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Technical Specification

Environmental Engineering (EE)
Measurement Methods and limits for Energy Consumption in Broadband Telecommunication Networks Equipment

Reference
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Foreword

This Technical Specification (TS) has been produced by ETSI Technical Committee Environmental Engineering (EE).

Introduction

The present document defines the energy consumption limits and measurement methods for fixed broadband (DSL) telecommunication network equipment.

1 Scope

The present document defines the power consumption limits, the methodology and the test conditions to measure the power consumption of broadband fixed telecommunication networks equipment.

The power consumption limits are based on the European Code of Conduct for Broadband Equipment [i.1].

The types of broadband access technologies covered by the present document are the ones widely deployed at the date of publication. Other access technologies may be included in further versions of the present document.

In addition to the full power state, power-saving states asdefined in DSL standards [i.2] and [i.3] are also covered.

Currently, the present document only considers DSLAM DSL equipment.Future versions will also include MSAN equipment.

Other access technologies (e.g. WiMAX, PLC, optical) are not yet considered because they are still in an early stage of development/deployment

The present document focuses on Network Equipment.The end-user equipment is not handled in the present document.For limits for end-user Equipment please refer to the current revision of the Code of Conduct for Broadband Equipment [i.1].

2 References

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NOTE: While any hyperlinks included in this clause were valid at the time of publication ETSI cannot guarantee their long term validity.

2.1 Normative references

The following referenced documents are indispensable for the application of the present document. For dated references, only the edition cited applies. For non-specific references, the latest edition of the referenced document (including any amendments) applies.

[1] ETSI TS 101 388: "Access Terminals Transmission and Multiplexing (ATTM); Access transmission systems on metallic access cables; Asymmetric Digital Subscriber Line (ADSL) - European specific requirements [ITU-T Recommendation G.992.1 modified]".

[2] ETSI EN 300 132-2: "Environmental Engineering (EE); Power supply interface at the input to telecommunications equipment; Part 2: Operated by direct current (dc)".

[3] ETSI TS 101 270-1: "Transmission and Multiplexing (TM); Access transmission systems on metallic access cables; Very high speed Digital Subscriber Line (VDSL); Part 1: Functional requirements".

2.2 Informative references

The following referenced documents are not essential to the use of the present document but they assist the user with regard to a particular subject area**.** For non-specific references, the latest version of the referenced document (including any amendments) applies.

[i.1] "Code Of Conduct on Energy Consumption of Broadband Communication Equipment European Commission Directorate-General, Joint Research Centre; Final v2: 17 July 2007".

[i.2] ITU-T Recommendation G.992.3 (01/2005): "Asymmetric digital subscriber line transceivers 2 (ADSL2)".

[i.3] ITU-T Recommendation G.992.5 (01/2005): "Asymmetric Digital Subscriber Line (ADSL) transceivers - Extended bandwidth ADSL2 (ADSL2plus)".

[i.4] ITU-T Recommendation G.993.2 (02/2006): "Very high speed digital subscriber line 2 (VDSL2)".

[i.5] ETSI TR 102 530: "Environmental Engineering (EE); The reduction of energy consumption in telecommunications equipment and related infrastructure".

3 Definitions and abbreviations

3.1 Definitions

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

active line: line in operational mode and carrying traffic as specified for that mode of operation (ADSL2plus or VDSL2)

broadband terminal equipment: equipment of broadband technology that is connected beyond the Network Termination Point of a telecommunication network

broadband telecommunication network equipment: equipment of broadband technology that is part of a telecommunication network

full-power state: state in which the maximal allowed data transmission is possible.The maximum is defined by the physical properties of the line and the settings of the operator (e.g. L0 for ADSL2/2plus)

low-power state: allows a limited power reduction capability and a limited data transmission is allowed

NOTE: It is entered automatically from the full power state after the data transmission during a certain time is lower than the limit. If more than the limited data has to be transmitted from either side a state change to the full power state is entered automatically. The low power state may comprise multiple sub-states with history dependant state transition rules (e.g. L2 for ADSL2/2plus).

stand-by state: has the largest power reduction capability and there is no transmission of data possible

NOTE: From this state a direct state change to the full-transmission state is possible, if data has to be transmitted from either side (e.g. L3 for ADSL2/2plus).

power consumption: power used by a device to achieve an intended application performance

telecommunication network: network operated under a license granted by a national telecommunications authority, which provides telecommunications between Network Termination Points (NTPs) (i.e. excluding terminal equipment beyond the NTPs)

3.2 Abbreviations

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

ADSL	Asymmetric Digital Subscriber Line
ADSL2plus	Second generation ADSL with extended bandwidth
CoC	Code of Conduct

NOTE: On Energy Consumption of Broadband Equipment.

CPE	Customer Premises Equipment
DSL	Digital Subscriber Line
DSLAM	Digital Subscriber Line Access Multiplexer
DSM	Dynamic Spectrum Management
MIMO	Multiple Input Multiple Output
MSAN	Multi Service Access Node
NPC	Normalized Power Consumption
PLC	Power Line Communication
PSTN	Public Switched Telephone Network
VDSL	Very high speed Digital Subscriber Line
VDSL2	Second generation VDSL
VoIP	Voice over Internet Protocol
WiMAX	Worldwide interoperability for Microwave Access

4 Definition of power consumption

4.1 Definition of power consumption per line of Broadband Equipment

The power consumption of broadband telecommunication network equipment (i.e. in the case of DSL access technology, the DSLAM) is defined as:

$$P_{BBline} = P_{BBeq} / N_{subscrib\text{-}lines}$$

where:

$\mathbf{P_{BBeq}}$ is the power consumption (in W) of a fully equipped broadband equipment (DSLAM), measured at the electric power input interface, placed at the premises of the operator or the equipment supplier, which connects multiple broadband subscribers to a backbone.

$\mathbf{P_{BBline}}$ is the power consumption per line in W of the broadband equipment for which the limits are defined in the present document.

$\mathbf{N_{suscrib\text{-}lines}}$ is the maximum number of subscriber lines served by the broadband equipment (DSLAM) under test.

$\mathbf{P_{BBeq}}$ is measured in determined environmental conditions defined in clause 5.1.7.

4.2. Definition of Normalized Power Consumption per line for Broadband Network Equipment

In addition to the power P_{BBline} that is defined for one equipment, an indication of global network power performance might be given.

The "Normalized Power Consumption" (NPC) is an indicator of the amount of power required to transport 1 Mbps of data over a 1 kilometre distance

$$NPC = 1000 \text{ x } \mathbf{P_{BBline}} \text{ /(bitrate x line length)}$$

NPC is expressed in mW/Mbps/km.

where:

Bitrate is in Mbps and line length is in km.

For DSLAM, the NPC shall be based on the bitrate and reach at full-power state as defined in the measurement method (see clause 5.1.5).The definition of the NPC can be found in TR 102 530 [i.5].

This NPC enables comparison of different technologies (such as ADSL2(plus) and VDSL2) regarding the efficiency of transporting information (in terms of power). It shall be calculated at relevant data points for each technology. These data points are derived from the typical or targeted working conditions of these technologies and are given in the clause on measurement methods (clause 5.1.5).

For instance, ADSL2plus might be deployed with a loop length of around 3 km with a data rate of 5 Mbps, or with shorter loops of 1 km with a data rate of 20 Mbps.

NOTE: NPC can be used for comparing different products with the same technology, different products in different technologies or different generations of the same technologies. Using the NPC to compare the different working states (e.g. L0 with L2 or L3) is not recommended as the intention of some of these working states is to save energy at times of no or low-rate transmission - i.e. when there is no need to transmit high data rates. NPC is not the only parameter to compare power consumption at service level. For comparing power consumption of certain service types (e.g. VoIP vs. PSTN) a different parameter might be more relevant.

4.2.1 Power consumption taking into account the low-power states

The low-power states are intended to reduce the power consumption during periods of no or minimal traffic needs (e.g. low data-rate applications or control signalling only). When these low-power states are used, the achievable power consumption reduction can be estimated by using profiles based on user traffic assumptions, as illustrated in annex A.

NOTE 1: Usage of power-saving states.

A number of power-saving states are defined in the DSL standards (L2, L3, ITU-T Recommendation G.992.3 [i.2], ITU-T Recommendation G.992.5 [i.3]).These power-saving states shall be implemented, both in the Network equipment subject of the present document and the CPE/end-user equipment deployed at the premises of the user of the broadband line; this will enable the operator to use these to further limit the power consumption of the equipment.

Further study is required to optimize the way in which the low-power states are controlled.In particular, to determine the levels of interference that might arise due to the fluctuating crosstalk caused by frequentmulti-state power transitions.

NOTE 2: Additional power saving solutions.

A number of additional power saving solutions are available.Some of these are listed below.However the list is not complete and both the developers and users of broadband equipment are encouraged to investigate and introduce new power saving solutions.

- Politeness algorithms.
- Dynamic Spectrum Management.
- Boards optimized for remote applications (reduced line power).

5 Measurement methods

This clause describes the methods to measure the power consumption of broadband equipment and also gives the conditions under which these measurements shall be performed.

5.1 Method and conditions for measurement of power consumption for DSLAM Equipment

5.1.1 Considered Equipment

The following items are considered part of the DSLAM and therefore their power consumption shall be taken into account to get the total power consumption (P_{BBeq}) of the DSLAM:

- Network Termination board, providing one or more links to the Core or Backhaul Network.

NOTE: The actual number of links should reflect the normal resilience practice for that type of equipment.

- Line Termination board, providing a number of xDSL ports connected to the end-user through the local loop.
- Splitter (Low Pass Filter) function.
- Backplane (or other) to interconnect the different blocks of the DSLAM.
- Inside Rack Cooling system (e.g. fans drawer inside cabinet based DSLAM systems).
- Normal operational power supply unit.

5.1.2 Not Considered Equipment

The following items are not considered part of the DSLAM and therefore their power consumption shall not be added to the power consumption of the DSLAM:

- Rectifier (AC/DC).
- Room or outdoor Cabinet Ventilation and Air Conditioning Unit (VAC Unit).
- Auxiliary power unit.
- Battery.
- Additional External signal processing (Dynamic Spectrum Management (DSM) and Multiple-Input Multiple Output (MIMO) techniques if not implemented as part of the Line Termination board)

5.1.3 Measurement Reference Points

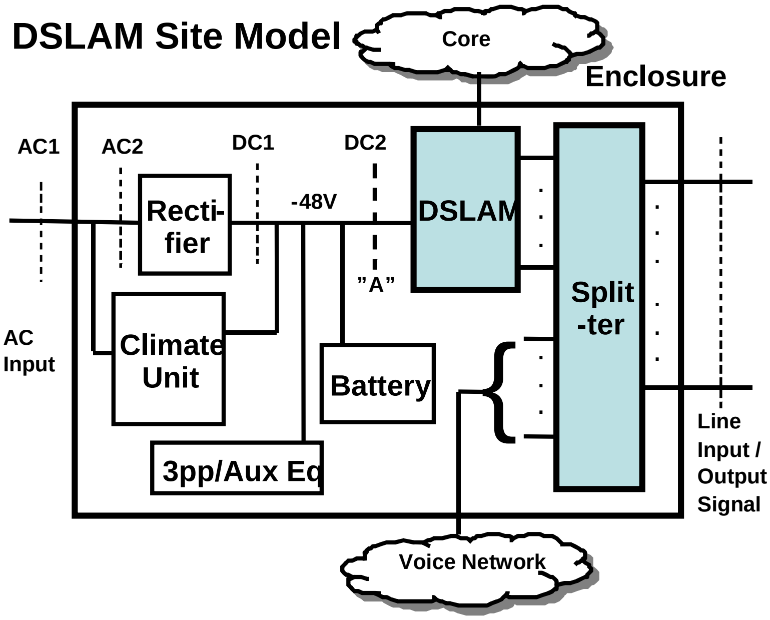


Figure 1: DSLAM Node site reference model

The power consumption requirements of the present document apply at Interface "A" [2] as shown in figure 1 (i.e. at the point DC2 for the configuration in figure 1).

5.1.4 Configuration parameters

The DSLAM shall be configured as defined below. The number of boards and lines shall not exceed the maximum operational capacity of the system.

Active lines shall be carrying traffic over an ETSI loop 1 in the presence of self-cross talk noise, as defined in TS 101 388 [1] and TS 101 270-1 [3]. The loop length is dependent on the xDSL technology (see ITU-T Recommendations G.992.3 [i.2], G.992.5 [i.3] and G.993.2 [i.4]) activated on the line.The test set-up is as shown in figure 2.

Equipment conditions:

- ADSL2plus configuration:
  - Loop length/type: see table 1.
  - Downstream/Upstream data-rate: maximum possible data rate.
    - For NPC calculation a datarate of 5 Mbps shall be used.
  - Operating Mode: Fast.
  - Target noise margin: 6 dB.
  - Self Xtalk (49 disturbers).
- VDSL2 configuration:
  - Loop-length/type: see table 1.
  - Downstream/Upstream data-rate: maximum possible data rate.
    - Operating mode: Interleaving (INP = 2, delay = 8).
  - Target noise margin: 6 dB.

- Self Xtalk (19 disturbers).

Table 1: Loop-lengths for various DSL technologies

Technology	Loop length	Reference loop
ADSL, ADSL2, ADSL2plus	3 000 m	TS 101 388 [1] clause 5.2 loop 1(0,4 mm)
VDSL2 profile 8a, 8b,	1 500 m	TS 101 270-1 [3] loop 1 (0,5 mm)
VDSL2 profile 8c, 8d	1 500 m	TS 101 270-1 [3] loop 1 (0,5 mm)
VDSL2 profile 12a, 12b	1 000 m	TS 101 270-1 [3] loop 1 (0,5 mm)
VDSL2 profile 17a	750 m	TS 101 270-1 [3] loop 1 (0,5 mm)
VDSL2 profile 30a	300 m	TS 101 270-1 [3] loop 1 (0,5 mm)
NOTE: The above DSL technology and profile are defined for the power consumption measurement.Representative looplengths for the corresponding DSL technology and profiles are also defined in this table.The worst case VDSL2 configurations are the configurations for profile 8b and 17a.		

5.1.5 Reference Measurement method

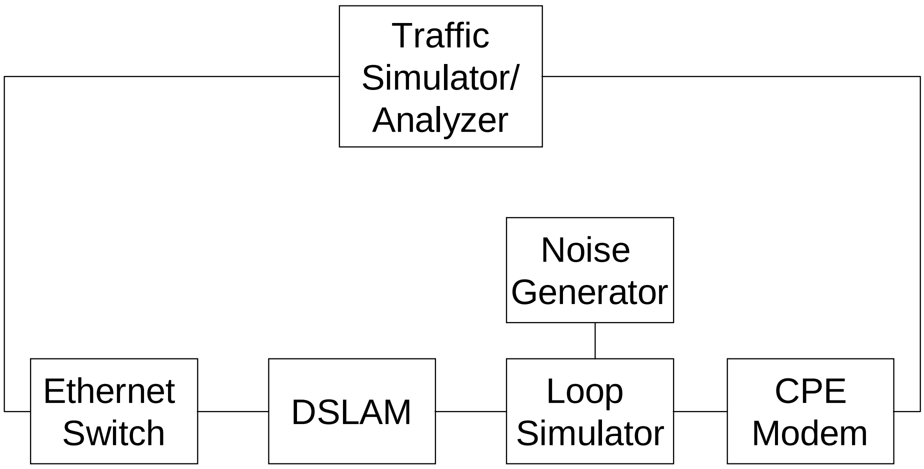


Figure 2: Test Setup for power measurement for DSLAM

Figure 2 shows the basic test setup, which is to be used during the power measurements.Both the network side (optionally through an Ethernet switch) and the end-user side (direct or also through an Ethernet switch) are connected to an Ethernet Traffic Simulator/Analyzer.

For the reference measurement method the DSLAM shall be fully equipped and all ports of the DSLAM shall be connected to CPE/End user modems through loop or line simulators.The Loop or line simulators are set at the appropriate line length as described above (depending on the ADSL2plus or VDSL2 mode).The DSLAM is configured properly such that traffic generated by the Traffic Simulator can flow properly through the DSLAM to the CPE and vice versa.The Traffic Analyzer will show that the traffic is indeed passing through the setup.

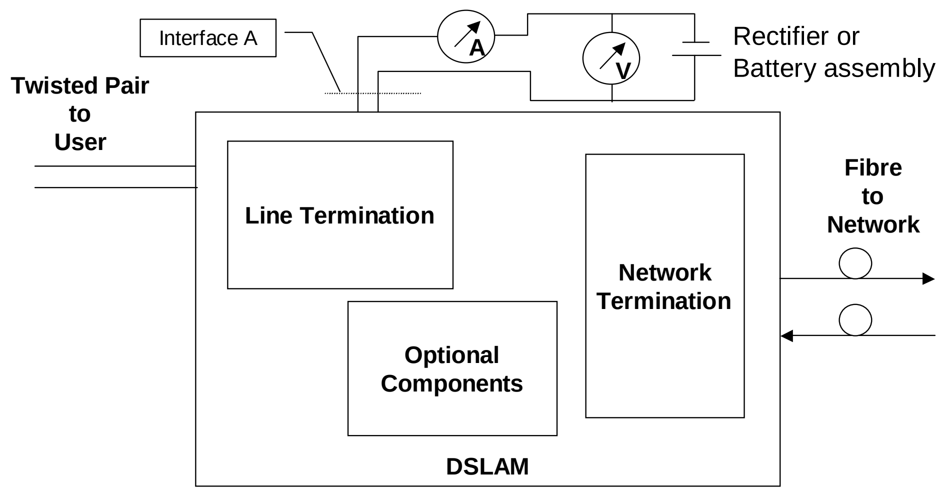


Figure 3: Power Consumption at System level

In figure 3, the actual DSLAM power measurement method is shown.The DSLAM comprises the line termination boards, the Network termination boards and some other components like the cooling system.The Network termination board has fibre connections to the traffic simulator/analyzer (as shown in figure 2) and the line termination boards have twisted pairs connected to loop/line simulators.

The power of the system is measured at the "A" interface of the DSLAM using both a current and voltage meter.The system can be powered either through a battery assembly or rectifier set at the nominal voltage as described in clause 5.1.7.

5.1.6 Alternative measurement method

This alternative technique reduces the number of line simulators and CPE required but requires extrapolation to give the correct per line result. A minimal configuration shall include at least one fully equipped Line Termination board connected to end-user equipments and configured to pass traffic.

This alternative measurement method comprises two phases:

- The power consumption (P_{empty}) ofthe DSLAM is first measured without any Line Termination board based on figure 3 setup. During both measurements (P_{empty} and $P_{1\ line\ card}$), it is important that the functional blocks, expected to have a power consumption varying with the number of users connected, are forced in a full load condition. Functional blocks which are known to increase power consumption under heavy load are the cooling system and the Network Termination board.
- In a second phase, one Line Termination board is added to the system with all lines connected to a CPE though line or loop simulators. All parameters are set based on values shown in clause 5.1.4. The power consumption of the DSLAM with the added Line Termination board ($P_{1\ line\ card}$) is measured once again and the difference ($P_{1\ line\ card}$ - P_{empty}) gives the power consumption ($P_{line\ card}$) of a fully equipped Line Termination board.

The total power consumption is given by the formula:

$$P_{BBline} = P_{empty} + n * P_{line\ card}$$

Where n is the maximum number of Line Termination boards per DSLAM.

5.1.7 Measurement conditions

The power measurements shall be performed in a laboratory environment under the following conditions:

- Room Temperature: 25 ± 2 °C.
- Supply voltage: -48 V DC as defined in EN 300 132-2 [2].

5.1.8 Reporting of the measurements

The following details shall be included in the power measurement report:

- System configuration - in particular the number of active line boards and ports.
- List of hardware items used in the system under test, showing both the vendor type number and serial number.
- List of software/firmware modules used in the system.
- List of test equipment used to measure the power consumption.This also includes the CPE used for the measurement.
- Ambient temperature.
- Actual supply voltage.
- Voltage and current at interface "A".
- The status and number of all end-user interfaces.

6 Power Consumption limits

6.1 DSLAM power limits

6.1.1 Current power limits (taken from the CoC)

Table 2: Current DSLAM power consumption limits (under specified test conditions)

	Pbb	**NPC (see note 1)**
	Full-power state (L0)	
ADSL2plus (19,8 dBm)	1,5 W	**100 mW/Mbps/km**
VDSL2	2,75 W	**91,67 mW/Mbps/km**
Low-power state (L2)		
ADSL2plus (19,8 dBm)	Not Specified in CoC	
VDSL2	See note 2	
Stand-by state (L3)		
ADSL2plus (19,8 dBm)	Not Specified in CoC	
VDSL2	See note 2	
NOTE 1: These values are not the actual requirements and are included for technology comparison purposes only. NOTE 2: Low-power states are currently not defined for ITU-T Recommendation G.993.2 [i.4] (VDSL2). NOTE 3: Start-up/Wake up time from L3 to L0: not specified in CoC.		

The figures shown in table 1 are for equipment, which is released to the market from 1st January 2007.

The above values are for fully equipped DSLAMs with more than 100 ports.

NOTE: For small network equipment (up to 100 ports), where the consumption of the common parts is shared among a limited number of ports, the power consumption per port might be slightly higher than the values given above. An additional 0,5 W per line is added to the above figures with a minimum of 10 W for a complete (small) DSLAM.

6.1.2 Future power limits (taken from the CoC)

Table 3: Future DSLAM power consumption limits

	Pbb	NPC (see note 1)
Full-power state (L0)		
ADSL2plus (19,8 dBm)	1,2 W	**79,6 mW/Mbps/km**
VDSL2	1,6 W	**53,3 mW/Mbps/km**
Low-power state (L2)		
ADSL2plus (19,8 dBm)	0,8W	
VDSL2	See note 2	
Stand-by state (L3)		
ADSL2plus (19,8 dBm)	0,4 W	
VDSL2	See note 2	
NOTE 1: These values are not the actual requirements and are included for technology comparison purposes only. NOTE 2: A value will be specified after a Low-power state is defined for VDSL2. NOTE 3: Start-up/Wake up time from L3 to L0 shall be less or equal to 3 sec (only applicable for ADSL2(PLUS)).		

The power limits shown in table 2 are for equipment to be released to the market from 1st January 2009.

The above values are for fully equipped DSLAMs with more than 100 ports.

NOTE: For small network equipment (up to 100 ports), where the consumption of the common parts is shared among a limited number of ports, the power consumption per port might be slightly higher than the values given above. An additional 0.5 W per line is added to the above figures with a minimum of 10 W for a complete (small) DSLAM.

6.2 MSAN Power Limits

These will be covered in future versions of the present document.

Annex A (informative): Example traffic profiles

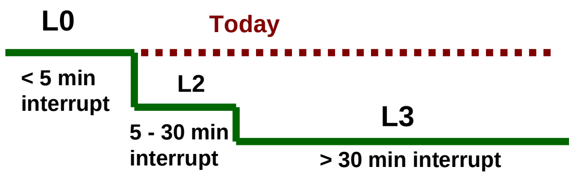
Power state control is based on payload inactivity timing (known here as 'interrupt').

The 24-hour time distribution over the states is based on the estimated typical traffic behaviour for a variety of user types.

NOTE: Further study is required to understand the effects of fluctuating crosstalk caused by systems transitioning between the L2/L3 and L0 states.This will potentially cause degradation in the performance of rate adaptive ADSL systems and therefore operators may decide to constrain the number of state transitions, which would result in a system spending longer in higher power modes.

DSLAM

Operational Modes & user traffic models



User type	L0 time/Day	L2 time/Day	L3 time/Day
Private DSL	1hr	1hr	22hr
Private 3-play & SOHO	6hr	2hr	16hr
Average user	3,5hr	1,5hr	19hr

Figure A.1: Example DSLAM operational states L0-L2-L3 and 24-hour traffic model

Annex B (informative): Bibliography

- DSL Forum TR-067, issue 2: "Technical Report ADSL Interoperability Test Plan; (September 2006)".
- DSL Forum TR-100: "ADSL2/ADSL2plus; Performance Test Plan".

History

Document history		
V1.1.1	June 2008	Publication