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SERIES G: TRANSMISSION SYSTEMS AND MEDIA,
DIGITAL SYSTEMS AND NETWORKS

Digital sections and digital line system – Access networks

Single-ended line testing for digital subscriber lines (DSL)

Recommendation ITU-T G.996.2

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Recommendation ITU-T G.996.2

Single-ended line testing for digital subscriber lines (DSL)

Summary

Recommendation ITU-T G.996.2 specifies line testing for xDSL transceivers in the form of single-ended line testing (SELT), dual-ended line testing (DELT) and metallic line testing (MELT).

Source

Recommendation ITU-T G.996.2 was approved on 22 May 2009 by ITU-T Study Group 15 (2009-2012) under Recommendation ITU-T A.8 procedures.

FOREWORD

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Recommendation ITU-T G.996.2

Single-ended line testing for digital subscriber lines (DSL)

1 Scope

This Recommendation specifies line testing for use on xDSL lines. This Recommendation contains annexes that describe specifications for single-ended line testing (SELT), dual-ended line testing (DELT) and metallic line testing (MELT). Separate annexes describe physical medium dependent (PMD) and processing functions for SELT, DELT and MELT. An informative appendix is also included describing SELT application models. In this Recommendation, one or more of the line testing (LT) functional blocks may, but are not required to, be the same as the xDSL transceiver unit (xTU) functional block.

2 References

This Recommendation does not contain any references to external documents.

3 Definitions

None.

4 Abbreviations

This Recommendation uses the following abbreviations:

ACS	Automatic Configuration System
ADC	Analogue-to-Digital Conversion
AFE	Analogue Front End
AGC	Automatic Gain Control
CO	Central Office
CPE	Customer Premises Equipment
DELT	Dual-Ended Line Test
DSLAM	DSL Access Multiplexer
DSP-FE	Digital Signal Processor – Front End
HPF	High-Pass Filter
LPF	Low-Pass Filter
LT	Line Test
ME	Management Entity
MELT	Metallic Line Test
MIB	Management Information Base
NSC	Number of SubCarriers
OSS	Operations Support System
PGA	Programmable Gain Amplifier
PMD	Physical Medium Dependent

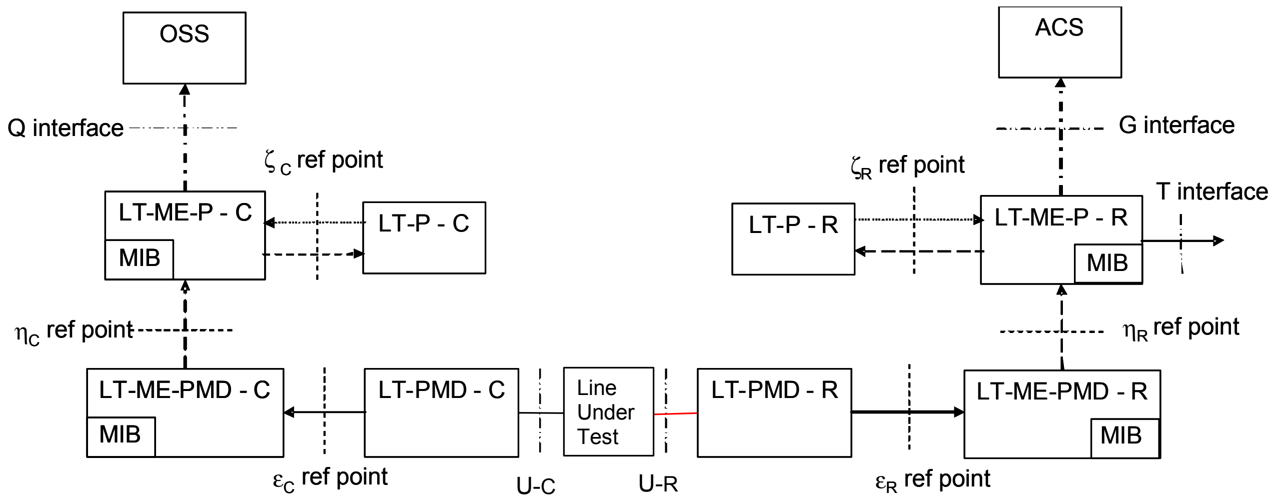
POTS	Plain Old Telephone Service
PSD	Power Spectral Density
QLN	Quiet Line Noise
Rx	Receive
SELT	Single-Ended Line Testing
Tx	Transmit
UER	Uncalibrated Echo Response
xDSL	Any DSL
xTU-C xDSL	Transceiver Unit at the Central side
xTU-R xDSL	Transceiver Unit at the Remote side (e.g., subscriber at the end of the loop)

5 Overview

Line testing involves the measurement of electrical signals on a line, with or without a stimulus applied to the near end or the far end of the loop. These measurements are used to determine measurement parameters which are the basic parameters that characterize the loop and its noise environment. Derived parameters are derived from the measurement parameters and provide specific features of the loop and the noise environment.

5.1 Line test reference model

In order to produce the parameters to be delivered to the management system from observations of the loop connected at one termination side to the U-C interface and at the other side to the U-R interface, a number of distinctive functions can be identified. Each of these functions is represented by a functional block (rectangle) in the functional reference model. Reference points are introduced into the model. Some reference points correspond to functional interfaces. Figure 5-1 depicts the functional reference model.



NOTE – Arrows show flow of data elements only; flow of control elements are bidirectional (not shown)

Figure 5-1 – Functional reference model

There are four functional blocks at each end of a line. The following general descriptions of the functionality of each block apply at both ends of the line but the detail of their functionality may be different at each end.

The first functional block is called the LT-PMD (line test – Physical medium dependent). The LT-PMD function performs measurements on the physical medium to which the line test device is connected. The result of a measurement is a quantity represented as a parameter (one or more dimensional, discrete or continuous). From these parameters, measurement parameters are derived, usually through multiple measurements.

The fact that the functional block is connected to the physical medium motivates calling it "PMD". The prefix LT indicates that this functional block is specific to line testing. However, in some instantiations, this may be the same as, or nearly the same as, instantiations of an xTU-PMD functional block.

The second functional block is called the LT-P (LT – Processing). The LT-P function transforms the measurement parameters into derived parameters. These derived parameters directly reflect the characteristics of the loop under test.

The third functional block is denoted LT-ME-P (LT – Management entity – P) and has the following functionalities:

a) Data plane:
   - to provide an interface point to the OSS, ACS or user for access to both derived and measurement parameters across the Q, G or T interfaces, respectively;
   - to access the measurement parameters in the LT-ME-PMD across the η reference point.

b) Management plane:
   - to manage the LT-P-MIB;
   - to control the functionality of the LT-P across the ζ reference point;
   - to communicate with the far end LT-ME-P across the U interface to coordinate testing and exchange derived and measurement parameters.

The fourth functional block is denoted LT-ME-PMD (LT – Management entity – PMD) and has the following functionalities:

a) Data-plane:
   - to provide to the LT-ME-P access to measurement parameters.

b) Management plane:
   - to manage the LT-PMD-MIB;
   - to control the measurements performed by the LT-PMD across the ε reference point.

The term "LT" in the line test reference model refers to all forms of line test (i.e., SELT, DELT and MELT). In Annexes A and B, which contain SELT requirements, the term "SELT" is used in place of the term "LT". In Annexes C and D, which contain DELT requirements, the term "DELT" is used in place of the term "LT". In Annexes E and F, which contain MELT requirements, the term "MELT" is used in place of the term "LT".

5.2 Test measurements

The test measurements are fundamental electrical measurements. Three types of measurements can be distinguished:

1) Measurements at the near end that are associated with an excitation of the physical medium from the PMD block at the near end.
2) Measurements at the near end that are associated with an excitation of the physical medium from the PMD block at the far end.
3) Measurements that do not require any excitation.

A sequence of measurements of the first two measurement types is defined as the measurements associated with a sequence of corresponding excitations. For the third measurement type, the PMD blocks at either end shall not inject any signal on to the line.

6 Test management and communications

Test management and communications are for further study.

Annex A

Specific requirements of a SELT-PMD

(This annex forms an integral part of this Recommendation)

A.1 SELT-PMD functions

A.1.1 SELT-PMD measurement functions

A.1.1.1 Measurement of uncalibrated echo response

The uncalibrated echo response function UER(f) is defined as the estimated mean value of the voltage ratio *V(f)*/E*(f)* measured inside the SELT-PMD.

$$UER(f) = Estimated\_Mean(X(f)) \quad \text{with} \quad X(f) = \left(\frac{V(f)}{E(f)} \right)$$

where *E(f)* is the excitation signal and *V(f)* the measured signal at frequency *f.*

E(f) is the voltage of a 0 ohm voltage source applied to the SELT-PMD transmitter front end, which transmits a voltage waveform V1+ on the SELT-PMD U-interface. The U-interface is connected to the one-port network (line) under test, that will generate a reflected voltage wave V1–. A linear combination of the voltage waveform V1+ and the reflected voltage wave V1– is transformed by the SELT-PMD receiver front end into a voltage *V(f)* measured with a high impedance voltage measurement unit.

The schematic representation of the SELT-PMD unit is shown in Figure A.1.

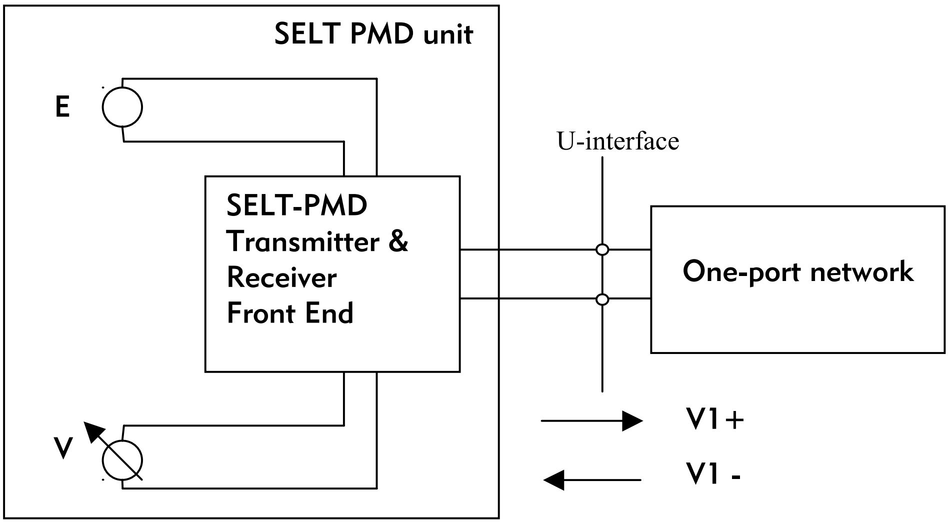


Figure A.1 – SELT-PMD during measurement of "uncalibrated echo response"

The transmit and receive parts of the front end includes all signal conditioning and processing until the U interface (linear time invariant networks, DSP-FE, amplifiers, filters, hybrid, POTS splitters, relays, connectors, protection circuitry, etc.). The SELT-PMD transmitter and receiver front end as a black box shall behave equivalently to a linear time invariant network. As a consequence, the UER(f) shall be independent of the analogue and digital gains used to perform the measurement. However, the UER(f) is the echo response measured without compensation of the time invariant effects of TX and RX AFE linear distortion.

The measurement and estimation duration shall be limited according to the configured SELT UER maximum measurement duration (see clause A.2.1.1). The actual physical line data acquisition time shall increase when the SELT UER maximum measurement duration is increased. This increase may have a step-wise character.

NOTE 1 – SELT-PMD units usually have some freedom when configuring their front ends. However, because calibration arrays are often computed and stored outside of the SELT-PMD, the response of the SELT-PMD should be consistent over time in order for the calibration arrays to be valid. Therefore, it is recommended that the SELT-PMD use the same analogue and digital front-end configurations for all data collection.

NOTE 2 – The requirement that the SELT-PMD transmitter and receiver front end (as a black box) shall behave equivalently to a linear time invariant network may be realized by using fixed settings for the transmit front end and for the receive front end. Alternatively, inside the black box, an implementation may use time/channel dependent analogue gains in the transmitter and/or receiver. It should be noted that in this case it is the responsibility of the UER PMD implementation to compensate these analogue gains in such a way that the external characteristics of the black box are made equivalent to a linear time invariant network to satisfy the accuracy requirements. Digital scaling is inherently linear (except for increased quantization noise). Analogue gain scaling could introduce tolerances and frequency-dependent behaviour that depends on the analogue gain (e.g., gain of the transmit power amplifier, gain of the receive programmable-gain amplifiers (PGAs)). Transmit power amplifiers and receive path PGAs should be set so as to maximize the UER accuracy without incurring into significant non-linear distortion.

NOTE 3 – The SELT-PMD unit should select settings that minimize the attenuation and dispersion through its analogue and digital front ends. Any filters (e.g., high-pass, low-pass, band-pass, notch, and compensation filters) in either the transmit or receive path, that cause the response to deviate from a linear-phase all-pass characteristic, should be disabled if possible.

NOTE 4 – Digital echo cancellers should be turned off. Analogue echo cancellers should not be allowed to adapt during data collection because adaptation invalidates port calibrations and might cancel the desired echo.

A.1.1.2 Measurement of SELT quiet line noise

The quiet line noise SELTQLN(f) is the power spectral density (PSD), referred to a 100 ohm impedance, of the noise present on the line at frequency *f* when no near-end and far-end transmit signals are present on the line.

The quiet line SELTQLN(f) per sub-carrier shall be measured by the near-end receive PMD function.

The measured SELTQLN(f) shall reflect the actual PSD at the near-end U-interface related with the receive PMD. This means that the receive PMD function shall compensate for any used amplifier gains in the receiver and shall perform a best effort attempt to remove any impact of the near-end receiver filter characteristics.

The quiet line noise SELTQLN(f) shall be measured over a time interval complying to the configured SELT quiet line noise maximum measurement duration (see clause A.2.1.2). The actual physical line data acquisition time shall increase when the SELT QLN maximum measurement duration is increased. This increase may have a step-wise character.

Accuracy of SELT quiet line noise is for further study.

A.1.1.3 Measurement of impulse noise

Measurement of impulse noise is for further study.

A.1.1.4 Estimation of uncalibrated echo response variance

Noise during the measurement process of the echo response can lead to variation of the reported parameter UER(f). The uncalibrated echo response variance characterizes this variation.

NOTE – The variance parameter can be used to estimate the precision of UER(f).

To define the uncalibrated echo response variance, the echo measurement is considered to be a random process *X(f)* with expected value or mean value UER(f) as defined in clause A.1.1.1. The quantity UER(f) is derived using a vendor discretionary algorithm.

UER(f) can also be written as:

$UER(f) = E[X(f)]$ where $E[\ ]$ is the mathematical expectation operator.

The variation of UER is characterized by the relative variance of the uncalibrated echo response REL_VAR_UER(f) defined by:

$$REL\_VAR\_UER(f) = 10\log_{10}\left(\frac{VAR\_UER(f)}{|UER(f)|^2}\right)$$

where VAR_UER(f) is defined as

$$VAR\_UER(f) = E\left[|X(f) - UER(f)|^2\right] = E\left[|X(f) - E[X(f)]|^2\right]$$

and $|x|$ denotes the absolute value of a complex valued number x.

The above definition of REL_VAR_UER(f) is an exact definition. The SELT-PMD entity shall report an estimate of this REL_VAR_UER(f). The exact algorithm to estimate the value of VAR_UER(f) estimation process is vendor discretionary.

The estimation of the uncalibrated echo response variance shall be performed within the same time period as the measurement of the uncalibrated echo response (see clause A.1.1.1).

A.2 SELT-PMD management entity

A.2.1 SELT-PMD configuration parameters

A.2.1.1 SELT UER maximum measurement duration

This parameter is the maximum allowed time for SELT uncalibrated echo response measurement, between the time of the start command written by the SELT-PMD-ME, and the time the result is available for read operation by SELT-PMD-ME.

NOTE – The above duration includes internal pre- and post-processing.

It is configurable between 5 seconds and 240 seconds, in steps of 1 second.

A.2.1.2 SELT quiet line noise maximum measurement duration

This parameter is the maximum allowed time for SELT quiet line noise measurement, between the time of the start command written by the SELT-PMD-ME, and the time the result is available for read operation by SELT-PMD-ME.

NOTE – The above duration includes internal pre- and post-processing.

It is configurable between 1 second and 240 seconds, in steps of 1 second.

A.2.2 SELT-PMD measurement parameters

A.2.2.1 SELT uncalibrated echo response

The uncalibrated echo response, UER(i* UER_G*Df), shall be represented in linear format by a scale factor and a normalized complex number a(i)+j*b(i), where i is a frequency index i ranging from 0 to NSC–1, the subcarrier spacing, Df = 4.3125 kHz, and (NSC–1) × UER_G × Df is the highest frequency supported by the SELT-PMD functionality. The UER granularity parameter, UER_G, has two valid values: 1 and 2, indicating whether the measurements were performed using a tone spacing of 4.3125 kHz or of 8.625 kHz. If the uncalibrated echo response is being reported over a frequency range of 17.664 MHz or lower, UER_G shall be set to 1. If the uncalibrated echo response is being reported over a frequency range that is greater than 17.664 MHz, UER_G shall be set to 2.

The scale factor shall be coded as a 32-bit unsigned integer. Both a(i) and b(i) shall be coded as 32-bit 2's complement signed integers. The value of UER(i* UER_G*Df) shall be defined as: UER(i* UER_G*Df) = $(scale/2^{31})*(a(i)+j*b(i))/2^{31}$. In order to maximize precision, the scale factor shall be chosen such that max(|a(i)|, |b(i)|) over all i is equal to $2^{31}-1$.

NOTE – This data format supports an UER(f) granularity of 2^{-31} and an UER(f) dynamic range of approximately +6 dB to –186 dB, however it does not imply any future accuracy requirements.

An UER(i*UER_G* Df) value indicated as a(i) = b(i) = -2^{31} is a special value. It indicates that no measurement could be done for this subcarrier either because it is not supported by the SELT-PMD function, or that the value is out of range to be represented.

A.2.2.2 SELT variance of uncalibrated echo response

The REL_VAR_UER(f) provides the relative variance of the uncalibrated echo response by the SELT-PMD function for each frequency i × UER_G × Df, where i ranges from 0 to NSC–1, Df = 4.3125 kHz, and (NSC-1) × UER_G × Df is the highest frequency supported by the SELT-PMD functionality.

The relative variance of the uncalibrated echo response REL_VAR_UER(i× UER_G ×Df) shall be represented as an 8-bit unsigned integer v(i), where i is the subcarrier index i = 0 to NSC–1. The value of REL_VAR_UER(i× UER_G ×Df) shall be defined as REL_VAR_UER(i× UER_G ×Df) = 3 – v(i)/2 dB. The number v(i) is an 8-bit unsigned integer in the range 0 to 254. This data format supports a REL_VAR_UER(i) over a range from –124 dB to +3 dB for each carrier with a granularity from 0.5 dB. Out of range values shall be clamped to the closest range bound. The special value v(i) = 255 indicates that no measurement is available for that carrier.

A.2.2.3 SELT quiet line noise

The SELT quiet line noise provides the quiet line noise PSD as measured by the SELT-PMD function (see clause A.1.1.2) for each sub-carrier frequency i × SELTQLN_G × Df where i ranges from 0 to NSC–1, Df = 4.3125 kHz, and (NSC–1) × SELTQLN_G × Df is the highest frequency supported by the SELT-PMD functionality. SELTQLN_G has two valid values: 1 and 2, indicating whether the measurements were performed using a tone spacing of 4.3125 kHz or of 8.625 kHz. If the SELT quiet line noise is being reported over a frequency range of 17.664 MHz or lower, SELTQLN_G shall be set to 1. If the SELT quiet line noise is being reported over a frequency range that is greater than 17.664 MHz, SELTQLN_G shall be set to 2.

SELT quiet line noise SELTQLN(i × SELTQLN_G × Df) shall be represented as an 8-bit unsigned integer n(i), where i is the subcarrier index i = 0 to NSC–1. The value of SELTQLN(i × SELTQLN_G × Df) shall be defined as SELTQLN(i × SELTQLN_G × Df) = –23 – (n(i)/2) dBm/Hz. This data format supports a SELTQLN(f) granularity of 0.5 dB and an SELTQLN(f) dynamic range of –150 to –23 dBm/Hz.

A.2.2.4 SELT impulse noise parameters

Impulse noise parameters are for further study.

A.2.3 SELT control parameters

A.2.3.1 SELT UER measurement enable C (SELT-UME-C)

This parameter is a binary variable, where "1" triggers the CO SELT PMD to start a UER measurement.

A.2.3.2 SELT UER measurement enable R (SELT-UME-R)

This parameter is a binary variable, where "1" triggers the CPE SELT PMD to start a UER measurement.

A.2.3.3 SELT QLN measurement enable C (SELT-QME-C)

This parameter is a binary variable, where "1" triggers the CO SELT PMD to start a QLN measurement.

A.2.3.4 SELT QLN measurement enable R (SELT-QME-R)

This parameter is a binary variable, where "1" triggers the CPE SELT PMD to start a QLN measurement.

A.2.4 SELT-PMD parameter partitioning

This clause defines the parameters which correspond to the specific reference points:

- η_C reference point.
- η_R reference point.

The parameters at the reference points are described by the following table, which indicates the status of the parameter at the corresponding reference points as:

- R are read only.
- W are write only.
- R/W are read and write.
- (M) are mandatory.
- (O) are optional.

R and W are defined as:

- η_C reference point:
  - W: parameter written by the SELT-ME-P-C to the SELT-ME-PMD-C.
  - R: parameter provided by the SELT-ME-PMD-C to be read by the SELT-ME-P-C.
- η_R reference point:
  - W: parameter written by the SELT-ME-P-R to the SELT-ME-PMD-R.
  - R: parameter provided by the SELT-ME-PMD-R to be read by the SELT-ME-P-R.

Table A.1 – Partitioning of SELT-PMD-ME parameters

Category/element	Defined in clause	η_C – reference point	η_R – reference point
SELT-PMD configuration parameters			
SELT UER maximum measurement duration C (SELT_UER_MMD_C)	A.2.1.1	R/W (M)	
SELT UER maximum measurement duration R (SELT_UER_MMD_R)	A.2.1.1		R/W (M)
SELT quiet line noise maximum measurement duration C (SELT_QLN_MMD_C)	A.2.1.2	R/W (M)	
SELT quiet line noise maximum measurement duration R (SELT_QLN_MMD_R)	A.2.1.2		R/W (M)

Table A.1 – Partitioning of SELT-PMD-ME parameters

Category/element	Defined in clause	η_C – reference point	η_R – reference point
SELT-PMD measurement parameters			
SELT uncalibrated echo response C (SELT-UER-C)	A.2.2.1	R (M)	
SELT uncalibrated echo response R (SELT-UER-R)	A.2.2.1		R (M)
SELT variance of uncalibrated echo response C (SELT-UER-VAR-C)	A.2.2.2	R (M)	
SELT variance of uncalibrated echo response R (SELT-UER-VAR-R)	A.2.2.2		R (M)
SELT quiet line noise C (SELT_QLN_C)	A.2.2.3	R (M)	
SELT quiet line noise R (SELT_QLN_R)	A.2.2.3		R (M)
SELT-PMD control parameters			
SELT UER measurement enable C (SELT-UME-C)	A.2.3.1	W(M)	
SELT UER measurement enable R (SELT-UME-R)	A.2.3.2		W(M)
SELT QLN measurement enable C (SELT-QME-C)	A.2.3.3	W(M)	
SELT QLN measurement enable R (SELT-QME-R)	A.2.3.4		W(M)

A.3 Test management and communications

Test management and communications are for further study.

Annex B

Specific requirements of a SELT-P

(This annex forms an integral part of this Recommendation)

B.1 SELT-P functions

B.1.1 SELT-P derived parameters

B.1.1.1 Loop termination indicator

Loop termination indicator is a three state indication of the loop termination defined as follows.

- 'Open',
- 'Short',
- 'Powered on CPE',
- 'Unknown' (i.e., failure in identifying the termination).

Accuracy is for further study.

B.1.1.2 Loop length

This parameter is the physical length (in metres) of the loop between the U-C and the U-R interface.

The loop length shall be measured with a granularity of 1 m, with valid range of 0 to 16'383 m.

Accuracy is for further study.

B.1.1.3 Loop topology

The loop topology consists of a description of the loop structure, with indication of the physical length of each loop segment. In this parameter, a loop segment is defined as delimited by either a loop termination, or the presence of a bridged tap.

NOTE 1 – Two cables with different gauges/cable-types connected in series are considered as a single loop segment.

The loop topology is reported as a list of loop segments, using the following conventions:

1) The first loop segment in the list shall be the segment connected to the SELT-PMD block measuring the SELT-PMD measurement parameters (i.e., the SELT-PMD block shall be the starting point of the topology description).
2) Subsequent loop segments in the list shall describe the loop in the direction toward the far-end loop termination.
3) Consecutive loop segments indicated as 'bridged tap' represent bridged taps, each branching off from the main loop at the same point.

NOTE 2 – Identification of a bridged tap branching off on a bridged tap is not supported by this parameter.

A single loop segment is specified with two sub-parameters: loop segment length (see clause B.1.1.3.1) and loop segment bridged tap indicator (see clause B.1.1.3.2).

If this parameter is supported, reporting of up to three segments is a mandatory capability. Reporting of additional segments is optional.

Accuracy is for further study.

B.1.1.3.1 Loop segment length (LOOP_SEGM_LENGTH)

This parameter specifies the physical length of the loop segment, in metres.

The loop segment length shall be measured with a granularity of 1 m, with a valid range of 0 to 16'383 m.

B.1.1.3.2 Loop segment bridged tap indicator (LOOP_SEGM_BRIDGEDTAP)

This parameter specifies whether the loop segment is a bridged tap or arranged in series (i.e., not branching, not a bridged tap).

The valid values are:

- 'in series',
- 'bridged tap'.

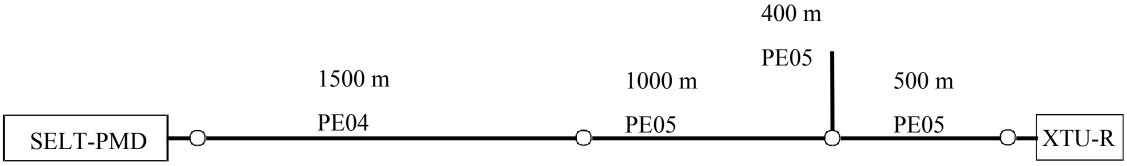


Figure B.1 – Example of loop

Table B.1 – Values of loop topology identification for the example loop

Loop topology	
LOOP_SEGM_LENGTH	**LOOP_SEGM_BRIDGEDTAP**
2500	0
400	1
500	0

B.1.1.4 Missing micro-filter or splitter

This parameter is a binary indication of a missing or incorrectly installed splitter or micro-filter at the U-R reference point. A value of 1 for this flag represents a missing splitter.

This parameter is only defined for the SELT-P-R functionality.

Accuracy is for further study.

B.1.1.5 Impulse noise statistics

Impulse noise statistics are for further study.

B.1.1.6 Attenuation characteristics

The line attenuation TFlog(f) is the logarithmic power transfer function of the line as a function of frequency when both the near-end and far-end line terminations have the following values:

- Source impedance = purely resistive equal to 100 ohms.
- Termination impedance = purely resistive equal to 100 ohms.

$$TF_{\log}(f) = 10\log_{10}\left(\left|\frac{V_{OUTPUT}(f)}{V_{INPUT}(f)}\right|^2\right)$$

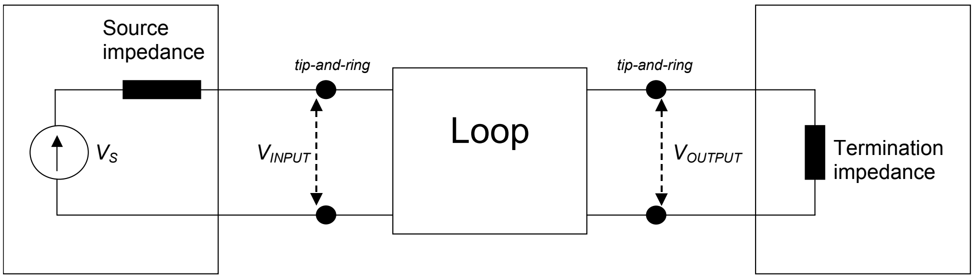


Figure B.2 – Attenuation characteristic

The function TFlog(f) consists of an array of values TFlog(i × Df), with Df = 4.3125 kHz.

NOTE – In the case where the instantiation of the LT unit is the same as the instantiation of the xTU transceiver unit, this value may be independent of the subcarrier spacing used for the xDSL DMT modulation.

The range of valid values for the index *i* is 0 to 8191.

The range of valid values for TFlog(i × Df) is from +6.0 dB down to –96.2 dB, with a granularity of 0.1 dB. A special value is used to indicate that no measurement could be done for this subcarrier because the attenuation is out of the range that can be represented.

Accuracy is for further study.

B.1.1.7 Capacity estimate

This parameter represents a best-effort estimate of the achievable net data rate (in kbit/s) on the loop under test, under the following assumptions:

- Fast mode (i.e., operation with interleaver depth D=1, and INP=0 (no impulse noise protection));
- use of Trellis coding;
- target margin equal to CAP-TARSNRM (see clause B.2.1.4);
- transmit signal PSD at the U-interface of the xTU-transmitter equal to CAP-SIGNALPSD (see clause B.2.1.2);
- noise PSD at the U-interface of the xTU-receiver equal to CAP-NOISEPSD (see clause B.2.1.3);
- support of bit loading from 1 to 15 bits included, in steps of 1 bit increments.

As the capacity is a best-effort estimate, accuracy for this parameter is vendor proprietary.

The parameter in the downstream direction is CAPACITYds, and the parameter in the upstream direction is CAPACITYus.

B.2 SELT-P management entity

B.2.1 SELT-P configuration parameters

B.2.1.1 Capacity estimate calculation enabling (CECE)

This parameter specifies if the SELT-P function shall perform the "downstream capacity" and "upstream capacity" estimations, if supported. This parameter is expressed as a binary flag and takes the value 0 if xDSL performance estimation is not required, 1 otherwise.

B.2.1.2 Capacity estimate signal PSD (CAP-SIGNALPSD)

This configuration parameter defines the PSD template of the transmit signal to be used in capacity estimate evaluation.

The PSD template CAP-SIGNALPSD shall be specified through a set of breakpoints. Each breakpoint shall consist of a frequency index, t_n, and a signal PSD level (expressed in dBm/Hz). The parameter shall be a set of breakpoints represented by $[(t_1, PSD_1), (t_2, PSD_2), \ldots, (t_N, PSD_N)]$, where t_1 and t_N represent, respectively, the lower frequency of the lowest band over which the capacity estimate is to be calculated, and the highest frequency of highest band over which the capacity estimate is to be calculated. In the case of an estimation of capacity for a multi-band xDSL, the set of breakpoints shall describe the stopbands situated inbetween passbands.

NOTE – Stopbands may be described as brickwall stopbands using the lowest valid value (–200 dBm/Hz) or may be described more elaborately.

The breakpoints shall be defined so that $t_n < t_{n+1}$ for $n = 1$ to $N - 1$. The frequency f_n corresponding to the index t_n can be found as: $f_n = t_n \times Df$. The value of $Df = 4.3125$ kHz and is independent of the subcarrier spacing used for the DMT modulation of the xDSL.

The range of valid values for index t_n is 0 to 8191 in steps of 1. The range of valid values for PSD is –30 to –200 dBm/Hz in steps of 0.1 dBm/Hz.

The PSD template in dBm/Hz, for any frequency $f = i \times Df$, shall be obtained by linear interpolation in dB on a linear frequency scale, as follows:

$$CAP-SIGNALPSD\ (i) = PSD_n + \left(PSD_{n+1} - PSD_n\right) \times \frac{(i - t_n)}{(t_{n+1} - t_n)} \quad t_n < i \le t_{n+1}$$

The parameter in the downstream direction is CAP-SIGNALPSDds, and the parameter in the upstream direction is CAP-SIGNALPSDus.

The maximum number of breakpoints in downstream is 48, and in upstream 48.

B.2.1.3 Capacity estimate noise PSD (CAP-NOISEPSD)

This configuration parameter defines the PSD template of the received noise to be used in capacity estimate evaluation.

The PSD template CAP-NOISEPSD shall be specified through a set of breakpoints. Each breakpoint shall consist of a frequency index t_n and a signal PSD level (expressed in dBm/Hz). The parameter shall be a set of breakpoints that are represented by $[(t_1, PSD_1), (t_2, PSD_2), \ldots, (t_N, PSD_N)]$, where t_1 and t_N are, respectively, the lower frequency of the lowest band over which the capacity estimate is to be calculated, and the highest frequency of highest band over which the capacity estimate is to be calculated.

In the case of an estimation of capacity for a multi-band xDSL, with the CAP-SIGNALPSD stopbands described as brickwall stopbands, the set of breakpoints for CAP-NOISEPSD is not required to describe the noise in the stopbands situated inbetween passbands. In case the CAP-SIGNALPSD stopbands are not described as brickwall stopbands, the set of breakpoints for CAP-NOISEPSD shall describe the noise in the stopbands situated inbetween passbands.

The breakpoints shall be defined so that $t_n < t_{n+1}$ for $n = 1$ to $N - 1$. The frequency f_n corresponding to the index t_n can be found as: $f_n = t_n \times Df$. The value of $Df = 4.3125$ kHz and is independent of the subcarrier spacing used for the DMT modulation of the xDSL.

The range of valid values for index t_n is 0 to 8191, in steps of 1. The range of valid values for PSD is –30 to –200 dBm/Hz, in steps of 0.1 dBm/Hz.

The PSD template in dBm/Hz, for any frequency $f = i \times Df$, shall be obtained by linear interpolation in dB on a linear frequency scale as follows:

$$CAP-NOISEPSD(i)=PSD_n+\left(PSD_{n+1}-PSD_n\right)\times\frac{(i-t_n)}{(t_{n+1}-t_n)}\quad t_n<i\leq t_{n+1}$$

The parameter in the downstream direction is CAP-NOISEPSDds, and the parameter in the upstream direction is CAP-NOISEPSDus.

The maximum number of breakpoints in downstream is 128, and in upstream 128.

B.2.1.4 Capacity estimate target noise margin (CAP-TARSNRM)

This is the noise margin to be used in capacity estimate evaluation, relative to a BER requirement of 1E-7.

The range of valid values for CAP-TARSNRM expressed in dB is 0 to 31 dB, in steps of 0.1 dB.

The parameter in the downstream direction is CAP-TARSNRMds, and the parameter in the upstream direction is CAP-TARSNRMus.

B.2.2 SELT-P derived parameters

B.2.2.1 Loop termination indicator

The parameter in the SELT-P ME shall have the same format as the one specified for the SELT-P.

B.2.2.2 Loop length

The parameter in the SELT-P ME shall have the same format as the one specified for the SELT-P.

B.2.2.3 Loop topology

The parameter in the SELT-P ME shall have the same format as the one specified for the SELT-P.

B.2.2.4 Missing micro-filter or splitter

The parameter in the SELT-P ME shall have the same format as the one specified for the SELT-P.

B.2.2.5 Impulse noise statistics

Impulse noise statistics are for further study.

B.2.2.6 Attenuation characteristics

The parameter in the SELT-P ME shall have the same format as the one specified for the SELT-P.

B.2.2.7 Capacity estimate

The parameter in the SELT-P ME shall have the same format as the one specified for the SELT-P.

B.2.3 SELT-PMD network management element partitioning

This clause defines the network management elements which correspond to the specific management interfaces:

- Q-interface,
- G-interface,
- T-interface.

The parameters at the management interfaces are described in the following table, which indicates the status of the parameter at the corresponding management interface as:

- R are read only.
- W are write only.

- R/W are read and write.
- (M) are mandatory.
- (O) are optional.

Table B.2 – Partitioning of SELT-P-ME reporting parameters

Category/element	Defined in clause	Q-interface	G-interface	T-interface
SELT-P parameters				
SELT-P derived parameters				
Loop termination indicator (LOOP-TERM)	B.2.2.1	R (M)	R (O)	
Loop length (LOOP_LEN)	B.2.2.2	R (M)	R (O)	
Loop topology (LOOP-TOPOLOGY)	B.2.2.3	R (O)	R (O)	
Attenuation characteristics TFlog(f) (ATT-CHAR)	B.2.2.6	R (O)	R (O)	
Missing micro-filter or splitter (MIS-FILTER)	B.2.2.4		R (O)	
Capacity estimate (CAP-EST)	B.2.2.7	R (O)	R (O)	
SELT-P configuration parameters				
Capacity estimate calculation enabling (CECE)	B.2.1.1	R/W (O)	R/W (O)	
Capacity estimate signal PSD (CAP-SIGNALPSD)	B.2.1.2	R/W (O)	R/W (O)	
Capacity estimate noise PSD (CAP-NOISEPSD)	B.2.1.3	R/W (O)	R/W (O)	
Capacity estimate target noise margin (CAP-TARSNRM)	B.2.1.4	R/W (O)	R/W (O)	
SELT-PMD parameters				
SELT-PMD measurement parameters				
SELT uncalibrated echo response C (SELT-UER-C)	A.2.2.1	R (M)		
SELT uncalibrated echo response R (SELT-UER-R)	A.2.2.1		R (M)	R(M)
SELT variance of uncalibrated echo response C (SELT-UER-VAR-C)	A.2.2.2	R (M)		
SELT variance of uncalibrated echo response R (SELT-UER-VAR-R)	A.2.2.2		R (M)	R(M)
SELT quiet line noise C (SELT_QLN_C)	A.2.2.3	R (M)		
SELT quiet line noise R (SELT_QLN_R)	A.2.2.3		R (M)	R(M)
SELT-PMD configuration parameters				
SELT UER maximum measurement duration C (SELT_UER_MMD_C)	A.2.1.1	R/W (M)		
SELT UER maximum measurement duration R (SELT_UER_MMD_R)	A.2.1.1		R/W (M)	R/W(M)

Table B.2 – Partitioning of SELT-P-ME reporting parameters

Category/element	Defined in clause	Q-interface	G-interface	T-interface
SELT quiet line noise maximum measurement duration C (SELT_QLN_MMD_C)	A.2.1.2	R/W (M)		
SELT quiet line noise maximum measurement duration R (SELT_QLN_MMD_R)	A.2.1.2		R/W (M)	R/W(M)
SELT-PMD control parameters				
SELT UER measurement enable C (SELT-UME-C)	A.2.3.1	W(M)		
SELT UER measurement enable R (SELT-UME-R)	A.2.3.2		W(M)	W(M)
SELT QLN measurement enable C (SELT-QME-C)	A.2.3.3	W(M)		
SELT QLN measurement enable R (SELT-QME-R)	A.2.3.4		W(M)	W(M)

B.3 Test management and communications

Test management and communications are for further study.

Annex C

Specific requirements for a DELT-PMD

(This annex forms an integral part of this Recommendation)

Specific requirements for a DELT-PMD are for further study.

Annex D

Specific requirements for a DELT-P

(This annex forms an integral part of this Recommendation)

Specific requirements for a DELT-P are for further study.

Annex E

Specific requirements for a MELT-PMD

(This annex forms an integral part of this Recommendation)

E.1 MELT-PMD functions

MELT-PMD functions are applicable at the η_C reference point only.

Various implementations of the MELT-PMD feature are possible including the use of a common functional block shared among multiple lines and capable of executing the procedures described herein on the basis of one line at a time.

It is assumed that the MELT-PMD measurements are performed when there is no transmission in the frequency band up to 4 kHz on the loop under test. The method of ensuring this is beyond the scope of this Recommendation.

E.1.1 MELT-PMD measurement functions

The maximum allowed time for single or combined measurement (see clause E.2.1.1), excluding the processing time in the MELT-P, shall not exceed 20 seconds for a test sequence made of foreign DC and AC voltage, 4-element resistance with a controlled metallic voltage, and 3-element capacitance with a controlled metallic voltage.

E.1.1.1 Measurement of the 4-element DC resistance with a controlled metallic voltage

This parameter defines a measurement, or a series of measurements, to measure the relevant resistance values from an equivalent DC resistance network located between tip, ring and GND as shown in Figure E.1.

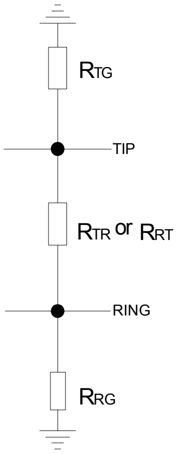


Figure E.1 – DC resistance between tip, ring and GND

Four resistance values R_{XY} shall be reported:

1) R_{TR} – DC resistance between tip and ring
2) R_{RT} – DC resistance between ring and tip
3) R_{TG} – DC resistance between tip and GND
4) R_{RG} – DC resistance between ring and GND

R_{TR} is measured with a voltage applied between tip and ring such that tip is positive with respect to ring. A reversed voltage is applied between the tip and ring leads for the measurement of R_{RT}.

In the case where the metallic branch elements, R_{TR} or R_{RT}, may be in parallel with a signature network containing a non-linear element such as a zener diode, it will be required to limit the metallic test voltage such as to remain below the conduction threshold when measuring the cable leakage resistances. To this effect, the metallic voltage used by this procedure shall be lower than the minimum far-end signature conduction voltage configuration parameter (see clause E.2.1.6).

The accuracy of this parameter is for further study.

E.1.1.2 Measurement of the 3-element capacitance with a controlled metallic voltage

This parameter defines a measurement, or a series of measurements, to measure the capacitance of the cable plus line equipment, if present, from an equivalent AC network located between tip, ring and GND as shown in Figure E.2.

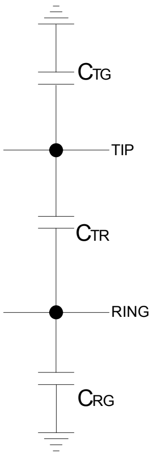


Figure E.2 – Capacitance between tip, ring and GND

The capacitance C_{XY} is defined as the measured capacitance between nodes X and Y. The measuring method for C_{XY} is vendor discretionary.

Three capacitance values C_{XY} shall be reported:

1) C_{TR} – Capacitance between tip and ring
2) C_{TG} – Capacitance between tip and GND
3) C_{RG} – Capacitance between ring and GND

In the case where the metallic branch element, C_{TR}, may be in parallel with a signature network containing a non-linear element such as a zener diode, it will be required to limit the metallic test voltage such as to remain below the conduction threshold when measuring the cable capacitances. To this effect, the metallic voltage used by this procedure shall be lower than the minimum far-end signature conduction voltage configuration parameter (see clause E.2.1.6).

The accuracy of this parameter is for further study.

E.1.1.3 Measurement of foreign voltages

Foreign voltages may occur differentially between tip and ring, in common mode between tip/ring and GND, or be single-ended, between tip and GND or between ring and GND. Therefore, three types of V_{XY} measurements are defined:

1) V_{TR} – Foreign voltage between tip and ring
2) V_{TG} – Foreign voltage between tip and GND

3) V_{RG} – Foreign voltage between ring and GND

The measurement parameter foreign voltage (see clause E.2.3.3) shall be reported for each of the three types, including the following information:

- Foreign DC voltage level ($V_{XY,DC}$)
- Foreign AC rms voltage level ($V_{XY,AC}$)
- Foreign AC voltage frequency ($f_{XY,AC}$) estimated on the basis that the foreign AC voltage is sine-shaped with a constant frequency.

When measuring the foreign voltages, the input impedance of the measuring instrument can affect the measurement and should be reported in addition to the results.

The accuracy of this parameter is for further study.

E.1.1.4 Measurement of the loop capacitance with a high metallic voltage

The loop capacitance $C_{TR,HV}$ is defined as the measured capacitance between tip and ring, using a high voltage to conduct current through the zener diode located in the far-end signature (see clause E.2.1.5). To this effect, the metallic voltage used by this procedure shall be higher than the maximum far-end signature conduction voltage configuration parameter (see clause E.2.1.5).

The measuring method is vendor discretionary.

The accuracy of this parameter is for further study.

E.1.1.5 Measurement of the loop resistance with a high metallic voltage

The loop resistances $R_{TR,HV}$ and $R_{RT,HV}$ are defined as the measured resistance between tip and ring and between ring and tip, respectively, using a high voltage to conduct current through the zener diode located in the far-end signature (see clause E.2.1.5). To this effect, the metallic voltage used by this procedure shall be higher than the maximum far-end signature conduction voltage configuration parameter (see clause E.2.1.5).

In order to identify the loop resistance, a dynamic resistance measurement using at least two voltages levels may be performed. However, the measuring method is at the vendor's discretion.

The accuracy of this parameter is for further study.

E.1.1.6 Measurement of the 3-element complex admittances with a controlled metallic voltage

When measuring a signature network made of a resistor in series with a capacitor, a simple 3-element capacitance measurement may not produce the correct component values depending on the load network topology. Better visibility is obtained by performing a test that takes the phase of the load impedance into consideration and reports its real and imaginary parts.

Three different types of admittance are defined using the following relationship:

$$Y_{XY} = G_{XY} + j \cdot B_{XY}$$

1) G_{TR}, B_{TR} – Conductance and susceptance between tip and ring
2) G_{TG}, B_{TG} – Conductance and susceptance between tip and GND
3) G_{RG}, B_{RG} – Conductance and susceptance between ring and GND

The measuring method is vendor discretionary.

In the case where the metallic branch element, G_{TR} and B_{TR}, may be in parallel with a signature network containing a non-linear element such as a zener diode, it will be required to limit the metallic test voltage such as to remain below the conduction threshold when measuring the cable admittances. To this effect, the metallic voltage used by this procedure shall be lower than the minimum far-end signature conduction voltage configuration parameter (see clause E.2.1.6).

NOTE – If the tip-to-ground and ring-to-ground impedances are large in comparison to the tip-to-ring impedance, the testing time can be reduced by only measuring the impedance in the metallic branch instead of executing the 3-element resistance and capacitance measurements.

The accuracy of this parameter is for further study.

E.1.1.7 Measurement of the loop complex admittance with a high metallic voltage

The loop branch elements $G_{TR,HV}$ and $B_{TR,HV}$ are defined as the measured conductance and susceptance between tip and ring, using a high voltage to conduct current through the zener diode located in the far-end signature (see clause E.2.1.5). To this effect, the metallic voltage used by this procedure shall be higher than the maximum far-end signature conduction voltage configuration parameter (see clause E.2.1.5).

The measurement is performed on the basis of a linear load and does not modify the result to compensate for the cross-over distortion introduced by the zener diode. To this effect, the metallic voltage applied between tip and ring should be set to a value well above the conduction threshold of the zener diode.

The measuring method is vendor discretionary.

The accuracy of this parameter is for further study.

E.1.2 MELT-PMD non-measurement functions

E.1.2.1 Pair identification tone generation

This function shall be used to generate a tone in the frequency range defined in clause E.2.1.4 at a signal level of at least 120 mVrms but not higher than 330 mVrms on 600 ohms between tip and ring of the MELT-PMD unit. The actual level is vendor discretionary. This function does not report any measurement result to the MELT-ME-PMD. In order to identify the individual wires (tip or ring), a DC voltage of 10 V ±2 V shall be superimposed on the pair identification tone between tip and ring such that the tip wire is positive with respect to the ring wire.

NOTE – The generated tone may be listened to or detected by a field technician.

E.2 MELT-PMD management entity

E.2.1 MELT-PMD configuration parameters

E.2.1.1 Measurement class

This parameter defines the list of measurements to be executed. It shall support a single measurement or a set of MELT measurements in a consecutive manner. The measurements of interest are selected via a flag register, or equivalent.

E.2.1.2 Peak metallic voltage between tip and ring

This parameter defines the peak metallic voltage which must not be exceeded in any active measurement applying a metallic voltage between tip and ring in order not to conduct current in a non-linear termination located at the far-end during the measurement. The range of valid values is from 0 to 100 V with a granularity of 1 V. In the case of a test performed with a sinewave signal, it applies to the peak of the sinewave, not to its rms value.

E.2.1.3 Signal frequency for active AC tests

This parameter controls the frequency used during the 3-element capacitance test, if performed with a sinewave signal, and during the 3-element complex admittance test. This parameter shall be represented in linear format with values from 10 to 1000 Hz with a granularity of 1 Hz.

The supported set of frequencies is at the vendor's discretion with an option to operate in automatic mode for which the testing routine will select the frequency on its own.

E.2.1.4 Pair identification tone frequency

This parameter sets up frequency of the pair identification tone as defined in clause E.1.2.1. The range of frequencies is from 300 to 3400 Hz in granularity of 1 Hz.

The supported set of frequencies is at the vendor's discretion.

E.2.1.5 Maximum far-end signature conduction voltage

This parameter specifies the maximum conduction voltage level of an expected far-end signature. It defines the minimum metallic voltage required for all measurements with a high metallic voltage between tip and ring in order to conduct current in a far-end signature during the measurement. The range of valid values is from 0 to 50 V with a granularity of 0.1 V.

E.2.1.6 Minimum far-end signature conduction voltage

This parameter specifies the minimum conduction voltage level of an expected far-end signature. It defines the maximum metallic voltage allowed for all measurements with a controlled metallic voltage between tip and ring in order not to conduct current in a far-end signature during the measurement. The range of valid values is from 0 to 50 V with a granularity of 0.1 V. In the case of a measurement performed with a sinewave signal, it applies to the peak of the sinewave, not to its rms value.

E.2.2 MELT-PMD reporting parameters

E.2.2.1 Measurement frequency for active AC tests

This parameter is the measurement frequency for a 3-element capacitance measurement, if performed with a sinewave signal, or a for 3-element complex admittance measurement. The range of valid values is from 10 to 1000 Hz with a granularity of 1 Hz.

E.2.2.2 Input impedance for foreign voltage measurements

This parameter reports the nominal input impedance of the measuring instrument during foreign voltage tests. The range of valid values is from 0 to 10 MΩ with a granularity of 1 Ω.

E.2.2.3 Test voltage for measurement of the loop complex admittance with a high metallic voltage

This parameter is the peak amplitude of the differential sinewave used by the measurement of the loop complex admittance with a high voltage metallic test (see clause E.1.1.7). The range of valid values is from 0 to 100 V and it shall be represented in linear format with a granularity of 0.1 V.

E.2.3 MELT-PMD measurement parameters

E.2.3.1 4-element DC resistance with controlled metallic voltage

The 4-element DC resistances R_{TR}, R_{RT}, R_{TG} and R_{RG}, shall be represented in linear format. The range of valid values is from 0 to 10 MΩ with a granularity of 1 Ω.

NOTE – The linear format is chosen for simplicity reason and does not imply any future accuracy requirements.

E.2.3.2 3-element capacitance with controlled metallic voltage

The 3-element capacitances C_{TR}, C_{TG} and C_{RG}, shall be represented in linear format. The range of valid values is from 0 to 5 µF with a granularity of 0.1 nF.

NOTE – The linear format is chosen for simplicity reason and does not imply any future accuracy requirements.

E.2.3.3 Foreign voltage

The range of valid values for the foreign DC voltages $V_{TR,DC}$, $V_{TG,DC}$ and $V_{RG,DC}$ is from –350 to 350 V. The range of valid values for the foreign AC voltages $V_{TR,AC}$, $V_{TG,AC}$ and $V_{RG,AC}$ is from 0 to 250 Vrms. The foreign AC and DC voltages shall be represented in linear format with a granularity of 100 mV. The range of valid values for the foreign AC voltage frequency is from 10 to 90 Hz with a granularity of 0.1 Hz.

NOTE – The voltage actually present on the tip and ring leads may be limited by the presence of protection components.

The reported DC voltage polarity is defined with respect to ground for the $V_{TG,DC}$ and $V_{RG,DC}$ measurements and returns a positive result for the $V_{TR,DC}$ measurement if the tip wire is more positive than the ring wire.

E.2.3.4 Loop capacitance with high metallic voltage

The loop capacitance $C_{TR,HV}$ shall be represented in linear format. The range of valid values is from 0 to 5 µF with a granularity of 0.1 nF. The $C_{TR,HV}$ value of the loop capacitance with high metallic voltage test is the total capacitance measured. The C_{TR} value obtained from the 3-element capacitance with controlled metallic voltage test is not subtracted from the results.

NOTE – The linear format is chosen for simplicity reason and does not imply any future accuracy requirements.

E.2.3.5 Loop resistance with high metallic voltage

The loop resistances $R_{TR,HV}$ and $R_{RT,HV}$ shall be represented in linear format. The range of valid values is from 0 to 10 MΩ with a granularity of 1 Ω. The $R_{TR,HV}$ and $R_{RT,HV}$ values of the loop resistance with high metallic voltage test are the total resistances measured. The R_{TR} and R_{RT} values obtained from the 3-element resistance with controlled metallic voltage test are not subtracted from the results.

NOTE – The linear format is chosen for simplicity reason and does not imply any future accuracy requirements.

E.2.3.6 3-element complex admittance with controlled metallic voltage

The range of valid values for the 3-element complex conductances and susceptances G_{TR}, B_{TR}, G_{TG}, B_{TG}, G_{RG} and B_{RG} is from 0.1 µSiemens to 0.1 Siemens. The values shall be represented in linear format with a granularity of 0.1 µSiemens.

NOTE – The linear format is chosen for simplicity reason and does not imply any future accuracy requirements.

E.2.3.7 Loop complex admittance with high metallic voltage

The range of valid values for the 3-element complex conductance and susceptance $G_{TR,HV}$, and $B_{TR,HV}$ is from 0.1 µSiemens to 0.1 Siemens. The values shall be represented in linear format with a granularity of 0.1 µSiemens. The $G_{TR,HV}$ and $B_{TR,HV}$ values of the loop complex admittance with high metallic voltage test are the total conductance and susceptance measured. The G_{TR} and B_{TR} values obtained from the 3-element complex admittance with controlled metallic voltage test are not subtracted from the results.

NOTE – The linear format is chosen for simplicity reason and does not imply any future accuracy requirements.

E.2.4 MELT-PMD parameter partitioning

This clause defines the parameters which correspond to the η_C reference point.

The parameters at the η_C reference point are described by Table E.1 indicating the status of the parameter as:

- R are read only.
- W are write only.
- R/W are read and write.
- (M) are mandatory.
- (O) are optional.

R and W are defined as:

- W: parameter written by the MELT-ME-P-C to the MELT-ME-PMD-C.
- R: parameter provided by the MELT-ME-PMD-C to be read by the MELT-ME-P-C.

Table E.1 – Partitioning of MELT-ME-PMD parameters

Category/element	**Defined in clause**	**η_C - reference point**
MELT-PMD configuration parameters		
Measurement class (MELT-MCLASS)	E.2.1.1	R/W (O)
Peak metallic voltage between tip and ring (MELT-PV)	E.2.1.2	R/W (M)
Signal frequency for active AC tests (MELT-AC-F)	E.2.1.3	R/W (O)
Pair identification tone frequency (MELT-PIT-F)	E.2.1.4	R/W (M)
Maximum far-end signature conduction voltage (MELT-MAXFE-SCV)	E.2.1.5	R/W (M)
Minimum far-end signature conduction voltage (MELT-MINFE-SCV)	E.2.1.6	R/W (M)
MELT-PMD reporting parameters		
Measurement frequency for active AC tests (MELT-MFREQ)	E.2.2.1	R (O)
Input impedance for foreign voltage measurements (MELT-IMP-V)	E.2.2.2	R (O)
Measurement voltage for loop complex admittance with a high voltage test (MELT-HCA-V)	E.2.2.3	R (O)
MELT-PMD measurement parameters		
4-element DC resistance with controlled metallic voltage R_{TR} (MELT-CDCR-TR)	E.2.3.1	R (M)
4-element DC resistance with controlled metallic voltage R_{RT} (MELT-CDCR-RT)	E.2.3.1	R (M)
4-element DC resistance with controlled metallic voltage R_{TG} (MELT-CDCR-TG)	E.2.3.1	R (M)
4-element DC resistance with controlled metallic voltage R_{RG} (MELT-CDCR-RG)	E.2.3.1	R (M)
3-element capacitance with controlled metallic voltage C_{TR} (MELT-CC-TR)	E.2.3.2	R (M)
3-element capacitance with controlled metallic voltage C_{TG} (MELT-CC-TG)	E.2.3.2	R (M)
3-element capacitance with controlled metallic voltage C_{RG} (MELT-CC-RG)	E.2.3.2	R (M)
Foreign DC voltage $V_{TR,DC}$ (MELT-FVDC-TR)	E.2.3.3	R (M)
Foreign DC voltage $V_{TG,DC}$ (MELT-FVDC-TG)	E.2.3.3	R (M)
Foreign DC voltage $V_{RG,DC}$ (MELT-FVDC-RG)	E.2.3.3	R (M)
Foreign AC voltage $V_{TR,AC}$ (MELT-FVAC-TR)	E.2.3.3	R (M)
Foreign AC voltage $V_{TG,AC}$ (MELT-FVAC-TG)	E.2.3.3	R (M)

Table E.1 – Partitioning of MELT-ME-PMD parameters

Category/element	Defined in clause	η_C - reference point
Foreign AC voltage $V_{RG,AC}$ (MELT-FVAC-RG)	E.2.3.3	R (M)
Foreign AC voltage frequency $F_{TR,AC}$ (MELT-FVACF-TR)	E.2.3.3	R (M)
Foreign AC voltage frequency $F_{TG,AC}$ (MELT-FVACF-TG)	E.2.3.3	R (M)
Foreign AC voltage frequency $F_{RG,AC}$ (MELT-FVACF-RG)	E.2.3.3	R (M)
Loop capacitance with high metallic voltage (MELT-HC-TR)	E.2.3.4	R (M)
Loop resistance with high metallic voltage (MELT-HDCR-TR)	E.2.3.5	R (M)
Loop resistance with high metallic voltage (MELT-HDCR-RT)	E.2.3.5	R (M)
3-element complex admittance with controlled metallic voltage real part G_{TR} (MELT-CAG-TR)	E.2.3.6	R (O)
3-element complex admittance with controlled metallic voltage imaginary part B_{TR} (MELT-CAB-TR)	E.2.3.6	R (O)
3-element complex admittance with controlled metallic voltage real part G_{TG} (MELT-CAG-TG)	E.2.3.6	R (O)
3-element complex admittance with controlled metallic voltage imaginary part B_{TG} (MELT-CAB-TG)	E.2.3.6	R (O)
3-element complex admittance with controlled metallic voltage real part G_{RG} (MELT-CAG-RG)	E.2.3.6	R (O)
3-element complex admittance with controlled metallic voltage imaginary part B_{RG} (MELT-CAB-RG)	E.2.3.6	R (O)
Loop complex admittance with high metallic voltage real part $G_{TR,HV}$ (MELT-HAG-TR)	E.2.3.7	R (O)
Loop complex admittance with high metallic voltage imaginary part $B_{TR,HV}$ (MELT-HAB-TR)	E.2.3.7	R (O)

E.3 Test management

For further study.

Annex F

Specific requirements for a MELT-P

(This annex forms an integral part of this Recommendation)

F.1 MELT-P functions

MELT-P functions are applicable at the Q-interface only.

F.1.1 MELT-P derived parameters

F.1.1.1 Identification of an open wire failure

In case of an open wire failure, this parameter provides information about the type of failure and the estimated distance from the central office.

F.1.1.1.1 Open wire failure type

This sub-parameter is a five state indication of the type of open wire failure defined as follows:

1) No open wire failure detected
2) Tip and ring wires open in equal distance
3) Tip wire open
4) Ring wire open
5) Undefined.

NOTE – An error-free loop will be classified as failure state 2) in case that the remote end of the loop was left open during the measurement, or the connected CPE equipment could not be detected (too low parallel CPE system capacitance).

F.1.1.1.2 Distance to the open wire failure

This parameter represents a best-effort estimate of the distance of the detected open wire failure from the measurement point, i.e., from the central office or of the total loop length if no failure is detected. *A priori* knowledge of the loop characteristics is required for reliable estimation of the distance (see clause F.2.1.2). The range of valid values is from 0 to 10'000 m with a granularity of 1 m.

The accuracy is for further study.

When the presence of the CPE equipment has been detected, the system capacitance at the CPE side (see clause F.2.1.7) shall be subtracted from the C_{TR} capacitance to calculate and report the cable length. If this value is not available, the calculation shall be based solely on the C_{TG} and C_{RG} capacitances.

F.1.1.2 Identification of a short circuit failure

In case of a short circuit failure, this parameter provides information about the type of failure.

F.1.1.2.1 Short circuit failure type

This parameter is a six-state indication of the type of short circuit failure defined as follows:

1) No short circuit detected
2) Tip and ring wires shorted to GND
3) Tip wire shorted to GND
4) Ring wire shorted to GND
5) Tip and ring wires shorted to each other

6) Undefined.

F.1.1.3 Leakage identification

This parameter indicates a leakage to GND failure, classified into the following states:

- No leakage detected
- Tip and ring wire leaking to GND
- Tip wire leaking to GND
- Ring wire leaking to GND.

F.1.1.4 Resistive fault identification

This parameter indicates a resistive fault to GND failure, classified into the following states:

- No resistive fault detected
- Resistive fault tip and ring to GND
- Resistive fault tip to GND
- Resistive fault ring to GND.

F.1.1.5 Foreign voltage classification

F.1.1.5.1 Foreign voltage type

The foreign voltage impairment in the loop under test is classified into the following states:

- No foreign voltage detected
- 16 2/3 Hz AC voltage
- 25 Hz AC voltage
- 50 Hz AC voltage
- 60 Hz AC voltage
- POTS equipment (–48 V DC)
- ISDN equipment (–96 V DC)
- Undefined foreign voltage detected.

This classification shall be done separately for both, the tip and the ring wire.

F.1.1.5.2 Foreign voltage level class

This parameter provides a general classification of the foreign voltage into the following classes:

- hazardous potential (e.g. power contact);
- foreign electromotive force;
- other.

F.1.1.6 Far-end signature topology identification

F.1.1.6.1 Far-end signature topology type

This parameter specifies the topology types of the detected far-end signature. The valid signature topology types are defined in Figure F.1.

NOTE 1 – The far-end signature capacitance C_{SIG} can be estimated from the capacitance measurement at low voltage C_{TR} (see clause E.1.1.2) and the capacitance measurement at high voltage $C_{TR,HV}$ (see clause E.1.1.4), using a vendor-discretionary algorithm.

NOTE 2 – The passive termination resistance (R_{PT}) can be estimated from two consecutive measurements of resistance (R_{TR} and R_{RT}, see clause E.1.1.1) using a vendor-discretionary algorithm.

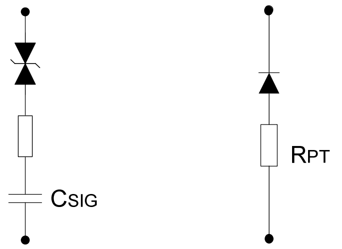


Figure F.1 – Valid signature topology types (resp. ZRC (left) and DR (right))

Valid response values are:

- no signature detected;
- unknown signature;
- signature type DR detected;
- signature type ZRC detected.

F.2 MELT-P management entity

F.2.1 MELT-P management entity configuration parameters

F.2.1.1 Loop resistance classification threshold

This parameter defines the limits for classification of the resistances to GND of the loop under test. The following limit values need to be defined:

- maximum resistance for a short-circuit to GND;
- minimum resistance for a leakage to GND;
- maximum resistance for a leakage to GND.

A resistance to ground measured as being:

- Below the maximum resistance for a short circuit shall be interpreted as a short circuit to GND.
- Above the maximum resistance for a short circuit and below the minimum resistance for a leakage shall be interpreted as a resistance fault to GND.
- Above the minimum resistance for a leakage and below the maximum resistance for a leakage shall be interpreted as a leakage to GND.
- Above the maximum resistance for a leakage shall be interpreted as a high impedance to GND.

F.2.1.2 Loop parameters per unit length

The *a priori* knowledge of some characteristic parameters per unit length of the loop under test is necessary to derive length or distance information from the MELT-PMD measurements. This parameter combines the set of required loop parameters:

1) Cable characteristic capacitance per unit length between tip and ring. The range of valid values is from 0 to 100 nF/km with a granularity of 0.1 nF/km.
2) Cable characteristic capacitance per unit length between tip and GND and ring and GND. The range of valid values is from 0 to 100 nF/km with a granularity of 0.1 nF/km.
3) Cable loop DC resistance per unit length (sum of both wires). The range of valid values is from 50 to 400 Ω/km with a granularity of 1 Ω/km.

F.2.1.3 Hazardous DC voltage level

This parameter defines the level above which DC voltage shall be identified as hazardous. The hazardous voltage level shall be configurable between 0 and 200 V with a granularity of 1 V.

F.2.1.4 Hazardous AC voltage level

This parameter defines the level above which AC voltage shall be identified as hazardous. The hazardous voltage level shall be configurable between 0 and 200 Vrms with a granularity of 1 Vrms.

F.2.1.5 Foreign EMF DC voltage level

This parameter defines the level above which a DC voltage shall be identified as a foreign EMF. The foreign EMF voltage level shall be configurable between 0 and 50 V with a granularity of 1 V.

F.2.1.6 Foreign EMF AC voltage level

This parameter defines the level above which an AC voltage shall be identified as a foreign EMF. The foreign EMF voltage level shall be configurable between 0 and 50 Vrms with a granularity of 1 Vrms.

F.2.1.7 System capacitance at the CPE side

This parameter is the expected value of the system capacitance at the CPE side as it appears in parallel between tip and ring in a corresponding MELT measurement. *A priori* knowledge of this capacitance improves accuracy of the results and offers additional degrees for interpretation.

The range of valid values is from 0 to 2 μF with a granularity of 0.1 nF.

F.2.2 MELT-P management entity derived parameters

F.2.2.1 Identification of an open wire failure

F.2.2.1.1 Open wire failure type

The parameter in the MELT-ME-P shall have the same format as specified for the MELT-P.

F.2.2.1.2 Distance to the open wire failure

The parameter in the MELT-ME-P shall have the same format as specified for the MELT-P.

F.2.2.2 Identification of a short circuit failure

F.2.2.2.1 Short circuit failure type

The parameter in the MELT-ME-P shall have the same format as specified for the MELT-P.

F.2.2.3 Leakage identification

The parameter in the MELT-ME-P shall have the same format as specified for the MELT-P.

F.2.2.4 Resistive fault identification

The parameter in the MELT-ME-P shall have the same format as specified for the MELT-P.

F.2.2.5 Foreign voltage classification

F.2.2.5.1 Foreign voltage type

The parameter in the MELT-ME-P shall have the same format as specified for the MELT-P.

F.2.2.5.2 Foreign voltage level class

The parameter in the MELT-ME-P shall have the same format as specified for the MELT-P.

F.2.2.6 Far-end signature topology identification

F.2.2.6.1 Far-end signature topology type

The parameter in the MELT-ME-P shall have the same format as specified for the MELT-P.

F.2.3 MELT-P network management element partitioning

This clause defines the network management elements which correspond to the Q-interface.

The parameters at the Q-interface are described by Table F.1 indicating the status of the parameter as:

- R are read only.
- W are write only.
- R/W are read and write.
- (M) are mandatory.
- (O) are optional.

Table F.1 – Partitioning of MELT-ME-P parameters

Category/element	Defined in clause	Q - interface
MELT-PMD configuration parameters		
Measurement class (MELT-MCLASS)	E.2.1.1	R/W (O)
Peak metallic voltage between tip and ring (MELT-PV)	E.2.1.2	R/W (M)
Signal frequency for active AC tests (MELT-AC-F)	E.2.1.3	R/W (O)
Pair identification tone frequency (MELT-PIT-F)	E.2.1.4	R/W (M)
Maximum far-end signature conduction voltage (MELT-MAXFE-SCV)	E.2.1.5	R/W (M)
Minimum far-end signature conduction voltage (MELT-MINFE-SCV)	E.2.1.6	R/W (M)
MELT-PMD reporting parameters		
Measurement frequency for active AC tests (MELT-MFREQ)	E.2.2.1	R (O)
Input impedance for foreign voltage measurements (MELT-IMP-V)	E.2.2.2	R (O)
Measurement voltage for loop complex admittance with a high voltage test (MELT-HCA-V)	E.2.2.3	R (O)
MELT-PMD measurement parameters		
4-element DC resistance with controlled metallic voltage R_{TR} (MELT-CDCR-TR)	E.2.3.1	R (M)
4-element DC resistance with controlled metallic voltage R_{RT} (MELT-CDCR-RT)	E.2.3.1	R (M)
4-element DC resistance with controlled metallic voltage R_{TG} (MELT-CDCR-TG)	E.2.3.1	R (M)
4-element DC resistance with controlled metallic voltage R_{RG} (MELT-CDCR-RG)	E.2.3.1	R (M)
3-element capacitance with controlled metallic voltage C_{TR} (MELT-CC-TR)	E.2.3.2	R (M)
3-element capacitance with controlled metallic voltage C_{TG} (MELT-CC-TG)	E.2.3.2	R (M)
3-element capacitance with controlled metallic voltage C_{RG} (MELT-CC-RG)	E.2.3.2	R (M)
Foreign DC voltage $V_{TR,DC}$ (MELT-FVDC-TR)	E.2.3.3	R (M)
Foreign DC voltage $V_{TG,DC}$ (MELT-FVDC-TG)	E.2.3.3	R (M)
Foreign DC voltage $V_{RG,DC}$ (MELT-FVDC-RG)	E.2.3.3	R (M)
Foreign AC voltage $V_{TR,AC}$ (MELT-FVAC-TR)	E.2.3.3	R (M)

Table F.1 – Partitioning of MELT-ME-P parameters

Category/element	Defined in clause	Q - interface
Foreign AC voltage $V_{TG,AC}$ (MELT-FVAC-TG)	E.2.3.3	R (M)
Foreign AC voltage $V_{RG,AC}$ (MELT-FVAC-RG)	E.2.3.3	R (M)
Foreign AC voltage frequency $F_{TR,AC}$ (MELT-FVACF-TR)	E.2.3.3	R (M)
Foreign AC voltage frequency $F_{TG,AC}$ (MELT-FVACF-TG)	E.2.3.3	R (M)
Foreign AC voltage frequency $F_{RG,AC}$ (MELT-FVACF-RG)	E.2.3.3	R (M)
Loop capacitance with high metallic voltage (MELT-HC-TR)	E.2.3.4	R (M)
Loop resistance with high metallic voltage (MELT-HDCR-TR)	E.2.3.5	R (M)
Loop resistance with high metallic voltage (MELT-HDCR-RT)	E.2.3.5	R (M)
3-element complex admittance with controlled metallic voltage real part G_{TR} (MELT-CAG-TR)	E.2.3.6	R (O)
3-element complex admittance with controlled metallic voltage imaginary part B_{TR} (MELT-CAB-TR)	E.2.3.6	R (O)
3-element complex admittance with controlled metallic voltage real part G_{TG} (MELT-CAG-TG)	E.2.3.6	R (O)
3-element complex admittance with controlled metallic voltage imaginary part B_{TG} (MELT-CAB-TG)	E.2.3.6	R (O)
3-element complex admittance with controlled metallic voltage real part G_{RG} (MELT-CAG-RG)	E.2.3.6	R (O)
3-element complex admittance with controlled metallic voltage imaginary part B_{RG} (MELT-CAB-RG)	E.2.3.6	R (O)
Loop complex admittance with high metallic voltage real part $G_{TR,HV}$ (MELT-HAG-TR)	E.2.3.7	R (O)
Loop complex admittance with high metallic voltage imaginary part $B_{TR,HV}$ (MELT-HAB-TR)	E.2.3.7	R (O)
MELT-P configuration parameters		
Loop resistance classification threshold (MELT-LRC-TH)	F.2.1.1	R/W (M)
Loop parameters per unit length (MELT-LOOP-PARAMS)	F.2.1.2	R/W (M)
Hazardous DC voltage level (MELT-HDCV-L)	F.2.1.3	R/W (M)
Hazardous AC voltage level (MELT-HACV-L)	F.2.1.4	R/W (M)
Foreign EMF DC voltage level (MELT-FDCV-L)	F.2.1.5	R/W (M)
Foreign EMF AC voltage level (MELT-FACV-L)	F.2.1.6	R/W (M)
System capacitance at the CPE side (MELT-SYSC-CPE)	F.2.1.7	R/W (O)
MELT-P derived parameters		
Identification of an open wire failure (MELT-O-WIRE-type) – Open wire failure type	F.2.2.1.1	R (M)
Identification of an open wire failure (MELT-O-WIRE-DIST) – Distance to the open wire failure	F.2.2.1.2	R (O)
Identification of a short circuit failure type (MELT-S-CCT-type)	F.2.2.2.1	R (M)
Leakage identification (MELT-LEAK-ID)	F.2.2.3	R (M)
Resistive fault identification (MELT-RFAULT-ID)	F.2.2.4	R/W(M)

Table F.1 – Partitioning of MELT-ME-P parameters

Category/element	Defined in clause	Q - interface
Foreign voltage type classification (MELT-FV-TYPE)	F.2.2.5.1	R (M)
Foreign voltage level classification (MELT-FV-LEVEL)	F.2.2.5.2	R (M)
Far-end signature topology type identification (MELT-FES-ID)	F.2.2.6.1	R (M)

F.3 Test management

For further study.

Appendix I

SELT application models

(This appendix does not form an integral part of this Recommendation)

I.1 CO SELT application models

I.1.1 CO SELT instantiation 1: SELT-P outside the DSLAM

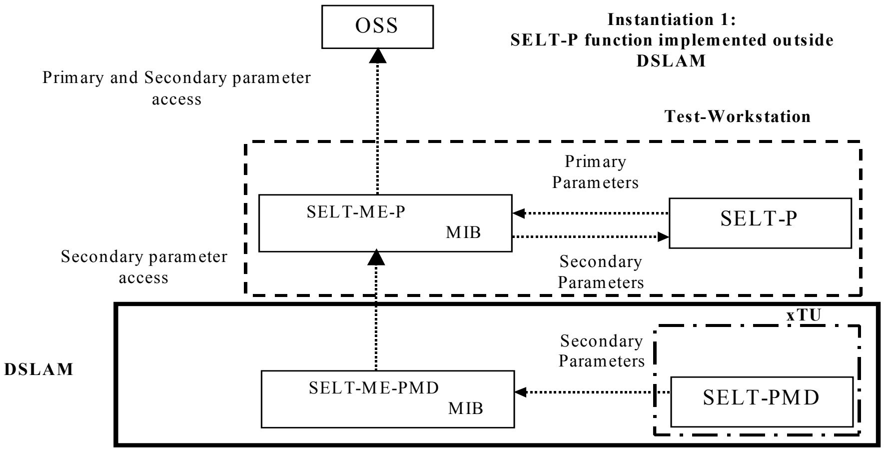


Figure I.1 – SELT instantiation 1: SELT-P function outside the DSLAM

I.1.2 CO SELT instantiation 2: SELT-P function inside DSLAM

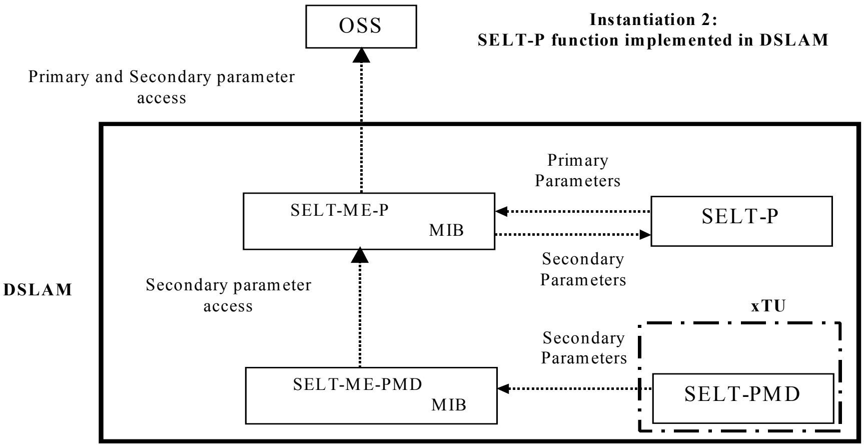


Figure I.2 – SELT instantiation 2: SELT-P function inside DSLAM

I.1.3 CO SELT instantiation 3: SELT-P inside xTU-C

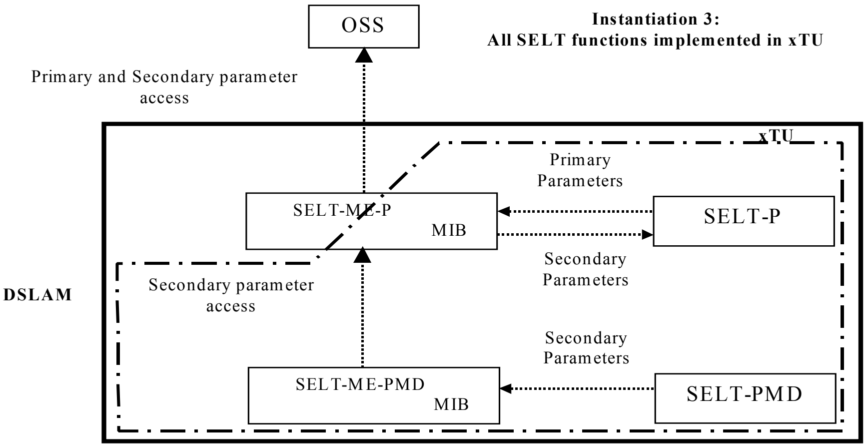


Figure I.3 – SELT instantiation 3: SELT-P inside xTU-C

NOTE 1 – For instantiation 3, the distinction between P and PMD functionality may not be observable. The communication part of the SELT-ME-PMD to the OSS is implemented by the DSLAM, the rest is inside the xTU-C.

NOTE 2 – Parts of SELT-ME-P and SELT-ME-PMD functions could be implemented as part of the AN-ME (access network ME, as defined in Figure 5-1 of [b-ITU-T G.997.1]).

Bibliography

[b-ITU-T G.997.1] Recommendation ITU-T G.997.1 (2009), *Physical layer management for digital subscriber line (DSL) transceivers*.

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