Outline

- Physical Basics of Cable Screening
  - Definitions, electrical length
  - Coupling Transfer Function
- Measuring of Screening of Cables & Connectors
  - Transferimpedance & Screening attenuation
  - Screening of Connectors & Connecting Hardware
- Further development
  - Screening of Feed-throughs and EMC gaskets
- Conclusion & Discussion
Definitions, electrical length

**high frequencies**: Screening attenuation

\[ a_S = 10 \log \left( \frac{P_1}{P_2} \right) = 20 \log_{10} \left( \frac{U_1}{U_2} \right) \] [dB]

Ratio of two powers --> length independent

**low frequencies**: Transferimpedance

\[ Z_T = \frac{U_1}{I_2} \] [mΩ/m]

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

Wave length
\[ \lambda = \frac{c_0 \cdot v_k}{f} \]

electrical long:
\[ f > \frac{c_0}{2 \cdot l \cdot \sqrt{\varepsilon_r l}} \]

electrical short:
\[ f < \frac{c_0}{10 \cdot l \cdot \sqrt{\varepsilon_r l}} \]

(EN 50289-1-6)

Coupling between two lines (equivalent circuit)

near end

\[ \sqrt{P_{2n}} \]

\[ Z_{2n} \]

\[ U_{2n} \]

Disturbed line (surrounding)

\[ Z_{2}, \varepsilon_{r2}, v_{12}, \gamma_2 \]

far end

\[ \sqrt{P_{2f}} \]

\[ U_{2f} \]

\[ Z_{2f} \]

receiver

reversible

generator

\[ \sqrt{P_{1n}} \]

\[ Z_{1n} \]

\[ U_{1n} \]

\[ Z_{1}, \varepsilon_{r1}, v_{1}, \gamma_1 \]

equivalent circuit

disturbing line

\[ \sqrt{P_{1f}} \]

\[ U_{1f} \]

\[ Z_{1f} \]
Summing function $S_{nf}$

$$S_{nf} = \frac{2 \sin \left( \frac{\beta_1 + \beta_2}{2} L_c \right)}{\left( \beta_1 + \beta_2 \right) L_c}$$

$$\approx \frac{\sin x}{x}$$

Low frequencies

$$\left| S_{nf} \right| \to 1$$

High frequencies

$$\left| S_{nf} \right| \to \frac{2}{(\beta_1 + \beta_2)^{-1}}$$

Calculated Coupling Transfer Function $T_{nf}$

$$T_{nf} = (Z_F + Z_T) \cdot \frac{1}{\sqrt{Z_1 \cdot Z_2}} \cdot \frac{I}{2} \cdot S_{nf}$$

$a_s$ and $Z_T$ vs frequency

Transferimpedance

Screening attenuation

$\epsilon_{r1} = 2.3$

$\epsilon_{r2} = 1.0$

$Z_F = 0$

$L = 1$ m

Bernhard Mund, bedea Berkenhoff&Drebes GmbH, Herbornerstrasse 100, D-35614 Asslar, Germany, bmund@bedea.com
Measuring with the Triaxial test set-up CoMeT

Transferimpedance & Screening attenuation
few kHz up to and above 8 GHz with one test set-up

Generator and receiver are included in a modern network analyser

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

Measured Transfer function of RG 058

Transferimpedance | Screening attenuation

Bernhard Mund, bedea Berkenhoff&Drebes GmbH, Herbornerstrasse 100, D-35614 Asslar, Germany, bmund@bedea.com
Differential & Common mode of balanced pairs

Differential mode
Gegentaktbetrieb

Common mode
Gleichtaktbetrieb

Measuring of Coupling attenuation

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

IEC/PAS 62338 Ed1, Coupling attenuation, triaxial method
IEC 62153-4-9, Coupling attenuation, triaxial method
Coupling attenuation of a CAT 6 Cable, S/FTP, log scale, Triaxial set up

![Graph showing coupling attenuation](image)

Triaxial set-up with “Tube in tube”

- Connector under test
- Mated adapter
- Generator
- RF-tight extension tube
- Connecting cable
- Measuring tube
- Screening cap
- Receiver

IEC 62153-4-7, Tube in tube test procedure
Coupling attenuation Nexans GG 45

Measuring of cable assemblies

IEC 62153-4-7, Tube in tube test procedure (connectors & assemblies)
Test set-up for connecting hardware with housing

Test procedure is under consideration at IEC TC46/WG 5

Test set-up CoMeT with housing

CATV wall outlet with tube in tube
CATV wall outlet with Tube in tube

![Graph showing signal attenuation vs. frequency for a CATV wall outlet with a tube in tube.](image)

Cable with small hole, tube in tube, 0.5 m

- Well screened CATV-Cable with F-Connector
- Same cable with one small hole, 3 mm

![Image showing a cable with a small hole and an F-connector.](image)
EMC of Feed-throughs & EMC Gaskets

Problem:
EMC of Feed-throughs & EMC Gaskets

Problem in Standardised Surrounding

feed in RF-wave

measure RF-wave

Z, l_{Line} represents the Transfer impedance

Y represents the Transfer impedance

Generator & receiver are included in the NWA
Test set-up for Feed-throughs & gaskets

the procedure is under discussion at IEC TC46/WG5 as IEC 62153-4-10

International Standards for triaxial set-up

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<tr>
<th>Standard</th>
<th>Description</th>
<th>Year</th>
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<tr>
<td>IEC TR 62153-4-1</td>
<td>Introduction to EMC measurements</td>
<td>46/199/DTR</td>
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<tr>
<td>IEC 62153-4-3</td>
<td>Surface transfer impedance - Triaxial method</td>
<td>2006-03</td>
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<td>IEC 62153-4-4</td>
<td>Shielded screening attenuation, test method for measuring the screening attenuation &quot;a_s&quot; up to and above 3 GHz</td>
<td>2006-05</td>
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<tr>
<td>IEC 62153-4-7</td>
<td>Shielded screening attenuation, test method for measuring the Transfer impedance (Z_T) and the screening attenuation (a_s) of RF-Connectors up to and above 3 GHz; Tube in Tube method</td>
<td>2006-04</td>
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<td>IEC 62153-4-9</td>
<td>Coupling attenuation, triaxial method</td>
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<td>EN 50289-1-6</td>
<td>Communication cables - Specifications for test methods Part 1-6: Electrical test methods - Electromagnetic performance (includes IEC 62153-4-3 and IEC 62153-4-3)</td>
<td>2002</td>
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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 frequency range from 100 kHz up to 8 GHz with one test set-up.
- Furthermore, the **Coupling attenuation** $a_C$ of screened balanced pairs may be measured.
- Test set-up is in acc. with EN 50289-1-6 & IEC 62153-4-3/-4-5/-4-7
- The Standards IEC 62153-4-9 & IEC 62153-4-10 are in preparation

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
- Further developments is a set-up to measure the EMC of Feed-throughs & EMC Gaskets

- This presentation & further information: [www.bedea.com](http://www.bedea.com)
- Contact person & further questions: bmund@bedea.com
CoMeT
Coupling Measuring Tube
Rohde & Schwarz ZVRE

Literature


[6] Bernhard Mund, IWCS (International wire and cable symposium) 2004-08-17, Measuring the EMC on RF-connectors and connecting hardware, Tube in tube test procedure

[7] IEC 62153-4-3 Transfer impedance, IEC 62153-4-4 Screening attenuation IEC 62153-4-7 Tube in tube IEC 62153-4-9, Coupling attenuation - Triaxial method, EN 50289-1-6 EMC on Communication cables,