ETSI TR 102 270 V1.1.1 (2003-12)

Technical Report

PowerLine Telecommunication (PLT);
Basic Low Voltage Distribution Network (LVDN)
measurement data

Reference

DTR/PLT-00015

Keywords

data, powerline, transmission

ETSI

650 Route des Lucioles
F-06921 Sophia Antipolis Cedex - FRANCE

Tel.: +33 4 92 94 42 00 Fax: +33 4 93 65 47 16

Siret N° 348 623 562 00017 - NAF 742 C
Association à but non lucratif enregistrée à la
Sous-Préfecture de Grasse (06) N° 7803/88

Contents

Intellectual Property Rights

IPRs essential or potentially essential to the present document may have been declared to ETSI. The information pertaining to these essential IPRs, if any, is publicly available for **ETSI members and non-members**, and can be found in ETSI SR 000 314: *"Intellectual Property Rights (IPRs); Essential, or potentially Essential, IPRs notified to ETSI in respect of ETSI standards"*, which is available from the ETSI Secretariat. Latest updates are available on the ETSI Web server (http://webapp.etsi.org/IPR/home.asp).

Pursuant to the ETSI IPR Policy, no investigation, including IPR searches, has been carried out by ETSI. No guarantee can be given as to the existence of other IPRs not referenced in ETSI SR 000 314 (or the updates on the ETSI Web server) which are, or may be, or may become, essential to the present document.

Foreword

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

Introduction

In order to study and compare characteristics of the LVDN network in different countries a STF (Special Task Force) was set up. The present document is one of four TRs which present the result of the work of the STF (TR 102 258) [6], TR 102 259 [7], and TR 102 269 [5]).

The present document takes into account matters like earthing variations, country variations, operator differences, phasing and distribution topologies, domestic, industrial housing types along with local network loading. The measurement set-up, the measurements as such, the used software the site reports and parts of the analysis are common for all the TRs and is collected in the present document.

1 Scope

The present document presents all the information that is common to the TR 102 269 [5], TR 102 258 [6] and TR 102 259 [7].

Auxiliary parameters, such as asymmetric impedance, return loss (symmetric) and Transverse Conversion Transfer Loss (TCTL) were measured at the same time and the results are also presented in the present document.

2 References

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

[1] Terms of Reference for Specialist Task Force 222 (MB), TC PLT, September 2002.

[2] ITU-T Recommendation G.117 (02/96): "Transmission aspects of unbalance about earth".

[3] Ian P. Macfarlane: "A Probe for the Measurement of Electrical Unbalance of Networks and Devices", IEEE Transactions on Electromagnetic Compatibility, Vol 41, No. 1, pp 3 to 14.

[4] ETSI TR 102 175: "PowerLine Telecommunications (PLT); Channel characterization and measurement methods".

[5] ETSI TR 102 269: "PowerLine Telecommunications (PLT); PLT Hidden Node Analysis".

[6] ETSI TR 102 258: "PowerLine Telecommunications (PLT); LCL review and statistical analysis".

[7] ETSI TR 102 259: "PowerLine Telecommunications (PLT); EMI review and statistical analysis".

[8] IEC 61000-4-6: "Electromagnetic compatibility (EMC) - Part 4-6: Testing and measurement techniques - Immunity to conducted disturbances, induced by radio-frequency fields".

3 Abbreviations and symbols

3.1 Abbreviations

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

Asym	Asymmetrical
ATT	ATTenuator
BALUN	BALanced to UNbalanced transformer
EMI	ElectroMagnetic Interference
LCL	Longitudinal Conversion Loss
LISN	Line Impedance Stabilization Network

NOTE: Used as decoupling filter

LVDN	Low voltage distribution network
PC	Personal computer
PE	Protection Earth
STF	Special Task Force
Sym	Symmetrical
TCTL	Transverse Conversion Transfer Loss
ToR	Terms of Reference
WI	Work Item

3.2 Symbols

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

A_L	Inductance factor
I	Current
L	Inductance
L_{PE}	Protective earth inductance
nF	nanoFarads
nH	nanoHenry
Z	Impedance
Z_{asy}	Asymmetric impedance

4 Major project phases

No.	Period	Topic	Event
01	Sept to Oct. 2002	Project organization Definition of characteristics Measurement set-up Planning	Task Force Meeting No. 1 and 2 Frankfurt, Germany
02	Nov to Dec. 2002	Measurement set-up familiarization, laboratory tests	Task Force Meeting No. 3 University Dortmund, Germany
03	Jan. 8 to 10 2003	Measurements in: 3 single family houses	Measurement campaign Eindhoven, The Netherlands
04	February 2003	Measurements in: 3 apartments and 1 office building	Measurement campaign Stuttgart, Germany
05	March 13 to 20 2003	Measurements in: 4 apartments 2 single family houses 2 office buildings 2 factory buildings	Measurement campaign Zaragoza, Spain
06	May to July 2003	Data analysis Reports	Task Force meeting No.4 Frankfurt, Germany

5 Measurement set-up description

5.1 Introduction

The STF 222 had to define the parameters to be measured and to build the corresponding measurement set-up. This clause shows the practical implementation, the various measurement set-ups and the instrumentation used.

The definition of the parameters to be assessed can be found in TR 102 175 [4].

Figure 5.1 shows the measurement-trolley with its ground plane and some instruments.

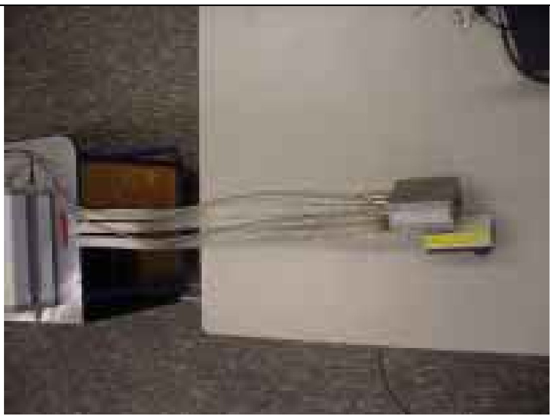
	
Measuring trolley, isolation transformer and LISN	Amplifier, Comb generator, EMI receiver
	
Rear view	Connection to LCL probe
	
Extension braids 70 cm	LCL probe and Safety box

Figure 5.1: Measurement trolley with various test equipment

5.2 Set-up for measurements of conducted signals at a single LVDN-port

The measurement set-up basically consists of a signal source connected via the Macfarlane Probe [3] to the mains.

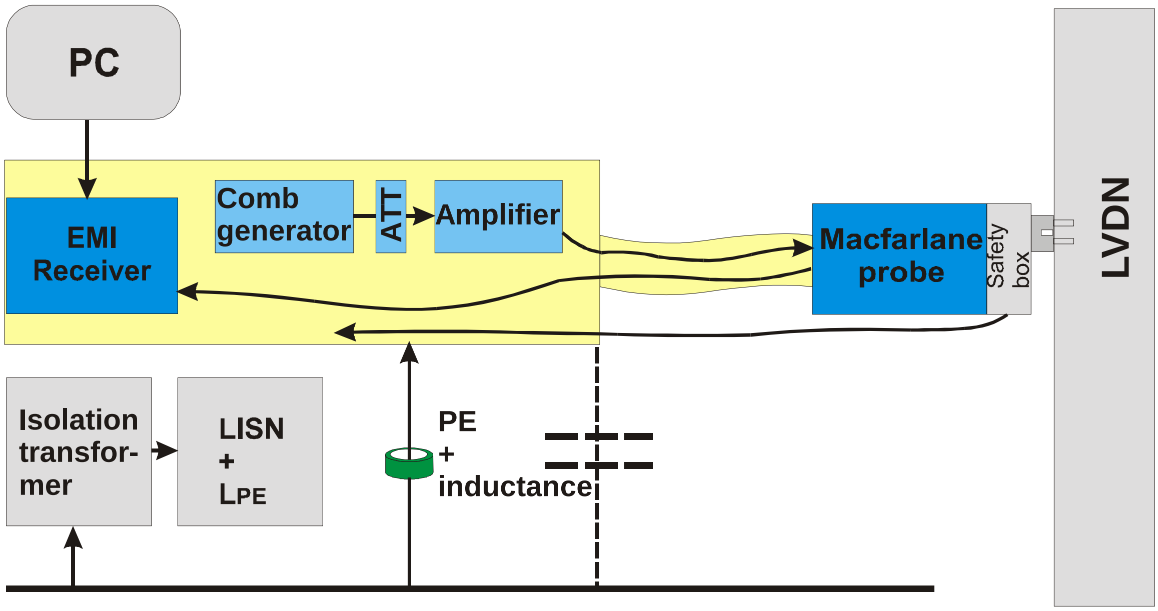


Figure 5.2: General measurement set-up for conducted signals at a isngle LDVN-port

The equipment is connected to a ground plane with a surface of ≥1 m^2. The function of this ground plane is to establish a capacitive coupling path to the reference of the common mode signal large enough to reduce measurement errors at lower frequencies. The proof for sufficient size is the fact, that an increase in size has a negligible effect upon the measured data. The Macfarlane probe with its associated safety box is directly inserted into the LVDN-socket to be measured. This eliminates connecting cables between the probe and the LVDN which produce impedance transformations and may be a cause for non-reproducible measurement results. The ground-connection between the ground plane and the probe is made with large, low impedance braids with a length of about 70 cm (see figure 5.1). The ground plane is decoupled from the Protective Earth (PE), as the only currents allowed to run through the ground plane (and hence through the receiver) should be the return currents that flow via the Macfarlane probe, via the mains unbalance and the reference back to the ground plane. Isolation in the frequency range 1 MHz to 30 MHz of mains connected equipment from PE is achieved by using a standard LISN with its PE inductance L_{PE} switched "on". The isolation transformer, used to prevent the earth leakage switches from tripping (the LISN has large capacitors to PE), provides additional attenuation of low frequency common mode signals. Safety is assured by connecting a green/yellow ferrite loaded wire between PE and the floating ground plane.

For Z_{asym} - measurements a current probe is built into the safety box. Its output is to be connected to the EMI receiver.

5.3 Set-up for measurements of conducted Signals between two LVDN-ports

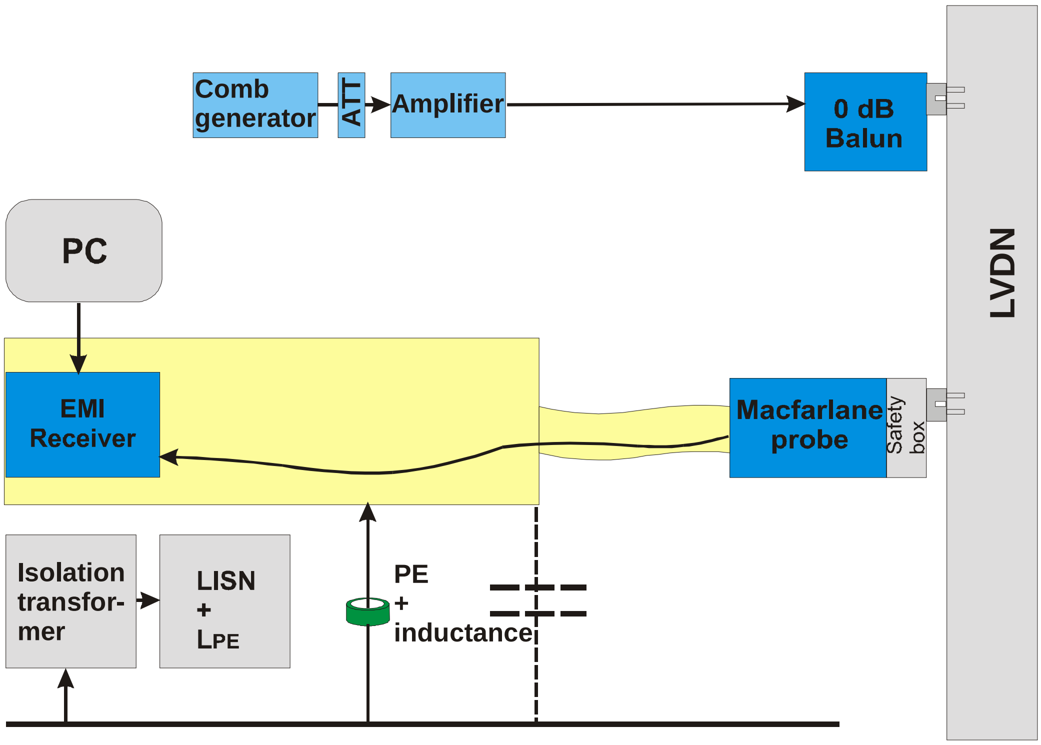


Figure 5.3: General measurement set-up for conducted signals with symmetrical injection

5.4 Return loss measurements

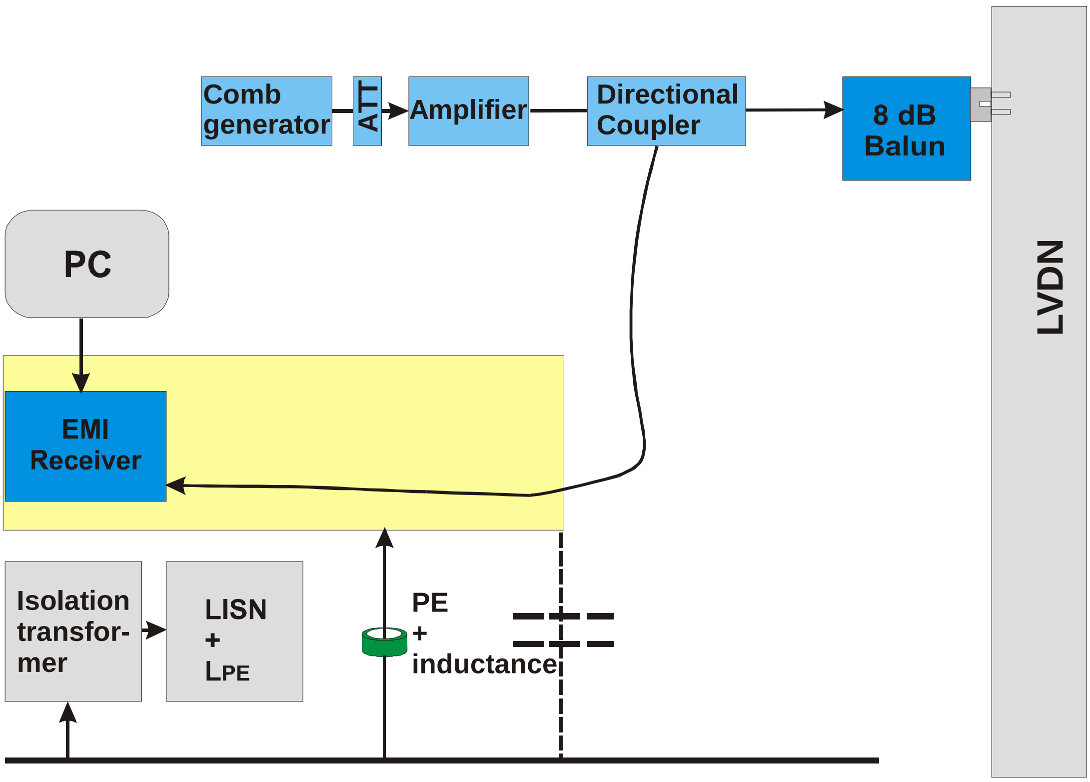


Figure 5.4: General measurement set-up for return loss

5.5 Set-up for measurements of radiated signals

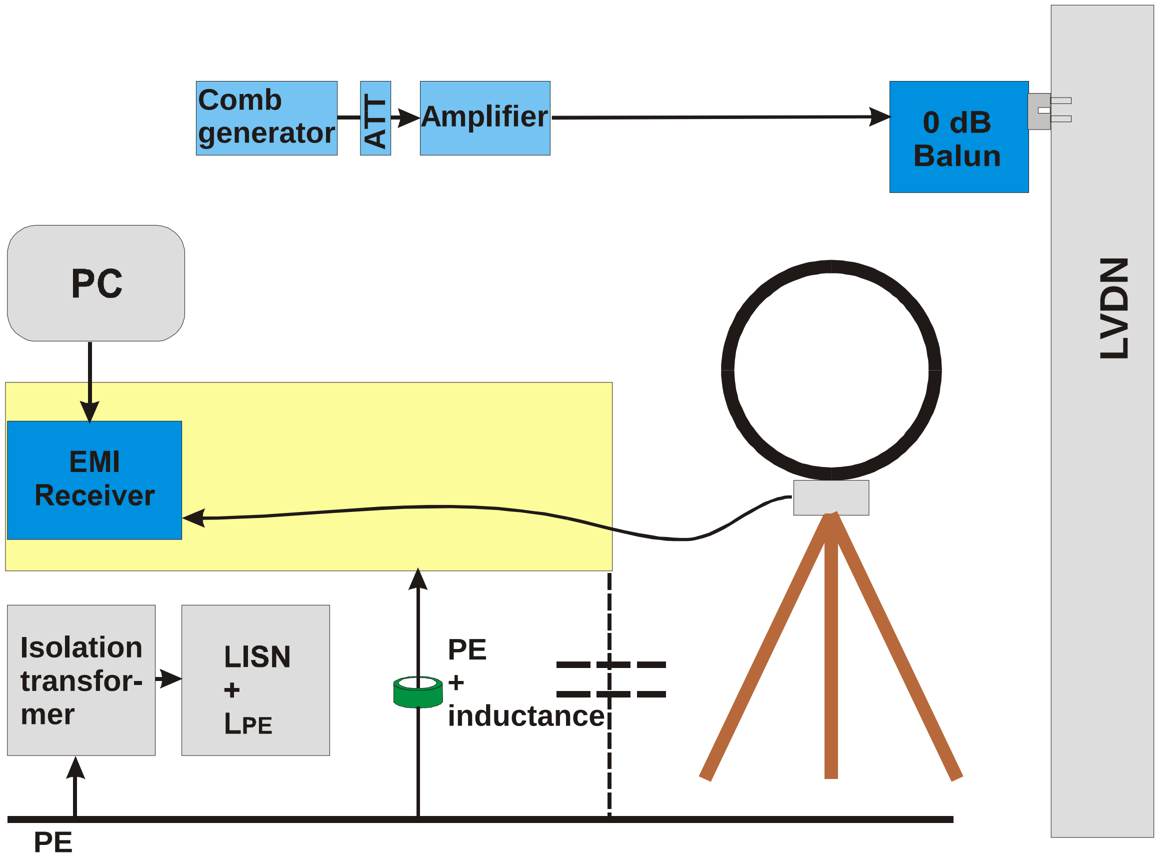


Figure 5.5: General measurement set-up for radiated signals with symmetrical injection

5.6 General equipment list

5.6.1 Comb generator

The published specifications of this commercially available comb generator are not very tight. The unit used for measurements, however, shows a flat spectrum in the range of interest between 1 MHz and 30 MHz and a very good stability of the output level.

Property	Value	Comment
Type	VSQ 1000	
Manufacturer	Bogerfunk	
Output level	78 dBμV	in the frequency domain; into 50 Ω
Output impedance	50 Ω	
Frequency range	> 100 MHz	
Repetition frequency	500 kHz	(also adjustable in 5 steps)

Figure 5.6: Comb generator

5.6.2 Amplifier

The specifications of the amplifier generator are not very tight; but the gain is very stable.

Property	Value	Comment
Type	102LC	10 Hz to 100 MHz
Manufacturer	Kalmus	
Output level	2 Watt	into 50 Ω
Output impedance	50 Ω	
Input impedance	50 Ω	
Gain	36 dB	100 kHz to 30 MHz

The amplifier is sufficiently linear for 500 kHz-spaced spectrum lines up to 100 dBuV or –7 dBm. For an output level of 100 dBuV a 14 dB attenuator must be inserted between the comb generator and the amplifier.

Figure 5.7: Amplifier

5.6.3 EMI Receiver

Property	Value	Comment
Type	ESPC	
Manufacturer	Rohde & Schwarz	
Detector	Peak and Average	Note this means: Peak- or Average value of the measured RMS voltage
Frequency range	0.1MHz to 2 400 MHz	
Frequency steps	100 kHz	4 noise readings between Comb generator peaks
Dwell time	20 ms default	
Resolution bandwidth	10 kHz	
Receiver noise	< -5 dBuV	up to 30 MHz

Figure 5.8: EMI receiver

5.6.4 Directional coupler

Property	Value	Comment
Type	DC 2600	
Manufacturer	AR	
Basic attenuation	50 dB	between main ports and coupled ports
Directivity	> 20 dB	

The specified directivity of 20 dB would be insufficient, because the particular type of balun used for STF 222 measurements has a total insertion loss (forward + return) of 8 + 8 = 16 dB. The available directional coupler fortunately showed - between 1 MHz and 30 MHz and in one direction - a directivity of > 35 dB, which is adequate.

Figure 5.9: Directional coupler

5.6.4 LISN

Property	Value	Comment
Type	ESH3-Z5	
Manufacturer	Rohde & Schwarz	
PE connection	50 µH "on"	

Figure 5.10: LISN

5.6.5 Loop Antenna

Property	Value	Comment
Type	HFH2-Z2	
Manufacturer	Rohde & Schwarz	
Antenna factor	20 dB (1/m)	Electric field strength derived from the measured magnetic field strength E = 377 * H
Antenna support	home-made, lower edge always at 1m above floor.	

Figure 5.11: Loop antenna with support

5.6.6 Current probe

Property	Value	Comment
Type	CT1	10 kHz to 30 MHz
Manufacturer	Tektronix	
Transfer Impedance	5 Ω	

This current probe is built into the Safety Box and is used to measure I_{asy}.

Figure 5.12: Current probe

5.6.7 PE-wire

Property	Value	Comment
Inductance	280 µH	Same value as coils in CDNs of IEC 61000-4-6 [8], fig D1-D6

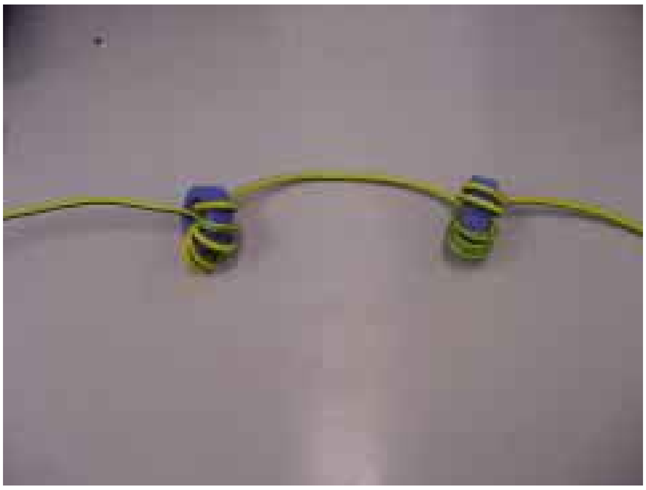


Figure 5.13: PE-wire

5.6.8 Isolation transformer

As this transformer is needed only to prevent the earth leakage circuit breakers from tripping due to the large capacitors in the LISN, no special properties are required from this mains isolation transformer.

5.6.9 Macfarlane probe

The probe was built according to the description in ITU-T Recommendation G.117 [2], except that it designed for the limited frequency range which is of interest to PLT that is 1 MHz to 30 MHz.

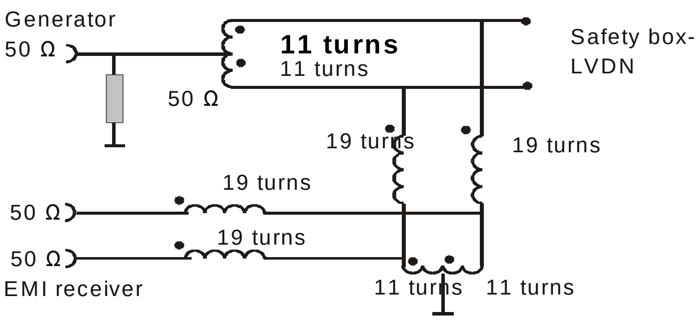


Figure 5.14: Schematic of the "Macfarlane probe" 1 MHz to 30 MHz

All toroids A_L 87 nH, material 4C65, bifilar wound.

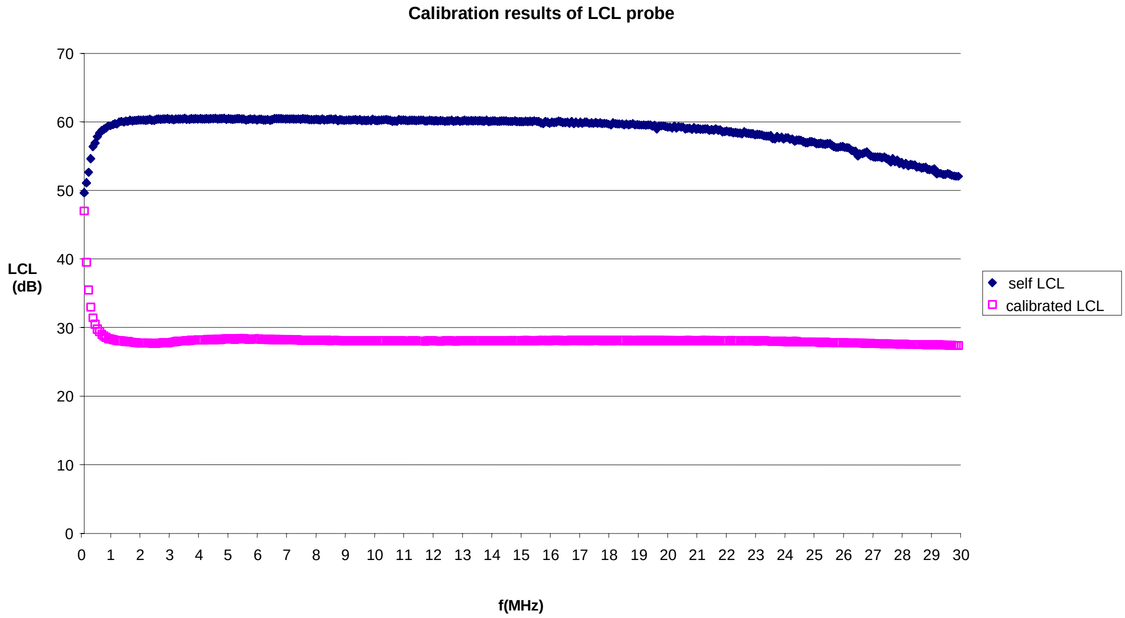


Figure 5.15: Verification of the Macfarlane probe

Figure 5.15 shows 2 lines:

1. The upper curve is the "self" LCL measured with a differential mode impedance of 100 Ω between the LVDN terminals of the Safety box. There is no $R_{unbalance}$ connected. The "self" LCL is high at low frequencies, and decreases to 52 dB at 30 MHz.

2. The lower straight line is the measured LCL if the verification unbalance resistor is installed. The LCL value is 27 dB over a frequency range of 1 MHz to 30 MHz. The deviations below 1 MHz are due to the restricted values of the safety capacitors in the Safety box.

5.6.10 Zero dB-Balun

This balun transforms 100 Ω symmetrical to 50 Ω asymmetrical. It was designed for low power loss with the aim to maximize the injected signal.

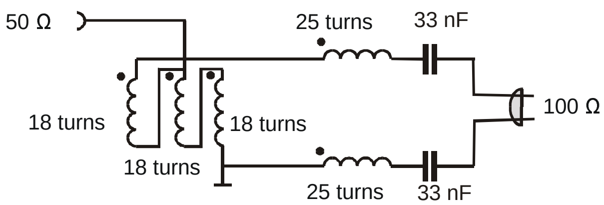


Figure 5.16: Schematic of the "Zero dB balun"

All toroids A_L = 87 nH, material 4C65, tri- resp. bifilar wound.

5.6.11 8 dB Balun

This balun was optimized for precise impedance matching between 100 Ω symmetrical and 50 asymmetrical.

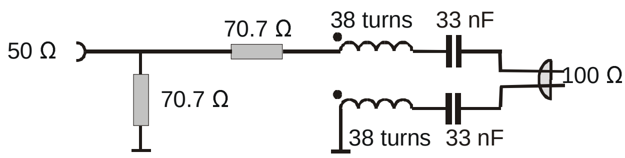


Figure 5.17 Schematic of the "8 dB balun"

Toroid A_L = 170 nH, material 4C65, bifilar wound.

5.6.12 Safety box

The safety box contains two 22 nF capacitors, two associated 1 M Ω discharge resistors and the current probe as described above.

The safety box is piggy-back mounted onto the Macfarlane probe.

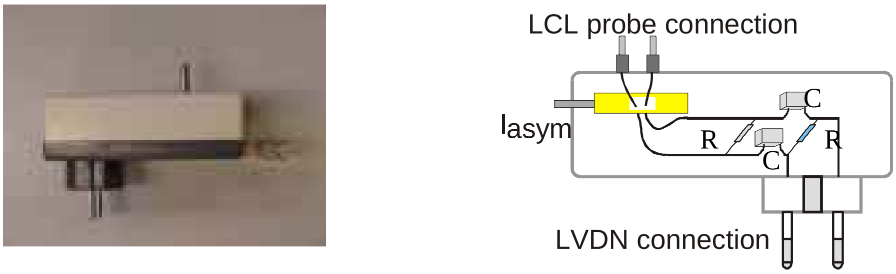


Figure 5.18: Safety box

6 Measurement software

Self written software was used to control the Rohde & Schwarz ESPC and to record measurement results. Only raw data is measured, no correction factors are used during the measurement. Specific settings are given in the so-called scan set-up. It contains all necessary settings for the measurements. The scan set-up was programmed to the ESPC automatically before the measurement started.

6.1 Description of the used software

The software was developed for the project to coordinate measurements and analysis of the measured data. The software can be used intuitively. In the central dialog the measurement site will be described. The corresponding feeding files are specified in the category "Feed files".

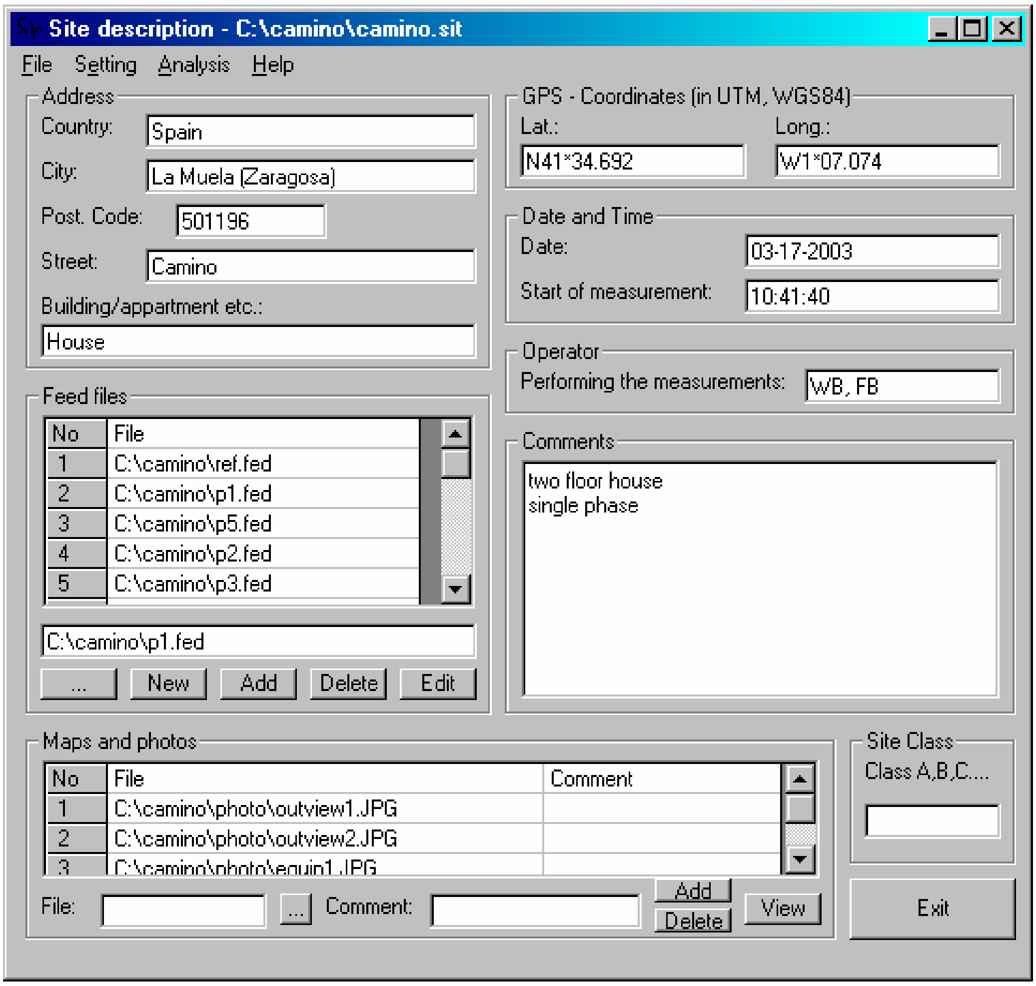


Figure 6.1

The transducer factors characterizing the used measurement equipment should be specified before the input of any other information. This is done by the menu item "Setting", which yield to the following dialog in figure 6.2:

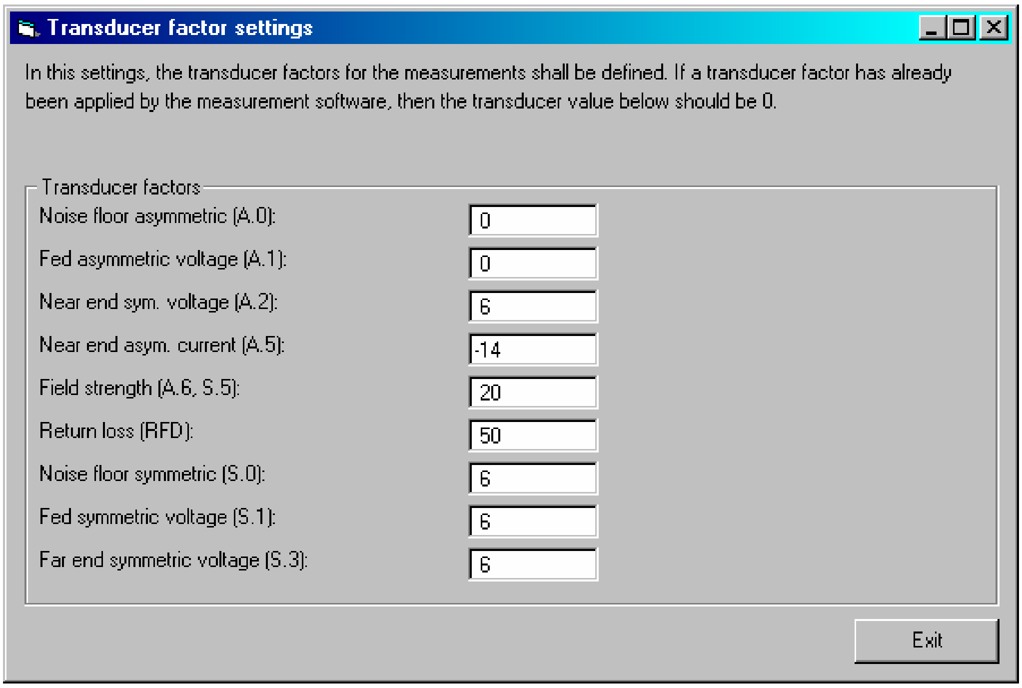


Figure 6.2

During analysis of the data the specified transducer factors are added to the measurement results.

A double click on an existing feeding file in the central dialog opens the feed file dialog in figure 6.3:

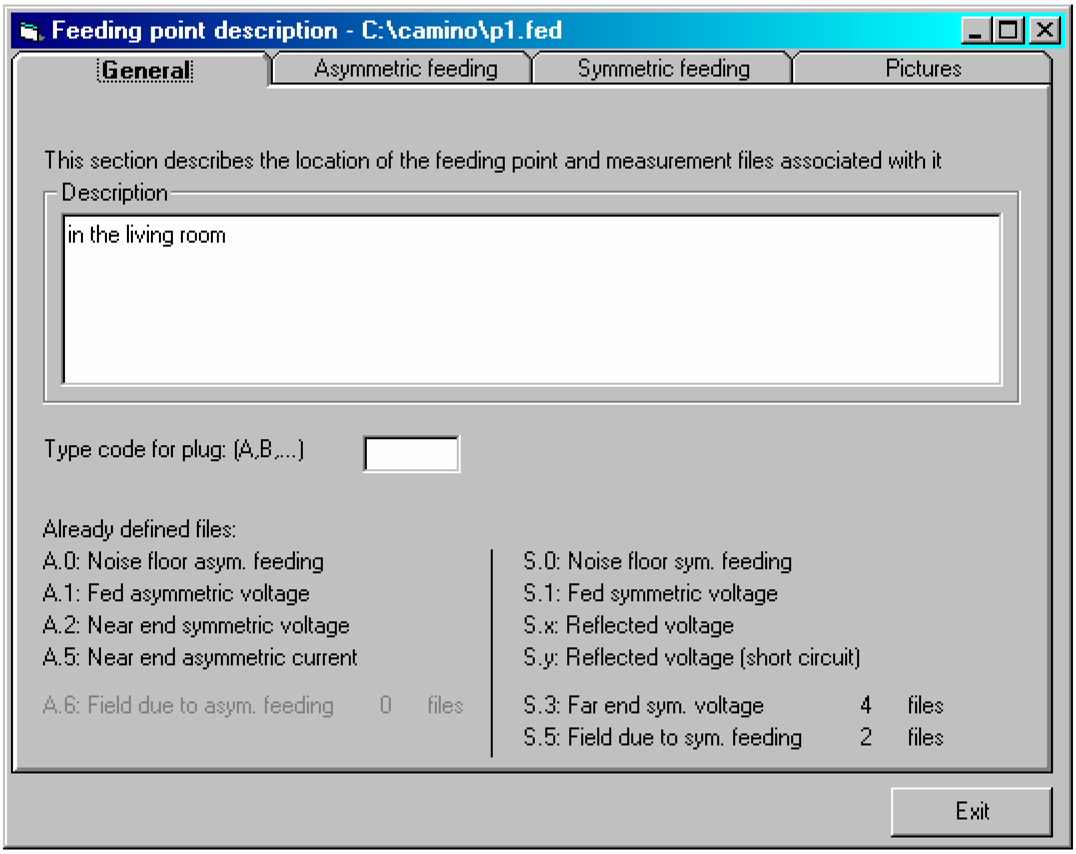


Figure 6.3

In the overview dialog in figure 6.3 the status of the feeding point is shown. For each feeding point only one A.0, A.1, A.2, A.5, S.0, S.1, S.x and S.y file exists. If the corresponding line is printed in dark a measurement file is already defined. Light grey indicates that a file has not been specified so far. The register "Pictures" in figure 6.4 can be used to include pictures and comments related to the feeding point:

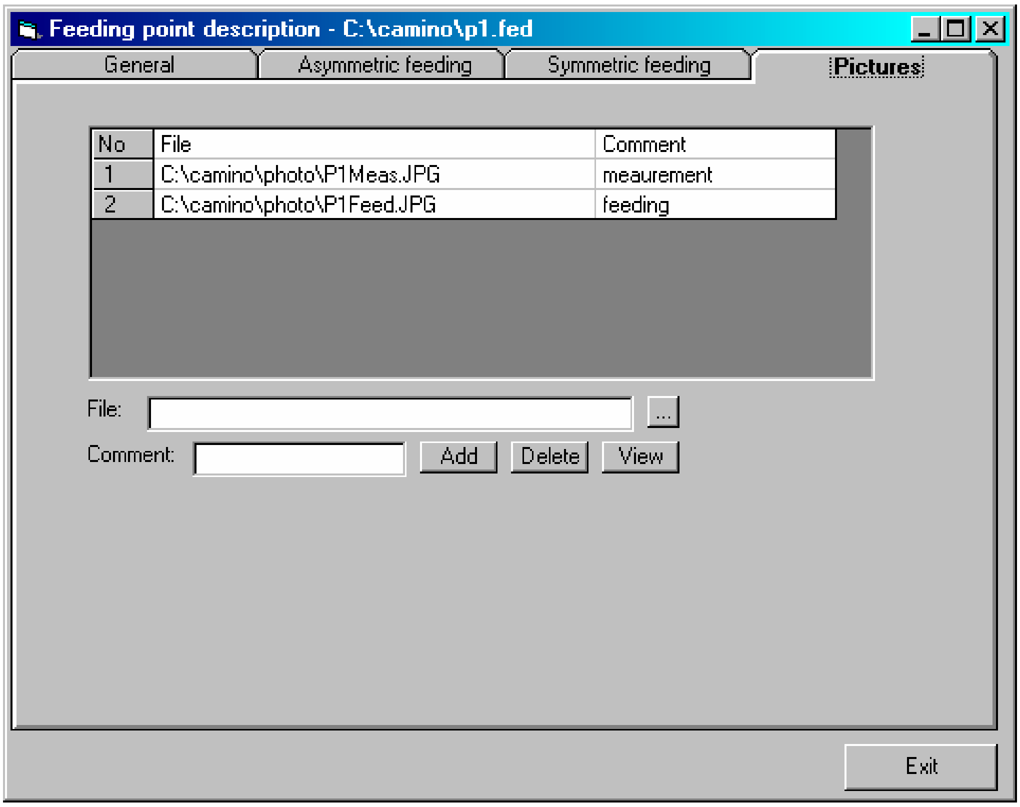


Figure 6.4

Choosing the register "Asymmetric feeding" in figure 6.5 opens the dialog, in which the file names for an asymmetric feeding can be specified:

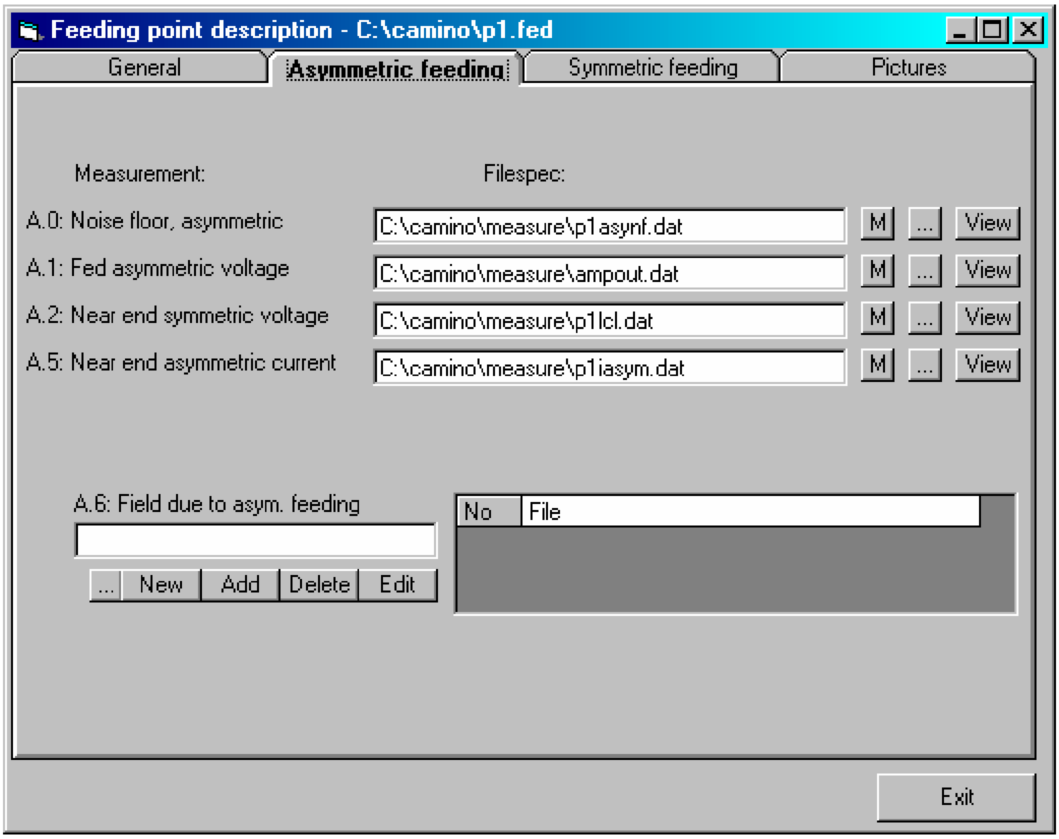


Figure 6.5

A click on "View" shows the measured raw data (if a file is specified).

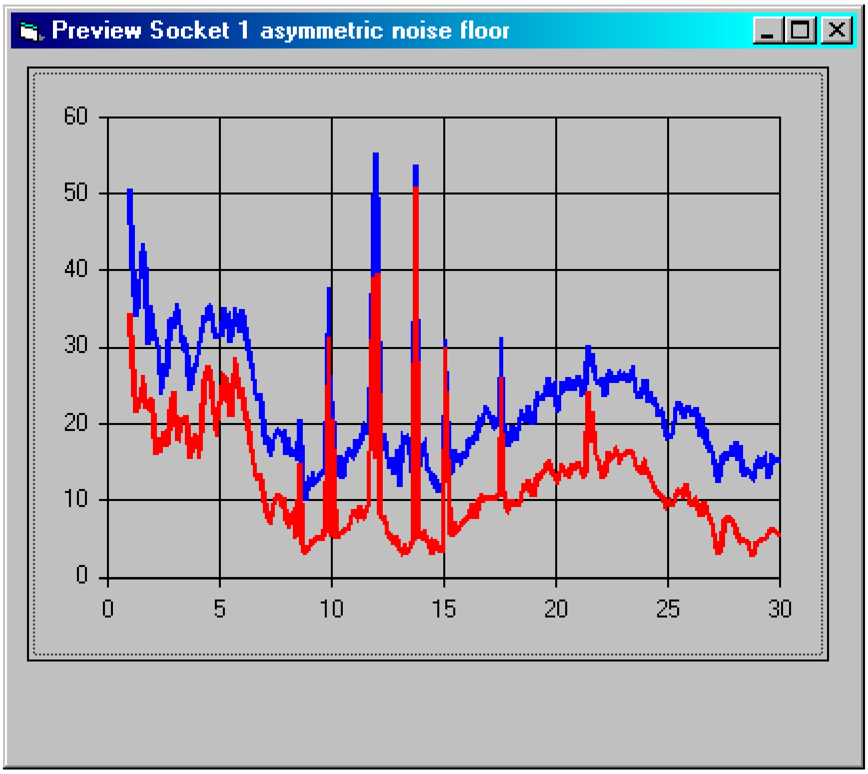


Figure 6.6

Pressing "…" allows to choose an existing file (see figure 6.5). Pressing "M" starts the measurement dialog after a filename has been defined.

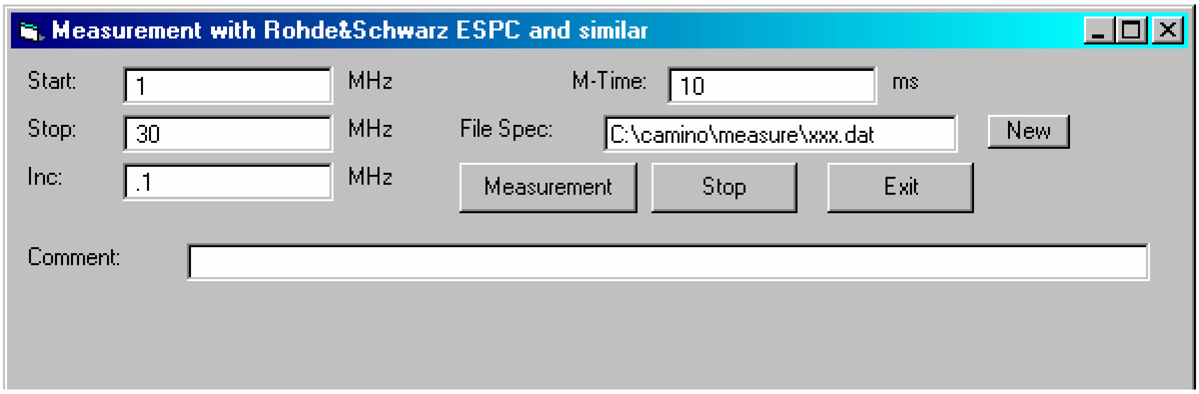


Figure 6.7

If a measurement receiver ESPC 30, ESHS 30, ESCS 30 or compatible (Rohde & Schwarz) is connected via National Instruments GPIB-Interface, the measurement data will be collected by a click on "Measurement" (see figure 6.7). During the measurement the measured data will be plotted below the comment line. A comment line must be specified before the measurement is started in order to include the comment in the measurement data file.

Back to the feeding point description dialog the register "Symmetric feeding" will show the dialog for the symmetric feeding files.

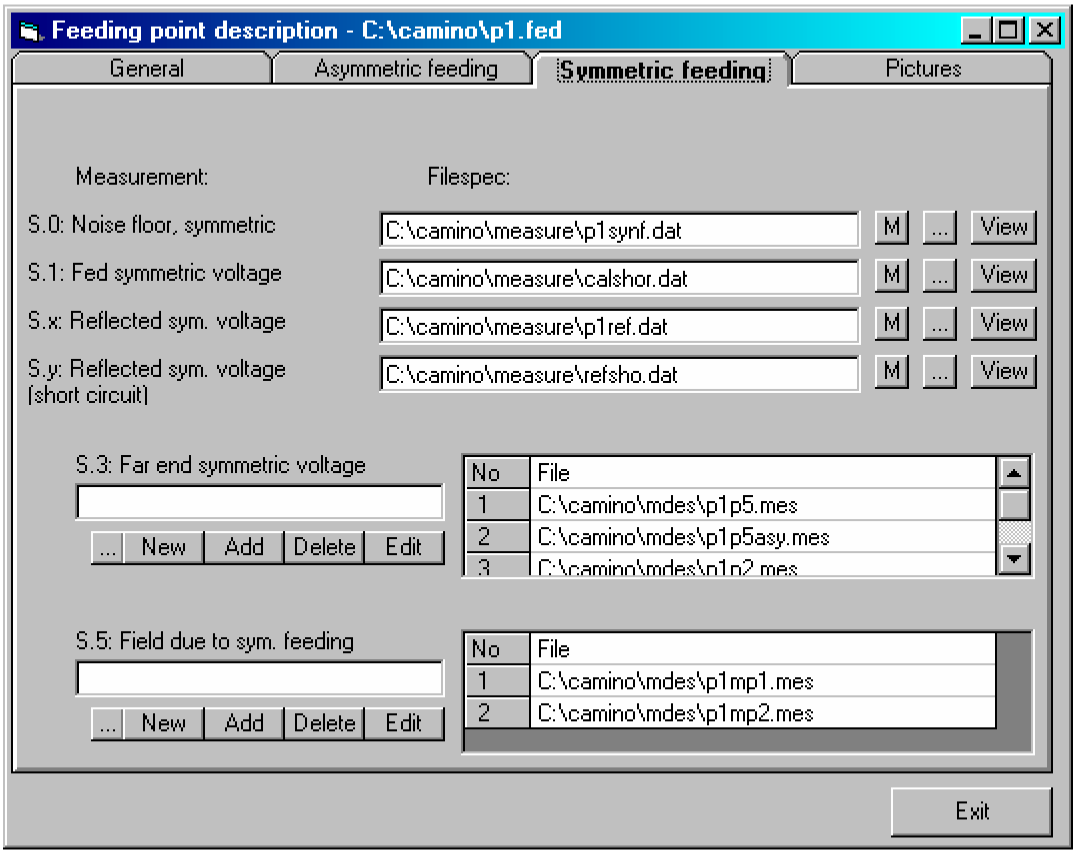


Figure 6.8

Besides the single measurement files, measurements at certain measurement points (S.3, S.5) can be defined (see figure 6.8). A double click on an existing S.3-file will lead to the dialog window in figure 6.9:

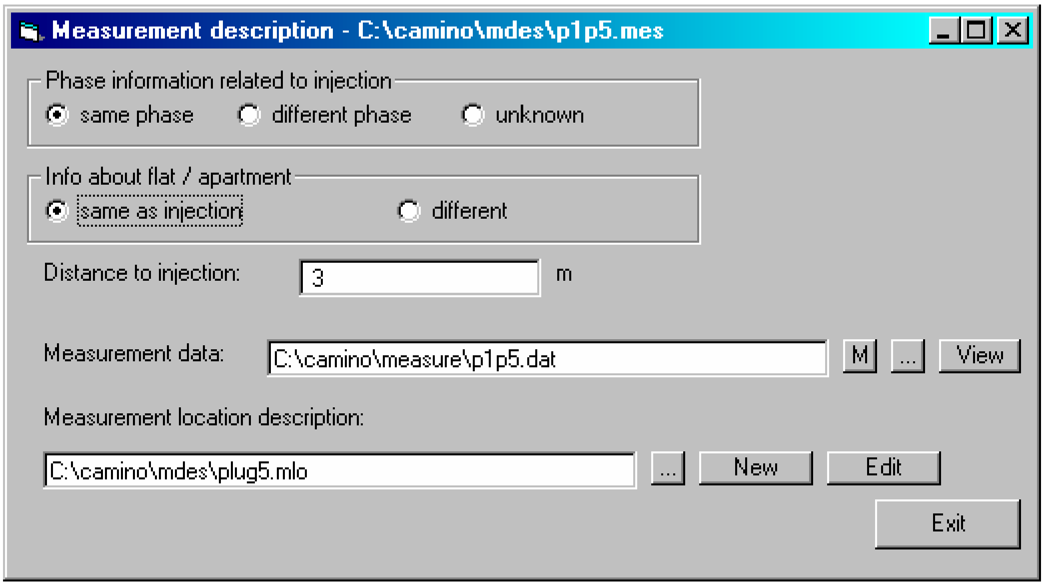


Figure 6.9

and double click on an existing S.5-file will give as a result the view in figure 6.10:

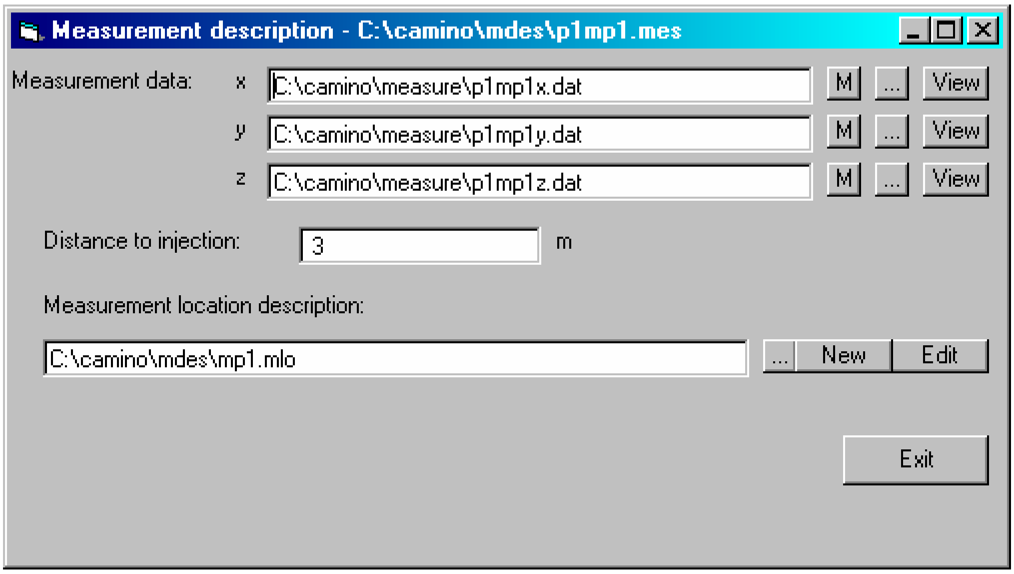


Figure 6.10

In these two dialogs windows in figures 6.9 and 6.10, additional information regarding the measurement location can be given in the measurement location description file. Defining such a file will open the dialog in figure 6.11 for general information.

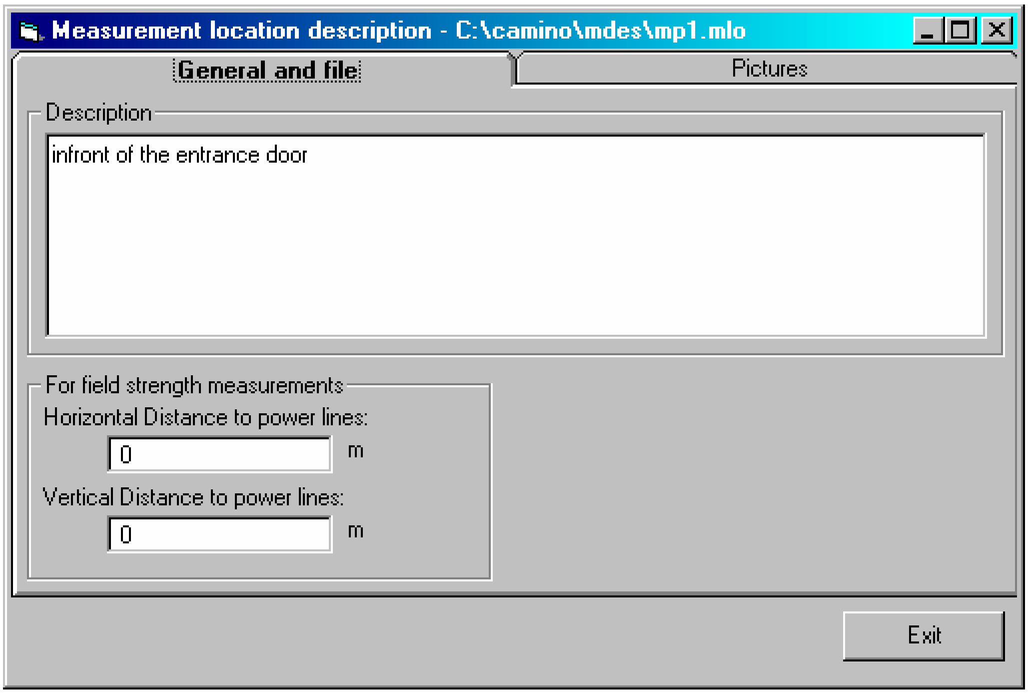


Figure 6.11

Respectively for pictures see figure 6.12.

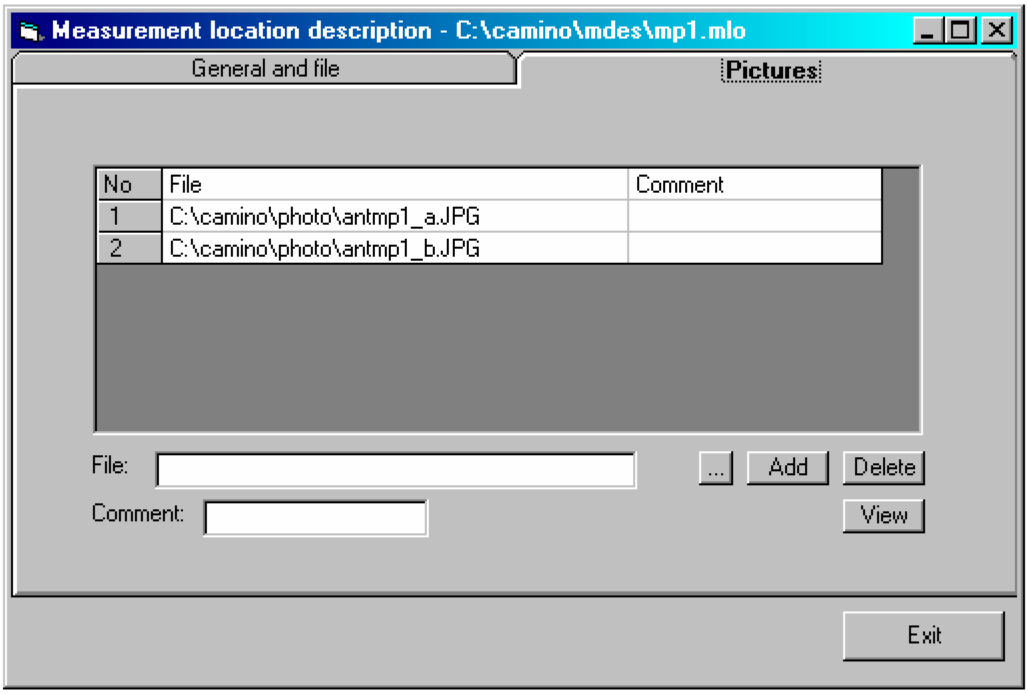


Figure 6.12

In the central dialog (Site description) the menu item "Analysis" – "Specific measurement" allows to analyse and preview one of the measured quantities, e.g. the LCL:

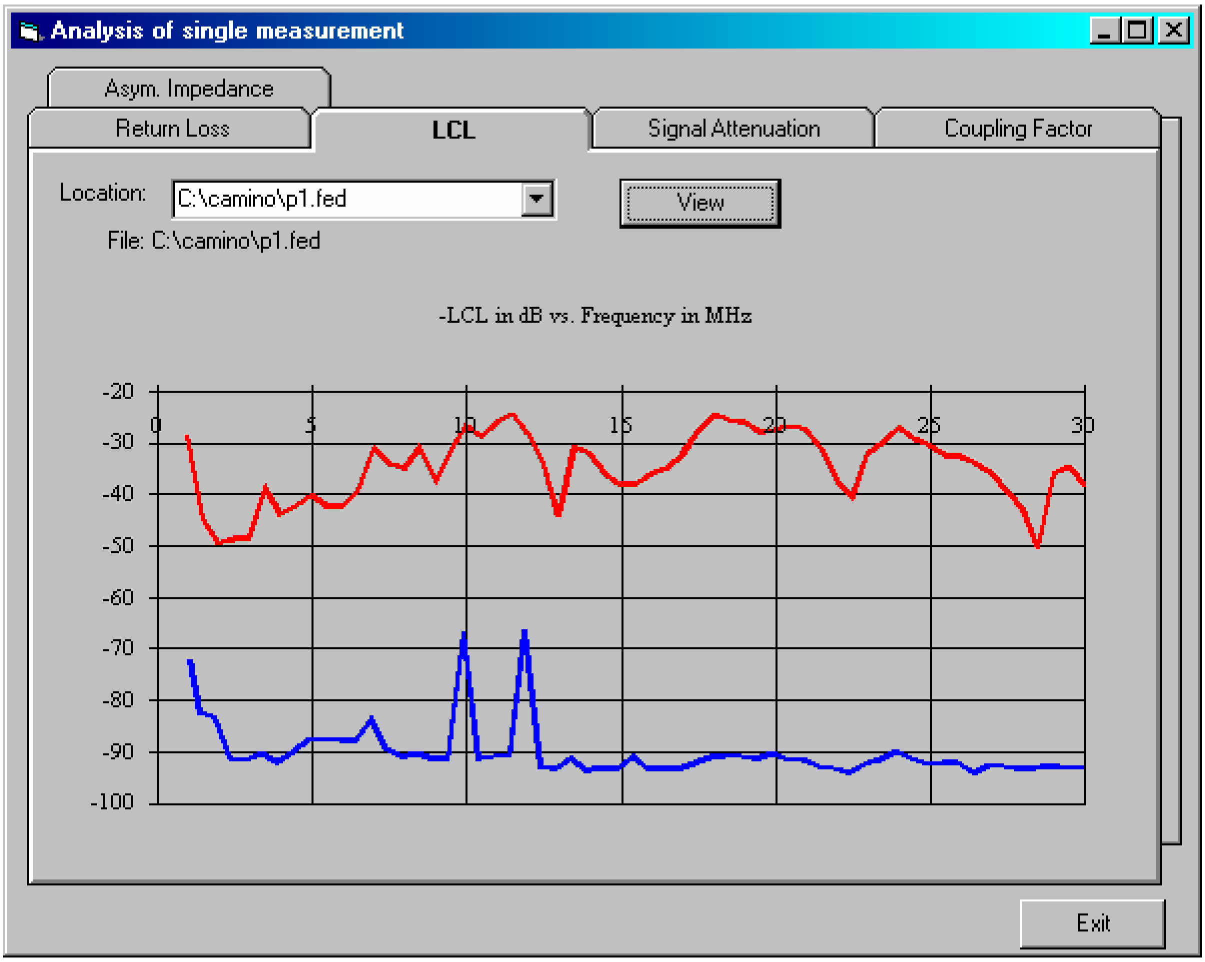


Figure 6.13

The red curve (upper) in figure 6.13 shows the measured quantity, whereas the blue curve represents the measurement dynamic. It is generated taking into account the measurement data points between the spikes of the comb generator.

The menu item "General Analysis" will start a data processing, which generates the data file "report.rep". A site-report can be generated using this file.

6.2 Evaluation of the results

For precise evaluation of the Attenuation measurements the 0 dB Balun and Macfarlane probe need to be calibrated. This was done by shortcutting the balun and probe. The feeding voltage was measured and this result file was used for calculation of the attenuation values.

Attenuation = Feeding sym. Signal - Received sym. Signal + Correction Factor in Transducer Settings.

Return Loss (RFD) = Reflected Sym. Signal + Correction Factor in Transducer Settings - Feed sym Signal.

LCL = Received Sym. Signal - Feed Asym. Signal + Correction Factor in Transducer Settings.

k-Factor = vector addition to the measurements of the 3 orientations (x,y,z) of the antenna position + Correction Factor in Transducer Settings - Feed sym Signal.

Z_{asy} = Feed asym Signal / asym. current.

TCTL = Received Sym. Signal - Feed Asym. Signal + Correction Factor in Transducer Settings.

7 Auxiliary parameters

The STF was able to include into its measurement campaign some additional parameters, such as asymmetric impedance see figure 7.1, return loss (symmetric), see figure 7.2 and TCTL see figure 7.3. Although they are not directly needed for the WI of the ToR, they are of general interest to the PLT-community. The results are presented for information in the present document.

The asymmetric impedances were determined by dividing the injected common mode voltages by the corresponding common mode currents. The results are absolute values of the asymmetric impedances.

The median value measured is 200 Ω for Germany and 250 Ω for the Netherlands and Spain.

The return losses related to 100 Ω were measured instead of the symmetrical impedances. The return losses describe the power loss due to mismatch.

The measured median value is 8 dB for Germany and 7 dB for the Netherlands and Spain.

The median measured TCTL is 54 dB for Spain and 64 dB for the Netherlands. The statistical basis for the Netherlands is too small for making any conclusions concerning country related differences.

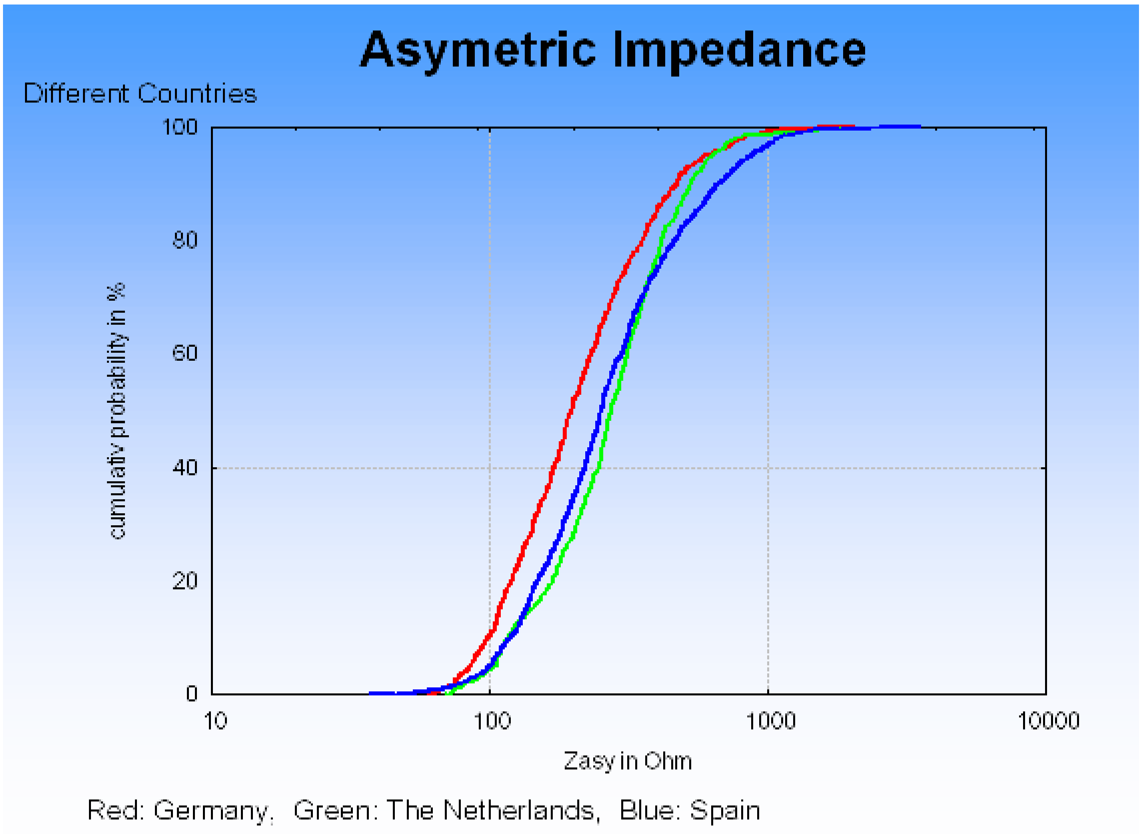


Figure 7.1: Asymetric impedance

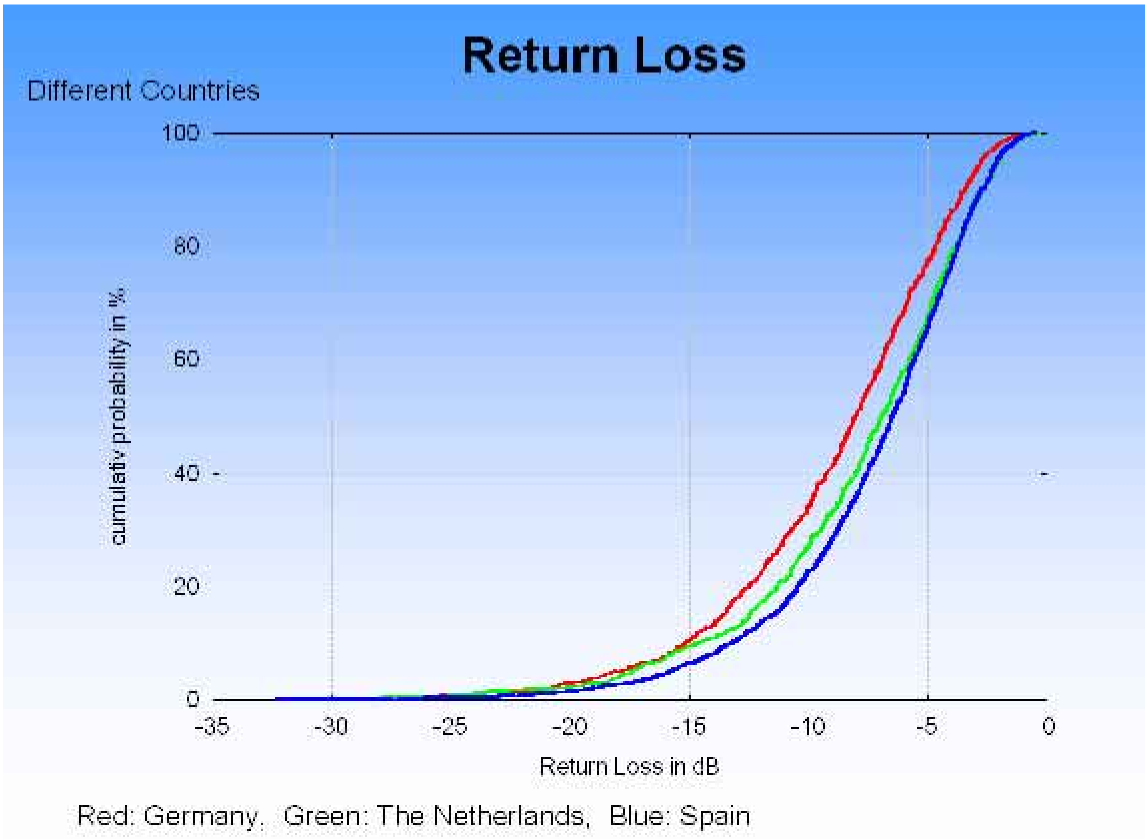


Figure 7.2: Return loss

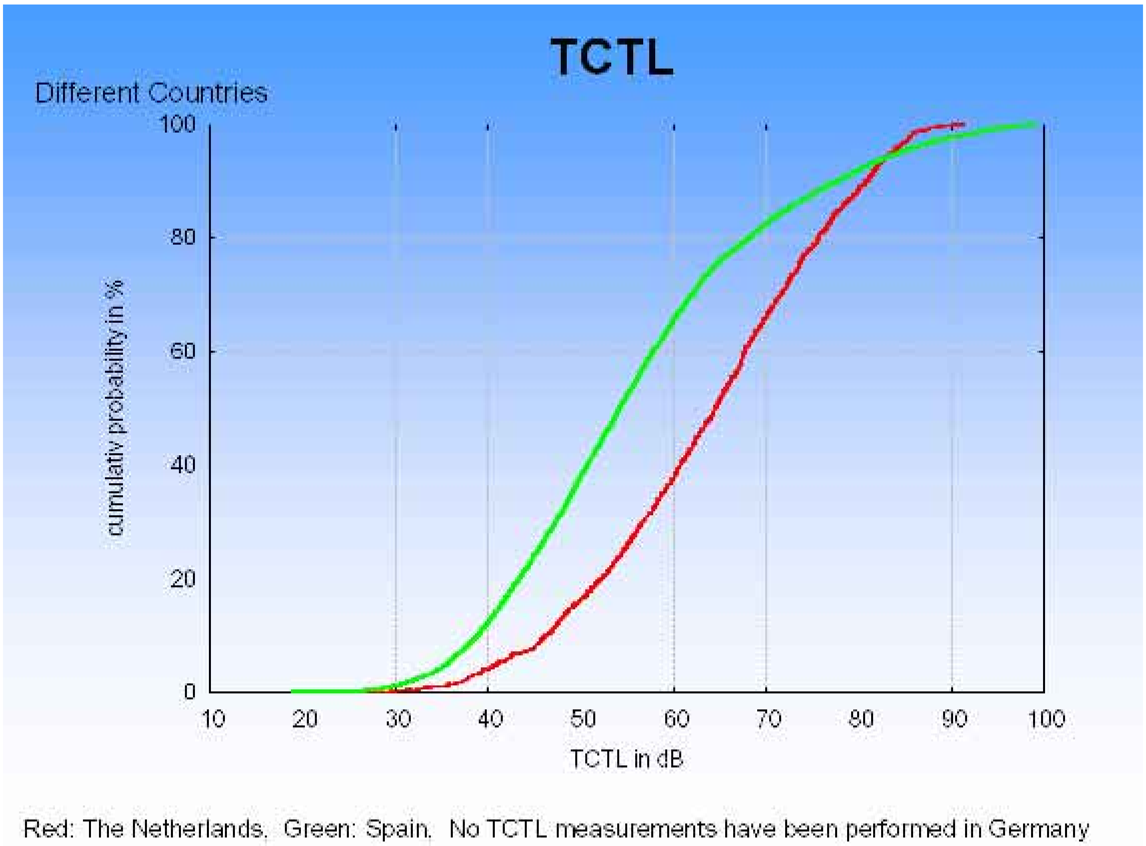


Figure 7.3: TCTL

History

Document history		
V1.1.1	December 2003	Publication