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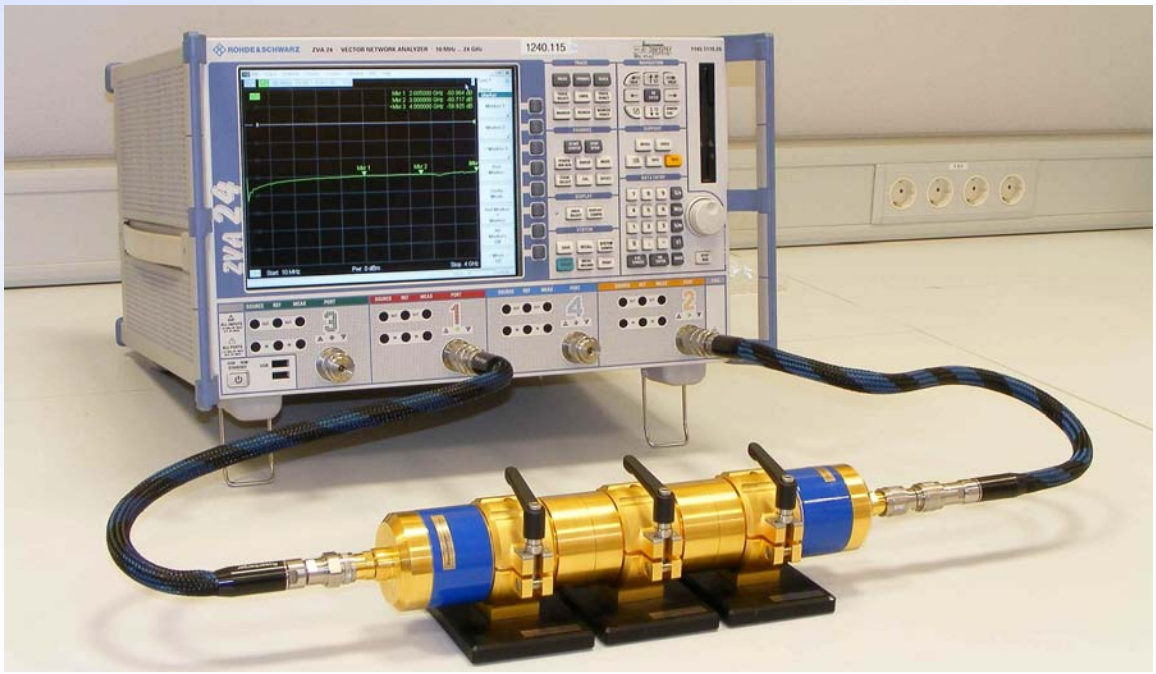
# EMC of Cables & Connectors & Test methods

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# EMC of Cables & Connectors & Test methods


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## EMC of Communication cables & test methods

- Author: Bernhard Mund,
  - *Radio & TV Technician, Radio Brand, Marburg, 1970*
  - *Dipl.-Ing. Communication-& Microproc. technologies,* FH Giessen *1984*
- *bedea* Berkenhoff&Drebes GmbH, Asslar *since 1985*
  - *bedea* Manufacturer of Communication Cables, Germany
- Responsible:
  - R&D Manager & RF- und EMC-measurements,
  - **Standardisation:**
  - Chairman of UK 412.3, Koaxialkabel, (German NC)
  - Secretary of CENELEC SC 46XA, Coaxial cables
  - Secretary of IEC SC 46A, Coaxial cables

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## 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

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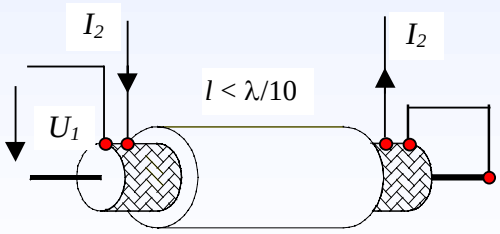
# Definitions, electrical length

*high frequencies:* Screening attenuation

$a_S = 10 \log (P_1/P_2) = 20 \log_{10} (U_1/U_2)$ [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
**$\lambda = (c_0 \bullet v_k) / f$**

**electrical long:**

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

**electrical short:**

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

***(EN 50289-1-6)***





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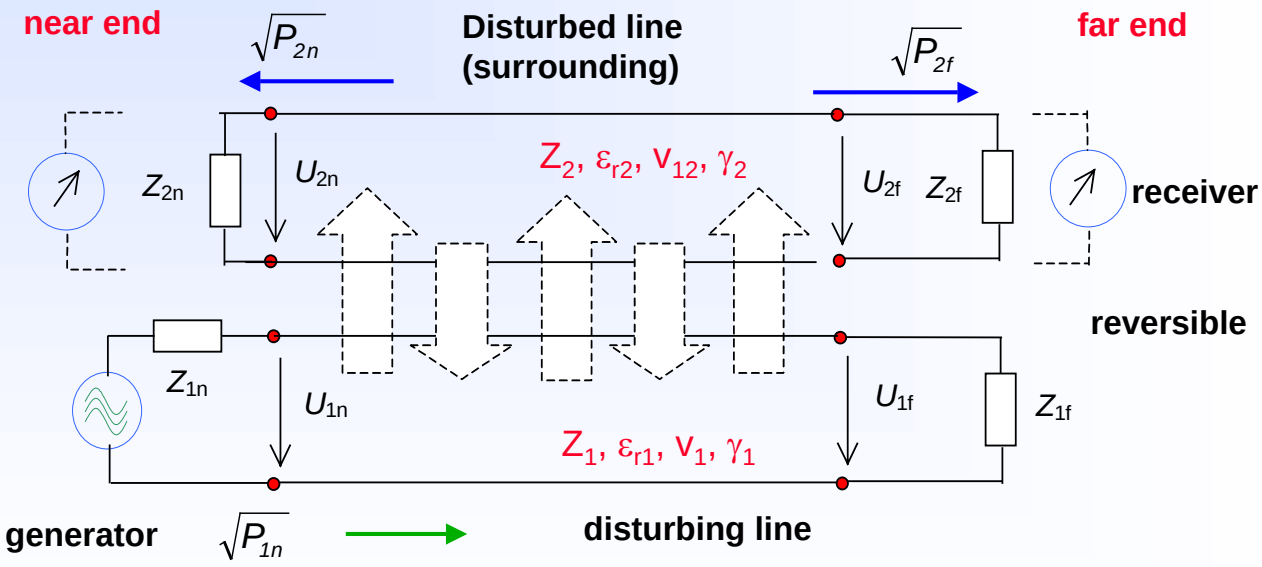
# Coupling between two lines (equivalent circuit)




equivalent circuit

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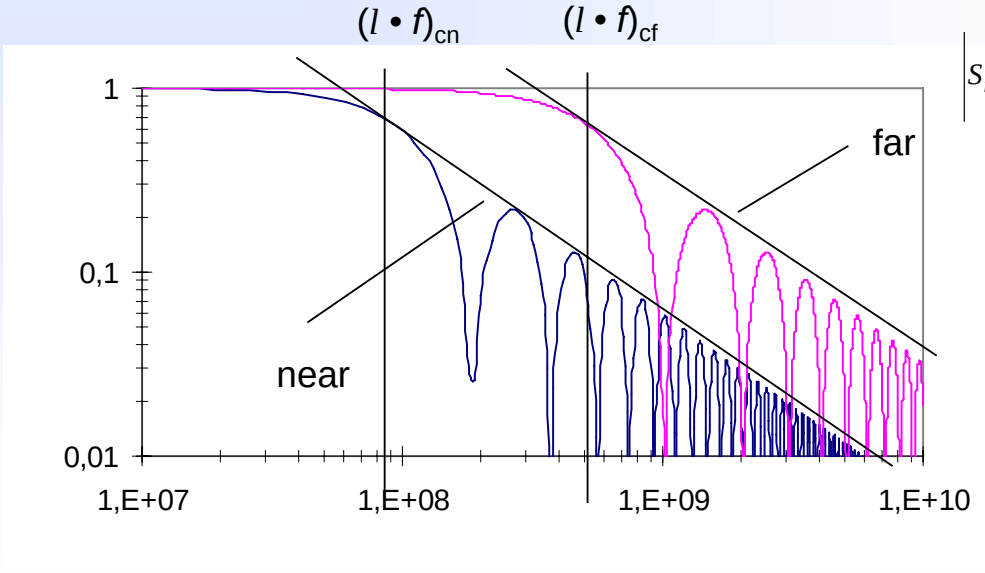
# Summing function $S_{nf}$




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

≈ sin x/x

low frequencies

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

high frequencies

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

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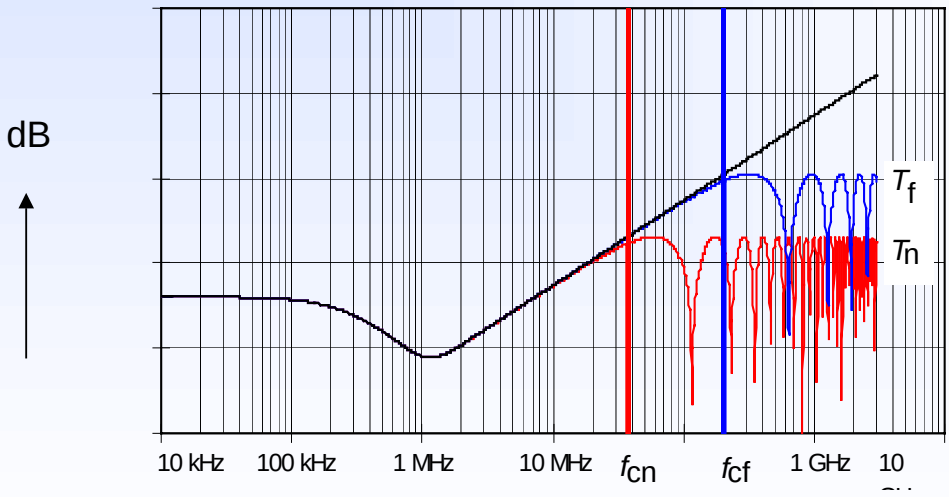
# Calculated Coupling Transfer Function $T_{nf}$

$a_s$ and $Z_T$ vs frequency

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




n = near end

f = far end

L = 1 m

$\varepsilon_{r1}$ = 2,3

$\varepsilon_{r2}$ = 1,0

$Z_F$ = 0

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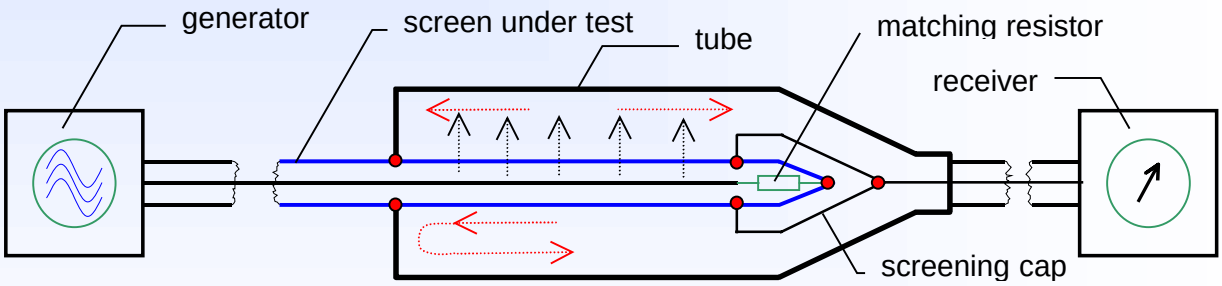
# Measuring with the Triaxial test set-up *CoMeT*

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

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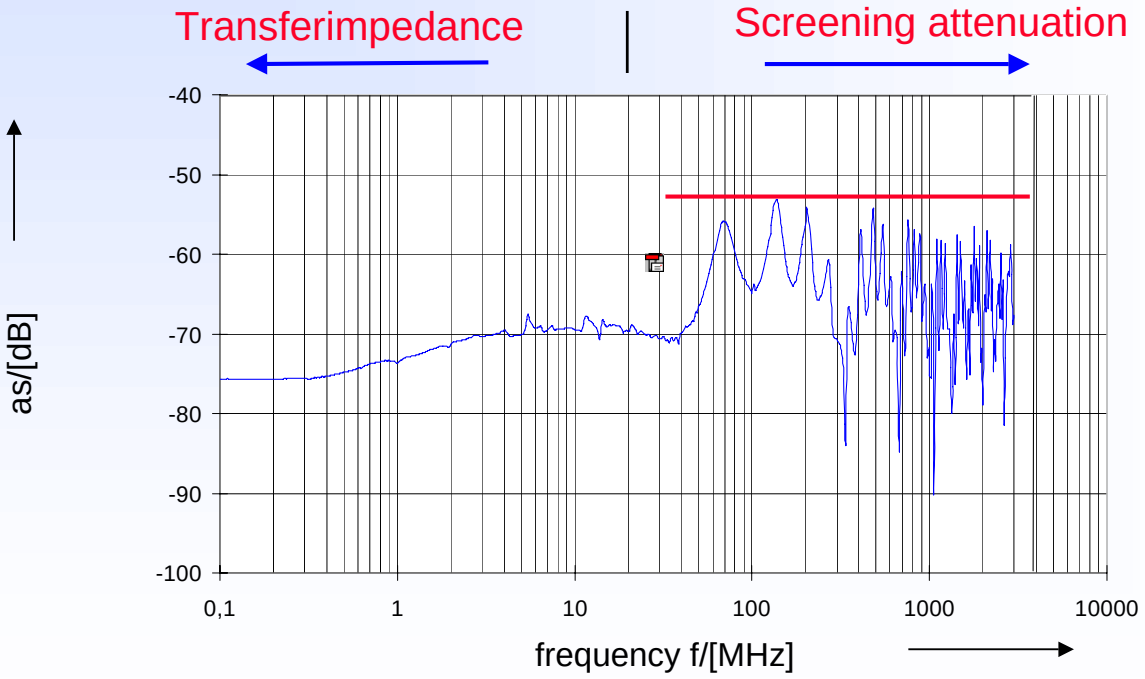
# Measured Transfer function of RG 058

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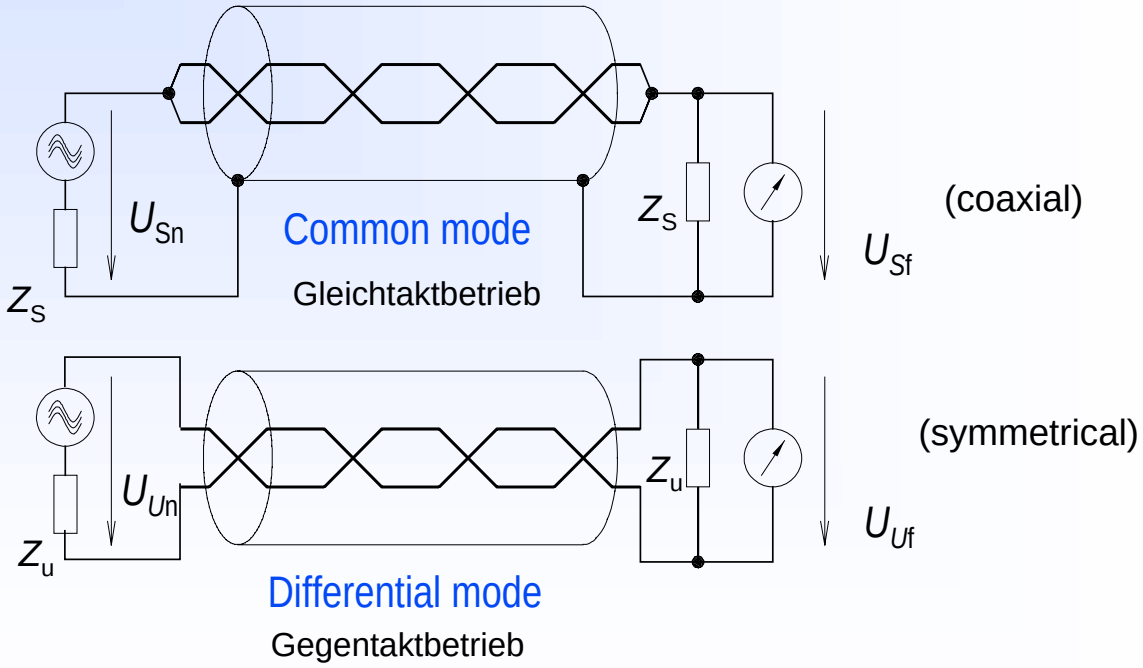
# Differential & Common mode of balanced pairs





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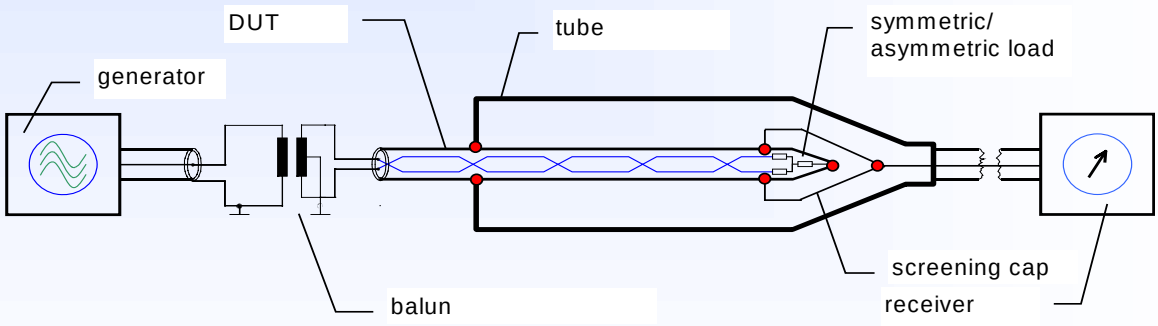
# Measuring of Coupling attenuation

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

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# Coupling attenuation of a CAT 6 Cable, S/FTP, log scale, Triaxial set up






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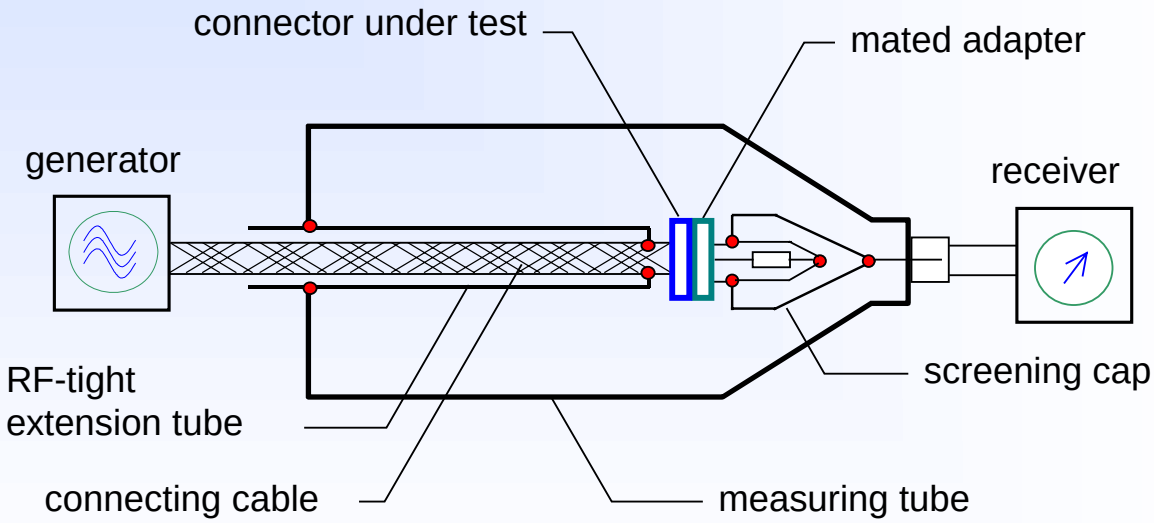
# Triaxial set-up with “Tube in tube“




**IEC 62153-4-7,Tube in tube test procedure**

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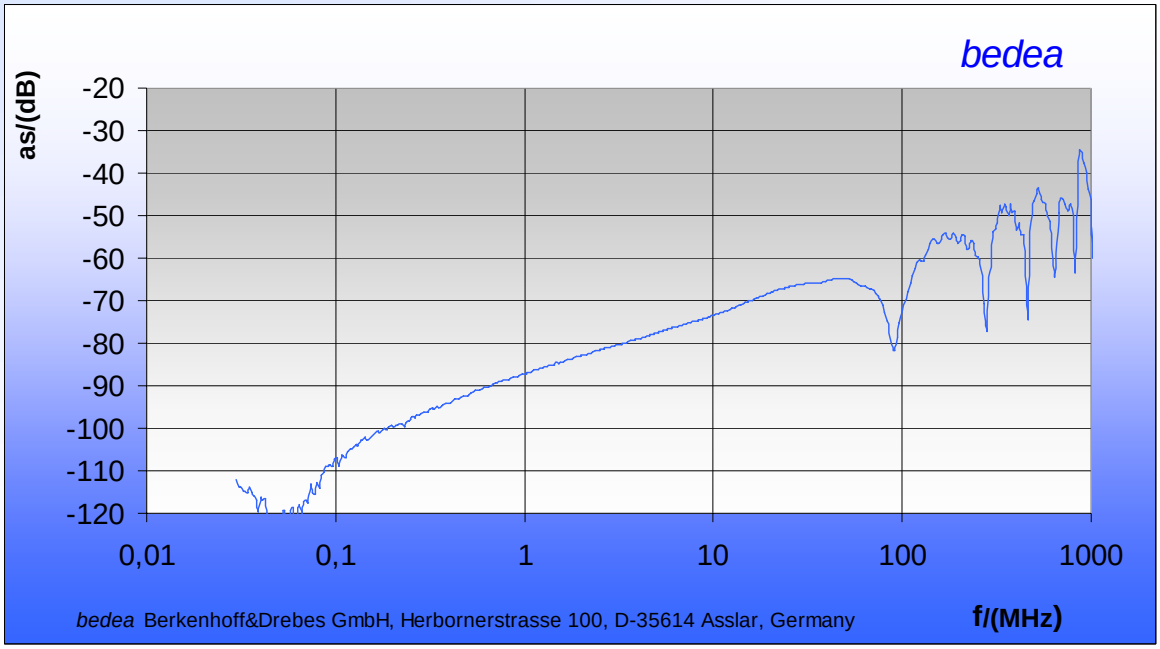
# Coupling attenuation Nexans GG 45





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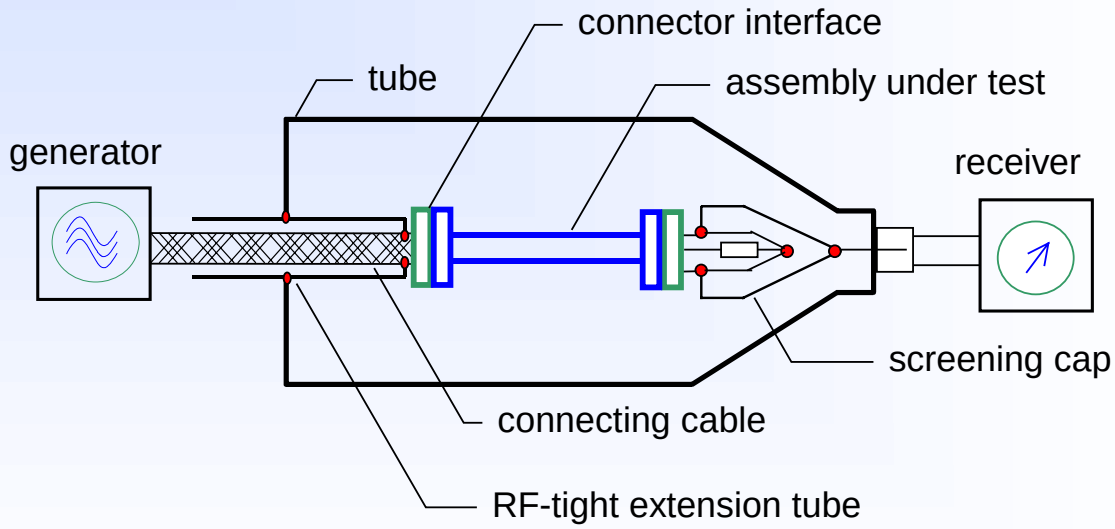
# Measuring of cable assemblies




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

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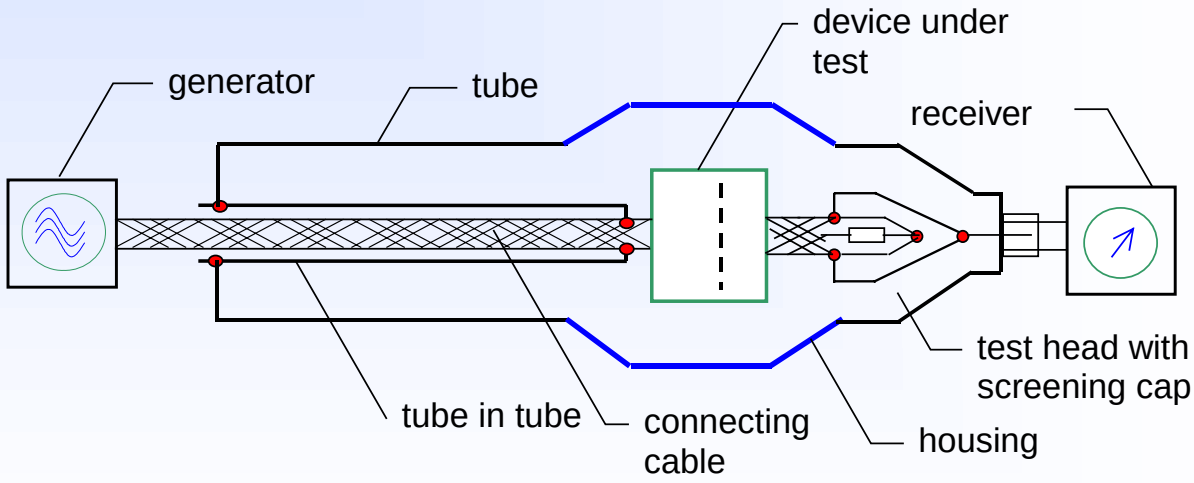
# Test set-up for connecting hardware with housing




Test procedure is under consideration at IEC TC46/WG 5





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# Test set-up CoMeT with housing

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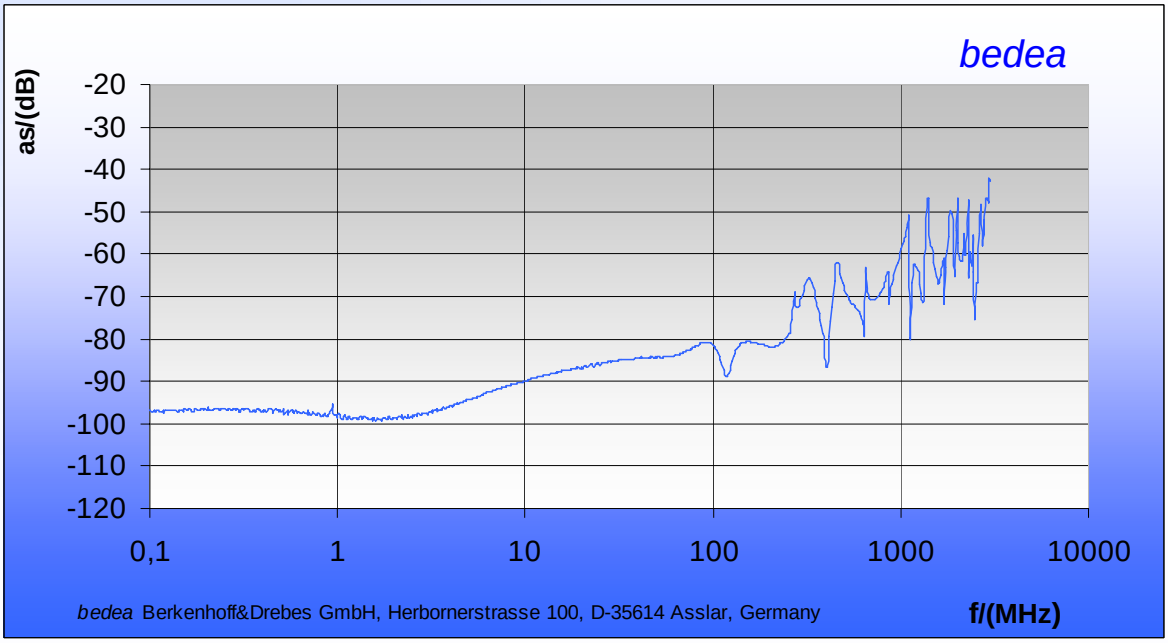
# CATV wall outlet with Tube in tube





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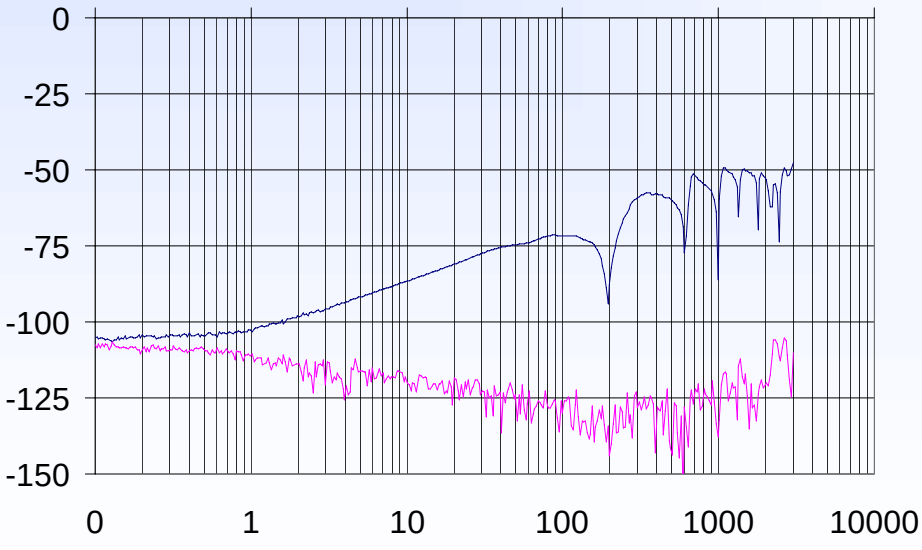
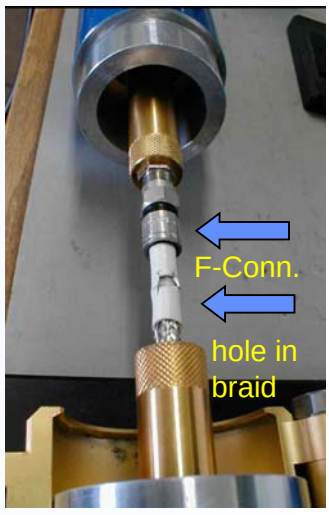
# Cable with small hole, tube in tube, 0,5 m

Well screened CATV-Cable with F-Connector

Same cable with one small hole, 3 mm



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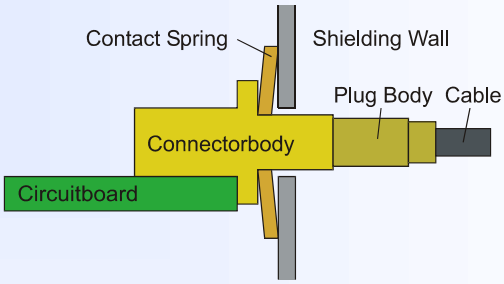
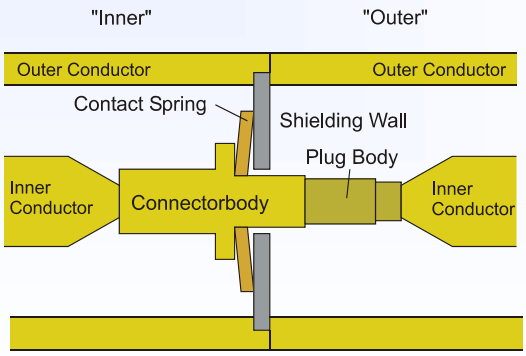
# EMC of Feed-throughs & EMC Gaskets

**Problem:**
**EMC of Feed-throughs & EMC Gaskets**




**Problem in Standardised Surrounding**

**feed in RF-wave**




**measure RF-wave**

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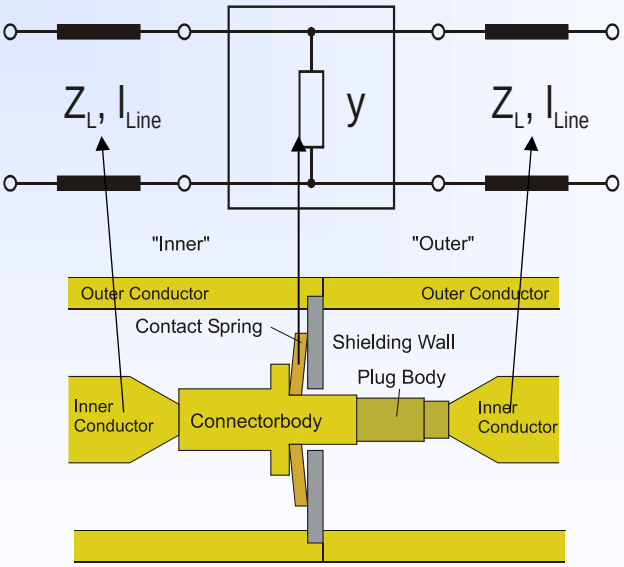
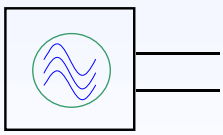
# EMC of Feed-throughs & EMC Gaskets

**equivalent circuit**

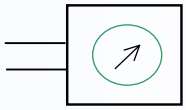



**Y represents the Transfer impedance**

**generator**



**receiver**



Generator & receiver are included in the NWA

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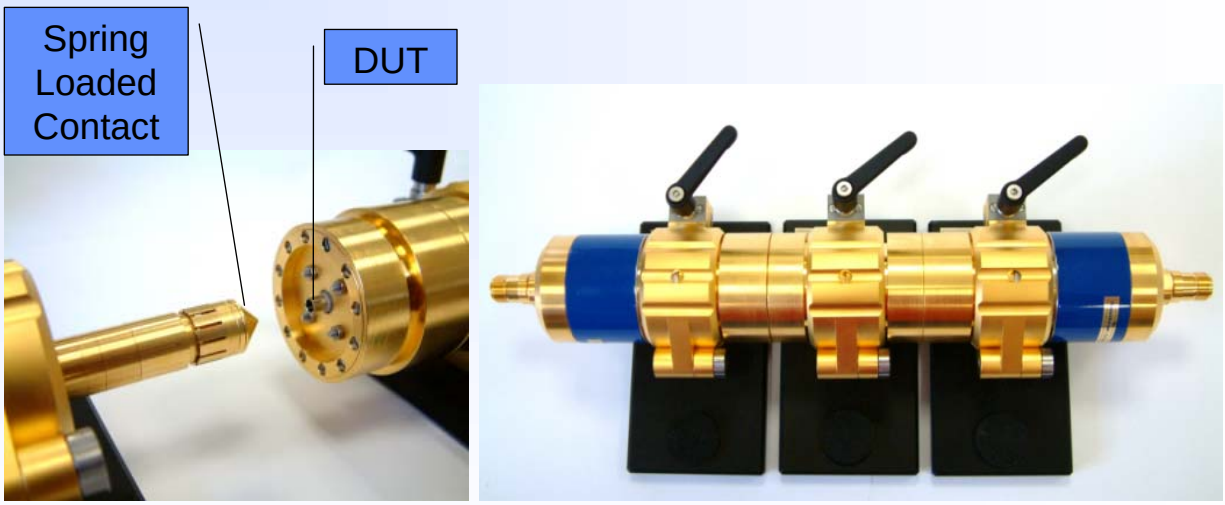
# Test set-up for Feed-throughs & gaskets




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

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# International Standards for triaxial set-up

| | | |
|---|---|---|
| **IEC TR 62153-4-1** | Introduction to EMC measurements | 46/199/DTR |
| **IEC 62153-4-3** | Surface transfer impedance - Triaxial method | 2006-03 |
| **IEC 62153-4-4** | Shielded screening attenuation, test method for measuring of the screening attenuation "$a_s$" up to and above 3 GHz | 2006-05 |
| **IEC 62153-4-7** | 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 | 2006-04 |
| | | |
| **IEC 62153-4-9 IEC/PAS 62338 Ed1** | Coupling attenuation, triaxial method | 46/190/CDV |
| **IEC 62153-4-10** | Shielded screening attenuation test method for measuring the Screening Effectiveness of Feedtroughs and Electromagnetic Gaskets | 46/xxx/CD |
| **EN 50289-1-6** | Communication cables - Specifications for test methods Part 1-6: Electrical test methods -Electromagnetic performance (includes IEC 62153-4-3 and IEC 62153-4-3) | 2002 |

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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

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# 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*
- Contact person & further questions *bmund@bedea.com*

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# Literature

[1] Halme, L./Szentkuti, B.: The background for electromagnetic screening measurements of cylindrical screens. Tech. Rep. PTT(1988) Nr. 3.

[2] Breitenbach, O./Hähner T.: Kabelschirmung im Übergang von MHz- zu GHz-Frequenzen. ntz Bd. 46(1993) H.8, S. 602-608.

[3] L. Halme, R. Kytönen, "Background and introduction to EM screening (shielding) behaviours and measurements of coaxial and symmetrical cables, cable assemblies and connectors", Colloquium on screening effectiveness measurements, Savoy Place London, 6 May 1998, Reference No:1998/452.

[4] O. Breitenbach, T. Hähner, B. Mund, "Screening of cables in the MHz to GHz frequency range extended application of a simple measuring method", Colloquium on screening effectiveness measurements, Savoy Place London, 6 May 1998, Reference No:1998/452.

[5] T. Hähner, B. Mund, "Test methods for screening and balance of communication cables", 13th international Zurich EMC Symposium, February 16-18 1999

[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,