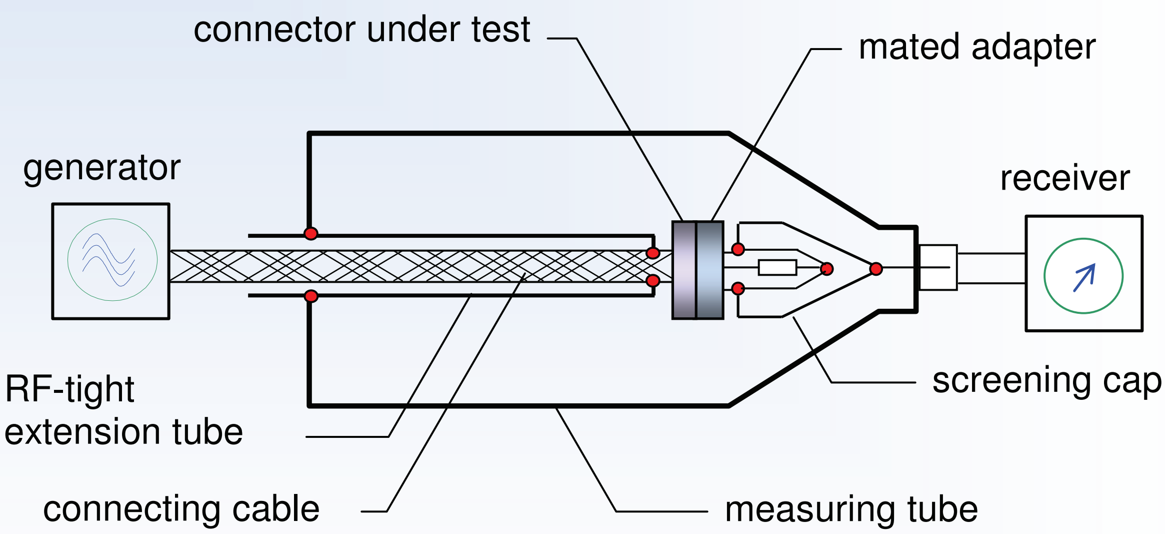
Transfer impedance & Screening attenuation
DC bis 12 GHz with one test set-up!

Triaxial test procedure - Equivalent circuit





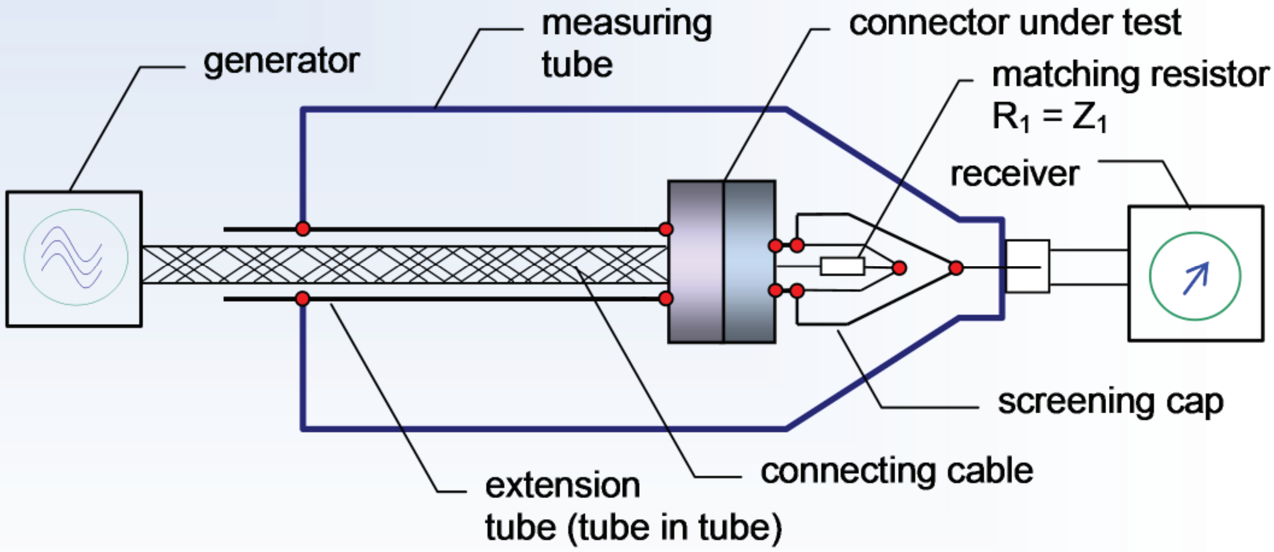
Triaxial set-up with “Tube in tube“



connectors with a short piece of connecting cables, a mated adapter is required

IEC 62153-4-7Ed2,Tube in tube test procedure (connectors & assemblies)

IEC 62153-4-7Ed2,Tube in tube procedure, Amendment 1

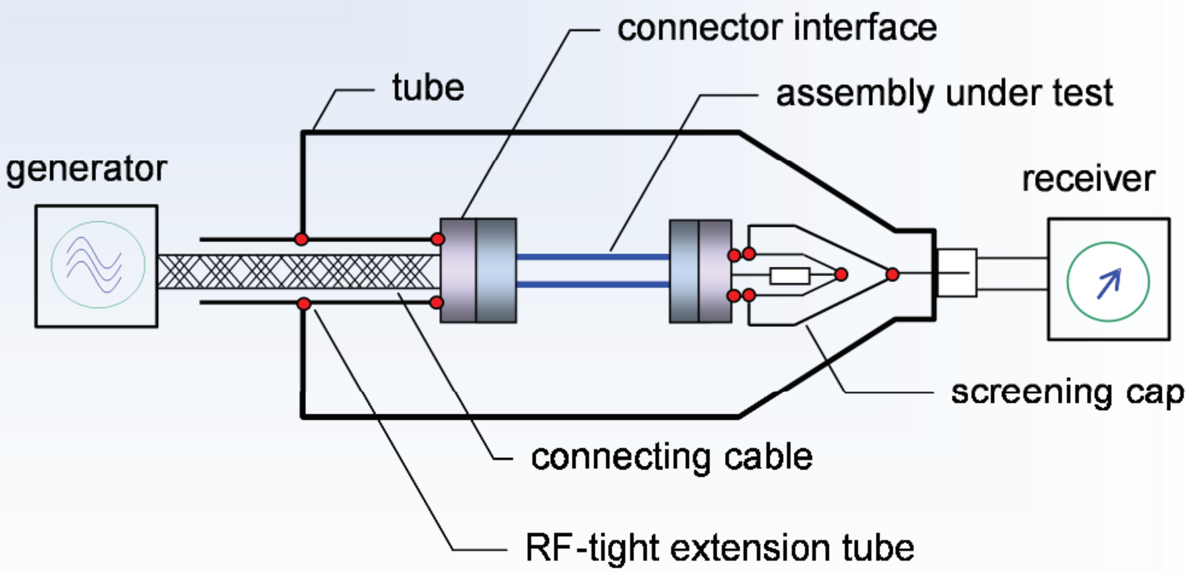


connectors direct connected to the tube in tube resp. to the adapter !

IEC 62153-4-7Ed2,Tube in tube procedure, Amendment 1

EMC of cables, connectors and components with Triaxial test procedure

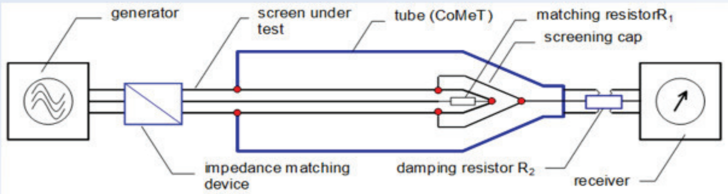
Measuring of cable assemblies



mated adapter direct connected to the tube in tube

IEC 62153-4-7Ed2,Tube in tube test procedure (connectors & assemblies)

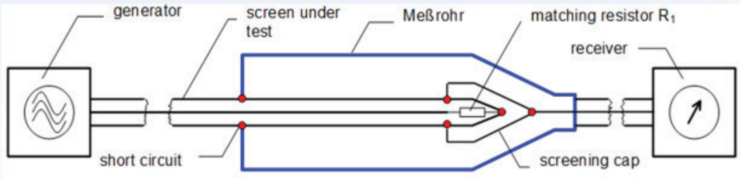
Changes of IEC 62153-4-3Ed2, Transfer impedance



Procedure A:
Matched inner circuit with damping resistor in outer circuit R_2

matched – matched – short

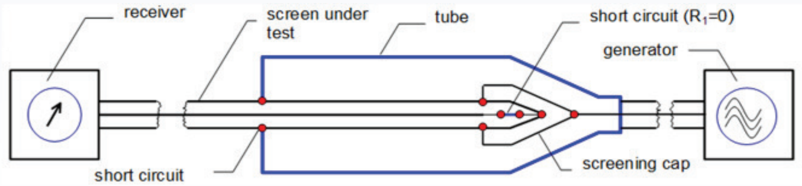
$$Z_T = \frac{R_1(Z_0+R_2)}{Z_0 L_c} 10^{-\left\{\frac{a_{meas}-a_{cal}-\left(a_{pad}+10\log_{10}\left(\frac{Z_0}{Z_{CUT}}\right)\right)}{20}\right\}}$$



Procedure B:
Inner circuit with load resistor and outer circuit without damping resistor

mismatched –matched– short

$$Z_T = \frac{R_1+Z_0}{2\cdot L_c}\cdot 10^{-\left\{\frac{a_{meas}-a_{cal}}{20}\right\}}$$

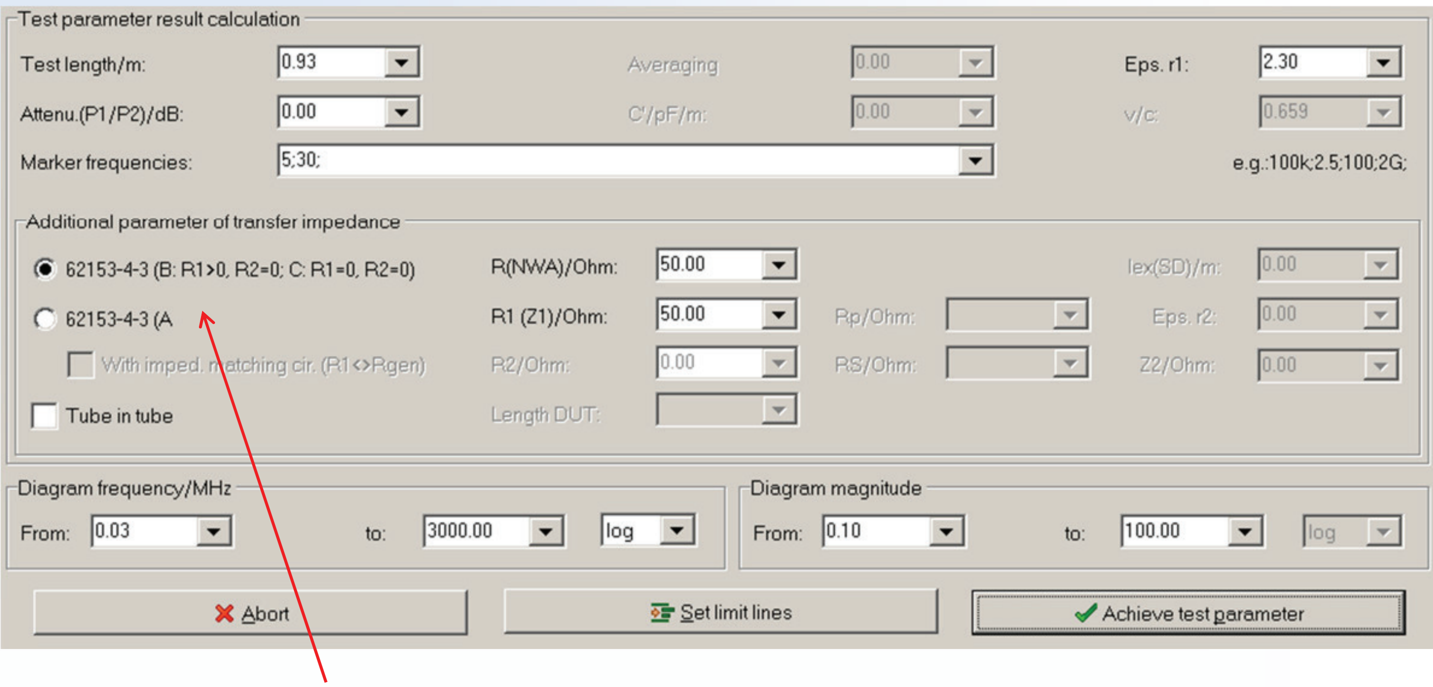


Procedure C:
(Mismatched)-Short-Short without damping resistor

mismatched – short – short

$$Z_T = \frac{Z_0}{2\cdot L_c}\cdot 10^{-\left\{\frac{a_{meas}-a_{cal}}{20}\right\}}$$

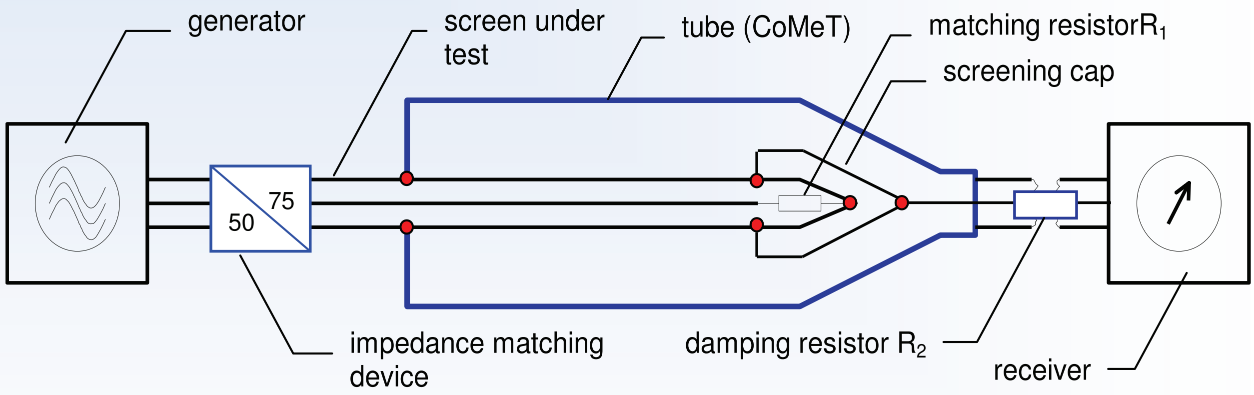
WinCoMeT-software



Select Procedure A, B or C

Procedure A: Matched inner circuit with damping resistor R_2

matched – matched – short with damping resistor R_2



$$Z_T = \frac{R_1(Z_0 + R_2)}{Z_0 L_c} 10^{-\left\{\frac{a_{meas} - a_{cal} - \left(a_{pad} + 10\log_{10}\left(\frac{Z_0}{Z_{CUT}}\right)\right)}{20}\right\}}$$

cut-off frequency

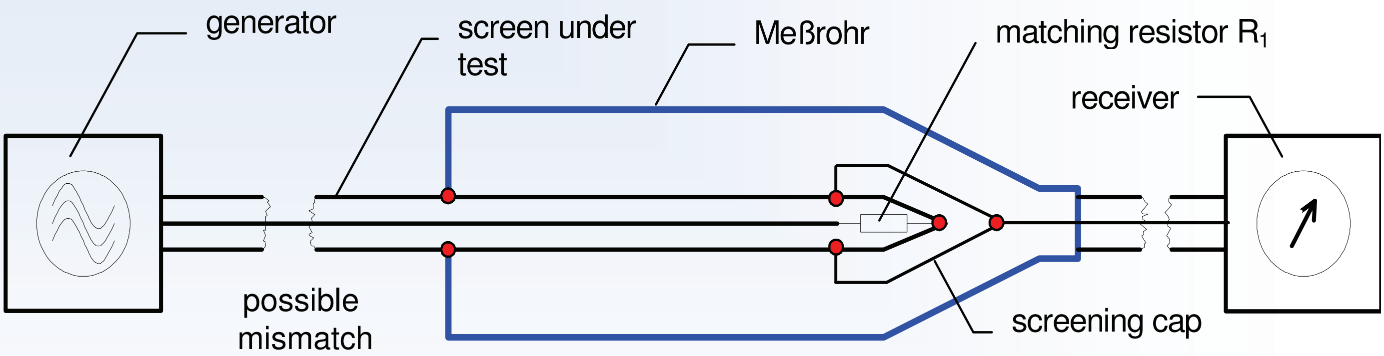
f_{cut} x $l \approx 80$MHz x m

$$R_2 = A \times 60 \ln\left(\frac{D}{d}\right) - 50$$

$$A = \sqrt{2} \text{ or } A = \sqrt{\frac{\varepsilon_{r1}}{\varepsilon_{r2}}}$$

Procedure B: Mismatched and inner circuit with load resistor

mismatched – matched – short



$$Z_T = \frac{R_1 + Z_0}{2 \cdot L_c} \cdot 10^{-\left\{\frac{a_{meas} - a_{cal}}{20}\right\}}$$

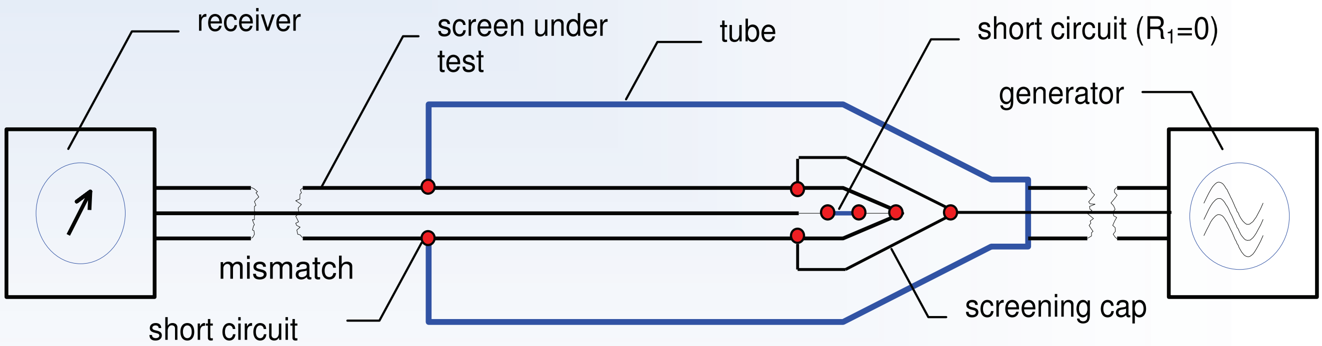
cut-off frequency

f_{cut} x $l \approx 25$MHz x m

usable for both, Transfer impedance and Screening attenuation

Procedure C: (Mismatched)-Short-Short without R_2

mismatched – short – short



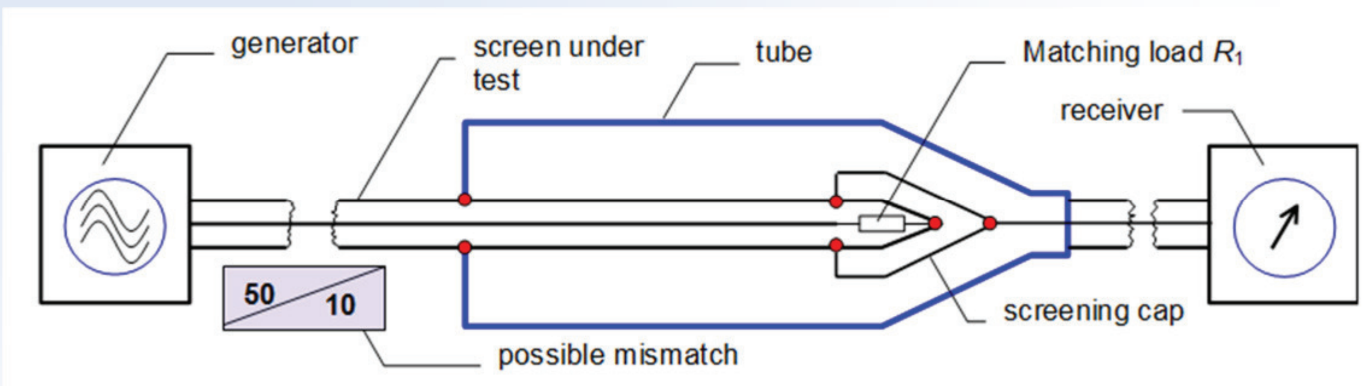
$$Z_T = \frac{Z_0}{2 \cdot L_c} \cdot 10^{-\left\{\frac{a_{meas} - a_{cal}}{20}\right\}}$$

cut-off frequency

$$f_{cut} \times l \approx 30\text{MHz} \times \text{m}$$

generator and receiver are interchanged vs. Proc. A and B, highest sensitivity up to the µOhm range

Changes of IEC 62153-4-4Ed2, Screening attenuation



innerer circuit with matching load $R_1 = Z_1$

$$a_S = 10 \cdot \log_{10}\left|\frac{P_1}{P_{r,max}}\right| = 10 \cdot \log_{10}\left|\frac{P_1}{P_{2,max}} \cdot \frac{2 \cdot Z_S}{Z_1}\right|$$

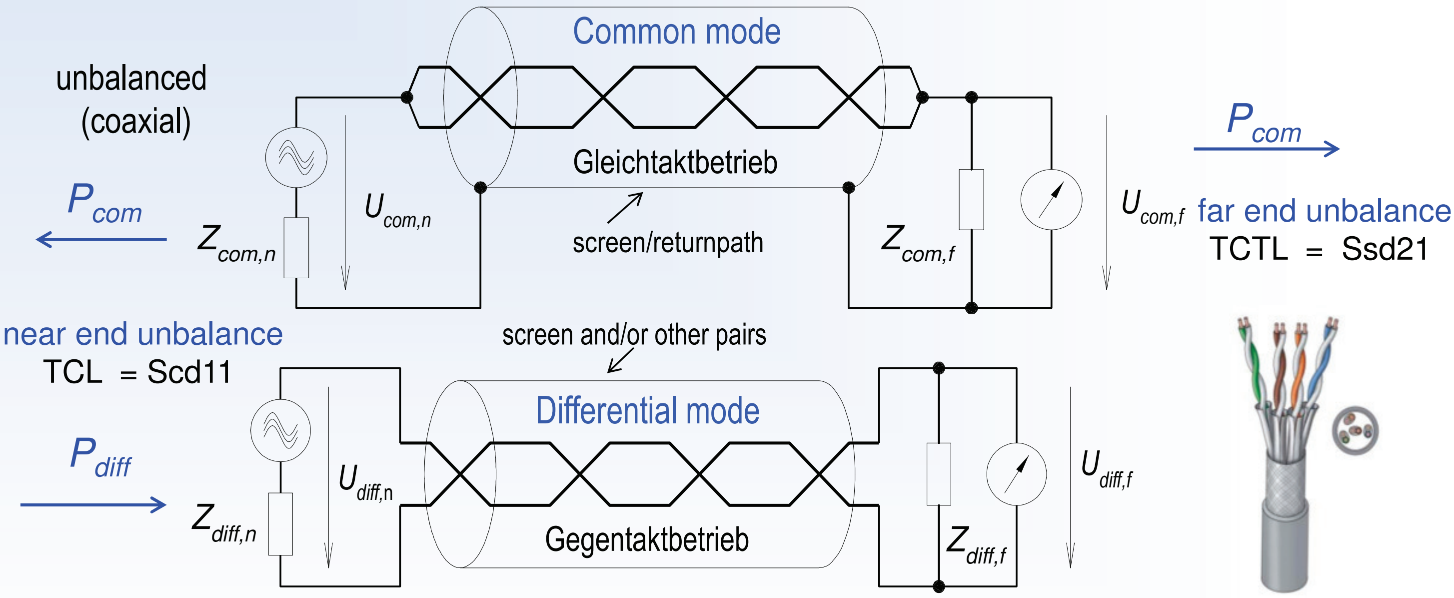
$$a_S = Env\left\{-20 \cdot \log_{10}|S_{21}| + 10 \cdot \log_{10}|1 - r^2| + 10 \cdot \log_{10}\left|\frac{300\Omega}{Z_1}\right|\right\}$$

The term $|1 - r^2|$ represents the reflexion attenuation
due to the mismatch between generator and DUT
In case of mismatch of 50 Ohm output imedance of the generator
to e.g. 10 Ohm impedance of the DUT, the correction value is about 2,5 dB !

50 10

Reflexion coefficient $r = \left|\left(\frac{Z_0 - Z_1}{Z_0 + Z_1}\right)\right|$

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}:

$$a_u = 10 \cdot \log\left(P_{diff} \,/\, P_{com}\right)$$

Coupling attenuation of balanced cables

Unbalance attenuation a_U of a balanced cable is the log. ratio of the input power in the differential mode P_{diff} to the coupled power P_{com} into the common mode.

$$a_u = 10 \cdot \log\left(\frac{P_{diff}}{P_{com}}\right)$$

P_{diff} = differntial mode power
P_{com} = common mode power

Screening attenuation a_S of a cable screen is the log. ratio of the input power P_1 in the common mode to max. radiated power $P_{r,max}$ resp. $P_{2,max}$. With the normalized value Z_S = 150 Ω one gets:

$$a_S = 10 \cdot \lg\left|\frac{P_1}{P_{r,max}}\right| = 10 \cdot \lg\left|\frac{P_1}{P_{2,max}} \cdot \frac{2 \cdot Z_S}{R}\right|$$

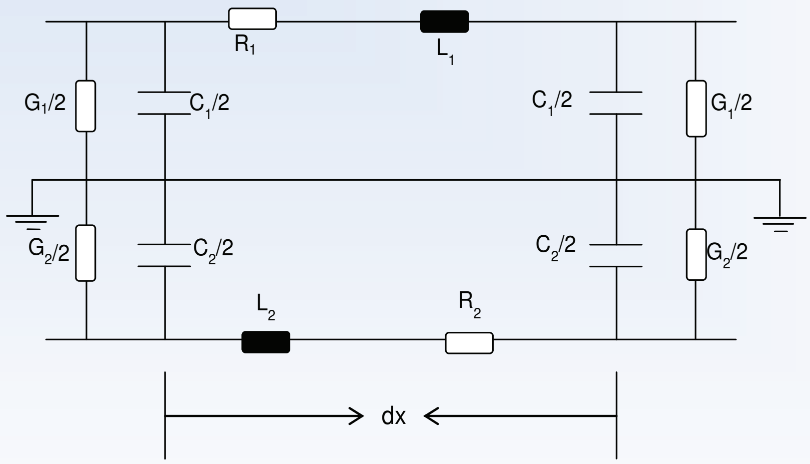
$P_{2,max}$ = max.radiated power
R = characteristic impedance
Z_S = 150 Ohm normalized value

Coupling attenuation a_C describes the global effect against electromagnetic interference (EMI) and takes into account both the effect of the screen and the symmetry of the pair.

$$\boxed{a_C \approx a_U + a_{smax}} \qquad a_C = 10 \cdot \lg\left|\frac{P_{diff}}{P_{com}}\right| + 10 \cdot \lg\left|\frac{P_{com}}{P_{r,max}}\right| \qquad a_C = 20 \cdot \lg\left|\frac{U_{diff}}{U_{2,max}}\right| + 10 \cdot \lg\left[\frac{2 \cdot Z_S}{Z_{diff}}\right] \qquad (P_{com} = P_1)$$

U_{diff} = input voltage, differential mode, $U_{2,max}$ = max. output voltage, common mode,
Z_{diff} = characteristic impedance, differential mode

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:

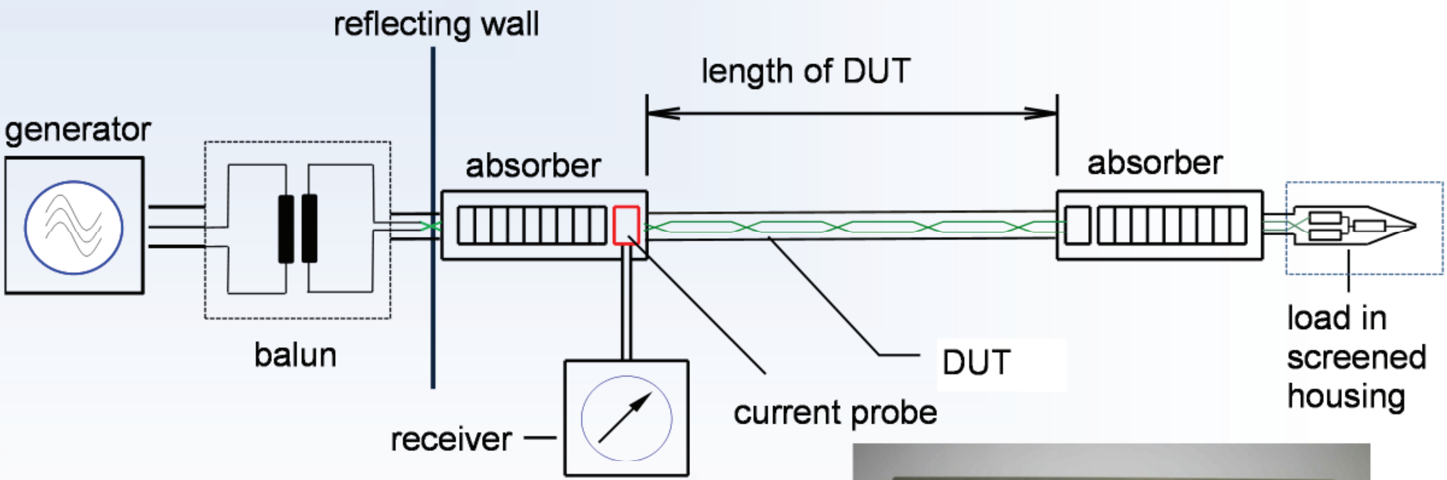
at high frequencies,
the asymptotic value approaches to: $\left|S_{\substack{n\\f}}\right| = \frac{2}{(\beta_{diff} \pm \beta_{com}) \cdot l}$

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

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

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

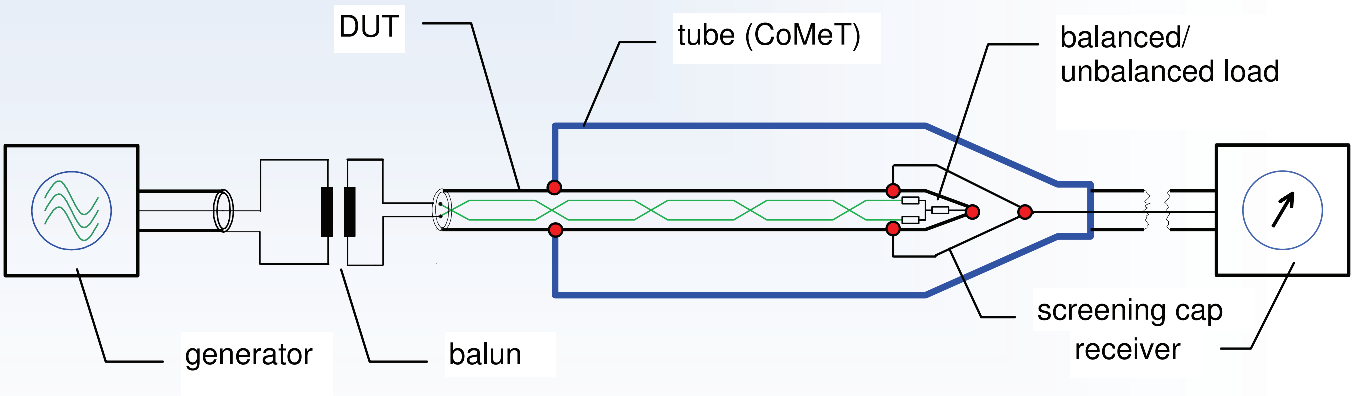


IEC 62153-4-5 (EN 50289-1-6)

IWCS

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

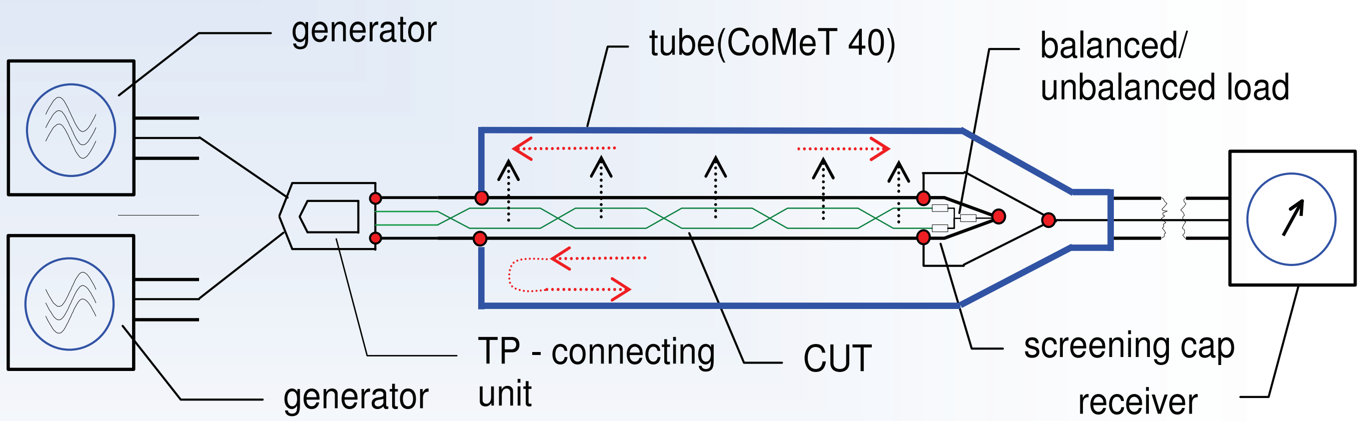


Screened balanced cables, (Cat-cables), multi core cables (and connectors)

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

IWCS

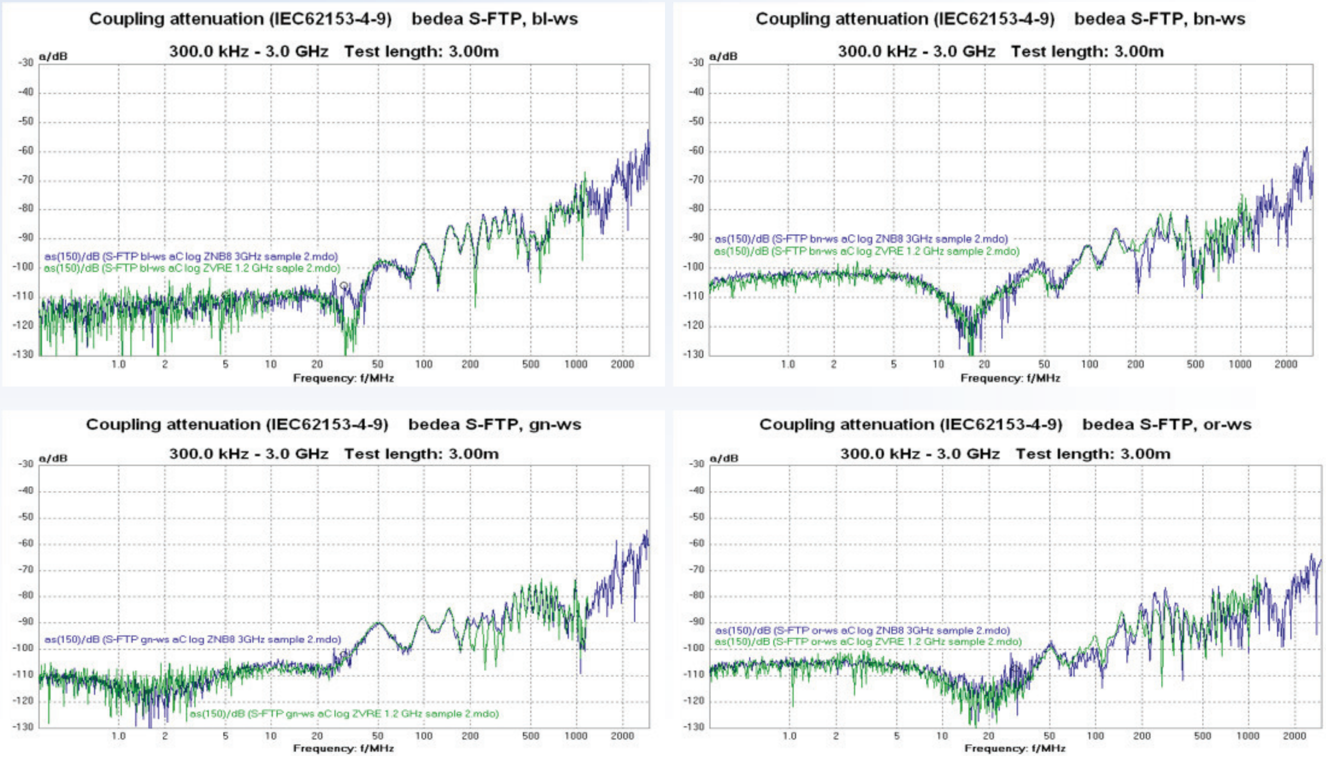
Screening & Coupling attenuation with Triaxial procedure



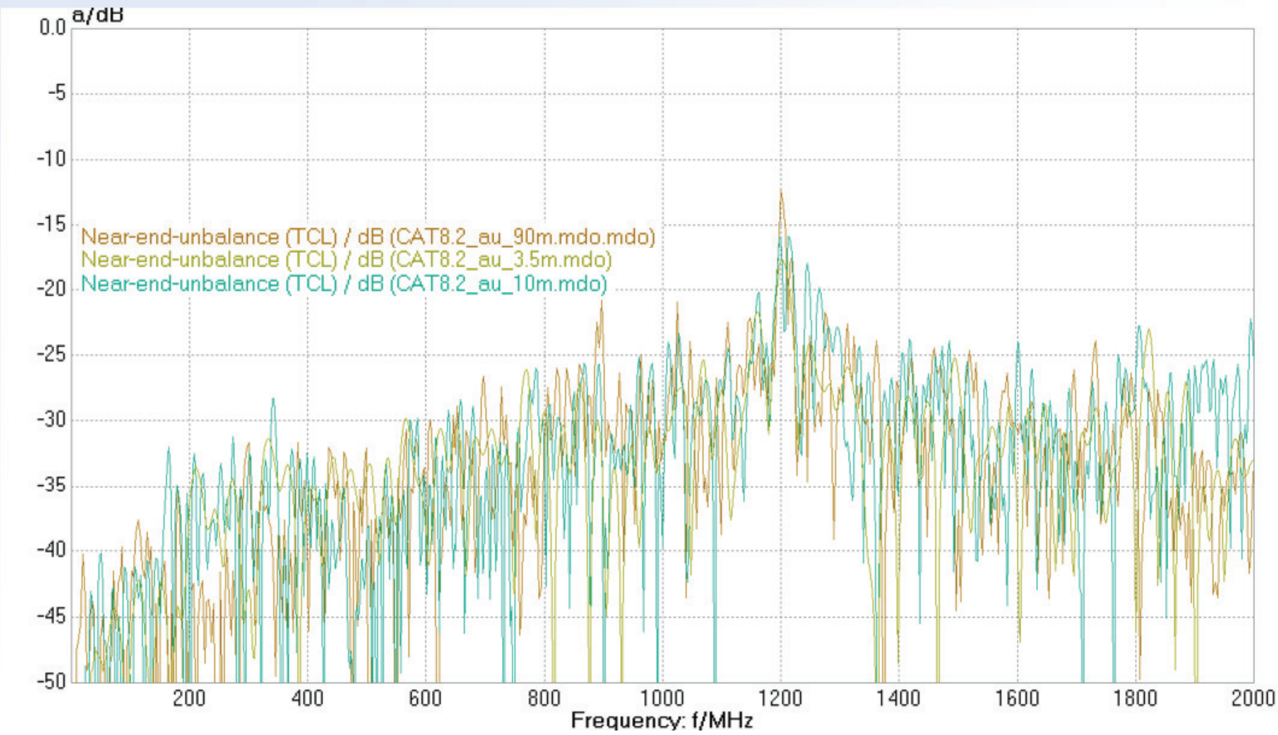
The principle for coupling attenuation measurement is the same than the basic triaxial procedure with generator and receiver and a short circuit at near end.
IEC 62153-4-9, Coupling attenuation on screened balanced cables was revised recently; Edition 2 was published in May 2018.
The revised version contains the balunless measurement of coupling attenuation with open test head as well as the measurement with standard test head up to 2 GHz.

IEC 62153-4-9Ed2, Coupling attenuation – Triaxial method

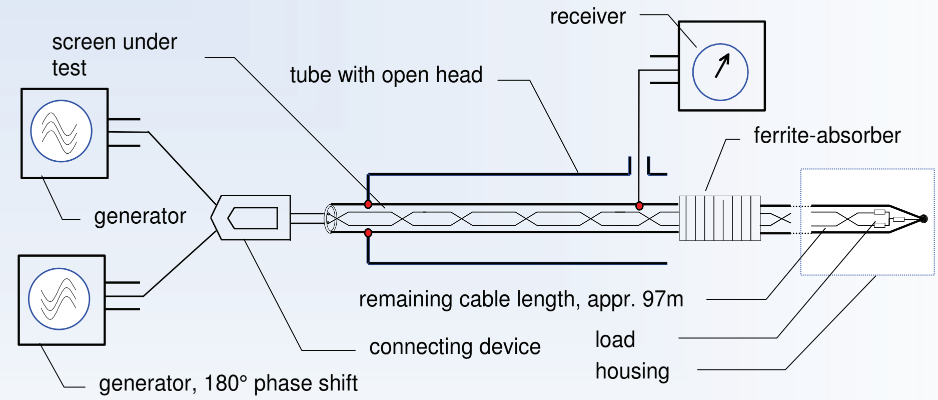
Balunless vs balun, Triax, standard, S-FTP cable



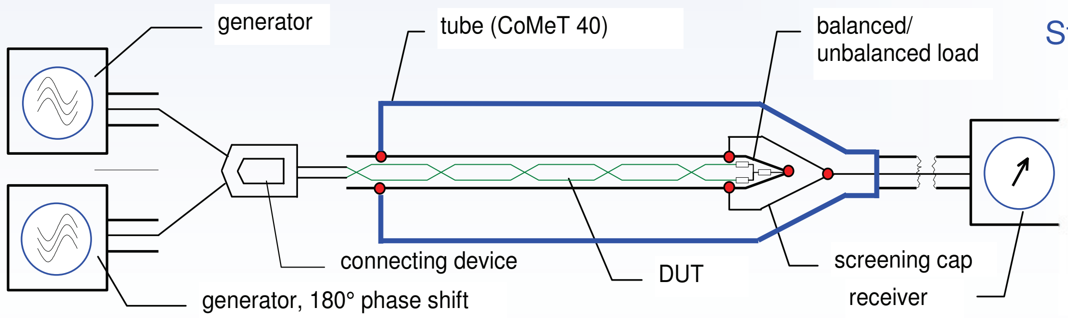
Near end Unbalance a_U resp. TCL at different length



Coupling attenuation up to 2 GHz with virtual Balun



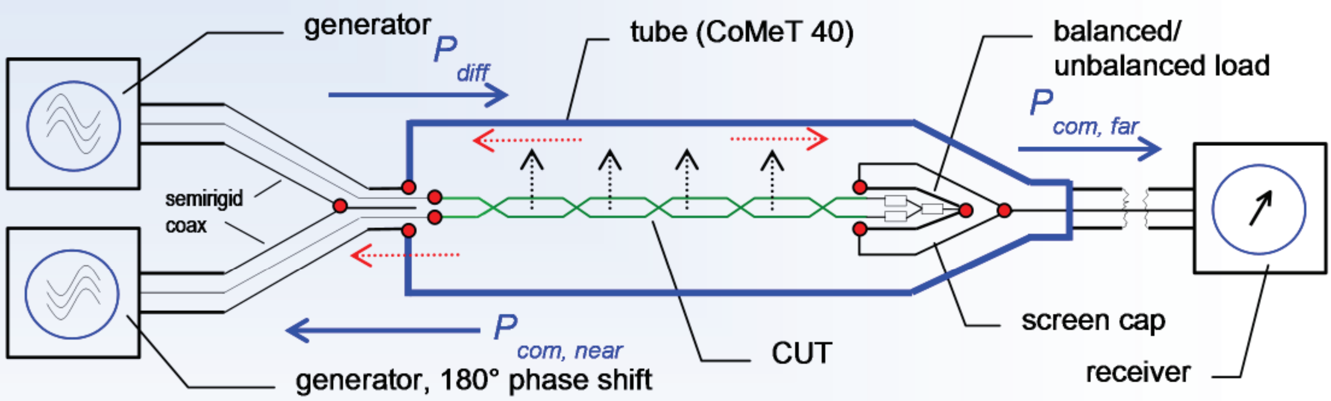
open test head



Standard test head

IEC 62153-4-9Ed2, Coupling attenuation, triaxial method, (with open & standard test head)

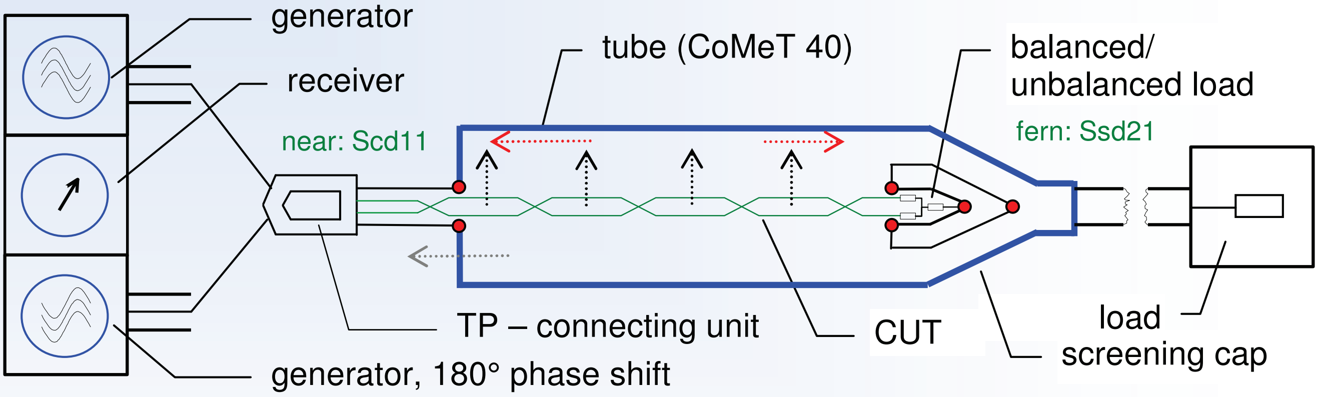
Unscreened pairs with Triaxial procedure - principle



This figure shows the principle set-up for balanced unscreened pairs. The signal is fed into the tube in the differential mode via two parallel semi rigid coax cables of equal length with the screens connected to the tube. Due to the conversion from the differential mode into the common mode (into the tube), a wave is travelling in both directions in the test section.

Since there is no screen on the unscreened pair, there is no short circuit at the near end as in the basic triaxial set-up acc. to fig. 6; hence coupling measurements can be performed on both ends.

Near end Coupling attenuation with Triaxial procedure

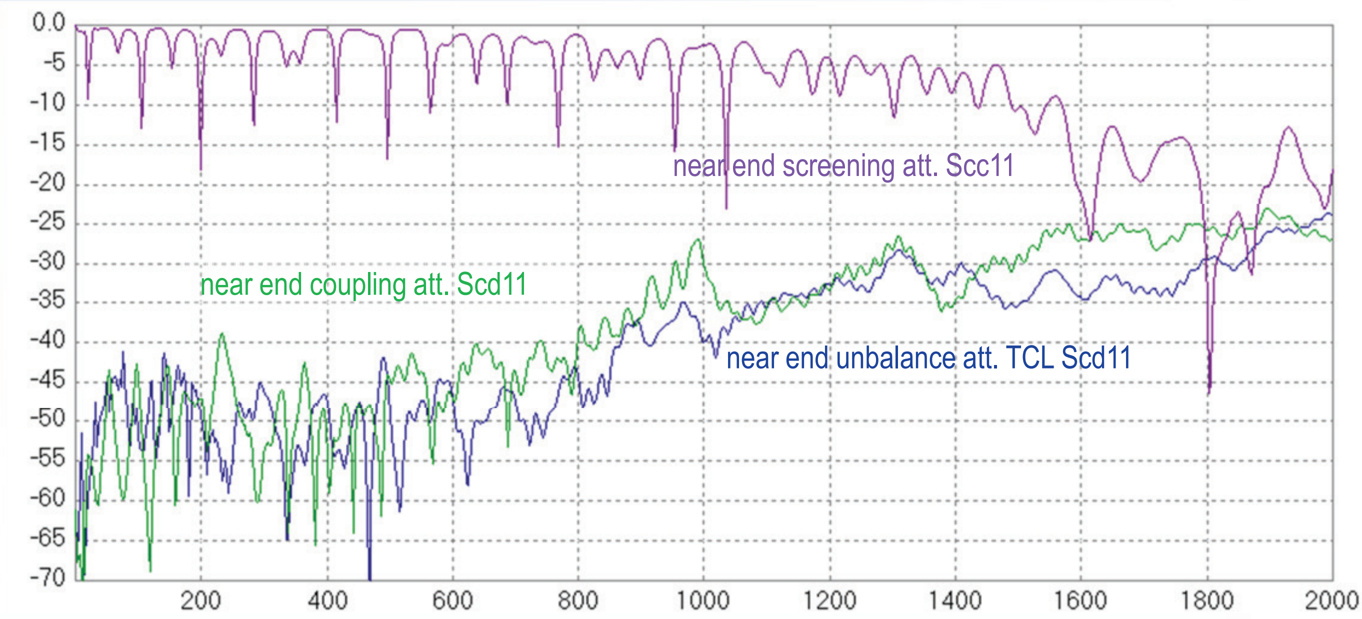


This figure shows the configuration for near end coupling attenuation measurement.
The back travelling energy at the near end as shown above is considered as the near end coupling attenuation.
It can be measured as Scd11 where Scd11 is also the unbalance attenuation (TCL) of the unscreened cable under test (CUT) at near end !

near end coupling attenuation of a single unscreened balanced pair = TCL !

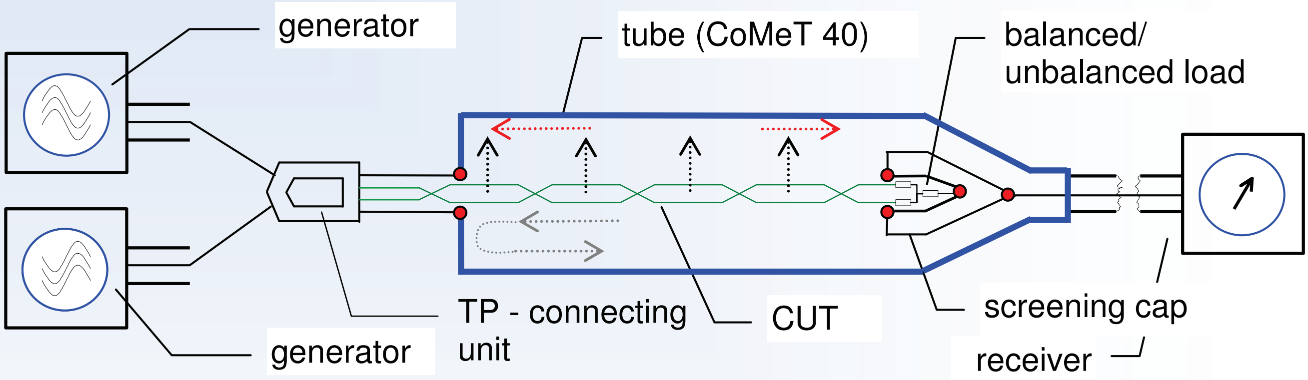
Near end coupling att. & TCL of an unscreened balanced pair

near end unbalance attenuation (TCL) of a 5m single unscreened balanced pair, laid on a wooden table and the near end coupling attenuation measurement (Scd11) in the triaxial set-up



near end coupling attenuation of a single unscreened balanced pair = TCL !

Screening- & Coupling attenuation of unscreened pairs, far end

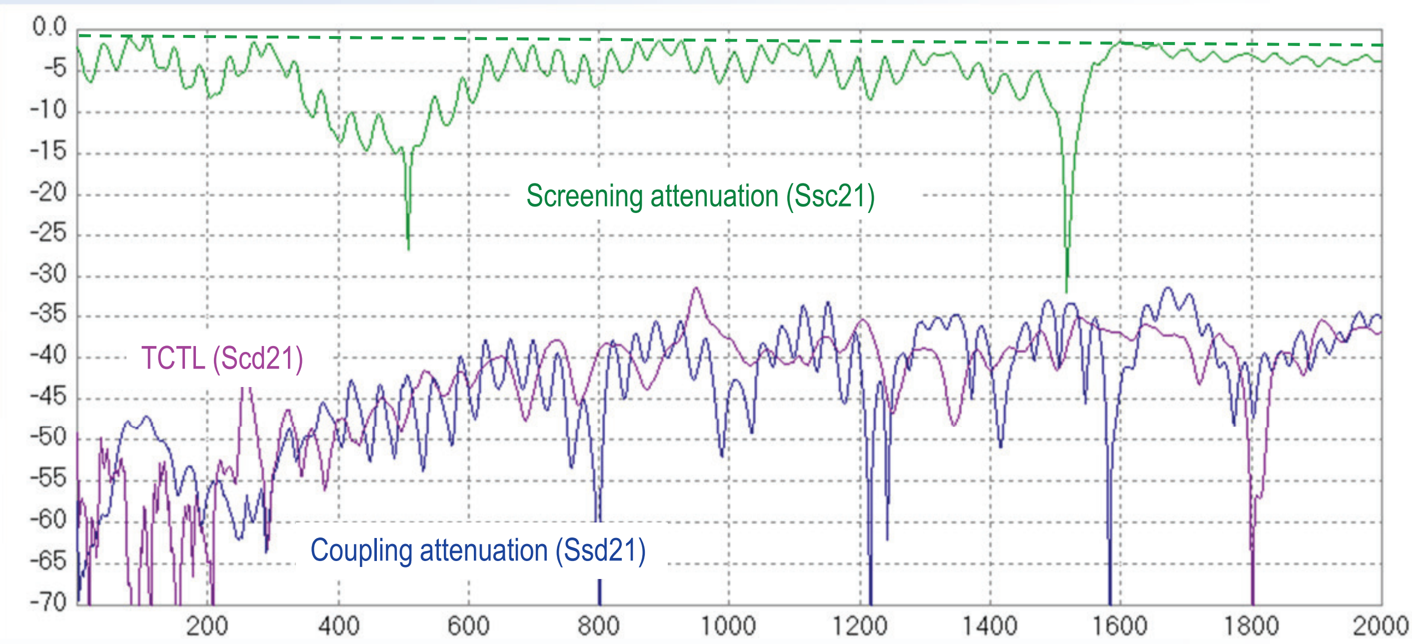


set-up for the far end screening attenuation (Ssc21) and the far end coupling attenuation (Ssd21) measurement of an unscreened pair.
The CUT is matched with 50/50/25 Ohm; that means 100 Ohm for the differential mode and 50 Ohm for the common mode.
The 50 Ohm common mode resistor is in series to the receiver of the network analyser.

The Ssd21 measurement (far end coupling attenuation) is in principle the same than a Scd21 measurement (far end unbalance attenuation).

far end coupling attenuation of an unscreened pair ≈ far end unbalance attenuation

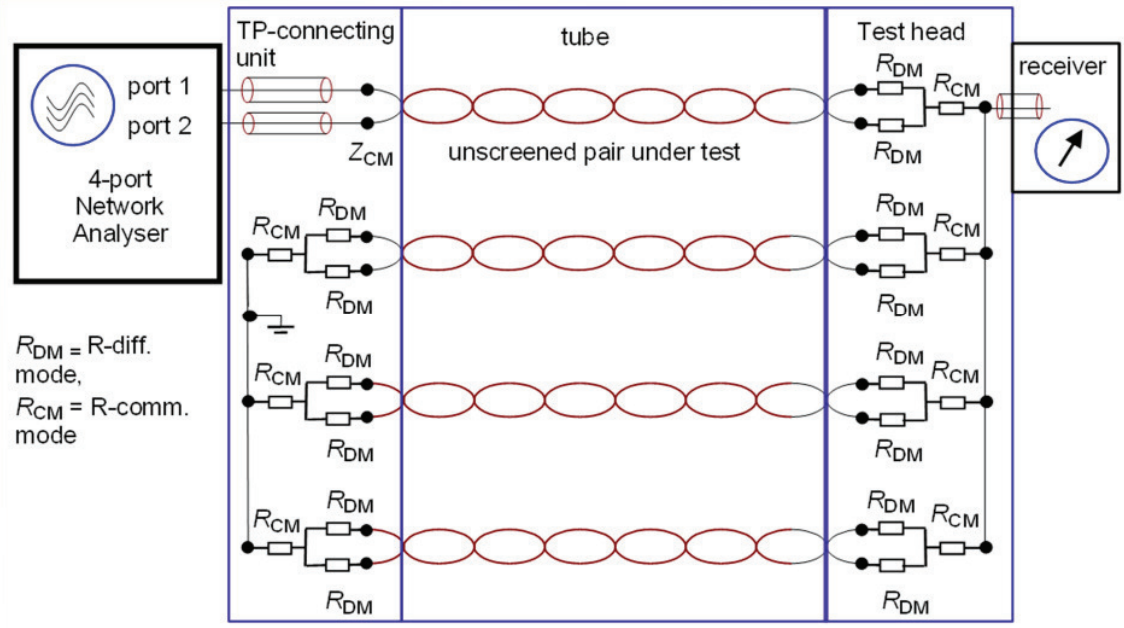
Far end Screening & Coupling attenuation of an unscreened balanced pair



far end screening attenuation of a single unscreened balanced pair = nearly zero !
far end coupling attenuation is nearly the far end unbalance attenuation (TCTL)

Screening- & Coupling att. of multiple balanced pairs

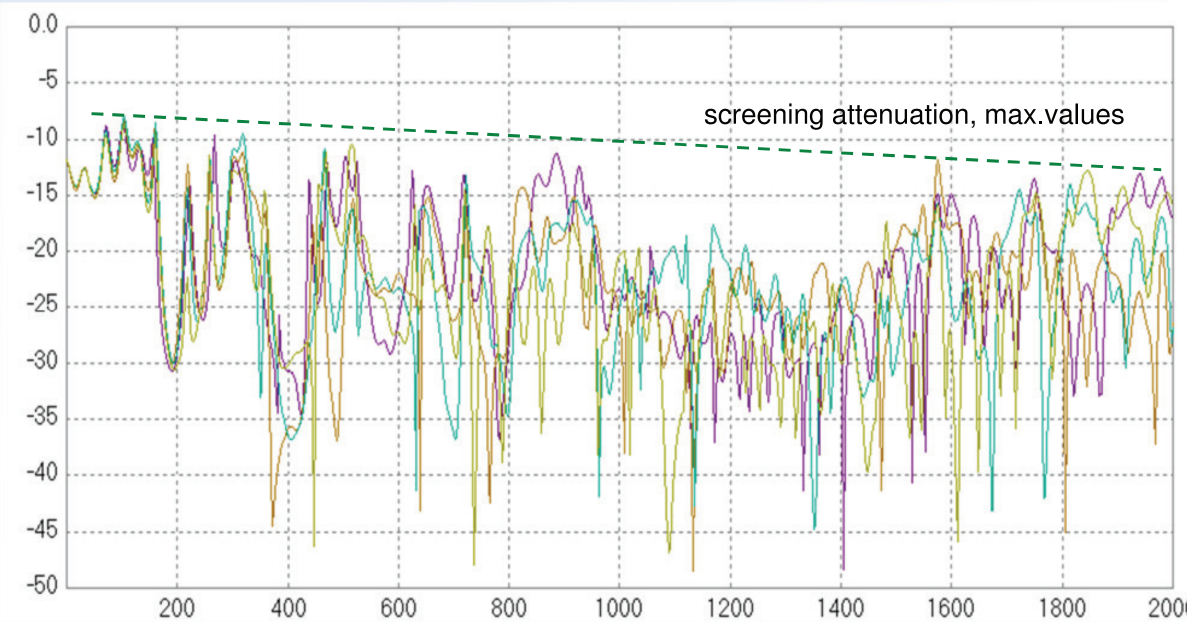
Basic configuration for coupling attenuation of multiple unscreened pairs



The pairs not under test are grounded by a resistor network 50/50/0. They act as an inner screen

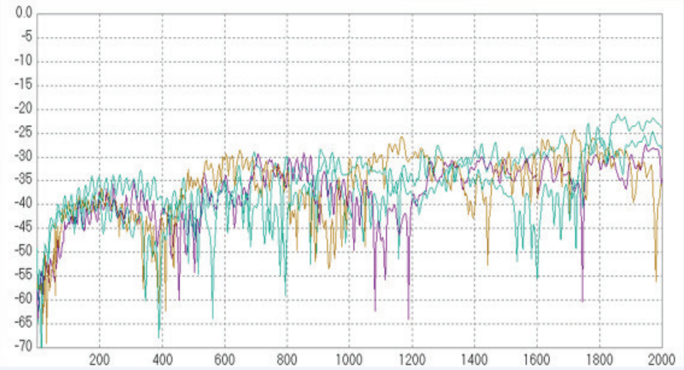
EMC of cables, connectors and components with Triaxial test procedure

Far end screening attenuation of an unscreened Cat5e

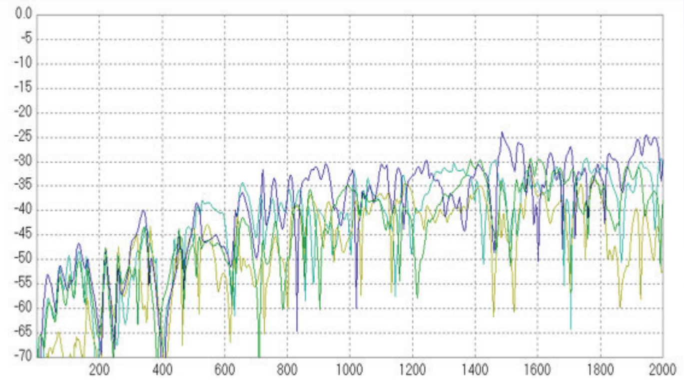


The measured screening attenuation (Ssc21) of about 8 to 12 dB of the unscreened pairs can be explained by the remaining pairs which acts as "**inner screen**".

Far end unbalance- & coupling attenuation of a Cat5e



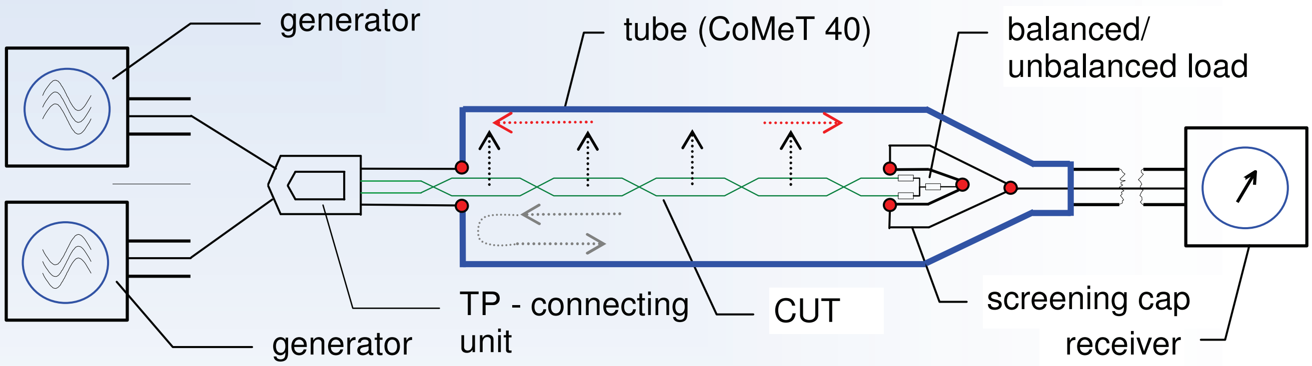
far end unbalance attenuation
of an unscreened Cat5e (Scd21)

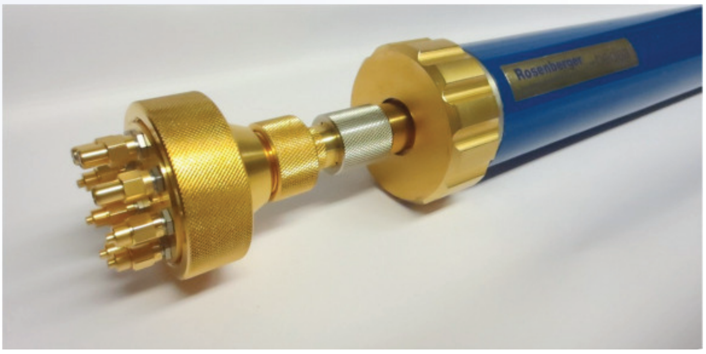


far end coupling attenuation
of an unscreened Cat5e (Ssd21)

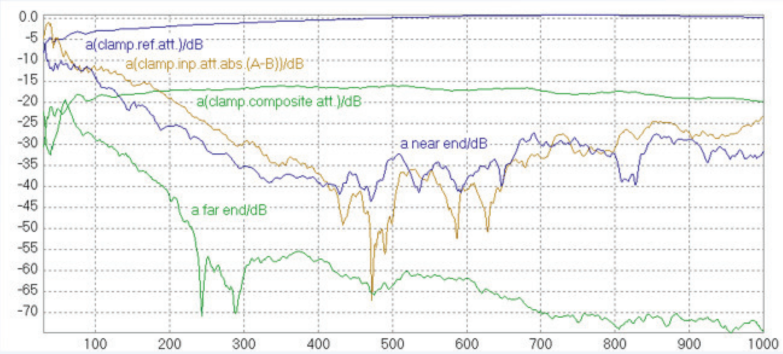
The far end coupling attenuation (Ssd21) is about 5 to 10 dB better than the far end unbalance attenuation (Scd21), probably due to the screening effect of the remaining pairs with a trend to get equal values at higher frequencies.

TP-connecting unit for balunless meassurement



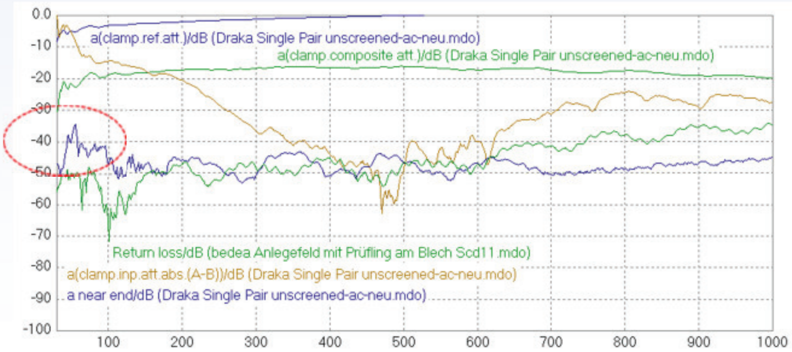


Screening- and Coupling attenuation with MDS 21



Screening attenuation of an unscreened balanced pair with absorbing clamp MDS 21

The absorber of the clamp suppresses the common mode currents.
At near end screening att. measurement, the attenuation of the absorber is actually measured;
hence Screening attenuation measurement of an unscreened balanced pair with clamps does not make any sense.

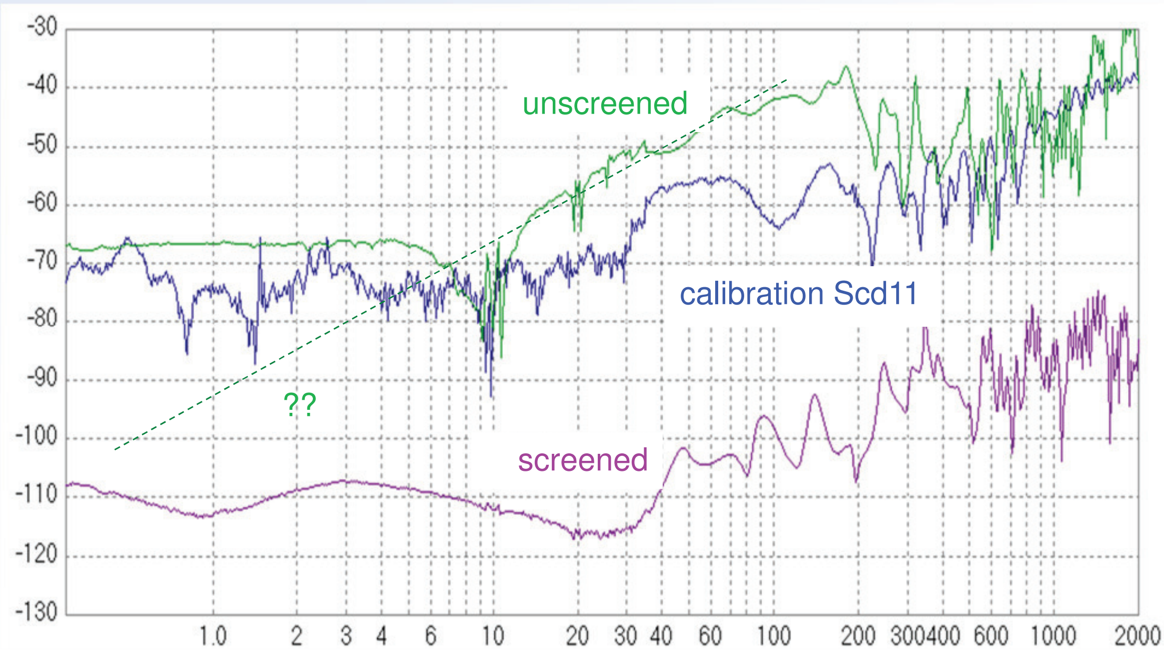


Coupling attenuation of an unscreened balanced pair with absorbing clamp MDS 21

Coupling attenuation measurements of an unscreened balanced pair shows poor values below 100 MHz;
due to the poor attenuation of the absorber below 100 MHz.
(should be discussed with IEC TC 46/WG5)

Low frequency Coupling attenuation

Low frequency Coupling attenuation of single balanced pairs can be measured with the same set-up as for Coupling attenuation but starting at 9 kHz



The unbalance of the TP-connecting unit shall be considered; test length 3m, **Ssd21**

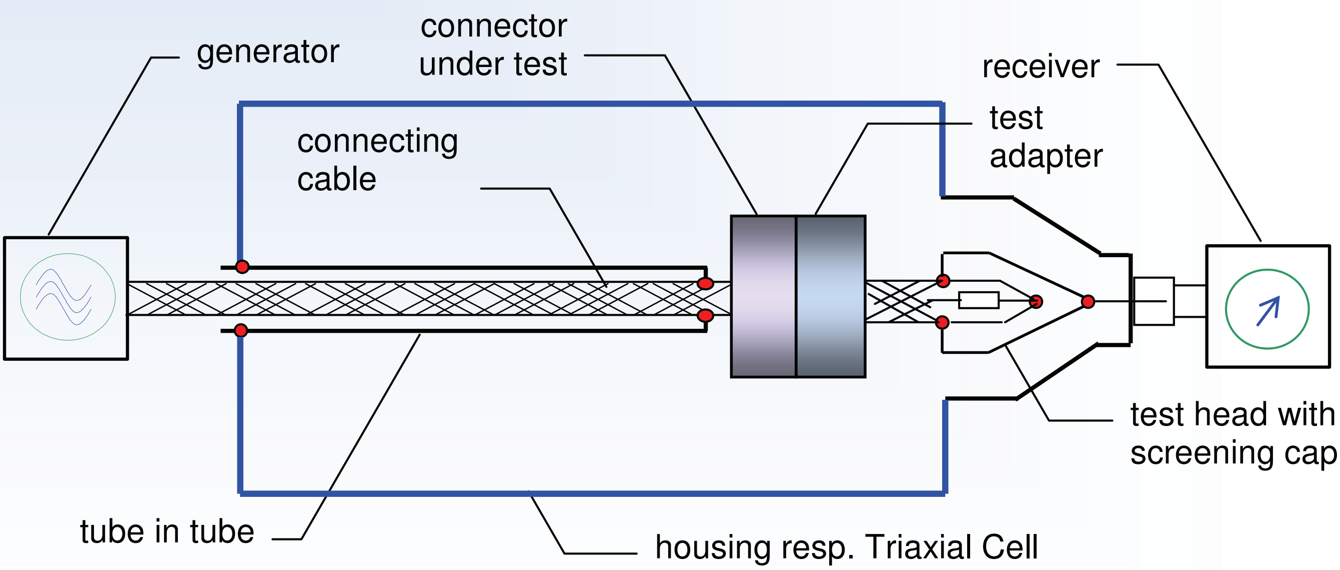
IEC
62153-4-9Amd1
46/710/CD

Different designs of Triaxial Cells

Different designs of Triaxial Cells

Triaxial Cell with tube in tube, principle

The Triaxial Cell procedure is based on the principles of the Triaxial procedures according to IEC 62153-4-3, Transfer impedance and IEC 62153-4-4, Screening attenuation

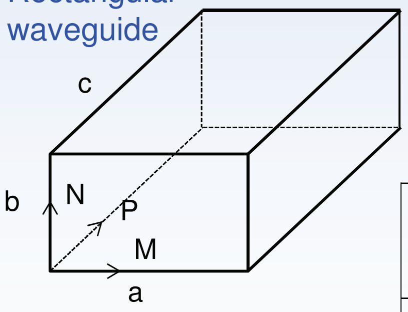


IEC 62153-4-15, Transfer impedance and Screening attenuation with Triaxial Cell

Higher order modes

The Triaxial test procedure uses the principle of Transverse electromagnetic wave propagation (TEM - waves). At higher frequencies the Triaxial cell becomes in principle a cavity resonator respectively a Rectangular waveguide which exhibits resonances depending on its dimensions. Above these resonance frequencies, propagation of TEM - waves is disturbed and measurements of screening attenuation with triaxial test method are limited.

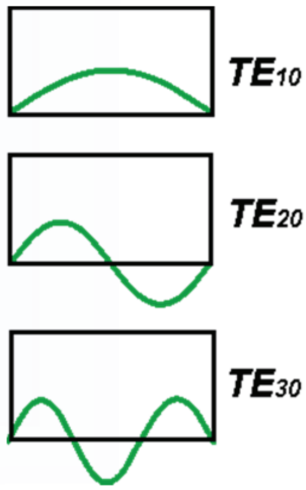
Rectangular waveguide



Resonance frequencies f_r are given by:

$$f_{mnp} = \frac{c_0}{2}\sqrt{\left(\frac{M}{a}\right)^2 + \left(\frac{N}{b}\right)^2 + \left(\frac{P}{c}\right)^2}$$

M,N,P	are the numbers of modes, where M,N stands for the transverse and P for the longitudinal integral multiple of the half of a wavelength (M,N,P = 1,2,3 where M or N can be set to zero)
a,b,c	are the dimensions of cavity; where a,b are coupled to the transverse and c to the longitudinal dimension
c_0	is the velocity of light in free space

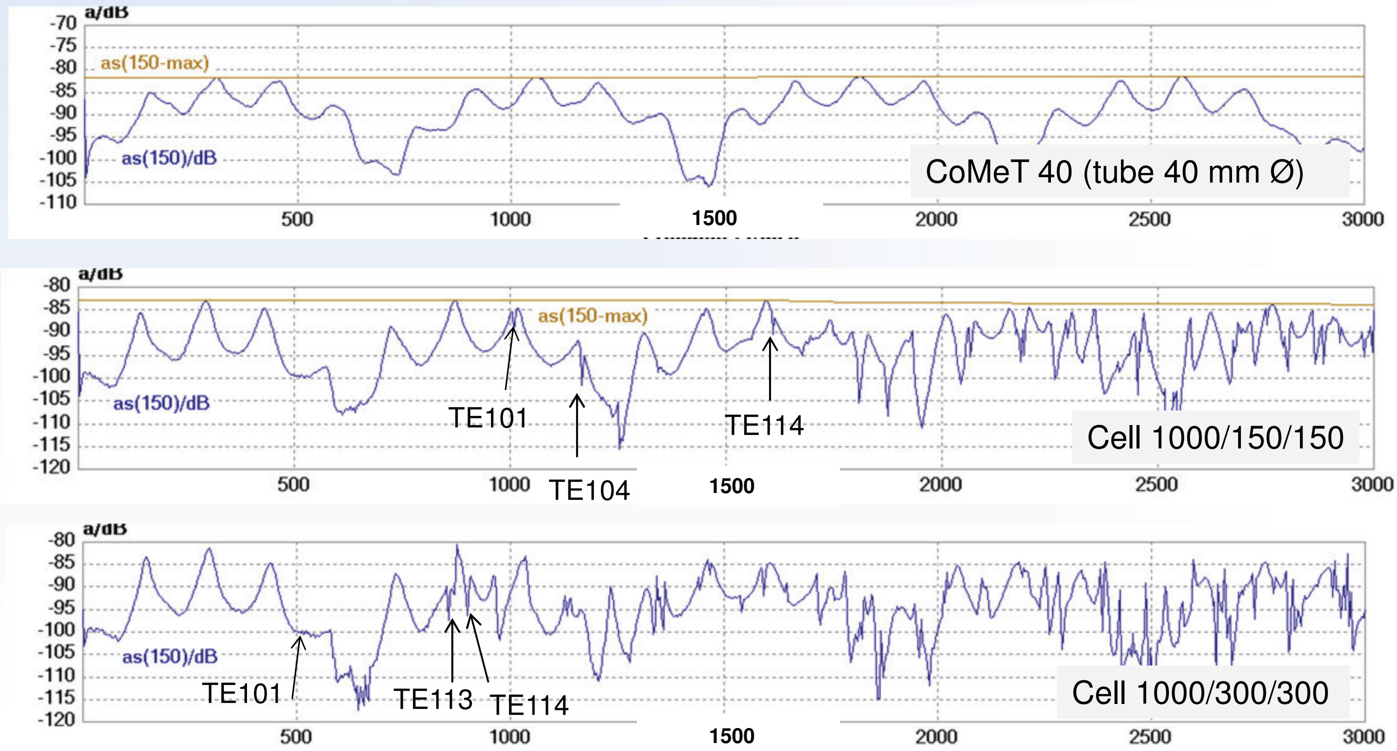


The cut-off frequency f_c of a cavity is given by:

$$f_c = \frac{c_0}{2a}$$

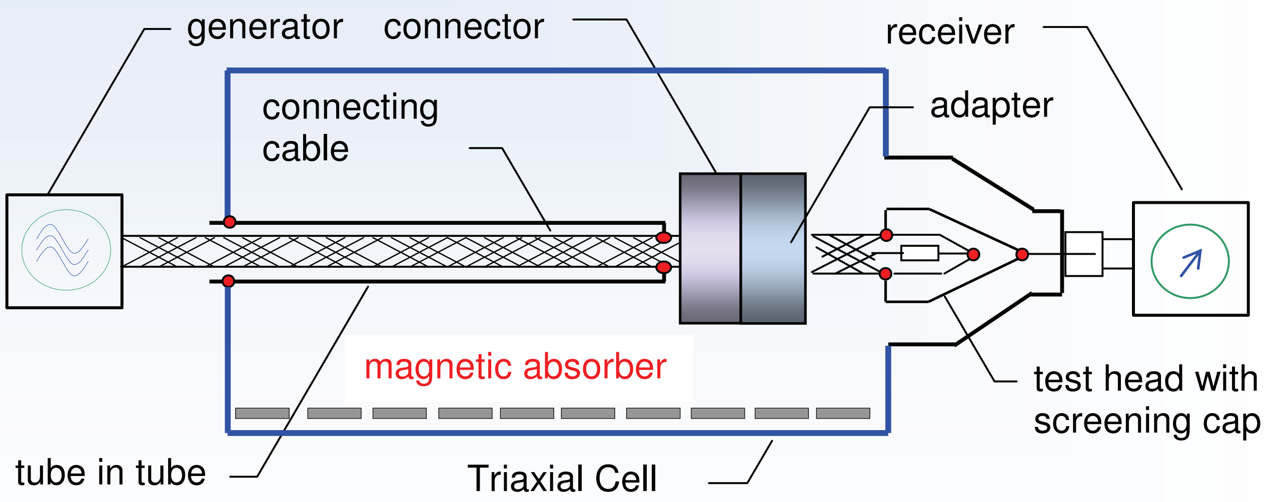
f_c = 500 MHz for Cell 1000/300/300 and 1 GHz for Cell 1000/150/150

Higher order modes in different Triaxial set-ups



Triaxial Cell with magnetic absorber

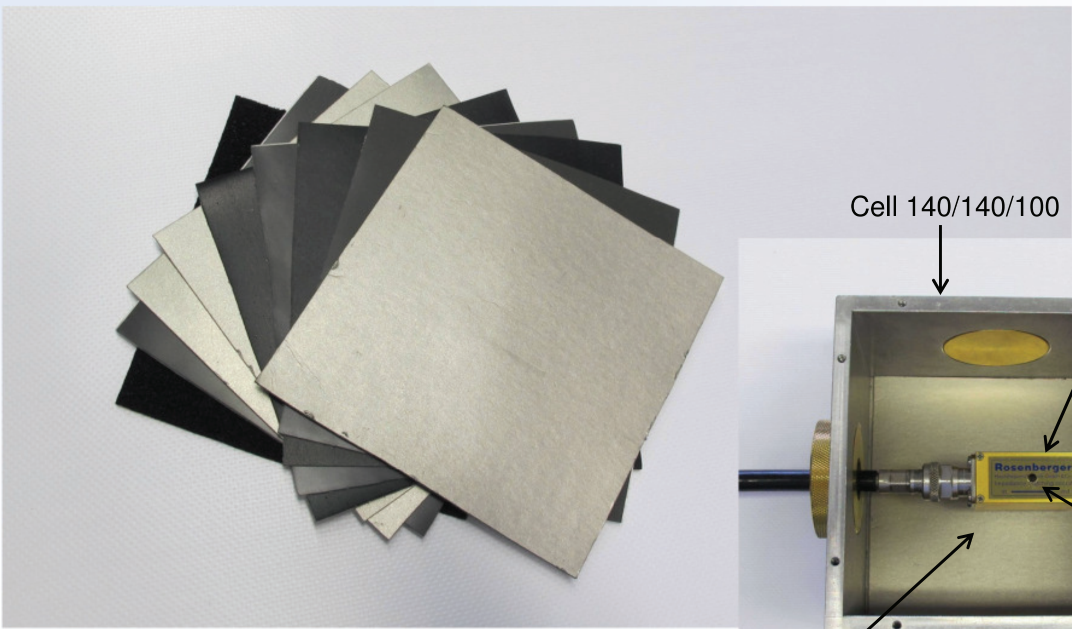
Higher order modes can be easily suppressed by using absorbing materials like ferrite tiles or by nanocrystalline or by magnetic absorbers placed in the Cell

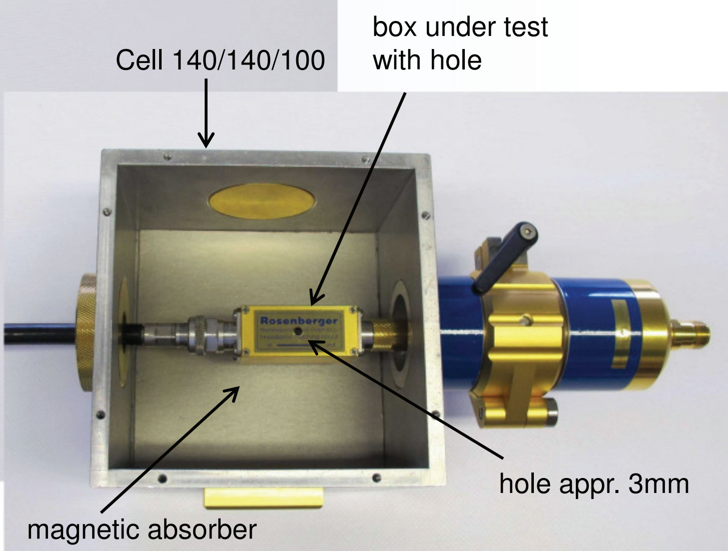


IEC 62153-4-15, Transfer impedance and Screening attenuation with Triaxial Cell

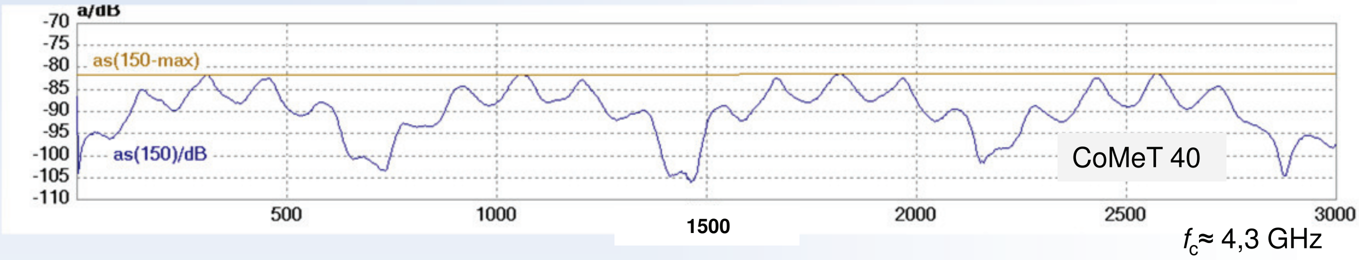
Magnetic absorbers

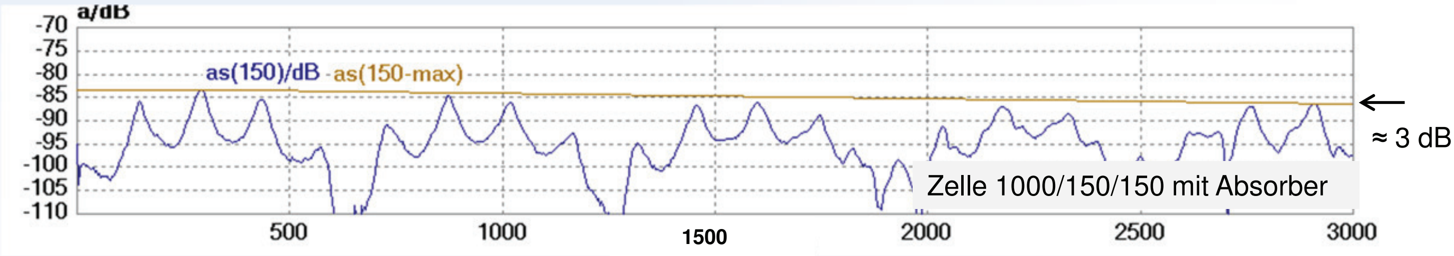
Although other absorber material like ferrites or nanocrystalline absorbers could be useful, measurements were performed with magnetic absorbers due to the good mechanical characteristics and easy handling.

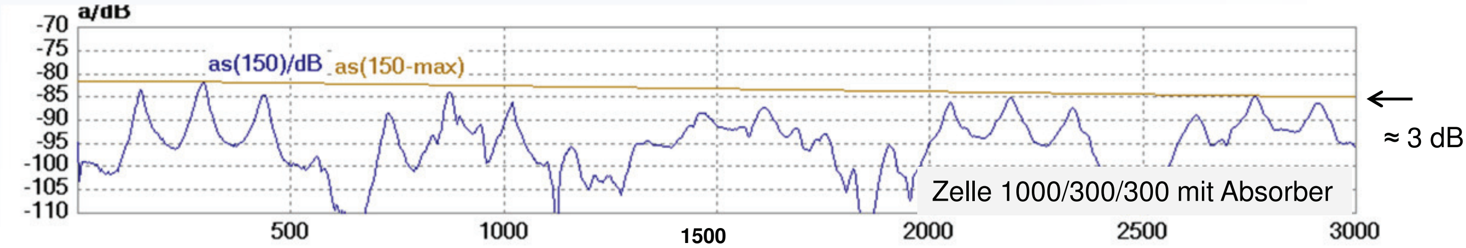




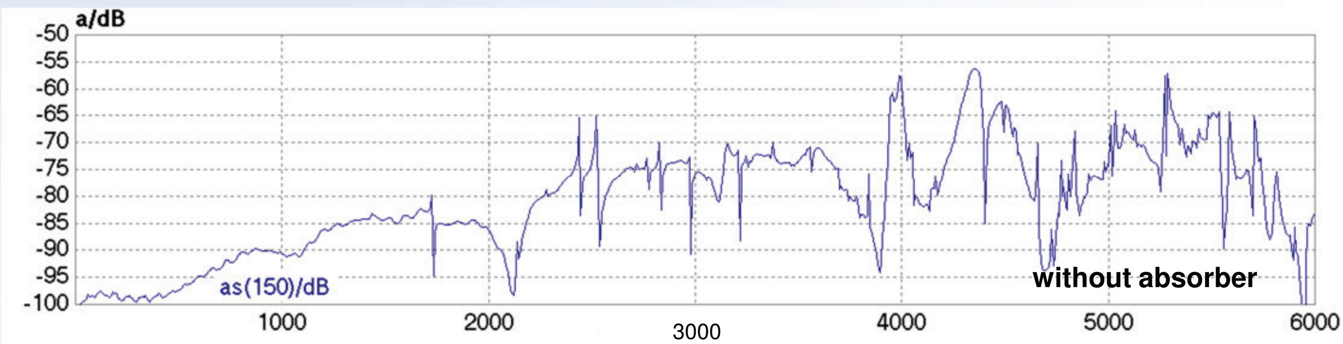
Measurements with magnetic Absorber

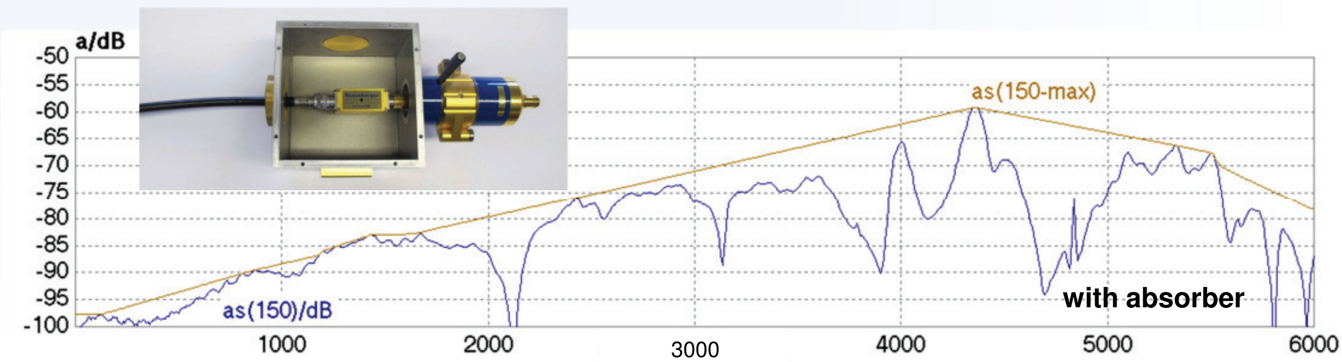




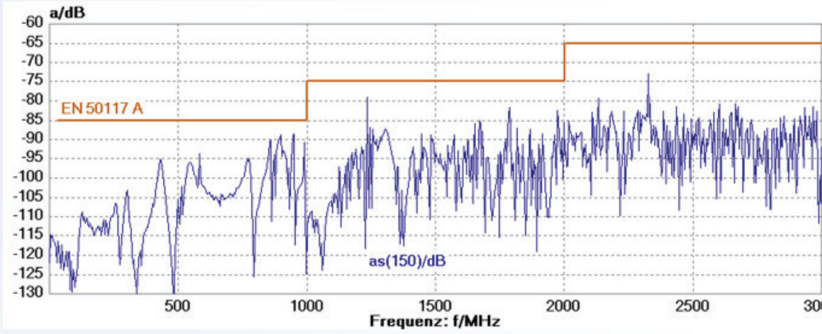


Box with hole in “Absorber – Cell“ 140/140/100

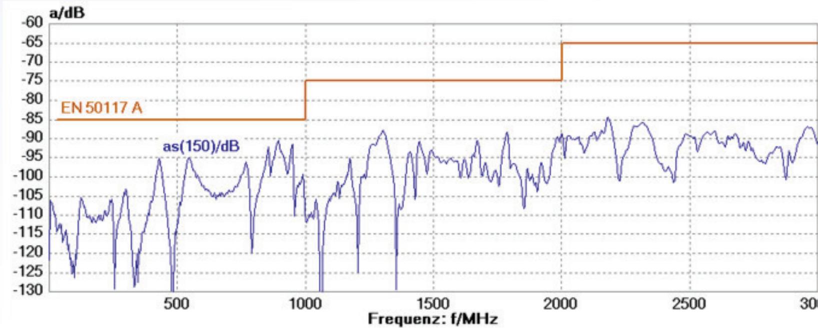




CATV-Tap-off with Triaxial Cell 1000/300/300

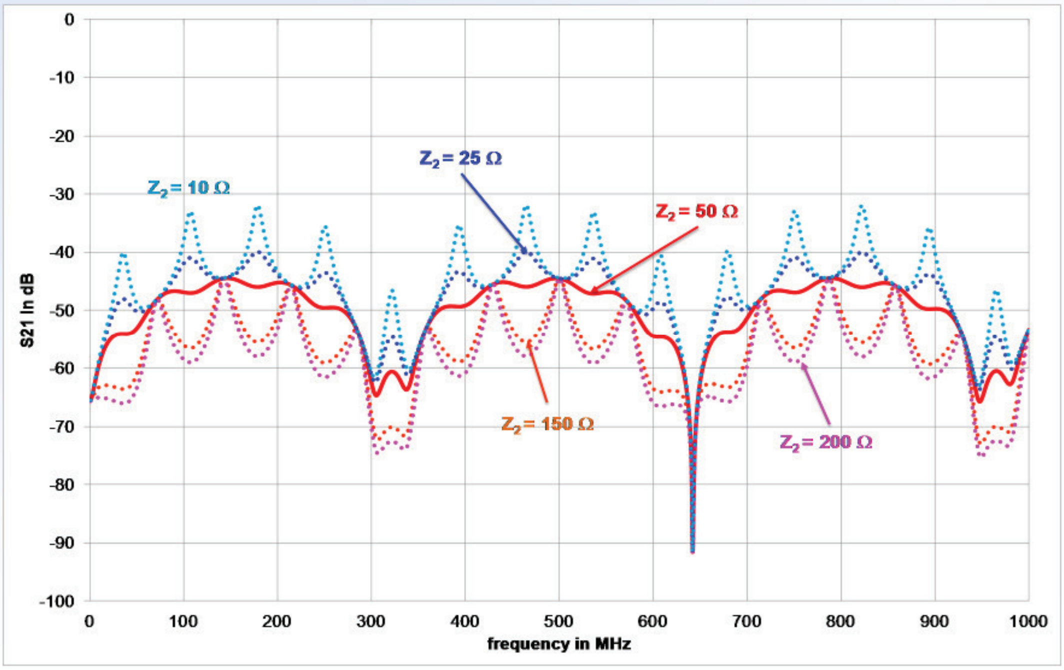


without absorber

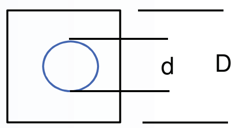


with absorber 3x30x30, 5mm

Impedance Z_2 lower than the input impedance of the receiver



If the characteristic impedance Z_2 of the outer circuit is smaller than the input impedance of the receiver, (50 Ohm) a correction factor shall be used to correct the test results.



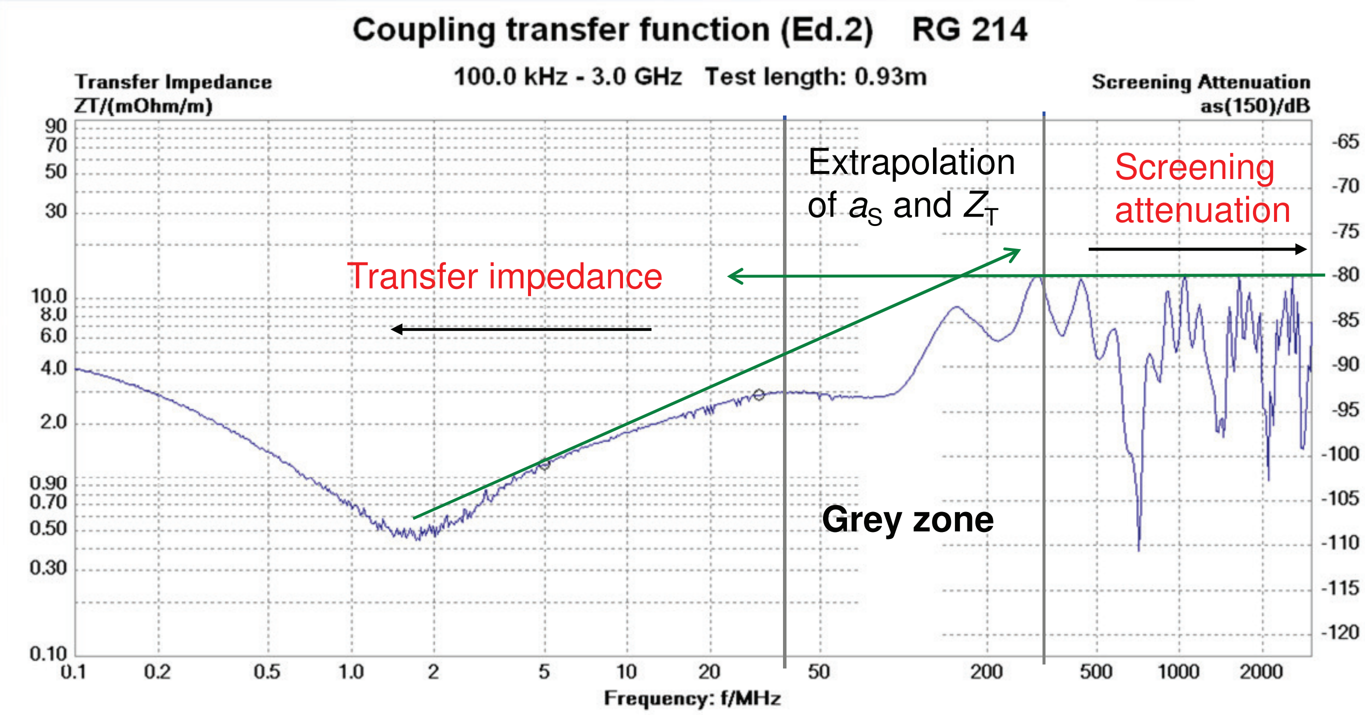
$$Z_2 = \frac{60\Omega}{\sqrt{\varepsilon_{r1}}} \cdot \ln\left(1{,}27 \cdot \frac{D}{d}\right)$$

$$a_{corr} = -20 \cdot \lg\left(\frac{R}{Z_2}\right)$$

(approximations)

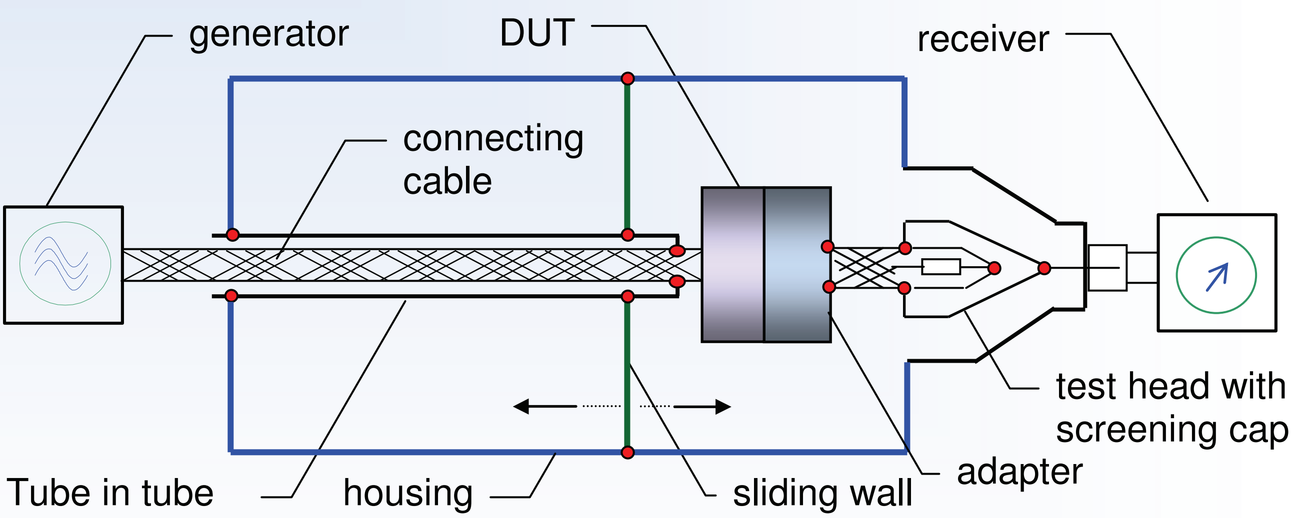
IEC 62153-4-15, Triaxial cell, Annex G: For nonuniform DUT the correction is not strait forward as additional reflections superpose the results. This case is under further study by IEC TC 46/WG 5

Draft IEC 62153-4-16, Conversion of a_S and Z_T



draft standard by Thomas Hähner

Triaxial Cell with tube in tube and sliding wall



IEC 62153-4-15, Triaxial cell, Annex F

Triaxial Cell with tube in tube & sliding wall

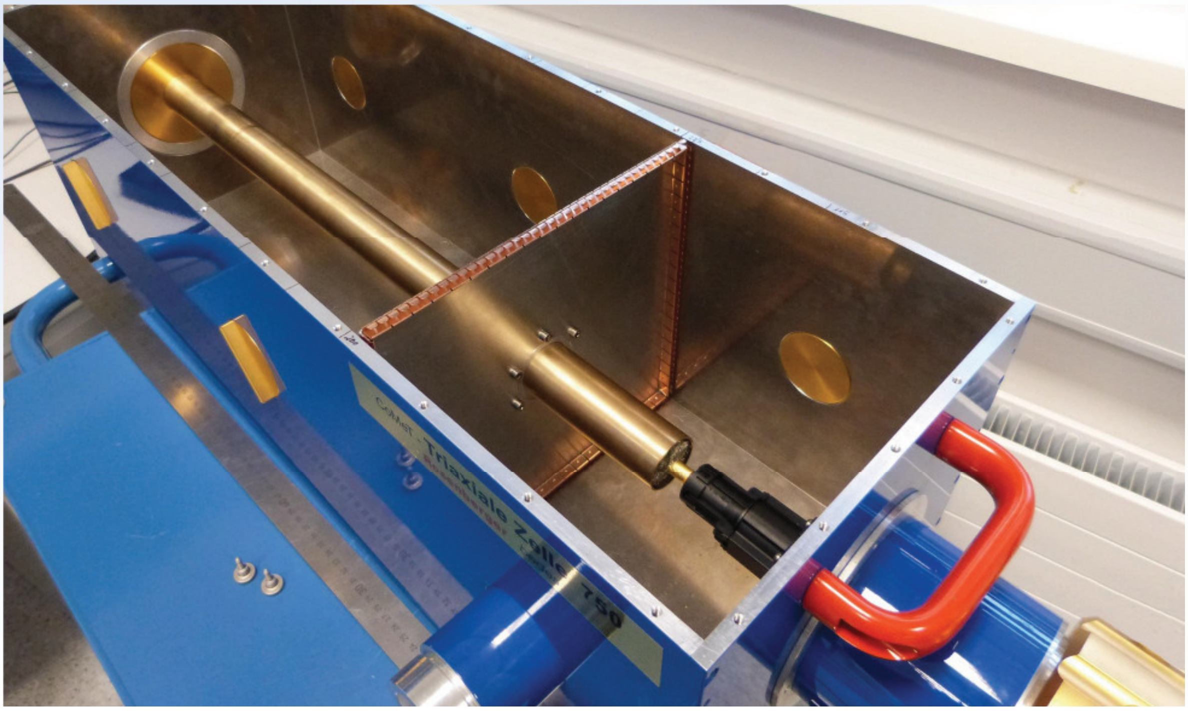
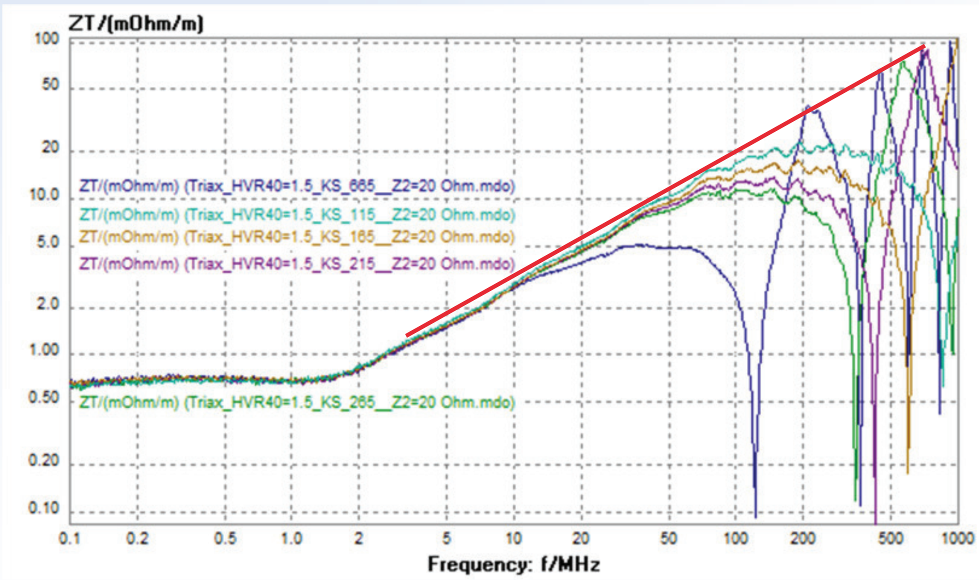
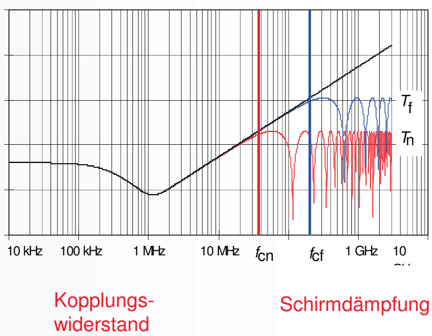


Foto: Thomas Schmid

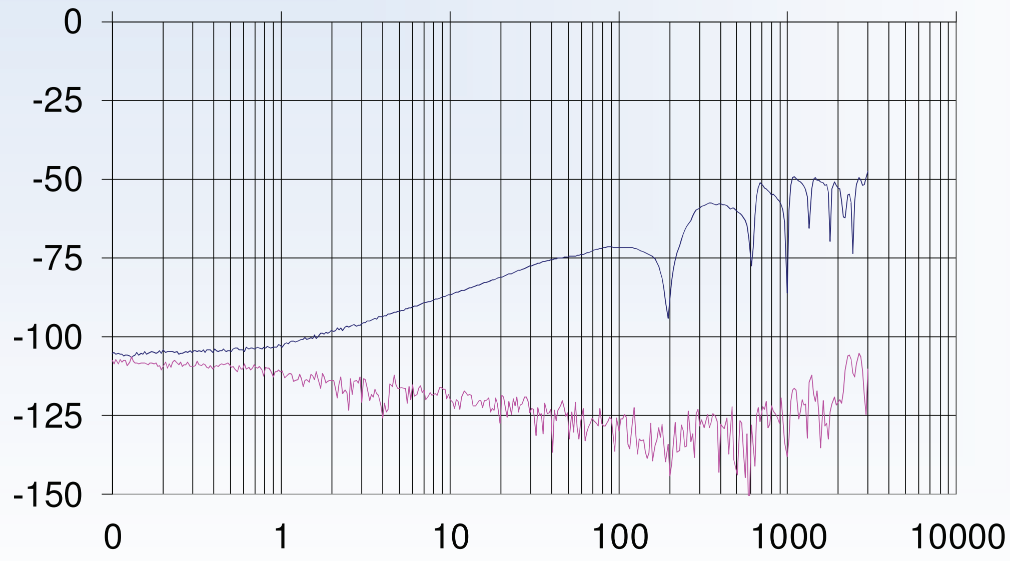
Triaxial Cell with tube in tube and sliding wall

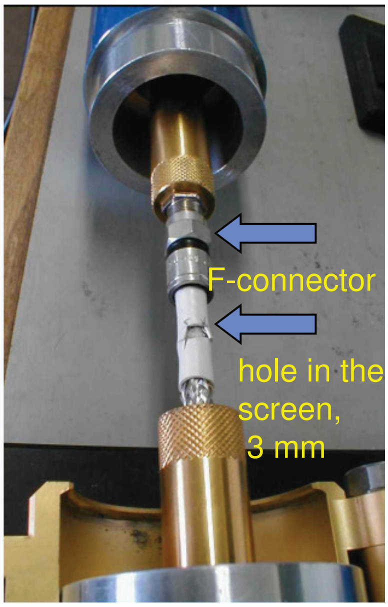




Durch Verschieben der Kurzschlussebene der Zelle verschiebt sich auch die Frequenz des Übergangs von Kopplungswiderstand zur Schirmdämpfung.
Die Hüllkurve ergibt Transferimpedanz bzw. den Kopplungswiderstand des Prüflings

influence of a small hole



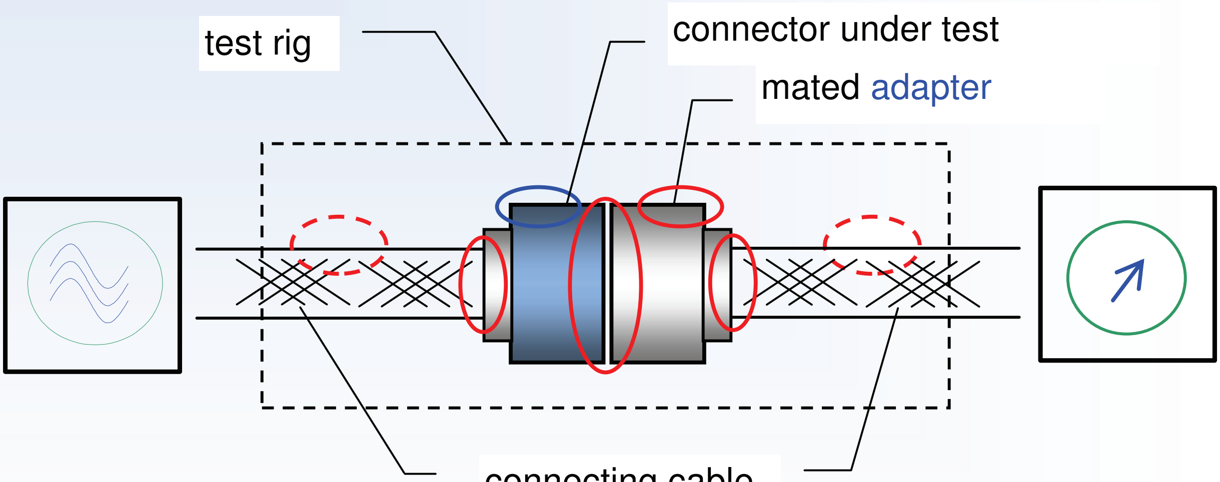


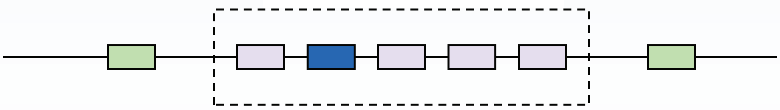
Telass 110 with F-connector

same device with hole, 3 mm

Common problems on connector test

Connectors can be measured mated only, respectively with appropriate test-adapter



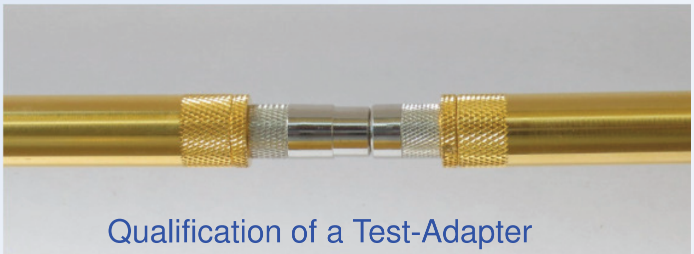


transfer impedances are adding !

Cable assemblies

To measure Z_T und a_S on connectors and assemblies, appropriate adapters are required

Test-Adapter for IEC 61169-2 - Connector, Tube in tube



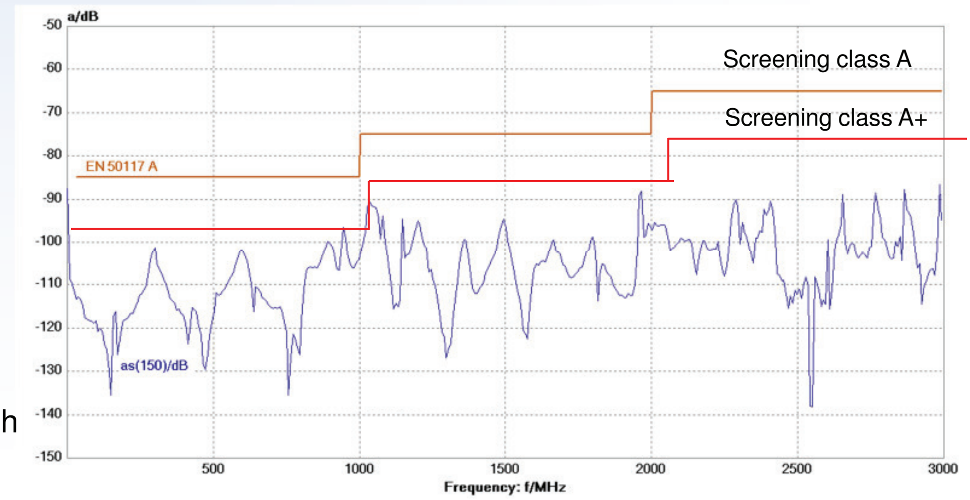
Test-Adapter
for IEC 61169-2 - connector
male and female with F- female
connector each
with “tube in tube“-procedure

The test adapter limits the sensitivity of the system

The test adapter used shall be reportet in the test report

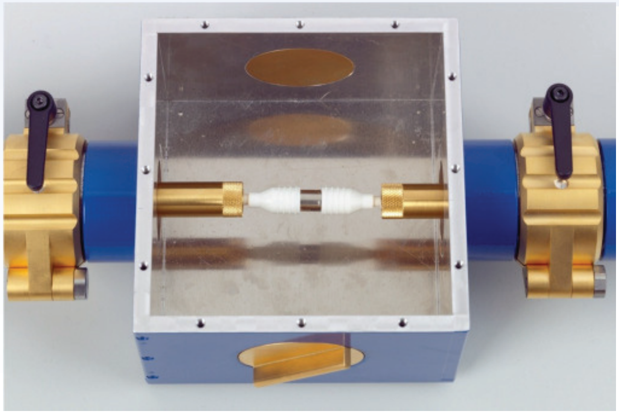
The distance of the curve of the DUT to the limits of the adapter curve should be 10 dB

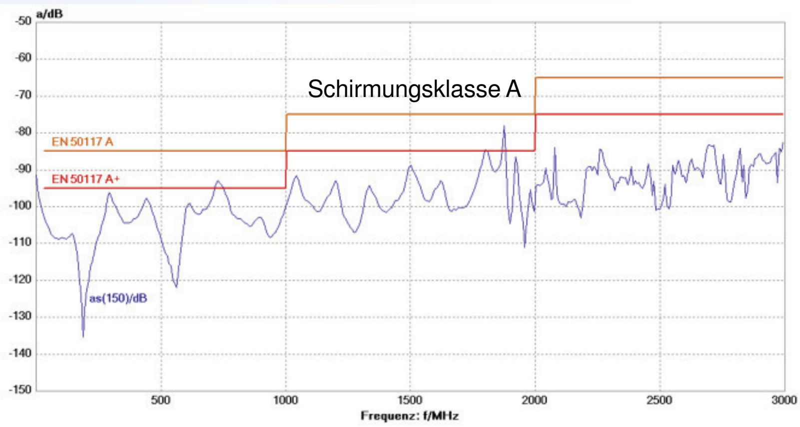
To measure an assembly with screening class A, an adapter with screening class A+ is required



Assembly with mated connectors

The cable assembly with mated connectors may be cut, connected together and treated as a coaxial cable.

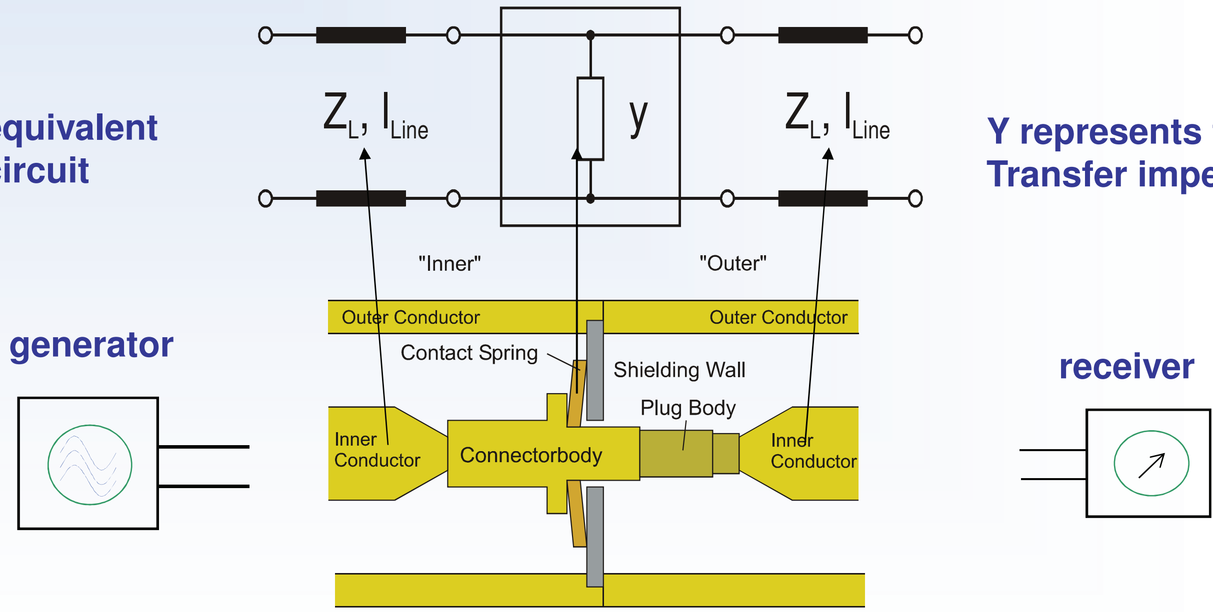




EMC of Feed-throughs & EMC Gaskets

equivalent circuit

generator

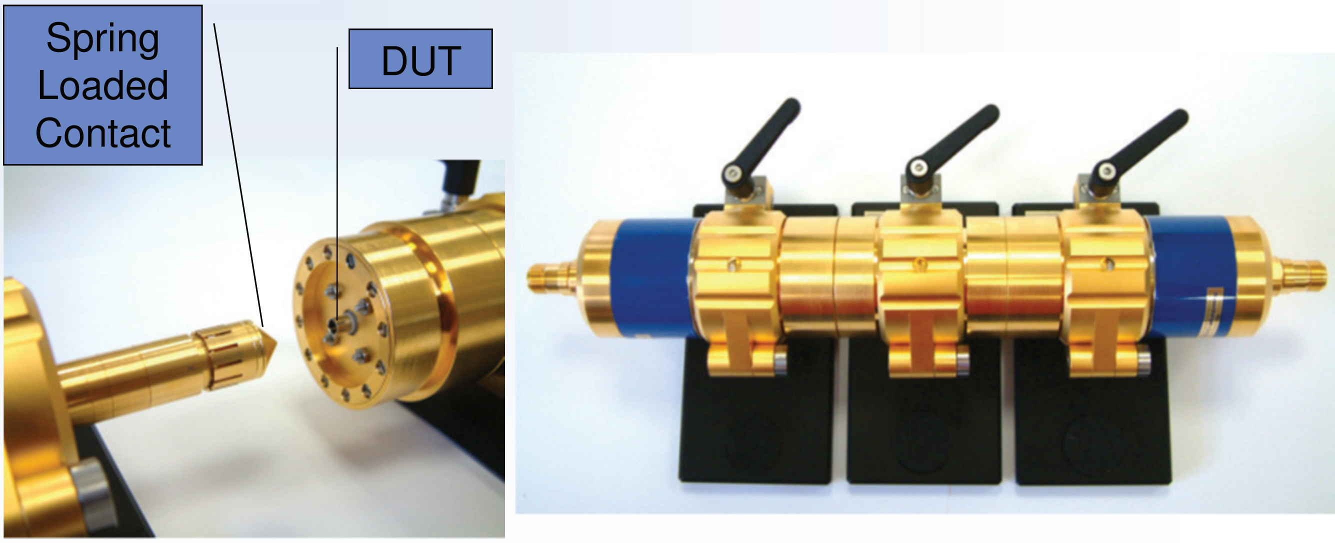


receiver

Y represents the Transfer impedance

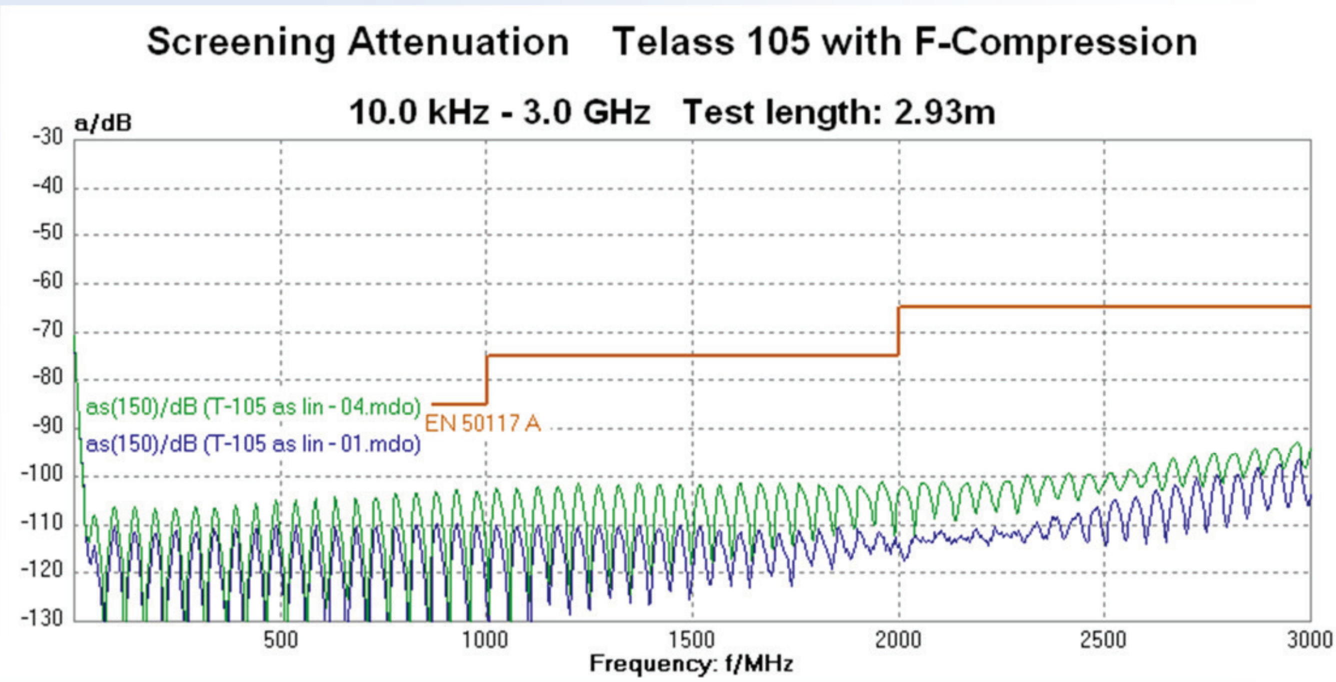
Generator & receiver are included in the NWA

Test set-up for Feed-throughs & gaskets



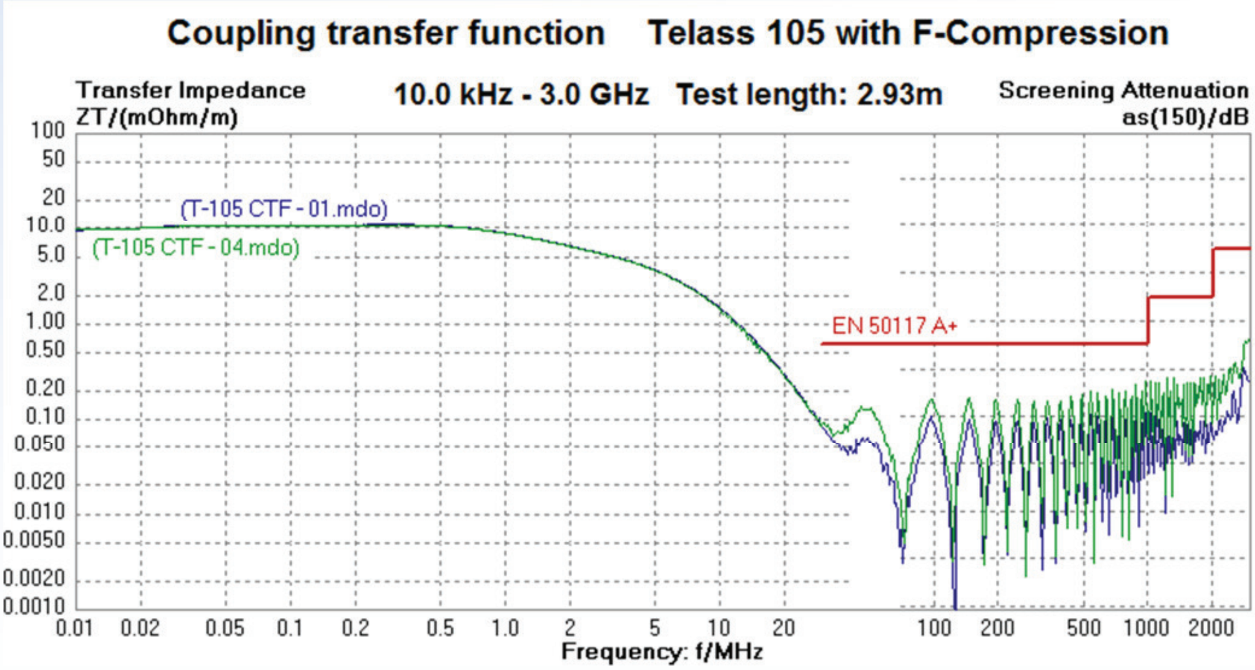
IEC 62153-4-10Ed2

Long term behaviour of foil braid screens



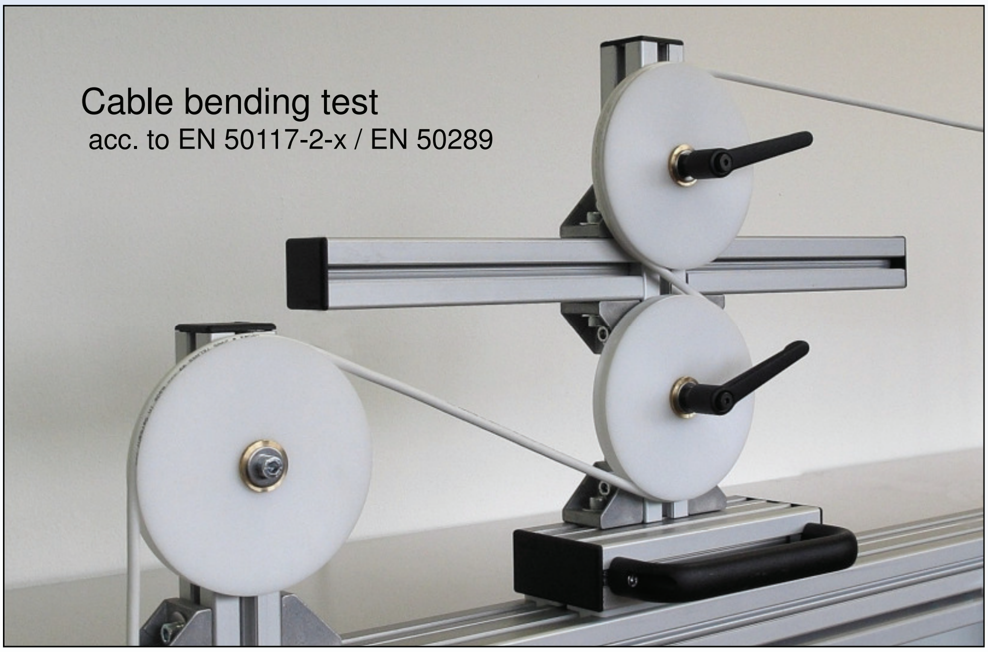
------- sample without bending test ------- after 4 days storage in the tube without any change

Long term behaviour of foil braid screen



------- sample without bending test ------- after 4 days storage in the tube without any change

Cable bending test according to EN 50117-2-x / EN 50289



EN 50117-2-1 to -2-5 and -4-1

Transfer impedance
Screening Class A: ≤ 5 mΩ/m from 5 MHz to 30 MHz;
Screening Class B: ≤ 15 mΩ/m from 5 MHz to 30 MHz.

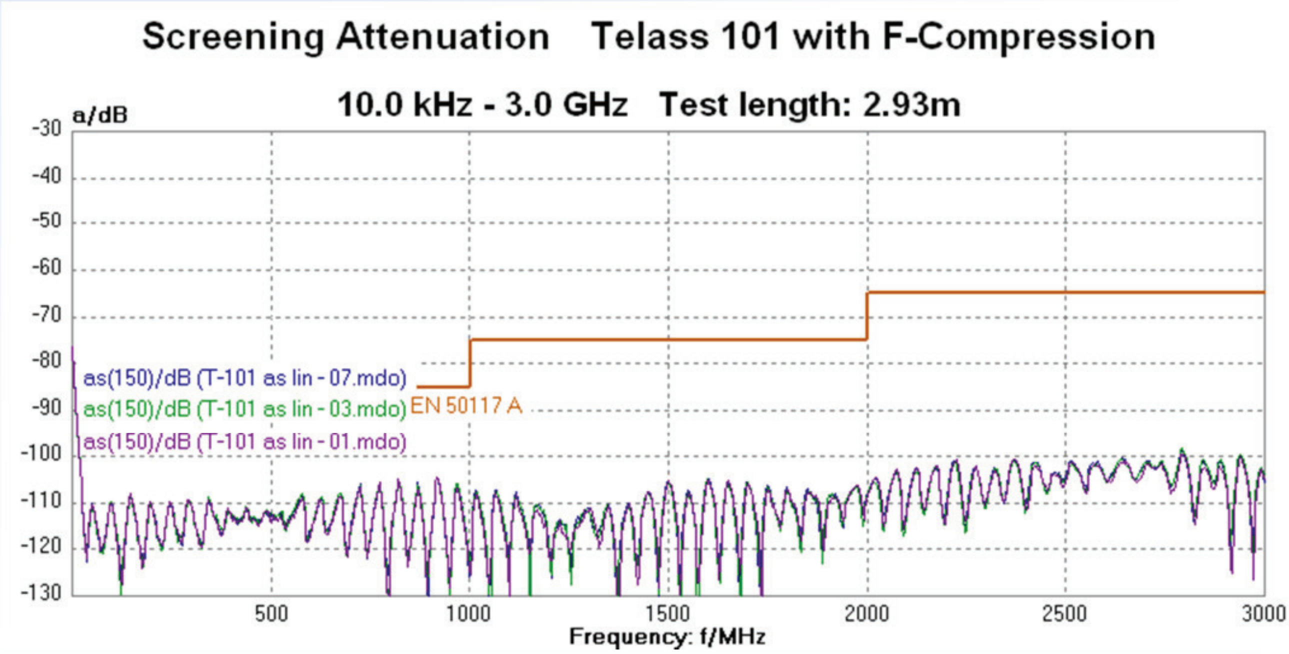
Test procedure according to EN 50289-1-6, triaxial method, **after completion of the flexure test according to 5.2.9 of this standard.**

Screening attenuation
Screening Class A: ≥ 85 dB from 30 MHz to 1 000 MHz;
Screening Class B: ≥ 75 dB from 30 MHz to 1 000 MHz;

Test procedure according to EN 50289-1-6, triaxial method, **after completion of the flexure test according to 5.2.9 of this standard.**

Bending test will be enhanced acc. to the proposal of Prof. Schwarzenau in the next Editions. of EN 50117 series

Long term behaviour after bending test



------- sample after bending test ------- after 4 days storage ------- after 7 days storage in the tube

Screening classes according to IEC 61196 & EN 50117

2002 - Introduction of screening classes into the standards of IEC 61196 series and EN 50117 series (CATV cables) Screening effectiveness shall be measured with Triaxial procedure acc. to IEC 62153-4-3 /-4-4 only.

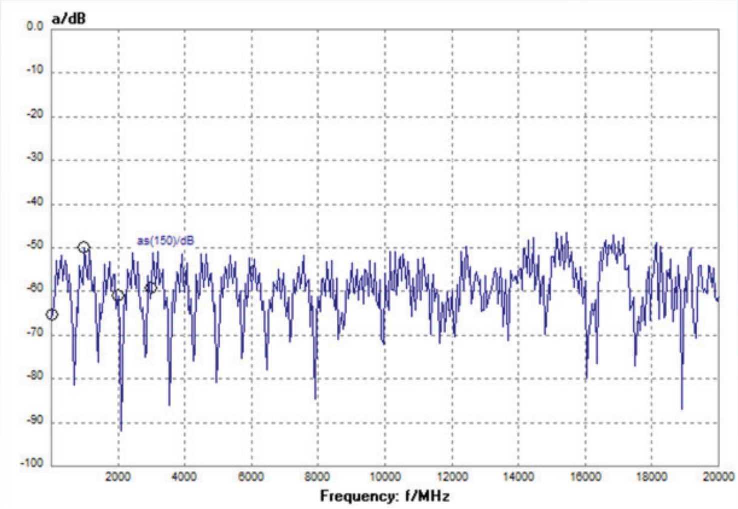
screening-class	5 - 30 MHz	30 -1000 MHz	1 GHz – 2 GHz	2 GHz – 3 GHz
C	*50 mOhm/m*	*75 dB*	*65 dB*	*55 dB*
B	15 mOhm/m	75 dB	65 dB	55 dB
A	**5 mOhm/m**	**85 dB**	**75 dB**	**65 dB**
A+	2,5 mOhm/m	95 dB	85 dB	75 dB
A++	0.9 mOhm/m	105 dB	95 dB	85 dB

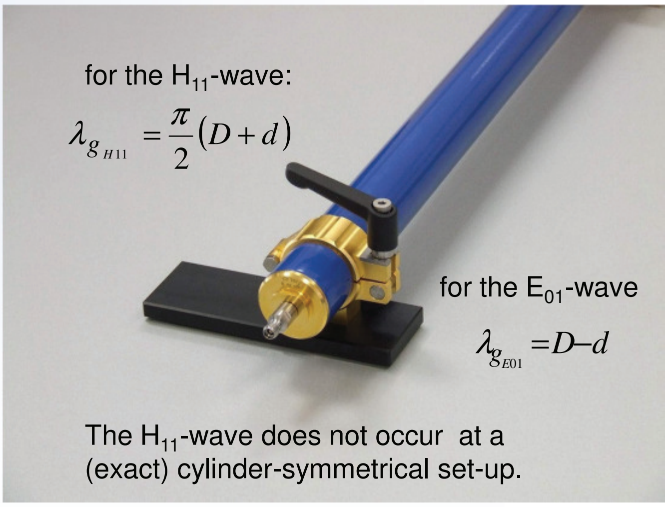
The same classification scheme is valid for coaxial cables according to TV receiver leads according to IEC 60966-2-n series

For non problematic coexistence between CATV networks and radio services like GSM, LTE, 5G …. a screening class of at least Class A is recommended.

2004 – CoMeT 18

2004, Customer wants to measure 9 GHz, according to the equation $f_g = \frac{2 \cdot c_0}{\pi \cdot \sqrt{\varepsilon_{r1}}(D+d)}$
the cut off frequency was expected at 9 GHz,
but the **CoMeT 18** works up to 18 GHz (20 GHz)





2005 - Diploma work Ballier, - Influence of higher order modes -
CoMeT 40 with "mode screw" – CoMeT 40 with modified test head now up to 12 GHz

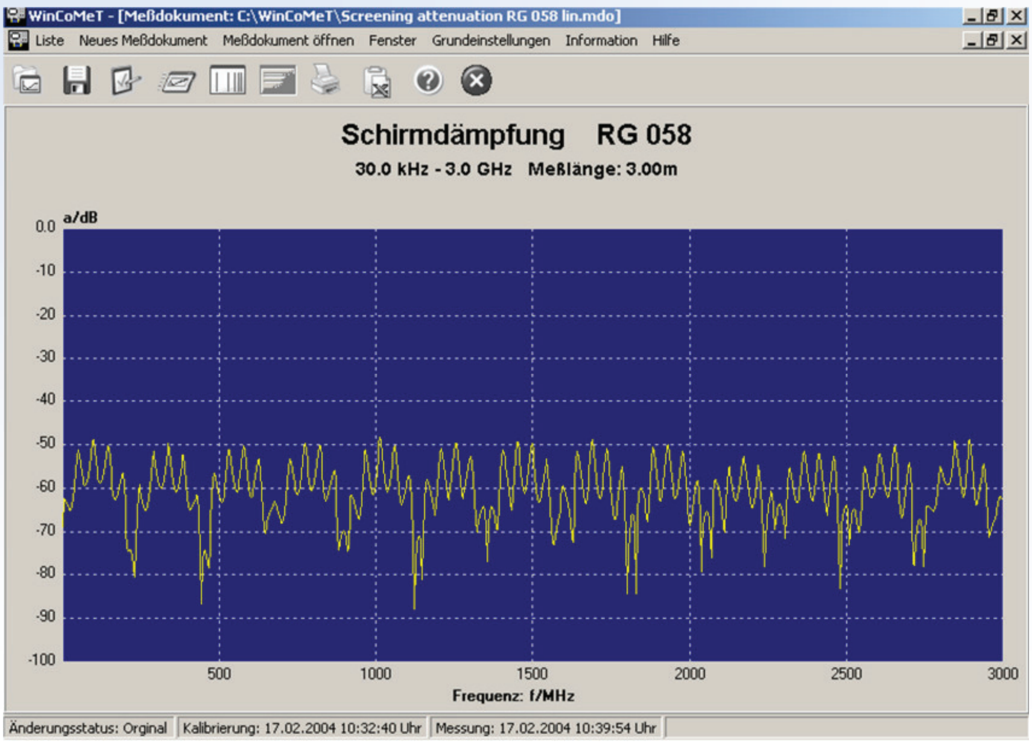
Conclusion 1

- The Screening effectiveness of Communication cables is described in the lower frequency range by the **Transfer impedance Z_T** and in the upper frequency range by the **Screening attenuation a_S**.
- At screened balanced cables, the **Coupling attenuation a_C** is the measure of the screening effectiveness as the sum of the **Unbalance attenuation** of the pair and the **Screening attenuation** of the screen.
- With the test system ***CoMeT*** of ***bedea*** one can measure the **Transfer impedance Z_T** as well as the **Screening attenuation a_S** in the from DC up to 8 (12) GHz with one test set-up
- Furthermore, the **Coupling attenuation a_C** of screened and unscreened balanced pairs may be measured.
- Test set-up is in acc. with IEC 62153-4-3/-4-5/-4-7
- as well as IEC 62153-4-9, IEC 62153-4-10 & IEC 62153-4-15

Conclusion 2

- **Advantages of the triaxial test-set-up**:
  - simple and easy sample preparation
  - only one test set up for Z_T, a_S & a_C
  - high sensitivity up to and above 125 dB (only limited by the NWA)
  - no radiation of electromagnetic energy
  - covers the whole frequency range from 10 kHz to 8 GHz
  - high reproducibility
- New developments are Measuring the screening effectiveness of unscreened balanced pairs and low freuency coupling attenuation acc. to IEC 62153-4-9
- Further information: *(www.bedea.com) www.bda-c.com*
- Contact person & further questions *bernhard.mund@bda-c.com*

Control and Evaluation Software WinCoMeT



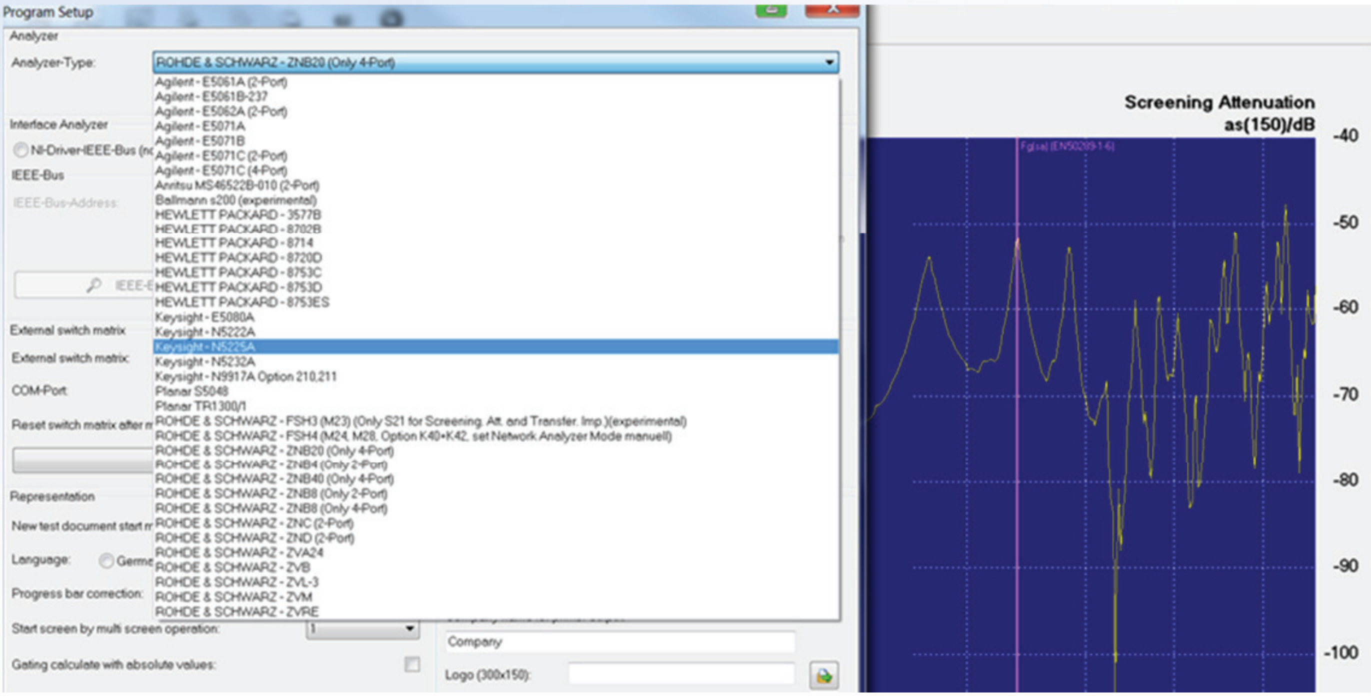
- Control of the Network analyser

- evaluation of test results
- documentation

- Data export to MS-Excel
- printing

- fullversion with transmission Parameters of Communikation cabes including
- FFT and

WinCoMeT – List of included network analyzer



Thanks for listening

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