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Technical Report

Power Line Telecommunications (PLT)
Channel characterization and measurement methods

Reference

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Contents

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Foreword

This Technical Report (TR) has been produced by ETSI Powerline Telecommunications (PLT).

Introduction

The objective of the present document is to describe the PLT channel characterization and the corresponding measurement methods chosen by ETSI PLT STF 222 as specified in the ToR of this STF.

1 Scope

The present document applies to measurements of the symmetry behaviour and the attenuation in Low Voltage Distribution Networks (LVDN) within premises. It also covers measurements for magnetic near fields within and in close vicinity of premises resulting from feeding HF-signals into LVDN. The measurements are intended for the measurement campaign of the ETSI Specialist Task Force (STF) 222, which investigates HF characteristics of LVDN relevant for the operation of PLT-systems as well as the hidden node aspect.

2 References

For the purposes of this Technical Report (TR) the following references apply:

[1] ITU-T Recommendation G.117: "Transmission aspects of unbalance about earth".

[2] CISPR 16-1: "Specification for radio disturbance and immunity measuring apparatus and methods- Part 1: Radio disturbance and immunity measuring apparatus".

[3] P. Macfarlane: "A probe for the measurement of electrical unbalance of networks and devices". (IEEE Transactions on EMC, Vol. 41, No. 1, February 1999)".

3 Abbreviations and symbols

3.1 Abbreviations

For the purposes of the present document, the following abbreviations apply:

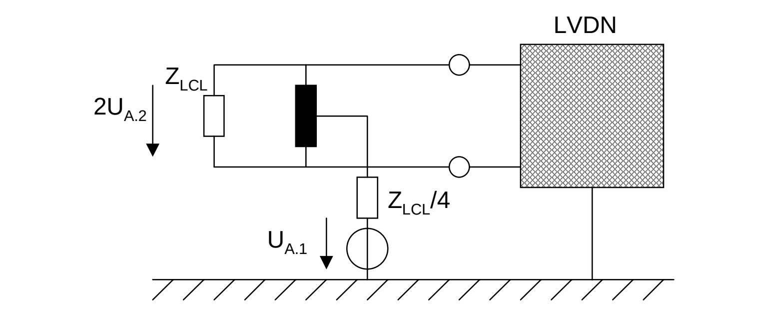
E_L	Electromagnetic force (EMF)of the asymmetric feeding voltage
EMF	ElectroMagnetic Force
HF	High Frequency
L	Line
LCL	Longitudinal Conversion Loss
LCTL	Longitudinal Conversion Transfer Loss
LTL	Longitudinal Transfer Loss
LVDN	Low voltage distribution network
N	Neutral
PE	Protection Earth
PLT	Power Line Telecommunications
S	Switch
STF	Special Task Force
TCTL	Transverse Conversion Transfer Loss
ToR	Terms of Reference
TTL	Transverse Transfer Loss

3.2 Symbols

k_{asy}	Coupling factor for asymmetric feed
k_{sym}	Coupling factor for symmetric feed
Z_{asy}	Asymmetric impedance
Z_{sym}	Symmetric impedance

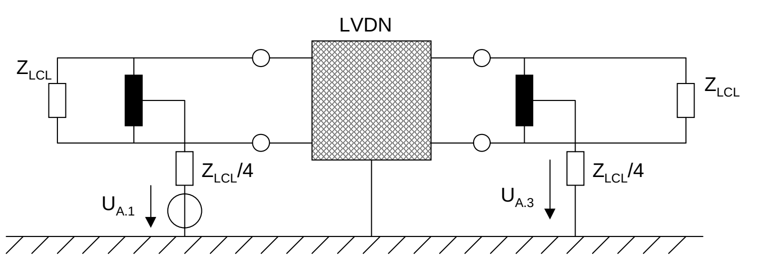
4 Terminology guide

The used terminology has been clarified by means of figures 1 to 9.



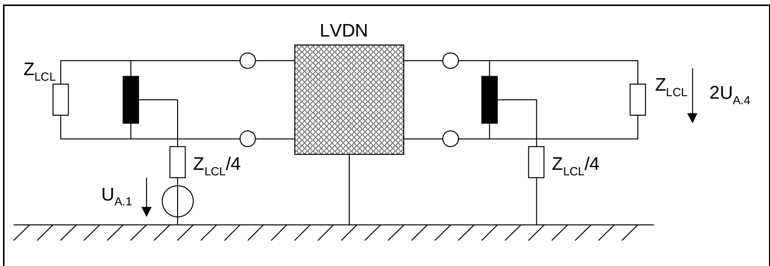
$$LCL = 20 \times \log\left(\frac{U_{A.1}}{2 \times U_{A.2}}\right)$$

Figure 1: Longitudinal Conversion Loss (LCL)



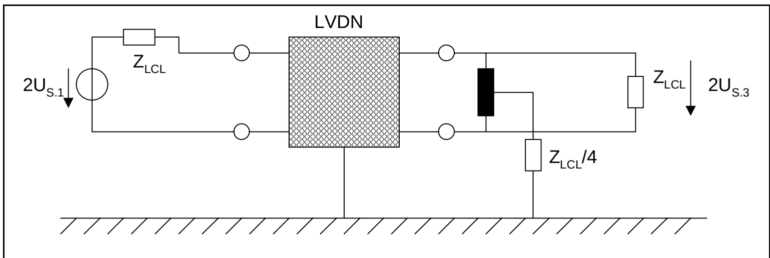
$$LTL = 20 \times \log\left(\frac{U_{A.1}}{U_{A.3}}\right)$$

Figure 2: Longitudinal Transfer Loss (LTL)



$$LCTL = 20 \times \log\left(\frac{U_{A.1}}{2U_{A.4}}\right)$$

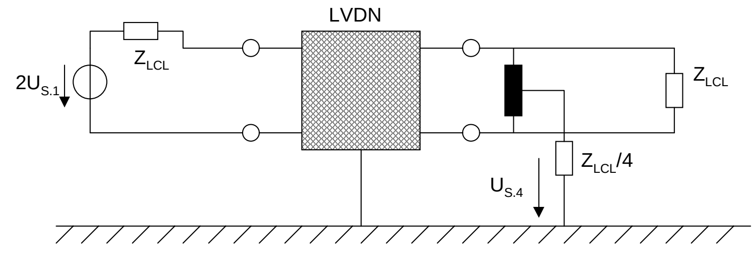
Figure 3: Longitudinal Conversion Transfer Loss (LCTL)



$$TTL = 20 \times \log\left(\frac{U_{S.1}}{U_{S.3}}\right)$$

NOTE: This definition differs from the definition in ITU-T Recommendation G.117 [1], which uses an asymmetric impedance in the feeding point and relates the output voltage to the voltage at the input of the LVDN-port directly.

Figure 4: Transverse Transfer Loss (TTL)

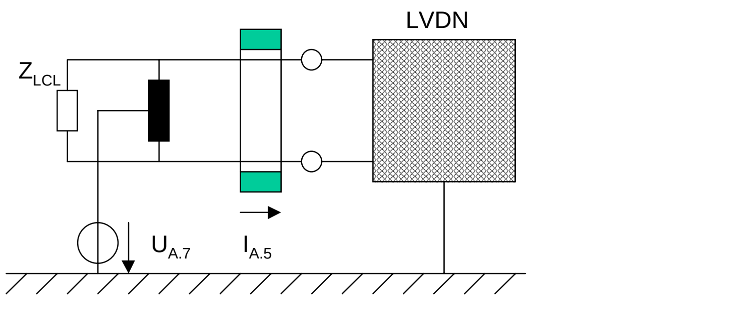


$$TCTL = 20 \times \log\left(\frac{2U_{S.1}}{U_{S.4}}\right)$$

NOTE 1: Factor 2 in the numerator due to the usage of a 1:4 impedance transformer.

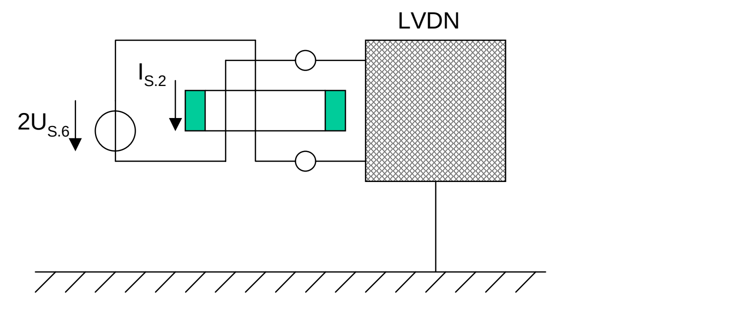
NOTE 2: This definition differs from the definition in ITU-T Recommendation G.117 [1], which uses an asymmetric impedance in the feeding point and relates the output voltage to the voltage at the input of the LVDN-port directly.

Figure 5: Transverse Conversion Transfer Loss (TCTL)



$$Z_{asy} = \frac{U_{A.7}}{I_{A.5}}$$

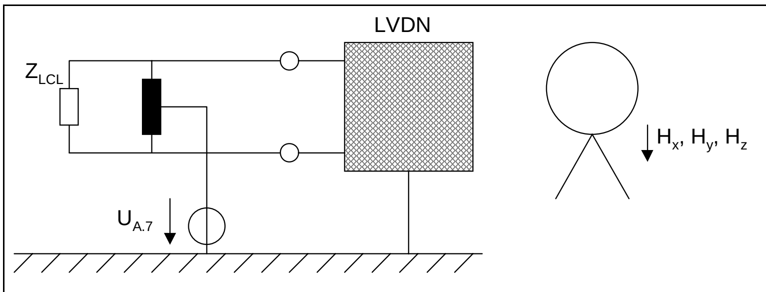
Figure 6: Asymmetric impedance (Z_{asy})



$$Z_{sym} = \frac{2U_{S.6}}{I_{S.2}}$$

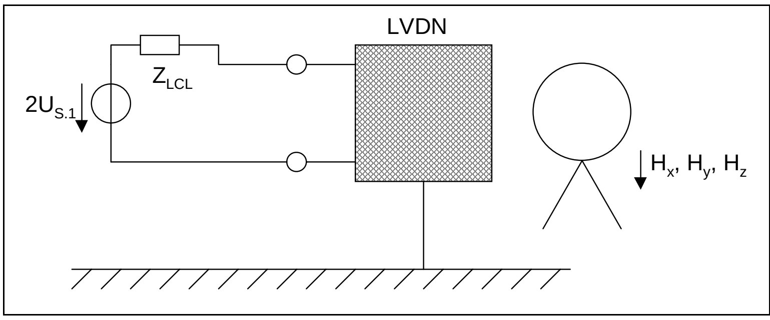
NOTE: Factor 2 in the numerator due to the usage of a 1:4 impedance transformer.

Figure 7: Symmetric impedance (Z_{sym})



$$k_{asy} = 20 \times \log \frac{377\ \Omega \times \sqrt{H_x^2 + H_y^2 + H_z^2}}{U_{A.7}}$$

Figure 8: Coupling factor for asymmetric feed (k_{asy})



$$k_{sym} = 20 \times \log \frac{377\ \Omega \times \sqrt{H_x^2 + H_y^2 + H_z^2}}{2U_{S.1}}$$

NOTE 1: Factor 2 in the denominator due to the usage of a 1:4 impedance transformer.
NOTE 2: This definition differs from the definition of the measurement campaign performed by plcforum (100 Ω).

Figure 9: Coupling factor for symmetric feed (k_{sym})

5 Measurement set-up

In contrast to other specifications or standards the present document defines a common measurement set-up for the collection of raw data, which is used for deriving quantities relevant for the operation of PLT. The main measurement concept is to use two independent subsystems, one for signal feeding and one for signal measurement. For simplification no synchronisation is used between the subsystems. Therefore a comb generator operates as signal source. Central elements of the measurements are two adapters for unbalance measurements as presented by Macfarlane [3]. Since the symmetric network impedance is a priori unknown, additional feeding adapters are necessary.

5.1 LCL measurement

The following impedance definitions are used:

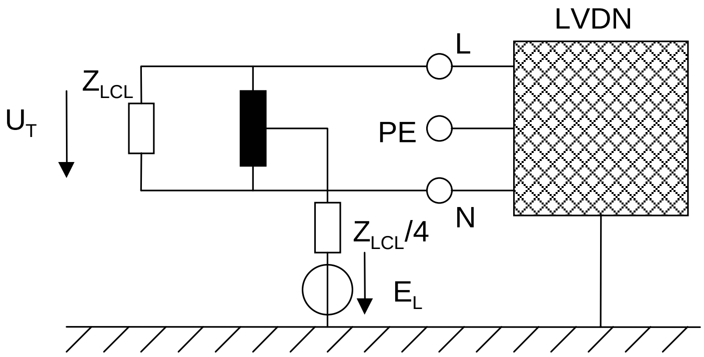


Figure 10: LCL measurement set-up

LCL is not only a function of the symmetric - and the asymmetric - impedance and the unbalance characteristic of the LVDN to be measured, but it is also a rather strong function of Z_{LCL} Thus it is essential that both, Z_{LCL} across the bridge transformer and the generator impedance $Z_{LCL}/4$ are correctly chosen. The value of 100 Ω corresponds approximately to the average value of the symmetric impedance of LVDN and is common practice.

The protection earth of the mains socket to be measured is not connected to the ground plate of the measurement set-up. The rationale for this decision of STF 222 is the fact that there is no low inductive connection between PE at the power plug and the earth, when a PLC modem operates at the power plug.

5.2 Field strength measurement

The magnetic field strength is measured with a loop antenna. Measurements shall be performed with three orthogonal orientations of the antenna. The raw data file shall contain the three readings.

5.3 Measurements with asymmetric feeding

For asymmetric feeding the LCL-measurement adapter shall be used. Therefore an asymmetric impedance of 25 Ω is applied. The signal feeding subsystem consists of a comb generator, producing narrowband signals in 1 MHz spacing. An amplifier with an output power of minimum 1 W may be required for the measurement of the magnetic field strength. For the measurements a measurement receiver or equivalent measurement device shall be used. The bandwidth is 10 kHz, the average detector shall be used. Additional readings at frequencies between the comb generator spikes shall be taken for estimating the measurement dynamic.

The following data shall be collected in the frequency range 1 MHz to 30 MHz:

A.0) Measurement according to A.1 without feeding a signal (noise floor measurement).

A.1) Fed asymmetric voltage at near end (S open).

A.2) Near end symmetric voltage (used for LCL-calculation).

A.3) Far end asymmetric voltage (used for LTL-calculation).

A.4) Far end symmetric voltage (used for LCTL-calculation).

A.5) Near end asymmetric current (used for Z_{asy}-calculation).

A.6) Magnetic field strength (used for k_{asy}-factor-calculation).

A.7) Fed asymmetric voltage at near end (reference without 25 Ω impedance) (S closed).

For each measurement the connectors of unused ports shall be terminated with 50 Ω. The current sensor must not be in the circuit for field strength or for voltage measurements.

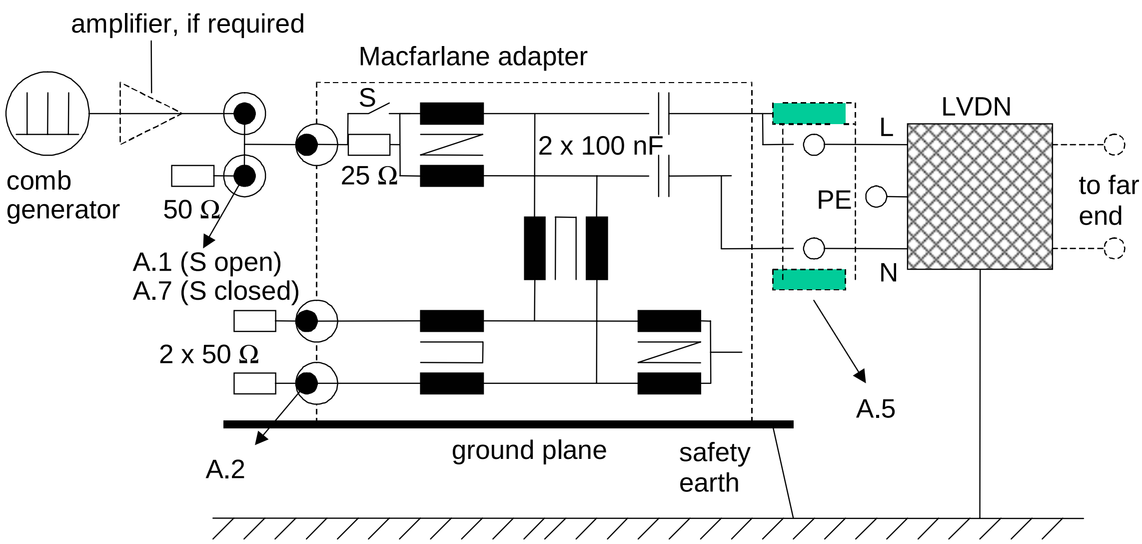


Figure 11: Near end measurements (asymmetric)

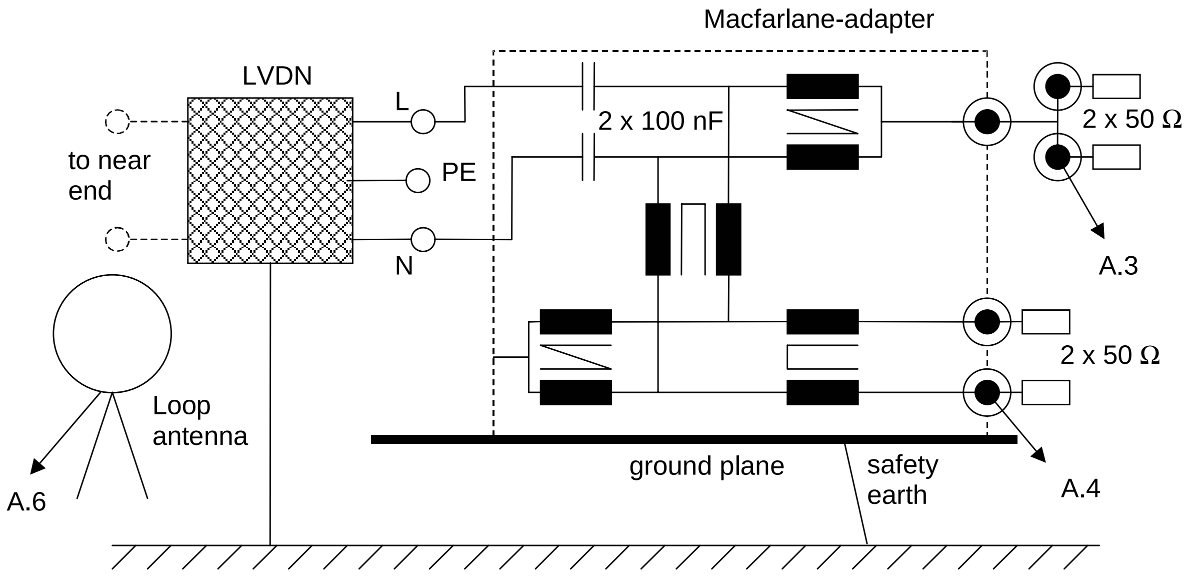


Figure 12: Far end measurements (asymmetric)

5.4 Measurements with symmetric feeding

For symmetric feeding a simple BALUN (impedance ratio 1:4) shall be used. Therefore a symmetric impedance of 100 Ω applies in conjunction with the circuit shown in the figures below. The signal feeding subsystem consists of a comb generator, producing narrowband signals in 1 MHz spacing. An amplifier with an output power of minimum 1 W may be required for the measurement of the magnetic field strength. For the measurements a measurement receiver or equivalent measurement device shall be used. The bandwidth is 10 kHz, the average detector shall be used. Additional readings at frequencies between the comb generator spikes shall be taken for estimating the measurement dynamic.

The following data shall be collected in the frequency range 1 MHz to 30 MHz:

S.0) Measurement according to S.1 without feeding a signal (noise floor measurement).

S.1) Fed symmetric voltage at near end (S open).

S.2) Near end symmetric current (used for Z_{sym}-calculation).

S.3) Far end symmetric voltage (used for TTL-calculation).

S.4) Far end asymmetric voltage (used for TCTL-calculation).

S.5) Magnetic field strength (used for k_{sym}-factor-calculation).

S.6) Fed symmetric voltage at near end (S closed).

For each measurement the connectors of unused ports shall be terminated with 50 Ω. The current sensor must not be in the circuit for field strength or for voltage measurements.

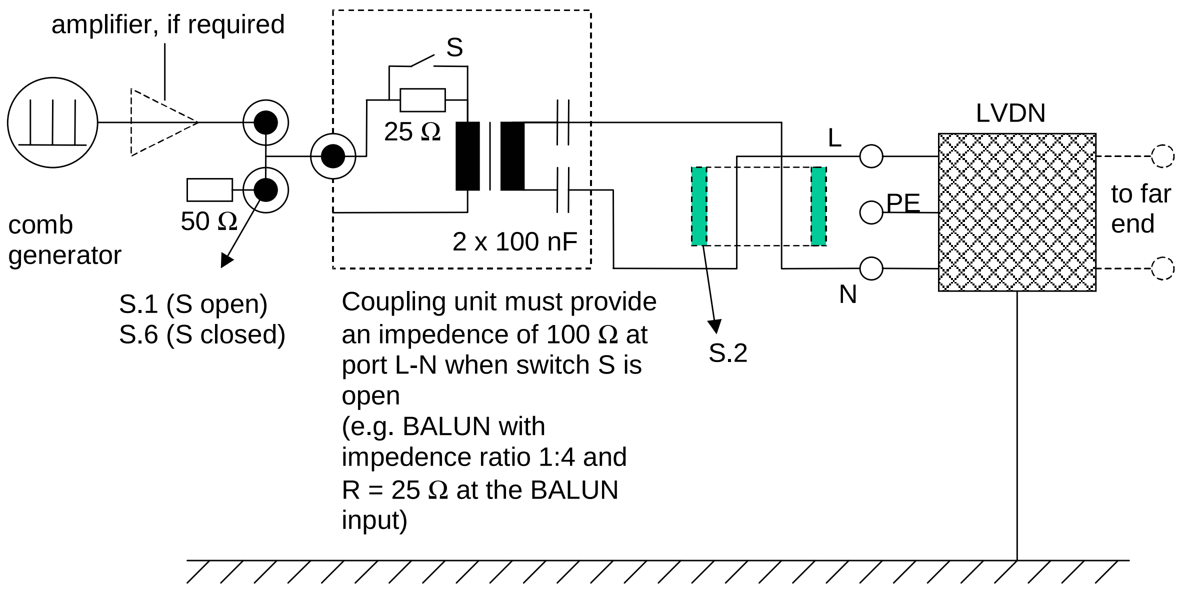


Figure 13: Near end measurements (symmetric)

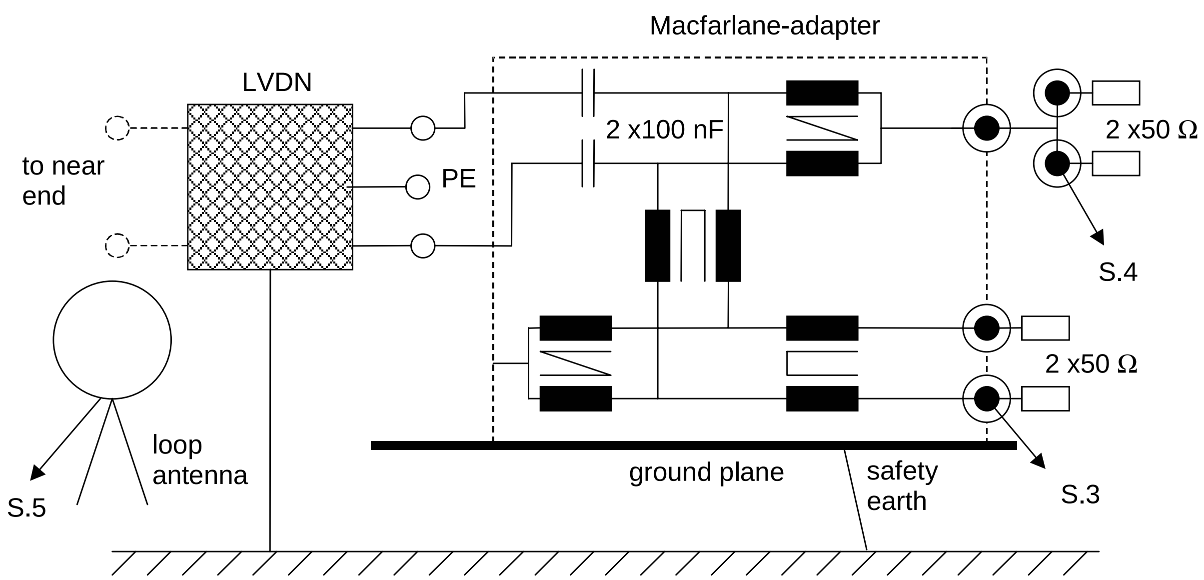


Figure 14: Far end measurements (symmetric)

5.5 Summary of necessary measurement equipment

- Comb generator, spikes in 1 MHz steps.
- Broadband amplifier (class A) minimum 1 W for field strength measurements.
- Measurement receiver, AV-detector, 10 kHz bandwidth, preselector.
- Power terminator 50 Ω (suitable for the amplifier).
- 6 terminator 50 Ω.
- 2 measurement adapters according to Macfarlane [3](with variable internal 25 Ω resistor and 0,1 µF decoupling capacitors).
- 1 BALUN for symmetric feeding with 0,1 µF decoupling capacitors and switchable resistor.
- Ground plane, surface not less than 1 m^2.
- Current sensor according to CISPR 16-1 [2].
- Loop antenna according to CISPR 16-1 [2].
- Additional cables and adapters.

History

Document history		
V1.1.1	March 2003	Publication