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Radiation of PLC Systems

Holger Hirsch

University of Dortmund

- Introduction of the Division Theory of EMC
- Aspects of Unwanted Emissions
- Conducted Emissions
- Electromagnetic Fields and Biological Effects
- Protection of Radio Services

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Division Theory of EMC

- Test and Measurement Procedures
- PLC
- EMC in Vehicles
- Consulting / Training
- Basic EMC-Investigations
- Software Development for EMC Test Systems
- Standardisation

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Standardisation

DKE UK 767.3 (Mirror of IEC TC77): Immunity to High Frequency Phenomena

DKE UK 767.4 (Mirror of CISPR/A): EMC-Measurement Systems and Procedures

DKE AK 767.17.3: ITE, PLC

„AMA FA Standardisation and Directives“ (convenor): EMC and other Standards

IEC SC77B WG10: Immunity to High Frequency Disturbances

CISPR/I WG 3: ITE: Broadband Communication

CISPR/D: (Secretary from 7/2003): Interference of Vehicles and their Components

Finished Work:

ISO/EN 14982: Agriculture Machinery

EN 13309: Construction Machinery

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Cooperation with EMC test facilities

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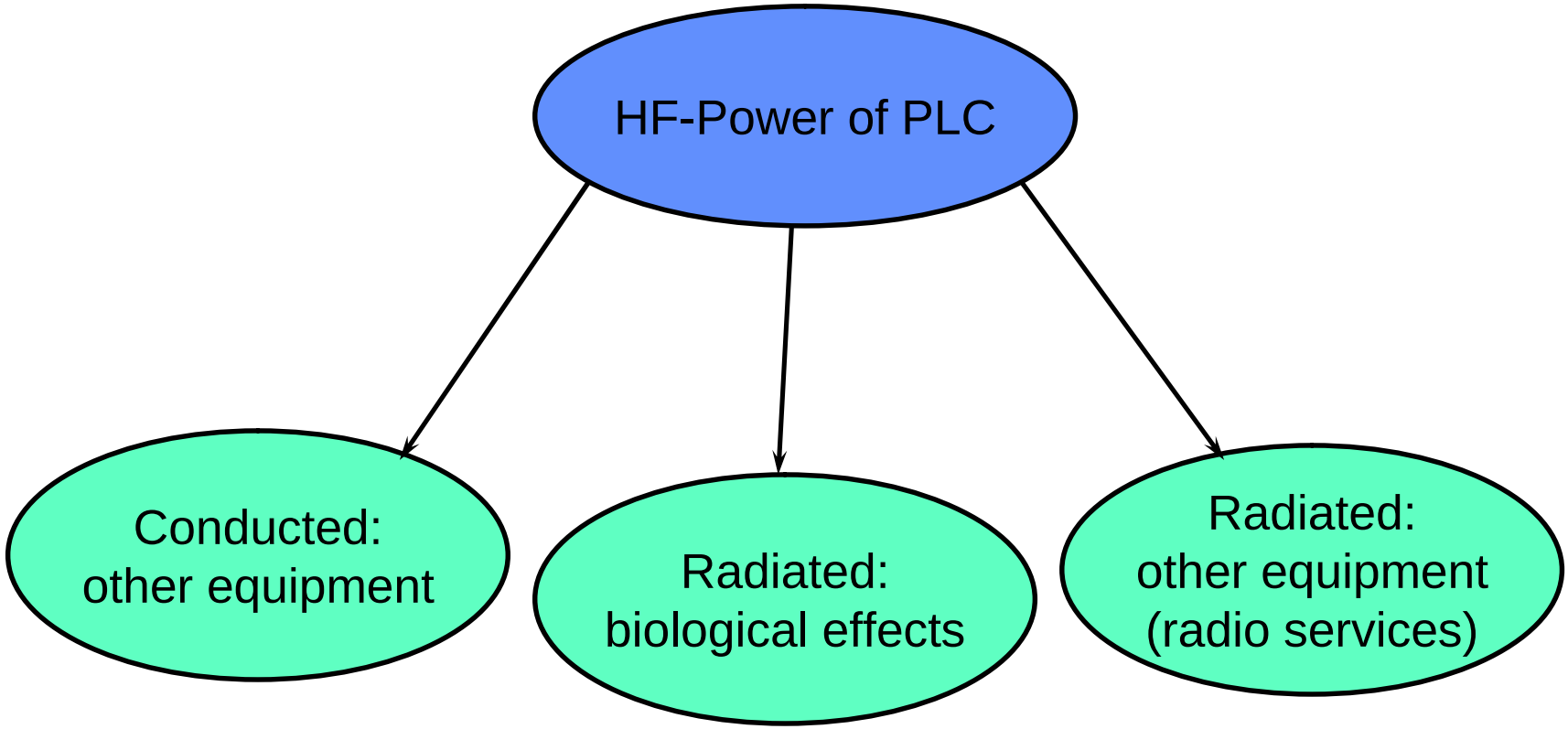
Unwanted Emission of PLC



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Conducted EMC

Mains

1,6-30MHz

≈ -60..-50 dbm/Hz

≡ -30..-20 dbm
@ 1kHz bandwidth (according to 1kHz modulation of susceptibility test)
≡0.01V.. 0.04V @ 150Ω symmetrical
less in the asymmetric mode

Special treatment of broadband sources is under investigation e.g. for CDMA based mobile radio systems !

Immunity requirements acc. to IEC 61000-4-6 and generic standards:
0.15 - 80 MHz
residential: 1.5 V (3V EMF)
industrial: 5 V (10V EMF)

Conducted emissions caused by PLC are by far below the standard limits.
⇒ Other devices will not be disturbed by conducted emissions caused by PLC!

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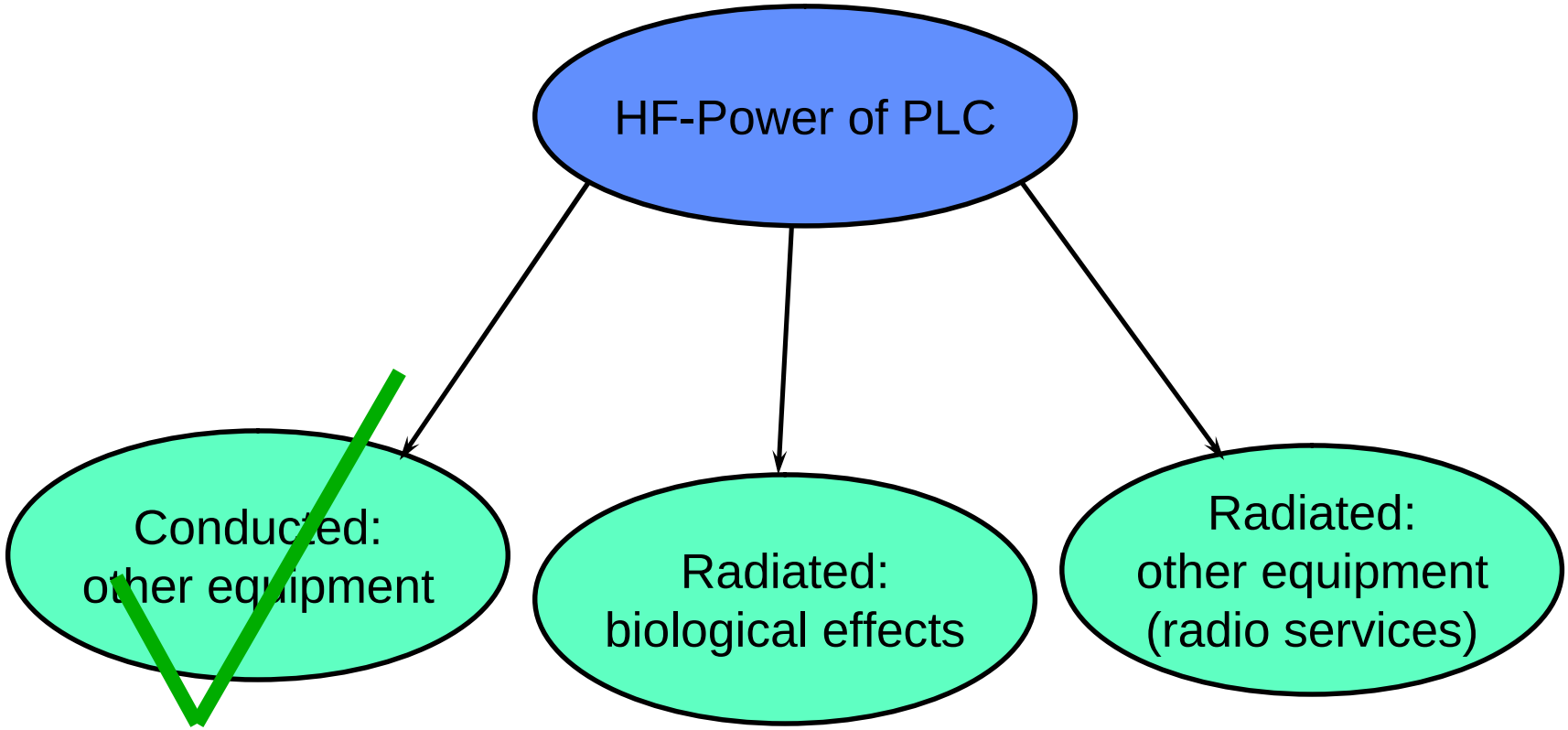
Unwanted Emission of PLC



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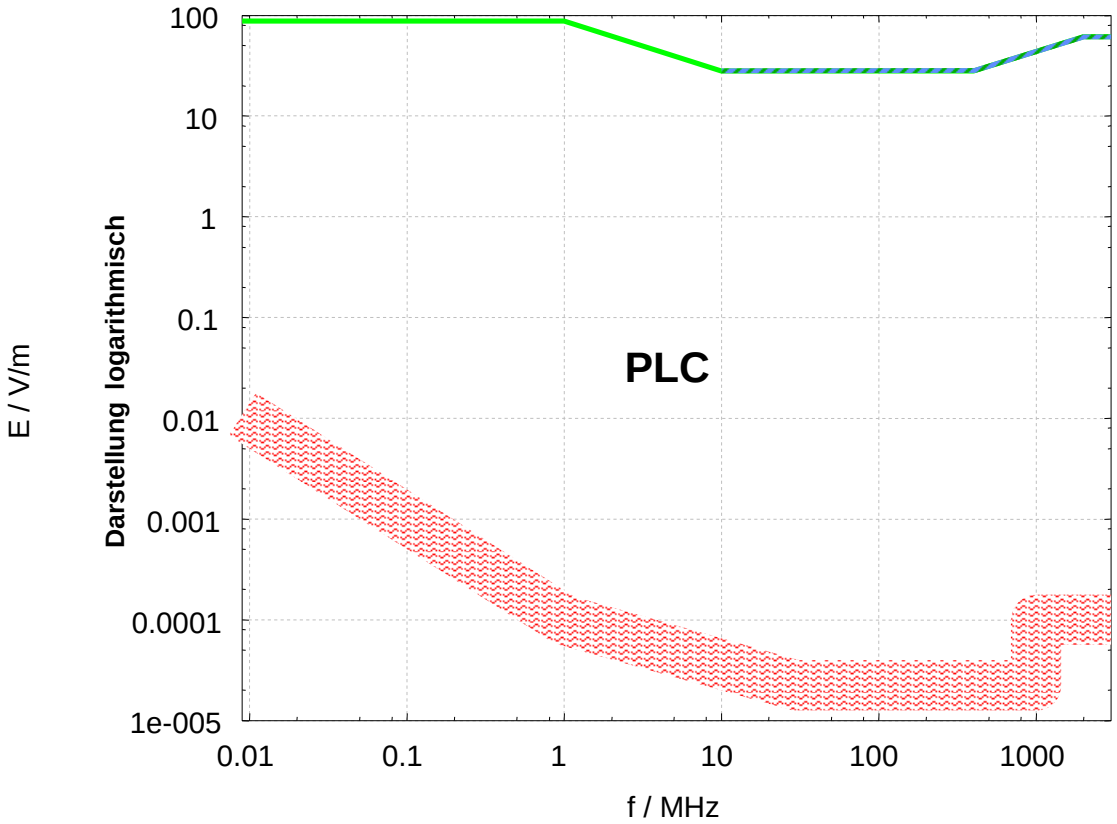
Safety in HF Electromagnetic Fields

Germany: Regulation in the 26. BImSchV covers noise, air pollution, etc.



Typical radiation by wires (e.g. DSL, PLC, LAN)

Limits for human exposure German law (26. BImSchV)

Limits for human exposure ICNIRP Guidelines equivalent to: Recommendation 1999/519/EC

ICNIRP: International commission on non-ionizing radiation protection

Radiation by PLC is by factor 1.000.000 lower than the limits.
⇒ Biological effects are improbable.

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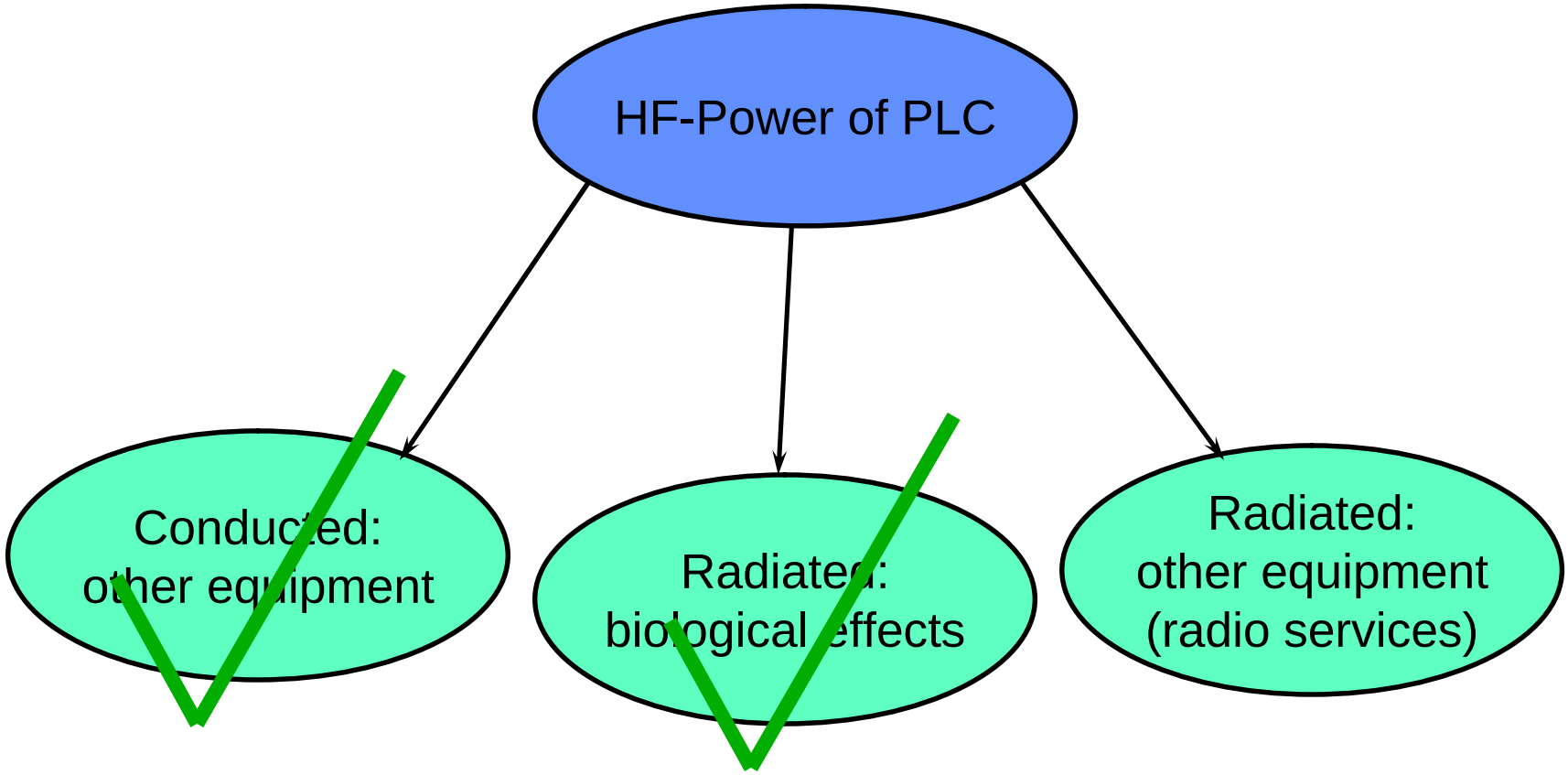
Unwanted Emission of PLC



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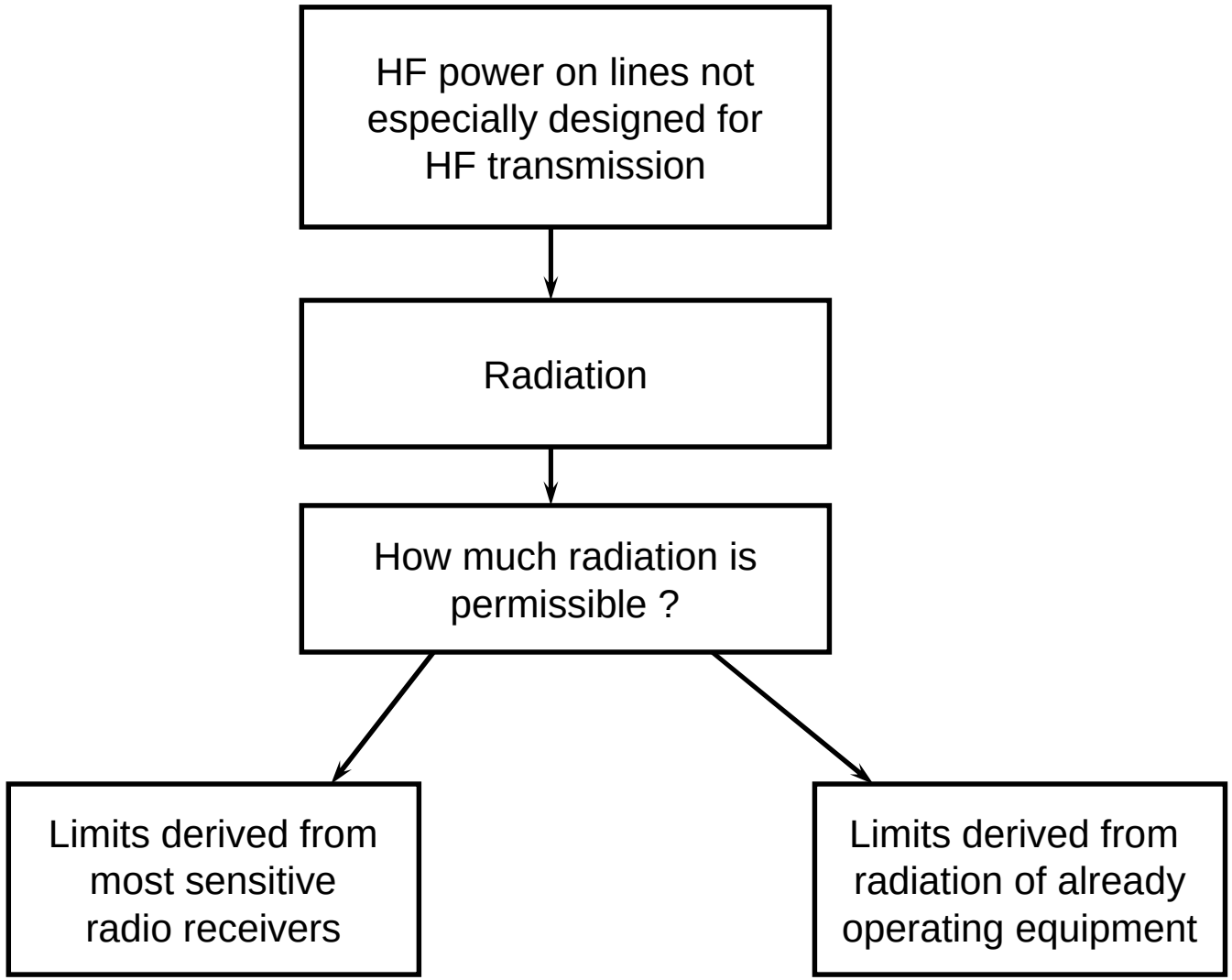
Treatment of Radiation



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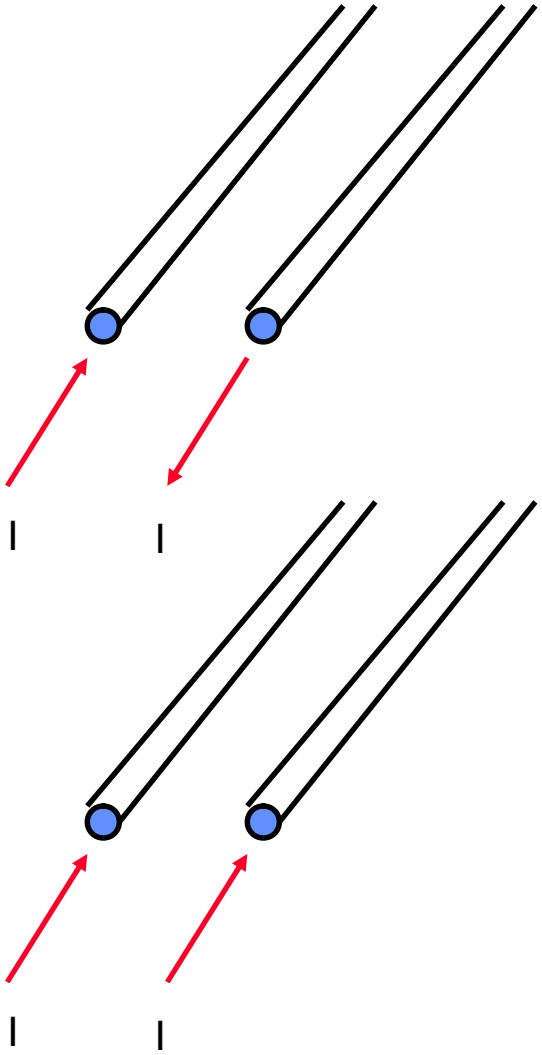
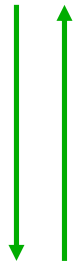
Mechanism of Radiation

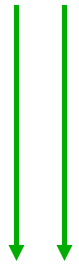


symmetrical mode



compensation of field produced by the two wires

asymmetrical mode



no compensation of field produced by the two wires

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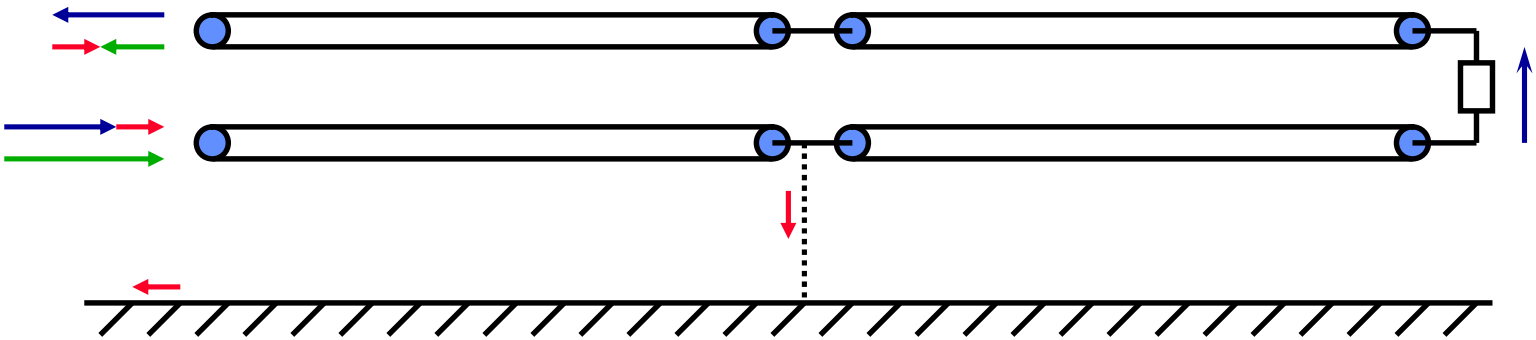
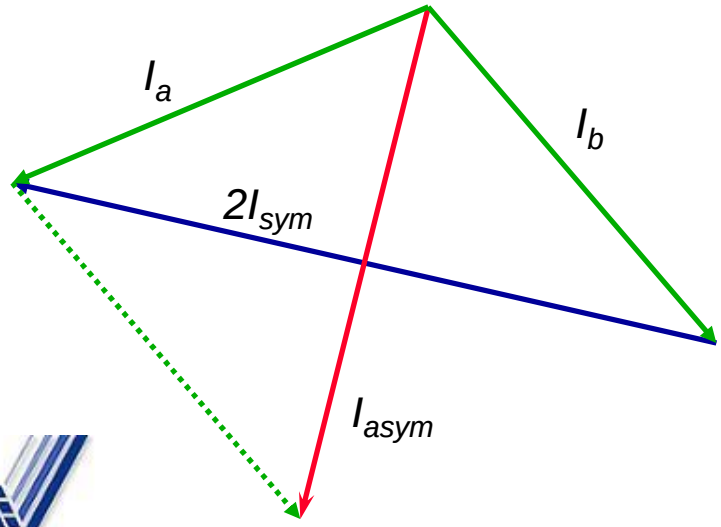
Importance of Symmetry

fed sym. signal

point of unsymmetry





$$I_{sym} = \frac{I_a - I_b}{2} \qquad U_{sym} = U_a - U_b$$

$$I_{asym} = I_a + I_b \qquad U_{asym} = \frac{U_a + U_b}{2}$$

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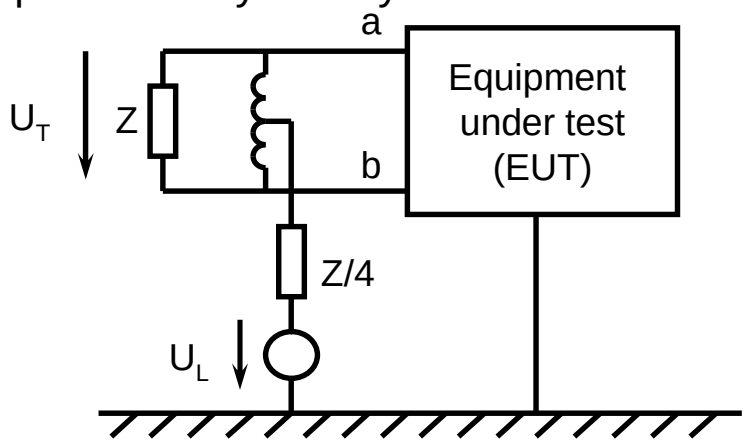
Measurement of Unsymmetry
Longitudinal Conversion Loss (LCL)

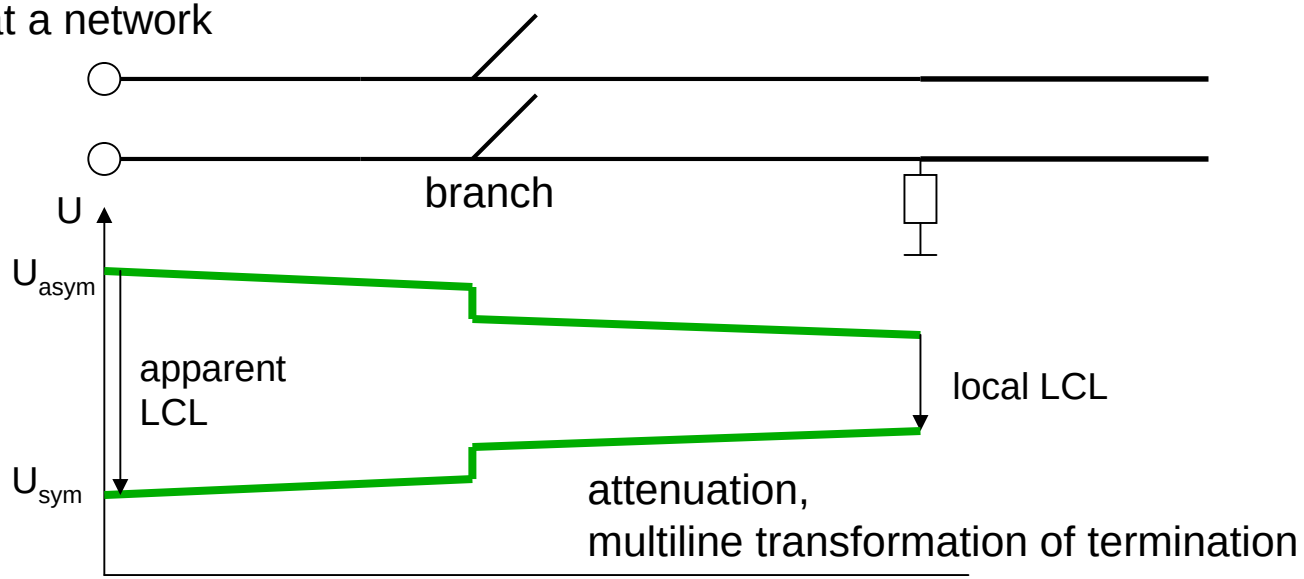
Measurement at a point of unsymmetry



ITU-G117:

$$LCL = 20 \cdot \log\left(\frac{U_L}{U_T}\right)$$

Measurement at a network



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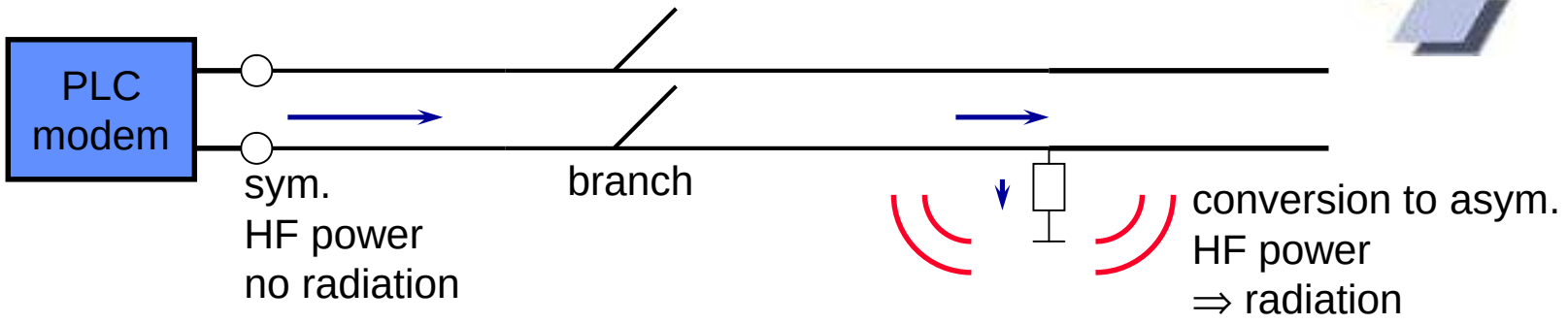
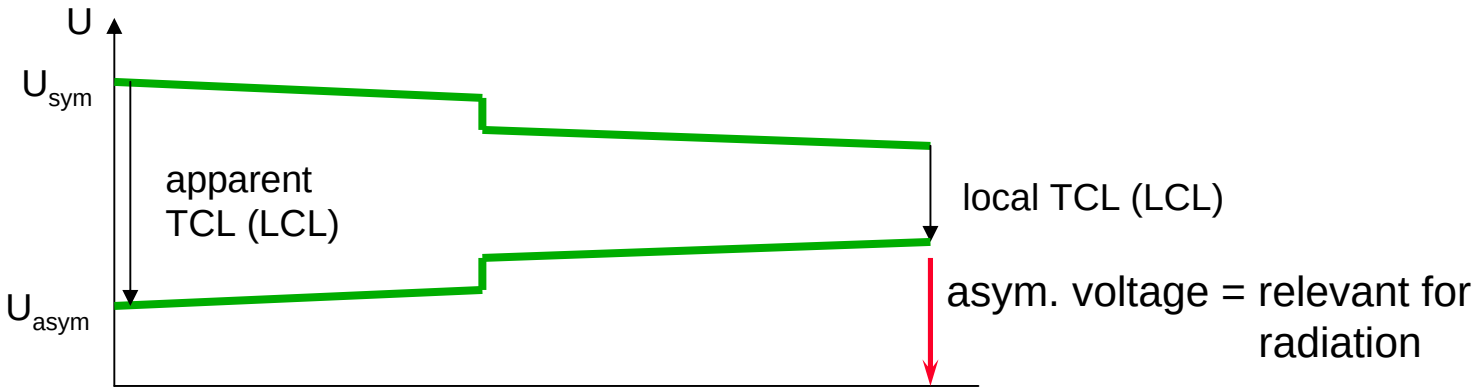
Relevance for Radiation





using apparent LCL only: underestimation of disturbance potential

using local LCL only: overestimation of disturbance potential

Need for a big data base of LCL measurements and of “antenna factor”

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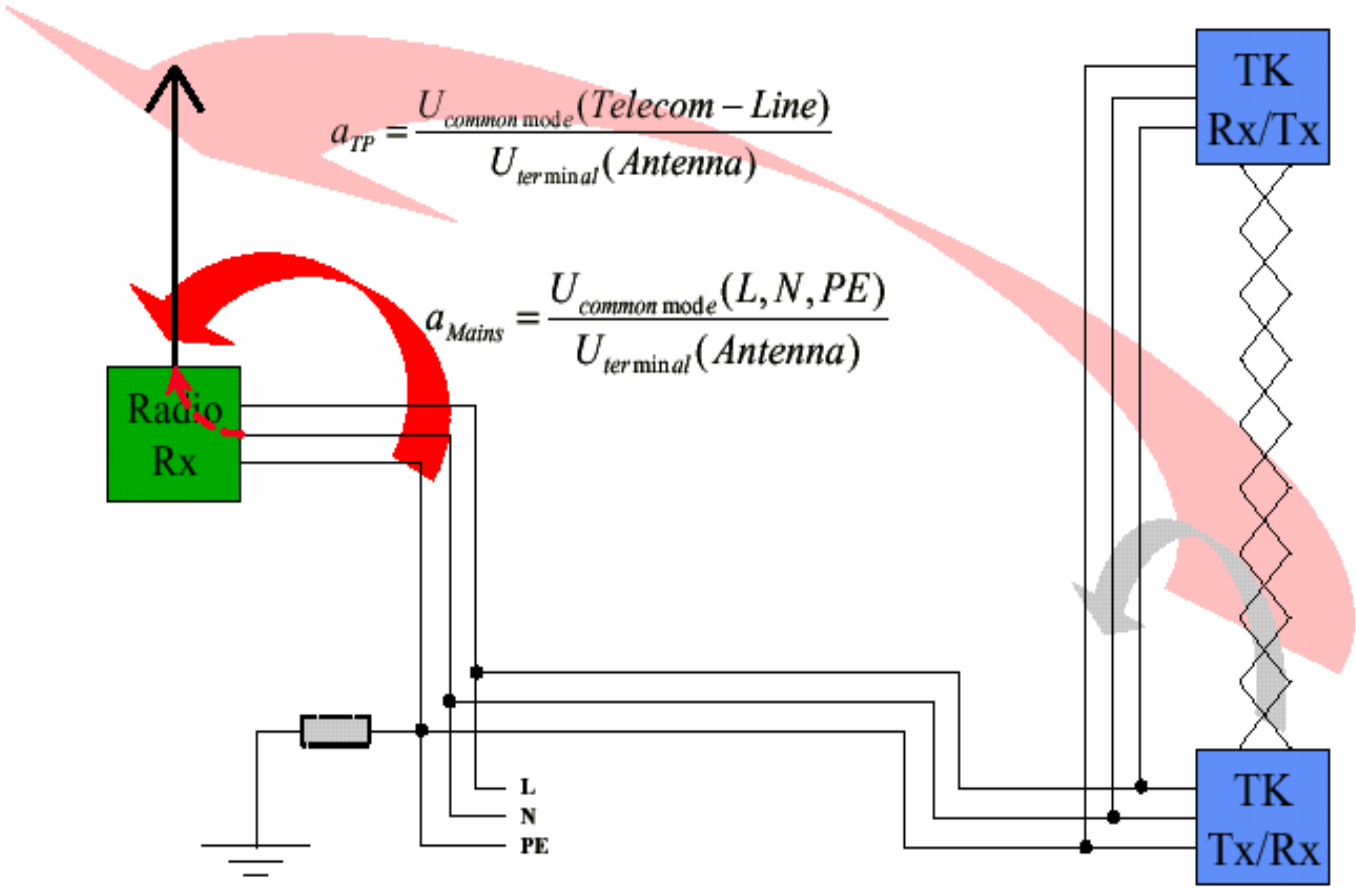
Disturbance modell



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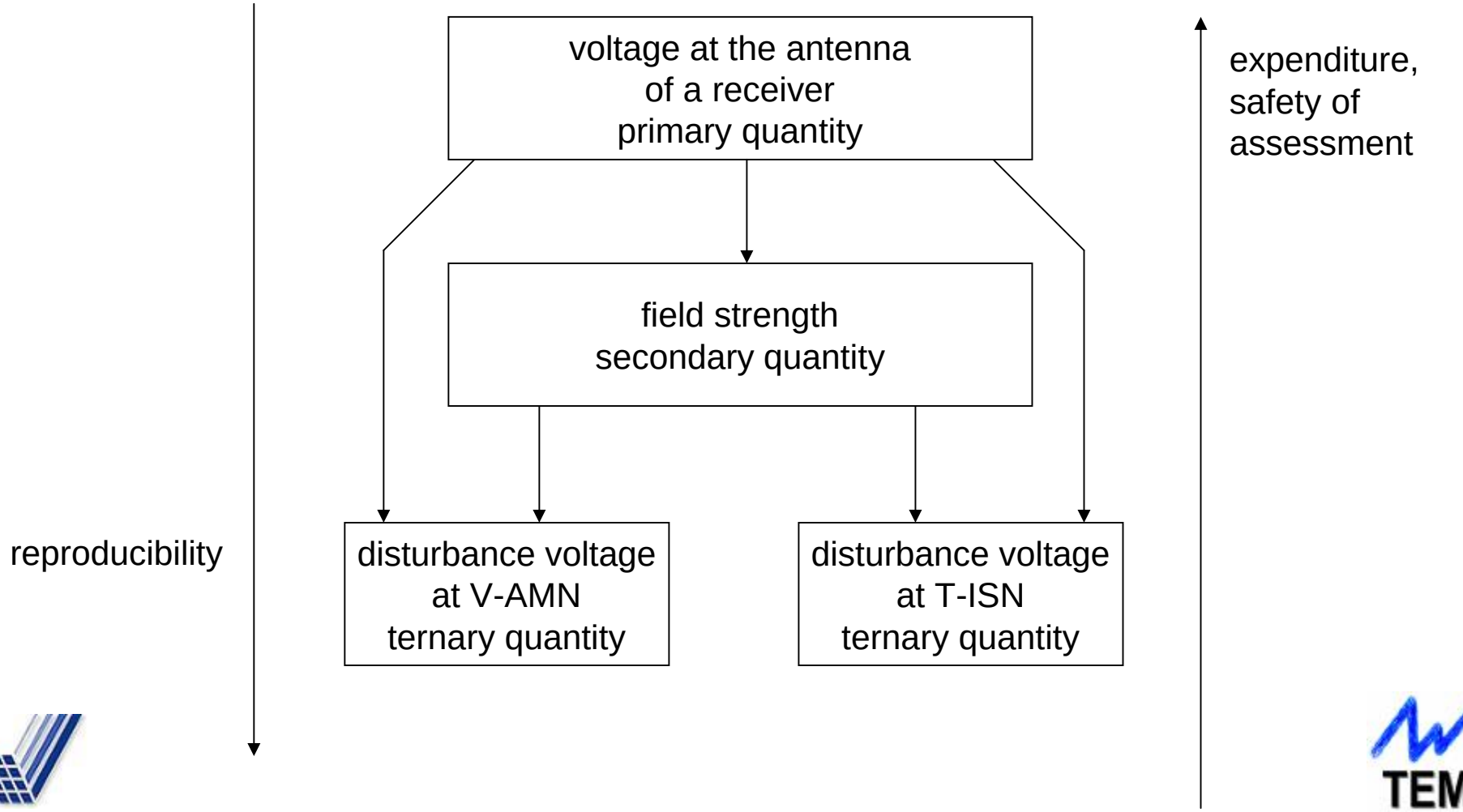
Protection of Radio Services - Measurement Quantities



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Conformity of Products and Installations

	product conformity	installation conformity
1. approach	measurement of radiation on a test site requires accepted test environment and limits	measurement of radiation in situ requires suitable limits
2. approach	a) Characterisation of typical power net b) definition of an artificial mains network (AMN), representing as precisely as possible the radiation behaviour of typical installations + definition of suitable limits c) measurement of disturbance voltages or disturbance currents at the AMN	a) Characterisation of the specific power net b) definition of the radiation behaviour of the specific power net + definition of suitable limits c) measurement or calculation of disturbance potential only in case of complaints

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Product Conformity

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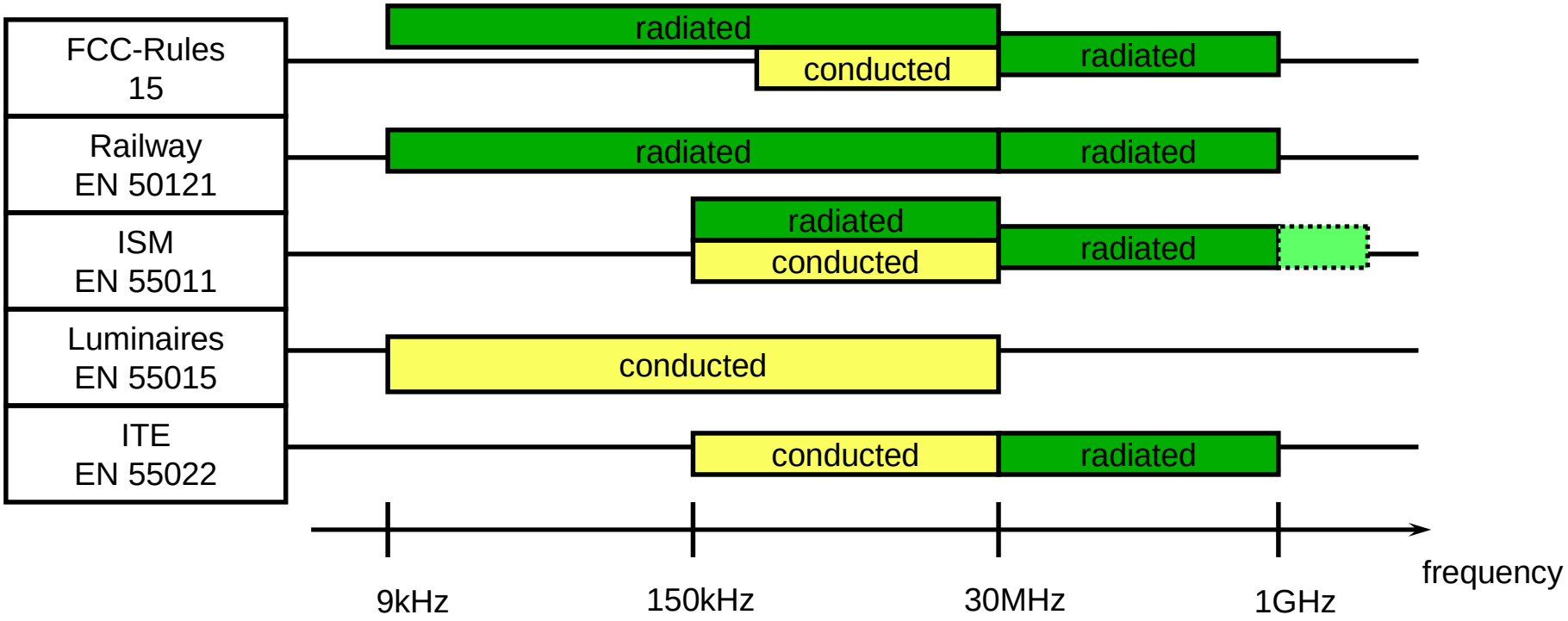
Procedure of some Product Standards



Products are mostly assessed by measurement of conducted disturbances. Radiation measurement only in special cases.

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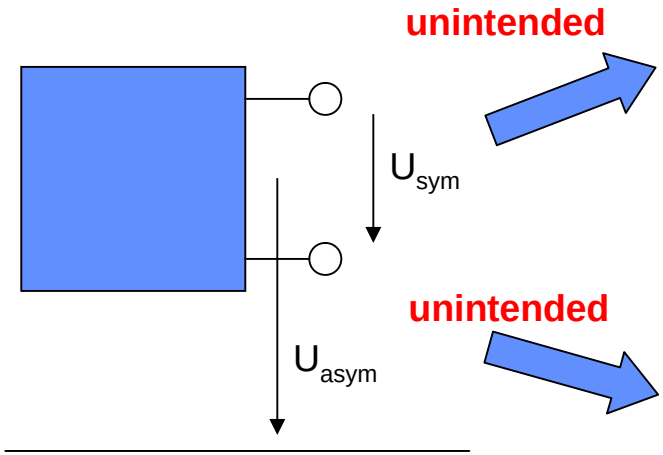
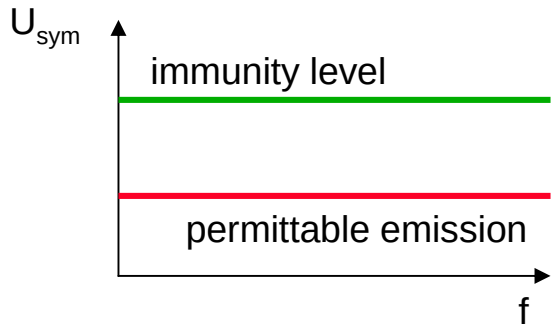
Asymmetric signals have the main influence on radio services

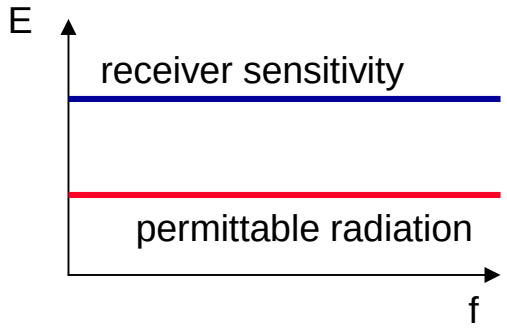
Non-PLC Equipment:



Influence on other equipment operated at same power net possible but not probable

Influence on radio services due to radiation possible





=> CISPR-22 limits conducted disturbances in general

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V-shaped AMN is used for non-telecommunication equipment

Definitions:

Conducted disturbance (IEV 161-03-27)
Electromagnetic disturbance for which the energy is transferred via one or more conductors.

Electromagnetic disturbance (IEV 161-01-05)
Any electromagnetic phenomenon which may degrade the performance of a device, equipment or system, or adversely affect living or inert matter.
Note. - Any electromagnetic disturbance may be an electromagnetic noise, an unwanted signal or a change in the propagation medium itself.

Unwanted signal (IEV 161-01-03)
A signal that may impair the reception of a wanted signal.

Non PLC-equipment: symmetric voltage / current: **unintended**
asymmetrc voltage / current: **unintended**

EMV-standards => method, where both signal components are measured, yields to successful assessment of protection requirement regarding conducted emission

=> Use of V-AMN sufficient for non-PLC equipment.

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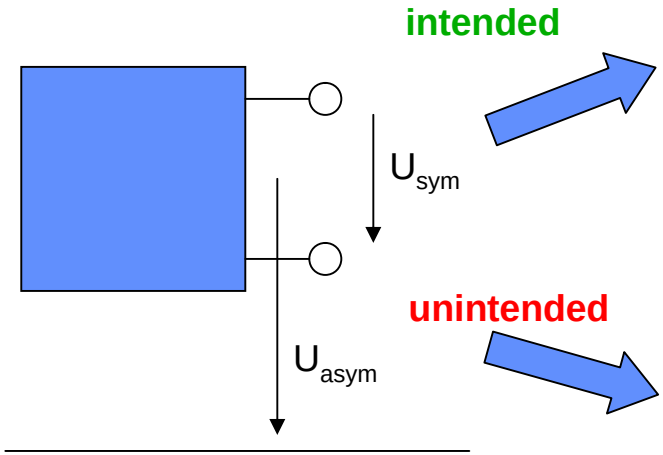
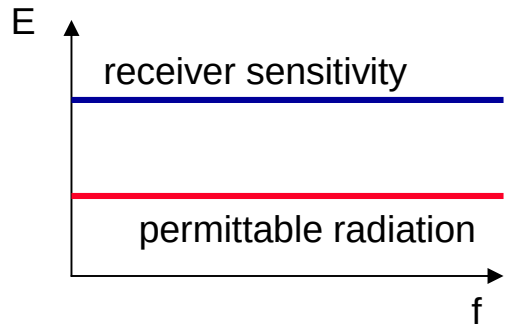
T-ISN is used for telecommunication products and thus for PLC as well

telecommunication-equipment:



level defined in appropriate product standards

Influence on radio services due to radiation possible



=> Only signals relevant for radiation (asymmetric) shall be measured according to an EMC standard

=> Use of T-ISN or Δ-ISN

T-ISN already defined in CISPR 22 for TC-ports

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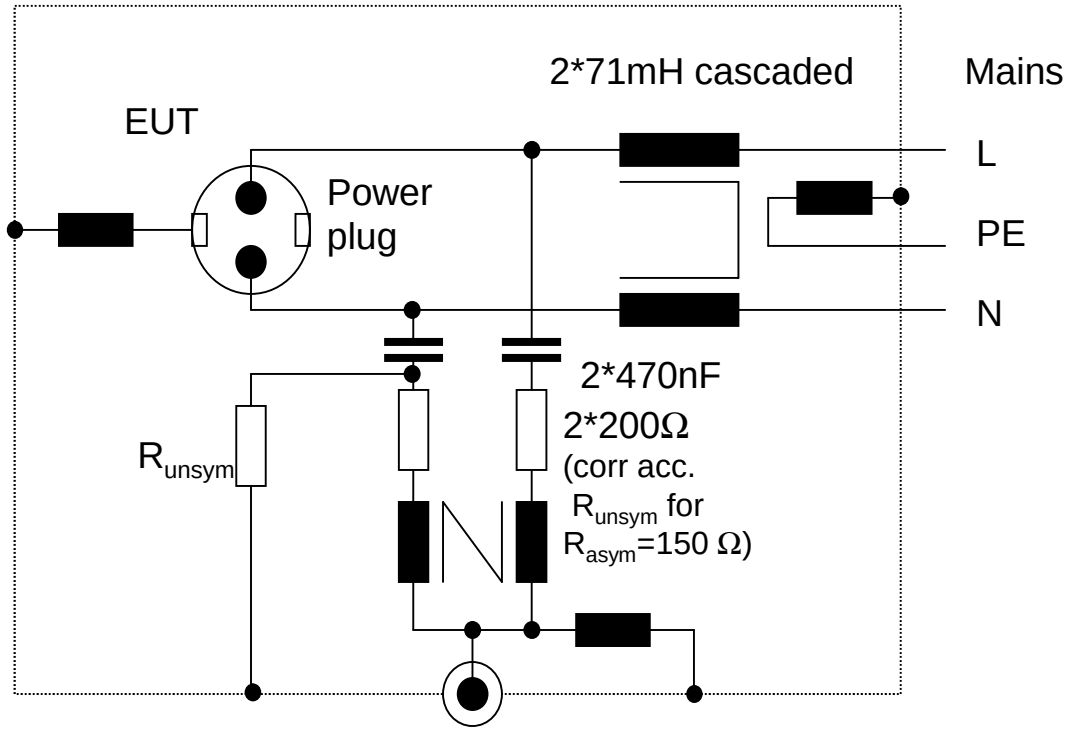
Usage of a T-ISN

150 Ohm T-ISN with LCL=30dB



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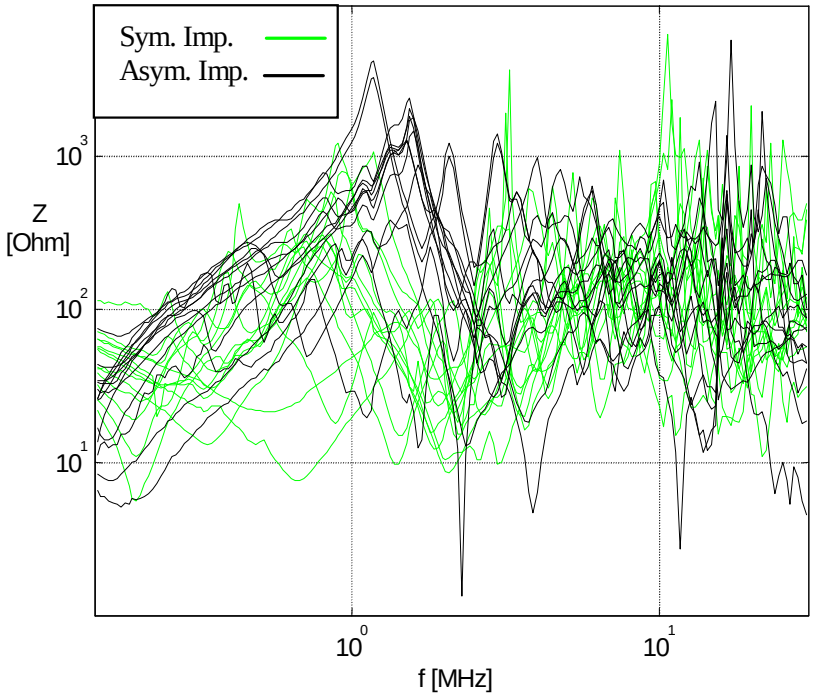
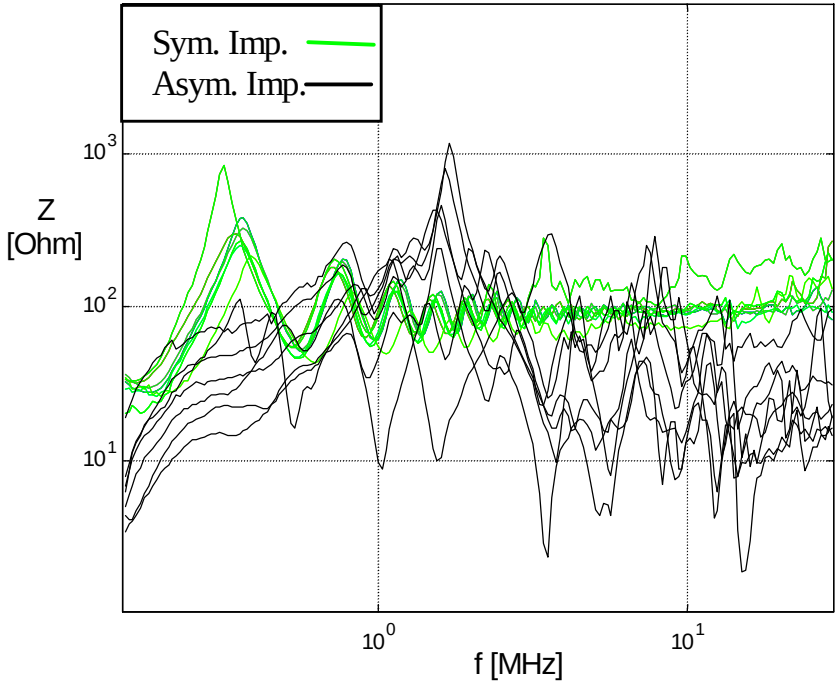
Impedances of power and TC nets





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Rationale for proposed LCL-value

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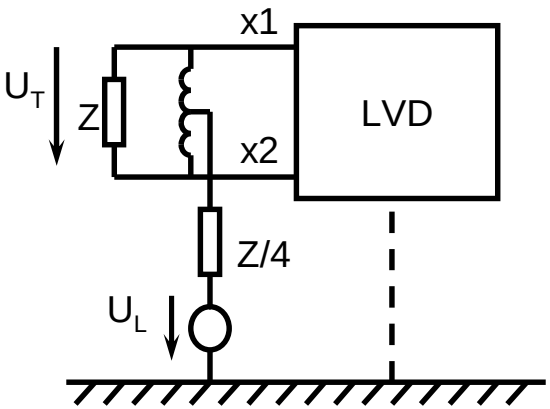
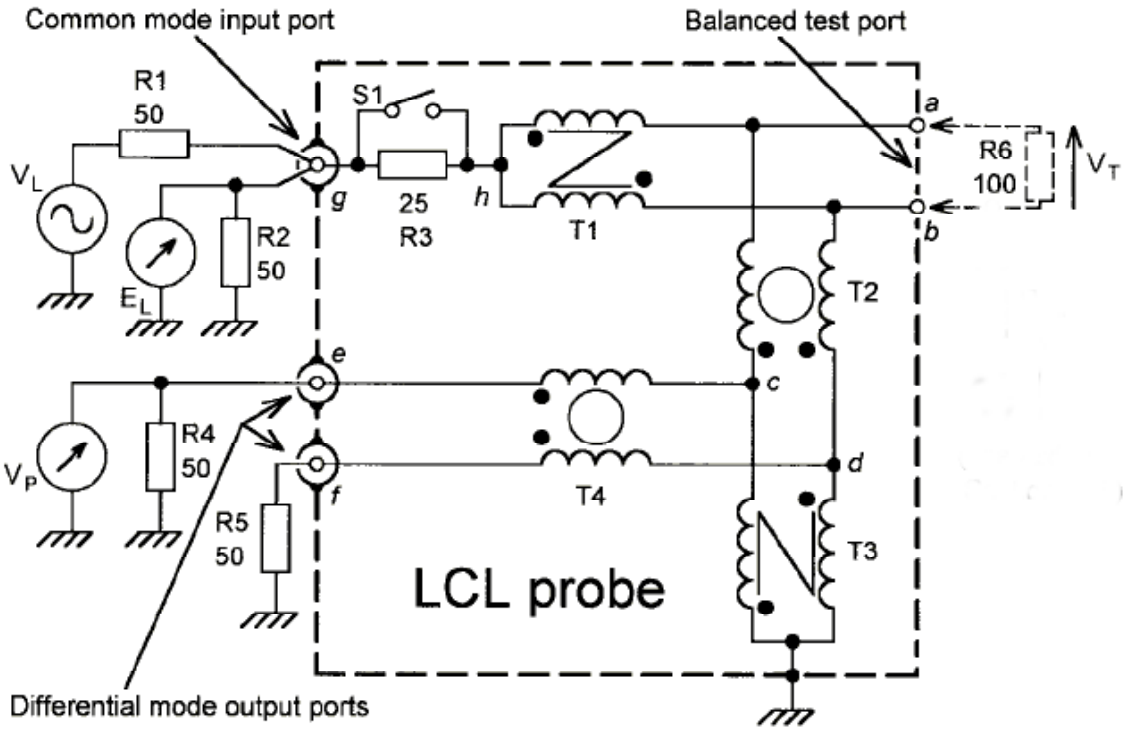
Measurement method for LCL of LVD

Design parameter:

Z = 100 Ω



Measurement adapter according to Macfarlane



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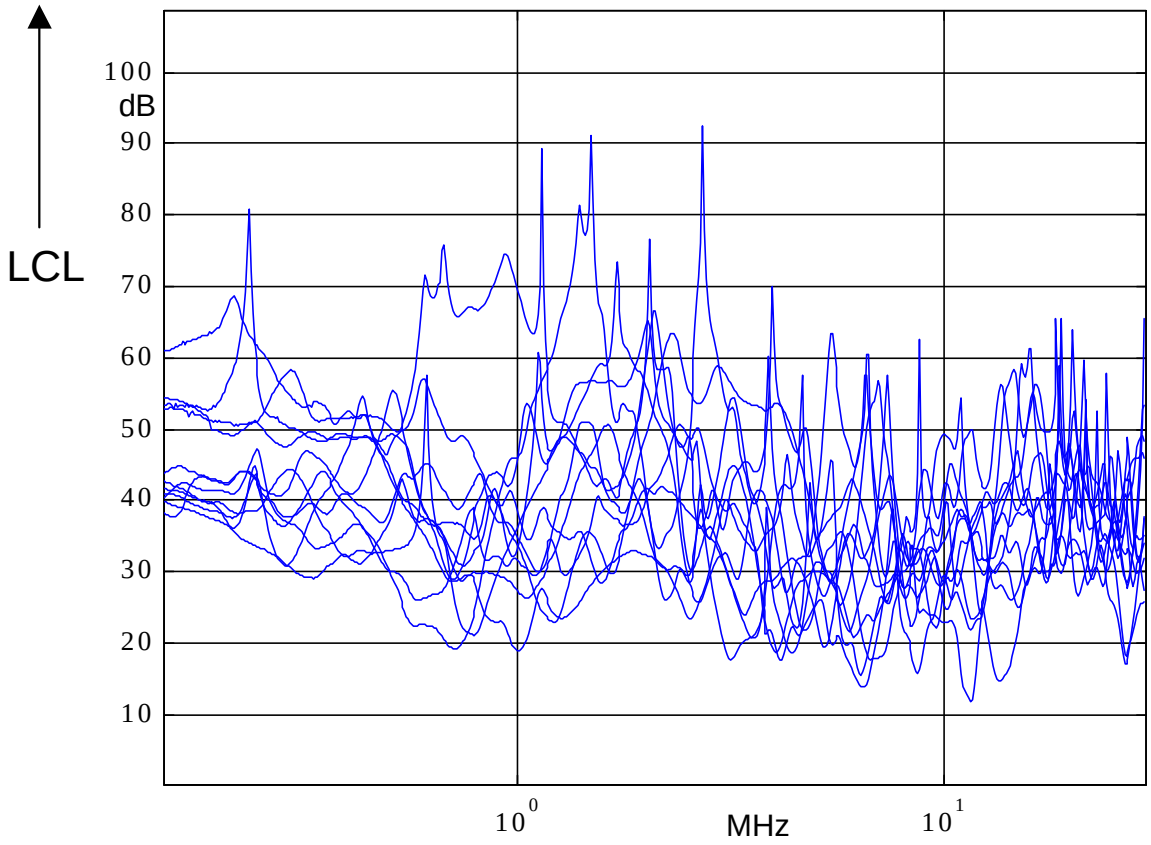
LCL measurement results (1)

Building of the University of Dortmund, usage as office and laboratory short distance to own transformer of the university

industrial environment



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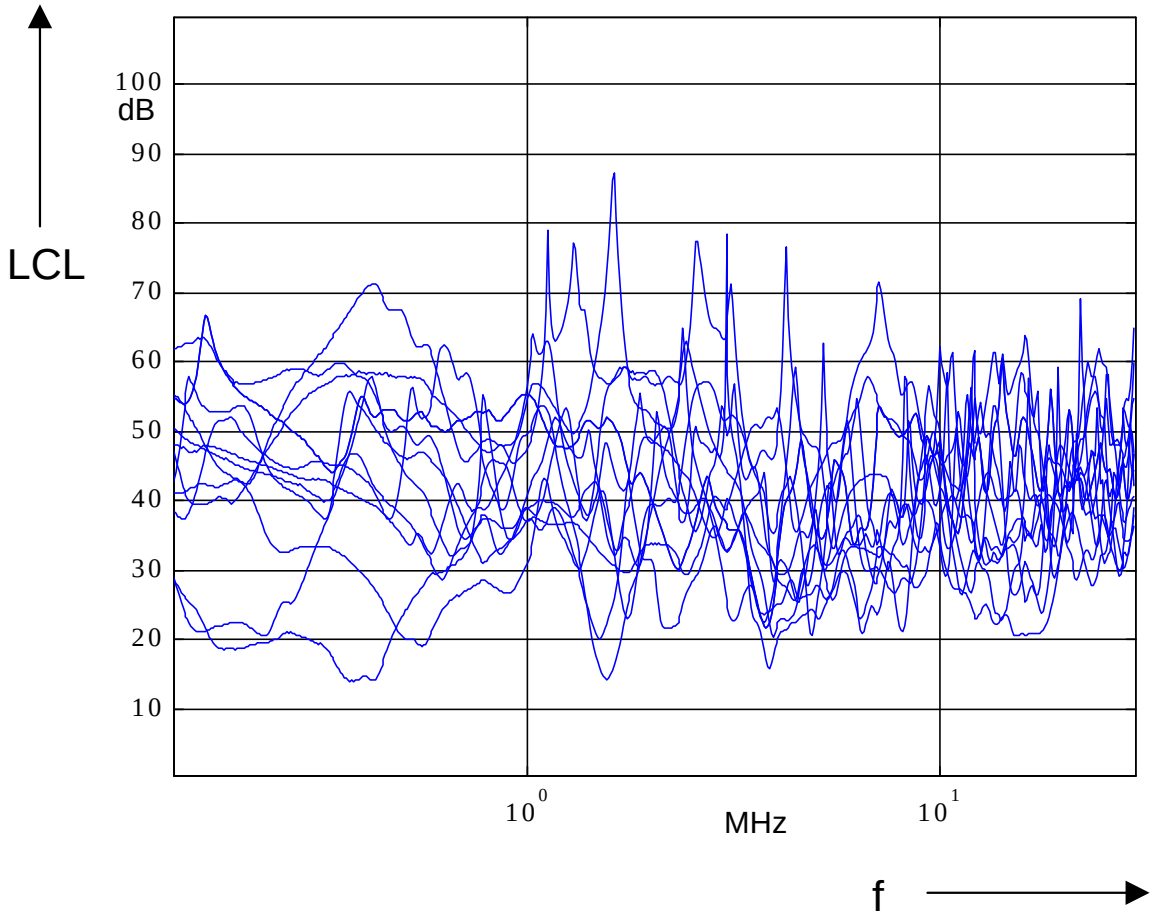
LCL measurement results (2)

Students hostel in Dortmund,
Several identical buildings, new installations, power feeding by common transformer compact station



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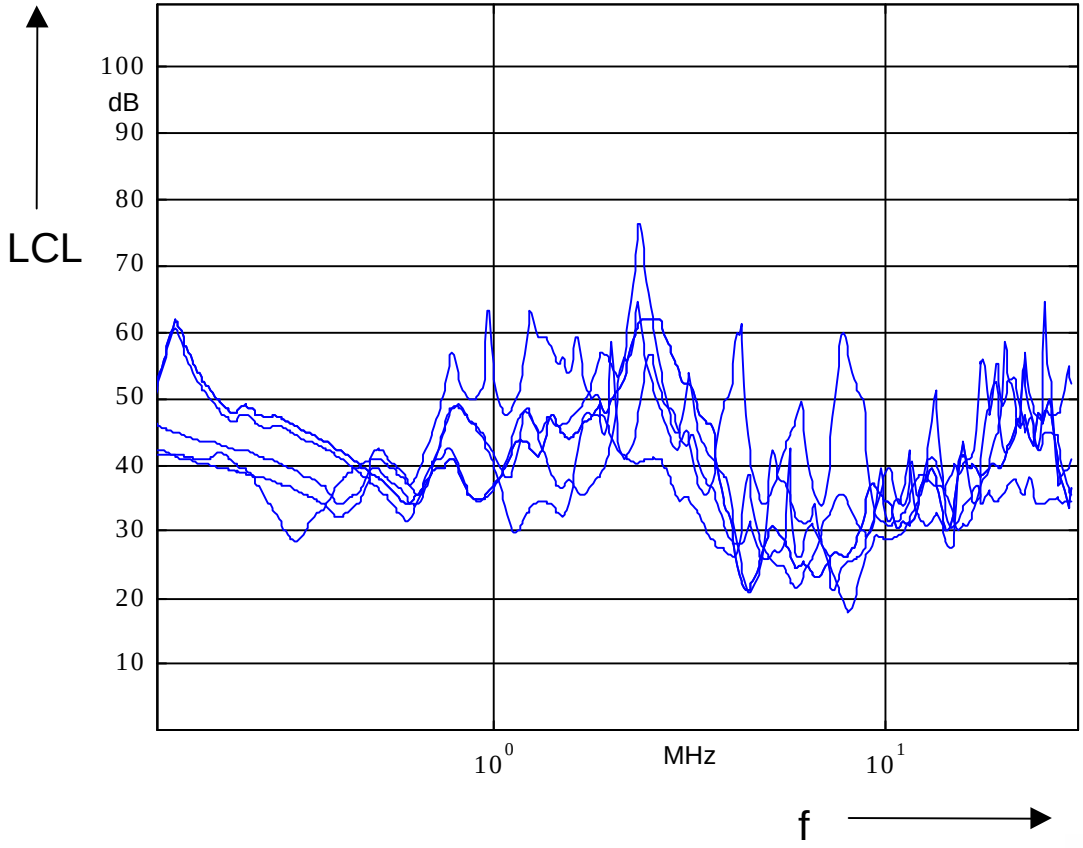
LCL measurement results (3)

Apartment in a multiple dwelling in Dortmund downtown, old installations, urban environment



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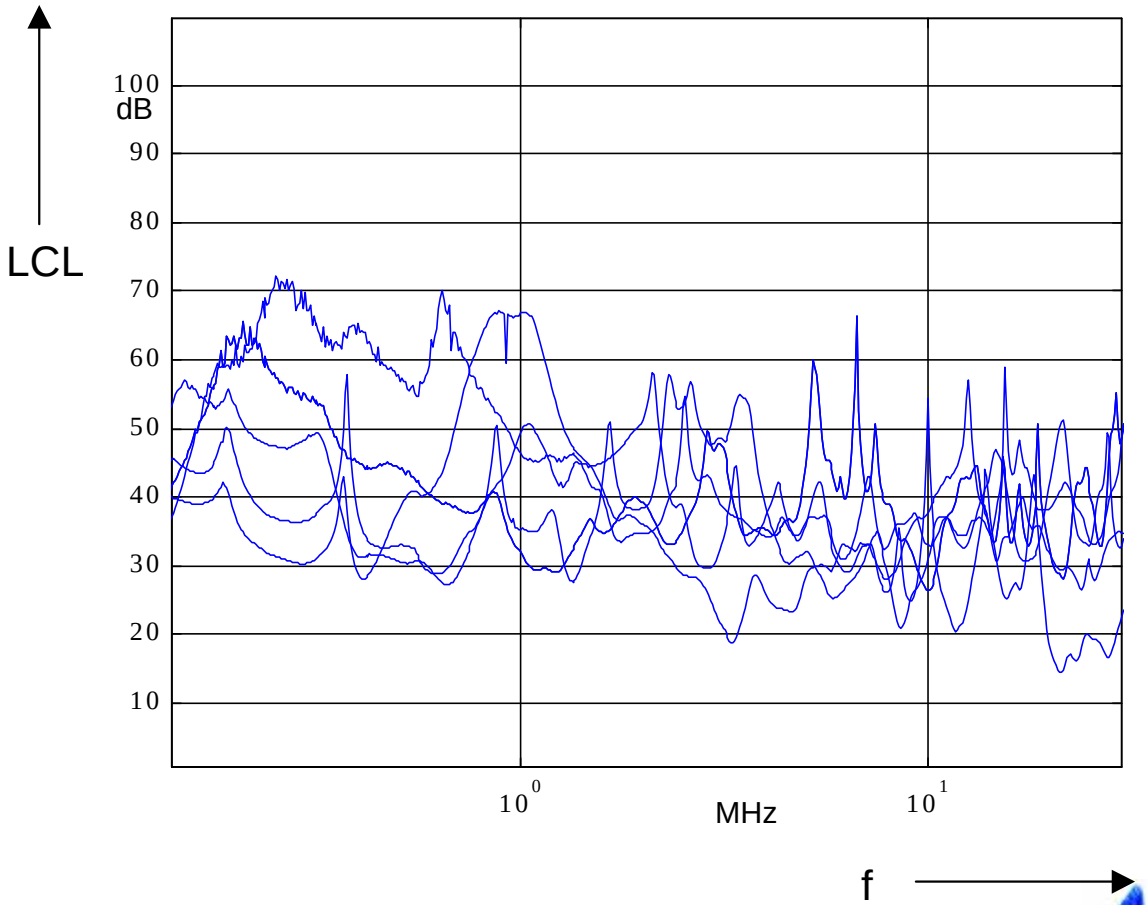
LCL-Messergebnisse (4)

Semi-detached house in a more rural environment in a small town near Dortmund,
500m distance to transformer compact station in the next street.



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Limits for disturbance voltages

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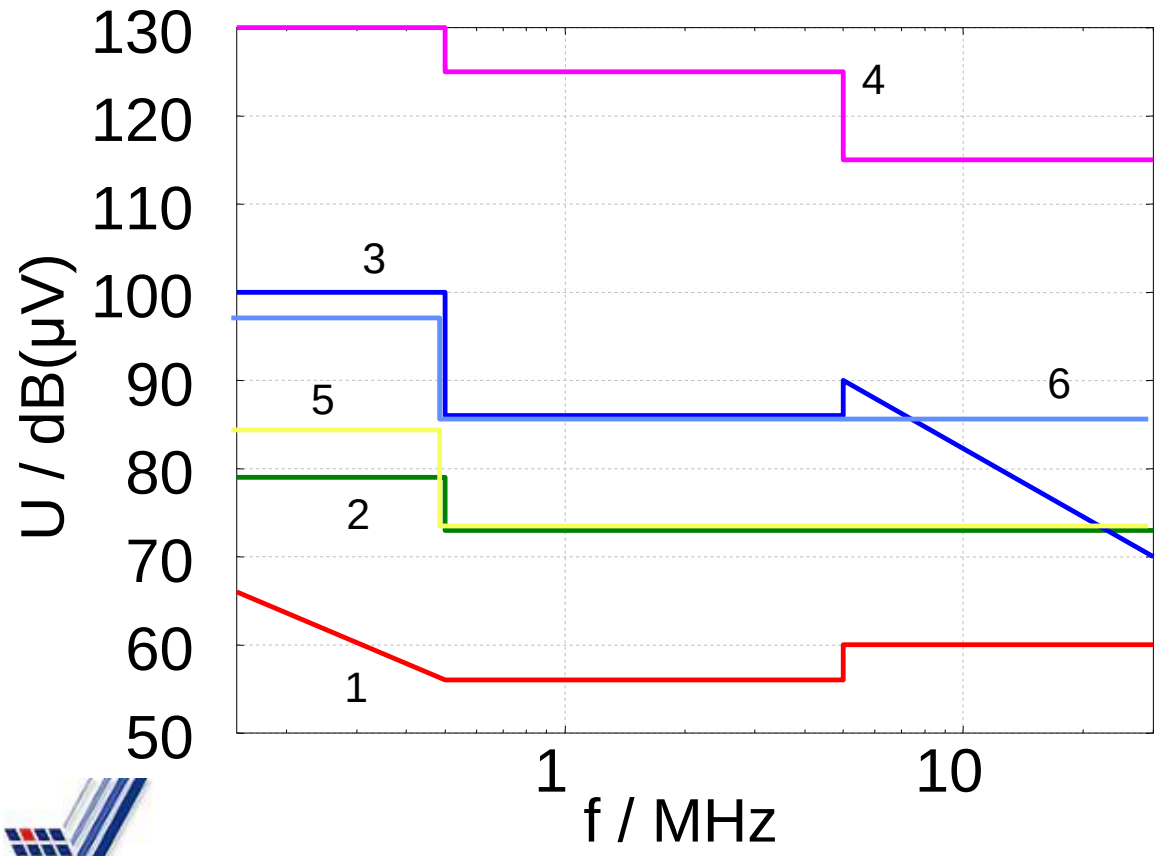
Comparison of disturbance voltage limits (QP) of various product standards



1: EN 55022, Class B
EN 61800-3, general sale
mains

2: EN 55022, Class A
EN 61800-3, limited sale
EN 12015, I<25A
mains

3: EN 61800-3, I<100A
EN 12015, I<100A
EN 50199
mains

4: EN 61800-3, I>100A
EN 12015, I>100A, sep. supply
mains

5: EN 55022, Class B
TC-port

6: EN 55022, Class A
TC-port

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Rationale for using same limits for TC-line-devices and PLC-devices

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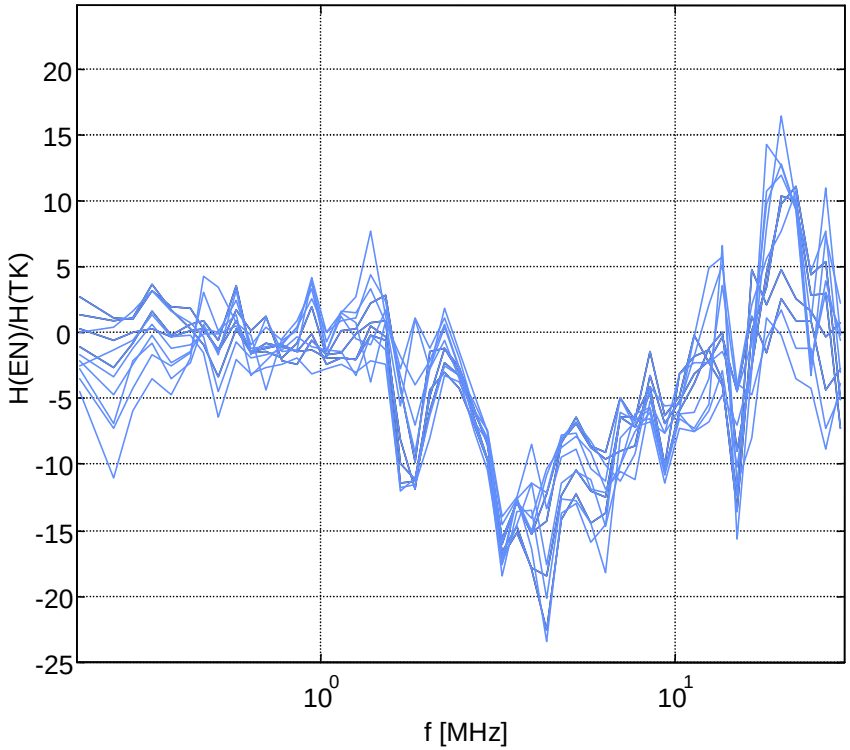
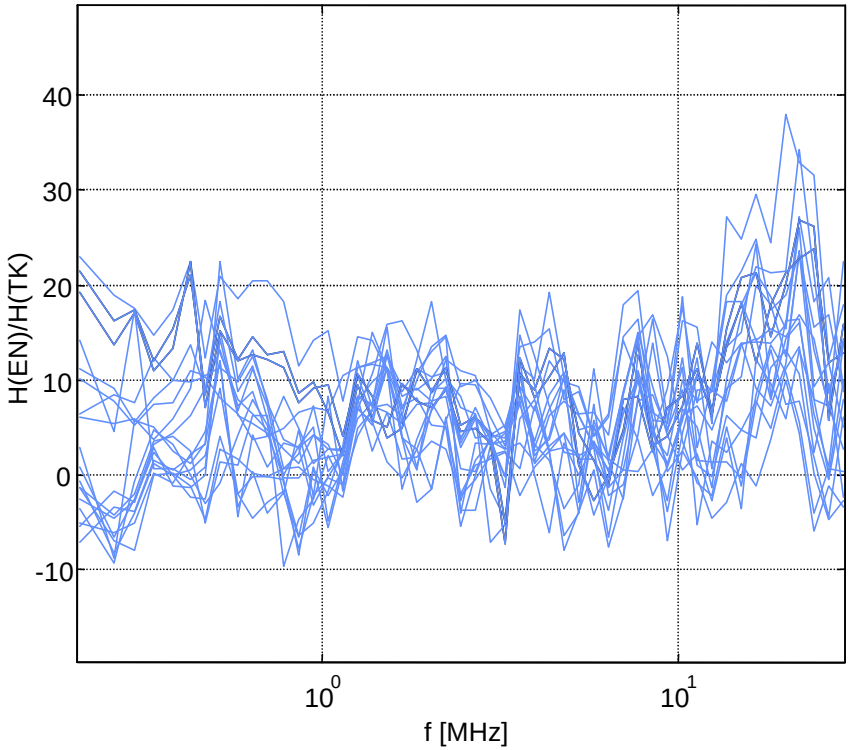
Measurement of radiation

A common mode signal is fed into power lines resp a TC-line. The figures show the quotients of radiation from energy net to radiation from TC-lines.





Measurement in 3m distance to building

Measurement inside the building

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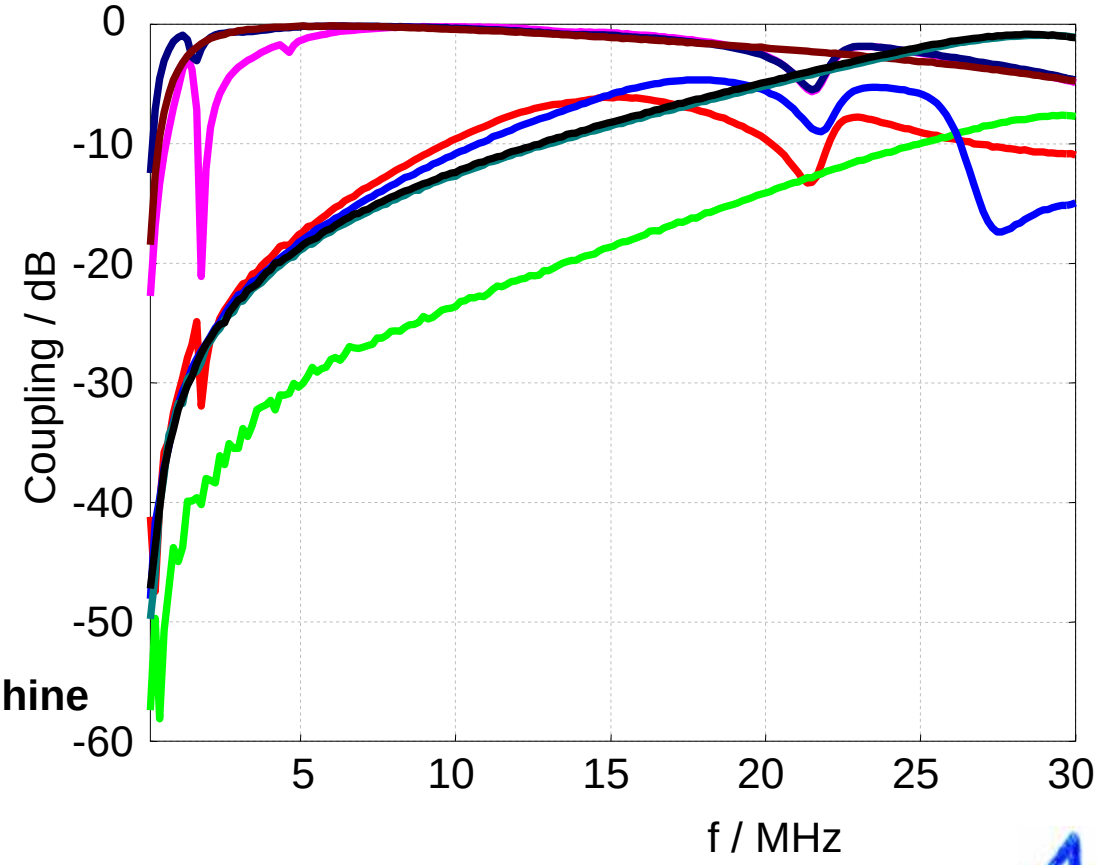
Coupling of devices with TC-line and powerline connection

Modem 1
TC - AC mains
TC - DC connector
TC - RS232-shield

Modem 2
TC - AC mains
TC - DC connector
TC - RS232-shield

Modem 3
TC - USB-port

Phone with answering machine
TC - AC mains



Higher frequencies: only a few db attenuation between TC and shield of data cable

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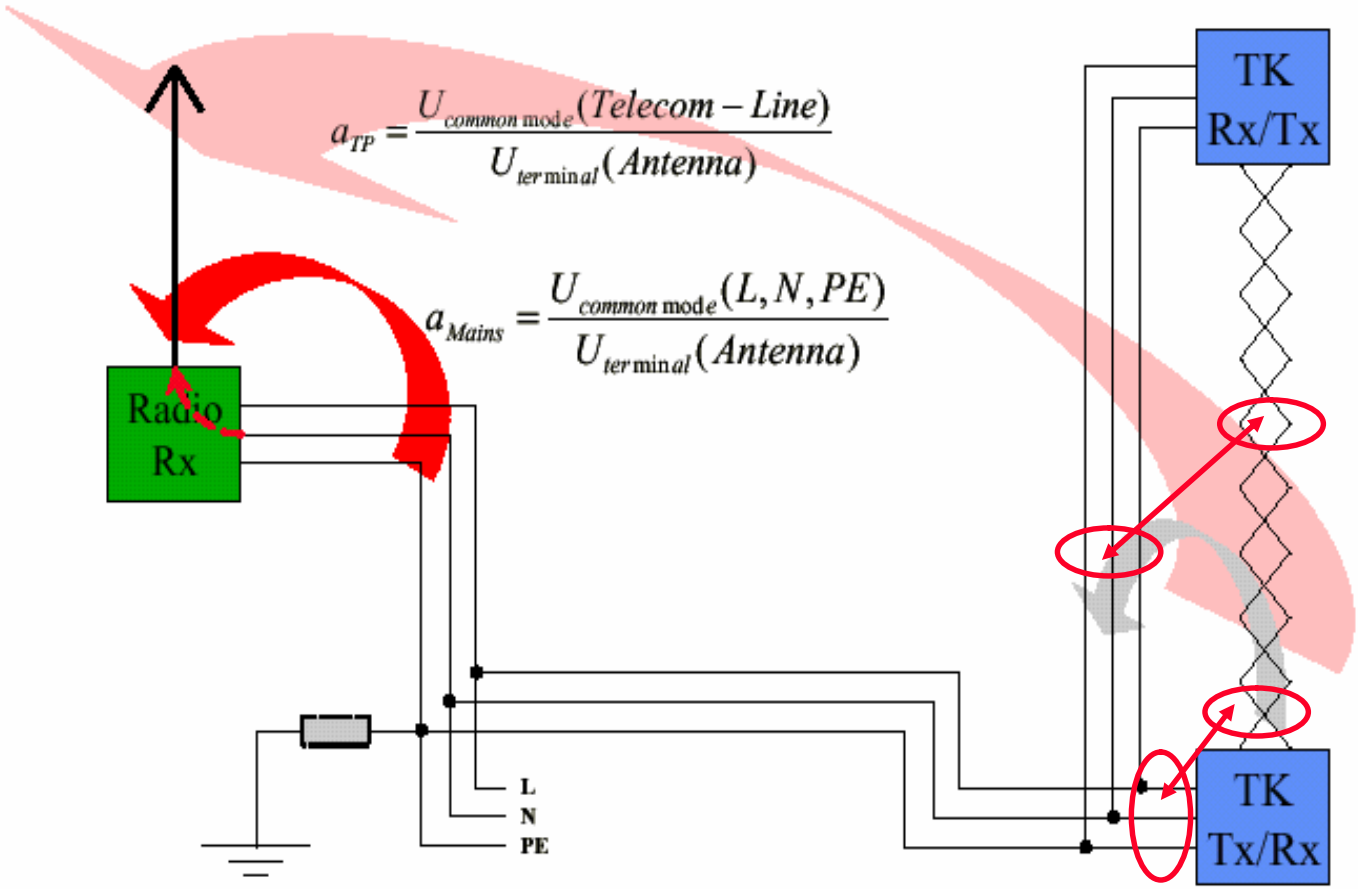
Modification of the model



Very low attenuation for CM-signals (less than 10dB!)

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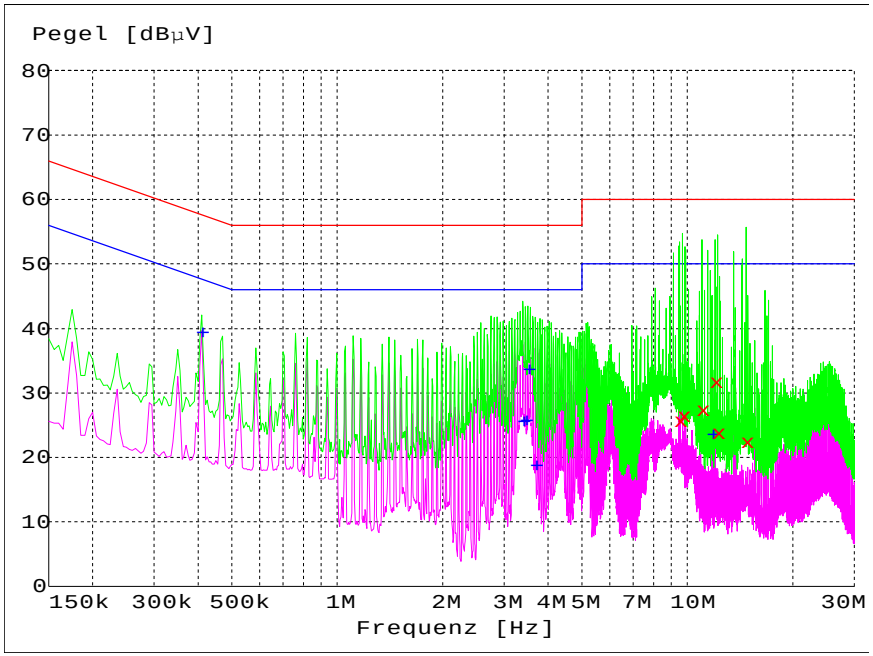
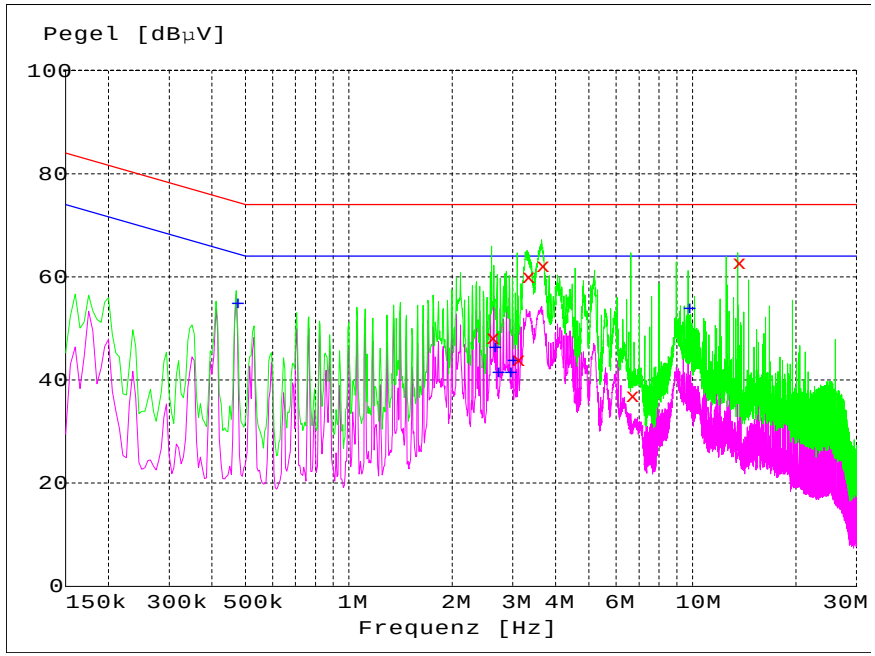
Difference of evaluation with T-ISN and V-AMN





Switching power supply of a notebook

V-NNB,
CISPR-22, Class B Mains

distance to limit line:
AV, 0.41 MHz: 8.5 dB
AV, 3.505 MHz: 12.5 dB

T-ISN, LCL=30dB
CISPR-22, Class B TC

distance to limit line:
AV, 0.47 MHz: 9.8 dB
AV, 3.5 MHz: 12.7 dB

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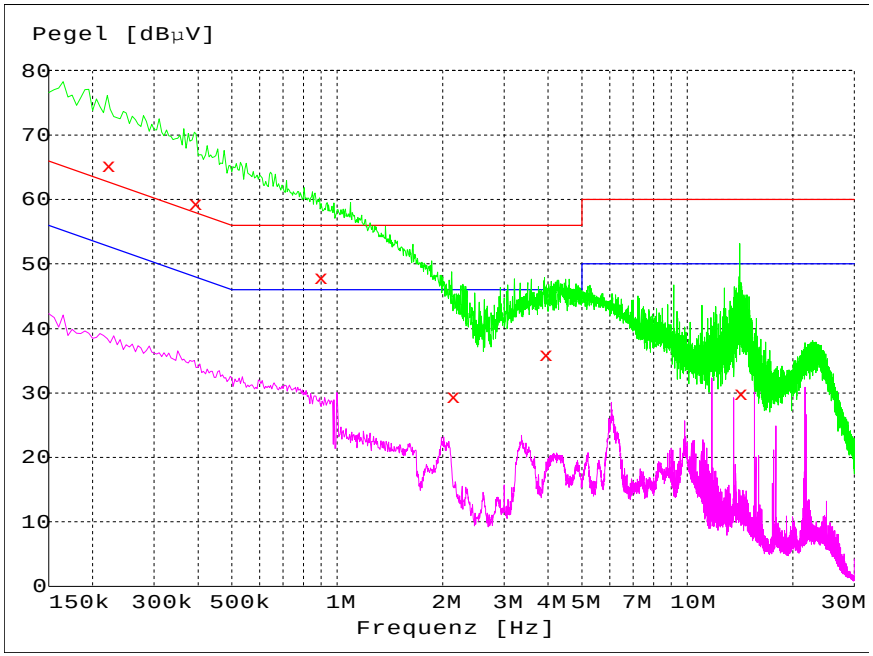
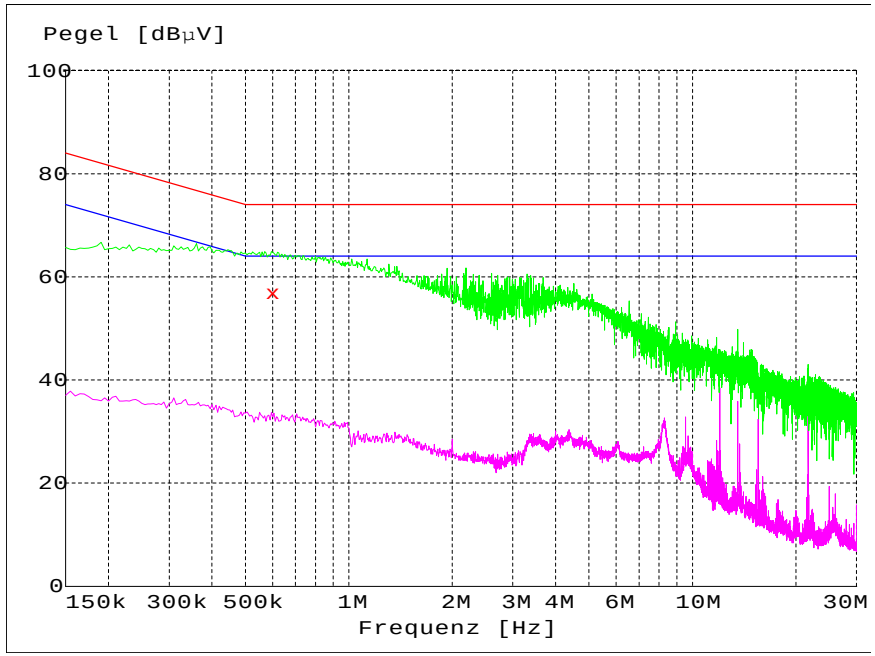
Difference of evaluation with T-ISN and V-AMN





Small drill machine

V-NNB,
CISPR-22, Class B Mains

distance to limit line:
QP, 0.22 MHz: -2.4 dB
QP, 0.89 MHz: 8.1 dB

T-ISN, LCL=30dB
CISPR-22, Class B TC

distance to limit line:
QP, 0.6 MHz: 17 dB

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Reason for relative low difference between the evaluation methods

It is claimed that T-ISN-method will give relieve of up to 40 dB.
The two examples show that this assumption is not generally true.

The reasons are:

	V-AMN	T-ISN
1) common mode impedance:	25 Ω	150 Ω

high impedance disturbance source yield to higher indication for T-ISN measurement (16 dB for pure current source)

2) symmetry of source

Both methods show the same indication for dominant asymmetric sources

Higher differences between the methods expected for low impedance, symmetric sources.

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Installation Assessment

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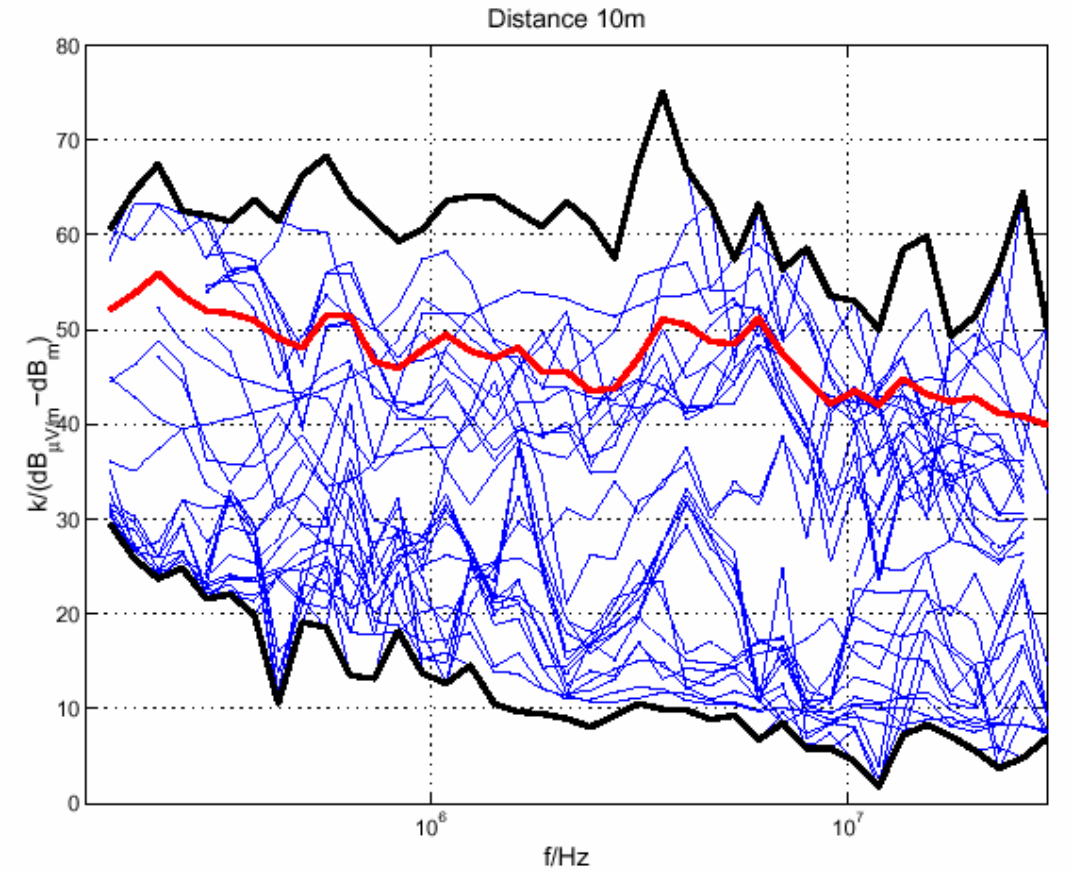
Examination of the coupling factor

Measurement methology:
- Injection of symmetrical signal into mains
- measurement of the radiation quotient (in log. scale differential) is the coupling factor



Statistical evaluation is necessary.

e.g. 80%-Quantil

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Usage of Detectors and limits in some harmonised standards

Curve	Standard / Draft	Measuring quantity	Detector
1	EN 55011:May 1998 + A1: August 1999, Group 2, Class A	Electr. field in 10m	QP
2	EN 55011:May 1998 + A1: August 1999, Group 2, Class B	Magn. field (<30MHz) in 3m Electr. field (>30MHz) in 10m Electr. field (>1GHz) in 3m	QP (<1GHz) weight. PK (>1GHz)
3	EN 55022:9/98, ITE Class A EN 55022:5/98 + A1:8/99, Group 1, Class A	Electr. field in 10m	QP
4	EN 55022:9/98, ITE Class B EN 55011:5/98 + A1:8/99, Group 1, Class B	Electr. field in 10m	QP
5	NB 30 Limits of German Reg TP	Electr. field in 3m	PK
6	MPT1570 limits from RA / Reg TP Ad Hoc WG (UK-limits)	1m (<1.6 MHz) 3m (>1.6 MHz)	PK
7	prEN 50121-3-1:10/99, stat. Train a) 25 kV System, b) 600V System	Magn. field (<30MHz) in 10m Electr. field (>30MHz) in 10m	PK
8	prEN 50121-2:10/99, substation	Magn. field (<30MHz) Electr. field (>30MHz) 3m from fence or 10m from Building	PK
9	FCC Rules part 15 – radio frequency devices	Covers “carrier current systems”, Limit for electric field in 30m (1.7-30MHz)	QP

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Comparison of different measurement distances and detector

The limit lines 1,3,4,5 and 7 (measurement in 10m distance) are recalculated to 3m distance by increase of 10dB.

Limit line 2 is partly (30-1000MHz) increased by 10dB (10m $\rightarrow$ 3m)

Limit line 6 is partly (<1.6 MHz) decreased by 10dB (1m $\rightarrow$ 3m)

Limit line 9 (measurement in 30m distance) is recalculated by the correction factor 20dB.

Since the signal of the different equipment is not known, no corrections are applied regarding the detector (QP or PK).

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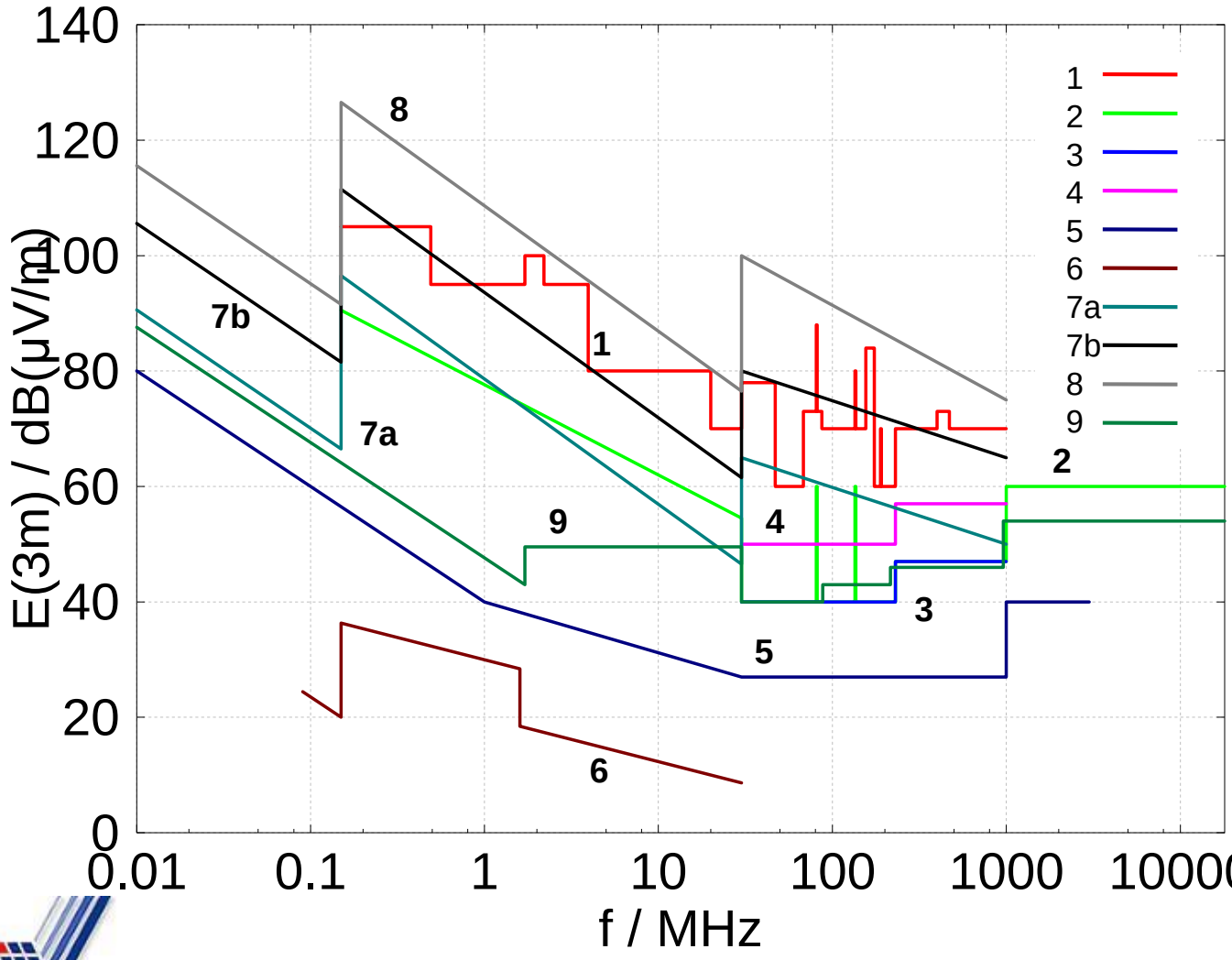
Limits for Radiated Disturbances



1: EN55011, Gr.2, Kl. A
2: EN55011, Gr.2, Kl. B
3: EN55022, Kl. B
4: EN55022, Kl. A
5: Reg TP
6: UK
7a: prEN50121,train 600V
7b: prEN50121,train 25kV
8: prEN50121, substation
9: FCC Rules part 15
„Carrier current systems“

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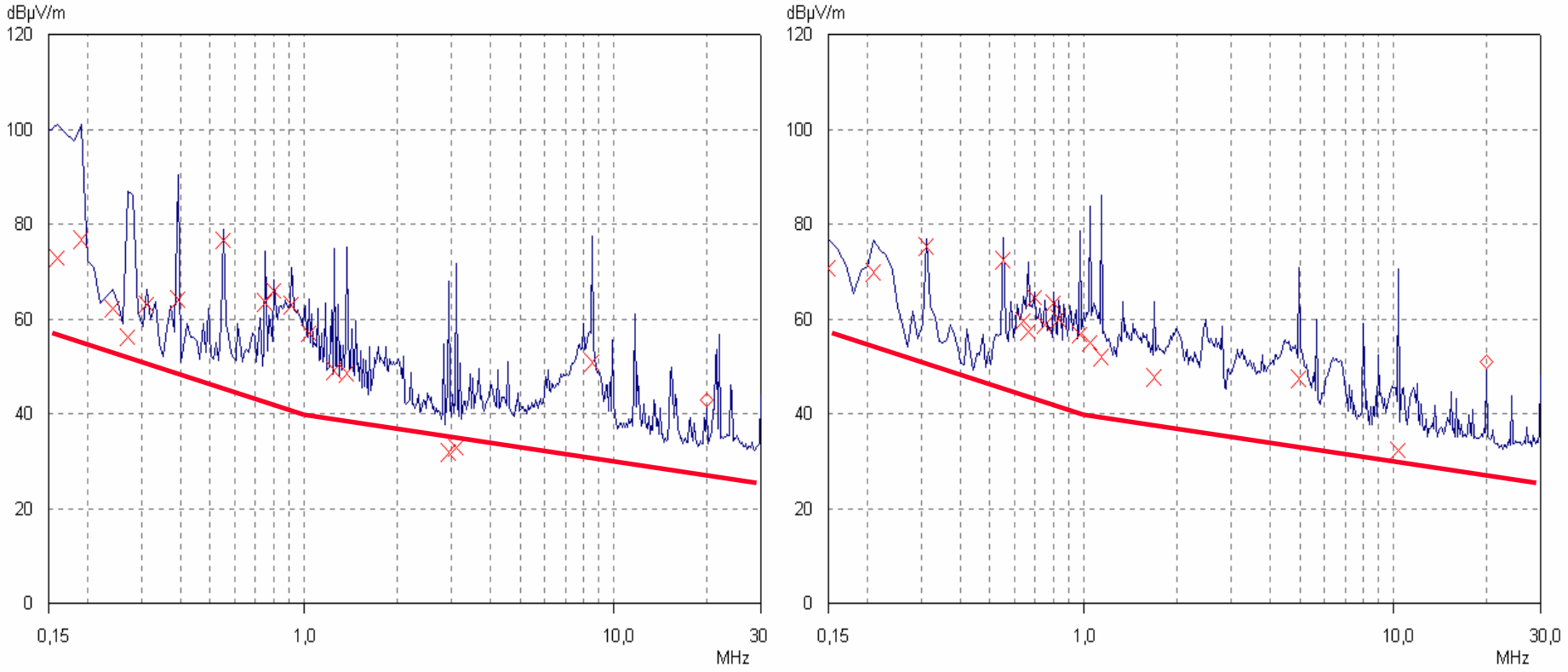
Typical Disturbances from Computer- Networks



Emission measured with MV05-method inside a building of the University of Dortmund. About 200 PCs and workstations are in operation in this building. Network: Ethernet with Cat 5-Cabling.

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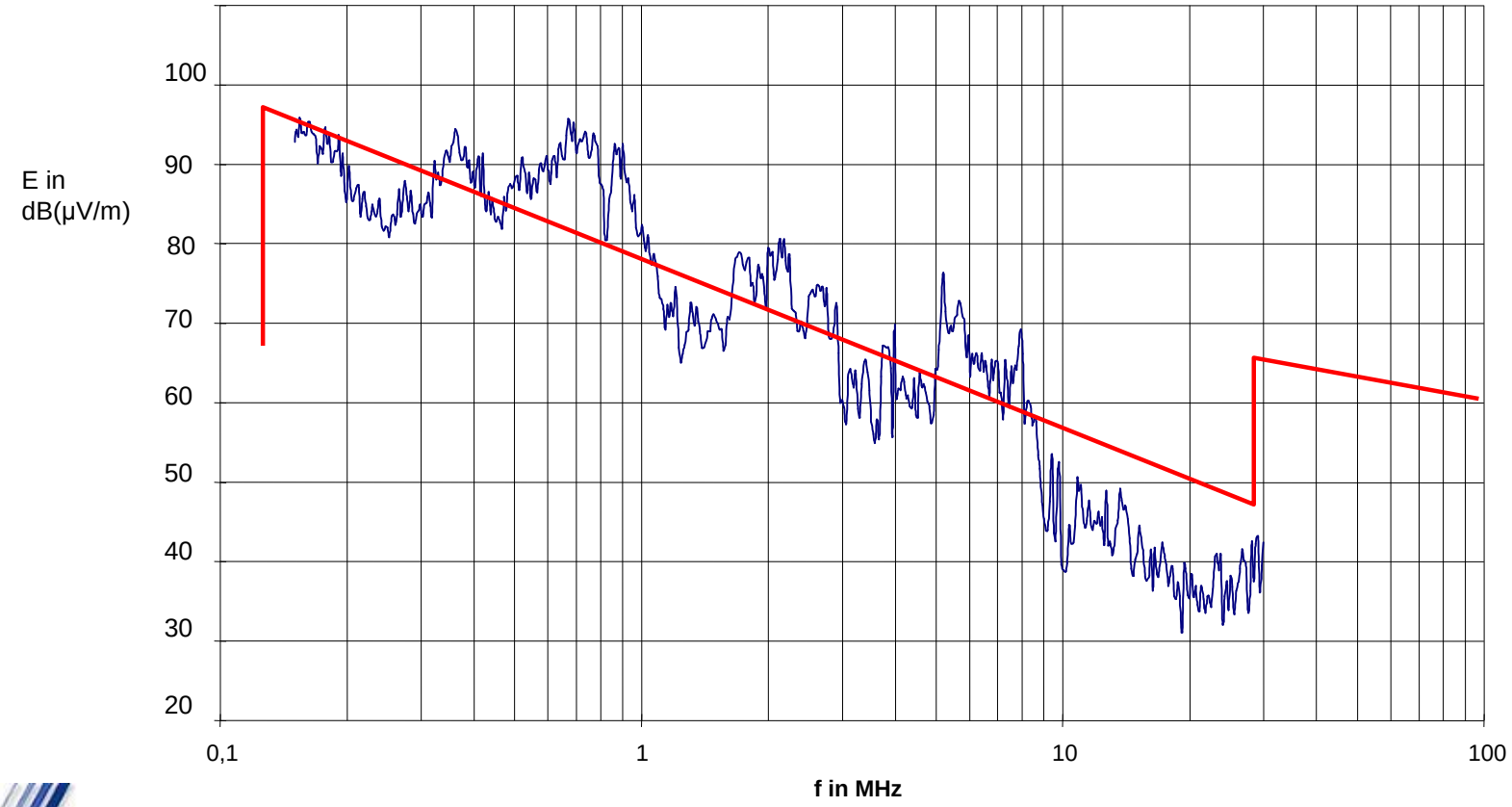
Typical Emissions from Tram Systems

Measured in a distance of 10 m from middle of track as given by the railway EMC-standard



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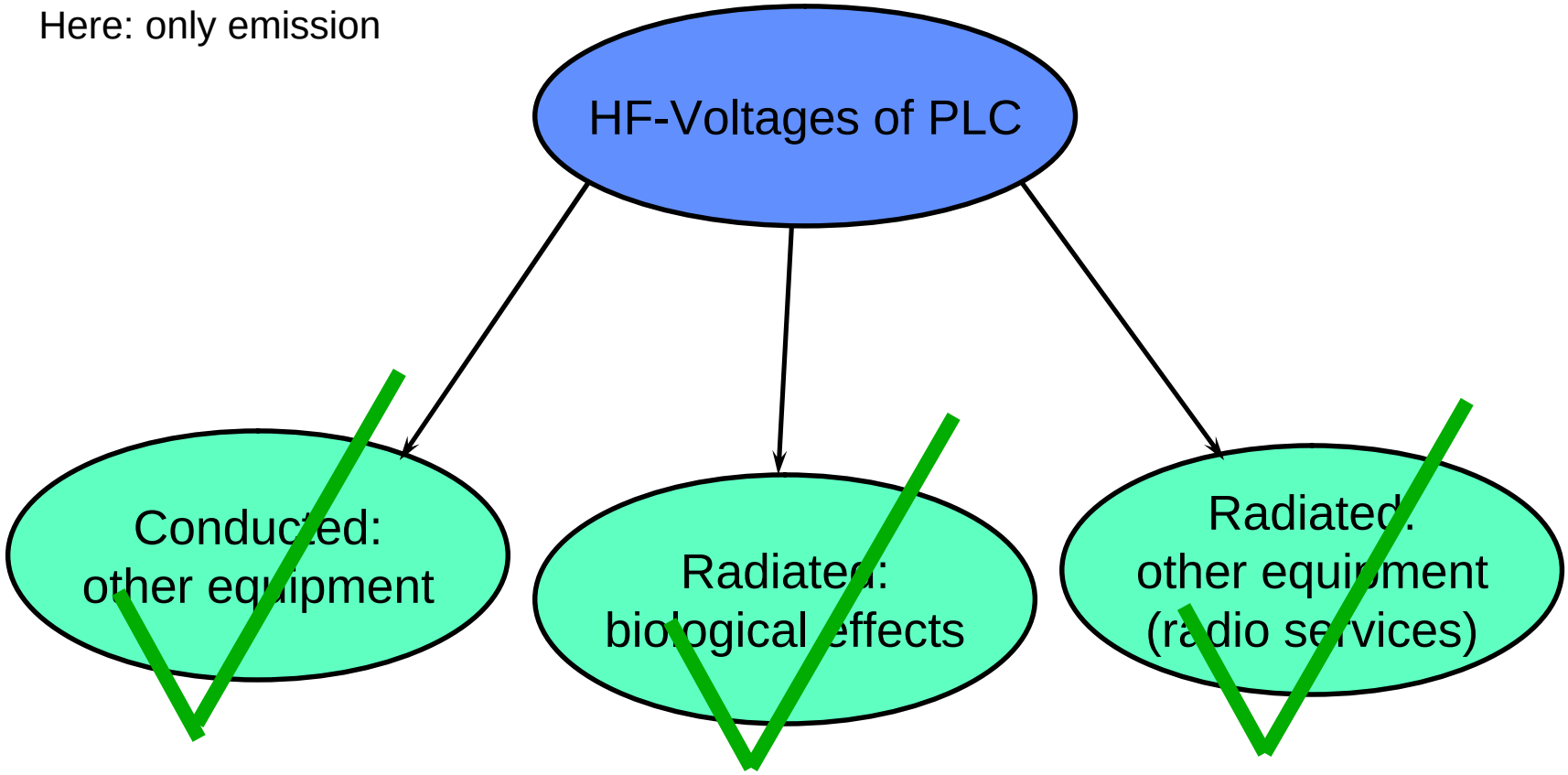
EMC of PLC

Here: only emission



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