Design, Installation & Standards of Coaxial CATV Cables

Examples of different coaxial communication cables

Since September 2018, the bda connectivity GmbH has overtaken the cable manufacturing division and the CoMeT test engineering department from the bedea Berkenhoff GmbH, Germany. https://bda-connectivity.com/

Outline

- Characteristics of Coaxial-cables
  - Characteristic impedance, Attenuation, Return loss
- Reflection properties
  - Measuring of return loss
- Installation practices
  - Installation precautions
- Standards
  - IEC 61196 series & EN 50117 series
- EMC of CATV-Cables
  - Triaxial test procedure
  - Screening classes
- Discussion

Data sheet of a coaxial CATV cable Telass 110

Data sheet *TELASS® 110 PN: 14310100*

Structure

Center conductor	∅ [mm]	1.13	Cu bare
Insulation	∅ [mm]	4.90	Foamed-PE
Outer conductor	∅ [mm]	5.50	
Foil		AL-PP-AL	
Braid		Cu tinned	
coverage	[%]	80	
Jacket	∅ [mm]	6.80	PVC white

Electrical properties

Characteristic impedance	[Ω]	75 ± 3
Capacitance approx.	[pF/m]	55
Velocity ratio	[v/c]	0.85

Attenuation at	[dB/100m]	max.
5 MHz		1,1
50 MHz		3,9
100 MHz		5,7
200 MHz		8,3
800 MHz		16,8
1000 MHz		19,1
1600 MHz		24,3
2400 MHz		29,9
3000 MHz		33,6

Direct-current resistance	[Ω/km]	
Center conductor		≤ 18
Outer conductor		≤ 11

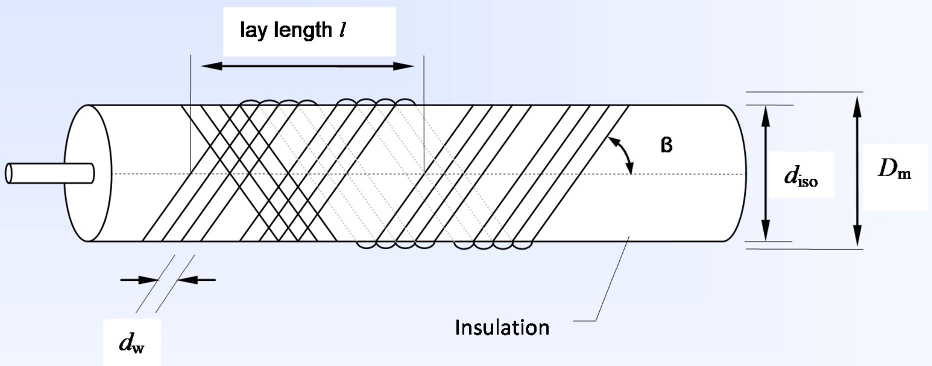
Structural return loss	[dB]	
5 - 30 MHz		23
30 - 470 MHz		23
470 - 862 MHz		20
862 - 2150 MHz		18

Transfer impedance	[mΩ/m]	< 2,5
Screening attenuation	[dB]	
at 50-1000 MHz		> 95
1000-2000 MHz		> 85
2000-3000 MHz		> 75

Mechanical values

Weight	[kg/km]	53
Minimum bendig radius	[mm]	70
Maximum tensile strength at 20°C	[N]	100

Optical coverage factor, IEC 61196-1



effective electric diameter

$$D_m = d_{iso} + 2.25 \cdot d_w$$

braid angle β

$$\beta = \text{arc tan} \frac{\pi D_m}{L}$$

lay factor, *KL*

$$K_L = \sqrt{1+\pi^2\left(\frac{D_m}{L}\right)^2} = \frac{1}{\cos\beta}$$

filling factor, *q*

$$q = \frac{m\,W}{2\pi\, D_m}\sqrt{1+\pi^2\left(\frac{D_m}{L}\right)^2}$$

$$q = \frac{m\,W}{2\,L\,\sin\beta}$$

coverage factor, *Kc*

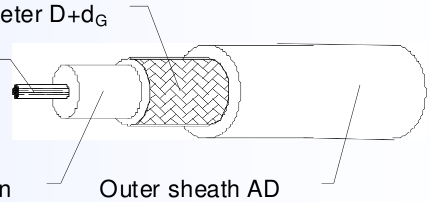
$$K_c = 2q - q^2$$

Variable	Description
d	Diameter of braid wire or thickness of braid tape
D_m	Mean diameter of braid
L	i.e. diameter over dielectric plus 2,25d
N	Lay length of braid
W	Number of ends of wire per spindle
m	Width of tape for tape braids or N•d for wire braids
	Total number of spindles

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 ε_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 ε_r of 2,28 and (physically) foamed Polyethylen (CELL-PE) with ε_r in the range of 1,35 - 1,5 is mainly used for CATV cables. (CELL-PE = cellular Polyethylene, µ = magnetic permeability)

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

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): $\boldsymbol{\alpha_1/\alpha_2 = \sqrt{(f_1/f_2)}}$, ($\alpha$/dB, f/MHz)

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

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

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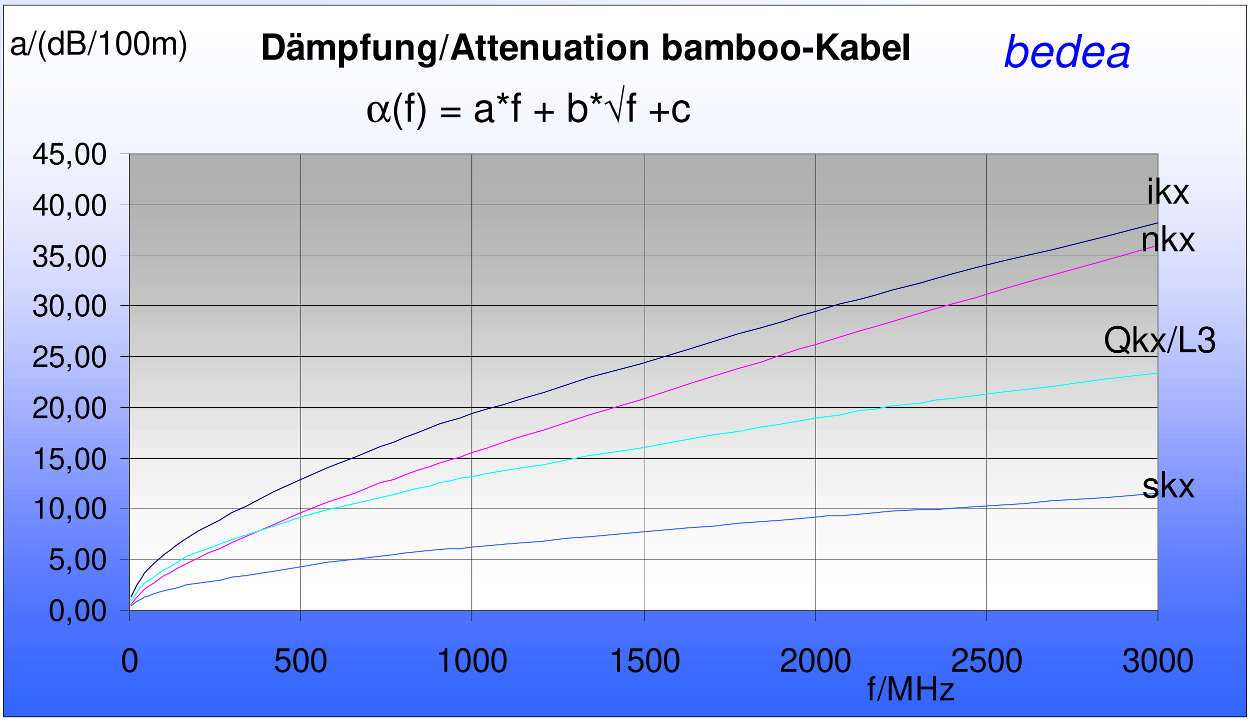
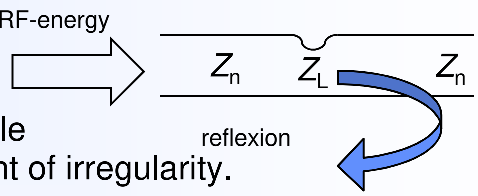
Attenuation curve



Reflection coefficient

A RF-signal which is travelling through a transmission line with the nominal characteristic impedance $\underline{Z}_n$ 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:

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



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.

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
ε_r is the relative dielectric permittivity of the insulation material

Note, that the wave length λ of the resonance frequency f_r is 2 l_0.

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: $s = \frac{(1+R)}{(1-R)}$

Return loss limits

IEC 61196-m-n series

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

IEC 61196-5-n / 6-n & -7-n

for cable with $\alpha \leq$ 18 dB/100 m at 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

(α is the attenuation of the cable)

Measurement accuracy:

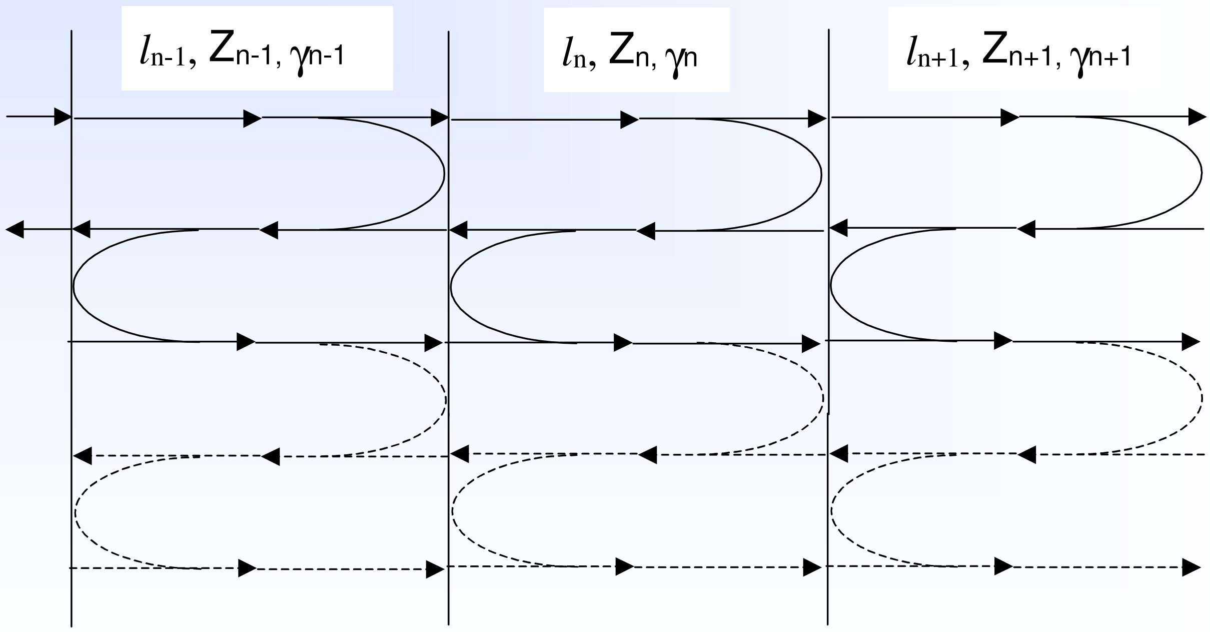
In case of digital signal processing, the accuracy of the return loss measurement, $\Delta_{ar,f}$ depends on the frequency step Δ_f in the measured frequency range. The frequency spacing in the measured frequency range is frequency dependent and shall be in accordance with the following equation:

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

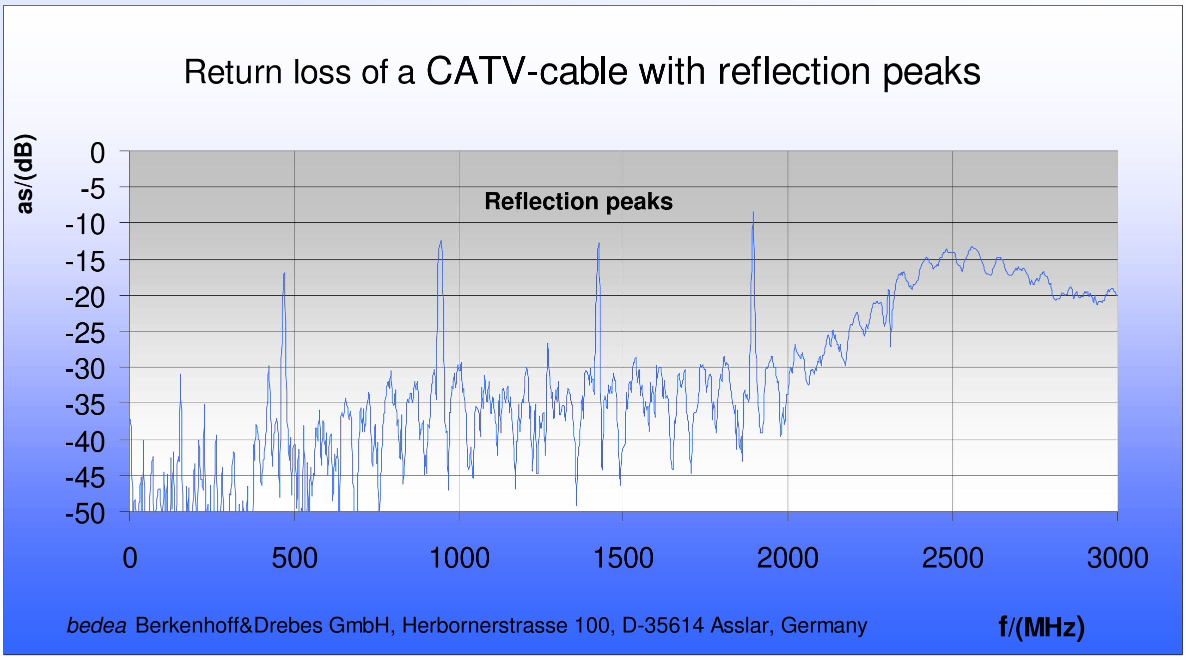
bedea is measuring with > 20.000 points

where a(f) is the attenuation of the cable at the measured frequency point in dB/100m, Δ_{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 $\leq$ 1 dB unless otherwise stated in the relevant detail spec.

Periodic disturbances

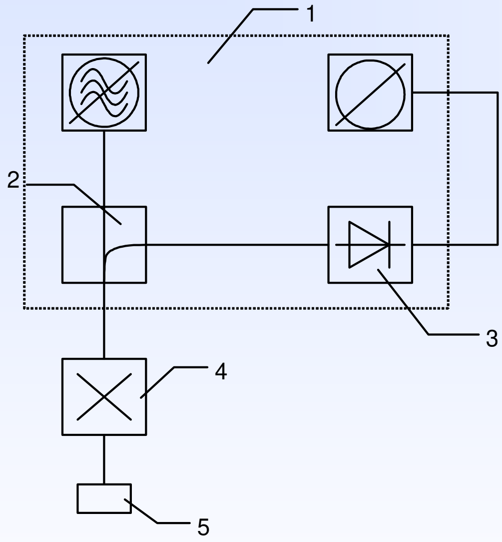


Reflection peaks



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 quality of the characteristic impedance respectively the length homogeneity 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

Quality control

Modern 4-port Network analyser
Rohde & Schwarz ZNB 8 4-port
For RF transmission and EMC measurements

bda cables are subjected
to continuous production and end control

Cable dimensions and transmision characteristics of bda RF cables like characteristic impedance and capacitance are permanently monitored,
return loss is observed by a self developed monitoring system
by Fast Fourier Transformation (FFT) permanent

permanent production and end control quaranties high quality level !

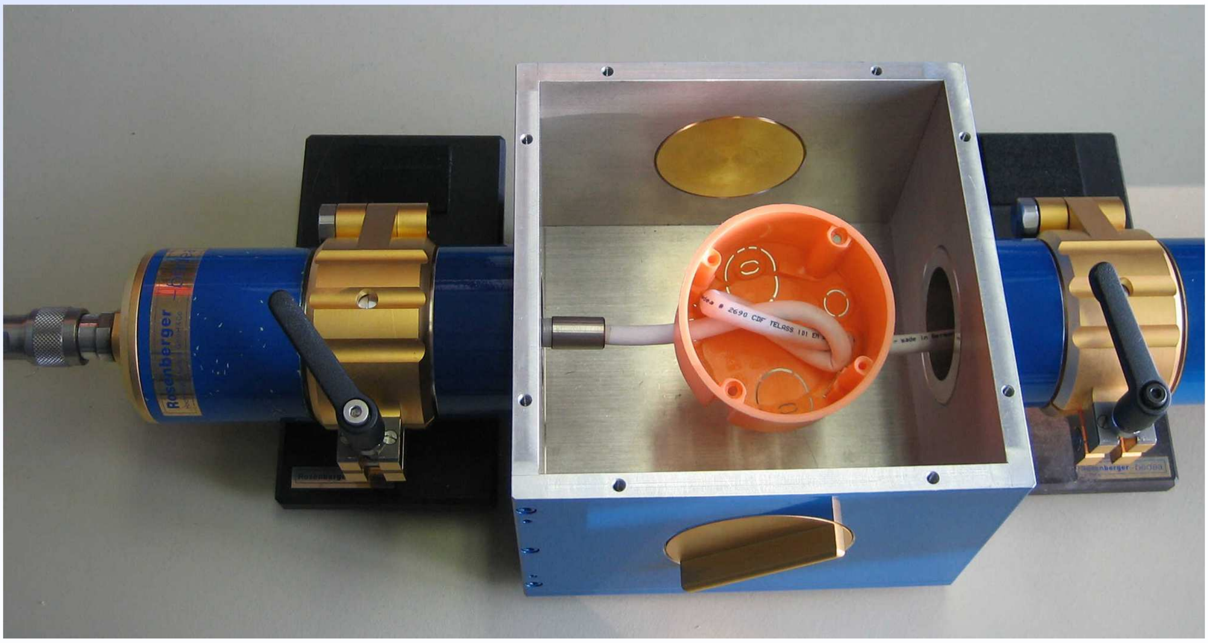
bda distribution and trunk cables for laying underground are 100 % sweep tested !

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

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

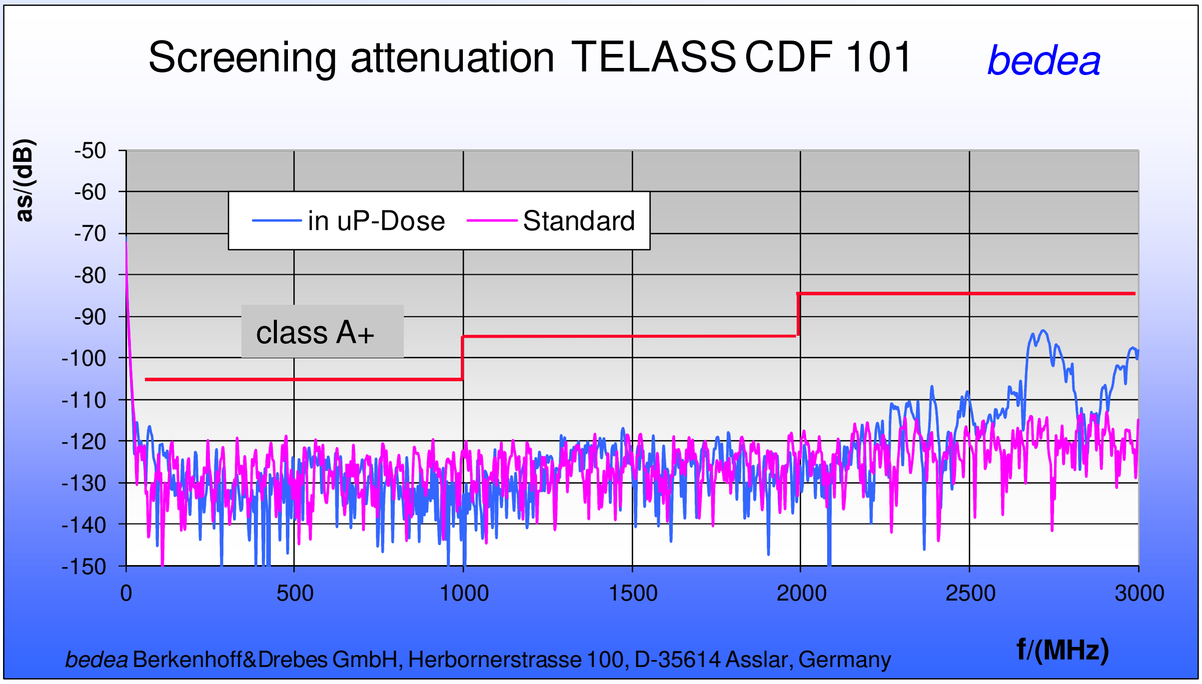
Bending of cables in a TV socket



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

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
- see also EN 50290-4-2, Communication cables - Guide to use

(EN 50290-4-1 &-4-2)

IWCS

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 !

IWCS

New structure for CATV cables according to EN 50117

EN 50117	**Coaxial cables -**	**replaces**
EN 50117-1	**Generic specification**	
	Sectional specification for coaxial cables for analoque and digital signal transmission -	
EN 50117-9-1	Indoor drop cables for systems operating at 5 MHz - 1 000 MHz	EN 50117-2-1
EN 50117-9-2	Indoor drop cables for systems operating at 5 MHz - 3 000 MHz	EN 50117-2-4/-4-1
EN 50117-9-3	Indoor drop cables for systems operating at 5 MHz - 6 000 MHz	EN 50117-4-2
EN 50117-9-4	Blank detail specification for Indoor drop cables	in preparation
EN 50117-10-1	Outdoor drop cables for systems operating at 5 MHz - 1 000 MHz	EN 50117-2-2
EN 50117-10-2	Outdoor drop cables for systems operating at 5 MHz to 3 000 MHz	EN 50117-2-2
EN 50117-10-3	Blank detail specification for Outdoor drop cables	in preparation
EN 50117-11-1	Distribution and trunk cables for systems operating at 5 MHz – 1 000 MHz	EN 50117-2-3
EN 50117-11-2	Distribution and trunk cables for systems operating at 5 MHz – 3 000 MHz	-
EN 50117-11-3	Blank detail specification for Distribution and trunk cables	in preparation

TV receiver leads acc. to EN 60966

	Radio frequency and coaxial cable assemblies	
EN 60966-1Ed.3	Part 1: Generic specification -	46/601/CDV FDIS to IEC
EN 60966-2-4Ed.4	Part 2-4: Detail specification for cable assemblies for radio and TV receivers - Frequency range 0 MHz to 3000 MHz, IEC 61169-2 connectors, **(IEC-60169-2 Connector).**	published 2016-05-18
EN 60966-2-5Ed.4	Part 2-5: Detail specification for cable assemblies for radio and TV receivers - Frequency range 0 MHz to 1000 MHz, IEC 61169-2 connectors, **(IEC-60169-2 Connector).**	published 2016-10-26
EN 60966-2-6Ed.4	Part 2-6: Detail specification for cable assemblies for radio and TV receivers - Frequency range 0 MHz to 3000 MHz, IEC 61169-24 connectors, **(F-Connector).**	published 2016-10-26
IEC 60966-2-7Ed1	Part 2-7: Detail specification for cable assemblies for radio and TV receivers - Frequency range 0 MHz to 3 000 MHz, **IEC 61169-47 connectors (F-Quick)**	published 2015-09-08
IEC 60966-2-8Ed1	Part 2-8: Detail specification for cable assemblies of radio and TV receivers-Frequency up to 3000MHz, **Screening class A++, IEC61169-47 connectors (F-Quick)**	46/668/RVN **rejected**

main source of error in CATV systems are TV receiver leads with insufficient screening attenuation

Screening Classes acc. to IEC 60966 & 61196 & EN 50117

Since 2002, CLC SC 46XA & IEC SC 46A have established screening classes for CATV-cables

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

Screening Classes A & B are valid for cables acc. to IEC 61196-6-n & series & EN 50117-9-n & /-10-n series as well as for TV receiver leads acc. to 60966-2-4 to -2-7 series, Screening Class A++ is valid for CATV-cables acc. to EN 50117-2-3

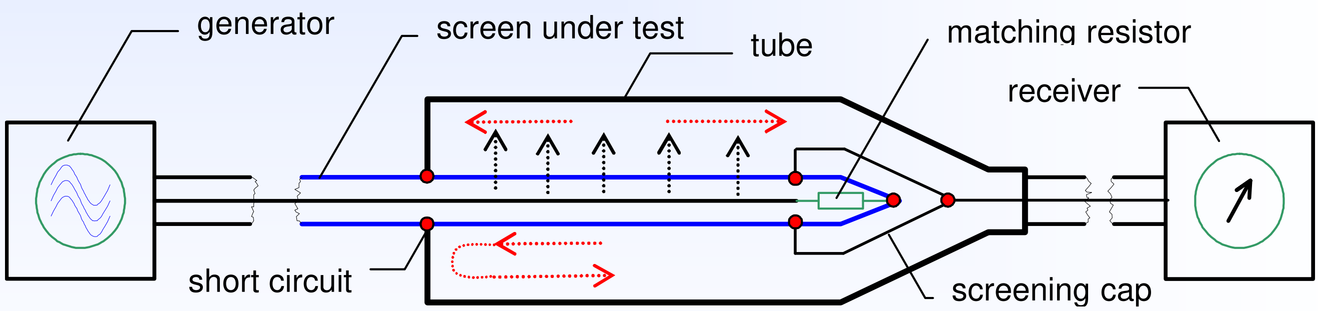
Transfer impedance and Screening attenuation of CATV cables shall be measured with the "Triaxial test procedure" according to IEC 62153-4-3 & /-4-4 (e.g. CoMeT-system)
Absorbing clamps are not allowed, due to large uncertainty and poor reproducibility

Screening measurement with test set-up CoMeT

Transferimpedance & Screening attenuation

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

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

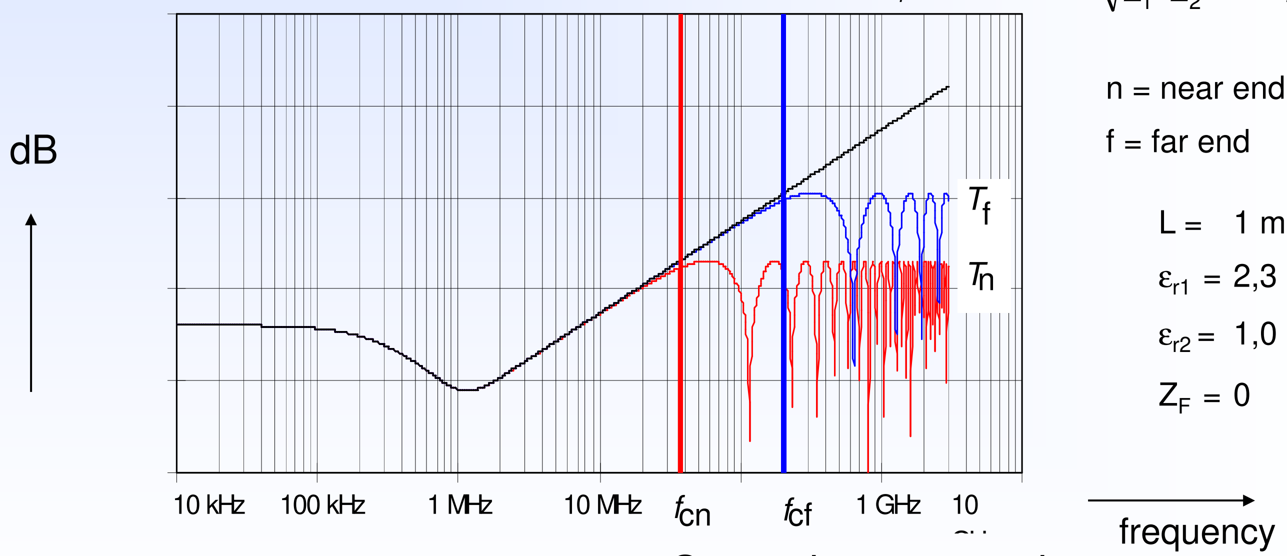


IEC 62153-4-3Ed.2 Transfer impedance, IEC 62153-4-4Ed.2 Screening attenuation

Calculated Coupling Transfer Function T_{nf}

Calculated Coupling Transfer Function T_{nf}

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



n = near end

f = far end

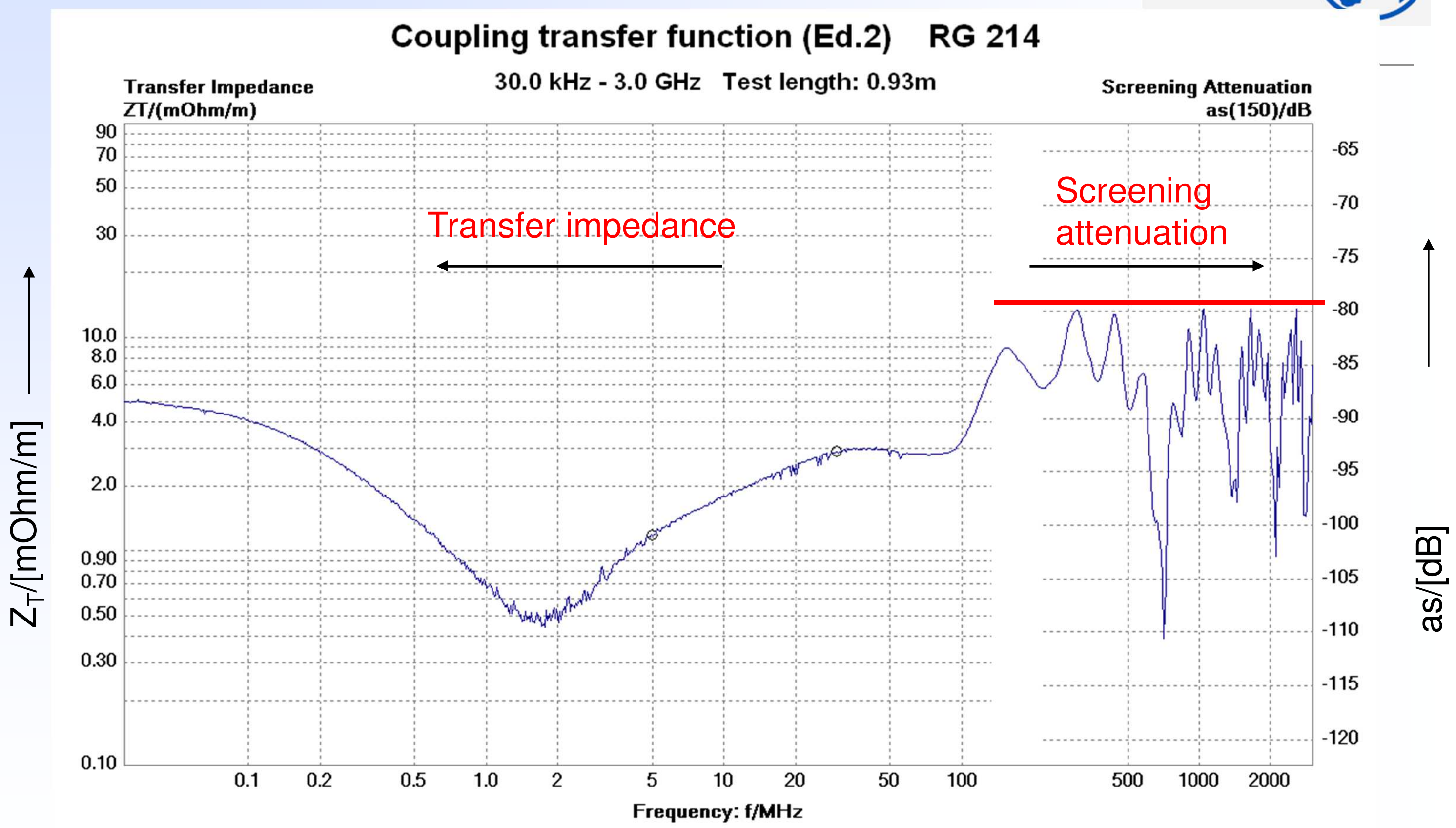
L = 1 m

ε_{r1} = 2,3

ε_{r2} = 1,0

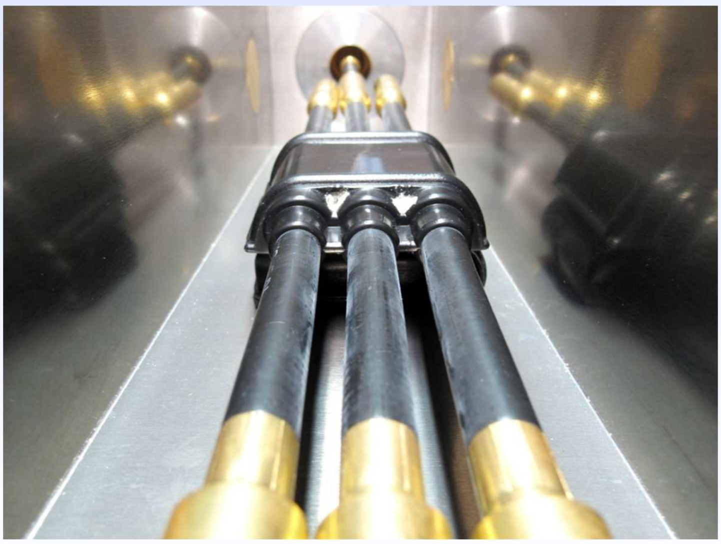
Z_F = 0

Transfer impedance ← Screening attenuation →

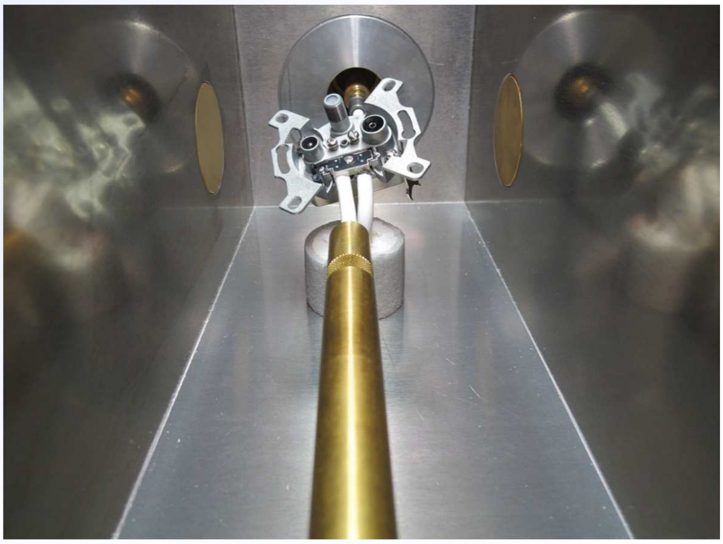


Design, Installation & Standards of Coaxial CATV Cables

EMC of Passive Components with CoMeT system



CATV - tap off with Triaxial Cell 1000/150



CATV - wall outlet in triaxial cell 1000/150 and with tube in tube

Common Path Distortions (CPD) on CATV cables

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 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/WG 6 has determined the specs for measuring PIM in mobile networks (50 Ohms at 900 MHz and 1800 MHz)
another testprocedure for CPD is described in ANSI/SCTE 109 2005

Hints to avoid PIM on coaxial cables

PIM = passive Intermodulation

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

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 ε_r
- 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.

Conclusion 2

- Coaxial cable characteristics are described in IEC 61196 series
- Standards for CATV-cables are IEC 61196 series and EN 50117 series
- 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
- The use of high Quality cables and connectors with Screening class A or better (acc. to IEC 61196 / EN 50117) is strongly recommended
- Appropriate TV receiver leads are standardised in EN 50966-2-x series
- 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 considered

Array of bda products of RF-cables / Antenna cables

Since September 2018, bda connectivity GmbH has overtaken the cable manufacturing division and the CoMeT test engineering department from the bedea Berkenhoff GmbH in Germany. https://bda-connectivity.com/

Examples of the product range of the bda connectivity GmbH in Asslar, Germany

Standards, Design & Installation of CATV-Cables

- Author: Bernhard Mund,
  - *Radio & TV Technician, Radio Brand, Marburg, 1970*
  - *Dipl.-Ing. Communication-& Microproc. technologies,* FH Giessen *1984*
- *bda* connectivity GmbH, Asslar (bedea) *since 1985*
  - *bda* is a manufacturer of Communication Cables in Germany
- Responsible:
  - EMC-Test Engineering, Standardisation,
  - **Standardisation:**
  - Chairman of UK 412.3, Koaxialkabel, (German NC)
  - Secretary of CENELEC SC 46XA, Coaxial cables
  - Secretary of IEC SC 46A, Coaxial cables
  - Member of different Working groups of IEC TC 46

bda connectivity GmbH, Asslar (Wetzlar), Germany

Connectivity – this is our passion.

For more than 60 years, we have been manufacturing special cables that are optimized for the respective field of application.
A new addition is a range of high-quality indoor antennas and passive components for the telecommunications market.
The "CoMeT" test system developed by the company is an important anchor for measuring the screening effectiveness of cables, connectors, cable assemblies.