



Radiation of PLC Systems

Holger Hirsch

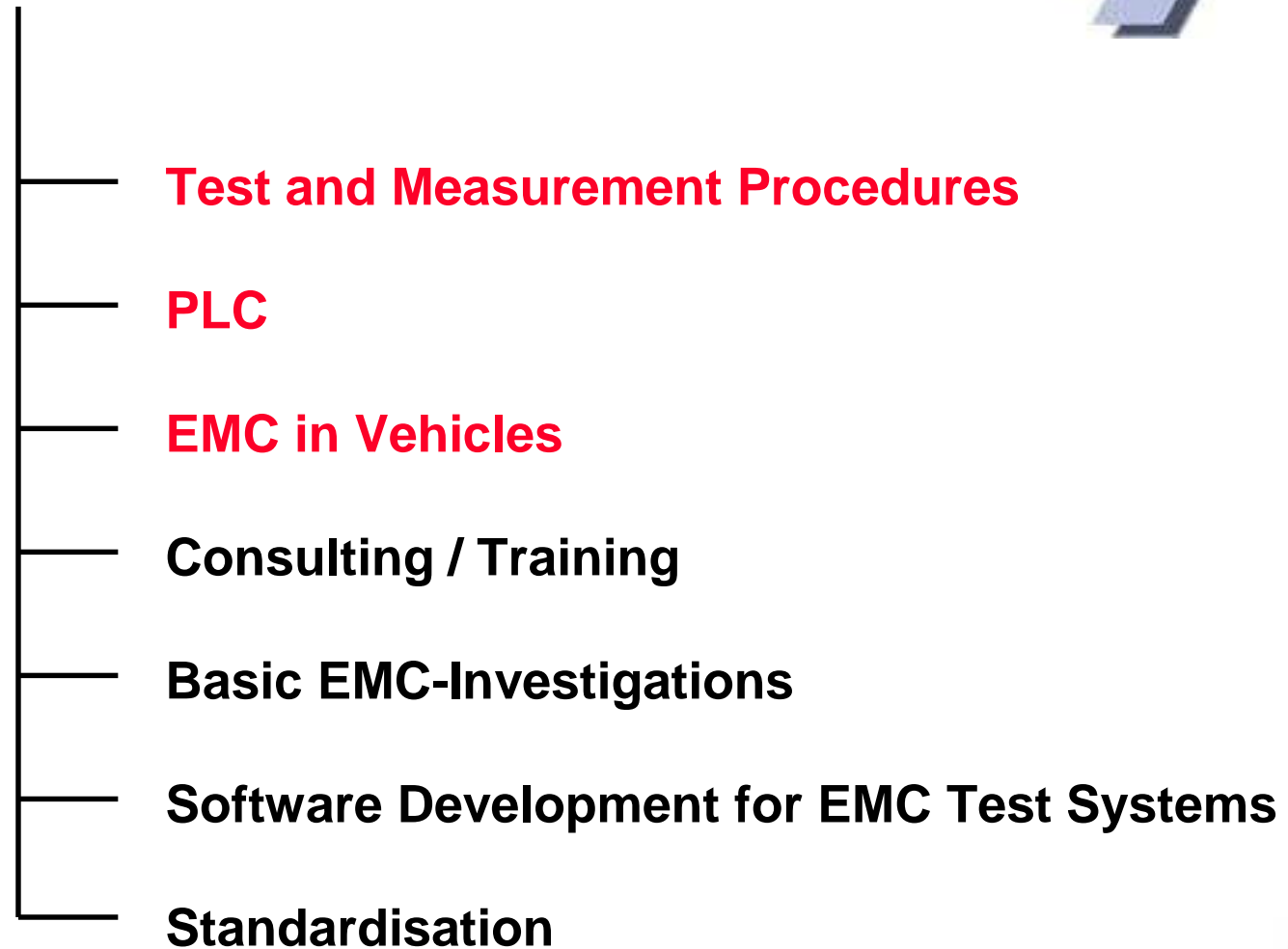
University of Dortmund

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





Division Theory of EMC





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



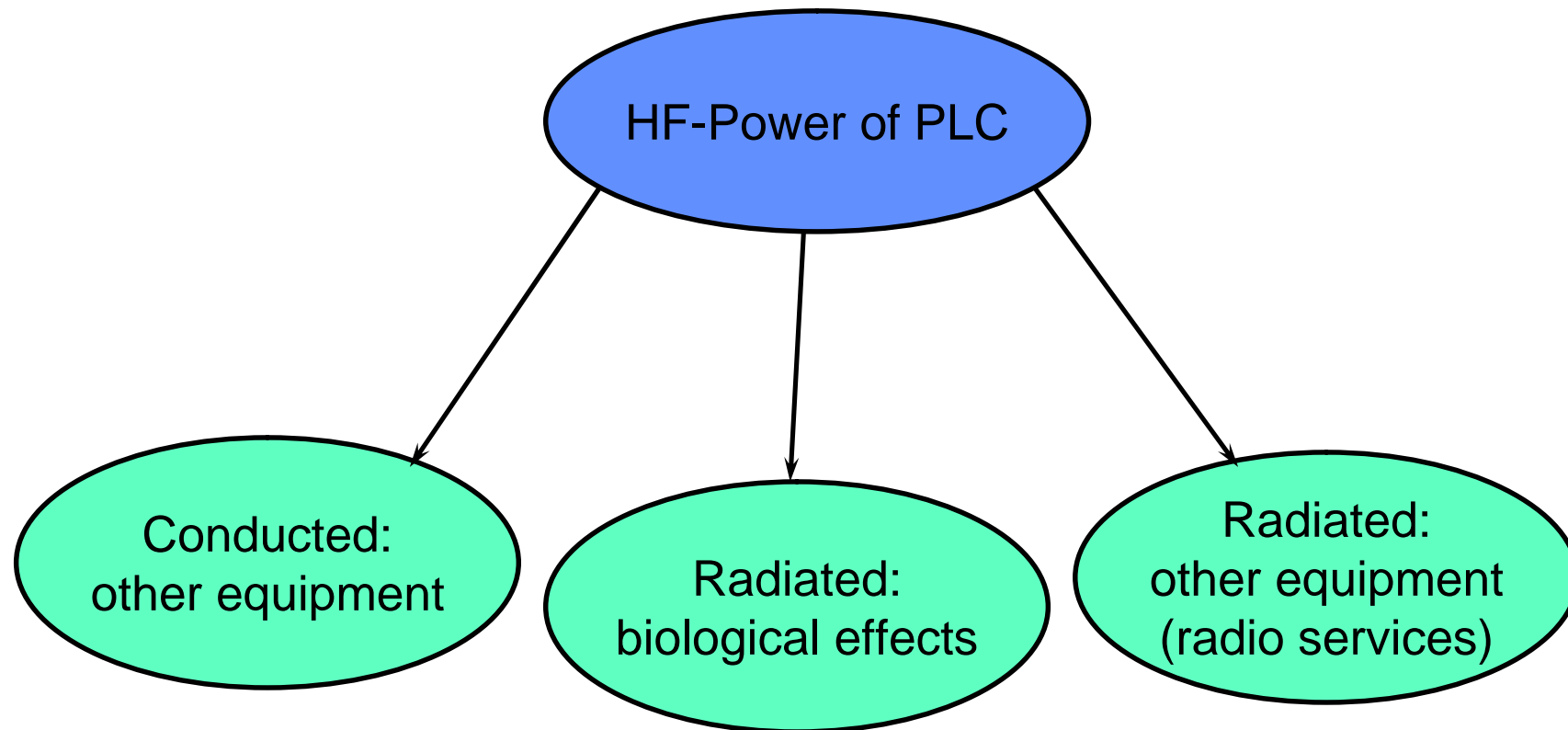


Cooperation with EMC test facilities

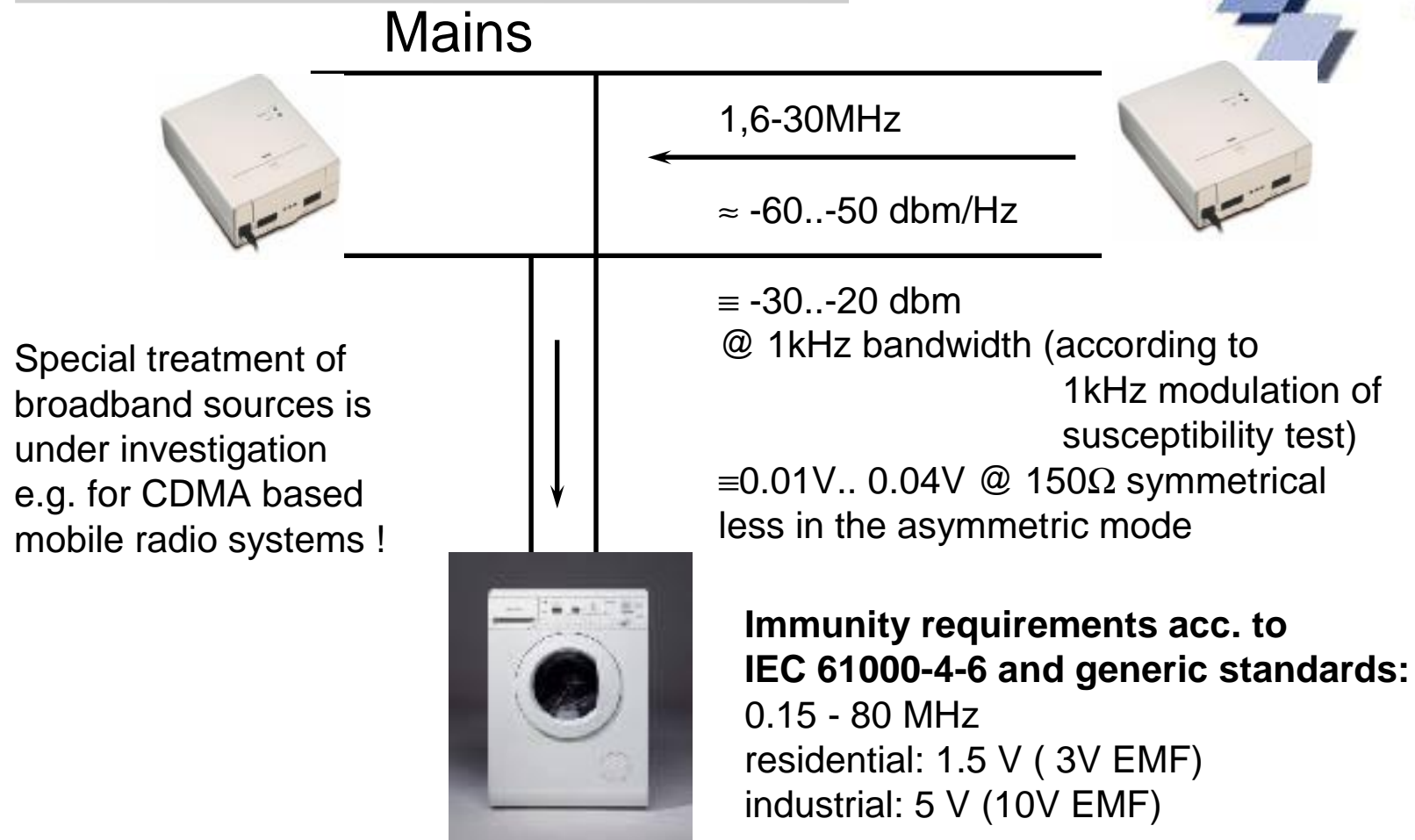




Unwanted Emission of PLC



Conducted EMC



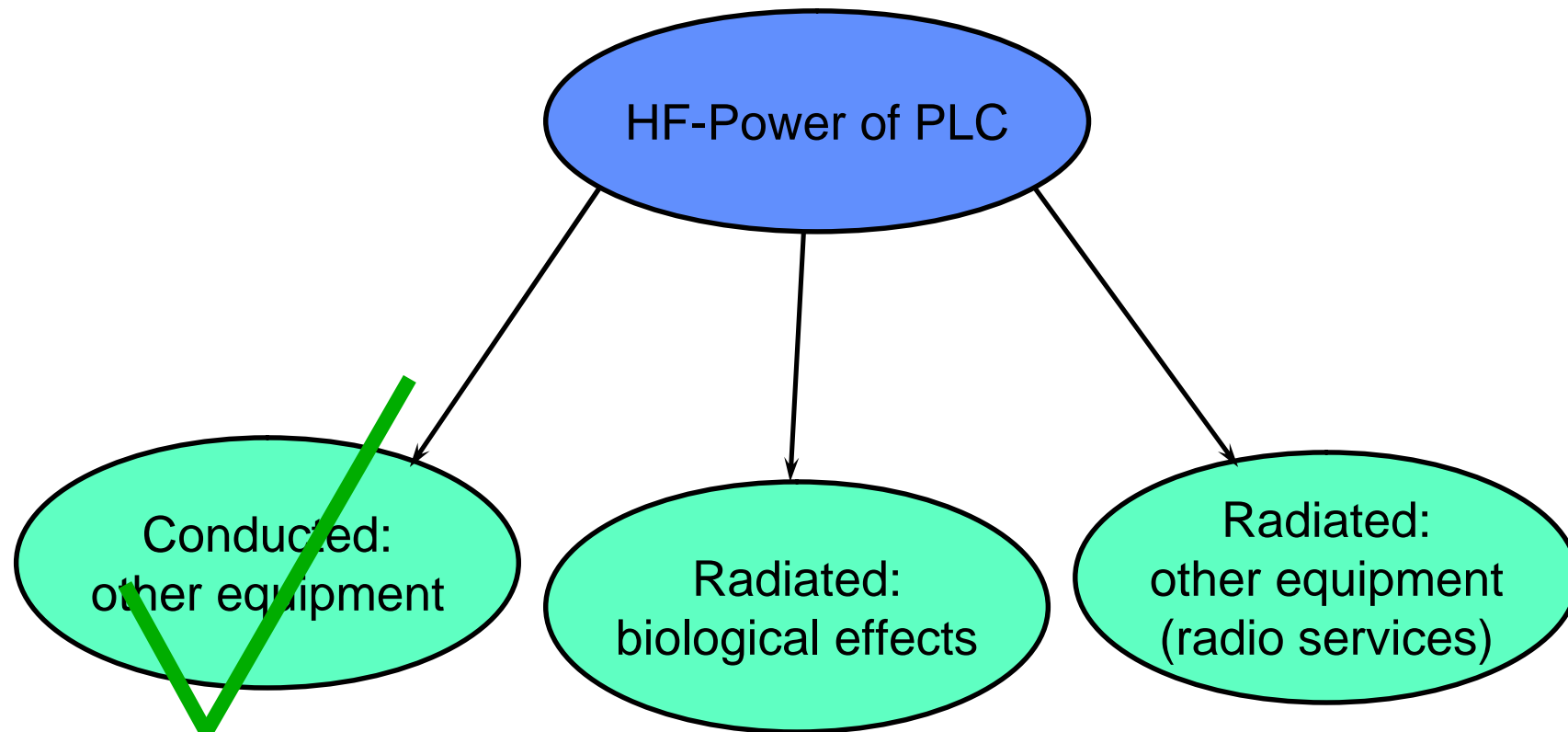
Conducted emissions caused by PLC are by far below the standard limits.

⇒ Other devices will not be disturbed by conducted emissions caused by PLC!





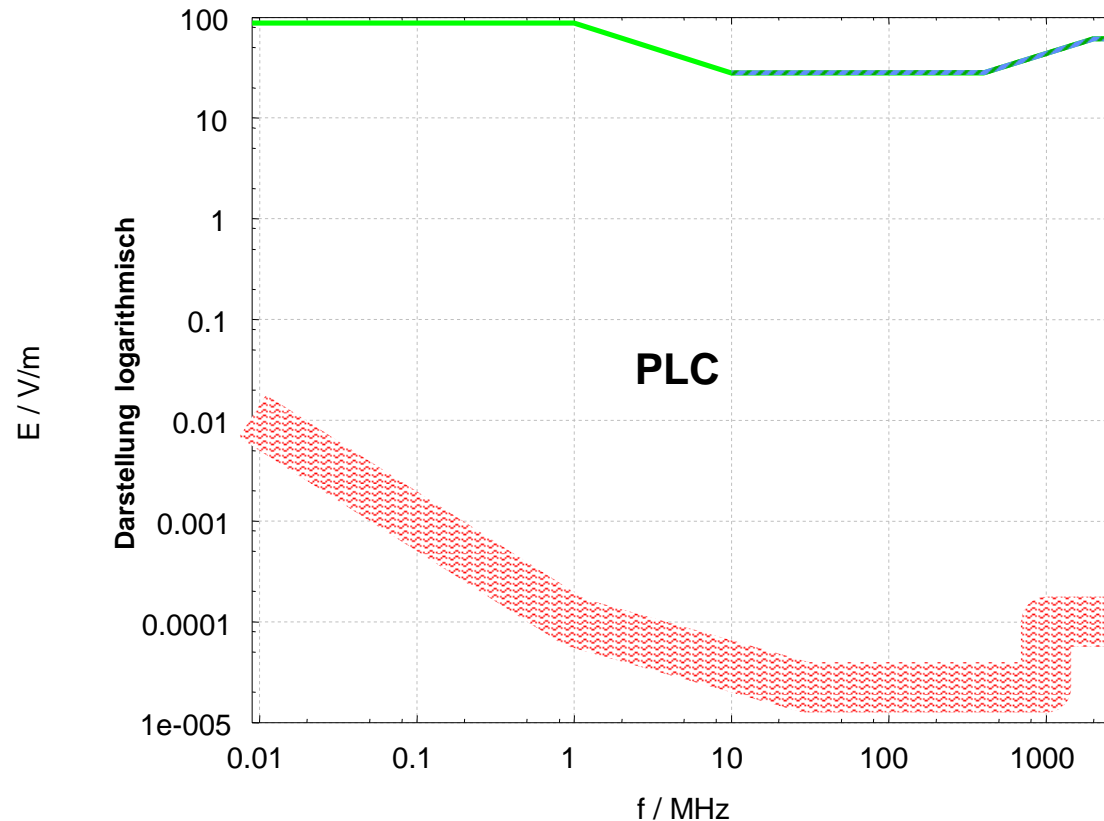
Unwanted Emission of PLC





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

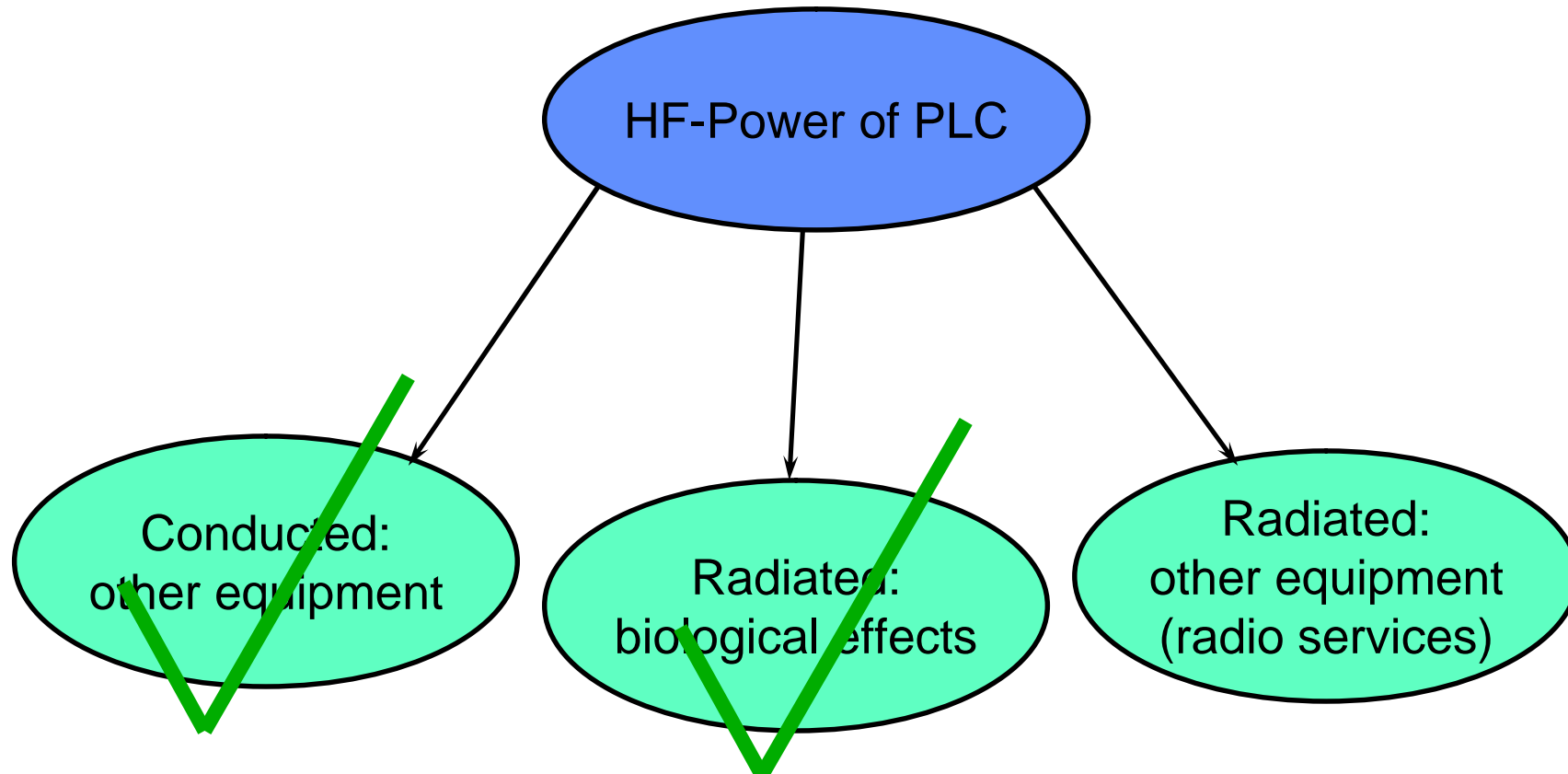


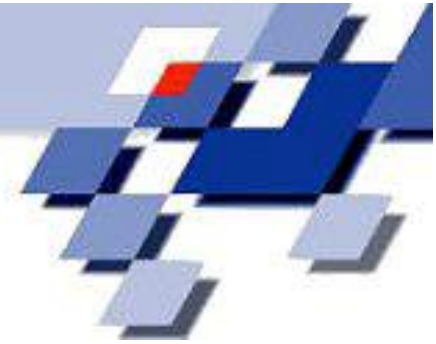
**Radiation by PLC is by factor 1.000.000 lower than the limits.
⇒ Biological effects are improbable.**



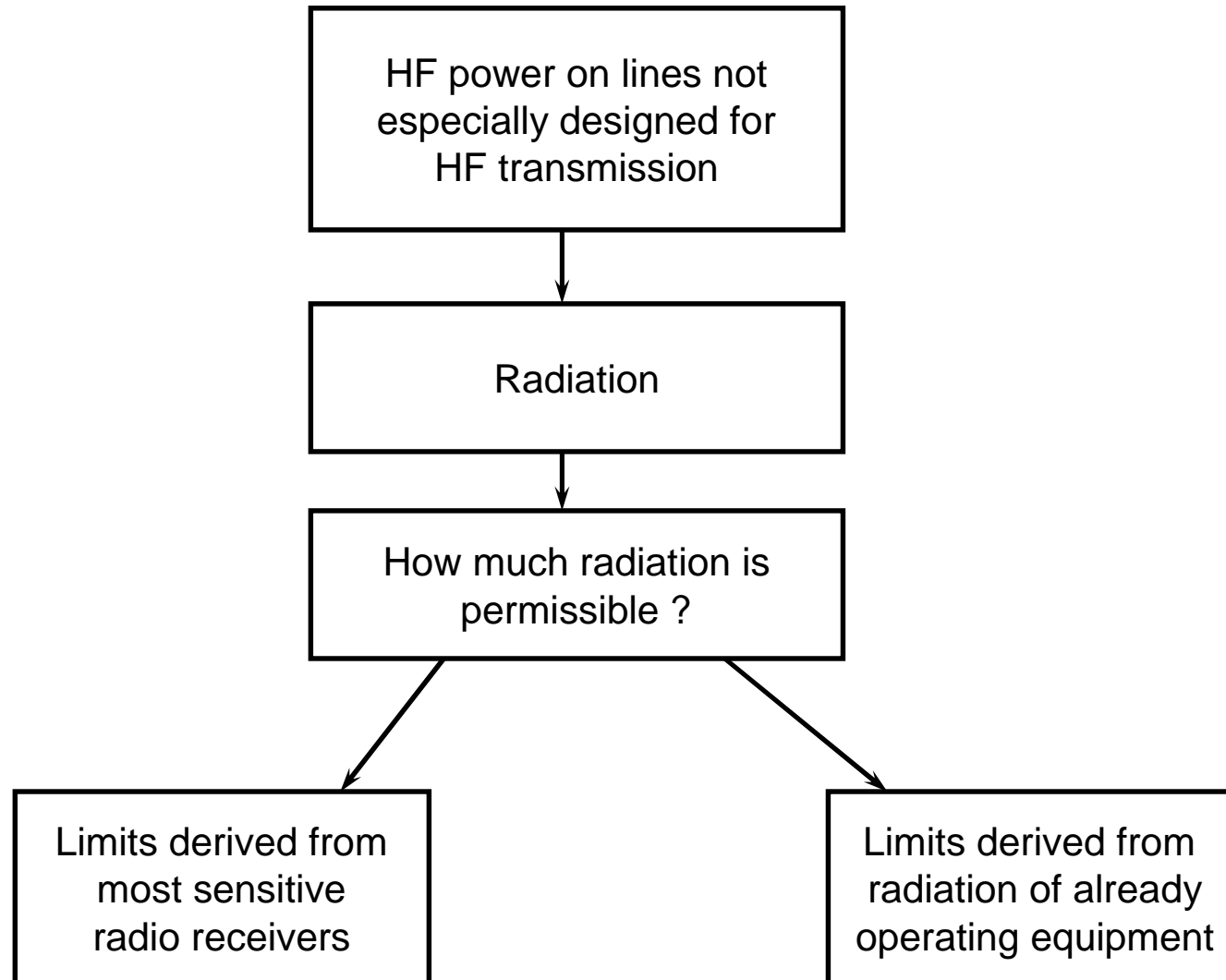


Unwanted Emission of PLC



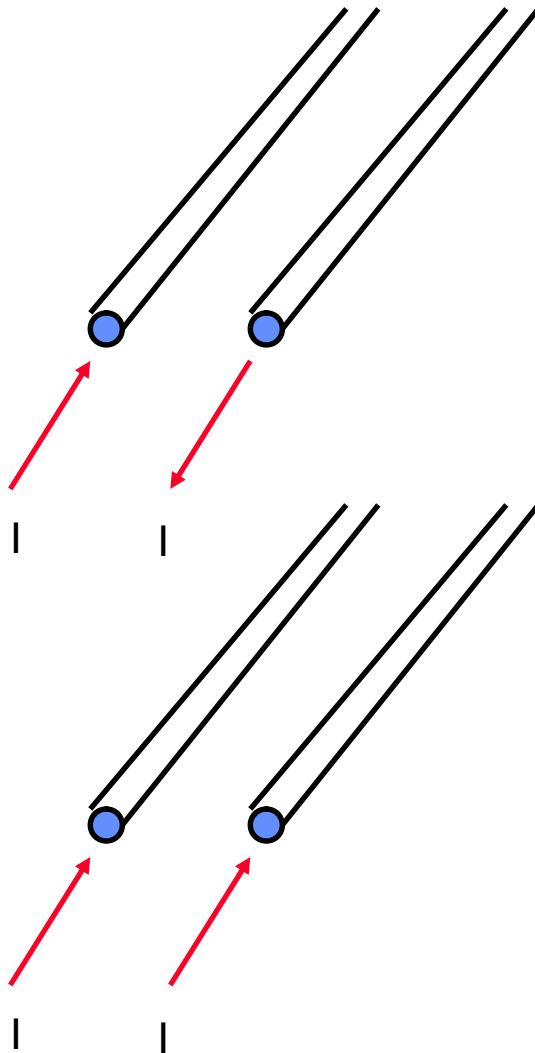


Treatment of Radiation





Mechanism of Radiation



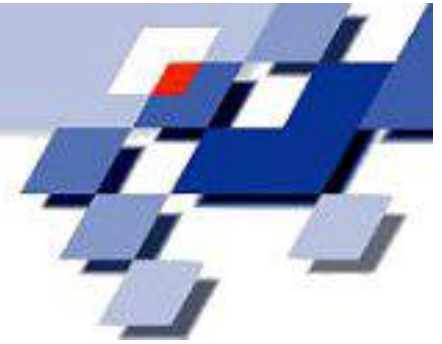
symmetrical mode

compensation of field produced by the two wires

asymmetrical mode

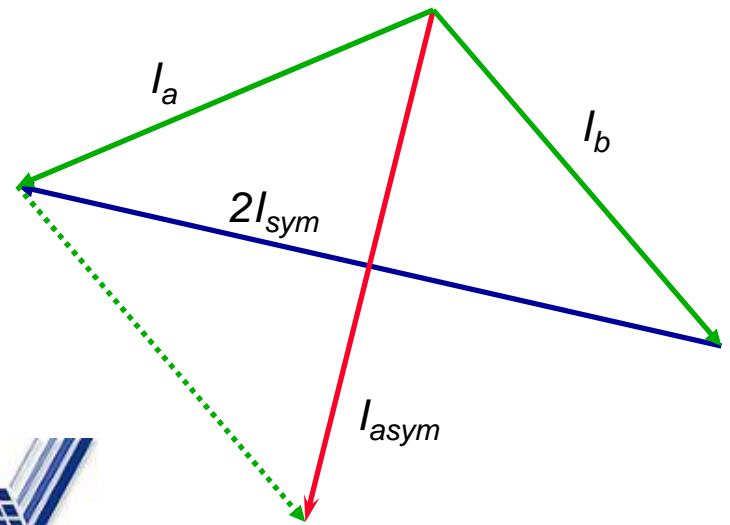
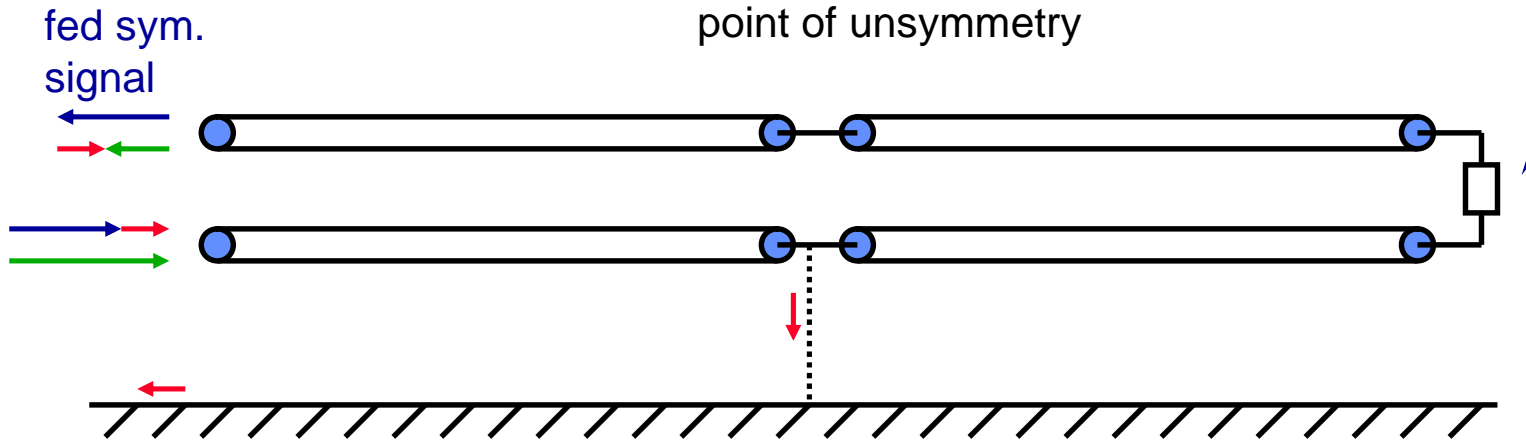
no compensation of field produced by the two wires





Importance of Symmetry

Universität Dortmund, Arbeitsgebiet Theorie der EMV, Emil-Figge-Str. 68, D-44227 Dortmund, Tel (0231) 755-5980



$$I_{sym} = \frac{I_a - I_b}{2}$$

$$U_{sym} = U_a - U_b$$

$$I_{asym} = I_a + I_b$$

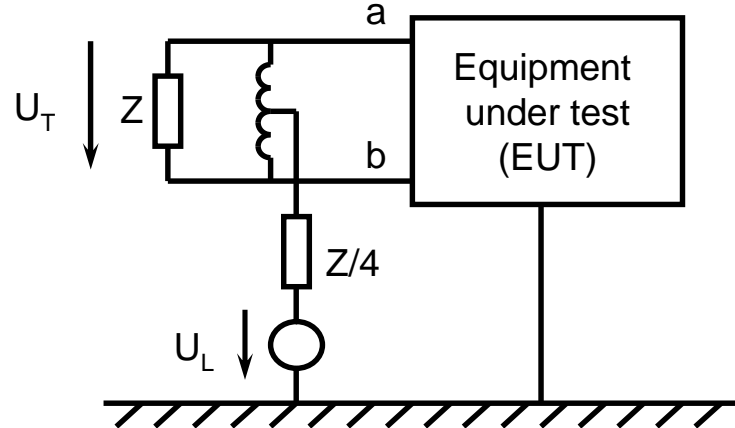
$$U_{asym} = \frac{U_a + U_b}{2}$$





Measurement of Unsymmetry Longitudinal Conversion Loss (LCL)

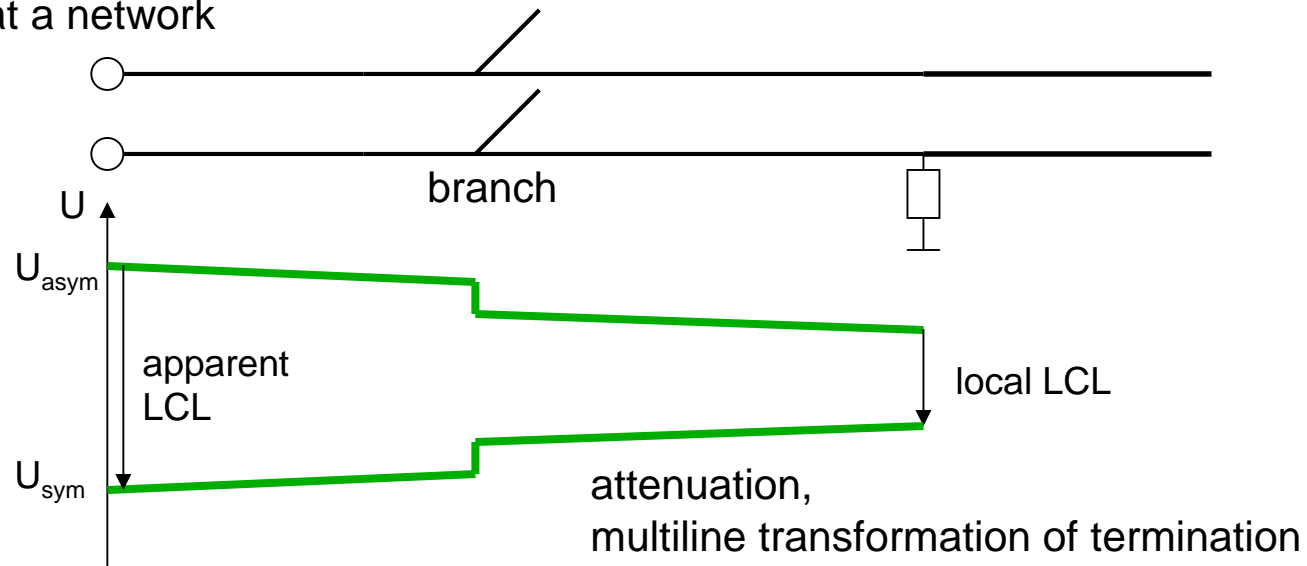
Measurement at a point of unsymmetry



ITU-G117:

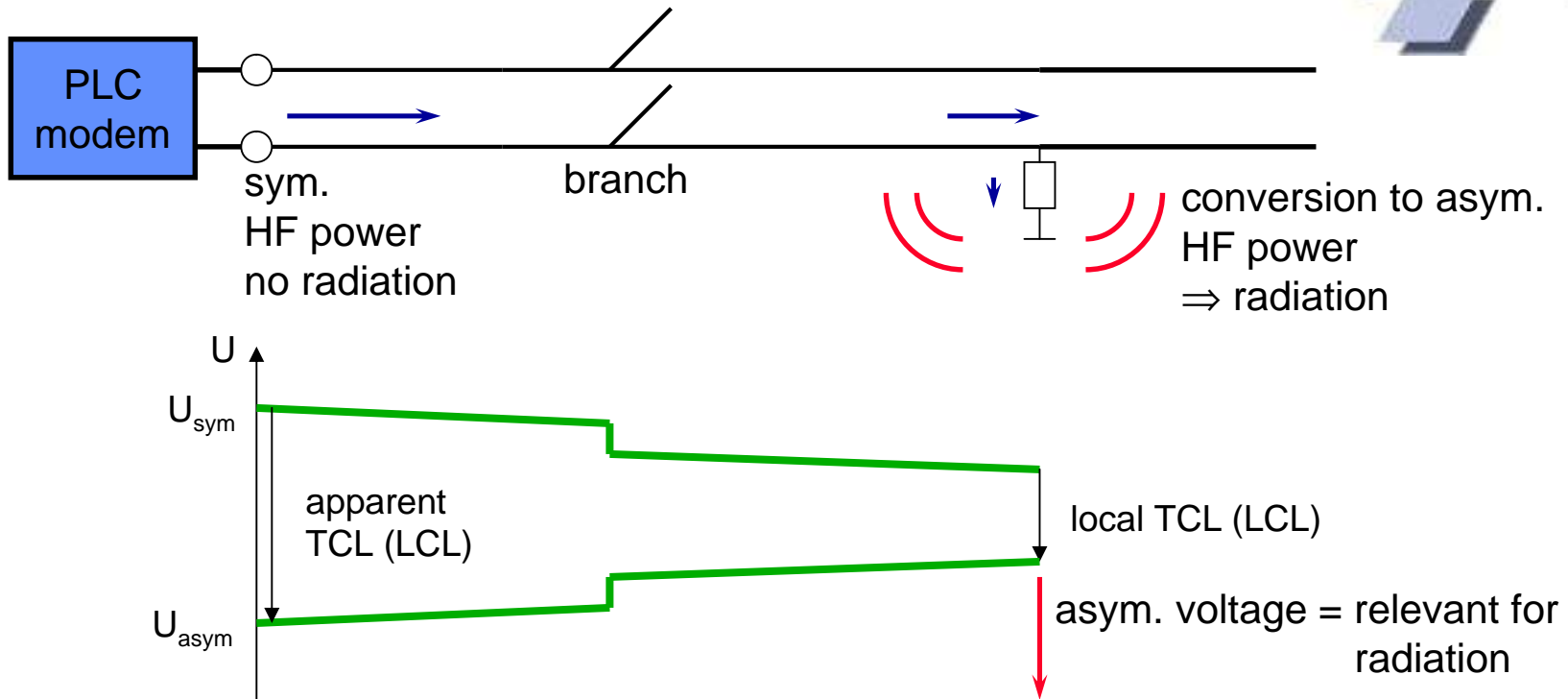
$$LCL = 20 \cdot \log \left(\frac{U_L}{U_T} \right)$$

Measurement at a network





Relevance for Radiation

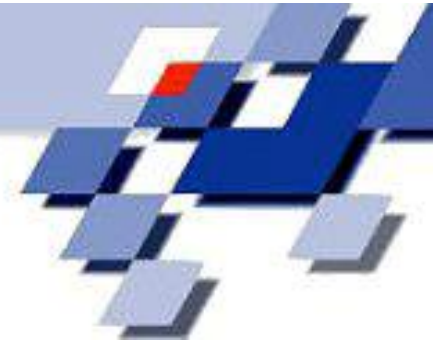


using apparent LCL only: underestimation of disturbance potential

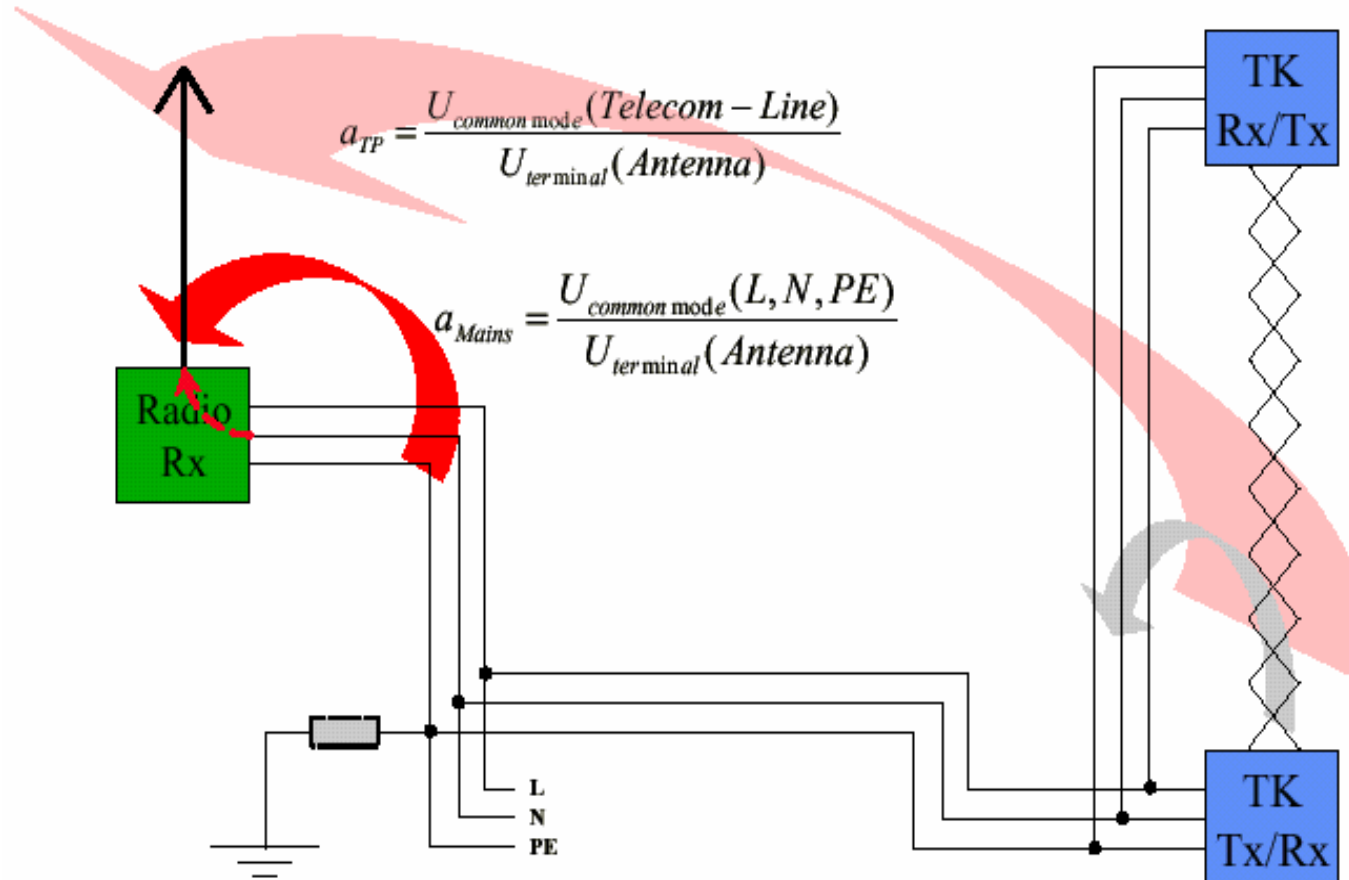
using local LCL only: overestimation of disturbance potential

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



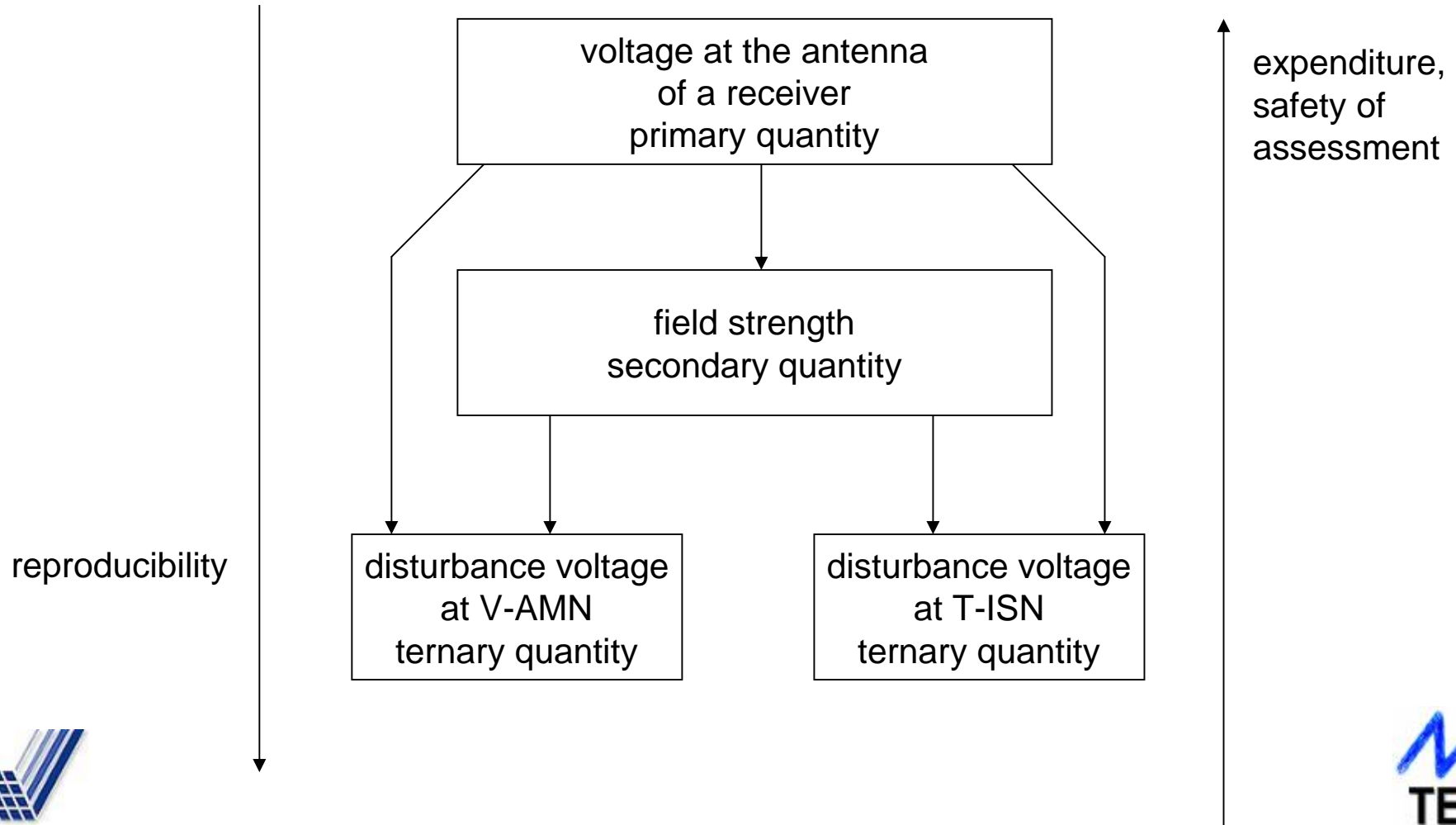


Disturbance modell





Protection of Radio Services - Measurement Quantities





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



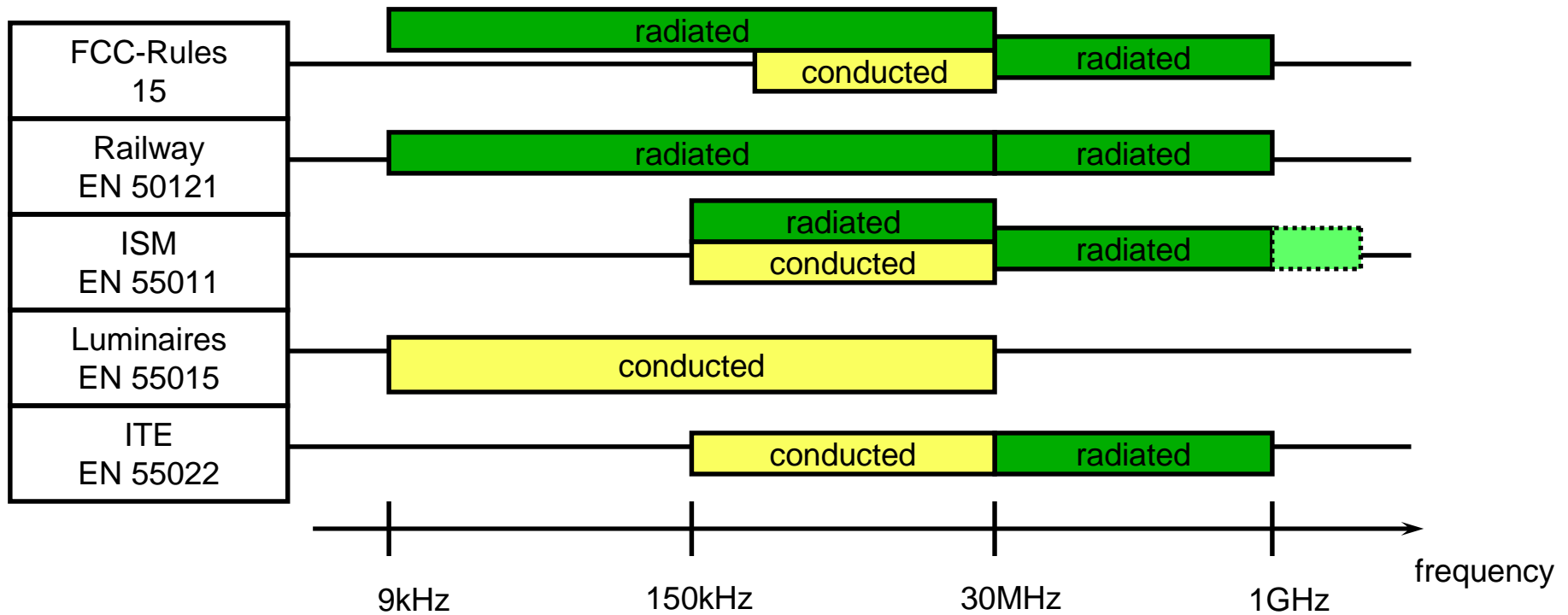


Product Conformity





Procedure of some Product Standards



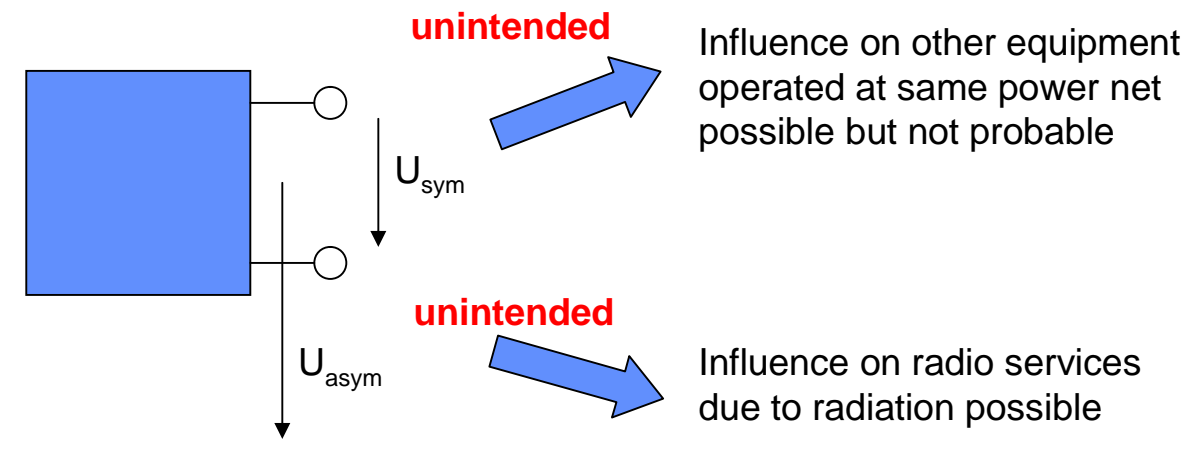
Products are mostly assessed by measurement of conducted disturbances. Radiation measurement only in special cases.



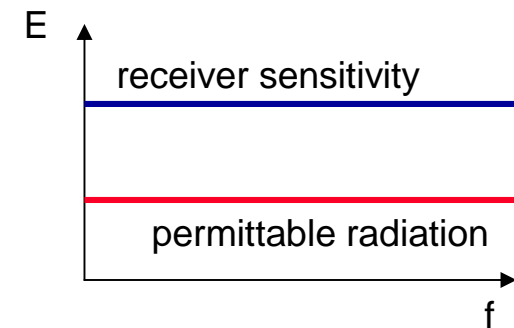
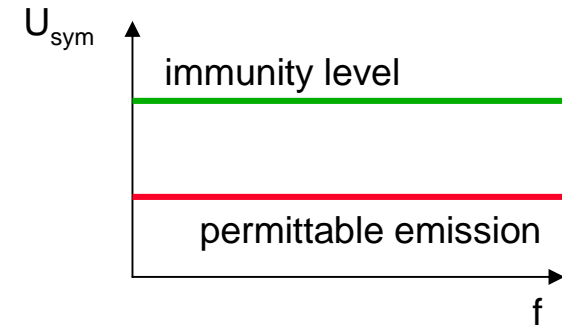


Asymmetric signals have the main influence on radio services

Non-PLC Equipment:



=> CISPR-22 limits conducted disturbances in general





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**
asymmetric voltage / current: **unintended**

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

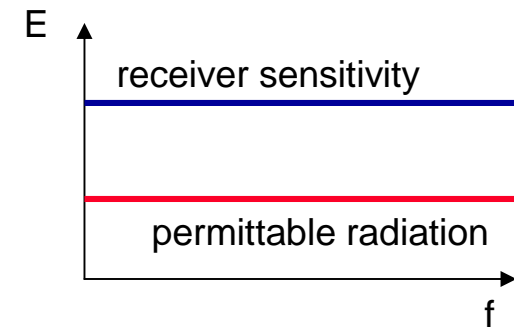
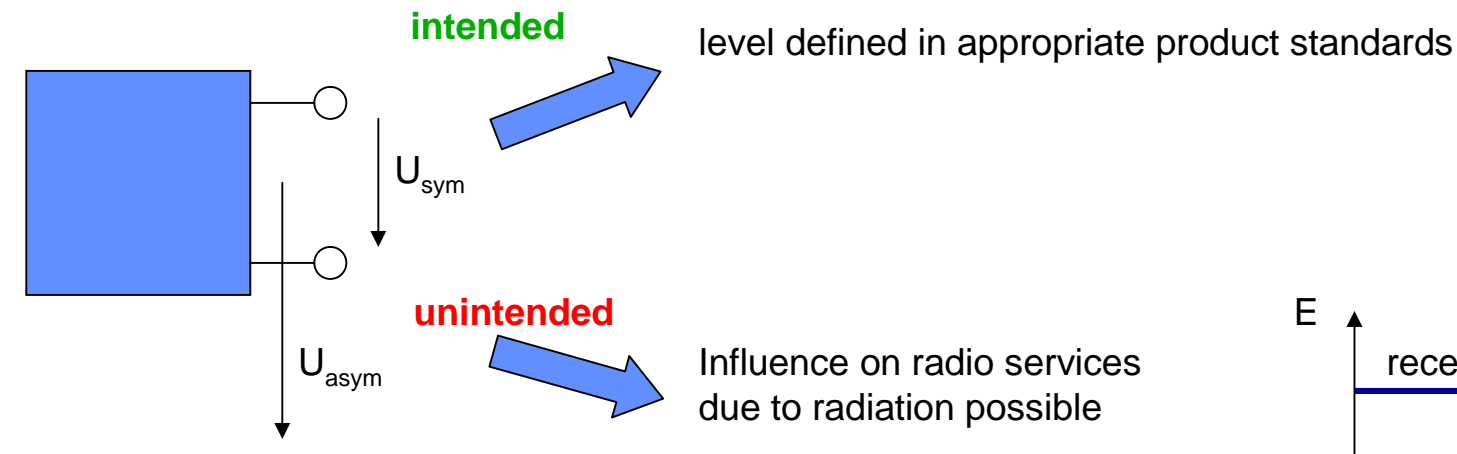
=> Use of V-AMN sufficient for non-PLC equipment.





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

telecommunication-equipment:



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

=> Use of T-ISN or Δ -ISN

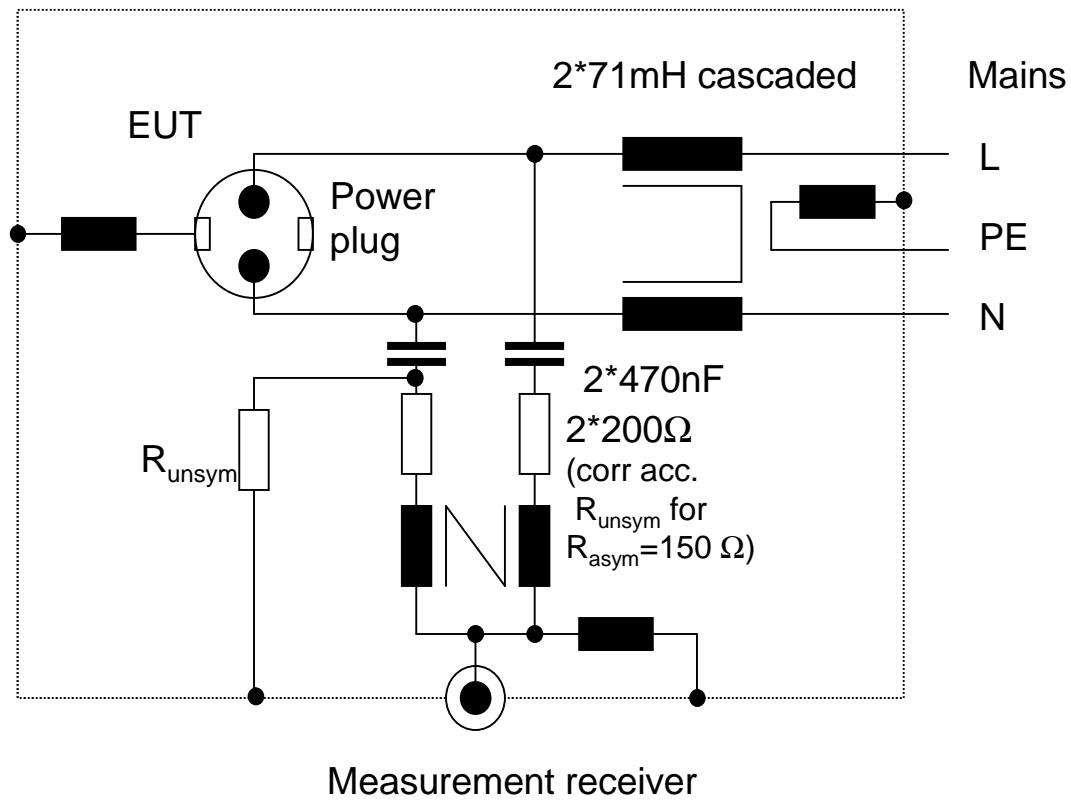
T-ISN already defined in CISPR 22 for TC-ports





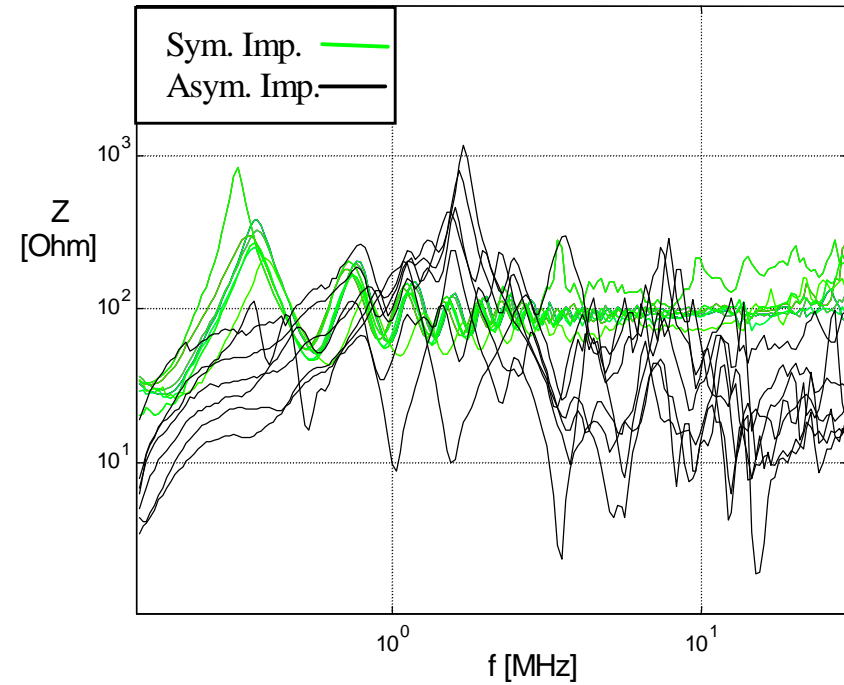
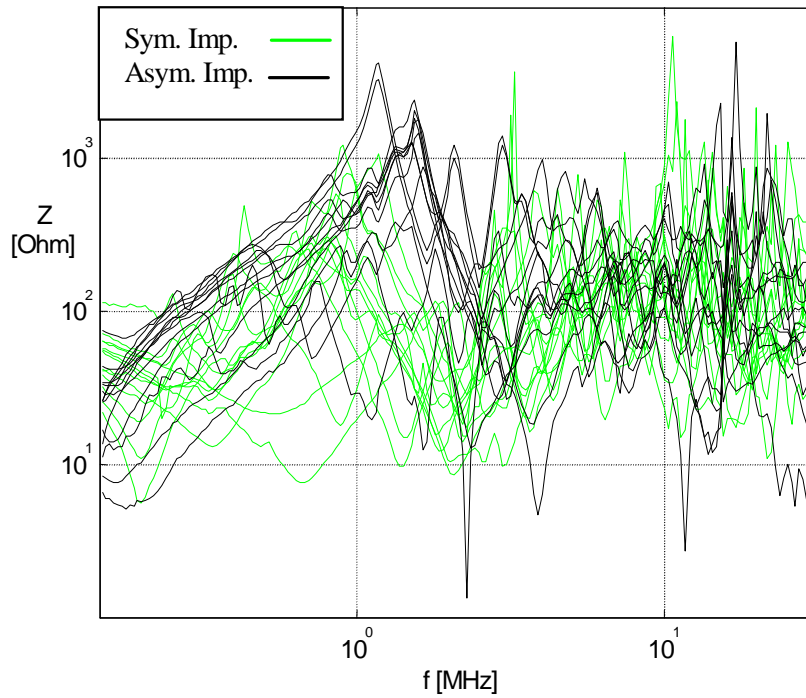
Usage of a T-ISN

150 Ohm T-ISN with LCL=30dB





Impedances of power and TC nets





Rationale for proposed LCL-value

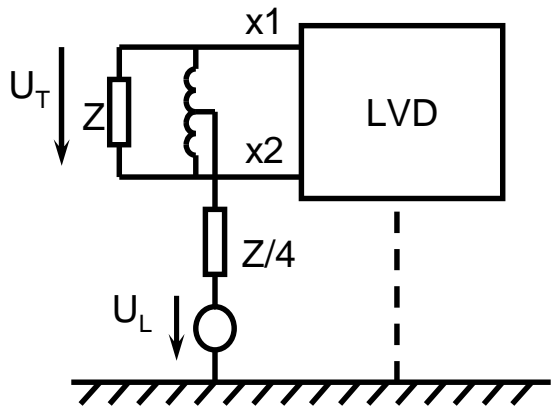




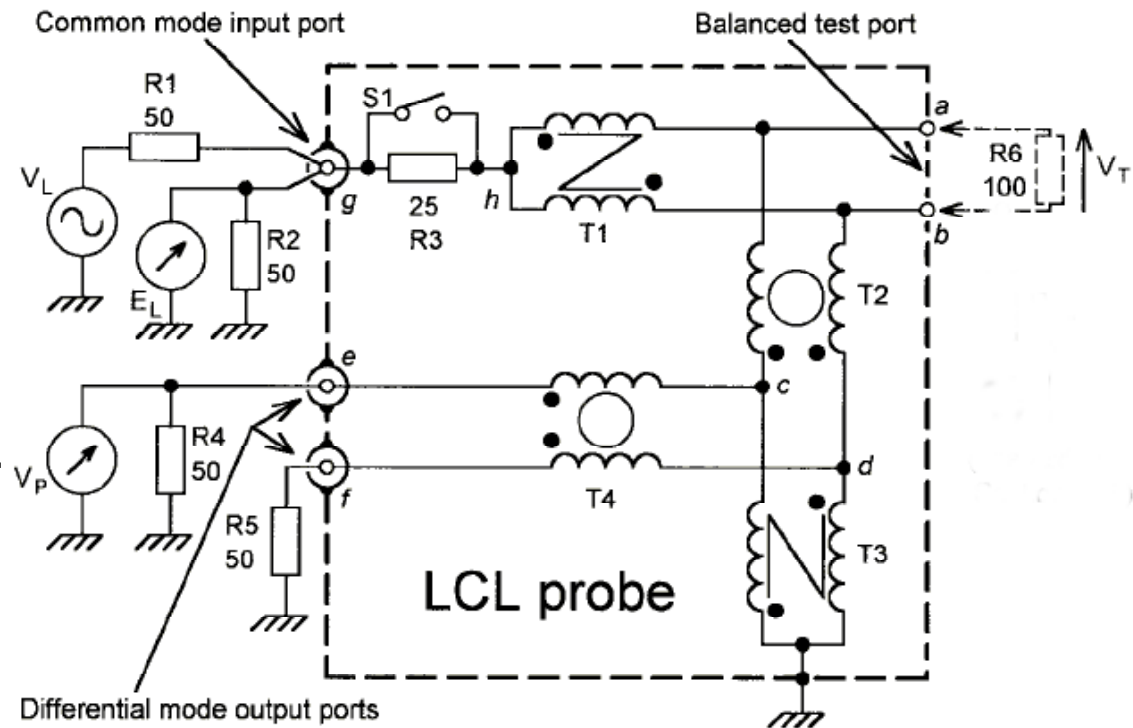
Measurement method for LCL of LVD

Design parameter:

Z = 100 W



Measurement adapter according to Macfarlane

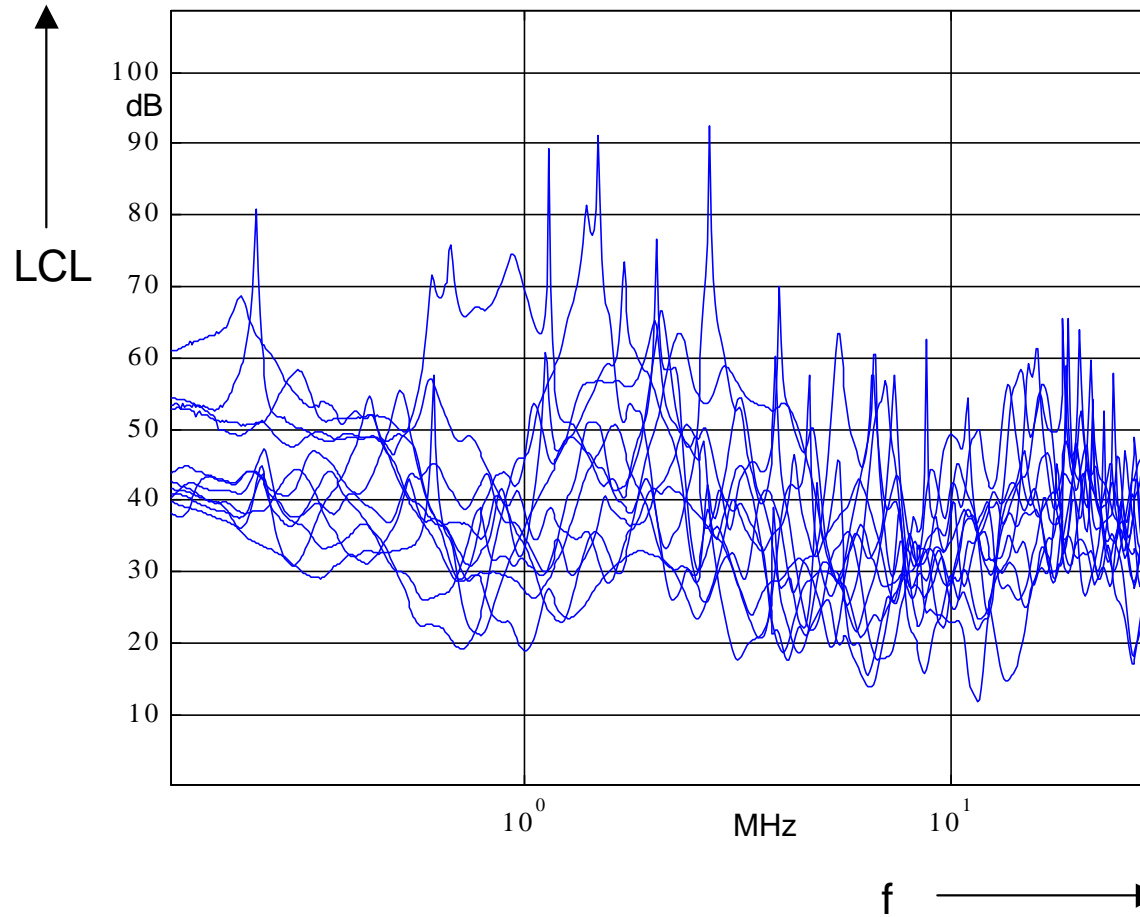




LCL measurement results (1)

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

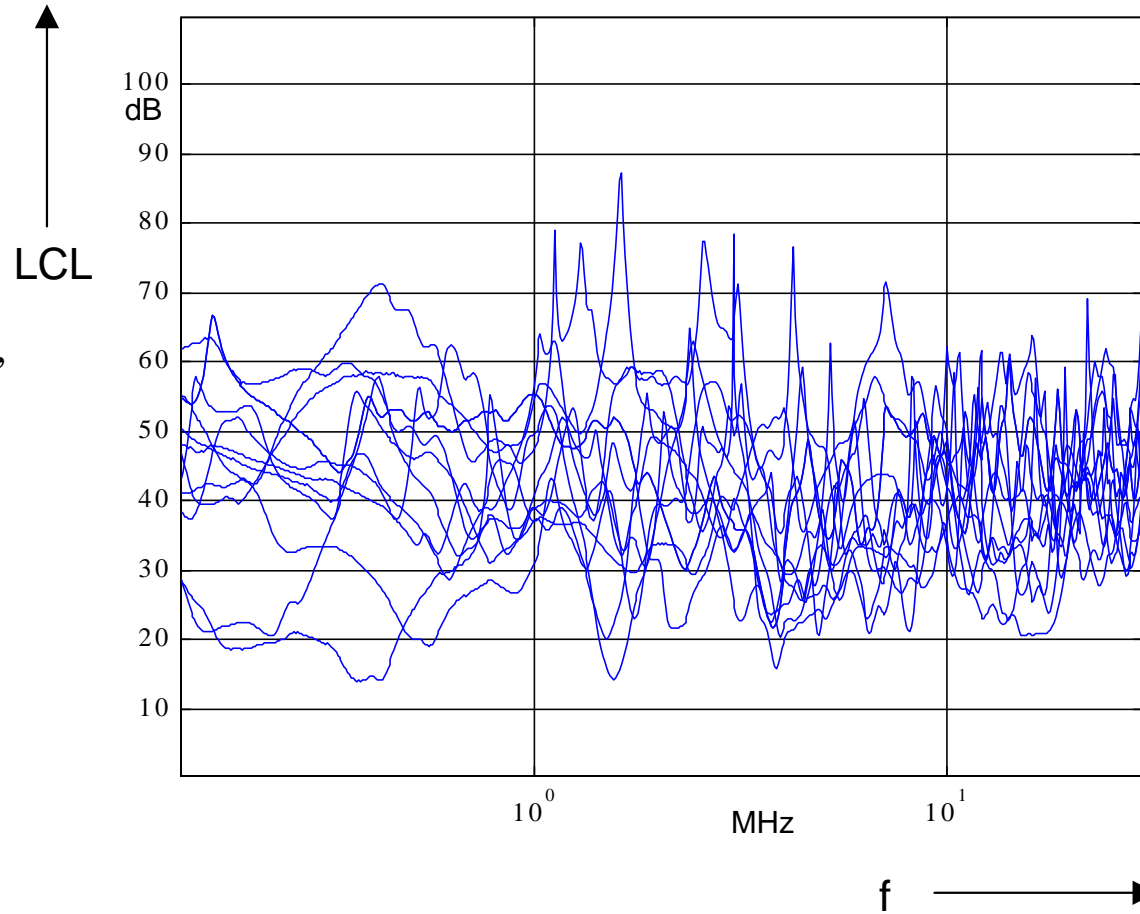
industrial environment





LCL measurement results (2)

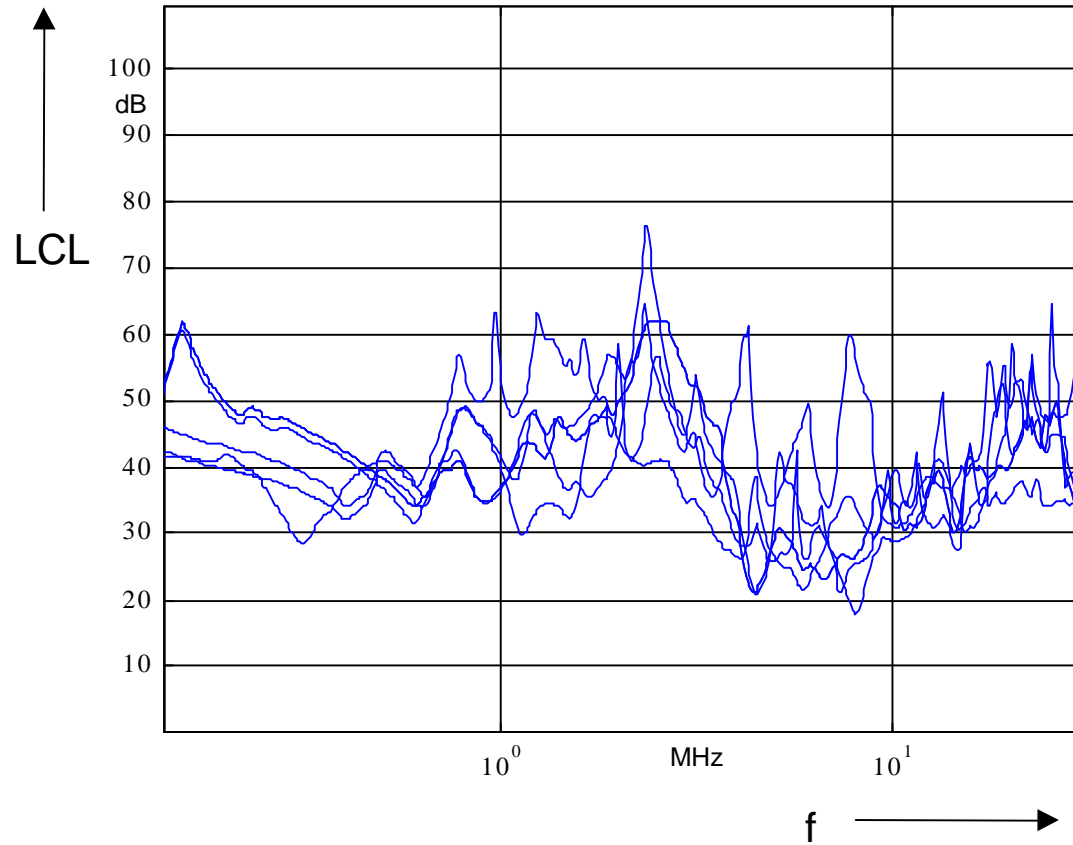
Students hostel in Dortmund,
Several identical buildings,
new installations, power feeding by common transformer compact station





LCL measurement results (3)

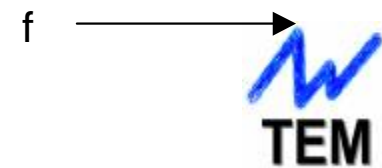
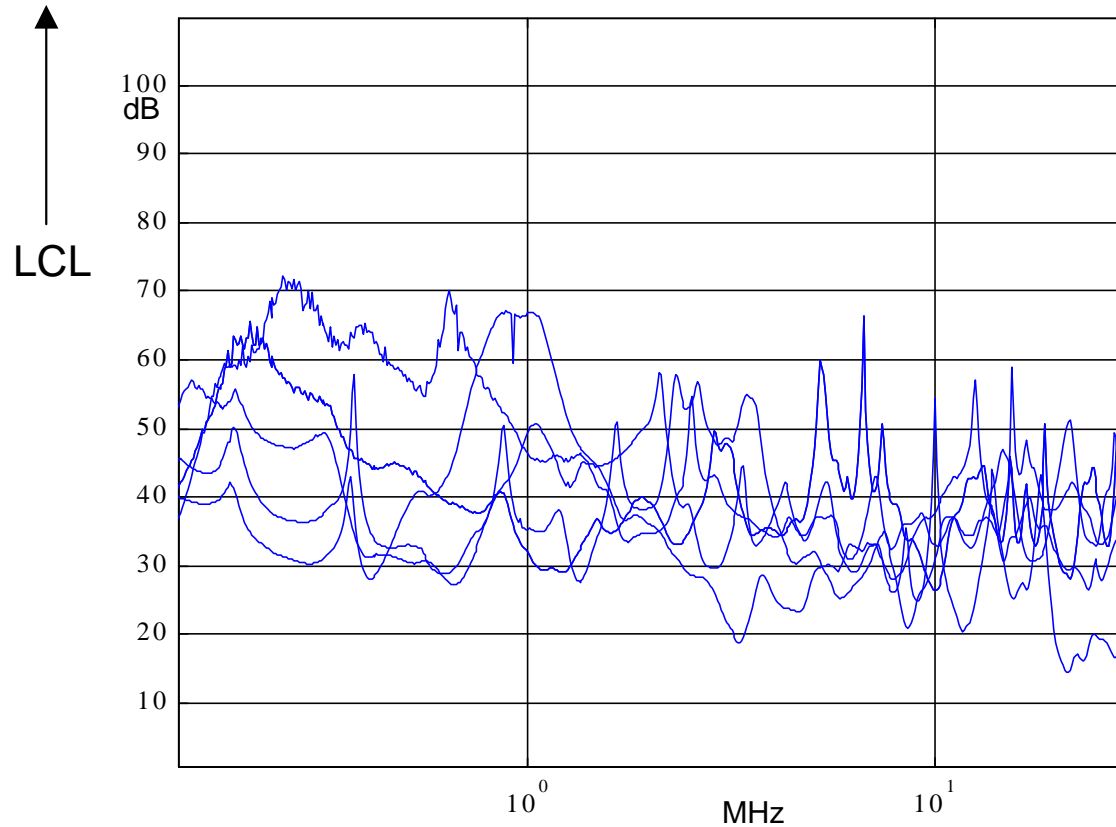
Apartment in a multiple dwelling in Dortmund downtown, old installations, urban environment





LCL-Messergebnisse (4)

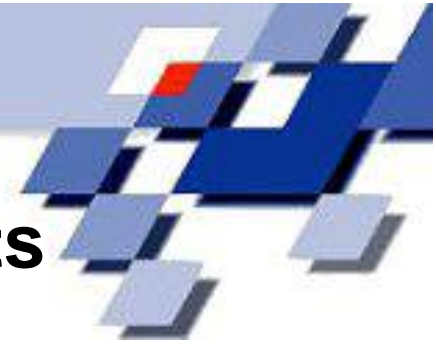
Semi-detached house in a more rural environment in a small town near Dortmund, 500m distance to transformer compact station in the next street.



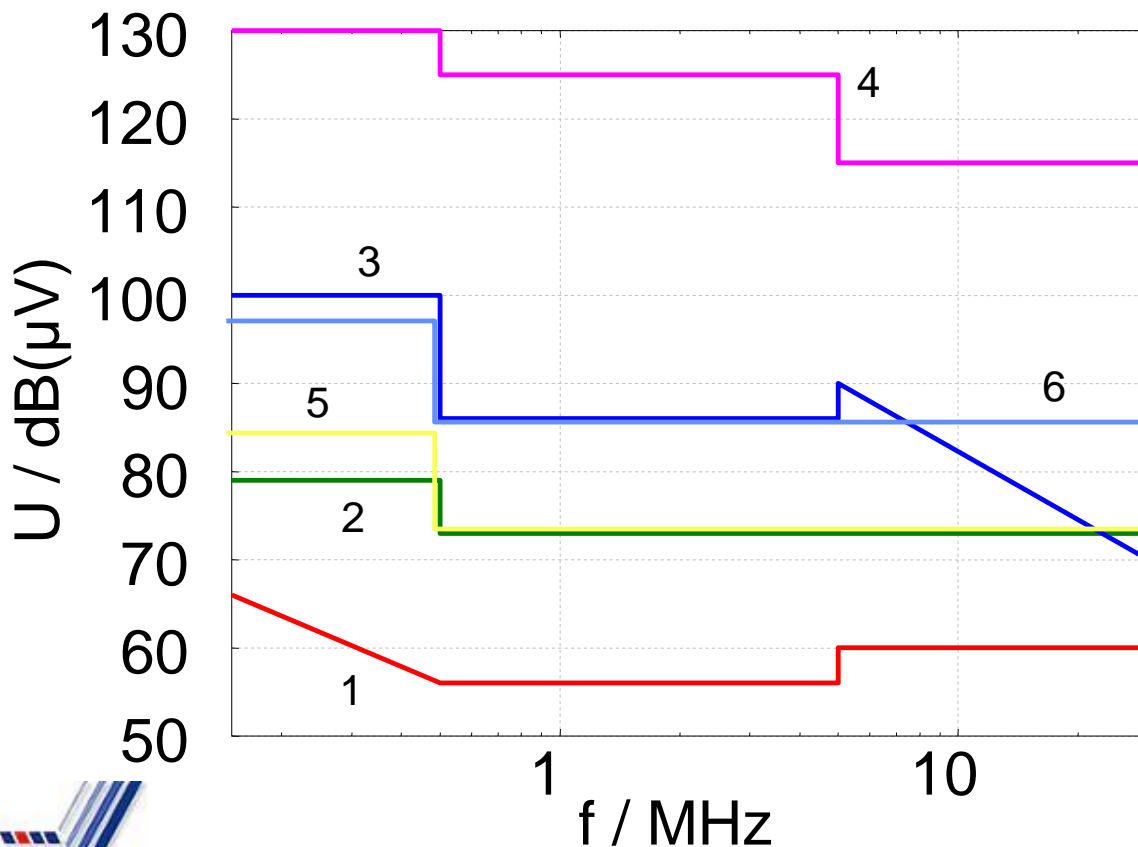


Limits for disturbance voltages





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





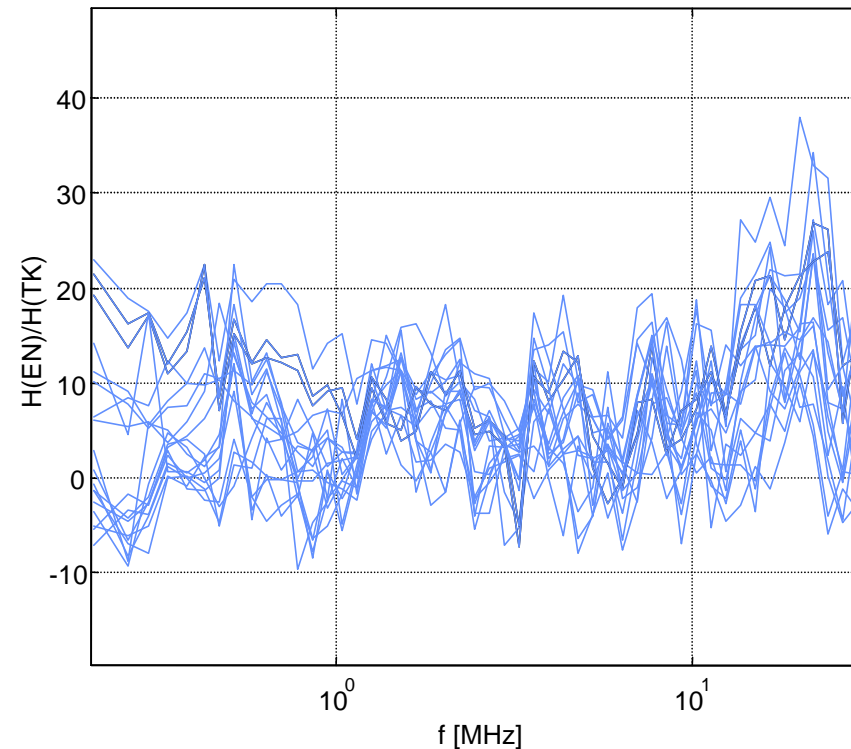
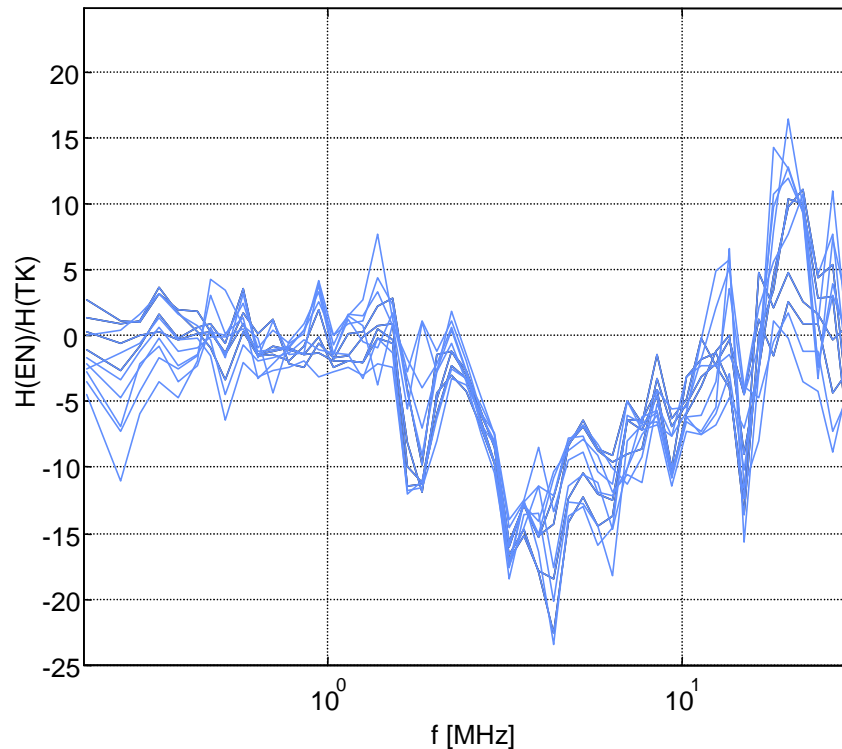
Rationale for using same limits for TC-line-devices and PLC-devices





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

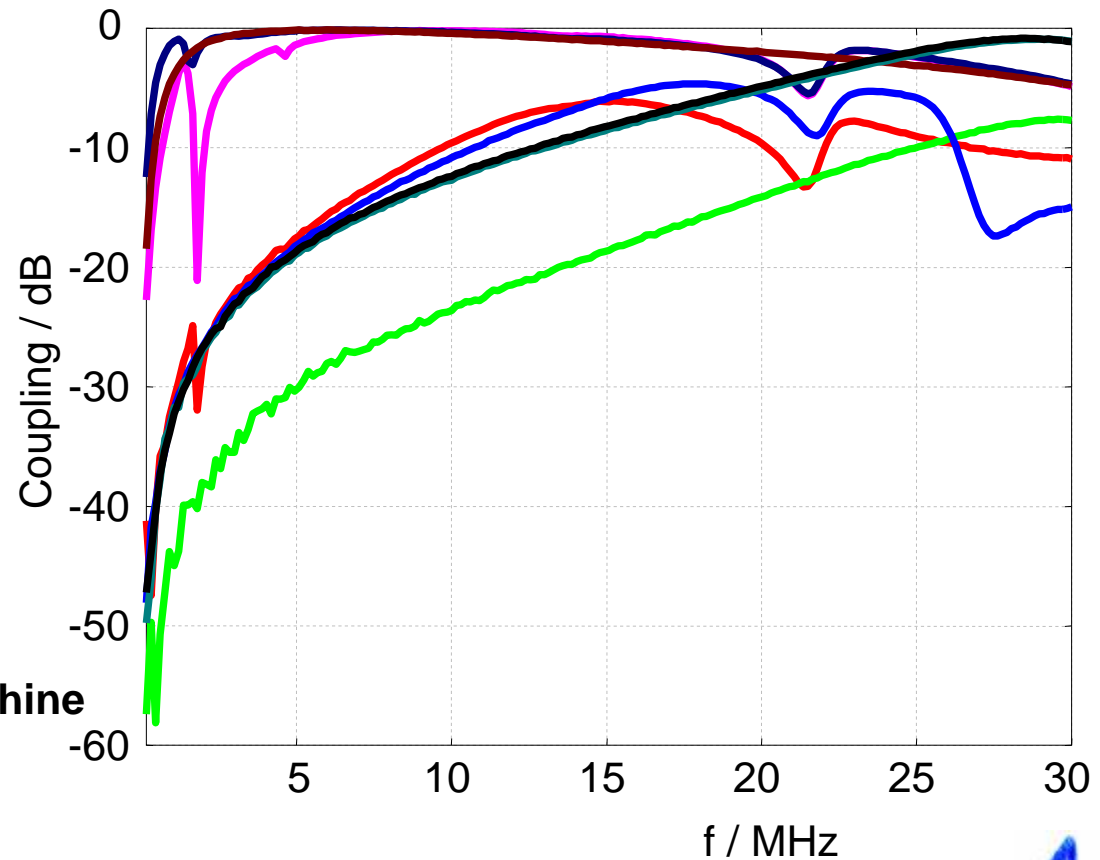
Measurement inside the building





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

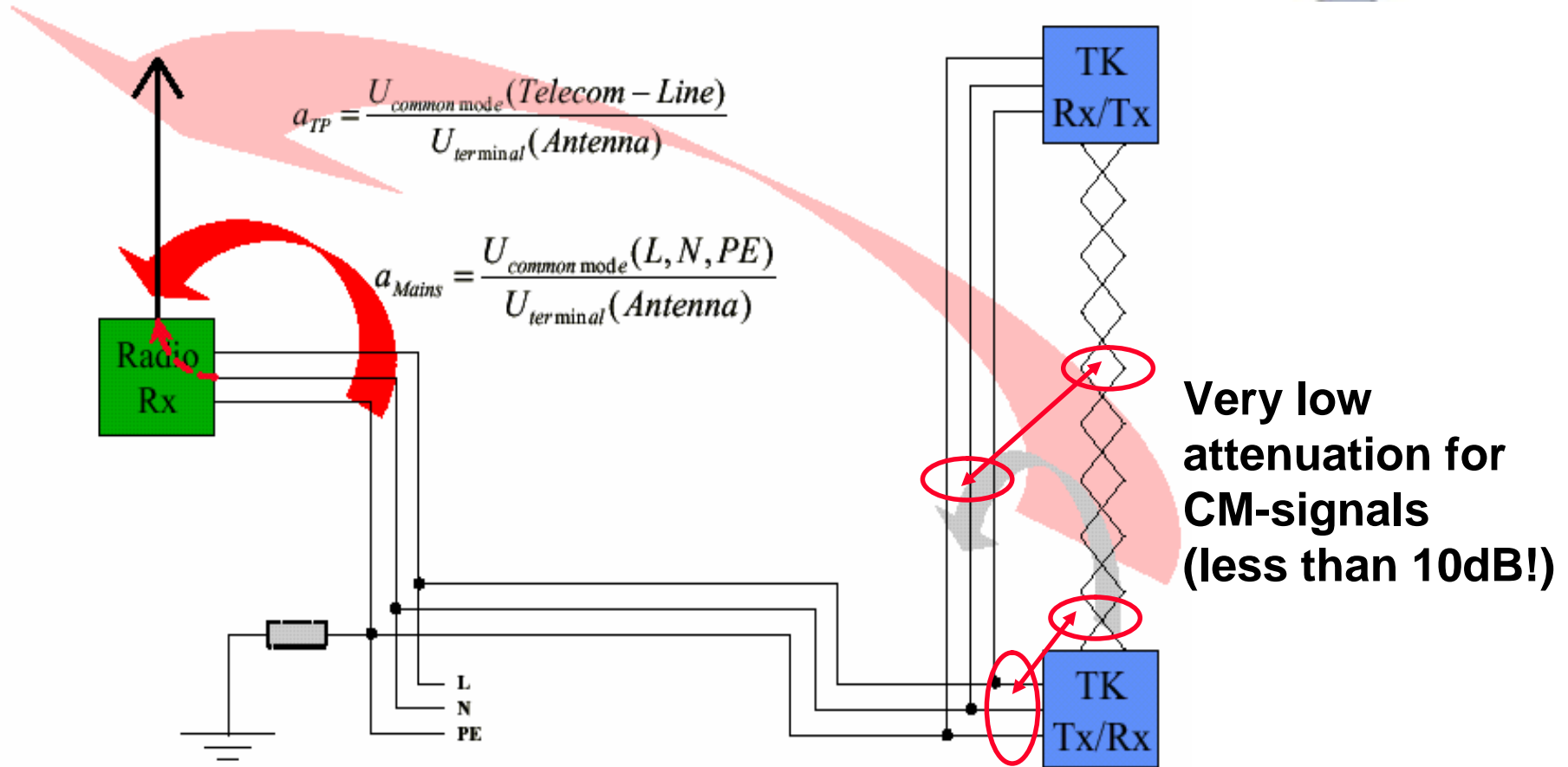


Higher frequencies: only a few db attenuation between TC and shield of data cable



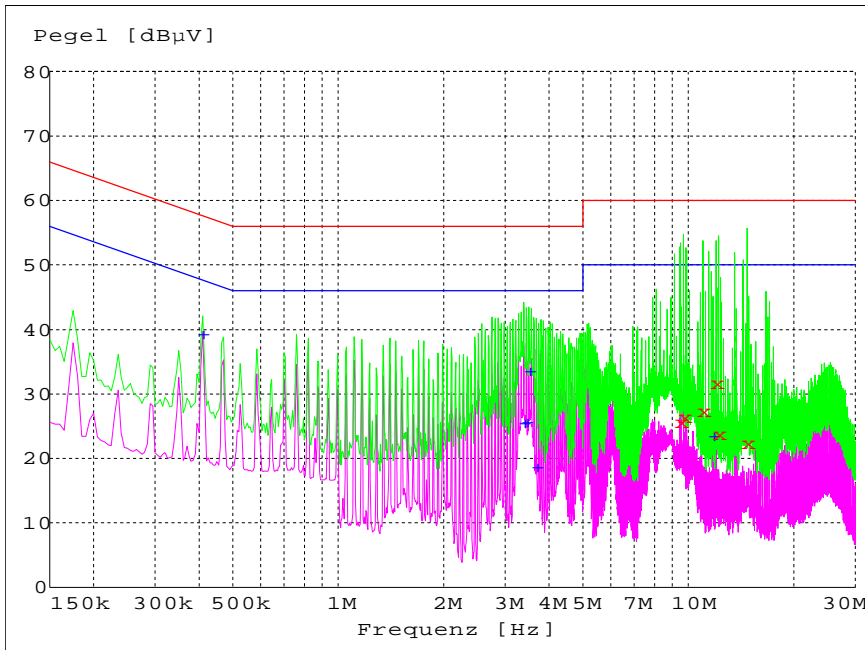


Modification of the model





Difference of evaluation with T-ISN and V-AMN



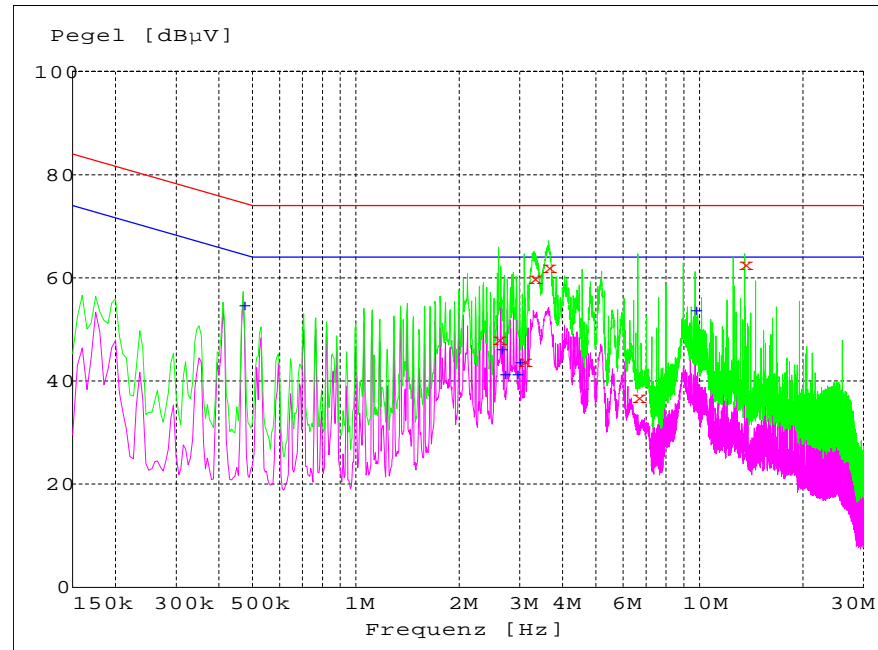
Switching power supply of a notebook

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

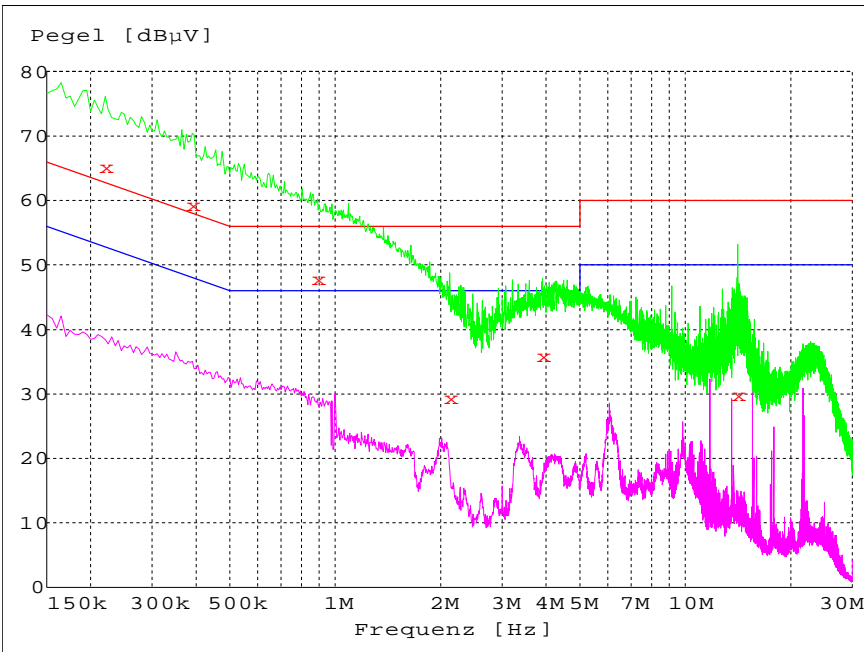
distance to limit line:

AV, 0.47 MHz: 9.8 dB
AV, 3.5 MHz: 12.7 dB





Difference of evaluation with T-ISN and V-AMN

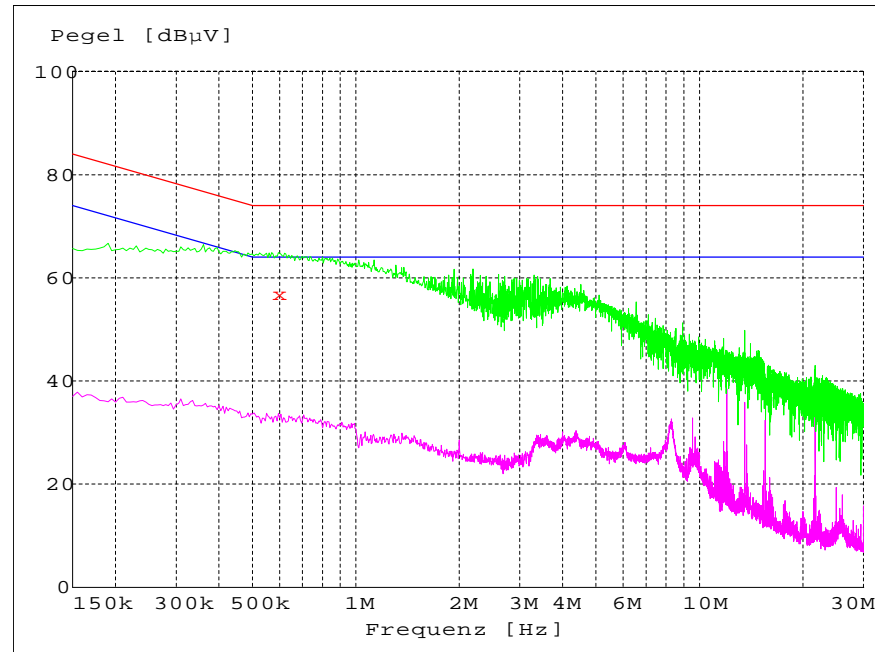


Small drill machine

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





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.





Installation Assessment

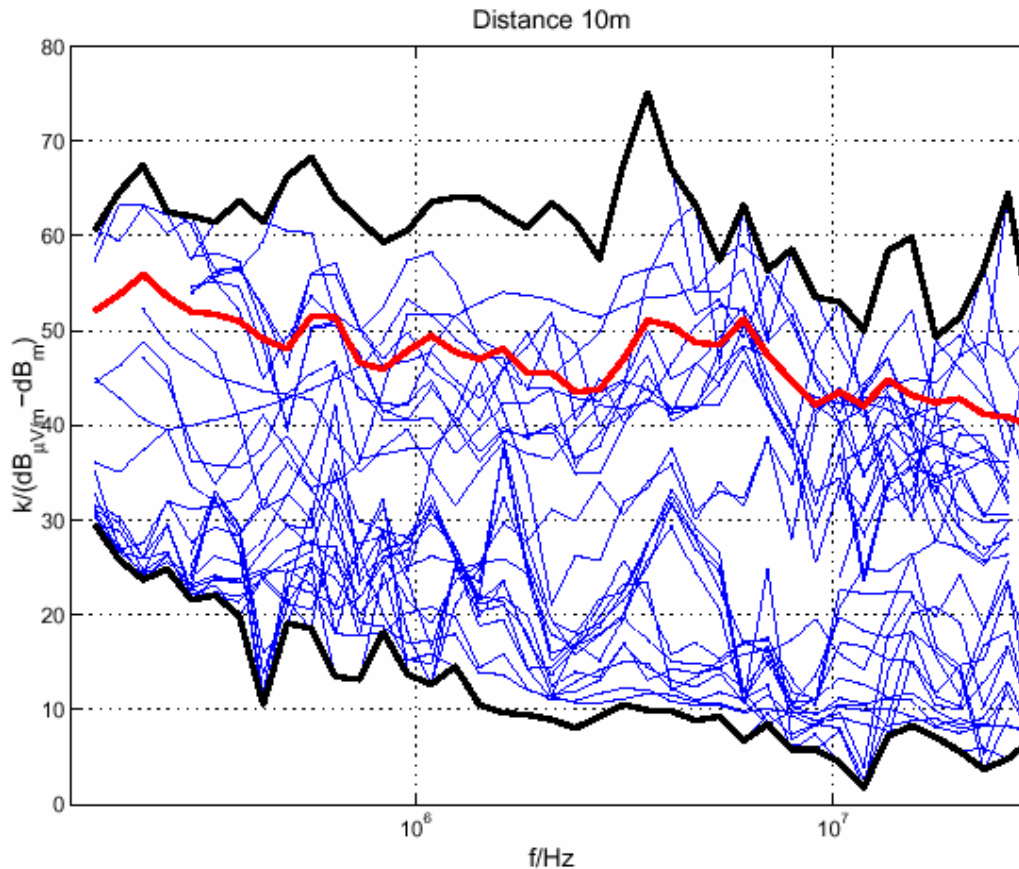




Examination of the coupling factor

Measurement methodology:

- 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





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





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.

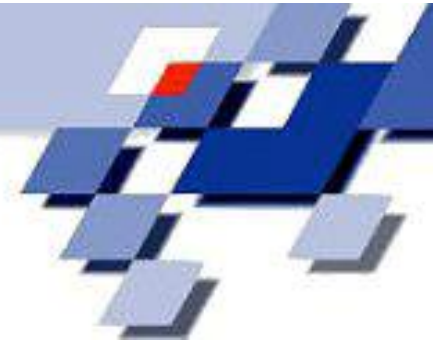
Limit line 2 is partly (30-1000MHz) increased by 10dB (10m → 3m)

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

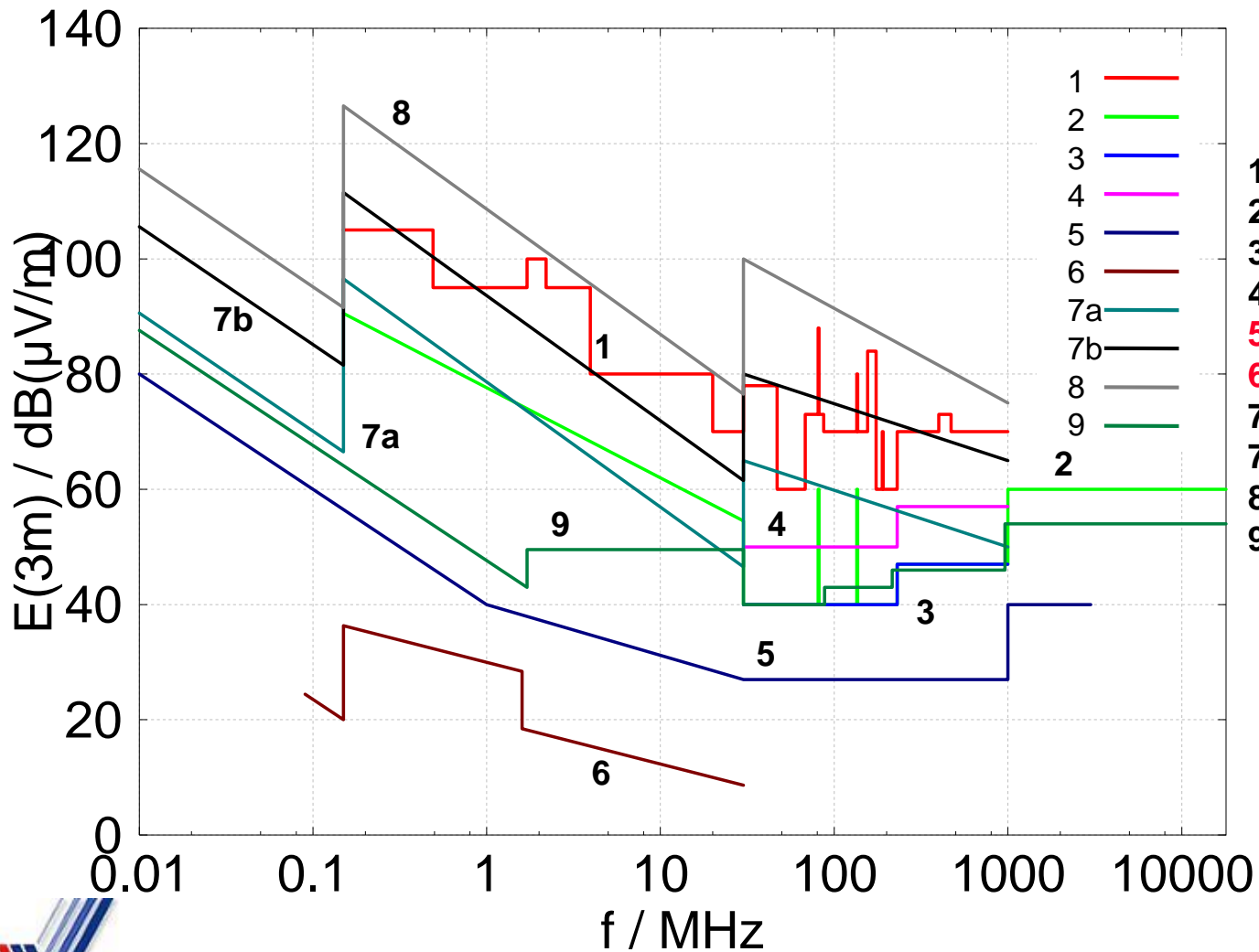
Limit line 9 (measurement in 30m distance) is recalculated by the correction factor 20dB.

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





Limits for Radiated Disturbances



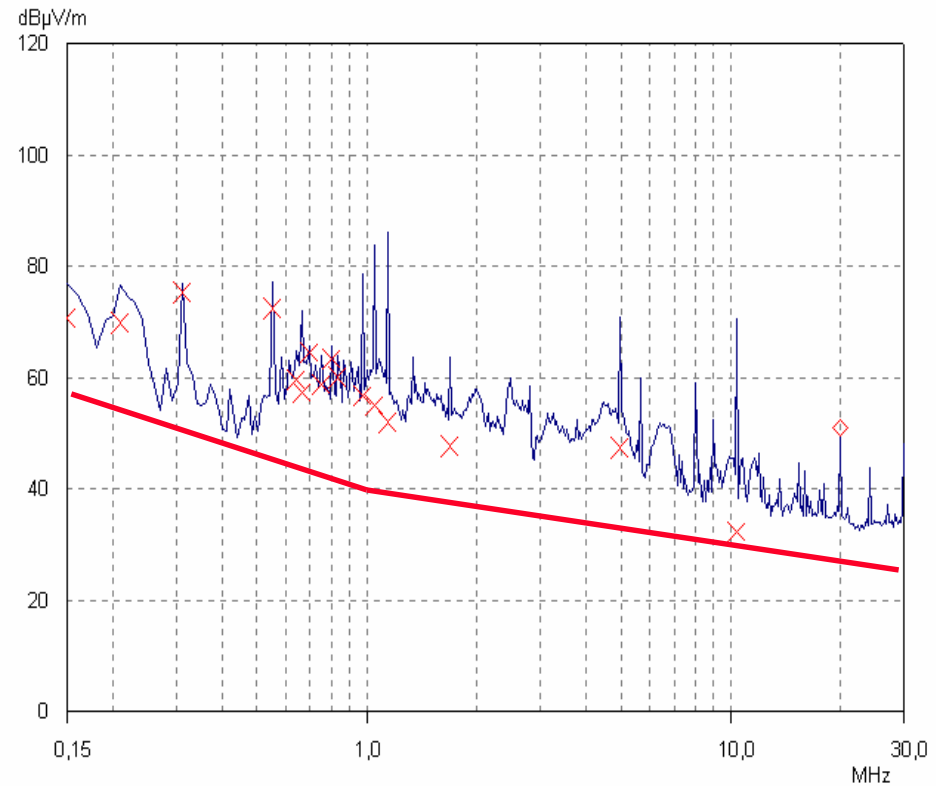
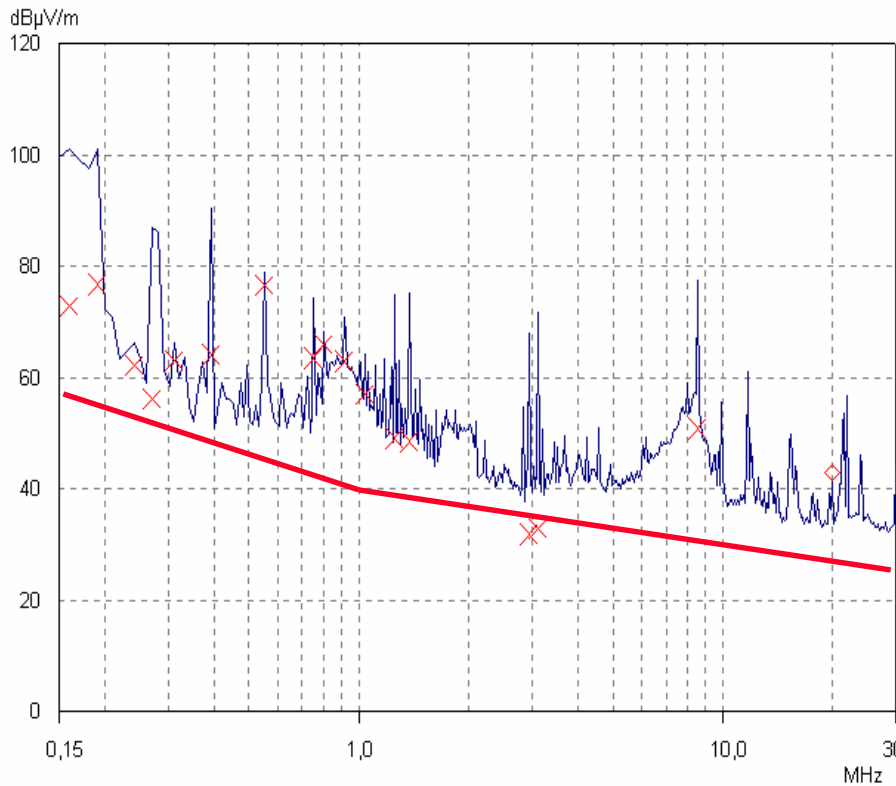
- 1: EN55011, Gr.2, Kl. A
- 2: EN55011, Gr.2, Kl. B
- 3: EN55022, Kl. B
- 4: EN55022, Kl. A
- 5: Reg TP
- 6: UK
- 7a: prEN50121, train 600V
- 7b: prEN50121, train 25kV
- 8: prEN50121, substation
- 9: FCC Rules part 15 „Carrier current systems“





Typical Disturbances from Computer- Networks

Universität Dortmund, Arbeitsgebiet Theorie der EMV, Emil-Figge-Str. 68, D-44227 Dortmund, Tel (0231) 755-5980



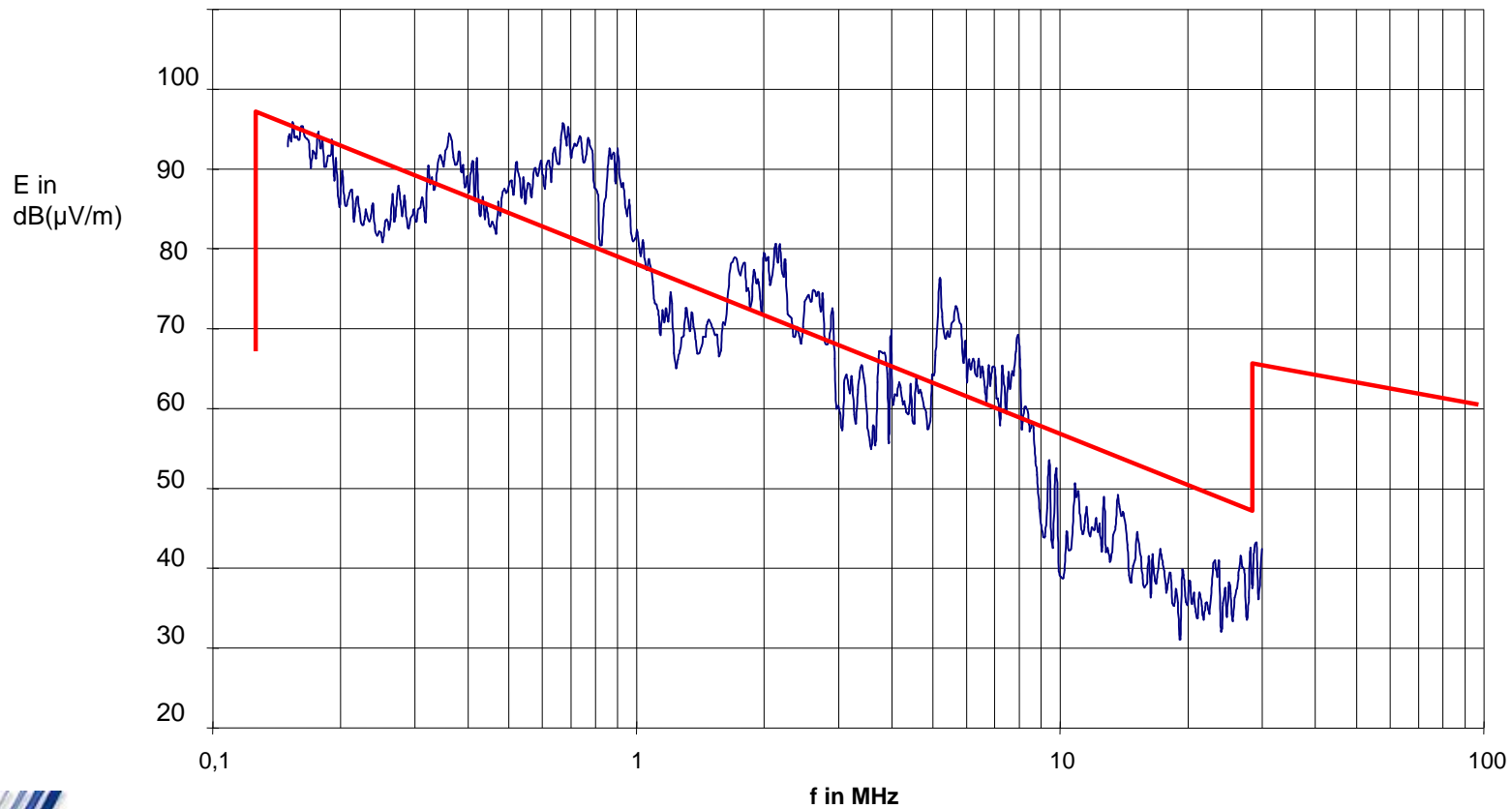
Emission measured with MV05-method inside a building of the University of Dortmund. About 200 PCs and workstations are in operation in this building. Network: Ethernet with Cat 5-Cabling.

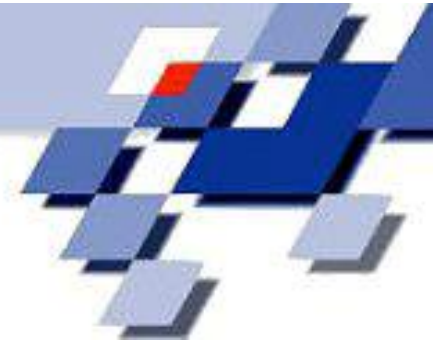




Typical Emissions from Tram Systems

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





EMC of PLC

Here: only emission

