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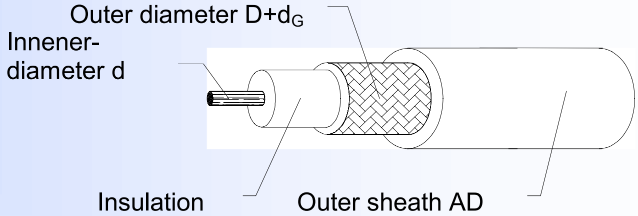
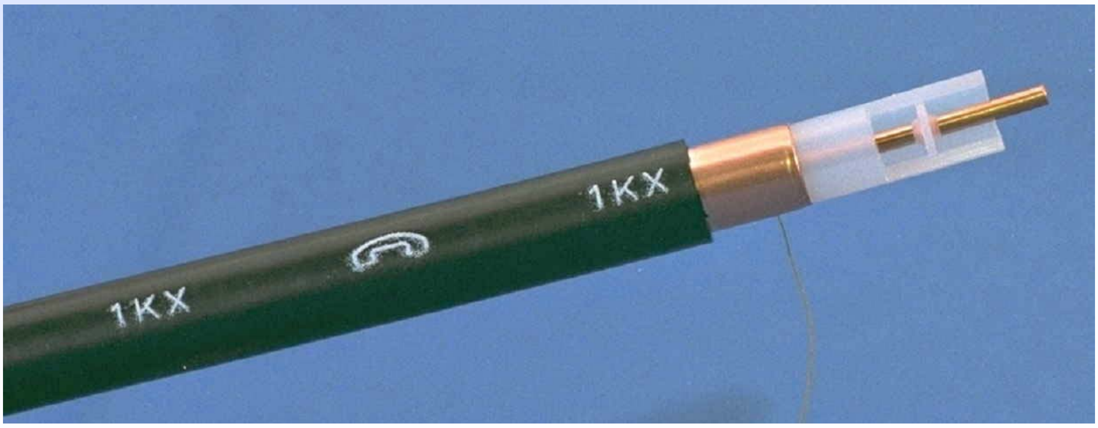
## Standards, Design & Installation of CATV-Cables

EMV-KLASSE
EMC-CLASS
EN 50117





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## Array of products of RF-Kabel / Antenna cables

EMV-KLASSE
EMC-CLASS
EN 50117

*bedea* = all at first hand

*bedea* = all “made in Germany”

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## Standards, Design & Installation of CATV-Cables

- 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- and 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

- Characteristics of CATV-cables
  - Characteristic impedance,
  - Attenuation, Return loss
- Installation practices
  - Tensile strength and bending
  - Installation precautions
- EMC of CATV-Cables, Screening classes
- Standards
  - EN 50117-2-1 to -2-5, EN 50117-4-1, CATV-Kabel
  - EN 60966-2-4 bis -2-6, TV receiver leads
- Discussion

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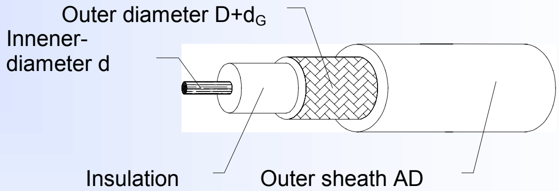
# Basic characteristics of coaxial cables

The characteristic impedance *Z* of a RF-coaxial cable is given by the ratio of inner conductor diameter d to outer conductor diameter D (D/d) and the dielectric constant $\varepsilon_r$ of the insulation material. For frequencies $>$ 10 MHz Z in Ohm is:

$$Z = \frac{60}{\sqrt{\varepsilon_r}} \cdot \ln\left(\frac{D}{d}\right)$$




Shunt Capacitance per unit length, in pico farads per meter is:

$$C' = \frac{55{,}6 \cdot \varepsilon_r}{\ln(D/d)}$$

Series Inductance per unit length, in Henrys per meter is:

$$L' = \frac{\mu_0 \mu_r}{2\pi} \cdot \ln\frac{D}{d}$$

As Insulation material Polyethylen (PE) with a dielectric constant $\varepsilon_r$ of 2,28 and (physically) foamed Polyethylen (CELL-PE) with $\varepsilon_r$ in the range of 1,35 - 1,5 is mainly used for CATV cables. (CELL-PE = cellular Polyethylene, µ = magnetic permeability)

**Test procedure to measure Characteristic impedance is given in: IEC 61196-1-108 and EN 50289-1-11**





# Reflection coefficient

A RF-signal which is travelling through a transmission line with the nominal characteristic impedance $Z_n$ will be reflected on every point of this line where it meets irregularities with a deviation from the nominal characteristic impedance $Z_n$ . The reflection factor at a point of irregularity is designated by the reflection coefficient $\underline{r}_e$ of a single reflection which is given by:

$$\underline{r}_e = \frac{\underline{Z}_L - Z_n}{\underline{Z}_L + Z_n}$$

where

$Z_n$ is the characteristic impedance of the cable
$\underline{Z}_L$ is the characteristic impedance at the point of irregularity.

The reflection coefficient $\underline{r}_e$ of a cable is "1" at an open end, "-1" at a shortened end and zero in the case of matching with the nominal characteristic impedance, (75 Ω at CATV-systems.)

At standard applications like CATV-networks random or stochastic distributed irregularities over the cable length will not affect signal transmission if the reflection coefficient $\underline{r}_e$ of a single reflection point is < 0,01 respectively > 40 dB.

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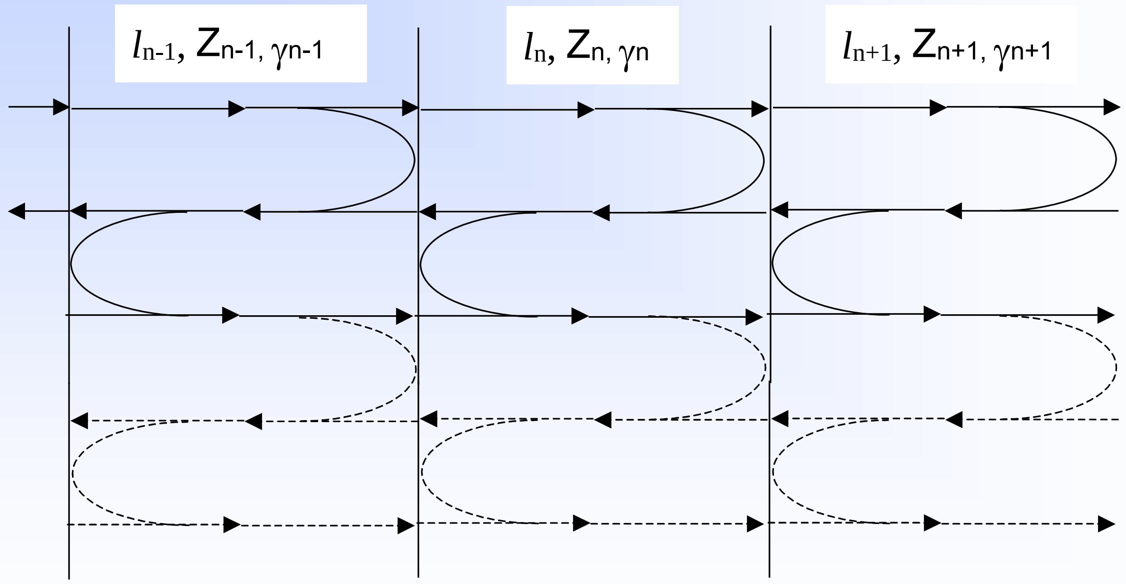
# Periodic disturbances





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# Input reflection factor

The total input reflection factor $\underline{R}$ at the input of the cable is the sum of the single reflections $\underline{r}_e$. If the irregularities of the cable are of a periodic distance $l_0$, the reflected signal and with that the total input reflection factor $\underline{R}$ at the input end of the cable will be a maximum at the resonance frequency $f_r$ which is obtained to:

$$f_r = \frac{c_0 \cdot v_K}{2 \cdot l_0}, \qquad = \frac{c_0}{2 \cdot l_0 \cdot \sqrt{\varepsilon_r}}$$

where

- $c_0$ is the propagation velocity in free space
- $v_K$ is the velocity ratio
- $\varepsilon_r$ is the relative dielectric permittivity of the insulation material

Note, that the wave length $\lambda$ of the resonance frequency $f_r$ is 2 $l_0$.

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# Return loss

The return loss $a_r$ is a measure of the deviation from the mean characteristic impedance of a cable in the frequency domain and is the most important quality characteristic of a RF-coaxial cable. The return loss $a_r$ is defined as:

$$a_r = 20 \cdot \log(u_i / u_r), \qquad = 20 \cdot \log(1/\underline{R}) \qquad \text{in dB}$$

where

- $u_i$ is the magnitude of the incident wave with reference to the impedance $Z_n$
- $u_r$ is the magnitude of the reflected wave with the cable terminated with $Z_n$
- $Z_n$ is the nominal characteristic impedance of the cable.
- $\underline{R}$ is the input reflection factor

The return loss $a_r$ is related to the total input reflection factor $\underline{R}$ by:

$$\underline{R} = (u_r / u_i) \quad = 10^{-(a_r/20)}$$

It is indirectly related to the standing wave ratio s by: $s = \frac{(1+R)}{(1-R)}$





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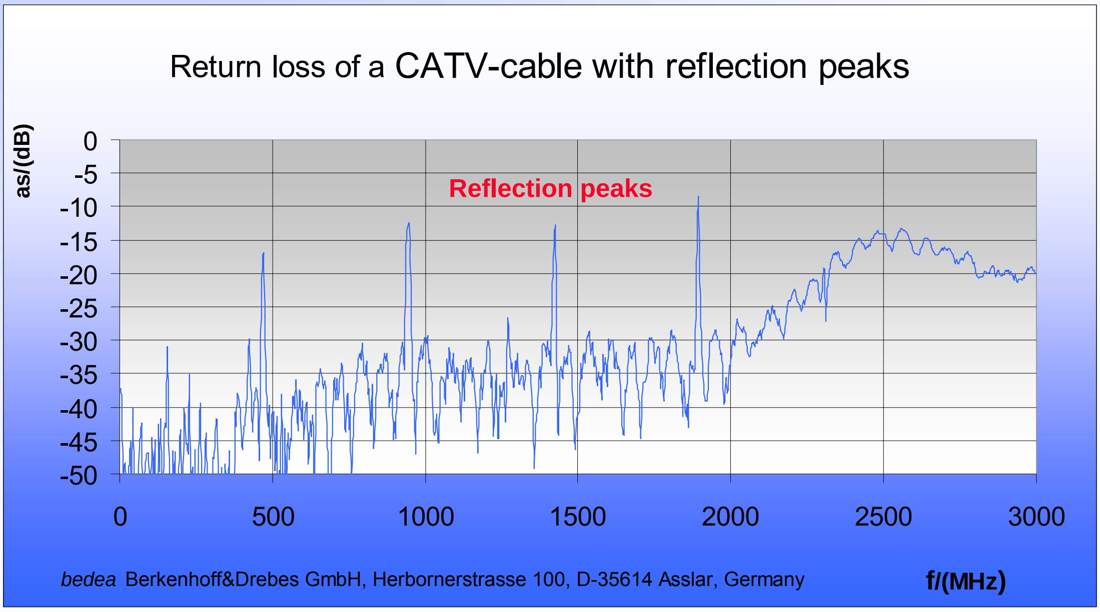
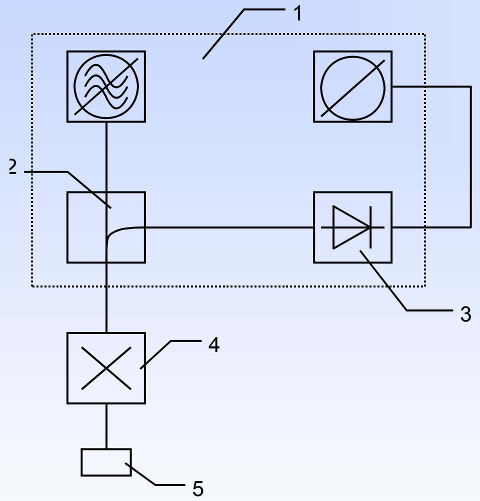
# Reflection peaks




The limit values of the return loss are stated in EN 50117-2-1 to-2-5 and in EN 50117-4-1

# Measuring of Return loss




- 1 network analyser
- 2 directional coupler or bridge
- 3 demodulator
- 4 DUT (device under test)
- 5 load

**Number of points shall be ≥ 20.000 per measuring !**

$$r = \frac{Z_0 - Z_L}{Z_0 + Z_L} \qquad a_r = 20 \cdot \log(1/r) \quad \text{(dB)}$$

The return loss is the measure for the equability of the characteristic impedance and therefore the essential Quality Criteria of a coaxial cable !

The test procedure to measure Return loss is given in: IEC 61196-1-112 and EN 50289-1-11





# Return loss limits

**EN 50117-2-3**

RL = 26 dB min. from 5 MHz to 30 MHz
RL = 26 dB min. from 30 MHz to 470 MHz
RL = 23 dB min. from 470 MHz to 1 000 MHz

**EN 50117-2-1/-2-2/-2-4/-2-5 & EN 50117-4-1**

Für Kabel mit $\alpha \le$ 18 dB/100 m bei 800 MHz

RL = 23 dB min. from 5 MHz to 30 MHz
RL = 23 dB min. from 30 MHz to 470 MHz
RL = 20 dB min. from 470 MHz to 1 000 MHz
RL = 18 dB min. from 1 000 MHz to 2 000 MHz
RL = 16 dB min. from 2 000 MHz to 3 000 MHz

($\alpha$ is the attenuation of the cable)

Measurement accuracy:

In case of digital signal processing, the accuracy of the return loss measurement, $\Delta_{ar,f}$ depends on the frequency step $\Delta_f$ in the measured frequency range. The frequency spacing in the measured frequency range is frequency dependent and shall be in accordance with the following equation:

$$\Delta f \le 1.4 \cdot \frac{300 \cdot v_r}{868.6 \cdot \pi} \cdot a(f) \cdot \sqrt{10^{\frac{\Delta a_{r,f}}{10}} - 1}$$

*bedea* is measuring with > 20.000 points

where a(f) is the attenuation of the cable at the measured frequency point in dB/100m, $\Delta_{ar1}$ is the max. uncertainty of measurement due to frequency spacing; and $v_r$ is the nominal velocity. The measurement inaccuracy $\Delta_{ar,f}$ shall be $\le$ 1 dB unless otherwise stated in the relevant detail spec.

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# Attenuation

On its way through the cable the signal strength will degrade
due to losses in the conductors and losses the dielectric.

This Attenuation is caused by the "Skin effect"
(current density near the surface of the conductor is greater than that at its core, which increases with increasing frequency)
and by increasing loss in the dielectric, which increases also with frequency.

in order to add the attenuation of different cable length as well as of different devices,
Attenuation is given in Decibels/m (dB/m),(resp. per unit), usually in dB/100 m

Attenuation is given in the data sheets of the manuafacturer at certain frequencies

Attenuation at $f_2$ at known $f_1$ (approach): $\alpha_1/\alpha_2 = \sqrt{(f_1/f_2)}$, ($\alpha$/dB, f/MHz)

Attenuation may also be given by Attenuation constants: $\alpha(f) = a*f + b*\sqrt{f} + c$

**The test procedure to measure Attenuation is given in: IEC 61196-1-113 and EN 50289-1-8**



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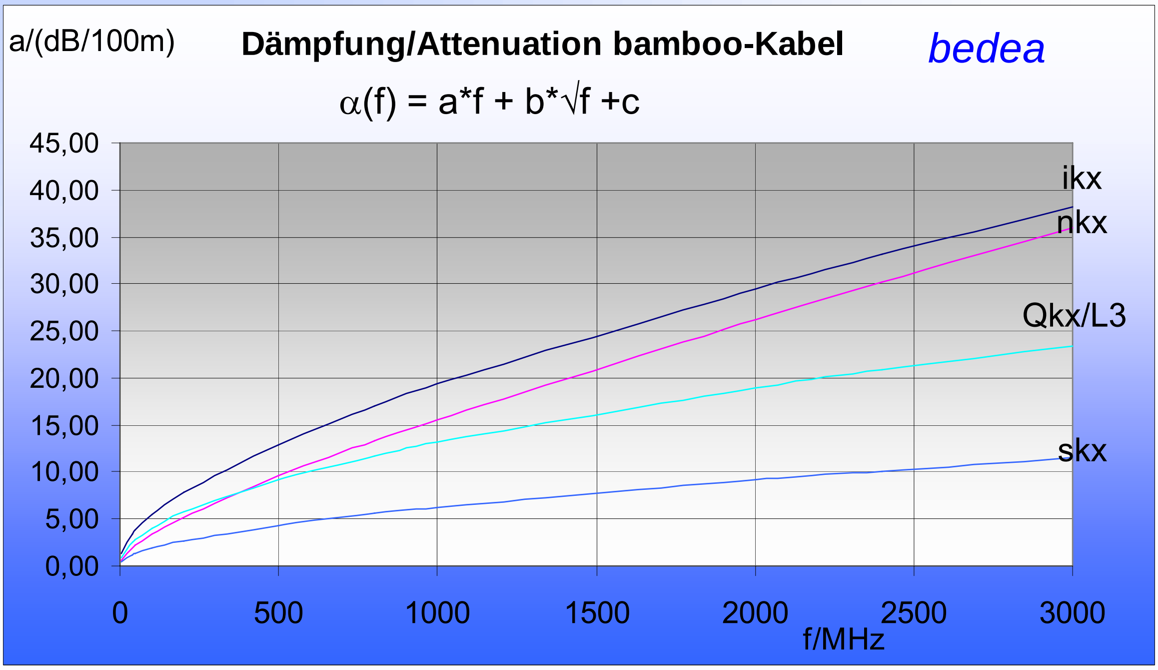
# Attenuation curve



# DIN 18015-1 Abschnitt 7.4, Rohr und Verteilnetz

- Kabel und Leitungen müssen auswechselbar und gegen Beschädigung geschützt verlegt werden,
- sie dürfen (unter Beachtung von DIN EN 50174-2 Abs. 6.5) in Schächten zusammen mit Starkstromkabeln bis 1000 V verlegt werden. EMV und Sicherheit !
- Eine Verlegung direkt in Putz ist nicht zulässig.
- Die Auswahl von Kabeln und Leitungen ist in Bezug auf äußere Einflüsse (z. B. mechanisch, thermisch, chemisch) zu treffen. Die Umgebungstemperatur der Leitung darf im Regelfall + 55 °C nicht überschreiten, dies ist insbesondere bei der Verlegung in Heizungskanälen oder -schächten und Dachräumen zu beachten.
- ... sind mindestens 2 Leerrohre zwischen oberstem Geschoss (Dachgeschoss) und unterstem Geschoss (Kellergeschoss) mit einem Innendurchmesser von je mindestens 30 mm vorzusehen, für die Wohnungszuführung solche mit mindestens 23 mm.
- Für die Montage von Antennensteckdosen sind 60 mm tiefe Unterputz-Geräteabzweigdosen zu verwenden.





# Operating datas of coaxial cables (IEC 60096-0-1)

| | |
|---|---|
| Minimum bending radius of Coaxial cables | 5 × outer diameter for single indoor laying<br>10 × outer diameter for single outdoor laying<br>(respectively bending under tensile strength or multiple bending) |
| Minimum permissible laying temperature | –15 °C dielectric PE, sheath PVC quality 1<br>–40 °C dielectric PE, sheath PVC quality 2<br>–55 °C dielectric and sheath FEP and PTFE<br>Cautious laying without shocks recommended |
| maximum Tensile strength | approx. 50 N pro mm$^2$ Copper (Inner- & Outer coductor),<br>see data sheet of the manufacturer |

Detailed operating information of cables shall be given in the relevant cable specification of the manufacturer (e.g. www.bedea.com)

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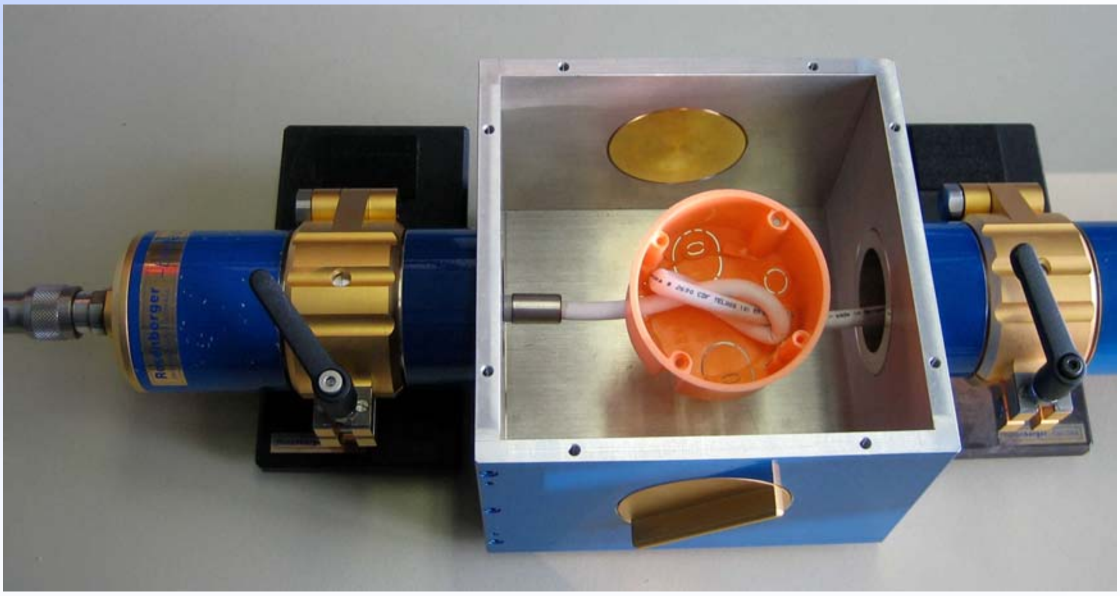
## Bending of cables in TV socket




Measuring of screening attenuation Telass CDF 101 in TV socket

Minimum bending radius of Coaxial cables in TV socket falls below IEC 60096-0-1





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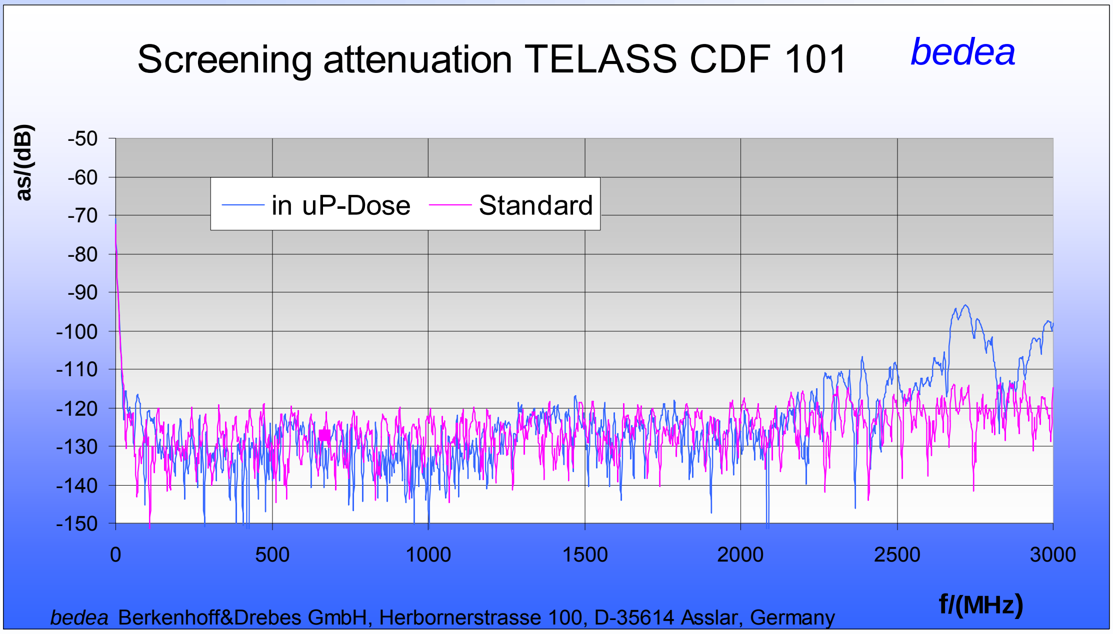
## Bending radius in TV socket box




from 30 MHz to 3 GHz, requirements of Screening class A+ are met also after extreme bending

# Installation instructions of CATV-cables

- Quality requirements:
  - Use only cables with gas injected insulation (physically foamed)
  - with screening class A or better
- Use of clamps:
  - avoid cable clamps (where possible) and use instead conduits or ducts
  - dont fix clamping straps too tight.
  - (pressure to the dielectric will lead to deviation of the Characteristic Impedance)´
- Installation close to heat sources:
  - dont install coaxial cables close to heat sources (heating intallations)
  - foamed dielectric starts to melt at about ca. 65 °C
- The use of cable conduits and ducts is strongly recommended





# Cable connections & EMC

- Cable connections are **EMC-error source No 1:**
- preparing of all cables with appropriate tools
  - fitting tools for all cables are available
  - note the assembly instructions of the manufacturer
  - also for buried boxes
- mounting of coaxial connectors to the coaxial cables
  - use only connectors which are designed for the relevant cable
  - in case of doubt ask the cable and/or the connector manufacturer
  - note the assembly instructions of the manufacturer
- good screening attenuation will be achieved with **F-Compression Connectors**
- Through connection of coaxial cables
  - coaxial cable connections shall be coaxial only !

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## Radiation limits (SchuTSEV) Ge

The “BundesNetzAgentur - BNetzA (ehem. (RegTP)”, has established the “Sicherheitsfunk-Schutzverordnung - SchuTSEV” (former NB 30) which gives Radiation limits for Telecommunication installations.

| **Frequency, f, in the range** | **Radiation limits (peak value in 3 m distance, dB(µV/m)** | **measuring bandwith** |
|---|---|---|
| 0,009 to 0,15 MHz | $40 - 20 \log_{10} f(MHz)$ | 200 Hz |
| > 0,15 to 1 MHz | $40 - 20 \log_{10} f(MHz)$ | 9 kHz |
| > 1 to 30 MHz | $40 - 8{,}8 \log_{10} f(MHz)$ | 9 kHz |
| > 30 to 108 MHz | 27 [1]) | 120 kHz |
| > 108 to 144 MHz | 18 [2]) 27 [1]) | 120 kHz |
| > 144 to 230 MHz | 27 [1]) | 120 kHz |
| > 230 to 400 MHz | 18 [2]) 27 [1]) | 120 kHz |
| > 400 to 1000 MHz | 27 [1]) | 120 kHz |
| > 1 to 3 GHz | 40 [2]) | 1 MHz |

[1]) Dies entspricht der äquivalenten Strahlungsleistung von 20 dBpW
[2]) Der Wert von 18 dB(µV/m) gilt nur für breitbandige, digitale leitergebundene (Rundfunk-)Signale. Für alle anderen Signale beträgt dieser Wert 27 dB(µV/m).
[3]) Dies entspricht der äquivalenten Strahlungsleistung von 33 dBpW





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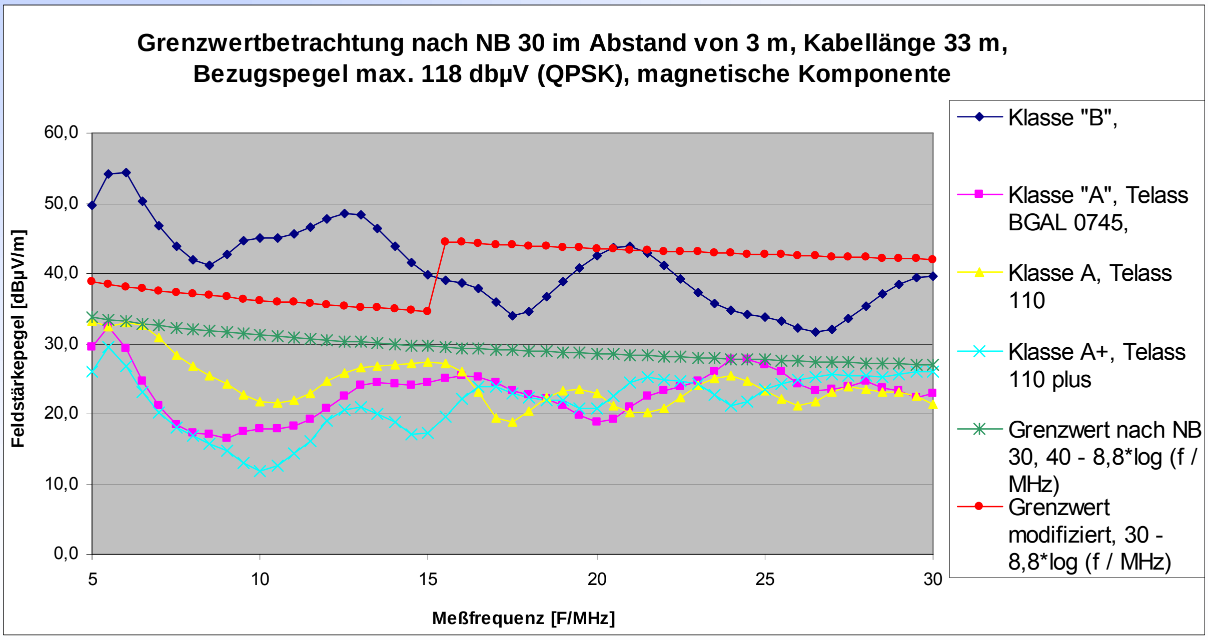
## Measuring of radiation, RegTP, airfield Asslar

To establish radiation limits of CATV-cables measurements have been achieved by RegTP in co-operation with bedea at the airfield in Asslar.

height: 5 meter,
length 33 meter

RegTP = German authority for Telecommunication & postal service (= BNetzA)

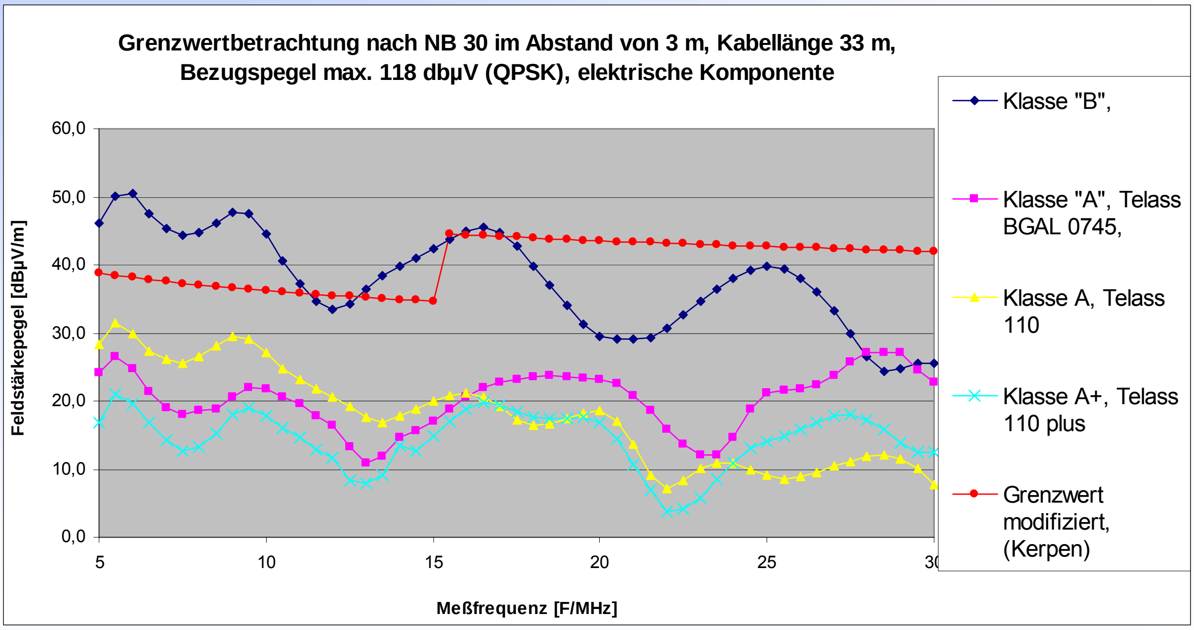
# Measuring of radiation, RegTP, airfield Asslar








# Measuring of radiation, RegTP, airfield Asslar



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# Screening Classes acc. to EN 50117

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| 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 |

Classe A & B are valid for cables acc. to EN 50117-2-1/-2-2/-2-4 und /-2-5
Screening Class A++ is valid for CATV-cables acc. to EN 50117-2-3

Transfer impedance and Screening attenuation shall be measured with the "Triaxial test procedure" according to EN 50289-1-6 **(CoMeT)**
Absorbing clamps are not allowed, due to large uncertainty and poor reproducibility



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# Measuring with the test set-up *CoMeT*

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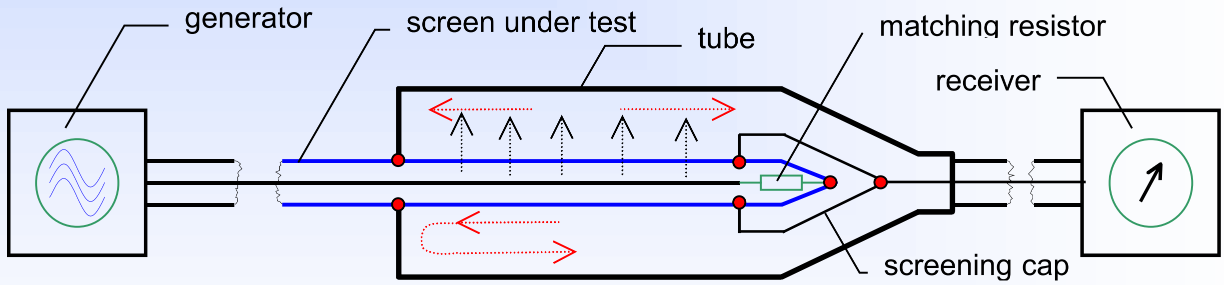
Transferimpedance & Screening attenuation

few kHz up to and above 8 GHz with one test set-up

Test set-up *CoMeT*
designed by *bedea*
and distributed worldwide




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

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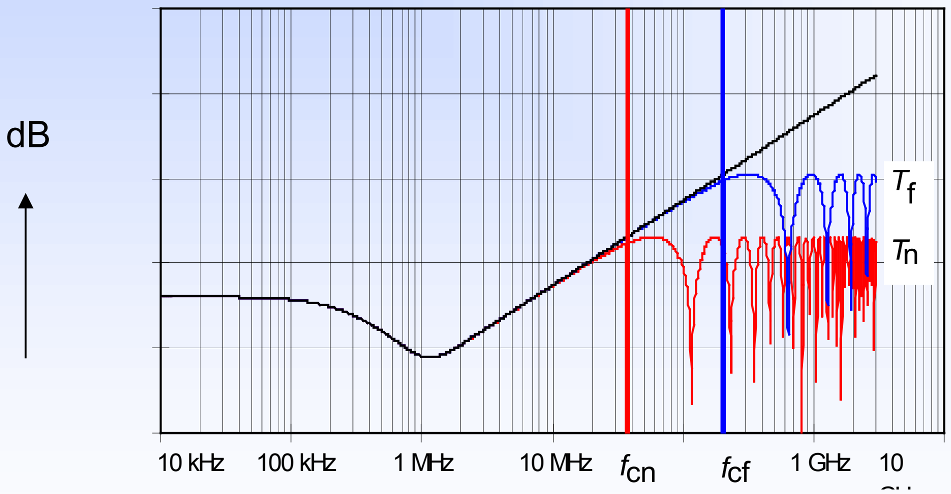
# Calculated Coupling Transfer Function $T_{nf}$

Calculated Coupling Transfer Function $T_{nf}$

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




n = near end

f = far end

L = 1 m

$\varepsilon_{r1}$ = 2,3

$\varepsilon_{r2}$ = 1,0

$Z_F$ = 0

frequency

Transfer impedance ← → Screening attenuation





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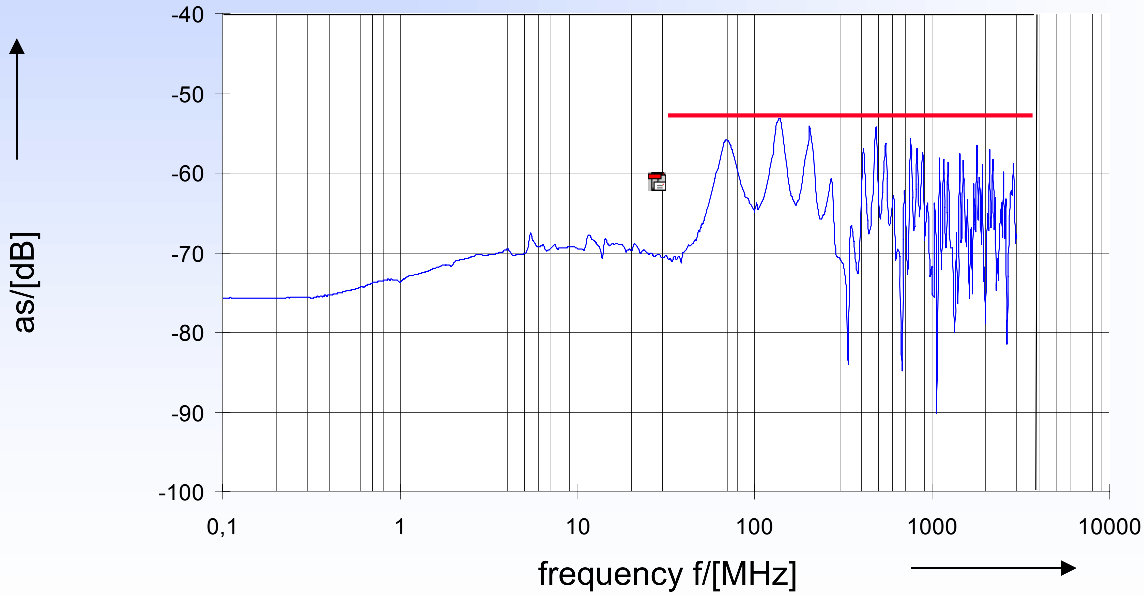
# Measured Transfer function of RG 058

Transferimpedance ← | → Screening attenuation

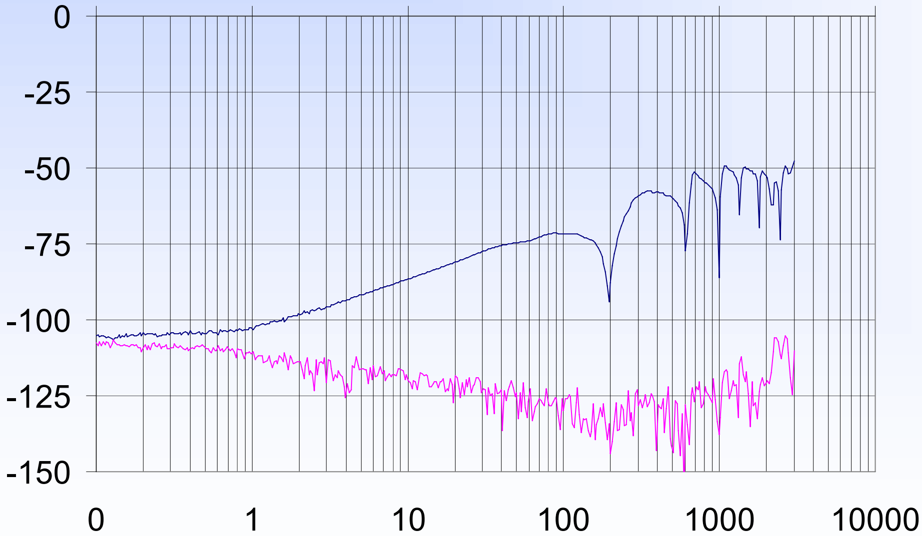


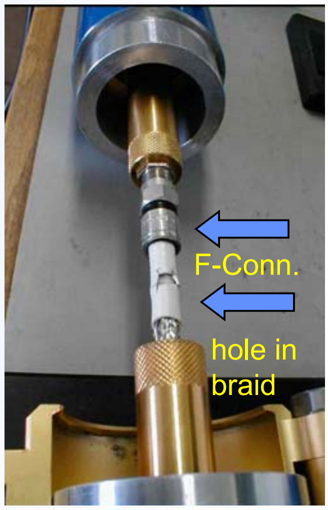
# Cable with small hole, tube in tube, 0,5 m

EMV-KLASSE EMC-CLASS A EN 50117

Well screened CATV-Cable with F-Connector

Same cable with one small hole, 3 mm








# EMC-measurements in Return path (KDG)

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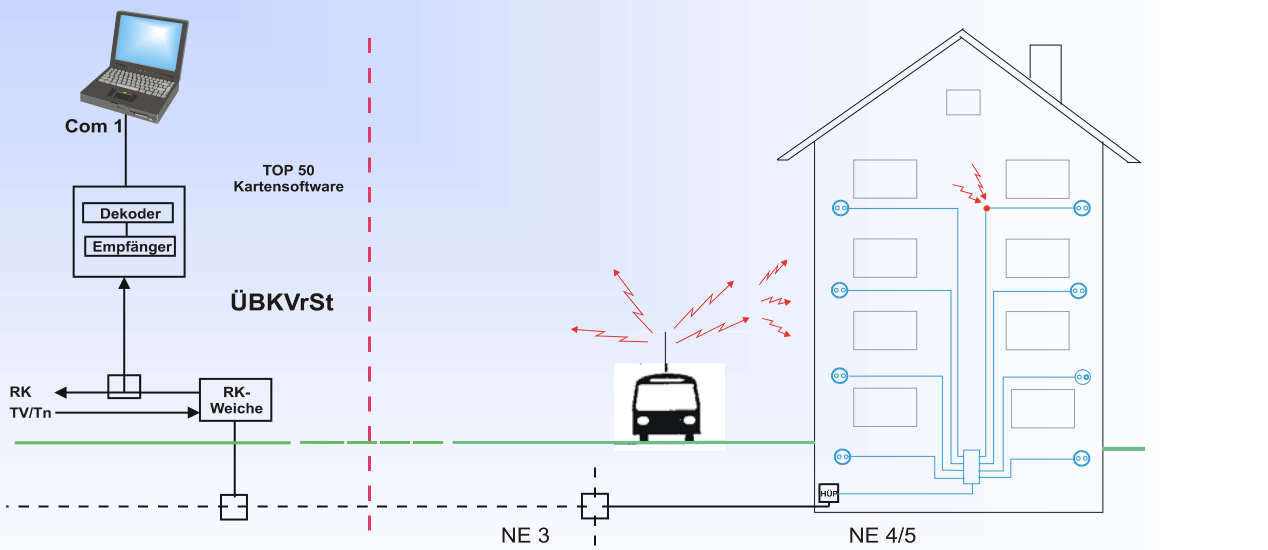


Car contains radio transmitter mit GPS-receiver, disturbing-signal is coupled into the CATV installation at a weak point and transmitted with GPS info to the head end (respective to CO) via return path

Mit freundlicher Genehmigung, H. Hünninghausen, KDG

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# TV receiver leads

- The main source of error in CATV systems are TV receiver leads with insufficient screening attenuation (DECT problems).
- Screening of TV receiver leads shall be in accordance with screening class A (EN 50117)
- appropriate TV receiver leads are standardised in EN 60966-2-x

| | Detail specification for cable assemblies for radio and TV receivers - | |
|---|---|---|
| EN 60966-2-4 Ed3 | 0 to 3000 MHz, IEC 61169-2 connectors | 2009-01 |
| EN 60966-2-5 Ed3 | 0 to 1000 MHz, IEC 61169-2 connectors | 2009-01 |
| EN 60966-2-6 Ed3 | 0 to 3000 MHz, IEC 61169-24 connectors | 2009-01 |





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# Standards for CATV-cables, EN 50117

| | | |
|---|---|---|
| **EN 50117-1, Ed.2** | Coaxial cables - Generic specification | 2007-07 |
| | Sectional specifications for cables used in cabled distribution networks **(CATV)** | |
| **EN 50117-2-1 Ed2** (replaces EN 50117-2) | Indoor drop cables for systems operating at 5 MHz - 1 000 MHz | 2008-08 |
| **EN 50117-2-2 Ed1** (replaces EN 50117-3) | Outdoor drop cables for systems operating at 5 MHz - 1000 MHz | 2008-08 |
| **EN 50117-2-3 Ed1** (replaces EN 50117-4) | Distribution and trunk cables, operating at 5 MHz - 1000 MHz | 2008-08 |
| **EN 50117-2-4 Ed1** (replaces EN 50117-5) | Indoor drop cables for systems operating at 5 MHz - 3000 MHz | 2008-08 |
| **EN 50117-2-5 Ed1** (replaces EN 50117-6) | Outdoor drop cables for systems operating at 5 MHz - 3000 MHz | 2008-08 |
| **EN 50117-4-1 Ed1** | Sectional specification for cables for BCT cabling in accordance with EN 50173 - Indoor drop cables for systems operating at 5 MHz - 3 000 MHz | 2009-02 |

# Common Path Distortions (CPD)

The Return Path has been a source of new income by majority of Cable operators. due to different applications like high Speed data, Telephony and other services.

Return Path has proven to be prone to Ingress, Noise and the dreaded **C**ommon **P**ath **D**istortions **(CPD)** respectively **P**assive **I**ntermodulation **(PIM)**

**CPD** is the generation of unwanted frequencies ($f_1 \pm f_2$) beside the useful frequencies $\mathbf{f_1}$ on connections between the cable and connectors or devices

due to **Diode or Bimetallic effects**

and also **ageing effects** due to **corrosion** (among other effects).

IEC Technical Commitee TC 46 WG6 has determined the specs for measuring PIM in mobile networks (50 Ohms at 900 MHz and 1800 MHz)
another testprocedure for CPC is described in ANSI/SCTE 109 2005





# Hints to avoid PIM on coaxial cables

avoid magnetic materials like Copper clad steel (Staku) as conductors

Copper Braid wires on Aluminium Foils shall be tinned (Galvanic Cell)

Aluminium in moist surrounding will lead to corrosion --> CPD

For buried cables and cables laid in moist surrounding, Cables with pure copper foil/band have been proven for over 25 years in Germany

The use of high quality cables and connectors is strongly recommended, also with respect to ageing effects

The CPD problem is under consideration at DKE(VDE) and CENELEC

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# Conclusion 1

- The characteristic impedance *Z* of a RF-coaxial cable is given by the ratio of inner conductor diameter d to outer conductor diameter D (D/d) and the dielectric constant $\varepsilon_r$
- Die return loss is a measure for the continuity of the characteristic impedance and therewith the main Quality characteristic of a coaxial cable.
- (Failure in manufacturing may lead to reflection peaks)
- Attenuation of Coaxial cables is given in logarithmic ratio in Decibel (dB) per length, e.g. in dB/100m,
- When installing coaxial cables, specification of the manufacturer regarding minimum bending radius, maximum tensile strength temperature range...... shall be noted
- Use only gas injected (physically foamed) Coaxial cables or cables with solid PE
- Dont use cable clamps to fix the cable (especially not preiodically)
- in order to avoid CPD (Common Path Distortion) resp. PIM the use of high quality Cables and Connectors is strongly recommended.





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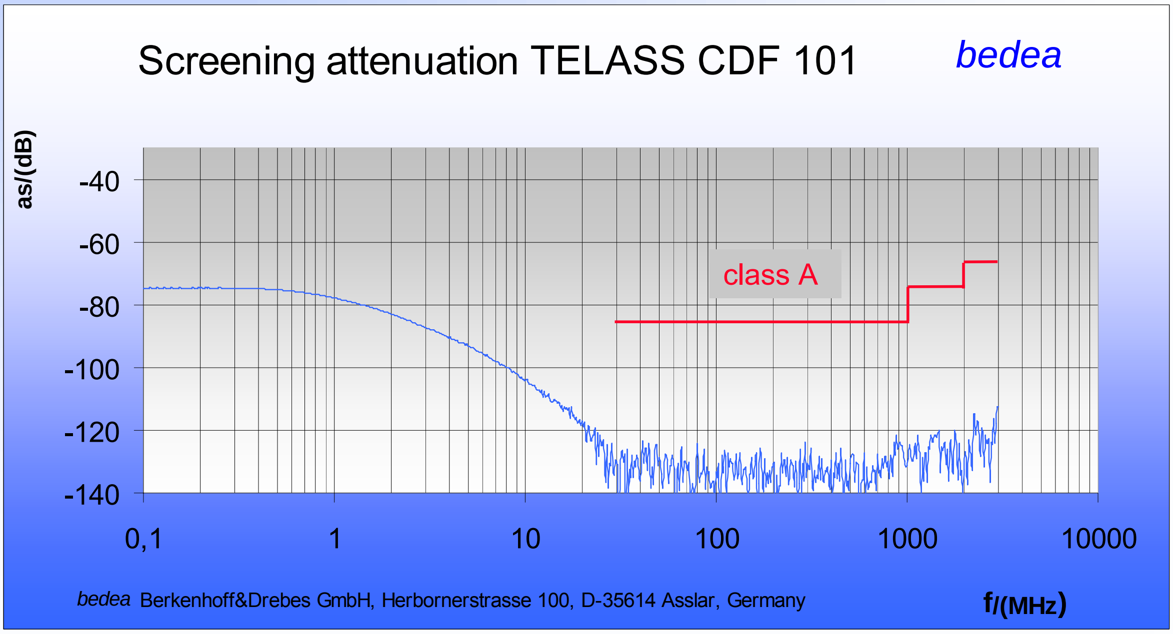
# Conclusion 2

- Coaxial cables shall not be installed close to heat sources
- Connections of cables are EMC error source No. 1
- Good screening will be achieved with F-Compression connectors
- Radiation limits of Telecommunication systems are established at SchuTSEV
- by BNetzA (Germany),
- Radiation limits at CENELEC are still under consideration
- The use of high Quality cables and connectors with Screening class A or better (acc. to **EN 50117**) is strongly recommended
- Appropriate TV receiver leads are standardised in EN 50966-2-x
- Standards for CATV-cables are EN 50117-2-1 to -2-5 and EN 50117-4-1
- Instructions of the manufacturer regarding tensile strength, bending, heat ... shall be noted
- ***bedea*** CATV cables of the TELASS® series ***guaranties*** proper operation

## High screened CATV cable




Screening attenuation acc. to EN 50117





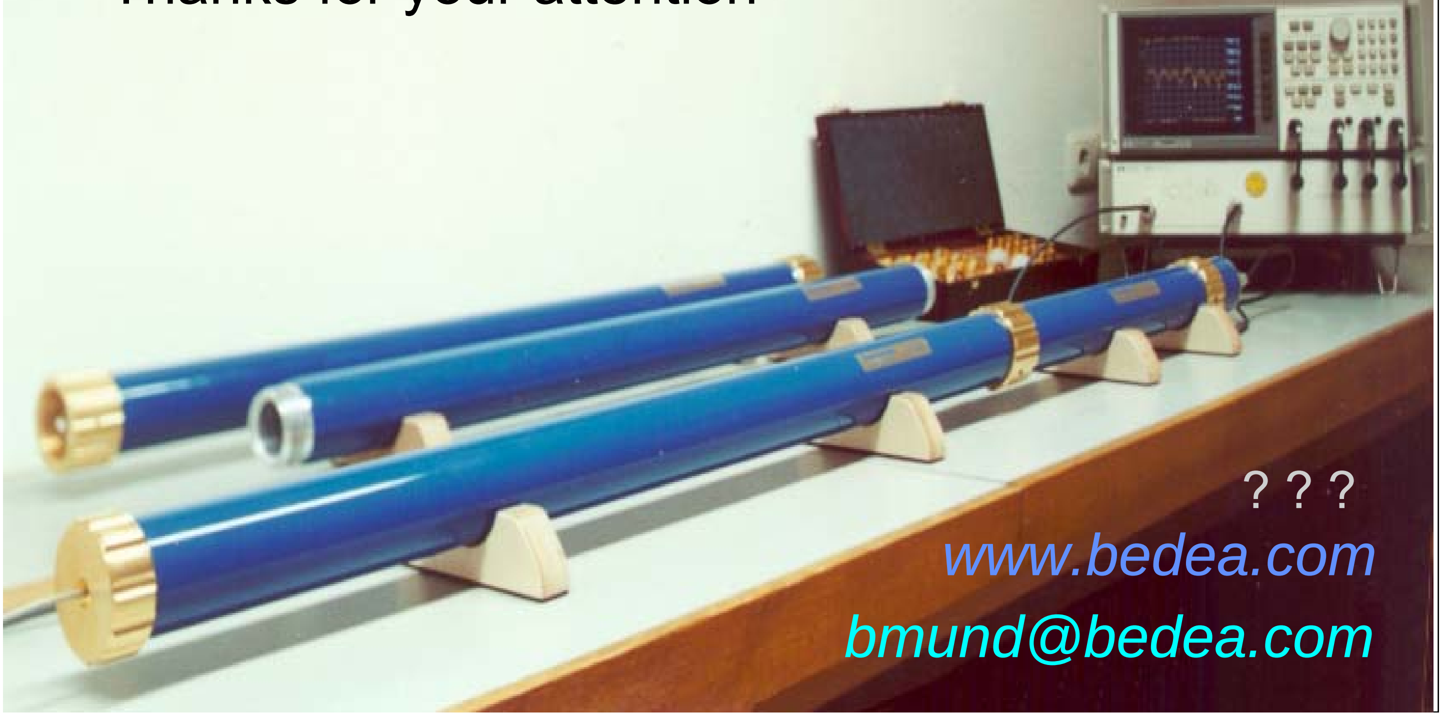
## Produktportfolio HF-Kabel / Antennenkabel

*bedea* = Alles aus einer Hand

*bedea* = Alles “made in Germany”

# *CoMeT* *Co*upling *Me*asuring *T*ube

## Thanks for your attention



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Communication cables/Technical Yarns/Mini ropes/Data technology/Fiber light