EMC of SPE cables, connectors and assemblies

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Abstract

The new Single Pair Ethernet technology (SPE) based on transmission standards according to IEEE 802.3cg is implemented at different areas, e.g. in new generations of automobiles and can replace CAN and other bus systems. In this context, SPE offers an alternative to existing industrial fieldbus systems. Industrial SPE-applications with up to 1000 m cable length and a frequency range from 100 KHz upwards are described among others.

A high level of electromagnetic compatibility (EMC) is generally required for SPE applications. This applies in particular to SPE cables, connectors and SPE assemblies. Amount of screening effectiveness at low frequencies is in question.

Measuring EMC or shielding effectiveness of shielded balanced cables and assemblies is standardized in IEC 62153-4-9 by the coupling attenuation (CA) from approx. 30 MHz upwards. With the expansion of IEC 62153-4-9Amd1 to include low frequencies, the "low frequency coupling attenuation (LFCA)" can also be measured now from 100 kHz upwards. This also applies to balanced connectors and cable assemblies for which IEC 62153-4-7 is used. When carrying out the measurements, high demands are placed on the symmetry and the sensitivity of the measurement set-up.

The following report describes the measurement of the coupling attenuation/low frequency coupling attenuation of SPE cables, connectors and assemblies in the range from 100 kHz upwards.

Specific characteristics of low frequency measurements are considered. Measurement results are presented and discussed.

Keywords: EMC, Coupling attenuation, Low frequency coupling attenuation, LFCA, Single pair Ethernet, SPE, Unbalance attenuation, Balanced cable, Cable assembly, SPE connector, Triaxial test procedure

1. Screening Parameters

1.1 General

The physical principles for measuring transfer impedance and screening or coupling attenuation on cables, connectors and other components using the triaxial method are described in detail in the literature, see [1, 2, 3, 4, 11] among others.

For coaxial cables, connectors and components, the transfer impedance Z_T applies at frequencies up to approx. 30 MHz. From 30 MHz the screening attenuation a_S is the measure of the shielding effect.

In the case of screened balanced cables, connectors and components, the coupling attenuation a_C is the measure of their shielding effectiveness and is largely responsible for the EMC of the systems implemented with it. The coupling attenuation of balanced pairs is proportional to the unbalance attenuation of the balanced pair and the screening attenuation of the screen.

Previously the coupling attenuation could only be measured from approx. 30 MHz upwards according to IEC 62153-4-9. With the supplement IEC 62153-4-9Amd1 coupling attenuation at low frequencies (LFCA) can be measured from 100 kHz upwards now, using the same test set-up.

1.2 Unbalance Attenuation

Screened balanced pairs may be operated in the differential mode (balanced) or in the common mode (unbalanced). In the differential mode one conductor carries the current $+I$ and the other conductor carries the current $-I$. In the common mode, both conductors of the pair carry half of the current $+I/2$, and the screen is the return path with the current $-I$, comparable to a coaxial cable [1, 2, 3, 4].

Under ideal conditions respectively with ideal cables both modes are independent of one another. Actually, both modes influence each other.

The unbalance attenuation a_U of a cable describes in a logarithmic ratio how much power is coupled over from the differential mode to the common mode system (or vice versa).

$$a_U = 10 \cdot \log\left(P_{diff}/P_{com}\right) \qquad (1)$$

It is the logarithmic ratio of the power fed in the differential mode P_{diff} to the power coupled over into common- mode P_{com}.

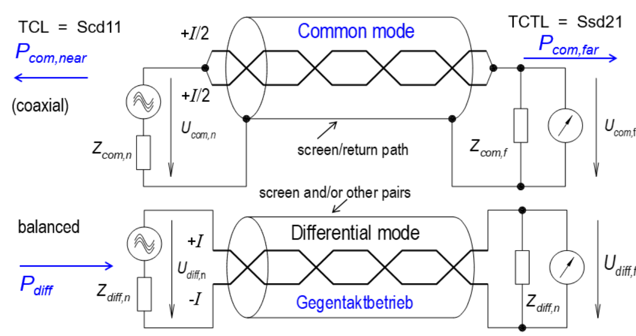

Figure 1 - Common and differential mode of a screened twisted pair (STP)

For low frequencies, the unbalance attenuation decreases with increasing length, see Figures 2a and 2b. With increasing frequency and/or length, the unbalance attenuation - similar to the shielding attenuation - asymptotically approaches a limit value (assuming systematic coupling). The unbalance can be determined for both the near end and the far end of a cable [5, 6].

Different conductor resistances, insulation diameters, core capacities, uneven stranding and changing distances between the inner conductor and the shield e.g. can be causes of the asymmetry.

Unbalance attenuation can be measured according to EN 50289-1-9 or according to IEC 61156-1 with a multi-port vector network analyzer (VNA) and "virtual balun" function. Unbalance attenuation at near end is Scd11 (TCL) and unbalance attenuation at the far end is Scd21 (TCTL), [3].

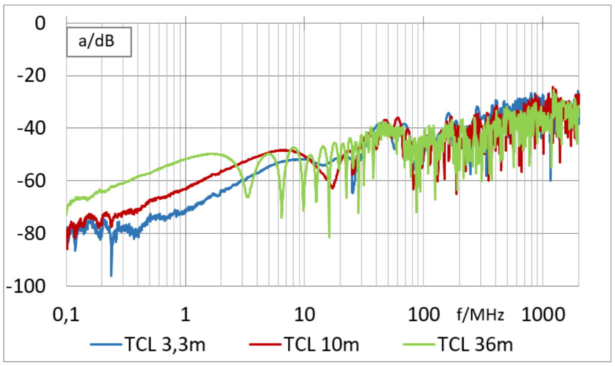

Figure 2a: Unbalance attenuation of a shielded SPE cable at the near end (TCL), different lengths

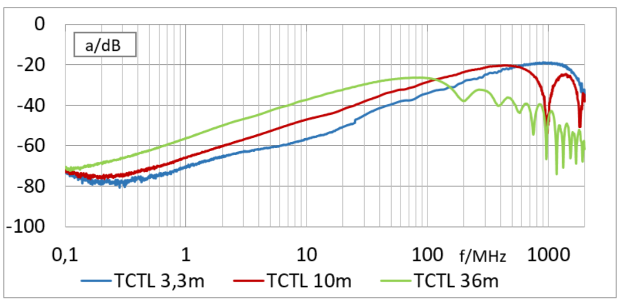

Figure 2b: Unbalance attenuation of a shielded SPE cable at the far end, (TCTL), different lengths

The transfer function of the unbalance attenuation of balanced (symmetrical) pairs as well as the coupling transfer function of screened balanced pairs are described more detailed in [6].

1.3 Screening Attenuation

The screening attenuation a_S of a cable screen is defined as the logarithmic ratio of the power P_1 fed into the matched cable and the maximum peak power $P_{2,\max}$ in the matched outer circuit, in a frequency range where the cable is electrical long.

$$a_S = 10\log_{10}\left|\frac{P_1}{P_{2,\max}}\right| \qquad (2)$$

Details of the screening attenuation measurement of cable screens are described in IEC 62153-4-4 [1, 2, 3, 11].

Below the cut off frequency according to IEC 62153-4-4, where the cables are electrical short, length dependence of a_S shall be considered.

1.4 Coupling Attenuation

The coupling attenuation of shielded balanced pairs describes the overall effect against electromagnetic interference (EMI) and takes into account both, the screening effect of the screen and the mode conversion or the unbalance attenuation of the pair. At a first approach (and at low frequencies) the coupling attenuation a_C of a single screened balanced pair can be considered as the addition of the near end unbalance attenuation of the balanced pair and the screening effectiveness of the screen.

In the case of multi-pair symmetrical cables, the influence of the pairs running in parallel to the cable under test must be taken into account, as these act as additional shielding, [4, 5].

1.5 Coupling Attenuation at Low Frequencies, LFCA

The lower cut-off frequency to measure coupling attenuation according to IEC 62153-4-9Ed2 is given by:

$$f > \frac{c_0}{2 * l * \left|\sqrt{\varepsilon_{r1}} - \sqrt{\varepsilon_{r2}}\right|} \qquad (3)$$

where:

c_0 = velocity of light
l = test length
ε_{r1}, ε_{r2} = dielectric constant of inner and outer circuit

That means, coupling attenuation on screened balanced pairs with manageable length can be measured only from about 30 MHz upwards. A test procedure for the EMC behavior of screened balanced cables at lower frequencies is needed.

EMC at lower frequencies of screened balanced pairs could be described by the "differential transfer impedance" $Z_{T,\mathrm{diff}}$ which would include the transfer impedance of the screen and the unbalance attenuation of the pair. The transfer impedance Z_T of a cable screen is considered usually as invariant to the used test procedure and the test length. The "differential transfer impedance" however depends also on the symmetry of the pair and would be therefore variable by the length and the unbalance attenuation of the cable.

In order not to confuse users and customers, $Z_{T\mathrm{diff}}$ should not be used for balanced cables. It is neither useful for unscreened pairs.

The extension of IEC 62153-4-9Amd1 describes the measurement of the coupling attenuation at low frequencies (LFCA) on symmetrical cables from 100 kHz upwards. The measurement set-up is the same as the set-up for measuring the coupling attenuation at higher frequencies, [5]. The LFCA can also be measured analogously for SPE connectors and SPE cable assemblies. The corresponding supplement to IEC 62153-4-7 is in preparation by IEC TC 46/WG5.

LFCA varies with length. In order to get comparable test results between different test laboratories respectively between different test samples, the same test length shall be applied. For LFCA measurements on balanced cables and connectors, a test length of 3m is recommended.

2. Measuring the Coupling Attenuation with the Triaxial Method

2.1 General

The coupling attenuation of screened balanced SPE cables can be measured according to IEC 62153-4-9 using the triaxial method, see Figure 3.

The balanced cable to be tested forms a three-wire system together with the measuring tube, consisting of the balanced pair, the cable shield and the measuring tube.

The balanced pair of the cable under test is fed with a differential 100 Ω signal via two 180° phase-shifted generators. Energy first couples from the differential mode into the common-mode circuit and then from the common-mode circuit into the measuring tube, (the outer circuit).

Due to the total reflection at the short circuit at the end close to the generator (the near end), all of the energy coupled into the outer circuit runs to the receiver, [5]. Measurement results of an SPE cable are shown in Figures 4a and 4b.

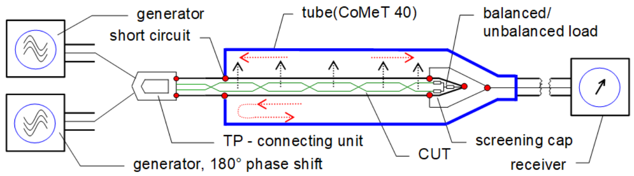

Figure 3: Measurement of the coupling attenuation a_C of a screened balanced SPE cable with multi-port VNA and with virtual balun according to IEC 62153-4-9

The measurement results of balanced cables change at low frequencies depending on the measurement length. In order to achieve comparable results, a measuring length of 3m for LFCA is required in the IEC standards for SPE cables [15].

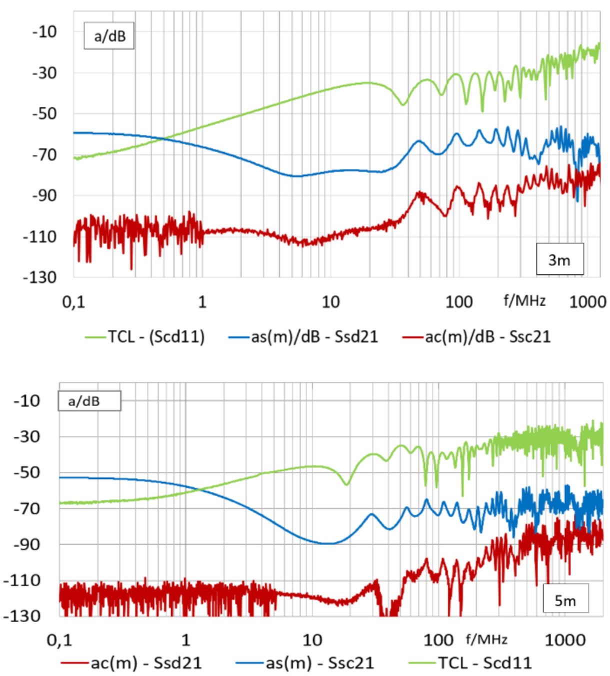

Figure 4a, b: Unbalance attenuation a_U (Scd11, TCL), screening attenuation a_S(m), (Ssc21) and coupling attenuation a_C(m), (Ssd21) of an 3m and an 5m SPE cable, raw values

2.2 Matching Resistors

The inner system of the test set-up respectively the cable under test must be matched in a suitable manner during the test. The aim here is both to avoid standing waves and to avoid additional mode conversion caused by asymmetry. According to Figure 5, the differential mode is terminated with 100 Ω and the common mode is matched with 25 Ω (R_2 is zero in case of multi-port VNA).

While the unbalance of the terminating resistors at high frequencies is negligible compared to the typical unbalance of the test objects, the unbalance of the terminating resistors at low frequencies can reach values that exceed the unbalance of the test objects and falsify the measurement results.

According to IEC 60512-28-100, terminating resistors of 50 Ω with a tolerance of ± 0.1% are required for measuring the coupling attenuation of balanced connectors. In worst case, this results in a resistance unbalance of 66 dB.

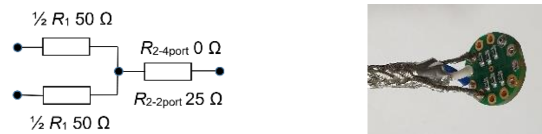

Figure 5: Matching resistors & PCB

The resistance unbalance $a_{U,r}$ is given by:

$$a_{U,r} = 20 \cdot log \frac{\Delta R}{4 \cdot \sqrt{Z_{diff} \cdot Z_{com}}} \qquad (4)$$

where:

ΔR	resistance unbalance of both resistors in Ω
Z_{diff}	characteristic impedance of differential mode
Z_{com}	characteristic impedance of common mode

The resistance unbalance of resistors with a tolerance of 0.1% is in the range of the system unbalance of the entire test system. Typical value is about 74 dB. A resistance tolerance of 0.1% is therefore considered sufficient for LFCA measurements. Appropriate PCBs to match the device under test are commercially available, see Figure 5.

2.3 Calibration and System-Verification

When measuring unbalance- and coupling attenuation with four-port VNAs, calibration of the VNA is mandatory. This can be done using an electronic e-cal kit or by hand. Usually, the selected calibration level is located at the end of the coaxial test leads. More reliable calibration procedure as well as calibration standards for calibration direct at the end of the balanced feeder cables are under discussion. Phase-stable leads should be used for balanced cable measurements. After calibration test leads should not be moved more than necessary.

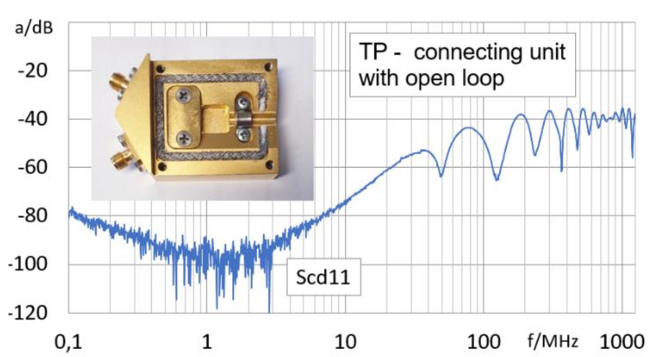

Figure 6: System verification by measuring the TCL (Scd11) on the TP connecting unit with open loop

Even optimally calibrated and phase-stabilized measuring devices (VNA, test leads and connection units) show a certain frequency-dependent behavior in a system mode conversion.

This value is between -80 and -70 dB at low frequencies and increases to around -60 to -40 dB with higher frequencies. Depending on the phase position, this system mode conversion is constructively or destructively superimposed on the mode conversion of the test object.

Consequently, the result of the measurement is falsified as a result and particularly severely when the magnitude of the mode conversion of the test object approaches or even falls below the magnitude of the system mode conversion.

All measurements of the coupling attenuation at low frequencies can be "victims" of such interference. The system values should therefore be recorded and included in the analysis of the measurement uncertainties. An estimation of the system mode conversion can be made e.g. by recording the reflected mode conversion parameter Scd11 of a TP-connecting unit with an open loop, see Figure 6.

System noise reduction may be required, especially when measuring the coupling attenuation. This is achieved by using high measurement signal power and low measurement bandwidth. In addition, the AGC mode (Automatic Gain Control) can be set for various multi-port VNAs. However, this should be done only after the VNA calibration.

3. Coupling Attenuation of SPE Connectors and Assemblies

3.1 SPE connectors

The IEC 62153-4-7Ed3 standard, based on IEC 62153-4-9, describes various methods for measuring the coupling attenuation of connectors and ready-made cable assemblies.

Figures 7a and 7b shows the basic measurement set-up for measuring the coupling attenuation of a screened balanced connector using the tube-in-tube method. An RF-tight tube is inserted into the measuring tube. The inner tube forms a 50 Ω system with the outer tube.

The shielded balanced connection cable is located in the inner tube. For mechanical reasons, the contact between the shield of the connection cable and the inner tube is approx. 3 cm in front of the connector to be tested.

This measures both the connector to be tested and the quality of the connection between the connector and the connection cable. The selected distance between tube-in-tube and the test object should be documented in the test report for comparison measurements.

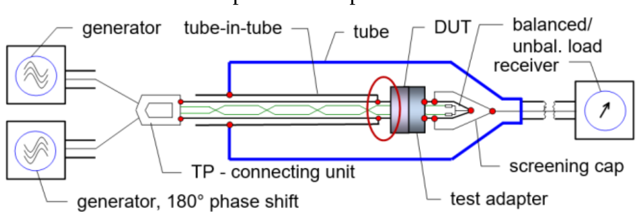

Figure 7a: Measuring CA/LFCA of a connector with tube-in-tube with short piece of connecting cable

Figure 7a shows the measurement CA/LFCA with tube-in-tube and a short piece of connecting cable. In this way the influence of assembling of cable and connector is also measured.

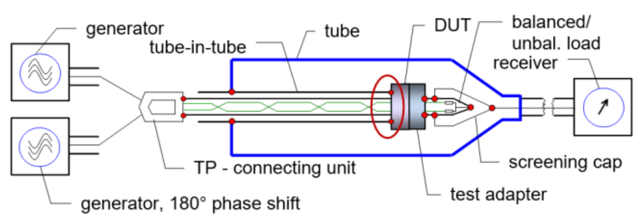

Figure 7b: Measuring CA/LFCA of a connector with tube-in-tube with direct connection

Figure 7b shows the measurement with direct connection of the tube-in-tube to the device under test (DUT). IEC 62153-4-7 allows both options.

Figure 8 shows the measurement of an SPE connector with ready-made test adapter and tube-in-tube procedure according to IEC 62153-4-7.

Figure 8: SPE connector with ready-made test adapter with tube-in-tube according to Figure 7a

In order to achieve a defined contribution to the mode conversion of the feeder line, a measurement length of 3m is suggested, analogous to the corresponding cable standards. According to IEC 62153-4-7Ed3. the transmission loss of the feeder cable is not taken into account A similar configuration is shown in Figure 22 with a pair of SPE connectors prepared for the measurement according to figure 7a. The termination required for the measurement together with the clamping devices and the screening case to connect the cable screen with the CoMeT40 test head acts as a self-made test adapter.

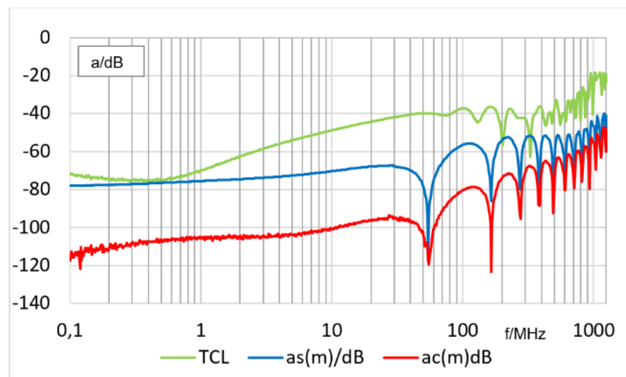

Figure 9: Unbalance attenuation a_U (Scd11, TCL), screening attenuation a_S(m) (Ssc21) and coupling attenuation a_C(m) (Ssd21) of an SPE connector with tube-in-tube acc. to Figures 7a & 10, raw values

3.2 Coupling Attenuation of Cable Assemblies

Measuring of coupling attenuation of cable assemblies is shown in Figures 10 to 12. If SPE cable assemblies are shorter than 3m, non-destructive measurements can be carried out in the measuring arrangement shown in Figure 10a and 10b.

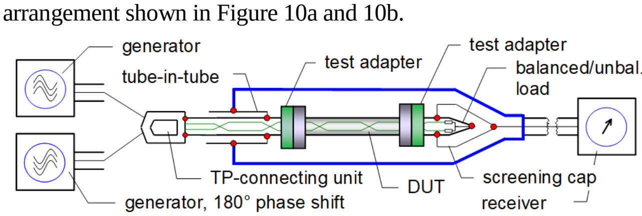

Figure 10a: Measuring the coupling attenuation a_C of an SPE assembly with tube-in-tube method according to IEC 62153-4-7, adaptation with prefabricated cable ends

In Figure 10a, the adaptation is realized with the help of ready-made cable ends, whereby the shield connection to the tube-in-tube and to the screening cap takes place in the area of the cable shield.

Figure 10b shows the measurement of a cable assembly with ready-made test adapters.

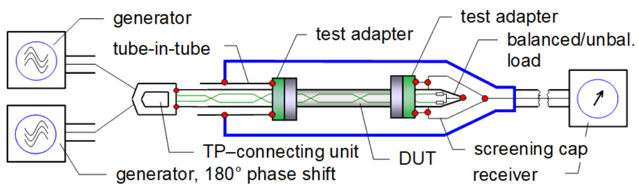

Figure 10b: Measuring the coupling attenuation a_C of a balanced assembly with tube-in-tube method according to IEC 62153-4-7 with test adapter

An option for measuring a paired connector arrangement is shown in Figure 11. The pair of connectors is placed in the middle of the measuring tube. This arrangement enables the measurement of long SPE cable assemblies (> 3m), splitting them in the middle and plugging them in at the ends.

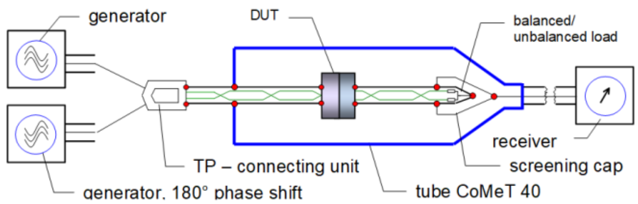

Figure 11: Measuring CA/LFCA (Scd21) of a long SPE assembly with connectors in the middle of the tube

In contrast to the tube-in-tube measurement set-up shown in Figure 7a and 7b, the contribution of the feed and termination lines is not eliminated by the tube-in-tube application, but is superimposed on the coupling through the connectors.

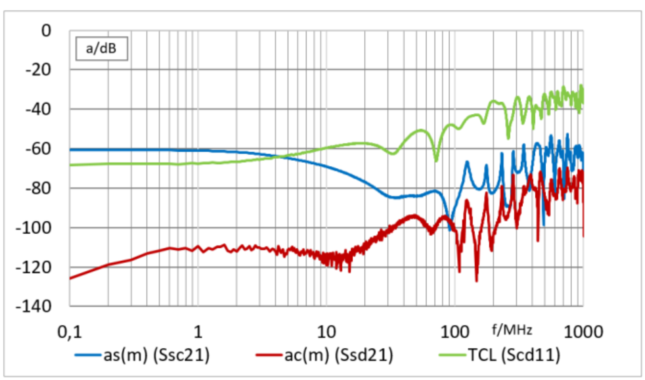

Figure 12: Coupling attenuation a_C(m) (Scd21), screening attenuation a_S(m), (Scc21) and unbalance attenuation a_U (Scd11) of an SPE connector pair in the middle of the tube, 3m, raw values

Another option for measuring long cable assemblies is given in Figure 13. If the assembly is longer than the tube (usually 3m) IEC 62153-4-7 allows to cut the assembly and measure both ends separate. The worst case is taken then as the coupling attenuation of the cable assembly. The test adapter used is integrated into the screening cap of the test head, see Figure 21.

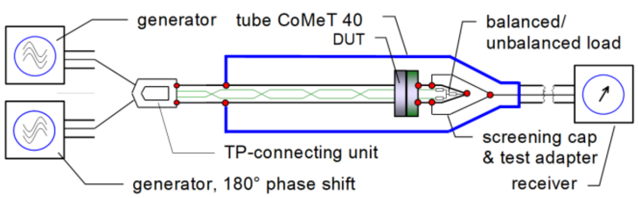

Figure 13: Coupling attenuation of long assemblies

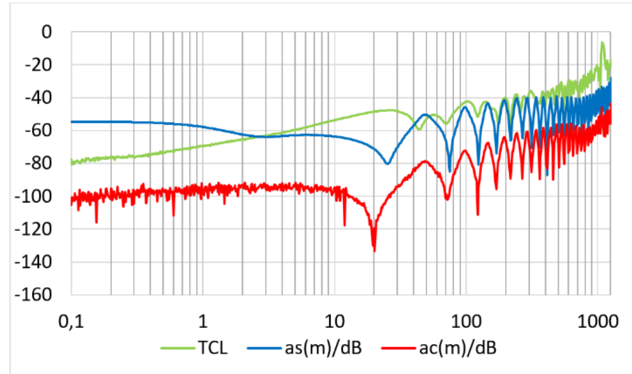

Figure 14: Unbalance attenuation a_U (Scd11, TCL), screening attenuation a_S(m) (Ssc21) and coupling attenuation a_C(m) CA/LFCA (Ssd21) of a long assembly acc. to figure 13

Figure 15 shows the associated measurement results of three SPE cable assemblies according to Figure 10a, each 2m long. The diagram shows the raw values of the screening attenuation and the coupling attenuation as well as the mode conversion at the near end (TCL). The sample spreads found show the largest deflection in the coupling attenuation on the dB scale, whereby it should be noted that this is a logarithmic representation, and the linear amounts of the spreads are similar.

Ideally, this measurement is carried out in an arrangement as shown in Figure 10b with suitable measurement adapters, with the shield connection of the adapter outer conductor taking place directly to the tube-in-tube and to the screening cap. This measure reduces unwanted coupling and thus measurement errors.

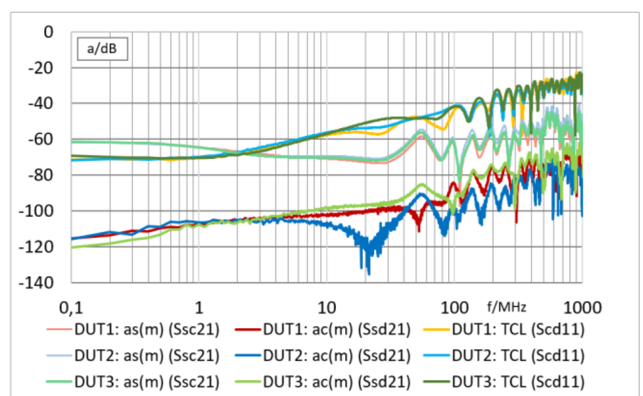

Figure 15: Coupling attenuation a_C(m) (Scd21), screening attenuation a_S(m) (Scc21) and unbalance attenuation a_U (Scd11) of three SPE assemblies according to Figure 10a, raw values

3.3 Unscreened Balanced Cables & Connectors

In case of unshielded balanced pairs, the inner system consists of the unshielded pair fed in differential mode. The outer system is formed by the the common mode of the test object and the measuring tube. Because there is no shield at the unshielded pair, there is no near-end short circuit. The wave towards the near end is not reflected and travels back to the VNA where it can be measured as Scd11. The wave towards the far end can be measured as Ssd21.

In this way, coupling measurements of unshielded pairs can be performed at both ends as near end and far end coupling attenuation.

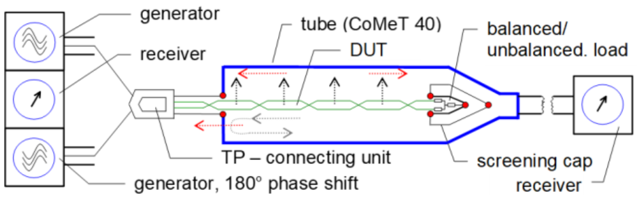

Figure 16: Coupling attenuation of unscreened balanced cables

Figure 16 shows the coupling attenuation measurement of an unshielded balanced pair. The wave running back towards the near end in can be measured as S-parameter Scd11.

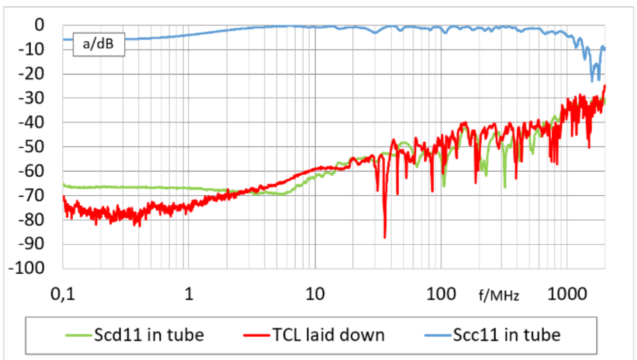

Figure 17: Near end coupling attenuation Scd11 and Scc11 inside the tube and Scd11 (TCL) outside the tube of an unscreened SPE cable at near end, 3m

The parameter Scd11 is also defined as the unbalance attenuation at the near end (TCL) of the unshielded cable, [3, 4, 5]. That means, in case of unshielded balanced pairs, the near end coupling attenuation is in principle the same as the near end unbalance attenuation.

The measurement of unshielded SPE connectors and assemblies can be performed in the same way as for unshielded SPE-cables.

4. Expression of Test Results

4.1 Normalization

According to IEC 62153-4-7Ed3 and IEC 62153-4-9Ed2 equation (15), the measurement results of the coupling attenuation are to be calculated from the measured voltage ratio $U_{diff}/U_{2,max}$. In order to compare the coupling attenuation a_C with measurements using absorbing clamps, an arbitrary normalized value Z_S = 150 Ω was introduced in the standards for triaxial procedures of IEC 62153-4 series. This results in the coupling attenuation a_C to:

$$a_C = 20log_{10}\left|\frac{U_{diff}}{U_{2,max}}\right| + 10log_{10}\left[\frac{2Z_S}{Z_{diff}}\right] \quad (5)$$

where:

U_{diff} input voltage at the DUT in V
$U_{2,max}$ max. voltage at the test head in V
Z_{diff} characteristic impedance of the DUT in Ω
Z_0 input impedance of the network analyzer
Z_S arbitrary inserted normalized value ZS = 150 Ω

With Z_S = 150 Ω and Z_{diff} = 100 Ω the correction value results in:

$$a_{corr} = 10log_{10}\left|\frac{300}{100}\right| = 4{,}8 \text{ dB.} \quad (6)$$

Due to the different characteristic impedances Z_{diff} of the balanced test object of 100 Ω and the input impedance of the network analyzer Z_0 of 50 Ω, the measured voltage ratio $U_{diff}/U_{2,max}$ does not correspond to the S-parameter Ssd21.

Since the term $U_{diff}/U_{2,max}$ is often interpreted as the S-parameter Ssd21 when calculating the coupling attenuation according to IEC 62153-4-9Ed2, IEC TC 46/WG5 proposes the following new presentation of the measurement results:

$$a_C = -20log_{10}|S_{sd21}| + 10log_{10}\left|\frac{Z_{diff}}{Z_0}\right| + 10log_{10}\left|\frac{2Z_S}{Z_{diff}}\right| \quad (7)$$

$$a_C = -20log_{10}|S_{sd21}| + 10log_{10}\left|\frac{2Z_S}{Z_0}\right| \quad (8)$$

With Z_S = 150 Ω and Z_0 = 50 Ω the correction value results in:

$$a_{corr} = 10log_{10}\left|\frac{300}{50}\right| = 7{,}8 \text{ dB.} \quad (9)$$

Whether such a correction also makes sense for the coupling attenuation at low frequencies is subject to further discussions.

The measured values of screening attenuation a_S(m) and coupling attenuation a_C(m) presented in this report are therefore raw values, i.e. without conversion to a normalized value of Z_S = 150 Ω.

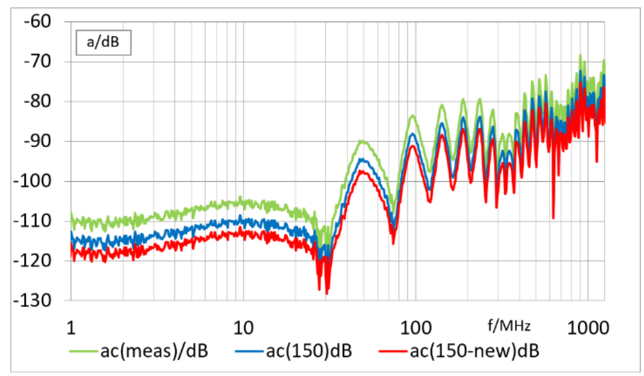

Figure 18: Different test results by normalization

4.2 Envelope Curve and Limit Lines

IEC TC 46/WG 5 proposes the following expression of test results:

The coupling attenuation is expressed by a value A of an envelope line. The value A shall be deduced by drawing a curve derived from the following equations:
30 MHz to 100 MHz: A dB;
100 MHz to 2 GHz: (A - 20 log10 (f/100)) dB (10)
where *f* is the frequency in MHz
This curve shall be moved until the first peak of the measurement trace is intersected.
The value A (in dB) is read where the curve intersects the Y axis.

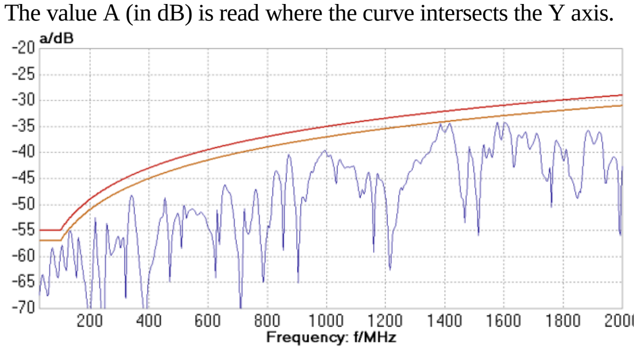

Figure 19 – Example of Coupling attenuation with Type II limit line and envelope test result line, lin. scale

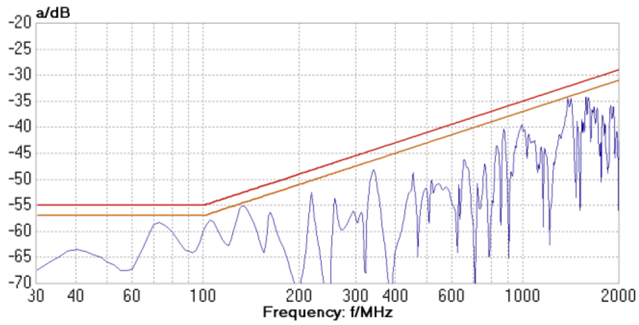

Figure 20 – Example of Coupling attenuation with Type II limit line and envelope test result line, log scale

5. Test adapter

When measuring CA/LFCA on SPE connectors or SPE cable assemblies, appropriate test adapters are required, see Figures 7a, b and 10a and b.

Test adapters can be made by hand from an SPE connector pair, see Figure 22 or can be machine made, see Figure 21. Preferably, test adapter should be integrated in the screening case of the test head. It should not have not larger diameter than screening case to avoid additional reflections. Test adapters shall include the terminating resistors, see Figure 21.

Test adapters shall be assembled in agreement between the manufacturer respectively the distributor of the device under test (DUT) and the test laboratory. Preferably, test adapters should be provided by the manufacturer of the DUT itself. If this is not possible, adapters can be self-made, e-g. by using a cable assembly respectively a connectorized cable and prepare it according to Figure 22.

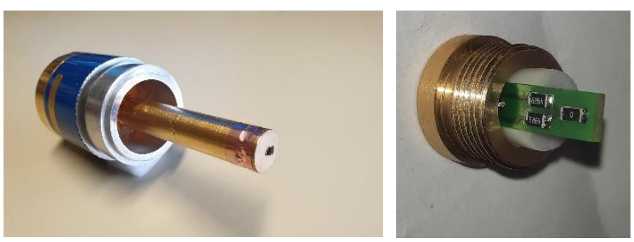

Figure 21: Test adapter for SPE connectors (Weidmüller)

Test adapters may limit the sensitivity of the test set-up. Therefore test laboratories should conduct qualification tests with their existing adapter hardware to establish the noise floor(s) for the entire test system.

Figure 22: SPE connector with self-made adapter made from a pair of connectors with tube-in tube according to Figure 7a

Should the qualification test require connecting cables, these shall have a well screened tubular outer conductor. Measurements are considered as 'valid' as long as the measured value is at least 6 dB above the sensitivity established.

Figure 22 shows a pair of SPE connectors prepared for the measurement according to figure 7a with the termination required for the measurement and the clamping devices to contact the cable screen together with the CoMeT40 test head. In order to terminate the cable in the test head, appropriate PCBs are commercially available.

6. Measurement Accuracy and Reproducibility

Screened balanced cables are unstable structures. They can change their symmetry and screening characteristics through tensile, compressive and bending loads. Deviating measurement results were obtained when the same test device with connector or the same assembly was installed and measured several times. These deviations are subject to further investigations, e.g. in IEC TC 46/WG5.

In order to avoid improper measurements, sample preparation and test set-up shall be prepared carefully. All connections shall be made as tight as possible and with low impedance.

7. Conclusion and Outlook

The coupling attenuation of balanced connectors and assemblies can be measured according to IEC 62153-4-7Ed3 using the tube-in-tube method. Based on the supplement IEC 62153-4-9Amd1, the coupling attenuation of balanced cables, connectors and assemblies can also be measured at low frequencies from 100 kHz upwards as LFCA.

In order to achieve a defined contribution to the unbalance attenuation or the mode conversion of the feeder cable, a measuring length of 3m is recommended when measuring coupling attenuation of connectors and assemblies, analogous to measuring of balanced cables. At the same time, this ensures that measurements from different laboratories can be compared with each other.

Depending on the lowest frequency to be measured, high demands are placed on the symmetry of the terminating resistors. A resistance tolerance of 0.1% is considered to be sufficient.

The reproducibility of the test results after repeated installation are subject to further investigations, including IEC TC 46/WG5. The position of the connector to be tested in the measuring tube (in the middle, close to the measuring head or close to the short circuit) and the required measuring length for the tube-in-tube method is also subject of further investigations, e.g. in IEC TC 46/WG5.

The correction of the transmission loss of the feeder cable according to IEC 62153-4-7Ed3 in the respective measurement set-up and calibration procedures and standards at the end of the feeder cables shall be discussed. The complete revision of IEC 62153-4-7 is in preparation at IEC TC 46/WG5.

This task requires further measurements as well as simulation of coupling attenuation of connectors and assemblies from different laboratories.

Standards and limits for SPE cables are being prepared by IEC SC 46C as 61156-n series. Standards and limits for SPE connectors are being prepared by IEC SC 48B as IEC 63171-n series.

Nevertheless, there are currently no international standards neither specified limits for screening effectiveness of SPE assemblies available yet. This task could be addressed to IEC TC 46/WG9.

8. Literature

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9. Standards

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

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

[14] IEC 62153-4-9Ed2Amd1, Measuring the screening effectiveness of unscreened single or multiple balanced pairs

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

[16] IEC 63171-n series – SPE connectors for balanced single-pair data transmission with current-carrying capacity

[17] EN 50289-1-9 – Electrical test methods – Unbalance attenuation.

10. Authors

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Bernhard Mund has been in the cable business since 1985 when he joined the cable manufacturer bda connectivity GmbH (former bedea Berkenhoff & Drebes GmbH) in Asslar, Germany.

Formerly being R&D Manager of communication cables, he is now with the bda RF- and EMC test engineering department responsible for R&D of the CoMeT system.

Besides his work for bda, Bernhard Mund has been contributing for more than 35 years in national and international standardization organizations.

He has served as Chairman of the German committee UK 412.3, Koaxialkabel as well as Secretary of IEC SC 46A, Coaxial cables and of CLC SC 46XA, Coaxial cables, among other standardization activities in different committees and working groups e.g. of IEC TC 46/WG5.

After having successfully completed his apprenticeship as Radio- and TV Technician in 1979, **Ralf Damm** received his diploma in Telecommunications and Microprocessor-Technologies at FH Giessen-Friedberg. In 1987 he joined bda connectivity GmbH (former bedea Berkenhoff & Drebes GmbH), working with electronic development of fibre optic components. In 2018 the bedea cable division has changed to bda connectivity GmbH.

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Thomas Schmid has been participating in international standardization since 2006. He is member of different committees and working groups of the IEC TC 46 family.

He was granted for the 1906 IEC Award in recognition of his outstanding technical contribution in developing, writing and finalizing TC 46's IEC 62153-4 series (Metallic communication cable test methods – Electromagnetic compatibility).