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

Digital sections and digital line system – Metallic access networks

Single-ended line testing for digital subscriber lines

Recommendation ITU-T G.996.2

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Recommendation ITU-T G.996.2

Single-ended line testing for digital subscriber lines

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).

This version of this Recommendation integrates all the previous amendments and corrigenda with the 2009 version of Recommendation ITU-T G.996.2.

This version of Recommendation ITU-T G.996.2 corrects or adds the following functionality:

– Amendment 2 provides updates to Annexes E and F, defining revised new measurement parameters for a MELT-PMD and a MELT-P.
– Amendment 3 updates Annex E defining accuracy values for MELT-PMD and MELT-P (new functionality).
– Amendment 4 updates Annex E on the accuracy values for multi-component 4-element resistance and 3-element capacitance parameters in MELT-PMD and on a definition on dealing with the xDSL input capacitance during measurements.
– Amendment 5 provides updates to Annexes A and B, defining SELT operating in conjunction with ITU-T G.9701 transceivers.
– Amendment 6 updates Annexes A, E, and F, defining the following new functionalities: SELT-PMD management, MELT-PMD management, report of negative capacitance values, pair identification tone with timeout, report of reliability indicator for measurements, report of time stamp, parallelism and polarity of far-end signature detection, and CPE identification capacitive.
– Corrigendum 1 fixes a number of inconsistencies.
– Fixes inconsistencies regarding accuracy requirements for MELT test voltages.

History

Edition	Recommendation	Approval	Study Group	Unique ID*
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1.2	ITU-T G.996.2 (2009) Amd. 2	2012-04-06	15	11.1002/1000/11503
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Keywords

Line test, MELT, SELT, xDSL.

* To access the Recommendation, type the URL http://handle.itu.int/ in the address field of your web browser, followed by the Recommendation's unique ID. For example, http://handle.itu.int/11.1002/1000/11830-en.

FOREWORD

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

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As of the date of approval of this Recommendation, ITU had received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at http://www.itu.int/ITU-T/ipr/.

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Recommendation ITU-T G.996.2

Single-ended line testing for digital subscriber lines

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

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T G.991.2] Recommendation ITU-T G.991.2 (2003), *Single-pair high-speed digital subscriber line (SHDSL) transceivers*.

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 Conventions

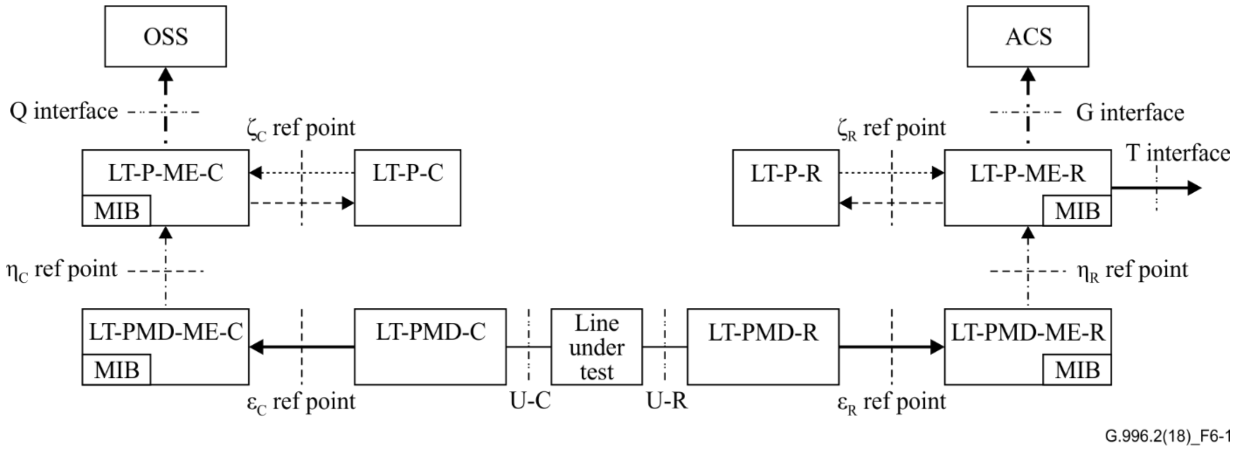
None.

6 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.

6.1 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 6-1 depicts the functional reference model.



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

Figure 6-1 – 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-P-ME (LT – P – Management entity) 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-PMD-ME 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-P-ME across the U interface to coordinate testing and exchange derived and measurement parameters.

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

a) Data-plane:
   - to provide to the LT-P-ME 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".

6.2 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.

7 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.

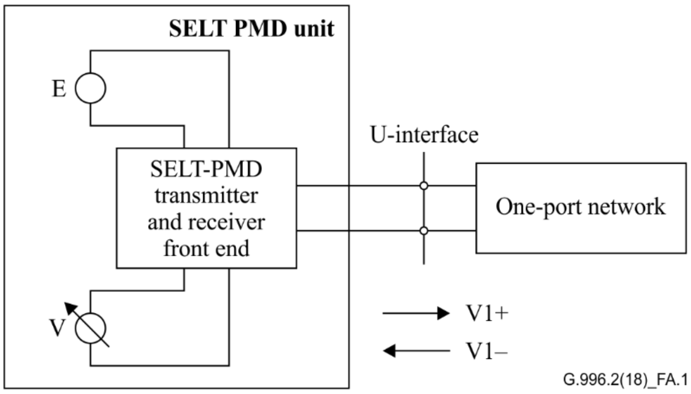


Figure A.1 – SELT-PMD during measurement of "uncalibrated echo response"

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.

If a SELT-PMD-C, operating in conjunction with [ITU-T G.9701] transceivers, transmits an excitation signal, this transmission shall be synchronized with the TDD timing of the [ITU-T G.9701] timing control entity (TCE) in order to minimize the impact onto other [ITU-T G.9701] transceivers in showtime.

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

The definition for reporting SELT uncalibrated echo response and SELT quiet line noise measurement parameters depends on whether or not the option for extended bandwidth SELT is applied.

NOTE – Using the option for extended bandwidth SELT facilitates SELT for [ITU-T G.993.2] profile 35b and [ITU-T G.9701] systems.

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.

If the option for extended bandwidth SELT is not applied, then:

– The UER granularity parameter, UER_G, has two valid values: 1 and 2, indicating whether the measurements were performed using a subcarrier 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.

If the option for extended bandwidth SELT is applied, then:

– The UER granularity parameter, UER_G, has three valid values: 1, 2 and 12, indicating whether the measurements were performed using a subcarrier spacing of 4.3125 kHz, 8.625 kHz, or 51.75 kHz, respectively.

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 uncalibrated echo response group size

The SELT uncalibrated echo response group size (SELT-UER_G) is a reported parameter identifying the UER frequency spacing, which is equal to SELT-UER_G × Df with Df = 4.3125 kHz. SELT-UER_G has three valid values: 1, 2 and 12. Clause A.2.2.1 refers to SELT-UER_G as the "UER granularity parameter, UER_G."

The SELT uncalibrated echo response group size shall be reported if the option for extended bandwidth UER SELT is supported; otherwise, reporting of the group size is optional. If the SELT uncalibrated echo response group size is not reported, the SELT uncalibrated echo response group size shall be equal to 1.

A.2.2.3 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.2.2.4 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.

If the option for extended bandwidth SELT is not applied, then:

– SELTQLN_G has two valid values: 1 and 2, indicating whether the measurements were performed using a subcarrier 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.

If the option for extended bandwidth SELT is applied, then:

– SELTQLN_G has three valid values: 1, 2, and 12, indicating whether the measurements were performed using a subcarrier spacing of 4.3125 kHz, 8.625 kHz, or of 51.75 kHz, respectively.

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.2.2.5 SELT quiet line noise group size

The SELT quiet line noise group size (SELTQLN_G) is a reported parameter identifying the SELTQLN frequency spacing, which is equal to SELTQLN_G × Df with Df = 4.3125 kHz. SELTQLN_G has three valid values: 1, 2, and 12.

The SELT quiet line noise group size shall be reported if the option for extended bandwidth QLN SELT is supported; otherwise, reporting of the group size is optional. If the SELT quiet line noise group size is not reported, the SELT quiet line noise group size shall be equal to 1.

A.2.2.6 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-P-ME-C to the SELT-PMD-ME-C.
  - R: parameter provided by the SELT-PMD-ME-C to be read by the SELT-P-ME-C.

– η_R reference point:
  - W: parameter written by the SELT-P-ME-R to the SELT-PMD-ME-R.
  - R: parameter provided by the SELT-PMD-ME-R to be read by the SELT-P-ME-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)
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 uncalibrated echo response group size C (SELT-UER_G-C)	A.2.2.2	R (M) (see Note 1)	
SELT uncalibrated echo response group size R (SELT-UER_G-R)	A.2.2.2		R (M) (see Note 1)
SELT variance of uncalibrated echo response C (SELT-UER-VAR-C)	A.2.2.3	R (M)	
SELT variance of uncalibrated echo response R (SELT-UER-VAR-R)	A.2.2.3		R (M)
SELT quiet line noise C (SELT_QLN_C)	A.2.2.4	R (M)	
SELT quiet line noise R (SELT_QLN_R)	A.2.2.4		R (M)
SELT quiet line noise group size C (SELTQLN_G-C)	A.2.2.5	R (M) (see Note 2)	
SELT quiet line noise group size R (SELTQLN_G-R)	A.2.2.5		R (M) (see Note 2)

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

Category/element	Defined in clause	η_C – reference point	η_R – reference point
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)
NOTE 1 – The SELT uncalibrated echo response group size (SELT-UER_G-C and SELT-UER_G-R) is mandatory only if the option for extended bandwidth UER SELT is supported; otherwise, reporting of the group size is optional. NOTE 2 – The SELT quiet line noise group size (SELTQLN_G-C and SELTQLN_G-R) is mandatory only if the option for extended bandwidth QLN SELT is supported; otherwise, reporting of the group size is optional.			

A.3 Test management and communications

The CO-side SELT-PMD is managed using the parameters defined in this clause. The NT-side SELT-PMD management is for further study.

A.3.1 CO SELT-PMD control

This parameter configures the CO SELT-PMD for a particular measurement.

The parameter is of type enumeration, with the following valid values:

– disable: the CO SELT-PMD is not configured for a measurement;

– enable: the CO SELT-PMD is configured for a measurement.

The CO SELT-PMD is by default "disable". When "disable", the line is in normal operation (e.g., in the L0 state if the line is configured with AdminStatus=up). When "enable", the AN/DPU ME shall force the line into the L3 state if necessary.

A.3.2 CO SELT-PMD request

While the CO SELT-PMD is "enable", this parameter is used to trigger the start of a particular measurement (either UER or QLN) or to trigger the abortion of a measurement.

The parameter is of type enumeration, with the following valid values:

– none: a measurement is not triggered.

– uer-measurement: triggers the CO SELT-PMD to start an Uncalibrated Echo Response (UER) measurement.

– qln-measurement: triggers the CO SELT-PMD to start a Quiet Line Noise (QLN) measurement.

– abort: triggers the CO SELT-PMD to abort any currently ongoing measurement.

A measurement is triggered when the value is configured from "none" to either "uer-measurement" or "qln-measurement". After completion of the current measurement, transition to "none" is required before a new measurement can be triggered. Transition from any measurement to "abort" shall stop the measurement. Transitions from "uer-measurement" to "qln-measurement" and vice versa are invalid. One or more measurements may be triggered while the CO SELT-PMD is configured "enable", possibly with different CO SELT-PMD configuration parameters. If the triggered measurement cannot be executed, then the AN/DPU ME rejects this request and the CO SELT-PMD status remains "inactive".

A.3.3 CO SELT-PMD status

This parameter reports the status of the measurement.

The parameter is of type enumeration, with the following valid values:

– inactive: the CO SELT-PMD is inactive;

– uer-ongoing: the CO SELT-PMD has a UER measurement ongoing;

– qln-ongoing: the CO SELT-PMD has a QLN measurement ongoing.

Upon the CO SELT-PMD request triggering a UER measurement, the CO SELT-PMD status shall become "uer-ongoing" if the measurement is executed.

Upon the CO SELT-PMD request triggering a QLN measurement, the CO SELT-PMD status shall become "qln-ongoing" if the measurement is executed.

Upon abortion, failure or successful completion of the UER or QLN measurement, the SELT-PMD status shall become "inactive" and the AN/DPU ME shall send a notification to the NMS.

A.3.4 CO SELT UER results status

This parameter reports the status of the CO SELT-PMD UER measurement results.

The parameter is of type enumeration, with the following valid values:

– no-measurement-results-available: no UER measurement results are available when no UER measurement has been performed yet or after UER measurement the results have been deleted;

– measurement-failed-results-invalid: UER measurement results are invalid after the most recent UER measurement failed;

– measurement-succeeded-results-valid: UER measurement results are valid after the most recent UER measurement succeeded.

A.3.5 CO SELT QLN results status

This parameter reports the status of the CO SELT-PMD QLN measurement results.

The parameter is of type enumeration, with the following valid values:

– no-measurement-results-available: no QLN measurement results are available when no QLN measurement has been performed yet or after QLN measurement the results have been deleted;

– measurement-failed-results-invalid: QLN measurement results are invalid after the most recent QLN measurement failed;

– measurement-succeeded-results-valid: QLN measurement results are valid after the most recent QLN measurement succeeded.

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'.

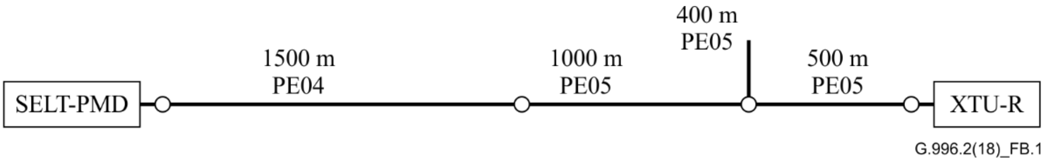


Figure B.1 – Example of loop

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.

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

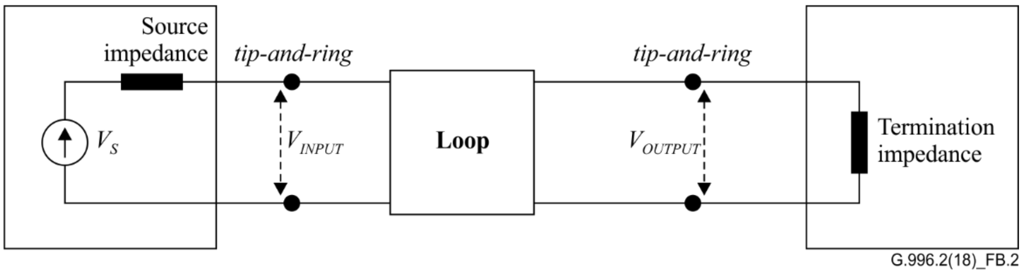


Figure B.2 – Attenuation characteristic

The definition for reporting the line attenuation TFlog(f) depends on whether or not the option for extended bandwidth SELT is applied.

The function TFlog(f) consists of an array of values TFlog(i × TFlog_G × 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.

If the option for extended bandwidth SELT is not applied, then TFlog_G = 1.

If the option for extended bandwidth SELT is applied, then:

– The attenuation characteristics group size, TFlog_G, has three valid values: 1, 2 and 12, indicating whether the measurements were performed using a subcarrier spacing of 4.3125 kHz, 8.625 kHz, or 51.75 kHz, respectively.

The range of valid values for TFlog(i × TFlog_G × 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 Attenuation characteristics group size

The attenuation characteristics group size (TFlog_G) is a reported parameter identifying the attenuation characteristics, TFlog(f), at a frequency spacing equal to TFlog_G × Df with Df = 4.3125 kHz. TFlog_G has three valid values: 1, 2 and 12.

The attenuation characteristics group size shall be reported if the option for extended bandwidth SELT is supported; otherwise, reporting of the group size is optional.

B.1.1.8 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), …, (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 49152 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), …, (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 brick wall stopbands, the set of breakpoints for CAP-NOISEPSD is not required to describe the noise in the stopbands situated in between passbands. In case the CAP-SIGNALPSD stopbands are not described as brick wall stopbands, the set of breakpoints for CAP-NOISEPSD shall describe the noise in the stopbands situated in between 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 49152, 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:

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

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)	
Attenuation characteristics group size (TFlog_G)	B.1.1.8	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 uncalibrated echo response group size C (SELT-UER_G-C).	A.2.2.2	R (M) (see Note 1)		
SELT uncalibrated echo response group size R (SELT-UER_G-R)	A.2.2.2		R (M) (see Note 1)	R (M) (see Note 1)
SELT variance of uncalibrated echo response C (SELT-UER-VAR-C)	A.2.2.3	R (M)		
SELT variance of uncalibrated echo response R (SELT-UER-VAR-R)	A.2.2.3		R (M)	R(M)
SELT quiet line noise C (SELT_QLN_C)	A.2.2.4	R (M)		
SELT quiet line noise R (SELT_QLN_R)	A.2.2.4		R (M)	R(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 group size C (SELTQLN_G-C)	A.2.2.5	R (M) (see Note 2)		
SELT quiet line noise group size R (SELTQLN_G-R)	A.2.2.5		R (M) (see Note 2)	R (M) (see Note 2)
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)
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)
NOTE 1 – The SELT uncalibrated echo response group size (SELT-UER_G-C and SELT-UER_G-R) is mandatory only if the option for extended bandwidth UER SELT is supported; otherwise, reporting of the group size is optional. NOTE 2 – The SELT quiet line noise group size (SELTQLN_G-C and SELTQLN_G-R) is mandatory only if the option for extended bandwidth QLN SELT is supported; otherwise, reporting of the group size is optional.				

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.

The accuracy values provided in this annex are based on an assumption that the MELT functionality has, or obtains, the value of the input capacitance looking into the xTU-C and subtracts it from the raw results to report the measurement of the external capacitance. The method to obtain the input capacitance of the xTU-C is vendor discretionary and is beyond the scope of this Recommendation. No part of the overall accuracy budget has been allocated to account for a possible change in the input capacitance of the xTU-C.

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. This requirement applies to a test executed on a typical loop without obtaining the optional measurement results (see Table E.12) and does not include an allowance for system or network delays.

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

E.1.1.1.1 4-element DC resistance

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.

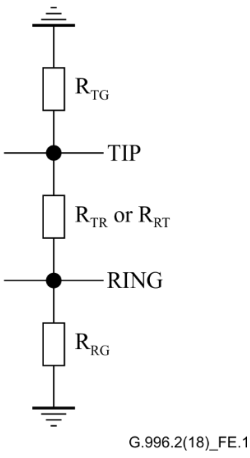


Figure E.1 – DC resistance between tip, ring and GND

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 numbers apply to a measurement performed with only one resistance component at a time connected to one of tip and ring, ring and tip, tip and GND, or ring and GND.

The accuracy for each element of this parameter is defined in Table E.1.

Table E.1 – 4-element DC resistance accuracy

R_{XY} Range	Accuracy
0 Ω – 250 Ω	±10 Ω
250 Ω – 1 kΩ	±4%
1 kΩ – 100 kΩ	±4%
100 kΩ – 1 MΩ	±8%
1 MΩ – 5 MΩ	±15%
5 MΩ – 10 MΩ	±25%

E.1.1.1.2 Test voltages for the measurement of the 4-element DC resistance with a controlled metallic voltage

This parameter reports the DC voltages present on the tip and ring wires while executing the measurement with a controlled metallic voltage and which are used to calculate the resistance results. Four values are reported in relation with the tip-to-ground, ring-to-ground, tip-to-ring, and ring-to-tip branches. If a branch is measured by comparing the load current at two different source voltages, the voltage delta is reported instead of each individual voltage.

NOTE – The voltage values can be based on a calculation, using the source voltage, the load current and the output impedance, or can be a direct measurement.

Four voltage values VDC_{XY} shall be reported:

1) VDC_{TR} – DC voltage between tip and ring
2) VDC_{RT} – DC voltage between ring and tip
3) VDC_{TG} – DC voltage between tip and GND
4) VDC_{RG} – DC voltage between ring and GND.

The accuracy for each element of this parameter is given in Table E.1.1, while the range of valid values and granularity are defined in clause E.2.3.2.

Table E.1.1 – Measurement test voltages (VDC_{TR}, VDC_{RT}, VDC_{TG} and VDC_{RG}) accuracy

Voltage range (V)	Accuracy	Granularity
$-20 \le VDC_{XY} \le 20$	±1 V	100 mV
$-150 < VDC_{XY} < -20$ $20 < VDC_{XY} < 150$	±5%	100 mV

E.1.1.1.3 Test currents for the measurement of the 4-element DC resistance with a controlled metallic voltage

This parameter reports the DC currents measured during the test execution. Those currents are useful to identify the possible presence of a foreign voltage source. To this effect, the current contribution resulting from the application of the test voltage to the measured external resistance shall be removed from the reported currents.

Four current values IDC_{XY} shall be reported:

1) IDC_{TR} – DC current between tip and ring
2) IDC_{RT} – DC current between ring and tip
3) IDC_{TG} – DC current between tip and GND
4) IDC_{RG} – DC current between ring and GND.

The accuracy for each element of this parameter is given in Table E.1.2, while the range of valid values and granularity are defined in clause E.2.3.3.

Table E.1.2 – Measurement test currents (IDC_{TR}, IDC_{RT}, IDC_{TG} and IDC_{RG}) accuracy

Current range (mA)	Accuracy	Granularity
$-20 \le IDC_{XY} \le 20$	±2 mA	1 µA
$-100 < IDC_{XY} < -20$ $20 < IDC_{XY} < 100$	±10%	1 µA

NOTE – Removing the current contribution resulting from the application of the test voltage only leaves the current due to a foreign potential, if any is present. To this effect, the IDC_{TR} and IDC_{RT} results are equivalent to the results that would be obtained when connecting a current meter between tip and ring. Similarly, the IDC_{TG} and IDC_{RG} results are equivalent to the results that would be obtained when connecting two current meters, one between tip and ground and one between ring and ground.

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

E.1.1.2.1 3-element capacitance

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.

If the consideration of internal components during the measurement process leads to negative values, these negative capacitance values shall be reported.

NOTE – The reporting of negative capacitance values may be used to detect hardware defects.

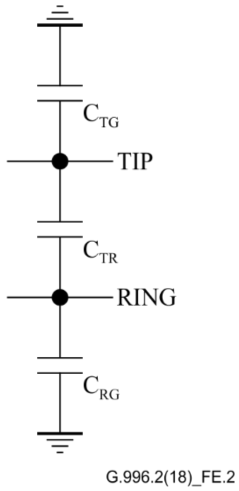


Figure E.2 – Capacitance between tip, ring and GND

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 each element of this parameter is defined in Tables E.2 and E.3.

The accuracy of each element of this parameter in cases of MELT measurements on SHDSL equipment according to [ITU-T G.991.2] is defined in Tables E.4 and E.5.

The accuracy numbers apply to a measurement performed with only one capacitance component at a time connected to one of tip and ring, tip and GND, or ring and GND.

NOTE – In cases of MELT measurements on loops connected to SHDSL equipment according to [ITU-T G.991.2], the accuracy requirements have to be relaxed. This accounts for the typically high input capacitance of SHDSL equipment ports.

Table E.2 – Capacitance accuracy C_{TR}

Capacitance range	**Accuracy**
0 nF – 60 nF	±3 nF
60 nF – 1 µF	±5%
1 µF – 5 µF	±10%

Table E.3 – Capacitance accuracy C_{TG}, C_{RG}

Capacitance range	Accuracy
0 nF – 20 nF	±1 nF
20 nF – 1 μF	±5%
1 μF – 5 μF	±10%

Table E.4 – Capacitance accuracy C_{TR} for MELT-measurements on SHDSL equipment according to [ITU-T G.991.2]

Capacitance range	Accuracy
0 nF – 1 μF	±50 nF
1 μF – 5 μF	±10%

Table E.5 – Capacitance accuracy C_{TG}, C_{RG} for MELT-measurements on SHDSL equipment according to [ITU-T G.991.2]

Capacitance range	Accuracy
0 nF – 100 nF	±5 nF
100 nF – 1 μF	±5%
1 μF – 5 μF	±10%

E.1.1.2.2 Test voltages for the measurement of the 3-element capacitance with a controlled metallic voltage

This parameter reports the AC rms voltages present on the tip and ring wires while executing a 3-element capacitance test with a controlled metallic voltage, as defined in clause E.1.1.2, if performed with a sine wave signal. Three values are reported in relation with the tip-to-ground, ring-to-ground and tip-to-ring branches.

Three values VAC_{XY} shall be reported:

1) $VAC_{TR\text{-}CC}$ – AC voltage between tip and ring
2) $VAC_{TG\text{-}CC}$ – AC voltage between tip and GND
3) $VAC_{RG\text{-}CC}$ – AC voltage between ring and GND.

The accuracy for each element of this parameter is defined in Table E.6, while the range of valid values and granularity are defined in clause E.2.3.11.

Table E.6 – Measurement test voltages ($VAC_{TR\text{-}CC}$, $VAC_{TG\text{-}CC}$ and $VAC_{RG\text{-}CC}$) accuracy

Voltage range (Vrms)	Accuracy	Granularity
$0 \le VAC_{XY\text{-}CC} \le 10$	±0.5 Vrms	100 mV
$10 < VAC_{XY\text{-}CC} < 150$	±5%	100 mV

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.2.3.5) 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 accuracies for each of these parameters are defined in Tables E.7 to E.9.

The accuracy requirements apply when only one foreign voltage source at a time is connected to one of tip and ring, ring and tip, tip and GND, or ring and GND.

The frequency accuracy numbers only apply to foreign AC voltages V_{XY} higher than 5 Vrms.

NOTE – Typically the maximum capacitance connected between tip and ring does not exceed 5 µF. The maximum foreign DC voltages error due to the residual charge at this maximum capacitance is not expected to be higher than 1 V.

Table E.7 – Foreign DC voltages accuracy

Foreign DC voltages V_{XY} range	Accuracy
0 V – 20 V	±1 V
20 V – 250 V	±5%

Table E.8 – Foreign AC voltages accuracy

Foreign AC voltages V_{XY} range	Accuracy
0 V – 20 Vrms	±1 V rms
20 V – 250 Vrms	±5%

Table E.9 – Foreign AC frequency accuracy

Foreign AC frequency V_{XY} range	Accuracy
10 Hz – 60 Hz	±3 Hz
60 Hz – 90 Hz	±10%

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

E.1.1.4.1 Loop capacitance

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.

If the consideration of internal components during the measurement process leads to negative values, these negative capacitance values shall be reported.

NOTE – The reporting of negative capacitance values may be used to detect hardware defects.

The accuracy of this parameter is defined in Table E.10.

The accuracy of this parameter in cases of MELT measurements on loops being connected to SHDSL equipment according to [ITU-T G.991.2] is defined in Table E.11.

The accuracy numbers apply to a measurement performed with only one capacitance component connected to tip and ring.

NOTE – When MELT measurements on loops are connected to SHDSL equipment according to [ITU-T G.991.2], the accuracy requirements have to be relaxed. This accounts for the typically high input capacitance of SHDSL equipment ports.

Table E.10 – Capacitance accuracy $C_{TR,\,HV}$

Capacitance range	Accuracy
0 nF – 60 nF	±3 nF
60 nF – 1 μF	±5%
1 μF – 5 μF	±10%

Table E.11 – Capacitance accuracy $C_{TR,\,HV}$ for loops connected to SHDSL equipment according to [ITU-T G.991.2]

Capacitance range	Accuracy
0 nF – 1 μF	±50 nF
1 μF – 5 μF	±10%

E.1.1.4.2 Test voltage for the measurement of the loop capacitance with a high metallic voltage

This parameter reports the rms AC voltage present on the tip and ring wires while executing a loop capacitance test with a high metallic voltage, as defined in clause E.1.1.4, if performed with a sine wave signal. One value is reported in relation with the tip-to-ring branch.

One value VAC_{XY} shall be reported:

1) $VAC_{TR\text{-}HC}$ – AC voltage between tip and ring

The accuracy for this parameter is defined in Table E.12, while the range of valid values and granularity are defined in clause E.2.3.12.

Table E.12 – Measurement test voltage ($VAC_{TR\text{-}HC}$) accuracy

Voltage range (Vrms)	Accuracy	Granularity
$0 \leq VAC_{TR\text{-}HC} \leq 10$	±0.5 Vrms	100 mV
$10 < VAC_{TR\text{-}HC} < 150$	±5%	100 mV

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

E.1.1.5.1 Loop resistance

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 for each element of this parameter is defined in Table E.13.

The accuracy numbers apply to a measurement performed with only one resistance connected between tip and ring.

Table E.13 – Loop resistance accuracy

$R_{XY,HV}$ range	Accuracy
0 Ω – 250 Ω	±10 Ω
250 Ω – 1 kΩ	±4%
1 kΩ – 100 kΩ	±4%
100 kΩ – 500 kΩ	±8%

E.1.1.5.2 Test voltage for the measurement of the loop resistance with a high metallic voltage

This parameter reports the DC voltage present on the tip and ring wires while executing the measurement with a high metallic voltage and which are used to calculate the resistance results. Two values are reported in relation with the tip-to-ring and ring-to-tip branches. If a branch is measured by comparing the load current at two different source voltages, the voltage delta is reported instead of each individual voltage.

NOTE – The voltage values can be based on a calculation, using the source voltage, the load current and the output impedance, or can be a direct measurement.

Two voltage values $VDCH_{XY}$ shall be reported:

1) $VDCH_{TR}$ – DC voltage between tip and ring
2) $VDCH_{RT}$ – DC voltage between ring and tip.

The accuracy for each element of this parameter is defined in Table E.13.1, while the range of valid values and granularity are defined in clause E.2.3.8.

Table E.13.1 – Measurement test voltages ($VDCH_{TR}$ and $VDCH_{RT}$) accuracy

Voltage range (V)	Accuracy	Granularity
$-20 \le VDCH_{XY} \le 20$	±1 V	100 mV
$-150 < VDCH_{XY} < -20$ $20 < VDCH_{XY} < 150$	±5%	100 mV

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

E.1.1.6.1 3-element complex admittances

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).

The accuracy of this parameter is for further study.

E.1.1.6.2 Test voltages for the measurement of the 3-element complex admittance with a controlled metallic voltage

This parameter reports the AC rms voltages present on the tip and ring wires while executing a 3-element complex admittance test with a controlled metallic voltage, as defined in clause E.1.1.6, if performed with a sine wave signal. Three values are reported in relation with the tip-to-ground, ring-to-ground and tip-to-ring branches.

Three values VAC_{XY} shall be reported:

1) $VAC_{TR\text{-}CA}$ – AC voltage between tip and ring
2) $VAC_{TG\text{-}CA}$ – AC voltage between tip and GND
3) $VAC_{RG\text{-}CA}$ – AC voltage between ring and GND.

The accuracy for each element of this parameter is defined in Table E.14, while the range of valid values and granularity are defined in clause E.2.3.13.

Table E.14 – Measurement test voltages ($VAC_{TR\text{-}CA}$, $VAC_{TG\text{-}CA}$ and $VAC_{RG\text{-}CA}$) accuracy

Voltage range (Vrms)	Accuracy	Granularity
$0 \leq VAC_{XY\text{-}CA} \leq 10$	±0.5 Vrms	100 mV
$10 < VAC_{XY\text{-}CA} < 150$	±5%	100 mV

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

E.1.1.7.1 Loop complex admittance

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.

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

This parameter reports the AC rms voltage present on the tip and ring wires while executing a loop complex admittance test with a high metallic voltage as defined in clause E.1.1.7, if performed with a sine wave signal. One value is reported in relation with the tip-to-ring branch.

One value VAC_{XY} shall be reported:

1) VAC_{TR-HA} – AC voltage between tip and ring.

The accuracy for this parameter is defined in Table E.15, while the range of valid values and granularity are defined in clause E.2.3.14.

Table E.15 – Measurement test voltage (VAC_{TR-HA}) accuracy

Voltage range (Vrms)	Accuracy	Granularity
$0 \leq VAC_{TR-HA} \leq 10$	±0.5 Vrms	100 mV
$10 < VAC_{TR-HA} < 150$	±5%	100 mV

E.1.1.8 Combined measurement of 4-element resistance and 3-element capacitance

The accuracy numbers defined in clauses E.1.1.1.1 and E.1.1.2 apply to a 4-element DC resistance and a 3-element capacitance measurement performed on a single component. This clause defines the accuracy numbers for a combined measurement performed on a multiple component network as shown in Figure E.3. The network consists of six components located tip-to-ring, tip-to-ground and ring-to-ground, with neither foreign voltages nor a signature network connected to it.

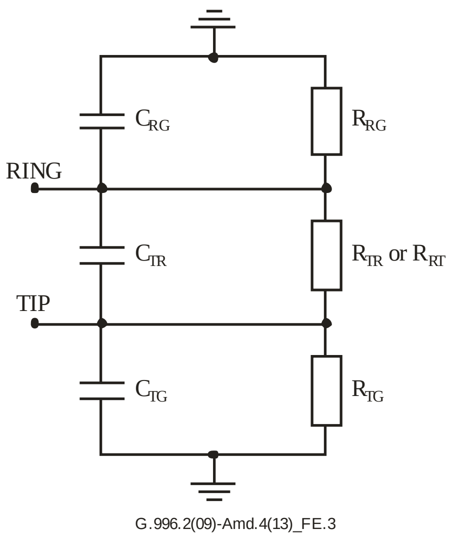


Figure E.3 – Multiple component network

The accuracy numbers included in Tables E.18 to E.22 are applicable to a combined measurement of 4-element DC resistance and 3-element capacitance when using any combination of external components selected within the range of values defined in Table E.16 or in Table E.17. Tables E.18 to E.19, indicating the accuracy of individual components when measured within a multi-component network, shall not be used for components outside of the range covered by Tables E.16 and E.17.

Table E.16 – Range of external components for MELT measurements on ADSLplus or VSDL equipment

Resistance range:	1 MΩ to 6.8 MΩ
C_{TG} and C_{RG} capacitance range:	22 nF to 470 nF
C_{TR} capacitance range:	10 nF to 100 nF

Table E.17 – Range of external components for MELT measurements on SHDSL equipment

Resistance range:	1 MΩ to 6.8 MΩ
C_{TG} and C_{RG} capacitance range:	22 nF to 470 nF
C_{TR} capacitance range:	100 nF to 1 µF

Tables E.18 to E.22 provide the accuracy of individual components when measured within a multi-component network. Those accuracy figures are applicable when all components have values selected within the ranges specified in Table E.16 for ADSL2plus or VDSL applications, or specified in Table E.17 for SHDSL applications. The accuracies are cumulative when both an absolute and a relative figure are provided. The 7-element parameter set, that is the four DC resistances (R_{TR}, R_{RT}, R_{TG} and R_{RG}) and the three capacitances (C_{TR}, C_{TG} and C_{RG}), shall be measured and reported.

Table E.18 – Resistance accuracy R_{TR}, R_{TG}, R_{RG}

Resistance range	Accuracy
1 MΩ – 4 MΩ	±15%
4 MΩ – 5 MΩ	±20%
5 MΩ – 6.8 MΩ	±25%

Table E.19 – Capacitance accuracy C_{TR} for MELT measurements on ADSLplus or VSDL equipment

Capacitance range	Accuracy
10 nF – 60 nF	±7 nF
60 nF – 100 nF	±(4 nF + 5%)

Table E.20 – Capacitance accuracy C_{TG}, C_{RG} for MELT measurements on ADSLplus or VSDL equipment

Capacitance range	Accuracy
22 nF – 60 nF	±6 nF
60 nF – 300 nF	±(3 nF + 5%)
300 nF – 470 nF	±6%

Table E.21 – Capacitance accuracy C_{TR} for MELT measurements on SHDSL equipment

Capacitance range	Accuracy
100 nF – 700 nF	±55 nF
700 nF – 1 µF	±(20 nF + 5%)

Table E.22 – Capacitance accuracy C_{TG}, C_{RG} for MELT measurements on SHDSL equipment

Capacitance range	Accuracy
22 nF – 250 nF	±25 nF
250 nF – 470 nF	±(15 nF + 4%)

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-PMD-ME. 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 management entity 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.

Following measurement tests can be enabled:

1) Measurement of the 4-element DC resistance with a controlled metallic voltage
2) Measurement of the 3-element capacitance with a controlled metallic voltage
3) Measurement of foreign DC voltage
4) Measurement of foreign AC voltage
5) Measurement of the loop capacitance with a high metallic voltage
6) Measurement of the loop resistance with a high metallic voltage
7) Measurement of the 3-element complex admittances with a controlled metallic voltage
8) Measurement of the loop complex admittance with a high metallic voltage.

As pair identification tone is a non-measurement-function of long duration, it is not part of measurement class. Its activation shall be an alternative to the measurement activation.

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 during the measurement. The range of valid values is from 0 to 150 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 Test frequency for active AC measurements

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 1 000 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 the frequency of the pair identification tone as defined in clause E.1.2.1. The range of frequencies is from 300 to 3 400 Hz in granularity of 1 Hz.

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

E.2.1.5 Pair identification tone timeout

This parameter specifies the duration of the pair identification tone. After timeout the pair identification tone shall be deactivated automatically, if not deactivated manually before.

E.2.1.6 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.2.1.7 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 management entity reporting parameters

E.2.2.1 Test frequency for active AC measurements

This parameter is the test 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 1 000 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 Peak source voltage for the measurement of the loop complex admittance with a high metallic voltage

This parameter reports the peak voltage of the differential signal generator used to execute the measurement of the loop complex admittance with a high metallic voltage (see clause E.1.1.7). The range of valid values is from 0 to 150 V and it shall be represented in linear format with a granularity of 0.1 V.

E.2.2.4 Reliability indicator for reporting parameters

The reliability indicator provides information about the reliability for each associated reporting parameter. It can have following content:

– unreliable: The associated reporting parameter is not reliable. Possible reasons:
  - The measurement may not have been able to run, due to external conditions.
  - The result is not reliable / the accuracy may be degraded due to external conditions.

– reliable: The measurement for the associated reporting parameter resulted in a reliable value.

The reliability indicator for all reporting parameters is contained in a flag register, or equivalent.

E.2.2.5 Time stamp

The Time stamp contains the time when results of last measurement test were stored. It is a string of ASCII characters formatted as '\d{4}-\d{2}-\d{2}T\d{2}:\d{2}:\d{2}(\.\d+)?'+ '(Z|[\+\-]\d{2}:\d{2})' (see [b-IETF RFC 6021] and [b-IETF RFC 3339]).

E.2.3 MELT-PMD management entity 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 DC test voltages for the measurement of the 4-element DC resistance with a controlled metallic voltage

The DC test voltages for the measurement of the 4-element DC resistance VDC_{TR}, VDC_{RT}, VDC_{TG}, and VDC_{RG}, shall be represented in linear format. The range of valid values is from −150 V to +150 V with a granularity of 0.1 V.

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

E.2.3.3 Test currents for the 4-element DC resistance with a controlled metallic voltage

The DC test currents for the measurement of the 4-element DC resistance IDC_{TR}, IDC_{RT}, IDC_{TG} and IDC_{RG}, shall be represented in linear format. The range of valid values is from −1 A to +1 A with a granularity of 1 µA.

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

E.2.3.4 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 -2 µF 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.2.3.5 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 frequencies $F_{TR,AC}$, $F_{TG,AC}$ and $F_{RG,AC}$ 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.2.3.6 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 −2 µF 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.2.3.7 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.2.3.8 Test voltage for the measurement of the loop resistance with a high metallic voltage

The DC test voltages for the measurement of the loop resistance with a high metallic voltage $VDCH_{TR}$ and $VDCH_{RT}$ shall be represented in linear format. The range of valid values is from −150 V to +150 V with a granularity of 0.1 V.

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

E.2.3.9 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.2.3.10 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.2.3.11 Test voltages for the measurement of the 3-element capacitance with a controlled metallic voltage

The range of valid values for the AC voltages VAC_{TR-CC}, VAC_{TG-CC}, and VAC_{RG-CC} for the 3-element capacitance test with a controlled metallic voltage is from 0 V rms to 150 V rms. The values shall be represented in linear format with a granularity of 0.1 V.

NOTE 1 – The linear format is chosen for simplicity and does not imply any future accuracy requirements.

NOTE 2 – The voltage is reported as rms in general. This does not necessarily imply usage of a sinewave.

E.2.3.12 Test voltage for the measurement of the loop capacitance with a high metallic voltage

The range of valid values for the AC voltage VAC_{TR-HC} for the loop capacitance test with a high metallic voltage is from 0 Vrms to 150 Vrms. The values shall be represented in linear format with a granularity of 0.1 V.

NOTE 1 – The linear format is chosen for simplicity and does not imply any future accuracy requirements.

NOTE 2 – The voltage is reported as rms in general. This does not necessarily imply usage of a sinewave.

E.2.3.13 Test voltages for the measurement of the 3-element complex admittance with a controlled metallic voltage

The range of valid values for the AC voltages VAC_{TR-CA}, VAC_{TG-CA}, and VAC_{RG-CA} for the 3-element complex admittance test with a controlled metallic voltage is from 0 Vrms to 150 Vrms. The values shall be represented in linear format with a granularity of 0.1 V.

NOTE 1 – The linear format is chosen for simplicity and does not imply any future accuracy requirements.

NOTE 2 – The voltage is reported as rms in general. This does not necessarily imply usage of a sinewave.

E.2.3.14 Test voltage for the measurement of the loop complex admittance with a high metallic voltage

The range of valid values for the AC voltage $VAC_{TR\text{-}HA}$ for the loop complex admittance test with a high metallic voltage is from 0 V rms to 150 V rms. The values shall be represented in linear format with a granularity of 0.1 V.

NOTE 1 – The linear format is chosen for simplicity and does not imply any future accuracy requirements.

NOTE 2 – The voltage is reported as rms in general. This does not necessarily imply usage of a sinewave.

E.2.3.15 Reliability indicator for measurement parameters

The reliability indicator provides information about the reliability for each associated measurement parameter. It can have following content:

– unreliable: The associated measurement parameter is not reliable. Possible reasons:
  - The measurement may not have been able to run, due to external conditions.
  - The result is not reliable / the accuracy may be degraded due to external conditions.

– reliable: The measurement for the associated measurement parameter resulted in a reliable value.

The reliability indicator for all measurement parameters is contained in a flag register, or equivalent.

E.2.4 MELT-PMD management entity 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.23 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-P-ME-C to the MELT-PMD-ME-C.

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

Table E.23 – Partitioning of MELT-PMD-ME parameters

Category/element	Defined in clause	ηC - 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)
Pair identification tone timeout (MELT-PIT-T)	E.2.1.5	R/W (O)
Maximum far-end signature conduction voltage (MELT-MAXFE-SCV)	E.2.1.6	R/W (M)
Minimum far-end signature conduction voltage (MELT-MINFE-SCV)	E.2.1.7	R/W (M)

Table E.23 – Partitioning of MELT-PMD-ME parameters

Category/element	Defined in clause	ηC - reference point
MELT-PMD reporting parameters		
Test frequency for active AC measurements (MELT-TFREQ)	E.2.2.1	R (O)
Input impedance for foreign voltage measurements (MELT-IMP-V)	E.2.2.2	R (O)
Peak source voltage for the measurement of the loop complex admittance with a high metallic voltage (MELT-HCA-V)	E.2.2.3	R (O)
Reliability indicator for reporting parameters	E.2.2.4	R (O)
Time stamp	E.2.2.5	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)
DC test voltage for the measurement of the 4-element DC resistance with a controlled metallic voltage VDC_{TR} (MELT-CDCV-TR)	E.2.3.2	R(O)
DC test voltage for the measurement of the 4-element DC resistance with a controlled metallic voltage VDC_{RT} (MELT-CDCV-RT)	E.2.3.2	R(O)
DC test voltage for the measurement of the 4-element DC resistance with a controlled metallic voltage VDC_{TG} (MELT-CDCV-TG)	E.2.3.2	R(O)
DC test voltage for the measurement of the 4-element DC resistance with a controlled metallic voltage VDC_{RG} (MELT-CDCV-RG)	E.2.3.2	R(O)
Test current for the measurement of the 4-element DC resistance with a controlled metallic voltage IDC_{TR} (MELT-CDCI-TR)	E.2.3.3	R(O)
Test current for the measurement of the 4-element DC resistance with a controlled metallic voltage IDC_{RT} (MELT-CDCI-RT)	E.2.3.3	R(O)
Test current for the measurement of the 4-element DC resistance with a controlled metallic voltage IDC_{TG} (MELT-CDCI-TG)	E.2.3.3	R(O)
Test current for the measurement of the 4-element DC resistance with a controlled metallic voltage IDC_{RG} (MELT-CDCI-RG)	E.2.3.3	R(O)
3-element capacitance with controlled metallic voltage C_{TR} (MELT-CC-TR)	E.2.3.4	R (M)
3-element capacitance with controlled metallic voltage C_{TG} (MELT-CC-TG)	E.2.3.4	R (M)
3-element capacitance with controlled metallic voltage C_{RG} (MELT-CC-RG)	E.2.3.4	R (M)
Foreign DC voltage $V_{TR,DC}$ (MELT-FVDC-TR)	E.2.3.5	R (M)
Foreign DC voltage $V_{TG,DC}$ (MELT-FVDC-TG)	E.2.3.5	R (M)
Foreign DC voltage $V_{RG,DC}$ (MELT-FVDC-RG)	E.2.3.5	R (M)
Foreign AC voltage $V_{TR,AC}$ (MELT-FVAC-TR)	E.2.3.5	R (M)
Foreign AC voltage $V_{TG,AC}$ (MELT-FVAC-TG)	E.2.3.5	R (M)
Foreign AC voltage $V_{RG,AC}$ (MELT-FVAC-RG)	E.2.3.5	R (M)
Foreign AC voltage frequency $F_{TR,AC}$ (MELT-FVACF-TR)	E.2.3.5	R (M)
Foreign AC voltage frequency $F_{TG,AC}$ (MELT-FVACF-TG)	E.2.3.5	R (M)
Foreign AC voltage frequency $F_{RG,AC}$ (MELT-FVACF-RG)	E.2.3.5	R (M)

Table E.23 – Partitioning of MELT-PMD-ME parameters

Category/element	Defined in clause	ηC - reference point
Loop capacitance with high metallic voltage (MELT-HC-TR)	E.2.3.6	R (M)
Loop resistance with high metallic voltage (MELT-HDCR-TR)	E.2.3.7	R (M)
Loop resistance with high metallic voltage (MELT-HDCR-RT)	E.2.3.7	R (M)
Test voltage for the measurement of the loop resistance with a high metallic voltage $VDCH_{TR}$ (MELT-HDCV-TR)	E.2.3.8	R (O)
Test voltage for the measurement of the loop resistance with a high metallic voltage $VDCH_{RT}$ (MELT-HDCV-RT)	E.2.3.8	R (O)
3-element complex admittance with controlled metallic voltage real part G_{TR} (MELT-CAG-TR)	E.2.3.9	R (O)
3-element complex admittance with controlled metallic voltage imaginary part B_{TR} (MELT-CAB-TR)	E.2.3.9	R (O)
3-element complex admittance with controlled metallic voltage real part G_{TG} (MELT-CAG-TG)	E.2.3.9	R (O)
3-element complex admittance with controlled metallic voltage imaginary part B_{TG} (MELT-CAB-TG)	E.2.3.9	R (O)
3-element complex admittance with controlled metallic voltage real part G_{RG} (MELT-CAG-RG)	E.2.3.9	R (O)
3-element complex admittance with controlled metallic voltage imaginary part B_{RG} (MELT-CAB-RG)	E.2.3.9	R (O)
Loop complex admittance with high metallic voltage real part $G_{TR,HV}$ (MELT-HAG-TR)	E.2.3.10	R (O)
Loop complex admittance with high metallic voltage imaginary part $B_{TR,HV}$ (MELT-HAB-TR)	E.2.3.10	R (O)
Test voltage for the measurement of the 3-element capacitance with a controlled metallic voltage $VAC_{TR\text{-}CC}$ (MELT-ACV-CC-TR)	E.2.3.11	R (O)
Test voltage for the measurement of the 3-element capacitance with a controlled metallic voltage $VAC_{TG\text{-}CC}$ (MELT-ACV-CC-TG)	E.2.3.11	R (O)
Test voltage for the measurement of the 3-element capacitance with a controlled metallic voltage $VAC_{RG\text{-}CC}$ (MELT-ACV-CC-RG)	E.2.3.11	R (O)
Test voltage for the measurement of the loop capacitance with a high metallic voltage $VAC_{TR\text{-}HC}$ (MELT-ACV-HC-TR)	E.2.3.12	R (O)
Test voltage for the measurement of the 3-element complex admittance with a controlled metallic voltage $VAC_{TR\text{-}CA}$ (MELT-ACV-CA-TR)	E.2.3.13	R (O)
Test voltage for the measurement of the 3-element complex admittance with a controlled metallic voltage $VAC_{TG\text{-}CA}$ (MELT-ACV-CA-TG)	E.2.3.13	R (O)
Test voltage for the measurement of the 3-element complex admittance with a controlled metallic voltage $VAC_{RG\text{-}CA}$ (MELT-ACV-CA-RG)	E.2.3.13	R (O)
Test voltage for the measurement of the loop complex admittance with a high metallic voltage $VAC_{TR\text{-}HA}$ (MELT-ACV-HA-TR)	E.2.3.14	R (O)
Reliability indicator for measurement parameters	E.2.3.15	R (O)

E.3 Test management

The MELT-PMD is managed using the parameters defined in this clause.

E.3.1 MELT-PMD control

This parameter configures the MELT-PMD for a MELT measurement or tone generation.

The parameter is of type enumeration, with the following valid values:

– disable: the MELT-PMD is not configured for a measurement or pair identification tone (PIT) generation;

– enable: the MELT-PMD is configured for a measurement or PIT generation.

The MELT-PMD is by default "disable".

E.3.2 MELT-PMD request

While the MELT-PMD is configured "enable", this parameter is used to trigger the start of either a measurement or a PIT generation or to trigger the abortion of an ongoing measurement or PIT generation.

The parameter is of type enumeration, with the following valid values:

– none: a measurement or PIT generation is not triggered.

– measurement: triggers the MELT-PMD to start the test or tests specified by the measurement class (MELT-MCLASS).

– pair-identification-tone-generation: triggers the MELT-PMD to start a PIT generation for the duration specified.

– abort: triggers the MELT-PMD to abort any ongoing measurement or PIT generation.

A measurement or PIT generation is triggered when the value is configured from "none" to either "measurement" or "pair-identification-tone-generation". After completion of the current measurement or PIT generation, transition to "none" is required before a new measurement or PIT generation can be triggered. Transition from any measurement to "abort" shall stop the measurement or PIT generation. Transitions from "measurement" to "pair-identification-tone-generation" and vice versa are invalid. One or more measurements or PIT generations may be triggered while the MELT-PMD is configured "enable", possibly with different MELT-PMD configuration parameters. If the triggered measurement or PIT generation cannot be executed, then the AN/DPU ME rejects this request and the MELT-PMD status remains "inactive".

E.3.3 MELT-PMD status

This parameter reports the status of the measurement or PIT generation.

The parameter is of type enumeration, with the following valid values:

– inactive: the MELT-PMD is inactive;

– measurement-ongoing: the measurement is ongoing;

– pit-generation-ongoing: the pair identification tone generation is ongoing.

Upon the MELT-PMD request triggering a measurement, the MELT-PMD status shall become "measurement-ongoing" if the measurement is executed.

Upon the MELT-PMD request triggering a PIT generation, the MELT-PMD status shall become "pit-generation-ongoing" if the PIT generation is executed.

Upon abortion, failure or successful completion of the measurement or PIT generation, the MELT-PMD status shall become "inactive" and the AN/DPU ME shall send a notification to the NMS.

E.3.4 MELT results status

This parameter reports the status of the measurement results.

The parameter is of type enumeration, with the following valid values:

– no-measurement-results-available: no measurement results are available when no measurement has been performed yet or after measurement the results have been deleted;

– measurement-failed-results-invalid: measurement results are invalid after the most recent measurement failed;

– measurement-succeeded-results-valid: measurement results are valid after the most recent measurement succeeded.

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:

– ZRC: e.g., signature for indicating a DSL-CPE
– DR: Passive test termination, e.g., for master socket.

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.

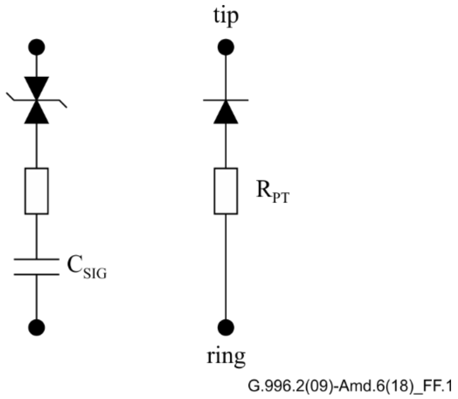


Figure F.1 – Valid signature topology types (resp. ZRC (left) and DR (right))

Valid response values are:

– no signature detected;
– unknown signature;
– signature type DR detected;
– signature type DR inverse detected;
– signature type ZRC detected;
– signature type DR + ZRC detected;
– signature type DR inverse + ZRC detected.

F.1.1.7 CPE identification capacitive

This parameter indicates if a CPE has been detected based on the termination capacitance. Valid response values are:

– no CPE detected;
– CPE detected.

CPE detected shall be reported if the measured capacitance value $C_{TR\text{-}Term}$ is ≥ MELT-SYSC-CPE. $C_{TR\text{-}Term}$ shall represent the termination capacitance only. Therefore, the line capacitance shall be subtracted from the measured C_{TR} value. For this equation to hold, the MELT-SYSC-CPE value should be derived from the nominal CPE capacitance by accounting for all tolerances in best efforts and be set to the minimum possible measurement result.

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-P-ME shall have the same format as specified for the MELT-P. See clause F.1.1.1.1.

F.2.2.1.2 Distance to the open wire failure

The parameter in the MELT-P-ME shall have the same format as specified for the MELT-P. See clause F.1.1.1.2.

F.2.2.2 Identification of a short circuit failure

F.2.2.2.1 Short circuit failure type

The parameter in the MELT-P-ME shall have the same format as specified for the MELT-P. See clause F.1.1.2.1.

F.2.2.3 Leakage identification

The parameter in the MELT-P-ME shall have the same format as specified for the MELT-P. See clause F.1.1.3.

F.2.2.4 Resistive fault identification

The parameter in the MELT-P-ME shall have the same format as specified for the MELT-P. See clause F.1.1.4.

F.2.2.5 Foreign voltage classification

F.2.2.5.1 Foreign voltage type

The parameter in the MELT-P-ME shall have the same format as specified for the MELT-P. See clause F.1.1.5.1.

F.2.2.5.2 Foreign voltage level class

The parameter in the MELT-P-ME shall have the same format as specified for the MELT-P. See clause F.1.1.5.2.

F.2.2.6 Far-end signature topology identification

F.2.2.6.1 Far-end signature topology type

The parameter in the MELT-P-ME shall have the same format as specified for the MELT-P. See clause F.1.1.6.1.

F.2.2.7 Reliability indicator for derived parameters

The reliability indicator provides information about the reliability for each associated derived parameter. It can have following content:

– unreliable: At least one of the PMD measurement parameters on which the associated derived parameter is based is indicated as unreliable.

– reliable: All PMD measurement parameters on which the associated derived parameter is based are indicated as reliable.

The reliability indicator for all derived parameters is contained in a flag register, or equivalent.

F.2.3 MELT-P management entity parameter 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-P-ME 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)
Pair identification tone timeout (MELT-PIT-T)	E.2.1.5	R/W (O)
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		
Test frequency for active AC measurements (MELT-TFREQ)	E.2.2.1	R (O)
Input impedance for foreign voltage measurements (MELT-IMP-V)	E.2.2.2	R (O)
Peak source voltage for the measurement of the loop complex admittance with a high metallic voltage (MELT-HCA-V)	E.2.2.3	R (O)
Reliability indicator for reporting parameters	E.2.2.4	R (O)
Time stamp	E.2.2.5	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)
DC test voltage for the measurement of the 4-element DC resistance with a controlled metallic voltage VDC_{TR} (MELT-CDCV-TR)	E.2.3.2	R(O)
DC test voltage for the measurement of the 4-element DC resistance with a controlled metallic voltage VDC_{RT} (MELT-CDCV-RT)	E.2.3.2	R(O)
DC test voltage for the measurement of the 4-element DC resistance with a controlled metallic voltage VDC_{TG} (MELT-CDCV-TG)	E.2.3.2	R(O)
DC test voltage for the measurement of the 4-element DC resistance with a controlled metallic voltage VDC_{RG} (MELT-CDCV-RG)	E.2.3.2	R(O)
Test current for the measurement of the 4-element DC resistance with a controlled metallic voltage IDC_{TR} (MELT-CDCI-TR)	E.2.3.3	R(O)
Test current for the measurement of the 4-element DC resistance with a controlled metallic voltage IDC_{RT} (MELT-CDCI-RT)	E.2.3.3	R(O)
Test current for the measurement of the 4-element DC resistance with a controlled metallic voltage IDC_{TG} (MELT-CDCI-TG)	E.2.3.3	R(O)
Test current for the measurement of the 4-element DC resistance with a controlled metallic voltage IDC_{RG} (MELT-CDCI-RG)	E.2.3.3	R(O)
3-element capacitance with controlled metallic voltage C_{TR} (MELT-CC-TR)	E.2.3.4	R (M)
3-element capacitance with controlled metallic voltage C_{TG} (MELT-CC-TG)	E.2.3.4	R (M)
3-element capacitance with controlled metallic voltage C_{RG} (MELT-CC-RG)	E.2.3.4	R (M)
Foreign DC voltage $V_{TR,DC}$ (MELT-FVDC-TR)	E.2.3.5	R (M)
Foreign DC voltage $V_{TG,DC}$ (MELT-FVDC-TG)	E.2.3.5	R (M)
Foreign DC voltage $V_{RG,DC}$ (MELT-FVDC-RG)	E.2.3.5	R (M)
Foreign AC voltage $V_{TR,AC}$ (MELT-FVAC-TR)	E.2.3.5	R (M)

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

Category/element	Defined in clause	Q - interface
Foreign AC voltage $V_{TG,AC}$ (MELT-FVAC-TG)	E.2.3.5	R (M)
Foreign AC voltage $V_{RG,AC}$ (MELT-FVAC-RG)	E.2.3.5	R (M)
Foreign AC voltage frequency $F_{TR,AC}$ (MELT-FVACF-TR)	E.2.3.5	R (M)
Foreign AC voltage frequency $F_{TG,AC}$ (MELT-FVACF-TG)	E.2.3.5	R (M)
Foreign AC voltage frequency $F_{RG,AC}$ (MELT-FVACF-RG)	E.2.3.5	R (M)
Loop capacitance with high metallic voltage (MELT-HC-TR)	E.2.3.6	R (M)
Loop resistance with high metallic voltage (MELT-HDCR-TR)	E.2.3.7	R (M)
Loop resistance with high metallic voltage (MELT-HDCR-RT)	E.2.3.7	R (M)
Test voltage for the measurement of the loop resistance with a high metallic voltage $VDCH_{TR}$ (MELT-HDCV-TR)	E.2.3.8	R (O)
Test voltage for the measurement of the loop resistance with a high metallic voltage $VDCH_{RT}$ (MELT-HDCV-RT)	E.2.3.8	R (O)
3-element complex admittance with controlled metallic voltage real part G_{TR} (MELT-CAG-TR)	E.2.3.9	R (O)
3-element complex admittance with controlled metallic voltage imaginary part B_{TR} (MELT-CAB-TR)	E.2.3.9	R (O)
3-element complex admittance with controlled metallic voltage real part G_{TG} (MELT-CAG-TG)	E.2.3.9	R (O)
3-element complex admittance with controlled metallic voltage imaginary part B_{TG} (MELT-CAB-TG)	E.2.3.9	R (O)
3-element complex admittance with controlled metallic voltage real part G_{RG} (MELT-CAG-RG)	E.2.3.9	R (O)
3-element complex admittance with controlled metallic voltage imaginary part B_{RG} (MELT-CAB-RG)	E.2.3.9	R (O)
Loop complex admittance with high metallic voltage real part $G_{TR,HV}$ (MELT-HAG-TR)	E.2.3.10	R (O)
Loop complex admittance with high metallic voltage imaginary part $B_{TR,HV}$ (MELT-HAB-TR)	E.2.3.10	R (O)
Test voltage for the measurement of the 3-element capacitance with a controlled metallic voltage VAC_{TR-CC} (MELT-ACV-CC-TR)	E.2.3.11	R (O)
Test voltage for the measurement of the 3-element capacitance with a controlled metallic voltage VAC_{TG-CC} (MELT-ACV-CC-TG)	E.2.3.11	R (O)
Test voltage for the measurement of the 3-element capacitance with a controlled metallic voltage VAC_{RG-CC} (MELT-ACV-CC-RG)	E.2.3.11	R (O)
Test voltage for the measurement of the loop capacitance with a high metallic voltage VAC_{TR-HC} (MELT-ACV-HC-TR)	E.2.3.12	R (O)
Test voltage for the measurement of the 3-element complex admittance with a controlled metallic voltage VAC_{TR-CA} (MELT-ACV-CA-TR)	E.2.3.13	R (O)
Test voltage for the measurement of the 3-element complex admittance with a controlled metallic voltage VAC_{TG-CA} (MELT-ACV-CA-TG)	E.2.3.13	R (O)
Test voltage for the measurement of the 3-element complex admittance with a controlled metallic voltage VAC_{RG-CA} (MELT-ACV-CA-RG)	E.2.3.13	R (O)
Test voltage for the measurement of the loop complex admittance with a high metallic voltage VAC_{TR-HA} (MELT-ACV-HA-TR)	E.2.3.14	R (O)
Reliability indicator for measurement parameters	E.2.3.15	R (O)

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

Category/element	Defined in clause	Q - interface
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)
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)
Derived parameters reliability indicator	F.2.2.7	R (O)

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

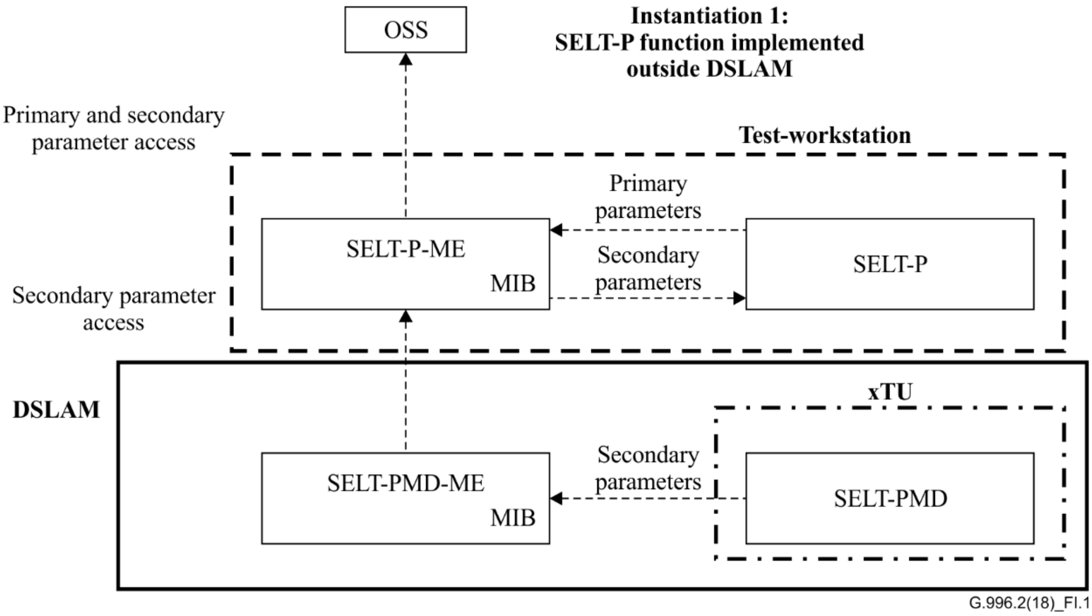


Figure I.1 – SELT instantiation 1: SELT-P function outside the DSLAM

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

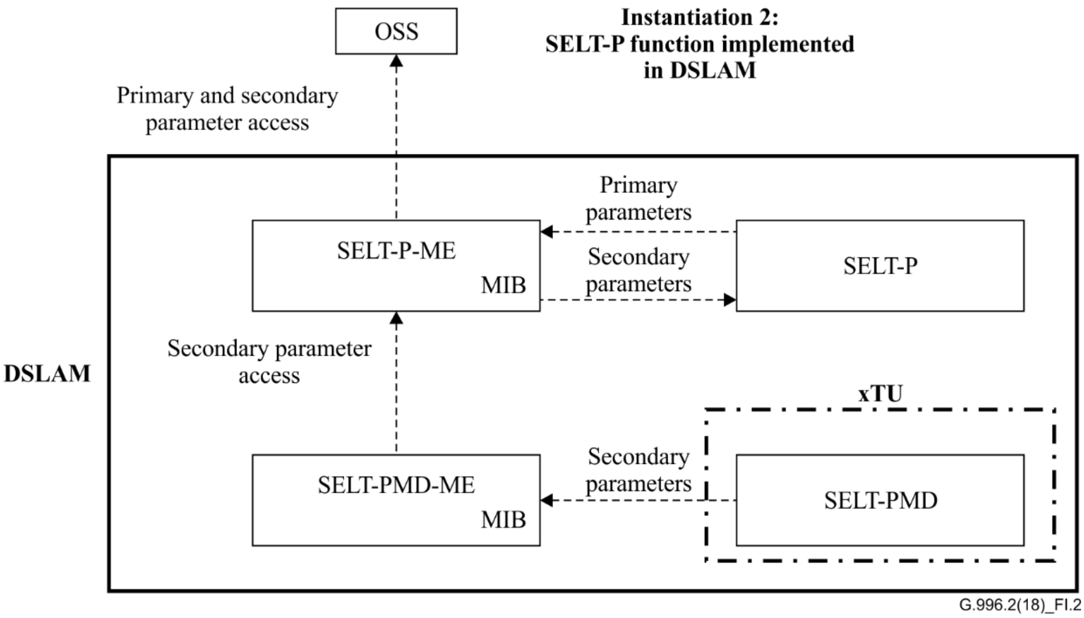


Figure I.2 – SELT instantiation 2: SELT-P function inside DSLAM

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

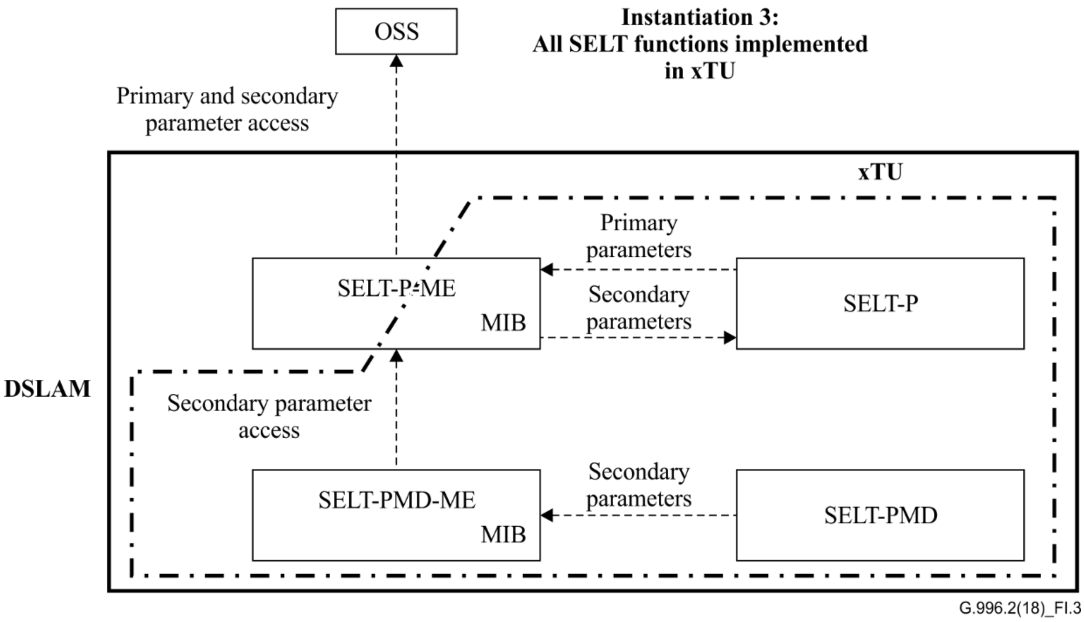


Figure I.3 – SELT instantiation 3: SELT-P inside xTU-C

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

NOTE 2 – Parts of SELT-P-ME and SELT-PMD-ME 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]).

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