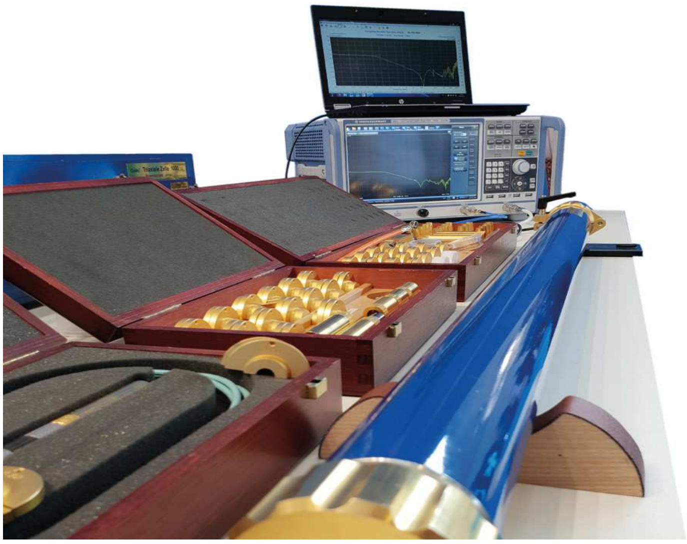
EMC of SPE Cables, Connectors & Assemblies



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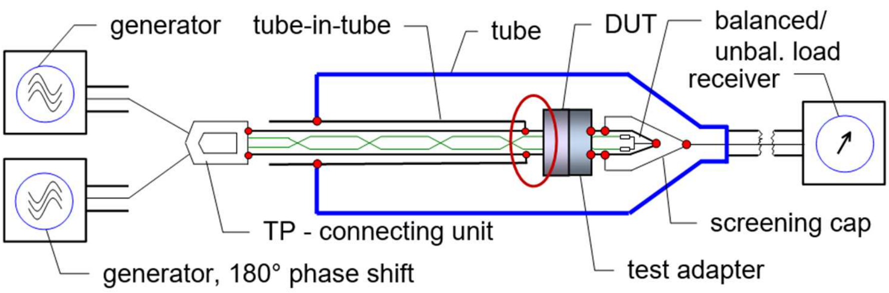
EMC of SPE Cables, Connectors and Assemblies

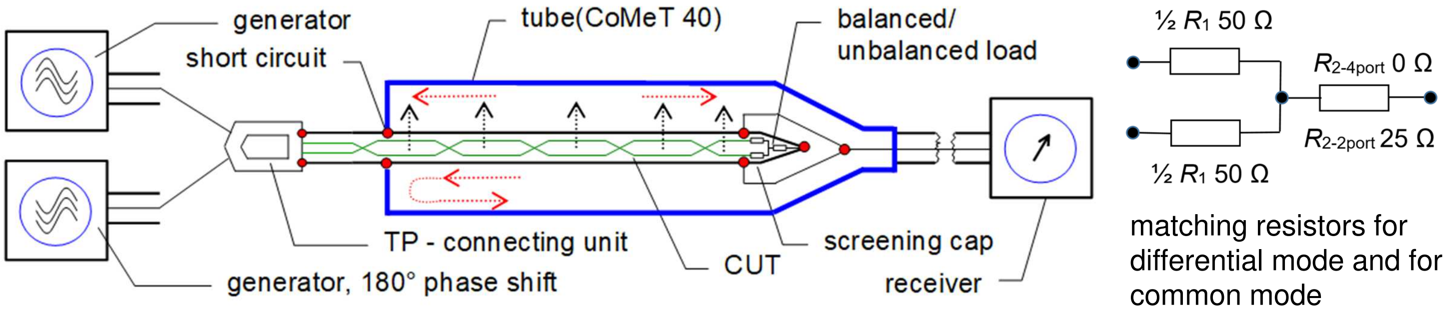
Overview

- Coupling Attenuation at Low Frequencies, LFCA
- Unbalance Attenuation resp. Mode Conversion
- System Verification
- Normalization
- Measurements
  - SPE cables
  - SPE connectors
- Outlook & Discussion



Abbreviations:
SPE = Single Pair Ethernet, **CA** = Coupling Attenuation, **LFCA** = Low Frequency Coupling Attenuation

Low Frequency Coupling Attenuation LFCA, Principle



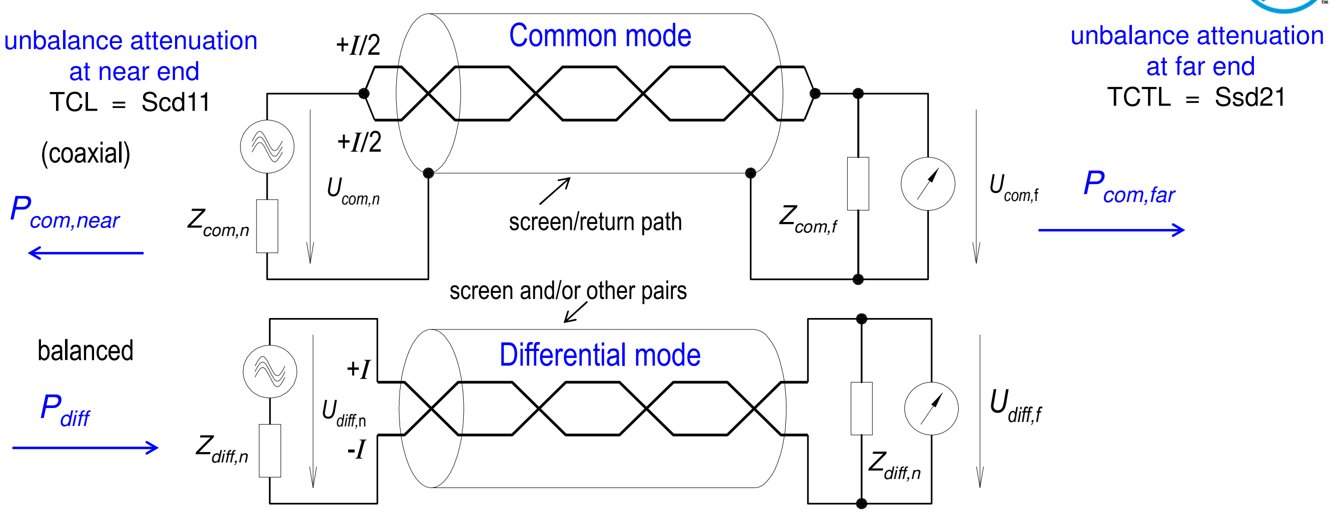
The balanced pair is fed with a 100 Ohm signal by two 50 Ohm generators with 180° phase shift (virtual balun). Energy couples from the “differential mode“ into the “common mode" (mode conversion) and then from the “common mode“ into the measuring tube (the outer circuit).

The short circuit at the near end causes a total reflection and the complete energy which coupled into the outer circuit is travelling to the receiver.

According to IEC 62153-4-9, Coupling attenuation can be measured only from 30 MHz upwards.

With the extension of IEC 62153-4-9Amd1 the **L**ow **F**requency **C**oupling **A**ttenuation, LFCA can be measured now from 100 kHz upwards. – Proposed test length is 3 meter.

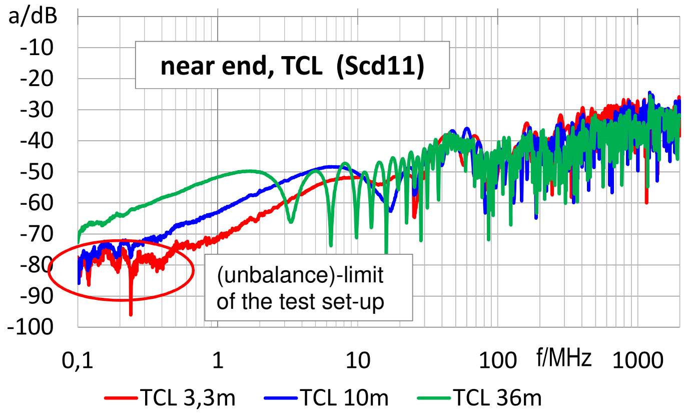
Unbalance Attenuation resp. Mode Conversion

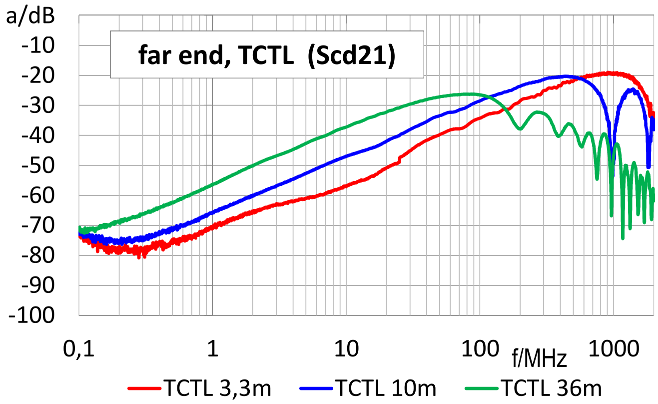


The "Unbalance Attenuation" of a pair describes as logarithmic ratio, how much power couples from the differential mode to the common mode and vice versa. It is the logarithmic ratio of the input power in the differential mode P_{diff} to the power which couples into the common mode P_{com}: $a_U = 10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

Unbalance Attenuation of an SPE Cable at different Length

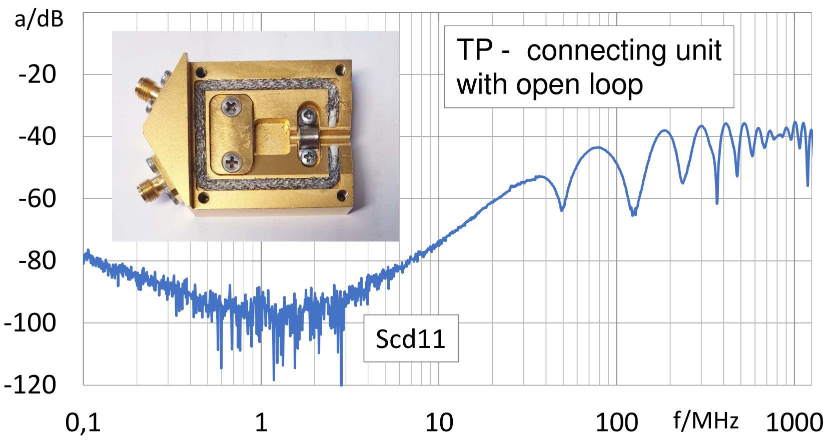
single pair screened AWG 23/1 cable at different length

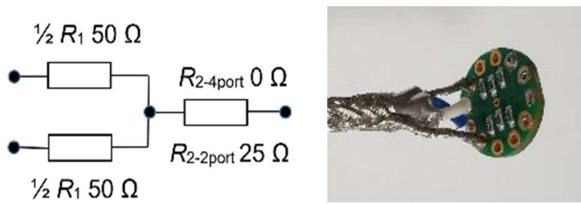




At high frequencies, the unbalance attenuation asymptotically approaches a limit value, (about -25 dB).
At low frequencies, the unbalance attenuation increases (the mode conversion decreases).
In addition, shorter lengths have a higher unbalance attenuation than longer lengths.
The (symmetry)-limit of the measuring system is reached in the range of approximately -80 dB.

System Verification





terminating resistors & PCB

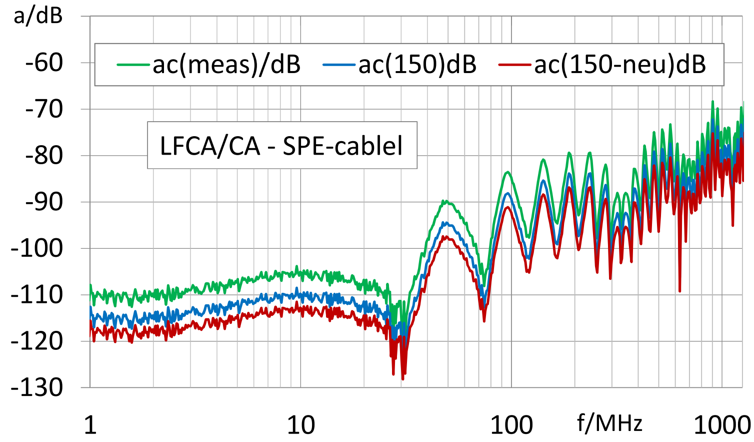
An estimation of the system mode conversion can be done by measuring the Scd11 parameter of a TP connecting unit with open loop.

The mode conversion of the test system at low frequencies is about -80 dB and rises to about -40 dB at high frequencies.

At low frequencies, the unbalance attenuation of the terminating resistors can exceed the unbalance agttenuation of the test objects and can therefore falsify the test t results.

A tolerance of 0.1% of the terminating resistors used is considered sufficient

Normalization of CA/LFCA of an SPE Cable



In order to compare triaxial measurements of the coupling attenuation with measurements using absorbing clamps, an arbitrary normalized value of $Z_S = 150\ \Omega$ was introduced in the standards.

This results in the coupling attenuation a_C to:

$$a_C = 20\log_{10}\left|\frac{U_{diff}}{U_{2,max}}\right| + 10\log_{10}\left[\frac{2Z_S}{Z_{diff}}\right]$$

with $Z_S = 150\ \Omega$ and $Z_{diff} = 100\ \Omega$ the correction value results in 4,8 dB.

However, instead of the voltage ratio $U_{diff}/U_{2,max}$ network analyzer give S-Parameter as result.

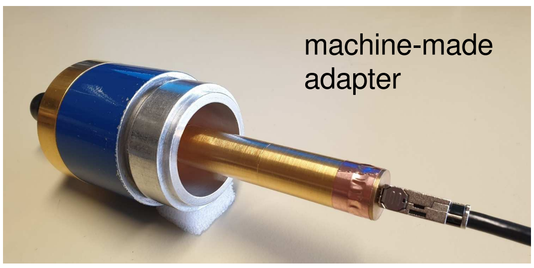
As the term $U_{diff}/U_{2,max}$ is often incorectly interpreted as S-Parameter Ssd21, IEC TC 46/WG5 proposes the following new expression:

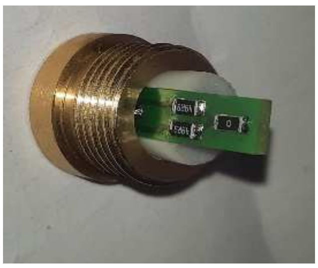
$$a_C = -20\log_{10}|S_{sd21}| + 10\log_{10}\left|\frac{Z_{diff}}{Z_0}\right| + 10\log_{10}\left|\frac{2Z_S}{Z_{diff}}\right| \rightarrow a_C = -20\log_{10}|S_{sd21}| + 10\log_{10}\left|\frac{2Z_S}{Z_0}\right|$$

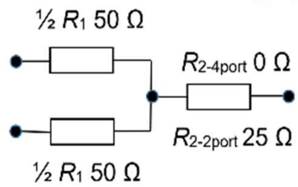
with $Z_S = 150\ \Omega$ and $Z_0 = 50\ \Omega$ the correction value results in 7,8 dB.

Test results in this presentation are raw values without correction.

Test Adapter







terminating resistors
integrated in the test adapter

When measuring CA/LFCA on SPE connectors or cable assemblies, appropriate test adapters are required. Test adapters can be machine-made or self-made by using a connectorized SPE cable.

Coupling Attenuation of an SPE Connector

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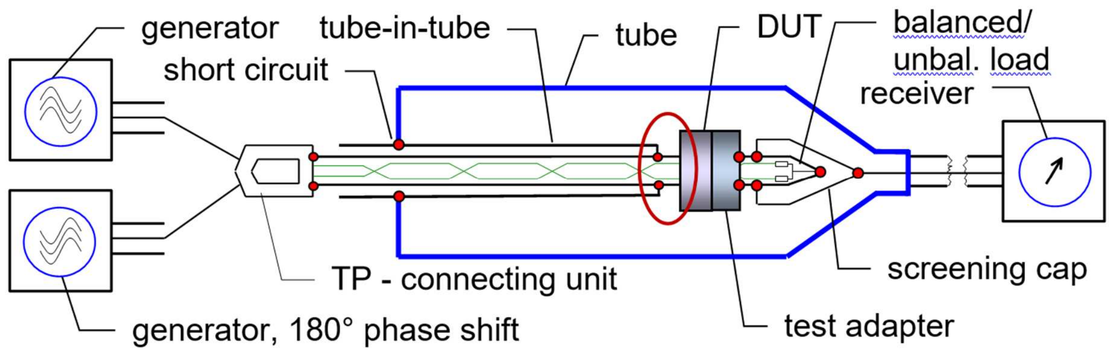
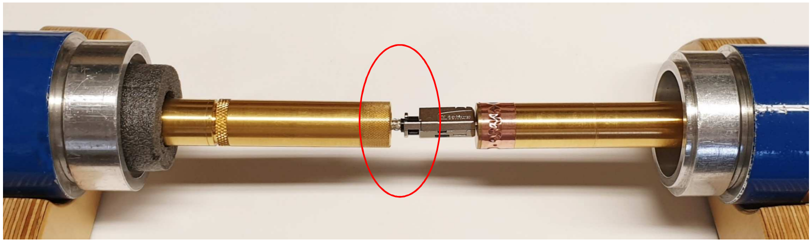


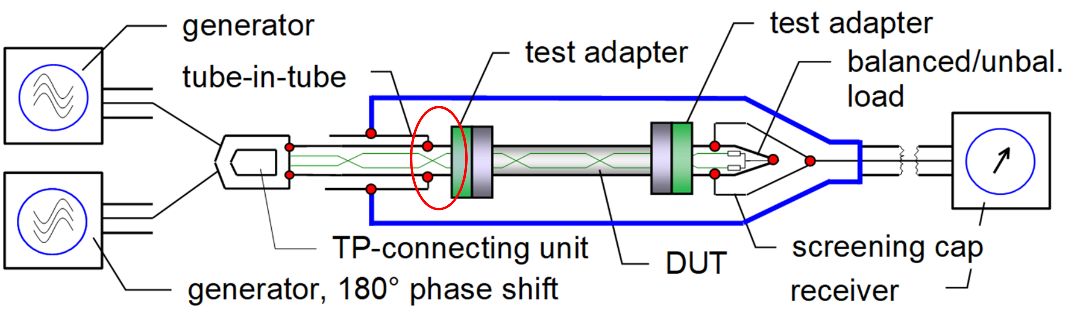


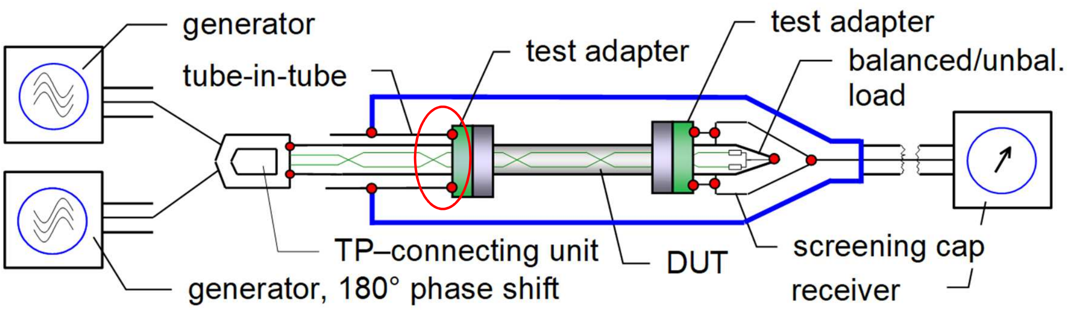
Measuring of **CA**/**LFCA** of an SPE connector with tube-in-tube procedure according to IEC 62153-4-7Ed3 with ready-made test adapter

recommended test length: 3 m (tbd further)

Coupling Attenuation of SPE Assemblies

IWCS



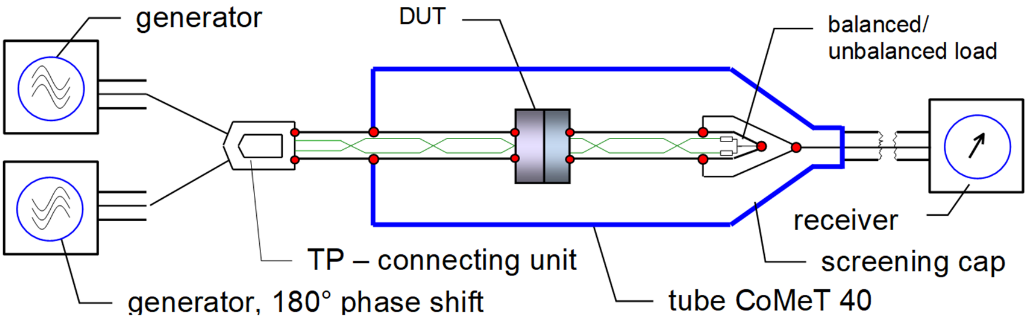


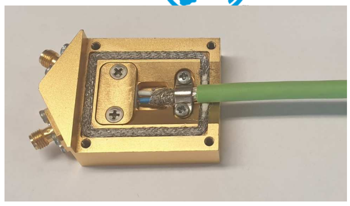
Test set-up for SPE assemblies with tube-in-tube.

the tube-in-tube can be connected to the feeding cable to measure both, the confection of connector and cable and the connector itself (upper graph)

another option is to connect the tube-in-tube directly to the test adapter

Assembly with Mated Connector Pair





TP-connecting unit

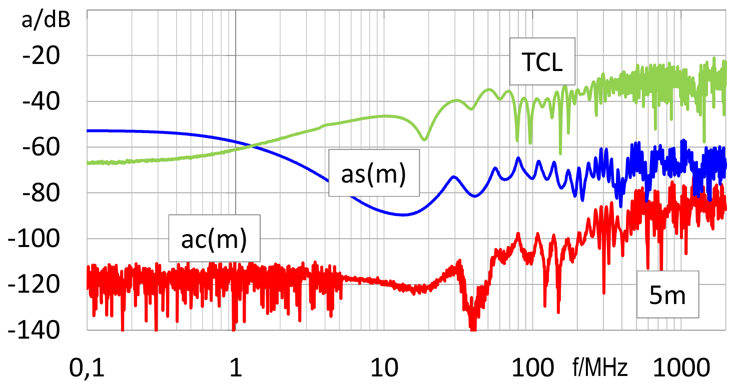
SPE connector under test

SPE assembly with mated connector pair in the middle of the tube

If the assembly is longer than the measuring tube, the assembly can be split in the middle and then coupled together.
The measurement is then analogous to the measurement of SPE cables

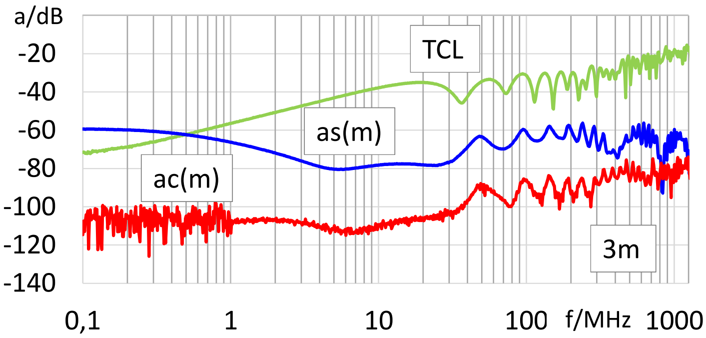
recommended test length: 3 m, (tbd further)

Test Results of different SPE-Cables



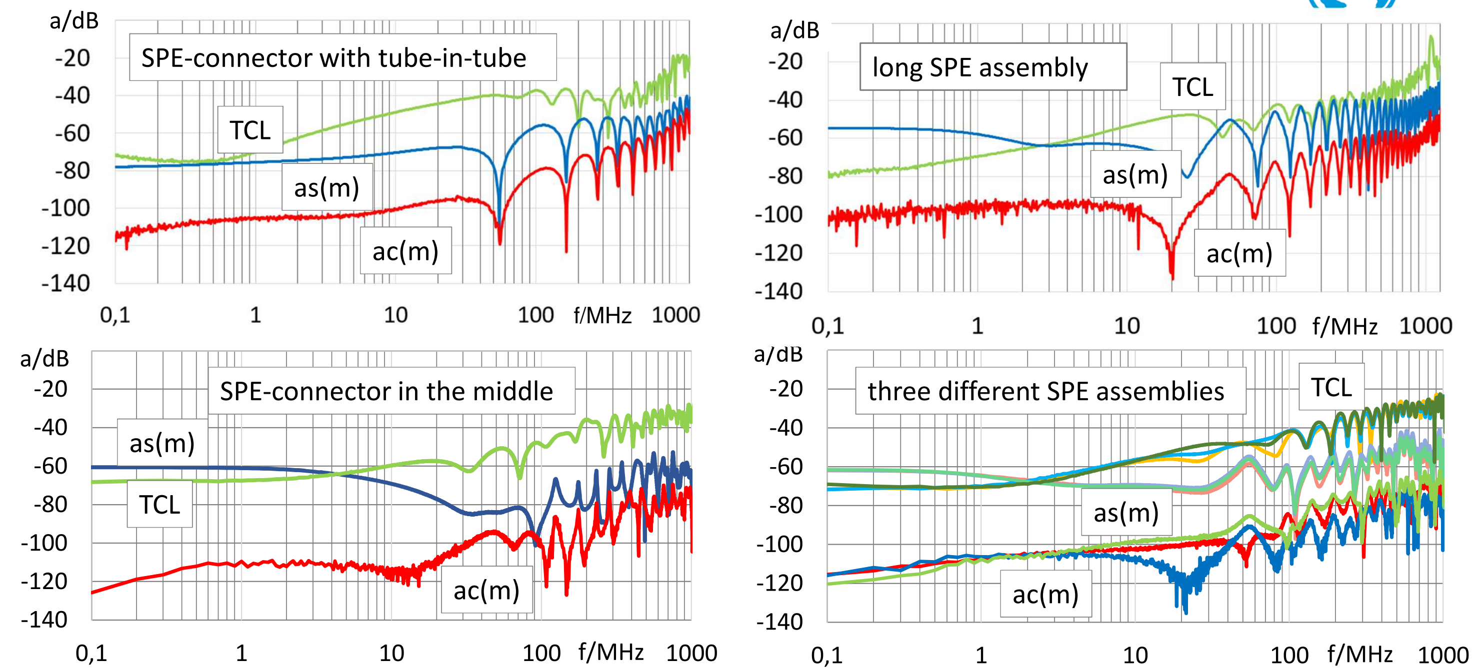
Unbalance attenuation, screening attenuation & coupling attenuation of two different SPE cables with foil and braid as outer screen.

Coupling attenuation is the result of the interaction of unbalance attenuation (TCL) of the pair and the screening attenuation of the screen.

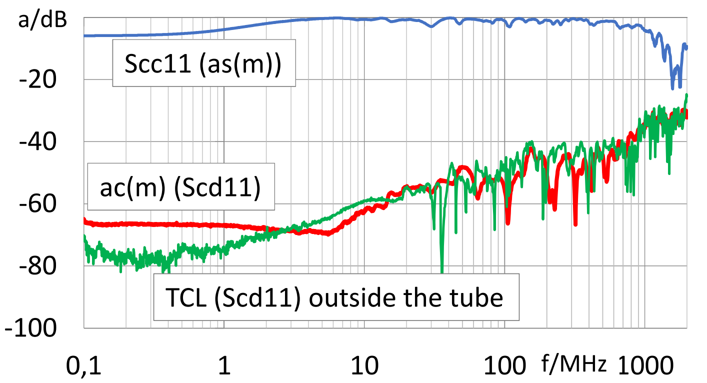


as(m) = measured screening attenuation
ac(m) = measured coupling attenuation
each without corection and without normalization.
TCL = unbalance attenuation at near end, Scd11

Test results of SPE Connectors and Assemblies, 3m length

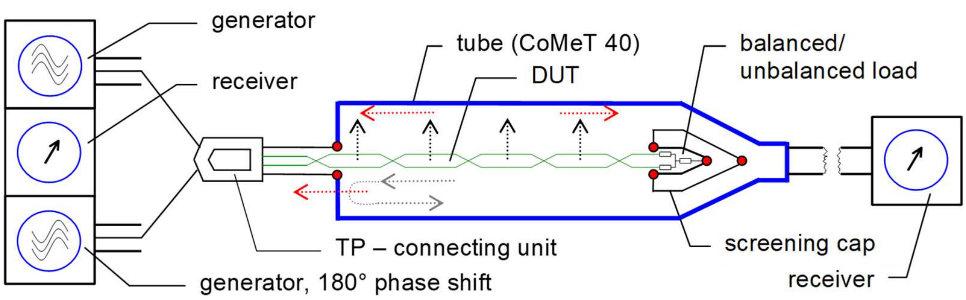


LFCA/CA of Unscreened SPE Cables



Because there is no shield in the unshielded pair, there is no near-end short circuit and no reflection. The near end wave runs back to the analyzer and can be measured there as Scd11.
Therefore, coupling attenuation measurements of unshielded cables and connectors can be performed at both ends. The coupling attenuation at the near end is Scd11, which in principle corresponds to the near end unbalance attenuation or the TCL of the test object

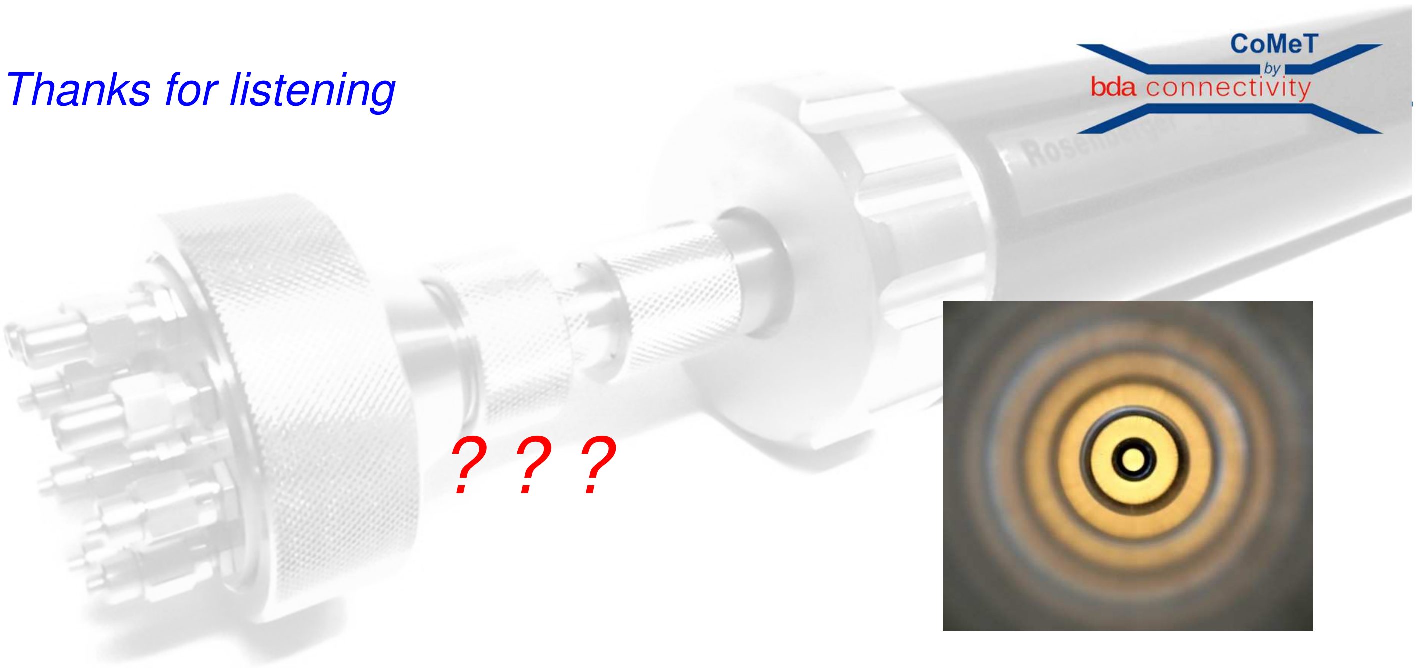
Coupling attenuation of an unscreened balanced pair, IEC 62153-4-9Amd1



Conclusion & Outlook

- The unbalance attenuation a_U of a balanced cable describes in log. representation, how much energy couples from the differential mode into the common mode (or vice versa).
- With the extension of IEC 62153-4-9Amd1 the low Frequency Coupling Attenuation LFCA can be measured now from 100 kHz upwards.
- The corresponding extension of IEC 62153-4-7 for connectors is in preparation at IEC TC 46/WG 5.
- Measurements of LFCA/CA of SPE connectors deviate only slightly from the values of the SPE cables. In the range up to 10 MHz they are below -100 dB and reach a value of about -70 dB at 1250 MHz,
- For verification of the test set-up, Scd11 should be measured on the TP-connecting unit with open loop. At low frequencies, a tolerance of 0,1 % for matching resistors is sufficient.
- The required test length should be discussed as well as the question, whether a normalized value of Z_S = 150 Ω should be introduced for LFCA measurements.
- For the revision of IEC 62153-4-7Ed3 by IEC TC 46/WG5, simulation and further measurements of CA/LFCA of SPE connectors and assemblies by different test labs is needed.
- Standards and limits for SPE cables and connectors are specified by IEC SC 46C and IEC SC 48B.
- There are no international standards and limits for SPE assemblies available yet. This task could be addressed to IEC TC 46/WG 9.

Thanks for listening



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IEC Standards for SPE Cables & Connectors

Symmetrical SPE cables according to **IEC SC 46C:**
IEC 61156-11 – Horizontal floor wiring - Sectional specification up to 1250 MHz, (46C/1219/CDV)
IEC 61156-12 - Work area wiring - Sectional specification up to 600 MHz, (pub. 2021-01-14)
IEC 61156-13 – (Horizontal floor wiring - Sectional specification up to 20 MHz, (46C/1219/CDV)

Symmetrical SPE-connectors according to **IEC SC 48B:**
IEC 63171 – Basic standard with all specifications and test sequences (Edition 1 published)
IEC 63171-1 – CommScope SPE connector based on LC interlock for M1I1C1E1 applications
IEC 63171-2 – SPE connectors from Reichle & De-Massari for M1I1C1E1 applications
IEC 63171-3 – SPE connector from Siemon based on a pair of the well-known Tera connector for M1I1C1E1 applications (withdrawn)
EC 63171- 4 – SPE connectors from BKS for M1I1C1E1 applications
IEC 63171-5 – SPE connectors from Phoenix Contact based on IEC 63171-2 mating face for M2I2C2E2 and M3I3C3E3 applications
IEC 63171-6 (previously IEC 61076-3-125) - SPE connectors from HARTING and TE Connectivity for M1I1C1E1, M2I2C2E2 and M3I3C3E3 applications (source: Harting application note)

Literature & Standards

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[2] Lauri Halme & Bernhard Mund: EMC of Cables, Connectors and Components with Triaxial Test set-up, IWCS, 62th International Wire & Cable Symposium, Charlotte, Nov. 2013

[3] B. Mund & C. Pfeiler: " Balunless measurement of coupling attenuation of screened balanced cables up to 2 GHz", Proceedings of the 64th IWCS Conference, Atlanta, US, October 2015

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[5] T. Hähner, B. Mund, T. Schmid: Screening effectiveness of unscreened balanced pairs, EMC Barcelona 2019

[6] T. Hähner, C. Pfeiler, B. Mund & T. Schmid: EMC Parameter of single pair Ethernet cables, Wire & Cable Technology International/May 2022

[11] IEC TR 62153-4-1 – Introduction to electromagnetic (EMC) screening measurements

[12] IEC 62153-4-7Ed3 – Test method for measuring of transfer impedance Z_T and screening attenuation a_S or coupling attenuation a_C of connectors and assemblies up to and above 3 GHz - Triaxial tube in tube method

[13] IEC 62153-4-9Ed2 – Coupling attenuation of screened balanced cables, triaxial method

[14] IEC 61156-13: Symmetrical single pair cables with transmission characteristics up to 20 MHz - Horizontal floor wiring - Sectional specification

[15] EN 50289-1-9 – Electrical test procedures – Unbalance attenuation