
TITLE **Classification of signals for spectral management specifications on access networks**

PROJECT Spectral Management (new item)

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STATUS For discussion

ABSTRACT This contribution is a basis for spectral management, by providing relevant definitions and a wide range of signal categories ranging from POTS to VDSL. Network owners, that want to set national rules for access to unbundled lines, can do this with a short national document that refers to a single ETSI document with relevant definitions and signal categories. This document (40 pages) provides a first basis for such a future document.

Problem Description

The unbundling of loops in European countries may cause that incompatible transmission systems from different network operators will be connected to wire pairs in the same cable of an access network cable. An incompatible mixture of transmission technologies that share the same cable bundel or binder group, will prevent an efficient use of the available capacity of these cables. Technical signal limits that distinct between what signals can be injected into a particular access network and what signals cannot, can prevent such a kind of spectral pollution. The process that enables an efficient use of the available capacity in cables is identified as “spectral management”.

Although rules for spectral management are regional in nature (set by network owners or national authorities), KPN beleives that a European framework around these regional approaches is required.

An essential part of such a European framework is a classification of a wide range of signals. Regional rules for spectral management can use such a classification to identify what signal limits are mandatory, for a particular cable.
This document is a detailed example of how such a European classification document may look like.

Aim of the discussion.

To conclude wether the approach, as proposed by this document, is the appropriate one to deal with Spectral Management on an European level.

The discussion should therefore focus on the structure and basic content of the document. The figures mentioned in the current document are to be considered as examples.

Contents

1. Scope

This document is a technical description of signal categories needed for spectral management in copper access networks. These technical classifications may be used by a telecommunication access network owner.

National or network-owner-specific documents, that rule the selected penetration limits and technology mix for spectral management purposes, can be kept compact by refering to the definitions in this document.

The approach of this document is to classify and summarize relevant limits for all kinds of signals, that may be considered for injection into an access network. Since many (potentially incompatible) systems have been defined in many different standards, these signal limits are brought together into one document and organized in clusters of categories, and without making any further selection. Each category defines, independent from other categories, a full set of signal limits between DC and 30 MHz. These categories are dominantly based on standards from ETSI, ANSI and ITU (existing or in progress), and on the technical understanding of additional requirements to protect future technology.

2. Spectral management (informative)

2.1. Objective

The frequency of the signals in cables increases substantially due to the introduction of broadband transmission systems. These transmission systems use the existing (copper-) access networks. Therefore measures have to be taken in order to cope with crosstalk between individual transmission channels using the existing access network.

Usually, systems are designed to function optimally when they are only impaired by identical systems in adjacent wire-pairs (self-crosstalk). In practice, it is quite common to mix different transmission technologies in one cable. This may cause some degradation of transmission performance, compared to the above mentioned idealized situation.

- If this degradation is minor, the technology mix is referred to as *compatible*.
- If this degradation is acceptable, the technology mix is referred to as *near-compatible*.
- If this degradation is not-acceptable, the technology mix is referred to as *incompatible*.

The objective for *spectral management* is to facilitate near-compatibility of systems that are connected to different wire-pairs in the *same cable* or cable bundle. Spectral management is an issue for both the network owner and the network operator (in some cases these are the organisations).

- The best that an *access network owner* can do to help the network operator(s) on its network, is to bound the spectral pollution in its network. This can be achieved by putting limits on signals (levels, spectra), diversity (technology mix) and penetration (number of systems). Defining relevant limits at the boundaries (or ports) of the access network is the most appropriate approach. This approach is not restricted to situations where more than one licenced operator make use of the same binders or cable bundles; it is also essential when one operator mixes different broadband technologies into one binder or cable bundle.
- The best that *network operators* can do is making estimates of the maximum impairment level in a wire-pair, and define adequate deployment rules. Deployment rules define the maximum reach or bitrate for a given transmission technology, with ‘sufficient’ noise margin (according to the network operator). Since the crosstalk coupling between the wirepairs in binders or cable bundles is only known by a very rough approximation, the maximum impairment level is also only known by a very rough estimate. In other words: the definition of adequate limits is an essential requirement for successfull deployment rules, but it can never *guarantee* that deployment rules can be adequate under all conditions. It is an inconvenience which each network operator has to face.

This document provides categories of signal limits, to simplify spectral management specifications that bound the spectral pollution of a network. Guidelines for deployment rules are beyond the scope of this document.

2.2. The origin of impairment

Impairment in a wire-pair of a binder or cable bundle is caused by crosstalk from signal sources that make use of the other wires in that binder or cable bundle. Connecting more systems to that cable will increase the crosstalk noise level in each wire-pair.
These impairments put a limit on the maximum bitrate that can be transported over a single wire-pair with given length, or the maximum length that can be reached with given bitrate. Above some impairment threshold, this noise causes harm to existing systems within the same binder or cable bundle, because the increased crosstalk noise will break down services to other users.

The crosstalk and attenuation characteristics of an existing access network are fixed and from an electrical point of view the network can be considered as a closed entity.
Figure 1 illustrates the impact of these cable characteristics on the transmission. Transceiver TR1.LT sends information to TR1.NT. The transmitted signal is attenuated by the insertion loss of the wire-pair, before it is received by TR1.NT. In addition, this transmitted signal impairs an adjacent transceiver TR2.LT through the NEXT coupling function (near end crosstalk), and an adjacent transceiver TR2.NT throught the FEXT coupling function (far end crosstalk). The same

applies in opposite direction by the transmitted signal from TR1.NT. The transmission between TR2.LT and TR2.NT is impaired by crosstalk noise.

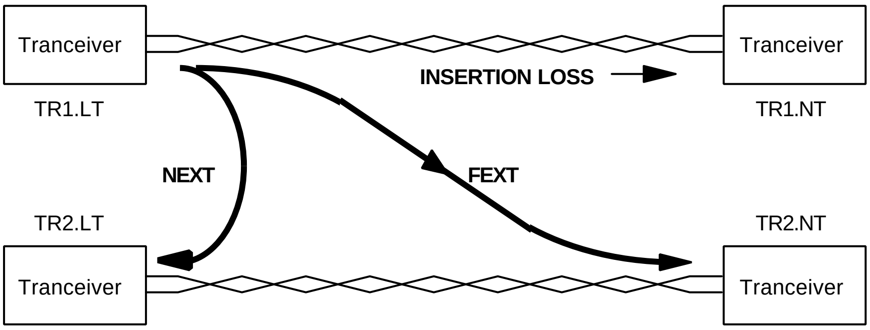


Figure 1. Various crosstalk paths .

Crosstalk and attenuation characteristics are frequency dependent. Because of the differences in crosstalk coupling at the near and the far end, the relation between frequency allocation and sending direction is of major importance for the management of the crosstalk noise.

The crosstalk coupling to the far end of the transmitter (FEXT) is relatively low due to the attenuation. The crosstalk on the near end (NEXT) will be relatively high. So if the transmitter and the receiver at one end of the line would use the same frequency band, the transmitter outputs should be limited in order not to disturb the adjacent receivers. The result would be that the achievable wire-pair length would be limited because crosstalk limits the maximum allowed sending level. By using different frequency bands for transmitters and receivers at one end of the binder or cable bundle, this effect can be eliminated and the achievable length will increase.

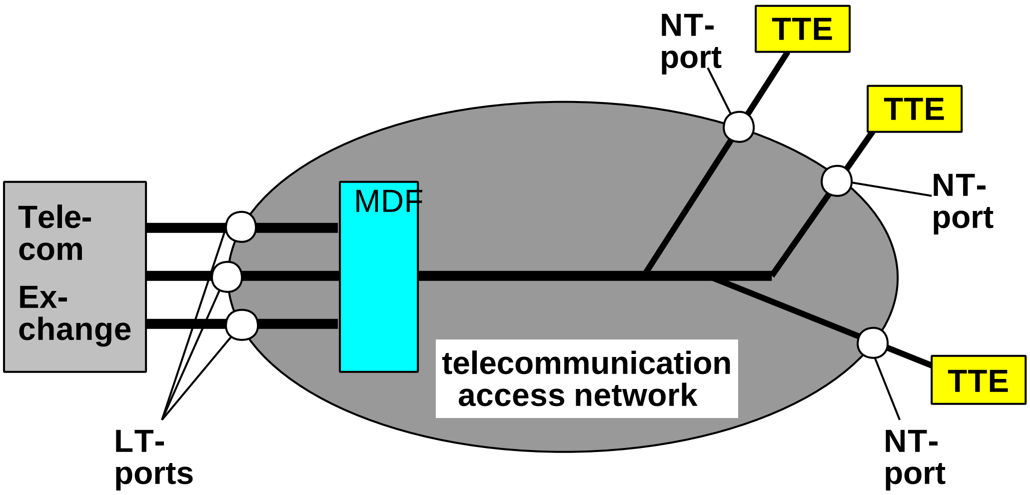
NOTE Some systems, such as FDM-based ADSL, take advantage from allocating different frequency bands for transmitting signals in upstream and downstream direction. By using spectra that are only partly overlapped (echo-cancelled systems), or not overlapped at all (FDM-systems), the NEXT between these systems can be reduced significantly. Ideally, if there is no spectral overlap between up and downstream signals, and the binder or cable bundle is only filled with these systems, the transmission performance becomes FEXT-limited only since all NEXT has been eliminated.

3. Reference model of access networks (normative)

Figure 2 shows the reference model of access networks from a spectral management point of view. It illustrates that access networks are asymmetrical in nature, that is characterized by the existence of LT-ports and NT-ports.
In addition to the cables, an access network may include a Main Distribution Frame (MDF), as is shown in this example, street cabinets, and other distribution elements.

Signals, generated by telecommunications equipment, flow into the wire-pairs of the access network, and enter the access network at so-called “ports”. Their location identify the interface (or connection point) between telecommunications equipment and the access network. Two kinds of ports are defined in this document.

- ***LT-port***: The Line Termination port is generally used for the telecommunication exchange connection.
- ***NT-port***: The Network Termination port is generally used for the Telecommunication terminal equipment (TTE) at the customer premises.



LT-port:	Line Termination Point
NT-port:	Network Termination Point
TTE:	Telecommunication Terminal Equipment
MDF:	Main Distribution Frame

Figure 2. Reference model of the access network. This model enables the definition of upstream and downstream directions.

Ports for upstream and downstream
Asymmetrical DSL systems, such as ADSL, generate different signals in different transmission directions. Therefore the signal limits for these systems are in this document subdivided into downstream and upstream limits throughout this document.

- ***Downstream*** signal limits are mandatory for signals that are injected into access network ports that are identified by the network owner as “LT-port”. These ports are usually located at the central office side of the access network.
- ***Upstream*** signal limits are mandatory for signals that are injected into access network ports that are identified by the network owner as “NT-port”. These ports are usually located at the customer premises

The network owner identifies for each port if this is an LT- or NT-port.

Note It is not recommended to reverse the transmission direction, which causes the injection of upstream signals into LT-ports and downstream signals into the NT-ports. This may occur when the MDF of another licenced operator is not co-located with the MDF of the network owner (at the local exchange).
In such a case, a binder or cable bundle *separated* from the standard access cables, is required to connect the two MDF’s. Such a binder or cable bundle will be fully dedicated to this purpose, having an NT-port at the local exchange of the network owner.

4. Definitions

The terminology used in this a document follows international conventions. This chapter defines deviations from the general conventions. For convenience of the reader of this document, some details are explained, even when there is no difference with the general meaning.
In all cases where this chapter gives no definition, the ETSI definition takes prevalence over any other.

4.1. Network owner

The company owning the telecommunication access network. (Mostly incumbent telecommunication network operators.)

4.2. Network operator
The company that make use of the access network of the Network owner, to transport telecommunication services.

4.3. Transmission technique
Electrical technique used for the transportation of information over the physical network.

4.4. Transmission equipment
Equipment connected to the access network that uses a transmission technique to transport information.

4.5. Line Termination Port (LT-port)
Port between telecommunication network equipment and the twisted pair access network, that is labeled by the network owner as “LT-port”. Such a port is commonly located near the telecommunication exchange.

4.6. Network Termination Port (NT-port)
Port between telecommunication network equipment and the twisted pair access network, that is labeled by the network owner as “NT-port”. Such a port is commonly located at the customer premises.

4.7. Upstream transmission
Transmission direction from an NT-port to an LT-port, usually from the customer premises, via the access network, to the telecommunication exchange.

4.8. Downstream transmission
Transmission direction from an LT-port to an NT-port, usually from the telecommunication exchange via the access network, to the customer premises.

4.9. Degree of penetration
Number and mixture of connected transmission techniques to the ports of a binder or cable bundle, that inject signals into the access network.

4.10. Unbalance about earth
The (LCL) longitudinal conversion loss is given by: LCL = 20 log (e_L/e_M) [dB] where e_L is the applied longitudinal voltage referenced to the building ground and e_M is the resultant metallic voltage appearing across a termination with the impedance as given in the relevant section.
References [29]: ***[ITU:O.9],***

4.11. Narrow band signal power (NBSP)
The narrow band signal power is defined as the average power **P** of a sending signal into a resistive load **R**, within a bandwidth **B** centred at any point of a frequency range. A sending signal shall never exceed the limits given in the tables in the relevant sections. These tables specify the break points of the limits. Limits for intermediate frequencies can be found by drawing a straight line between the break points on a logarithmic (Hz) - linear (dB) scale.

Note: The purpose of NBSP definitions (narrow band signal power), instead of a PSD definition (power spectral density) is that NBSP definitions are more tolerant to signals that are not near random in nature but carry some harmonic components. A PSD mask will exclude signals with irrelevant peaks in their PSD, while a NBSP mask is more tolerant to these peaks. Therefore all categories in this document are specified in terms of NBSP, while PSD mask, or sliding window PSD-masks are provided to demonstrate compliance with associated standards.

References [2,3,20]: ***[ETR80: A.12.4], [TS80: A.12.4], [ETSI WG TM 6 Living list A.12.4.1]***

5. List of Abbreviations

ADSL	Asymmetrical Digital Subscriber Line
ATU-C	ADSL Transceiver Unit, Central office end
ATU-R	ADSL Transceiver Unit, Remote terminal end
AMI	Alternate Mark Inversion
ANSI	American National Standards Institute
BME	Basisband Modem Eenheid
BRA	Basic Rate Access
CAP	Carrier Amplitude Modulation
CCITT	Commité Consultatif International du Téléphone et de la Télégraphie
CDSL	Customer Digital Subscriber Line
DC	Direct Current
EMC	Electro Magnetical Compatibility
ETSI	European Telecommunications Standards Institute
EZ DSL	Easy Asymmetrical Digital Subscriber Line
HDSL	High bitrate Digital Subscriber Line
HDTP	Hoofd Directie Telecommunicatie en Post
ISDN	Integrated Services Digital Network
ITU	International Telecommunication Union
LCL	Longitudinal Conversion Loss
LT	Line Terminator
LVD	Low Voltage Directive
MDF	Main Distribution Frame
NBSP	Narrow band signal power
NT	Network Terminator
NTE	Network Terminal equipment
NTI	Network Terminal Interface
OLO	Other Licensed Operator
ONP	Open Network Provision
OPTA	Onafhankelijke Post en Telecommunicatie Autoriteit
PCM	Pulse Code Modulation
PSD	Power Spectral Density
POTS	Plain Old Telephony Services
PSTN	Public Switched Telephone Network
RADSL	Rate adaptive Asymmetrical Digital Subscriber Line
R&TTE	Radio and Telecommunications Terminal Equipment
TBR	Technical Basis for Regulation
TTE	Telecommunications Terminal Equipment
SDSL	Symmetrical Digital Subscriber Line
xDSL	(all systems) Digital Subscriber Line
U-ADSL	Universal Asymmetrical Digital Subscriber Line
VDSL	Very high bit rate Digital Subscriber Line

6. Clusters of Signal categories

6.1. Cluster 1: transmission equipment (voice band)

This cluster covers analogue transmission equipment, including POTS, voice band modems, analogue leased lines, telex signals encoded as voiceband signals and music lines.

> **ED NOTE** Existing equipment connected to voice band lines like POTS and leased lines is not specified up to 30 MHz. Extension of the current frequency range up to 30 MHz is recommended to guaranty the proper working of VDSL systems which will be deployed in the near future (for ADSL, extension up to 1.1 MHz is required).

For this the next steps are recommended :

1. Establish extended requirements (up to 30 MHz) for out of band signals and LCL of voice band Terminal Equipment. (definition of the maximum "out of band noise" produced by voice band equipment which is acceptable by ADSL and VDSL systems is necessary)

2. Check if the current equipment fulfils the extended requirements or not.

3. Define a reasonable date from which the produced equipment should fulfil the extended requirements (this date depend on the fact if the current equipment fulfils the extended requirements with or without modification of the design).

4. Adapt the relevant equipment standards with the extended requirements and the date of coming into force of the extension.

6.1.1. Category 1a: Equipment for voice band lines (300 - 3400Hz)

This category covers telephony transmission equipment (e.g. telephones, voice band modems, Faxes, analogue leased lines etc.) on a single wire pair. This is based on new ETSI reports that supersede the (national) HDTP-T14.01.

Unless other specified, the requirements on DTMF-signals (Dual Tone Multi-Frequency), as defined in [14], are equal to the voice signal.

6.1.1.1. Impedance unbalance about earth

The longitudinal conversion loss shall be better than:

Frequency range	Minimum value	Impedance
50 Hz to 600 Hz	40 dB	600 Ω
600 Hz to 3400 Hz	46 dB	600 Ω
3400 Hz to 300 kHz	55 dB	135 Ω
300 kHz to 3 MHz	55 to 35 dB	135 Ω
3 MHz to 30 MHz	35 dB	135 Ω

ED NOTE: This is an extension of the frequency range of the current recommandation / standard, with the goal of protection of VDSL transmission.

Systems deployed after <day - month - year > <under study> have to meet this extended LCL requirement.

References [14, 19, *27, 28]* ***ETSI-TBR 21, 4.4.3, ETSI-TS 101 270-1 clause 8.3.3, ETSI-ETS 300 450 clause 4.4.2, ETSI-ETS 300 453 clause 4.4.2***

6.1.1.2. Feeding requirements

The feeding bridge of the local exchange shall provide: (see figure 3)

A DC Voltage of:	A DC Current of :
Maximum 78 V	Maximum xxxx mA

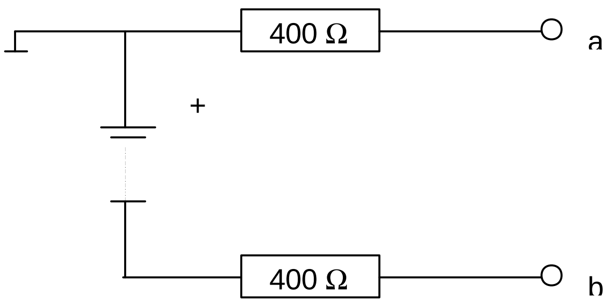


Figure 3 : The classic feeding bridge. Modern realisations use current sources.

Reference [2] ***ETSI- TRS 300 001, 1.5***

6.1.1.3. Ringing signal

The ringing voltage, supplied by the local exchange, shall be within:

Frequency	Voltage
23 to 27 Hz	maximum 90 V_{eff}

Reference [2] ***ETSI- TRS 300 001, 1.7.2,*** *using the Dutch system*

6.1.1.4. Metering

When required metering can be added on POTS lines
The pulses shall be according to the Dutch system, which applies common mode pulses:

Frequency	Voltage	Puls width
48 to 52 Hz	maximum 100 V_{eff}	70 to 200 ms

Note: KPN uses for a to earth and b to earth an impedance > 13 k0

Reference [2] ***ETSI- ETS 300 001, 1.7.8****, using the Dutch system.*

6.1.1.5. Total signal voltage

The mean sending level in the frequency range from 200 Hz to 3.8 kHz over a one-minute period shall not be greater than -9,7 dBV when the equipment interface is terminated with the category 1a reference impedance Z_R (figure 4). This requirement does not apply to DTMF signals.

Reference [14]: ***[ETSI-TBR21, 4.7.3.1]****, (tested according to annex A, sub clause A.4.7.3.1)*

The level of any tone in the DTMF high frequency group shall not be greater than -9,0 dBV + 2,0 dB = -7,0 dBV. The level of any tone in the low frequency group shall not be greater than -11,0 dBV + 2,5 dB = -8,5 dBV. This is to be measured when the TE interface is terminated with the reference impedance Z_R.

Reference [14]: ***[ETSI-TBR21, 4.8.2.2.1]*** *(tested according to annex A, sub clause A.4.8.2.2)*

6.1.1.6. Peak amplitude

The peak to peak voltage in the frequency range 200 Hz to 3.8 kHz shall not exceed 5,0 volts when the equipment interface is terminated with the reference impedance Z_R.

Reference [14]: ***[ETSI-TBR21, 4.7.3.2]*** *(tested according to annex A, sub clause A.4.7.3.2)*

6.1.1.7. Narrow-band signal voltage

The average voltage ***U*** of a category 1a sending signal into a (complex) load impedance ***Z***, within a bandwidth ***B***, centered at any point in the frequency range 100 Hz to 30 MHz, shall not exceed the limits given in table 1. This table specifies the break points of these limits. Limits for intermediate frequencies can be found by drawing a straight line between the break points on a logarithmic (Hz) - linear (dB) scale. This requirement does not apply to DTMF signals.

> ED NOTE: This is an extension of the frequency range of the current recommendation / standard, with the goal of protection of VDSL transmission
>
> Systems deployed after <date , month , year > <under study> have to meet this extended PSD requirement

Points	frequency f	impedance Z	Sending level U	Bandwidth B	U/ÖB
A	30 Hz	Z_R	-33.7 dBV	10 Hz	–43.7 dBV/√Hz
B	100 Hz	Z_R	-10.7 dBV	10 Hz	–20.7 dBV/√Hz
C	200 Hz	Z_R	-6.7 dBV	10 Hz	–16.7 dBV/√Hz
D	3.8 kHz	Z_R	-6.7 dBV	10 Hz	–16.7 dBV/√Hz
E	3.9 kHz	Z_R	-10.7 dBV	10 Hz	–20.7 dBV/√Hz
F	4.0 kHz	Z_R	-16.7 dBV	10 Hz	–26.7 dBV/√Hz
G	4.3 kHz	Z_R	-44.7 dBV	10 Hz	–54.7 dBV/√Hz
G	4.3 kHz	Z_R	-40 dBV	300 Hz	–65 dBV/√Hz
H	5.1 kHz	Z_R	-44 dBV	300 Hz	–69 dBV/√Hz
I	8.9 kHz	Z_R	-44 dBV	300 Hz	–69 dBV/√Hz
J	11.0 kHz	Z_R	-58.5 dBV	300 Hz	–73.5 dBV/√Hz
J	11.0 kHz	Z_R	-58.5 dBV	1 kHz	–88.5 dBV/√Hz
K	200 kHz	Z_R	-58.5 dBV	1 kHz	–88.5 dBV/√Hz
K	200 kHz	135 Ω	-60 dBV	1 kHz	–90 dBV/√Hz
L	600 kHz	135 Ω	-100 dBV	1 kHz	–130dBV/√Hz
M	30 MHz	135 Ω	-100 dBV	1 kHz	–130dBV/√Hz

Table 1 *Break points of the narrow-band voltage limits. A voltage of 1 V, equals 0 dBV, and causes a power of 2.2 dBm in 600 W and 8.7 dBm in 135 W.*

Some narrow band violations could occur and should be tolerated.

Reference [14]: [ETSI-TBR21], (30 Hz - 4.3kHz, clause 4.7.3.3), (4.3 kHz - 200kHz, clauses 4.7.3.4) the requirements above 200kHz are extended from [14]. This extension is essential to guarantee compatibility with xDSL systems (Category 3 and higher).

During tone signalling the limits given in table 1 do not apply to DTMF signals and are replaced by the following limits:

- In the range 4,3 kHz to 20 kHz, the individual level of any single frequency component shall not exceed -35,7 dBV, when terminated with Z_R.
- In the range 20 kHz to 200 kHz, the individual level of any single frequency component shall not exceed -40,7 dBV, when terminated with Z_R.
- In the range 200 kHz to 30 MHz, the individual level of any single frequency component shall not exceed]<value for further study> when terminated with 135 Ω.

Reference [14]: ***[ETSI-TBR21, 4.7.3.4]***

6.1.1.8. Power spectral density (PSD)

Due to their nature, voice signals in this document are not restricted in terms of PSD, but narrow-band signal power.

Note: Voice band modems shall meet the Narrow-band signal voltage requirement. The technology of these modems is such that there is no need for an additional PSD requirement.

6.1.1.9. Reference impedance Z_R

The category 1a reference impedance Z_R is a complex impedance made up of 270 Ω in series with a parallel combination of 750 Ω and 150 nF as shown in figure 4.

Reference [14]: ***[ETSI-TBR21, A.2.1]***

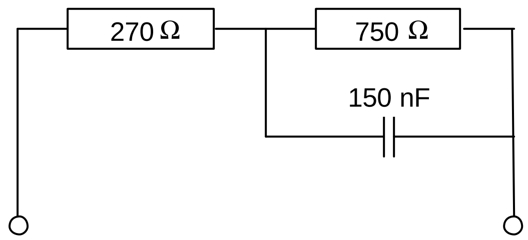


***Figure 4**: Reference impedance Z_r*

6.1.2. Category 1b: Music lines (40 - 15000Hz)

This category covers equipment for transmitting analogue music signals on a single wirepair. This technology is obsolete. Existing equipment is still allowed on the network for some years to come. For new applications digital technology recommended.

This sub clause is based on the HDTP-T14.04 report [17], but has been extended to protect signals in category 3 and higher.

Music lines are not supposed to be multiplexed with other services (like xDSL) on the same twisted pair.

6.1.2.1. Total signal power

The average power of a category 1b sending signal into a resistive load of 600Ω shall not exceed a level of 6 dBm (1.55 Veff), over the frequency band from 40 Hz to 15 kHz.
Reference [17]: ***[HDTP-T14.04]***

6.1.2.2. Peak amplitude

The nominal peak of the largest pulse into a resistive load of 150 Ω shall not exceed 2.2 V (+9 dBm). This means that a harmonic signal shall not exceed an effective value of +6 dBm (1.55 Veff) into 150 Ω.

Reference [17]: ***[HDTP-T14.04]***

6.1.2.3. Narrow-band signal power

The average power **P** of a category 1b sending signal into a resistive load **R**, within a bandwidth **B** centred at any point in the frequency range 100 Hz to 30 MHz, shall not exceed the limits given in table 2. This table specifies the break points of the limits. Limits for intermediate frequencies can be found by drawing a straight line between the break points on a logarithmic (Hz) **-** linear (dB) scale. These limits are frequency independent between 40 Hz to 15 kHz, decrease with 12 dB/octave above 15 kHz, with 18 dB/octave above 30 kHz, and with 24 dB/octave above 120 kHz.
Reference [17]: These numbers are extended from the requirements in ***[HDTP-T14.04].*** *This extension is essential to guarantee compatibility with xDSL systems (Category 3 and higher).*

Points	frequency f	impedance R	Sending level P	bandwidth B	P/B
A	40 Hz	150Ω	+6 dBm	10 Hz	–4 dBm/Hz
B	15 kHz	150Ω	+6 dBm	10 Hz	–4 dBm/Hz
B	15 kHz	150Ω	+6 dBm	300 Hz	–19 dBm/Hz
D	30 kHz	150Ω	–6 dBm	300 Hz	–31 dBm/Hz
E	60 kHz	150Ω	–24 dBm	300 Hz	–49 dBm/Hz
F	120 kHz	150Ω	–42 dBm	300 Hz	–67 dBm/Hz
G	200 kHz	150Ω	–60 dBm	300 Hz	–85 dBm/Hz
G	200 kHz	135Ω	–60 dBm	1000 Hz	–90 dBm/Hz
H	500 kHz	135Ω	–90 dBm	1000 Hz	–120 dBm/Hz
I	30 MHz	135Ω	–90 dBm	1000 Hz	–120 dBm/Hz

Table 2: *Break points of the narrow-band power limits.*

Note: The transmission level is often manually controlled by a technician during Radio / TV broadcast. It is his task to maintain this level. The level between 40 Hz and 15 kHz shall never exceed +9 dBm.

6.1.2.4. Power spectral density (PSD)

Due to their nature, music signals in this document are not restricted in terms of PSD, but narrow-band signal power.

Note: The HDTP- T14.4 is based on the ITU recommendations N.11 to N.16 [15] and J.21 [16]. It is an adaptation to the Dutch situation. The spectrum was not modified. More information in Reference [18].

6.2. Cluster 2: transmission equipment (semi broad band)

This cluster covers digital transmission equipment up to 160 kb/s, including ISDN-BRA and 64 and 128 kb/s leased lines.

6.2.1. Category 2a: "ISDN-2B1Q"

This category covers ISDN transmission equipment on a single wire-pair, based on 2B1Q line coding. This sub clause is based on the ETSI reports on ISDN [2,3]. There are no category 2 repeaters allowed, and there are currently no repeaters in use.

6.2.1.1. Impedance unbalance about earth

The longitudinal conversion loss shall be better than

Points	Frequency range	Minimum value in any band of 4kHz	Impedance
A	500 Hz to 5 kHz	25 to 45 dB (slope 6 dB /oct)	135Ω
B	5 kHz to 60 kHz	45 dB	135Ω
C	60 kHz to 190 kHz	45 to 40 dB (slope)	135Ω
D	190 kHz to 30 MHz	40 dB	135Ω

Table 3: *Break points of the unbalance about earth of cat2 equipment*

*Reference [2]:**[ETSI-ETR80: A.13.3.1]***
*Reference [3]:**[ETSI-TS 101 080: A.13.3.1]***
*Reference[19] **ETSI-TS 101 270-1 clause 8.3.3***

6.2.1.2. Power feeding from the LT-port

The power delivered by the LT-port to the network (U- interface) is limited to:

Voltage	Power
maximum 99 V	maximum 1100 mW

The value for power includes a possible overload or short circuit condition at the user-network interface.

*Reference [2]: **[TS80: 10.5** (using the Dutch situation) **and 10.6.1.1]***

6.2.1.3. Total signal power

The average power of a category 2a sending signal into a resistive load of 135 Ω shall not exceed a level of 13.5 dBm (± 0.5 dBm), over the frequency band from 100 Hz to 80 kHz.

*Reference [2,3]: **[ETR80: A.12.3]** and **[TS80: A.12.3]***

6.2.1.4. Peak amplitude

The nominal peak of the largest pulse into a resistive load of 135Ω shall be 2,5 V (± 5%)
*Reference [2,3]: **[ETR80: A.12.1]** and **[TS80: A.12.1]***

6.2.1.5. Power spectral density (PSD)

The upper bound of the single sided power spectral density of the sending signal shall be as shown in figure 5. Table 4 specifies the break points of this figure. Measurements to verify compliance with this requirement shall use a noise power bandwidth of 1 kHz and a resistive load of 135Ω. See also the additional sliding window requirements, as specified in table 5.

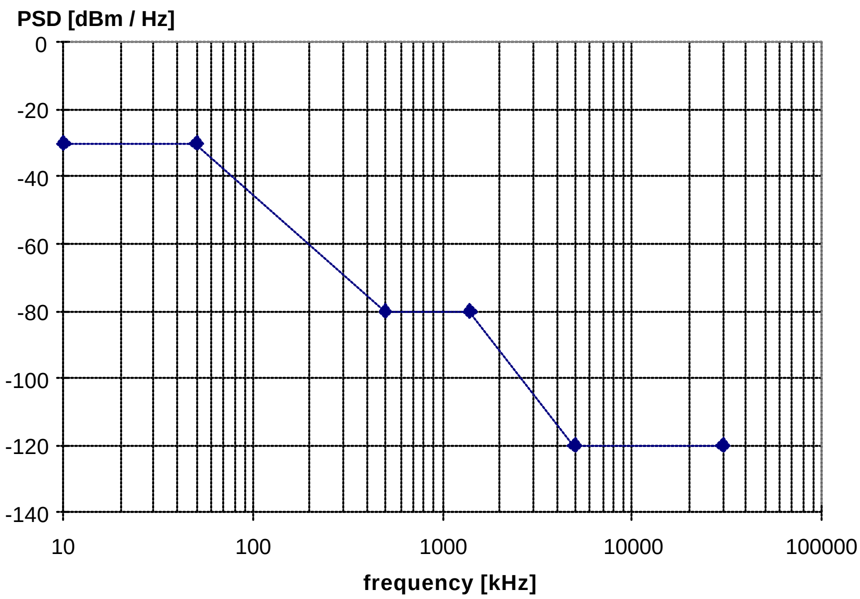


Figure 5*: Upper bound of the average power spectral density of category 2a equipment (ISDN 2B1Q)*

Points	Impedance	Frequency	PSD
A	135 Ω	10 Hz	–30 dBm/Hz
B	135 Ω	50 kHz	–30 dBm/Hz
C	135 Ω	500 kHz	–80 dBm/Hz
D	135 Ω	1400 kHz	–80 dBm/Hz
E	135 Ω	5 MHz	–120 dBm/Hz
F	135 Ω	30 MHz	–120 dBm/Hz

Table 4: Upper bound of the average power spectral density of category 2a equipment (ISDN 2B1Q)

Note 1: Systems deployed before January 1, 2000, do not have to meet this PSD requirement but shall meet the PSD requirements as defined in ETR 080 edition 2. It is however expected that these systems will also meet the PSD requirements of TS 080 edition 3. Some narrow band violations could occur and should be tolerated.

Note 2: This PSD mask is compliant with ETR80 [2], revision 2 up to 300 kHz, but has been extended to 30 MHz. This extension is essential to guarantee compatibility with future VDSL systems (Category 5 signals). It is updated conform TS80 [3], revision 3.

References [2,3,20]: ***[ETR80: A.12.4], [TS80: A.12.4], [ETSI WG TM 6 Living list A.12.4.1]***

6.2.1.6. Narrow-band signal power

The average power ***P*** of a category 2a sending signal into a resistive load ***R***, within a bandwidth ***B***, centred at any point in the frequency range 100 Hz to 30 MHz, shall not exceed the limits given in table 5. This table specifies the break points of these limits. Limits for intermediate frequencies can be found by drawing a straight line between the break points on a logarithmic (Hz) - linear (dB) scale.

Table 5 is reconstructed from the PSD requirements, as defined in figure 5. Measurements to verify compliance with this requirement above 10 kHz shall use a bandwidth of 10 kHz. Above 300 kHz, an additional sliding window requirement shall be met. This is to perform a higher bandwidth measurement in order to make sure that different systems do not fill the entire allowable bandwidth with noise up to the PSD limit shown in figure 5.

This sliding window approach is defined in chapter [*]. Above 3.6 MHz, the result shall be less than -120 dBm/Hz or at least more than 10 dB below the PSD limit shown in figure 5. The requirement is applicable between 300 kHz and 30 MHz. Systems deployed before January 1, 2000, do not have to meet the additional sliding window PSD requirement.

Points	Frequency f	Impedance R	Sending level P	Bandwidth B	P/B
A	0.1 kHz	135Ω	-0 dBm	1 kHz	-30 dBm/Hz
B	10 kHz	135Ω	-0 dBm	1 kHz	-30 dBm/Hz
B	10 kHz	135Ω	10 dBm	10 kHz	-30 dBm/Hz
C	50 kHz	135Ω	10 dBm	10 kHz	-30 dBm/Hz
D	300 kHz	135Ω	-30 dBm	10 kHz	-69 dBm/Hz
D	300 kHz	135Ω	-19 dBm	1 MHz	-79 dBm/Hz
E	500 kHz	135Ω	-30 dBm	1 MHz	-90 dBm/Hz
F	1.4 MHz	135Ω	-30 dBm	1 MHz	-90 dBm/Hz
G	3.637 MHz	135Ω	-60 dBm	1 MHz	-120 dBm/Hz
H	30 MHz	135Ω	-60 dBm	1 MHz	-120 dBm/Hz

***Table 5**: Break points of the narrow-band power limits. When measured at 1MHz bandwidth, the center frequency is 500 kHz above the lowest frequency that is specified in this table (sliding window approach)*

Reference: These numbers have been reconstructed from PSD requirements in ETSI-ETR80 [2] and ETSI-TS 101 080 [3]
References [2,3,20]: ***[ETR80: A.12.4], [TS80: A.12.4], [ETSI WG TM 6 Living list A.12.4.1]***

6.2.2. Category 2b: "BME160" (BME160 and LT160, 160 kb leased lines)

This category covers BME160 and LT160 transmission equipment on a single wirepair, based on BiPhase linecoding using a carrier of 160 kHz. (BMExxx on the NT side; LTxxx on the LT side).

Note: Comparison with other categories of equipment (other line coding schemes) show a poor use of the lower part of the frequency spectrum. This causes a relatively high sensitivity to crosstalk from other sources. Therefore this equipment is only recommended on relative short lines.

6.2.2.1. Impedance unbalance about earth

The impedance unbalance shall be the same as for category 2a (ISDN-2B1Q)

6.2.2.2. Total signal power

The average power of a category 2b sending signal into a resistive load of 150Ω shall not exceed a level of 0 dBm (0.39 Veff) ± 0.5 dB, over the frequency band from 100 Hz to 1 MHz.

6.2.2.3. Peak amplitude

The nominal peak of the largest pulse into a resistive load of 150Ω shall be 0.56 V (± 5%)

6.2.2.4. Power spectral density (PSD)
The upper bound of the single sided power spectral density of the sending signal shall be as shown in figure [*]. Table 6 specifies the break points of this figure. Measurements to verify compliance with this requirement shall use a noise power bandwidth of 1 kHz and a resistive load of 150Ω.
Reference: fitted from an unofficial FAX from the manufacturer, and extended to 30 MHz.

Points	frequency	PSD
A	0.1 kHz	–60 dBm/Hz
B	15 kHz	–60 dBm/Hz
C	90 kHz	–50 dBm/Hz
D	140 kHz	–50 dBm/Hz
E	160 kHz	–52 dBm/Hz
F	200 kHz	–56 dBm/Hz
G	400 kHz	–84 dBm/Hz
H	800 kHz	–100 dBm/Hz
I	2 MHz	–120 dBm/Hz
J	30 MHz	–120 dBm/Hz

Table 6: ***Break points of the spectral mask***

6.2.2.5. Narrow-band signal power
The average power ***P*** of a category 2b sending signal into a resistive load ***R***, within a bandwidth ***B***, centred at any point in the frequency range 100 Hz to 30 MHz, shall not exceed the limits given in table [7]. This table specifies the break points of these limits. Limits for intermediate frequencies can be found by drawing a straight line between the break points on a logarithmic (Hz) - linear (dB) scale.

Reference: fitted from an unofficial FAX from the manufacturer, and extended to 30 MHz.

Points	Frequency f	Impedance R	Sending level P	Bandwidth B	P/B
A	0.1 kHz	150Ω	–30 dBm	1 kHz	–60 dBm/Hz
B	15 kHz	150Ω	–30 dBm	1 kHz	–60 dBm/Hz
C	90 kHz	150Ω	–20 dBm	1 kHz	–50 dBm/Hz
D	140 kHz	150Ω	–20 dBm	1 kHz	–50 dBm/Hz
E	160 kHz	150Ω	–22 dBm	1 kHz	–52 dBm/Hz
F	200 kHz	150Ω	–26 dBm	1 kHz	–56 dBm/Hz
G	400 kHz	150Ω	–54 dBm	1 kHz	–84 dBm/Hz
H	800 kHz	150Ω	–70 dBm	1 kHz	–100 dBm/Hz
I	2 MHz	150Ω	–90 dBm	1 kHz	–120 dBm/Hz
J	30 MHz	150Ω	–90 dBm	1 kHz	–120 dBm/Hz

Table 7: *Break points of the narrow-band power limits.*

6.2.3. Category 2d: "BME/2" (19.2 kb/s leased lines:)
This category accommodates baseband modems for 19,2 kB/s and sub rates, such as BME/2 and DAG9600. They use vendor dependent modulation schemes. BME/2 is a rack model; DAG9600 is a table modem. The actual (de)-modulator prints are of the UEB 12-0x type. The modulation is pseudoternary (AMI, duty cycle unknown). (Coded-Diphase modulation is also available and may be used by clients on short analogue leased lines.)

When this spectrum is significantly higher than the ISDN mask the properties are not known. (1200-19200 baud? spectrum up to 40 kHz, power unknown)

6.2.3.1. Impedance unbalance about earth
The impedance unbalance about earth shall be the same as for category 2a (ISDN) clause 2.2.1.1.

6.2.3.2. Total signal power

The average power of a category 2d sending signal into a resistive load of 150Ω shall not exceed a level of 2 Vtt, (0 dBm) over the frequency band from 50 Hz to 620 kHz.

Note:
This is an example of a manufacturers advice for the power settings:

Modem type	< 9600 B/s	= 9600 B/s
UEB 12-5	1.4 Vtt	2 Vtt
UEB 12-6	1 Vtt	1.4 Vtt

Table 8: Manufacturers advise for the power settings. The impedance can be set to 150W for non-loaded and 1000W for loaded lines.

6.2.3.3. Peak amplitude

AMI modulation is not expected to produce peaks above the normal power level.

6.2.3.4. Power spectral density (PSD)

The upper bound of the single sided power spectral density of the sending signal shall be as shown in figure 6 and table 9. Measurements to verify the compliance with this requirement shall use a power bandwidth of 1kHz for frequencies from 1 kHz to 30 MHz. The impedance to be used is 150 Ω.

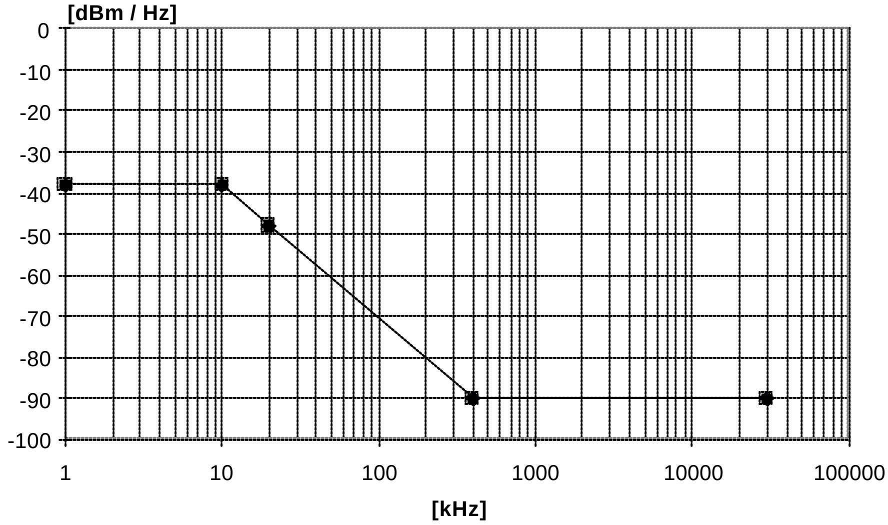


Figure 6: Upper bound for the PSD of cat 2d equipment

Points	Impedance	Frequency	PSD
A	150 Ω	100 Hz	-38 dBm / Hz
B	150 Ω	10 kHz	-38 dBm / Hz
C	150 Ω	20 kHz	-48 dBm / Hz
D	150 Ω	400 kHz	-90 dBm / Hz
F	150 Ω	30 MHz	-90 dBm / Hz

Table 9: Upper bound for the PSD of cat 2d equipment

6.2.3.5. Narrow-band signal power

The spectrum has been measured in sliding window with the listed bandwidth.

Points	frequency f	Impedance R	Sending level P	Bandwidth B	P/B
A	100 Hz	150 Ω	-18 dBm	100 Hz	-38 dBm / Hz
B	10 kHz	150 Ω	-18 dBm	100 Hz	-38 dBm / Hz
C	20 kHz	150 Ω	-28 dBm	100 Hz	-48 dBm / Hz
D	20 kHz	150 Ω	-13 dBm	3100 Hz	-48 dBm / Hz
E	400 kHz	150 Ω	-55 dBm	3100 Hz	-90 dBm / Hz
F	30 MHz	150 Ω	-55 dBm	3100 Hz	-90 dBm / Hz

Table 10: Break points of the narrow-band power limits

6.2.4. Category 2e: "BME64" (64 kb leased lines)

These BME64 or UEB64 modems use a 50% AMI line coding. It uses independent transmit and receive lines (4 wire modem. The data capacity can be either 64 or 48 kb/s.

6.2.4.1. Impedance unbalance about earth

The impedance unbalance shall be the same as for category 2a (ISDN-2B1Q)

6.2.4.2. Total signal power

The average power of a category 2e sending signal into a resistive load of 150Ω shall not exceed a level of +1.5 dBm (2 Vtt) ± 0.5 dB, over the frequency band from 0 Hz to 1 MHz.

Note 1:
An example of available settings for sending levels can be found in table 7. The 1 Vtt transmission level used in the past and is not adequate any more. 2 Vtt is now used as a rule. Incidentally the level may have been set to 4 Vtt in case of problems.

Line Voltage	Sending level (150 W)	Receive level (150 W)
1 Vtt	- 4.5 dBm	- 52 dBm
2 Vtt	+ 1.5 dBm	- 46 dBm
4 Vtt	+ 7.5 dBm	- 40 dBm

***Table 7**: Available settings for the modems UEB 64*[1].

6.2.4.3. Peak amplitude

<for further study>
(AMI modulation is not expected to produce peaks above the normal power level)

6.2.4.4. Power spectral density

This information is based on the Narrow-band power (chapter 2.3.5.2). The spectrum has been extrapolated above 200 kHz.

[1] Datentechnik

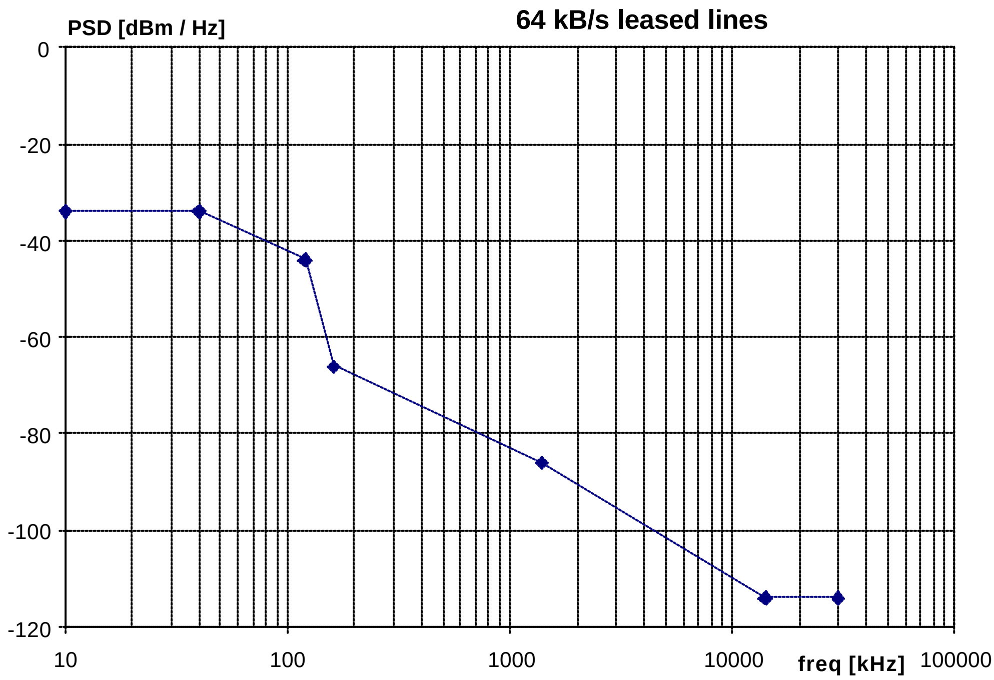


Figure 8: ***Maximum Power Spectral Density of 64 kb/s modems***

Points	frequency	Impedance	PSD
A	0 kHz	150 Ω	-34 dBm/Hz
B	40 kHz	150 Ω	-34 dBm/Hz
C	120 kHz	150 Ω	-44 dBm/Hz
D	160 kHz	150 Ω	-66 dBm/Hz
E	1400 kHz	150 Ω	-86 dBm/Hz
F	14000 kHz	150 Ω	-114 dBm/Hz
G	30000 kHz	150 Ω	-114 dBm/Hz

Tabel 11: Maximum Power Spectral Density of 64 kb/s modems

6.2.4.5. Narrow-band signal power

The source of the following information is unknown. The spectrum has been measured in sliding window with a bandwidth of 1 kHz up to 200 kHz. Above the spectrum has been extrapolated.

Points	frequency	Impedance	Sending level	Bandwidth	PSD
A	0 kHz	150 Ω	-4 dBm	1kHz	-34 dBm/Hz
B	40 kHz	150 Ω	-4 dBm	1kHz	-34 dBm/Hz
C	120 kHz	150 Ω	-14 dBm	1kHz	-44 dBm/Hz
D	160 kHz	150 Ω	-36 dBm	1kHz	-66 dBm/Hz
E	1400 kHz	150 Ω	-56 dBm	1kHz	-86 dBm/Hz
F	14000 kHz	150 Ω	-84 dBm	1kHz	-114 dBm/Hz
G	30000 kHz	150 Ω	-84 dBm	1kHz	-114 dBm/Hz

Tabel 9: Break points of the narrow-band power limits

6.3. Cluster 3 transmission equipment (symmetrical broadband)

This cluster covers symmetrical digital transmission equipment up to 2 Mb/s, such as HDSL. If such a system requires more than one wire-pair for carrying that bitrate, the specifications in this document hold for each individual wire-pair.
This type of equipment is commonly used for services like high quality leased lines, with symmetrical bit rates (in up- and downstream directions).

6.3.1. Category 3a: “HDSL.2B1Q/3” (392 kbaud /s leased lines)

This category covers HDSL transmission equipment on three wire-pairs, based on 2B1Q line coding. This sub clause is based on the ETSI reports on HDSL [4,5]. These are essentially 392 kbaud/s systems (per wire-pair).

Unless otherwise indicated, the following signal specifications apply with a resistive load impedance of 135Ω, and does not apply to the DC remote power feeding (if any).

6.3.1.1. Unbalance about earth

The (LCL) longitudinal conversion loss of the system shall meet the requirement of: - 50 dB between 5 kHz and 196 kHz for a 392 kbaud system as shown in fig 10.

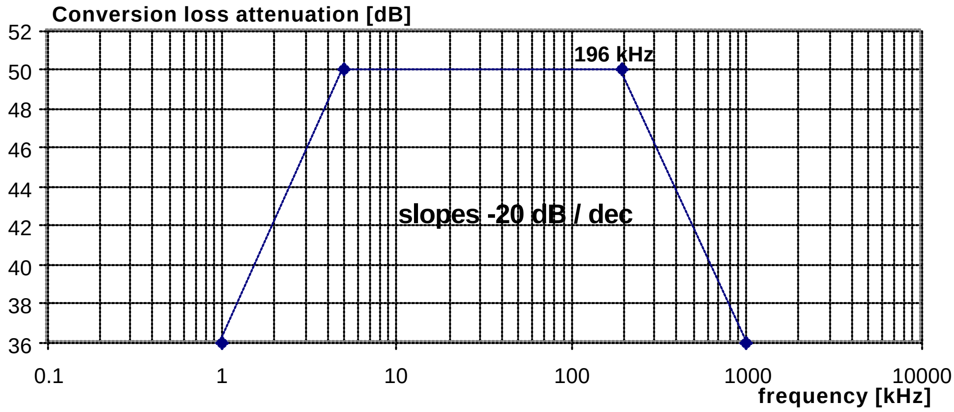


Figure 10: *Minimum longitudinal conversion loss for a 392 kbaud system*

Reference [4,5]: ***[ETR152: 5.8.5.1]***

6.3.1.2. Total signal power

The average power of a sending signal shall not exceed a level of 13.5 dBm (± 0.5 dBm), over the frequency band from 0 Hz to 784 kHz.

Reference [4,5]: ***[ETR152: 5.8.4.4]***

6.3.1.3. Peak amplitude

The nominal peak of the largest pulse shall be 2.64 V (±7%) into a resistive load of 135 Ω.

Reference [4,5]: ***[ETR152: 5.8.4.1]***

6.3.1.4. Power spectral density (PSD)

The upper bound of the single sided power spectral density of the sending signal shall be as shown in figure 11. Table 12 specifies the break points of this figure. Measurements to verify compliance with this requirement shall use a noise power bandwidth of 1 kHz (and a resistive load of 135Ω).

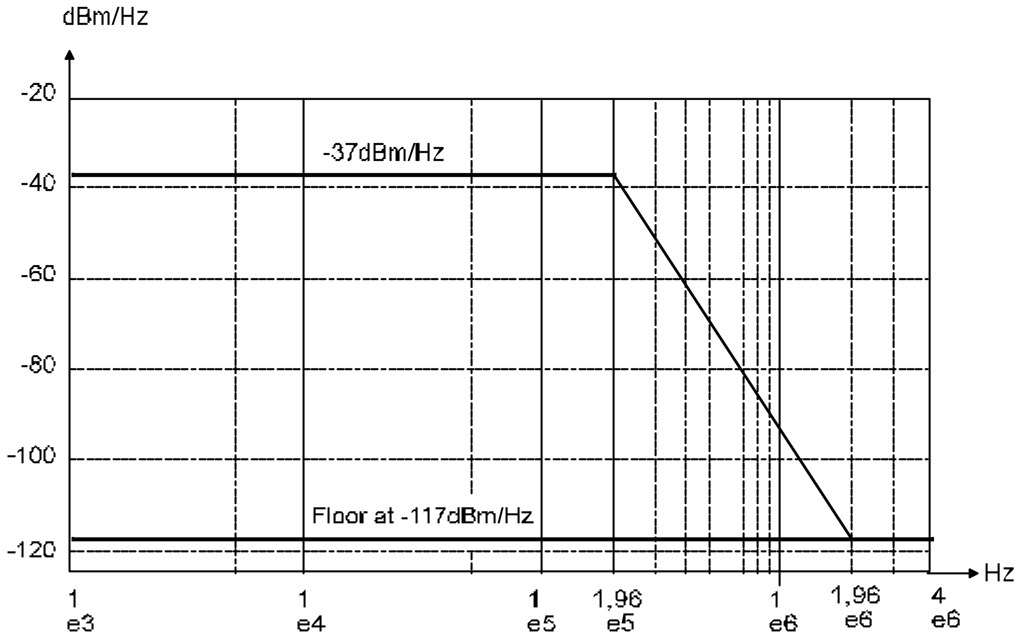


***Figure 11**: Upper bound of the average power spectral density of category 3a equipment*

Points	frequency	PSD
A	0.1 kHz	-37 dBm/Hz
B	196 kHz	-37 dBm/Hz
C	1.96 MHz	-117 dBm/Hz
D	30 MHz	-117 dBm/Hz

***Table 12**: Break points of the spectral mask in figure 11*

Reference [4,5]: ***[ETR152: 5.8.4.3.1]***

6.3.1.5. Narrow-band signal power

The average power ***P*** of a category 3a sending signal into a resistive load ***R***, within a bandwidth ***B*** centred at any point in the frequency range 100 Hz to 30 MHz, shall not exceed the limits given in table 13. This table specifies the break points of the limits. Limits for intermediate frequencies can be found by drawing a straight line between the break points on a logarithmic (Hz) - linear (dB) scale. These limits are frequency independent between 100 Hz to 196 kHz, and decrease with 24 dB/octave (80 dB/decade) above 196 kHz.

Points	Frequency f	Impedance R	Sending level P	Bandwidth B	P/B
A	0.1 kHz	135Ω	-7 dBm	1 kHz	-37 dBm/Hz
B	196 kHz	135Ω	-7 dBm	1 kHz	-37 dBm/Hz
C	1.96 MHz	135Ω	-87 dBm	1 kHz	-117 dBm/Hz
D	30 MHz	135Ω	-87 dBm	1 kHz	-117 dBm/Hz

***Table 13** Break points of the narrow-band power limits.*

Reference: These numbers have been reconstructed from PSD requirements in ETSI-ETR152 [4,5].

6.3.2. Category 3b: "HDSL.2B1Q/2" (584 kbaud /s leased lines)

This category covers HDSL transmission equipment on two wire-pairs, based on 2B1Q line coding. This sub clause is based on the ETSI reports on HDSL [4,5]. These are essentially 584 kbaud/s systems (per wirepair).

This category 3b transmission is only acceptable for applications that cannot be handled by category 3c equipment.

Note: Category 3b equipment is a candidate for becoming obsolete, however a successor is not yet available

Unless otherwise indicated, the following signal specifications apply with a resistive load impedance of 135Ω, and does not apply to the DC remote power feeding (if any).

6.3.2.1. Unbalance about earth

The LCL (longitudinal conversion loss) is given by: LCL = 20 log (e_l/e_m) [dB]
where e_l is the applied longitudinal voltage referenced to the building ground and e_m is the resultant
metallic voltage appearing across a 135 Ω termination. The LCL of the system shall meet the requirement of: - 50 dB between 5 kHz and 292 kHz for a 584 kbaud system as shown in fig 12.

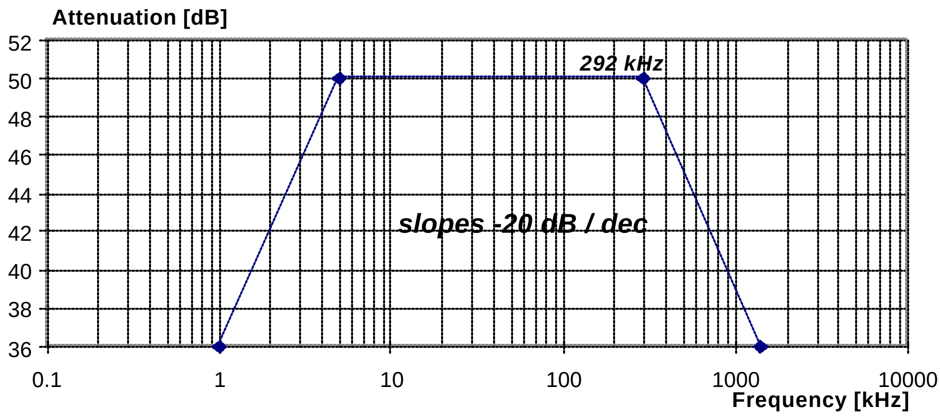


Figure 12: *Minimum longitudinal conversion loss for a 584 kbaud system*

Reference [4,5]: ***[ETR152: 5.8.5.1]***

6.3.2.2. Total signal power

The average power of a sending signal shall not exceed a level of 13.5 dBm (±0.5 dBm), over the frequency band from 0 Hz to 1168 kHz.
Reference [4,5]: ***[ETR152: 5.8.4.4]***

6.3.2.3. Peak amplitude

The nominal peak of the largest pulse shall be 2.64 V (±7%) into a resistive load of 135 Ω.
Reference [4,5]: ***[ETR152: 5.8.4.1]***

6.3.2.4. Power spectral density (PSD)

The upper bound of the single sided power spectral density of the sending signal shall be as shown in figure 13. Table 14 specifies the break points of this figure. Measurements to verify compliance with this requirement shall use a noise power bandwidth of 1 kHz (and a resistive load of 135 Ω).
Reference [4,5]: ***[ETR152: 5.8.4.3.1]***

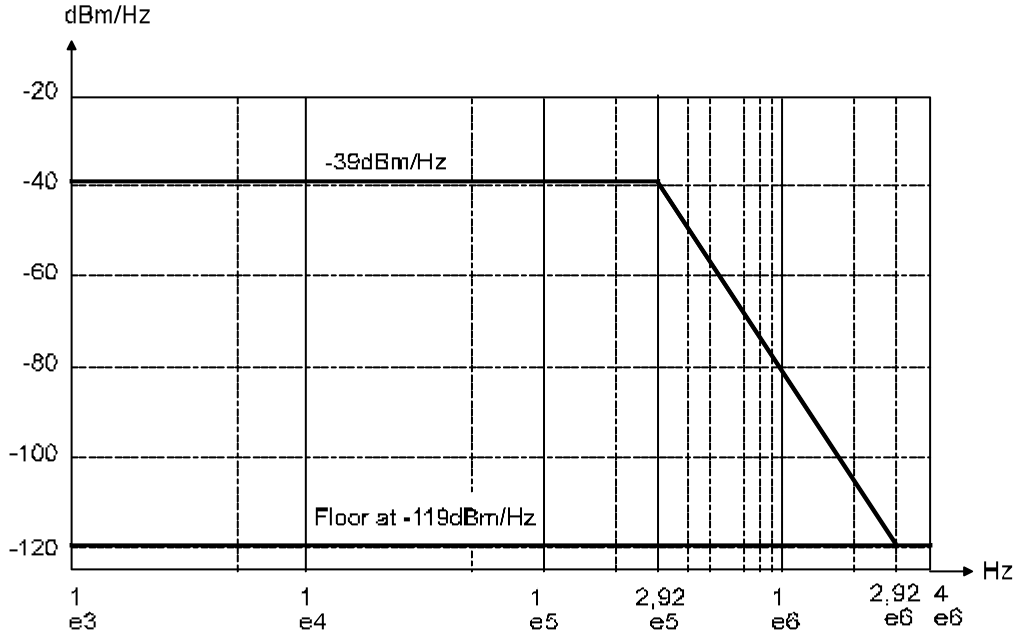


Figure 13*: Upper bound of the average power spectral density of category 3b equipment.*

Points	frequency	PSD
A	0.1 kHz	-39 dBm/Hz
B	292 kHz	-39 dBm/Hz
C	2.92 MHz	-119 dBm/Hz
D	30 MHz	-119 dBm/Hz

Table 14: ***Break points of the PSD mask in figure 13***

6.3.2.5. Narrow-band signal power

The average power ***P*** of a category 3b sending signal into a resistive load ***R***, within a bandwidth ***B*** centred at any point in the frequency range 100 Hz to 30 MHz, shall not exceed the limits given in table 15. This table specifies the break points of the limits. Limits for intermediate frequencies can be found by drawing a straight line between the break points on a logarithmic (Hz) - linear (dB) scale. These limits are frequency independent between 100 Hz to 292 kHz, and decrease with 24 dB/octave (80 dB/decade) above 292 kHz.
Reference: These numbers have been reconstructed from PSD requirements in ETSI-ETR152 [4,5].

Points	frequency f	Impedance R	Sending level P	Bandwidth B	P/B
A	0.1 kHz	135Ω	-9 dBm	1 kHz	-39 dBm/Hz
B	292 kHz	135Ω	-9 dBm	1 kHz	-39 dBm/Hz
C	2.92 MHz	135Ω	-89 dBm	1 kHz	-119 dBm/Hz
D	30 MHz	135Ω	-89 dBm	1 kHz	-119 dBm/Hz

Table 15: ***Break points of the narrow-band power limits.***

6.3.3. Category 3c: "HDSL.CAP/2" (2 Mb/s leased lines)

This category covers HDSL transmission equipment on two wire-pairs, based on CAP modulation. This sub clause is based on the ETSI reports on HDSL [4,5].
Unless otherwise indicated, the following signal specifications apply with a resistive load impedance of 135Ω, and does not apply to the DC remote power feeding (if any).

6.3.3.1. Unbalance about earth

The LCL (longitudinal conversion loss) is given by: LCL = 20 log (e_l/e_m) [dB] where e_l is the applied longitudinal voltage referenced to the building ground and e_m is the resultant metallic voltage appearing across a 135 Ω termination. The LCL of the system shall meet the requirement of: -50 dB between 5 kHz and 485 kHz for a 1160 kbaud system as shown in fig 14.
Reference [4,5]: ***[ETR152: 5.8.5.1]7***

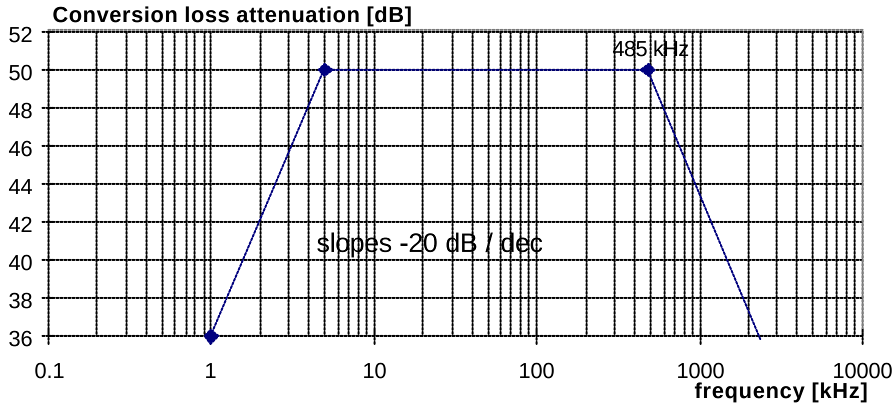


Figure 14: *Minimum longitudinal conversion loss.*

6.3.3.2. Total signal power

The average power of a sending signal shall not exceed a level of 13.5 dBm (± 0.5 dBm), over the frequency band from 0 Hz to 1 MHz.

Reference [4,5]: ***[ETR152: B.5.8.4.1.1]***

6.3.3.3. Peak amplitude

<For discussion, not in the recommendation, difficult to measure>
The nominal peak of the largest pulse shall be 2,64 V (±7%) into a resistive load of 135Ω.
(no ETSI reference)

6.3.3.4. Power spectral density (PSD)

The single sided power spectral density of the sending signal shall not exceed a level of P_0=–40 dBm/Hz (± 1,5 dBm) at any frequency. The upper bound of this PSD shall be as shown in figure 15. Table 16 specifies the break points of this figure. The signal power spectral density in the frequency band below f_1=3.98 kHz shall be at least 17 dB below the nominal signal power density in the pass band.
Measurements to verify compliance with this requirement shall use a noise power bandwidth of 1 kHz (and a resistive load of 135Ω).
Reference [4,5]: ***[ETR152: B.5.8.4.2]***

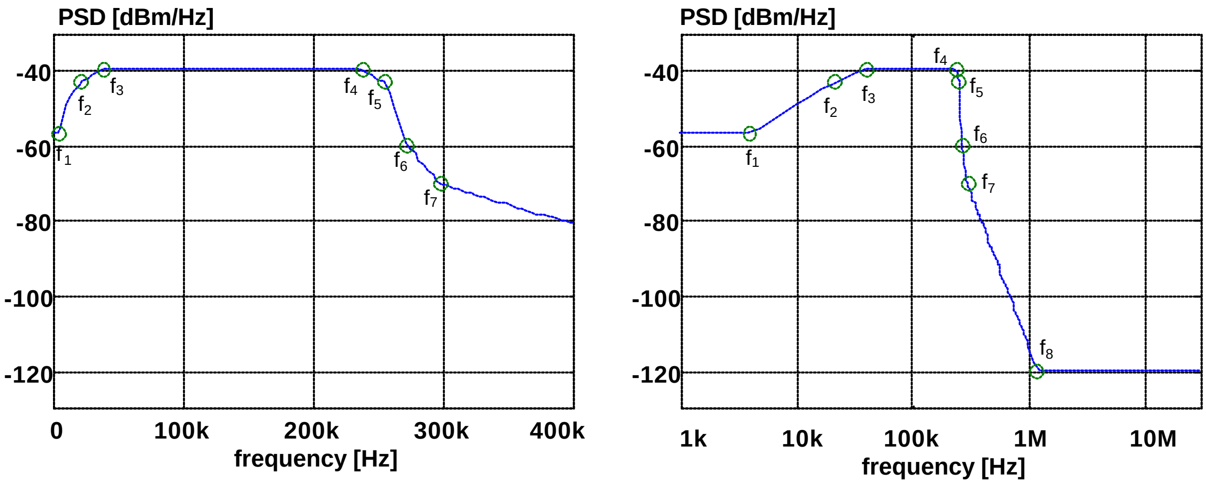


Figure 15: ***Upper bound of the average power spectral density of category 3b equipment.***

Points	Frequency	PSD P_0 = -40 dBm/Hz	
f0	0.1 kHz	P_0-17 dBm/Hz	± 3,0 dB
f1	3.98 kHz	P_0-17 dBm/Hz	± 3,0 dB
f2	21.50 kHz	P_0-3 dBm/Hz	± 1 dB
f3	39.02 kHz	P_0 dBm/Hz	
f4	237.58 kHz	P_0 dBm/Hz	
f5	255.10 kHz	P_0-3 dBm/Hz	± 1 dB
f6	272.62 kHz	P_0-20 dBm/Hz	± 3,0 dB
f7	297.00 kHz	P_0-30 dBm/Hz	
f8	1200.00 kHz	-120 dBm/Hz	
f9	30000.00 kHz	-120 dBm/Hz	

Table 16*: Break frequencies of the spectral mask in figure 15.*

6.3.3.5. Narrow-band signal power

The average power ***P*** of a category 3a sending signal into a resistive load ***R***, within a bandwidth ***B*** centred at any point in the frequency range 100 Hz to 30 MHz, shall not exceed the limits given in table 17. This table specifies the break points of the limits. Limits for intermediate frequencies can be found by drawing a straight line between the break points on a logarithmic (Hz) - linear (dB) scale.

Reference: These numbers have been reconstructed from PSD requirements in ETSI-ETR152 [4,5].

Points	frequency f	Impedance R	Sending level P	Bandwidth B	P/B	
f0	0.1 kHz	135Ω	–27 dBm	1 kHz	–57 dBm/Hz	± 3,0 dB
f1	3.98 kHz	135Ω	–27 dBm	1 kHz	–57 dBm/Hz	± 3,0 dB
f2	21.50 kHz	135Ω	–13 dBm	1 kHz	–43 dBm/Hz	± 1 dB
f3	39.02 kHz	135Ω	–10 dBm	1 kHz	–40 dBm/Hz	
f4	237.58 kHz	135Ω	–10 dBm	1 kHz	–40 dBm/Hz	
f5	255.10 kHz	135Ω	–13 dBm	1 kHz	–43 dBm/Hz	± 1 dB
f6	272.62 kHz	135Ω	–30 dBm	1 kHz	–60 dBm/Hz	± 3,0 dB
f7	297.00 kHz	135Ω	–40 dBm	1 kHz	–70 dBm/Hz	
f8	1200.00 kHz	135Ω	–90 dBm	1 kHz	–120 dBm/Hz	
f9	30000.00 kHz	135Ω	–90 dBm	1 kHz	–120 dBm/Hz	

Table 17: ***Break points of the narrow-band power limits.***

6.3.4. Category 3d: “SDSL”

This category covers Symmetrical DSL transmission equipment on a single wire-pair. **This standard is still in progress, and therfore not defined here.**

Reference [25]: ***ETSI WG TM6(98)9, Rev. 1, living list***

6.3.5. Additional categories within cluster “3”

Various HDSL-related products have recently been developed for symmetrical broadband transmissions. Examples are single wire-pair HDSL systems based on 2B1Q or CAP modulation. The spectra of CAP-based HDSL/1 systems are for instance wider than 450 kHz and 2B1Q-based HDSL/1 systems are wider than 500 kHz.
<for future description>

6.4. Cluster 4 transmission equipment (asymmetrical broadband)

This cluster is intended for transmission equipment up to about 8Mb/s on a single wire-pair, combined with POTS or ISDN services on the same wire-pair. The service is expected to be asymmetrically, which means a higher bit rate in the downstream direction and a significantly lower bitrate (e.g. 20%) in the upstream direction.

NOTE Asymmetrical DSL systems generate different signals in different transmission directions. Reversal of their transmission direction, which means the injection of upstream signals into LT-ports and downstream signals into the NT-ports, will cause a substantial reduction of the maximum reach. Such a reduction is even significant for all asymmetrical DSL systems when only one such system is reversed. Therefore the classification of asymmetrical DSL systems is consequently splitted into upstream and downstream specifications.

6.4.1. Category 4a: “ADSL over POTS” (Echo cancelled with POTS window)

This category covers ADSL transmission equipment on a single wire-pair, that can coexist with a POTS service on the same wire-pair. This sub clause is based on ETSI [6] and ANSI [8,9,10] reports on ADSL.
Its a technology, that leaves the signal spectrum unused from DC to about 25 kHz, to enable a simultaneously delivery of ADSL based services and POTS based services on the same wire-pair.

6.4.1.1. Downstream unbalance about earth

Longitudinal balance of equipment connected to the LT-port shall be > 40 dB over the frequency range 30 kHz to 1104 kHz and >30 dB over 300 Hz to 30 MHz, whichever is the highest demand. The modem shall meet this requirement both, switched on and off.
*Reference [9]: [**ANSI-T1.413, issue 2]** clause 12.3.1 (extended to 30 MHz) and E.3.2.*

6.4.1.2. Downstream total signal power

The aggregate transmit power of a sending downstream signal shall not exceed a level of 20.4 dBm into 100Ω, over the frequency band from 4 kHz to 3 MHz.
*Reference [9]: [**ANSI-T1.413, issue 2]** clause 6.15.1*

If measurement of the upstream power indicates that downstream power back-off is necessary, as described for the downstream PSD, then the aggregate transmit power shall be reduced accordingly.
*Reference [9]: [**ANSI-T1.413, issue 2]** clause 6.15.1*
<Details are for further study>

The aggregate transmit power of a sending downstream signal shall not exceed a level of –61.5 dBm into 600Ω, over the frequency band from 0 to 4 kHz.

6.4.1.3. Downstream peak amplitude

The nominal peak of the largest pulse shall be 7.5 V into a resistive load of 100Ω.
(no ETSI reference)
<For further study>

6.4.1.4. Downstream power spectral density (PSD)

The ***nominal PSD*** in the band from 25.875 to 1104 kHz shall be set at –40 dBm/Hz into 100Ω. If measurement of the upstream power indicates that power cut-back is necessary, then the nominal

PSD shall be set at –42, –44, –46, –48, –50, or –52 dBm/Hz (i.e., the nominal PSD is (–40–2 ×n) dBm/Hz with n = (0 to 6).
*Reference [9]: [**ANSI-T1.413, issue 2]** clause 6.15.1*

Power back-off. If the total received upstream power from 28.035 to 79.791 kHz (ADSL sub-carriers 7–18) is greater than 3 dBm, then the nominal downstream PSD shall not exceed the values shown below. The received upstream power measurement shall be performed with an accuracy of ± 1 dB or better.

Upstream received power (dBm)	< 3	< 4	< 5	< 6	< 7	< 8	< 9
Max downstream PSD (dBm/Hz)	–40	–42	–44	–46	–48	–50	–52

*Reference [9]: [**ANSI-T1.413, issue 2]** clause 9.4.6*

The pass band ***ripple*** during steady-state shall be no greater than +3.5 dB; the maximum PSD of (–40 – 2n + 3.5) dBm/Hz applies across the whole pass band. The transmit PSD within the 25.875 kHz to 1104 kHz pass band shall therefore be no greater than –36.5 dBm/Hz into 100Ω, reduced by power cut-back in multiples of 2 dB.
*Reference [9]: [**ANSI-T1.413, issue 2]** clause 6.14.1*

The single sided power spectral density of the sending signal shall not exceed the values shown in figure 17 and table 18. This table specifies the break points of these limits. Limits for intermediate frequencies can be found by drawing a straight line between the break points on a logarithmic (Hz) - linear (dB) scale.
All PSD measurements above 4kHz are in 100 Ω. Above 25.875 kHz, the peak PSD shall be measured with a 10 kHz resolution bandwidth.
See also the additional sliding window requirements, as specified in table [*]. The dashed lines in figure 17 indicate the resulting narrow band signal power in 1 MHz, divided by the measurement bandwidth of 1 MHz.
*Reference [9]: [**ANSI-T1.413, issue 2]** clause 6.14*

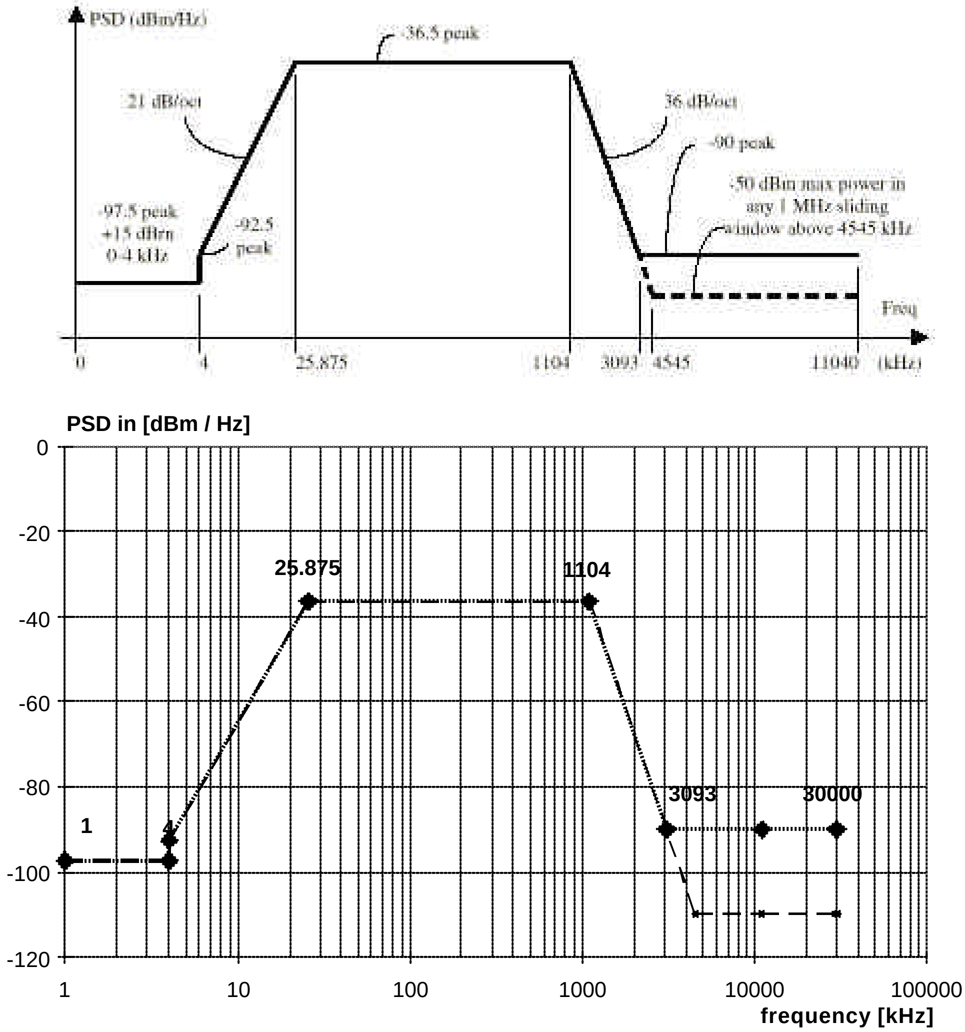


Figure 17: Upper bound of the downstream spectral density of ADSL over POTS

Points	Frequency	Impedance W	PSD [dBm / Hz]
F0	0	600	-97.5
F1	4 kHz	600	-97.5
F2	4 kHz	100	-92.5
F3	25.875 kHz	100	-36.5
F4	1.104 MHz	100	-36.5
F5	3.093 MHz	100	-90
F6	11.040 MHz	100	-90
F7	30 MHz	100	-90

Table 18: *Break points of the upper bound of the downstream spectral density of ADSL over POTS*

6.4.1.5. Downstream narrow-band signal power

The average power ***P*** of a category 4a sending downstream signal into a resistive load ***R***, within a bandwidth ***B***, centred at any point in the frequency range 100 Hz to 30 MHz, shall not exceed the limits given in table 19. This table specifies the break points of these limits. Limits for intermediate frequencies can be found by drawing a straight line between the break points on a logarithmic (Hz) - linear (dB) scale.

Table 19 is reconstructed from the PSD requirements, as defined in figure 17 and table 18.

Measurements to verify compliance with this requirement above 4 kHz shall use a bandwidth of 10 kHz. Above 3 MHz, an additional sliding window requirement shall be met, with 1MHz resolution bandwidth. At all frequencies above 3 MHz, the transmit downstream power in the [f, f + 1 MHz] window shall not exceed -50 dBm. This is to perform a higher bandwidth measurement in order to make sure that different systems do not fill the entire allowable bandwidth with noise up to the PSD limit shown in figure 17. The dashed line in figure 17 indicate the resulting narrow band signal power in 1 MHz, divided by the measurement bandwidth of 1 MHz. This sliding window approach is defined in section [*][*].
*Reference [9]: [**ANSI-T1.413, issue 2]** clause 6.14*

Points	Frequency f	Impedance R	Sending level P	Bandwidth B	P/B
F0	0	600Ω	–67.5 dBm	1 kHz	–97.5 dBm/Hz
F1	4 kHz	600Ω	–67.5 dBm	1 kHz	–97.5 dBm/Hz
F1	4 kHz	100Ω	–52.5 dBm	10 kHz	–92.5 dBm/Hz
F2	25.875 kHz	100Ω	+3.5 dBm	10 kHz	–36.5 dBm/Hz
F3	1.104 MHz	100Ω	+3.5 dBm	10 kHz	–36.5 dBm/Hz
F4	3.093 MHz	100Ω	–50 dBm	10 kHz	–90 dBm/Hz
F4	3.093 MHz	100Ω	–30 dBm	1 MHz	–90 dBm/Hz
F5	4.545 MHz	100Ω	–50 dBm	1 MHz	–110 dBm/Hz
F6	11.040 MHz	100Ω	–50 dBm	1 MHz	–110 dBm/Hz
F7	30 MHz	100Ω	–50 dBm	1 MHz	–110 dBm/Hz

***Table 19**: Downstream narrow band signal powers. The power in a 1 MHz sliding window is measured in 1 MHz bandwidth, starting at the measurement frequency, (F4) and in the [f, f+1MHz] window.*

6.4.1.6. Upstream unbalance about earth

Longitudinal balance of equipment connected to the NT-port shall be > 40 dB over the frequency range 30 kHz to 1104 kHz and >30 dB over 300 Hz to 30 MHz, whichever is the highest demand. The modem shall meet this requirement both, switched on and off.
*Reference [9]: [**ANSI-T1.413, issue 2]** clause 12.3.1 (extended to 30 MHz) and E.3.2.*

6.4.1.7. Upstream total signal power

The aggregate transmit power of a sending upstream signal shall not exceed a level of 12.5 dBm into 100Ω, over the frequency band from 4 kHz to 3 MHz.
*Reference [9]: [**ANSI-T1.413, issue 2]** clause 7.15.1*

The aggregate transmit power of a sending downstream signal shall not exceed a level of –61.5 dBm into 600Ω, over the frequency band from 0 to 4 kHz.

6.4.1.8. Upstream peak amplitude

The nominal peak of the largest pulse shall be 7.5 V into a resistive load of 100Ω.
(no ETSI reference)
<For further study>

6.4.1.9. Upstream power spectral density (PSD)

The ***nominal*** PSD in the band from 25 to 138 kHz shall be –38 dBm/Hz into 100Ω.
*Reference [9]: [**ANSI-T1.413, issue 2]** clause 7.15.1*

The pass band ***ripple*** during steady state shall be no greater than +3.5 dB; the maximum PSD applies across the whole pass-band. The transmit PSD within 25.875 kHz to 138 kHz shall therefore be no greater than –34.5 dBm/Hz into 100Ω.
*Reference [9]: [**ANSI-T1.413, issue 2]** clause 7.14.1*

The single sided power spectral density of the sending signal shall not exceed the values shown in figure 18 and table 20. This table specifies the break points of these limits. Limits for intermediate frequencies can be found by drawing a straight line between the break points on a logarithmic (Hz) - linear (dB) scale.
All PSD measurements above 4kHz are in 100Ω. Above 25.875 kHz, the peak PSD shall be measured with a 10 kHz resolution bandwidth.
See also the additional sliding window requirements, as specified in table 21. The dashed lines in figure 18 indicate the resulting narrow band signal power in 1 MHz, divided by the measurement bandwidth of 1 MHz.
*Reference [9]: [**ANSI-T1.413, issue 2]** clause 7.14*

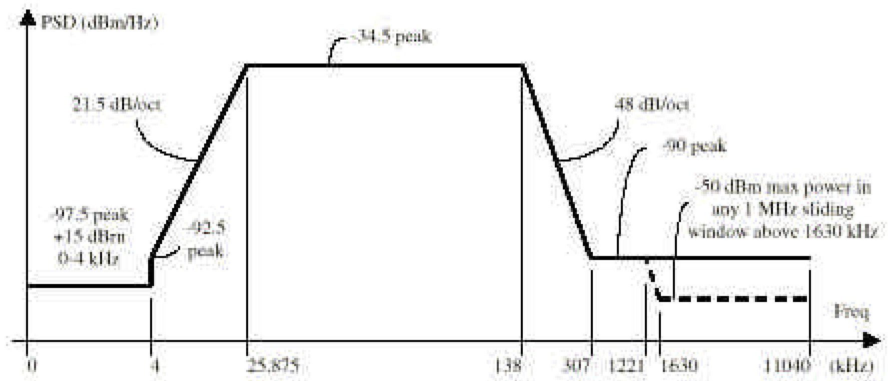


***Figure 18**: Upper bound of the upstream spectral density of ADSL over POTS*

Points	Frequency	Impedance W	PSD [dBm / Hz]
F0	0	600	-97.5
F1	4 kHz	600	-97.5
F2	4 kHz	100	-92.5
F3	25.875 kHz	100	-34.5
F4	138 kHz	100	-34.5
F5	307 kHz	100	-90
F6	11.040 MHz	100	-90
F7	30 MHz	100	-90

***Table 20**: Break points of the upper bound of the upstream spectral density of ADSL over POTS.*

6.4.1.10. Upstream narrow-band signal power

The average power ***P*** of a category 4a sending upstream signal into a resistive load ***R***, within a bandwidth ***B***, centred at any point in the frequency range 100 Hz to 30 MHz, shall not exceed the limits given in table 21. This table specifies the break points of these limits. Limits for intermediate frequencies can be found by drawing a straight line between the break points on a logarithmic (Hz) - linear (dB) scale.

Table **21** is reconstructed from the PSD requirements, as defined in figure 18 and table 20. Measurements to verify compliance with this requirement above 4 kHz shall use a bandwidth of 10 kHz. Above 1.630 MHz, an additional sliding window requirement shall be met, with 1MHz resolution bandwidth. At all frequencies above 1.630 MHz, the transmit upstream power in the [f, f + 1 MHz] window shall not exceed -50 dBm. This is to perform a higher bandwidth measurement in order to make sure that different systems do not fill the entire allowable bandwidth with noise up to the PSD limit shown in figure 18. The dashed line in figure 18 indicate the resulting narrow band

signal power in 1 MHz, divided by the measurement bandwidth of 1 MHz. This sliding window approach is defined in section [*][*].
*Reference [9]: [**ANSI-T1.413, issue 2]** clause 7.14*

Points	Frequency F	Impedance R	Sending level P	Bandwidth B	P/B
F0	0	600Ω	–67.5 dBm	1 kHz	–97.5 dBm/Hz
F1	4 kHz	600Ω	–67.5 dBm	1 kHz	–97.5 dBm/Hz
F1	4 kHz	100Ω	–52.5 dBm	10 kHz	–92.5 dBm/Hz
F2	25.875 kHz	100Ω	+5.5 dBm	10 kHz	–34.5 dBm/Hz
F3	138 kHz	100Ω	+5.5 dBm	10 kHz	–34.5 dBm/Hz
F4	307 MHz	100Ω	–50 dBm	10 kHz	–90 dBm/Hz
F5	1.221 MHz	100Ω	–50 dBm	10 kHz	–90 dBm/Hz
F5	1.221 MHz	100Ω	–30 dBm	1 MHz	–90 dBm/Hz
F6	1.630 MHz	100Ω	–50 dBm	1 MHz	–110 dBm/Hz
F7	11.040 MHz	100Ω	–50 dBm	1 MHz	–110 dBm/Hz
F8	30 MHz	100Ω	–50 dBm	1 MHz	–110 dBm/Hz

Table 21*: Upstream narrow band signal powers. The power in a 1 MHz sliding window is measured in 1 MHz bandwidth, starting at the measurement frequency, (F4) and in the [f, f+1MHz] window.*

6.4.2. Category 4b: "ADSL over ISDN" (Echo cancelled with ISDN window)

This category covers ADSL transmission equipment on a single wire-pair, which can coexist with a POTS or ISDN service on the same wire-pair. This sub clause is based on ETSI-TM6 studies on ADSL. over ISDN.
Its a modified version for ADSL over POTS, that leaves the signal spectrum unused from DC to about 138 kHz, to enable a simultaneously delivery of ADSL based services and ISDN based services on the same wire-pair.

6.4.2.1. Downstream unbalance about earth

Longitudinal balance of equipment connected to the LT-port shall be > 40 dB over the frequency range 30 kHz to 1104 kHz and >30 dB over 300 Hz to 30 MHz, whichever is the highest demand. The modem shall meet this requirement both, switched on and off.
*Reference [9]: [**ANSI-T1.413, issue 2]** clause 12.3.1 (extended to 30 MHz) and E.3.2.*

6.4.2.2. Downstream total signal power

The aggregate transmit power of a sending downstream signal shall not exceed a level of 19.83 dBm into 100 Ω, over the frequency band from 50 kHz to 3 MHz.
*Reference [26]: **[ETSI/TC TM WG TM6(97)5]** clause 5.2*

If measurement of the upstream power indicates that downstream power back-off is necessary, as described for the downstream PSD, then the aggregate transmit power shall be reduced accordingly.
<Details are for further study>

The aggregate transmit power of a sending downstream signal shall not exceed a level –48.5 dBm into 600Ω, over the frequency band from 0 to 80 kHz.

6.4.2.3. Downstream peak amplitude

The nominal peak of the largest pulse shall be 7.5 V into a resistive load of 100Ω.
(no ETSI reference)
<**For further study**>

6.4.2.4. Downstream power spectral density (PSD)

The ***nominal PSD*** in the band from 50 to 1104 kHz shall be set at –40 dBm/Hz into 100Ω. If measurement of the upstream power indicates that power cut-back is necessary, then the nominal PSD shall be set at –42, –44, –46, –48, –50, or –52 dBm/Hz (i.e., the nominal PSD is (–40–2 ×n) dBm/Hz with n = (0 to 6).
*Reference [20]: **ETSI/TC TM WG TM6,** clause 5.4 extended to 30 MHz*
*Reference [9]: [**ANSI-T1.413, issue 2]** clause 6.15.1*

Power back-off. If the total received upstream power from 140.156 to 191.906 kHz (ADSL sub-carriers 33-44) is greater than 0 dBm, then the nominal downstream PSD shall not exceed the values shown below. The received upstream power measurement shall be performed with an accuracy of ± 1 dB or better.

Upstream received power (dBm)	< 0	<1.5	< 3	< 4.5	< 5.5	< 6.5	< 7.5
Max downstream PSD (dBm/Hz)	–40	–42	–44	–46	–48	–50	–52

*No reference, but calculated by insertion loss scaling from reference [9]: [**ANSI-T1.413, issue 2]** clause 9.4.6*
<For further study>

The pass band ***ripple*** during steady-state shall be no greater than +3.5 dB; the maximum PSD of (–40 – 2n + 3.5) dBm/Hz applies across the whole pass band. The transmit PSD within the 50 kHz to 1104 kHz pass band shall therefore be no greater than –36.5 dBm/Hz into 100Ω, reduced by power cut-back in multiples of 2 dB.
*Reference [9]: [**ANSI-T1.413, issue 2]** clause 6.14.1*

The single sided power spectral density of the sending signal shall not exceed the values shown in figure 19 and table 22. This table specifies the break points of these limits. Limits for intermediate frequencies can be found by drawing a straight line between the break points on a logarithmic (Hz) - linear (dB) scale.
All PSD measurements above 4kHz are in 100Ω. Above 50 kHz, the peak PSD shall be measured with a 10 kHz resolution bandwidth.
See also the additional sliding window requirements, as specified in table [*]. The dashed lines in figure 19 indicate the resulting narrow band signal power in 1 MHz, divided by the measurement bandwidth of 1 MHz.
*Reference [9]: [**ANSI-T1.413, issue 2]** clause 6.14*

Transmitter PSD masks that reduce the spectral overlap between upstream and downstream signals are ***for further study***. Their purpose is to reduce the NEXT.
*Reference [9]: [**ANSI-T1.413, issue 2]** Annex F.*

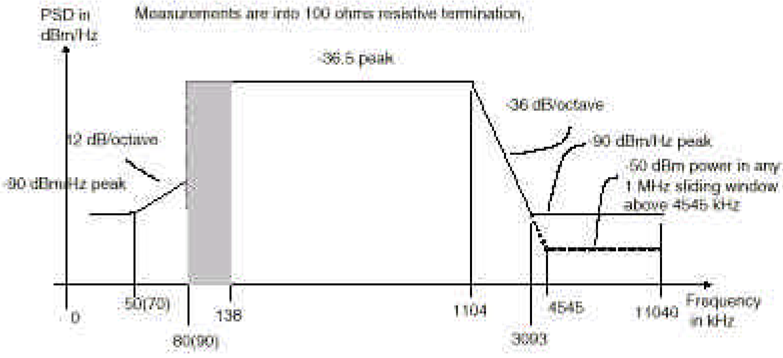


***Figure 19**: Upper bound of the downstream spectral density of ADSL over ISDN*

Points	Frequency	Impedance W	PSD [dBm / Hz]
F0	0	600	–90
F1	50 kHz	600	–90
F1	50 kHz	100	–90
F2	80 kHz	100	–81.8
F2	80 kHz	100	See
F3	138 kHz	100	Note
F3	138 kHz	100	–36.5
F4	1.104 MHz	100	–36.5
F5	3.093 MHz	100	–90
F6	11.040 MHz	100	–90
F7	30 MHz	100	–90

Table 22: *Break points of the upper bound of the downstream spectral density of ADSL over ISDN.*
NOTE*: The PSD between 80 and 138 kHz is an area of further study and will be addressed by ETSI-TM6.*

6.4.2.5. Downstream narrow-band signal power

The average power ***P*** of a category 4b sending downstream signal into a resistive load ***R***, within a bandwidth ***B***, centred at any point in the frequency range 100 Hz to 30 MHz, shall not exceed the limits given in table 23. This table specifies the break points of these limits. Limits for intermediate frequencies can be found by drawing a straight line between the break points on a logarithmic (Hz) - linear (dB) scale.

Table 23 is reconstructed from the PSD requirements, as defined in figure 19 and table 22. Measurements to verify compliance with this requirement above 4 kHz shall use a bandwidth of 10 kHz. Above 3 MHz, an additional sliding window requirement shall be met, with 1MHz resolution bandwidth. At all frequencies above 3 MHz, the transmit downstream power in the [f, f + 1 MHz] window shall not exceed -50 dBm. This is to perform a higher bandwidth measurement in order to make sure that different systems do not fill the entire allowable bandwidth with noise up to the PSD limit shown in figure 19. The dashed line in figure 19 indicates the resulting narrow band signal power in 1 MHz, divided by the measurement bandwidth of 1 MHz. This sliding window approach is defined in section [*].
Reference [20]: ***ETSI/TC TM WG TM6,*** *clause 5.4 extended to 30 MHz*

Points	Frequency f	Impedance R	Sending level P	Bandwidth B	P/B
F0	0	600Ω	–60 dBm	1 kHz	–90 dBm/Hz
F1	50 kHz	600Ω	–60 dBm	1 kHz	–90 dBm/Hz
F1	50 kHz	100Ω	–50.0 dBm	10 kHz	–90 dBm/Hz
F2	80 kHz	100Ω	–42.2 dBm	10 kHz	–81.8 dBm/Hz
F2	80 kHz	100Ω	See	10 kHz	See
F3	138 kHz	100Ω	note	10 kHz	note
F3	138 kHz	100Ω	+3.5 dBm	10 kHz	–36.5 dBm/Hz
F4	1.104 MHz	100Ω	+3.5 dBm	10 kHz	–36.5 dBm/Hz
F5	3.093 MHz	100Ω	–50 dBm	10 kHz	–90 dBm/Hz
F5	3.093 MHz	100Ω	–30 dBm	1 MHz	–90 dBm/Hz
F6	4.545 MHz	100Ω	–50 dBm	1 MHz	–110 dBm/Hz
F7	11.040 MHz	100Ω	–50 dBm	1 MHz	–110 dBm/Hz
F8	30 MHz	100Ω	–50 dBm	1 MHz	–110 dBm/Hz

Table 23*: Downstream narrow band signal powers. The power in a 1 MHz sliding window is measured in 1 MHz bandwidth, starting at the measurement frequency, (F4) and in the [f,*

f+1MHz] window.
***NOTE:** The narrow band power between 80 and 138 kHz is an area of further study and will be addressed by ETSI-TM6.*

6.4.2.6. Upstream unbalance about earth

Longitudinal balance of equipment connected to the LT-port shall be > 40 dB over the frequency range 30 kHz to 1104 kHz and >30 dB over 300 Hz to 30 MHz, whichever is the highest demand. The modem shall meet this requirement both, switched on and off.
*Reference [9]: [**ANSI-T1.413, issue 2]** clause 12.3.1 (extended to 30 MHz) and E.3.2.*

6.4.2.7. Upstream total signal power

The aggregate transmit power of a sending upstream signal shall not exceed a level of 13.26 dBm into 100Ω, over the frequency band from 4 kHz to 3 MHz.
*Reference [26]: **[ETSI/TC TM WG TM6(97)5]** clause 6.3*

6.4.2.8. Upstream peak amplitude

The nominal peak of the largest pulse shall be 7.5 V into a resistive load of 100Ω.
(no ETSI reference)
<For further study>

6.4.2.9. Upstream power spectral density (PSD)

The ***nominal*** PSD in the band from 25 to 138 kHz shall be –38 dBm/Hz into 100Ω.
*Reference [26]: **[ETSI/TC TM WG TM6(97)5]** clause 6.10*
*Reference [9]: [**ANSI-T1.413, issue 2]** clause 7.15.1*

The pass band ***ripple*** during steady state shall be no greater than +3.5 dB; the maximum PSD applies across the whole pass-band. The transmit PSD within 25.875 kHz to 138 kHz shall therefore be no greater than –34.5 dBm/Hz into 100Ω.
*Reference [9]: [**ANSI-T1.413, issue 2]** clause 7.14.1*

The single sided power spectral density of the sending signal shall not exceed the values shown in figure 20 and table 24. This table specifies the break points of these limits. Limits for intermediate frequencies can be found by drawing a straight line between the break points on a logarithmic (Hz) - linear (dB) scale.
All PSD measurements above 4kHz are in 100Ω. Above 50 kHz, the peak PSD shall be measured with a 10 kHz resolution bandwidth.
See also the additional sliding window requirements, as specified in table 25. The dashed lines in figure 20 indicate the resulting narrow band signal power in 1 MHz, divided by the measurement bandwidth of 1 MHz.
*Reference [9]: [**ANSI-T1.413, issue 2]** clause 7.14*

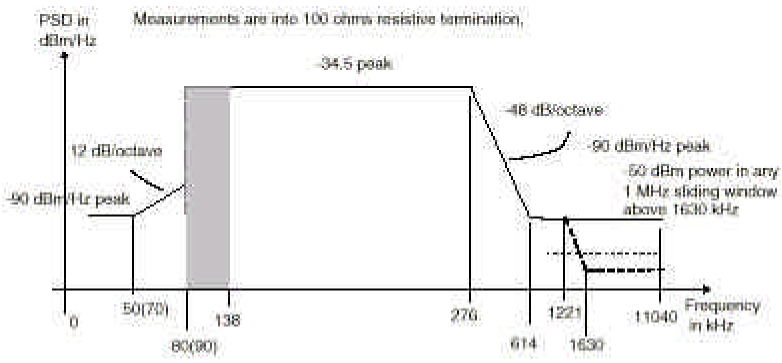


***Figure 20:** Upper bound of the upstream spectral density of ADSL over ISDN*

Points	Frequency	Impedance W	PSD [dBm / Hz]
F0	0	135	–90
F1	50 kHz	135	–90
F1	50 kHz	100	–90.0
F2	80 kHz	100	–81.8
F2	80 kHz	100	See
F3	138 kHz	100	Note
F3	138 kHz	100	–34.5
F4	276 kHz	100	–34.5
F5	614 kHz	100	–90
F6	11.040 MHz	100	–90
F7	30 MHz	100	–90

***Table 24**: Break points of the upper bound of the upstream spectral density of ADSL over ISDN.*
***NOTE**: The narrow band power between 80 and 138 kHz is an area of further study and will be addressed by ETSI-TM6.*

6.4.2.10. Upstream narrow-band signal power

The average power ***P*** of a category 4b sending upstream signal into a resistive load ***R***, within a bandwidth ***B***, centred at any point in the frequency range 100 Hz to 30 MHz, shall not exceed the limits given in table 25. This table specifies the break points of these limits. Limits for intermediate frequencies can be found by drawing a straight line between the break points on a logarithmic (Hz) - linear (dB) scale.

Table 25 is reconstructed from the PSD requirements, as defined in figure 20 and table 24. Measurements to verify compliance with this requirement above 4 kHz shall use a bandwidth of 10 kHz. Above 1.630 MHz, an additional sliding window requirement shall be met, with 1MHz resolution bandwidth. At all frequencies above 1.630 MHz, the transmit upstream power in the [f, f + 1 MHz] window shall not exceed -50 dBm. This is to perform a higher bandwidth measurement in order to make sure that different systems do not fill the entire allowable bandwidth with noise up to the PSD limit shown in figure 20. The dashed line in figure 20 indicates the resulting narrow band signal power in 1 MHz, divided by the measurement bandwidth of 1 MHz. This sliding window approach is defined in section [*].
*Reference [9]: [**ANSI-T1.413, issue 2]** clause 7.14*

Points	Frequency F	Impedance R	Sending level P	Bandwidth B	P/B
F0	0	135Ω	–60.0 dBm	1 kHz	–90 dBm/Hz
F1	50 kHz	135Ω	–60.0 dBm	1 kHz	–90 dBm/Hz
F1	50 kHz	100Ω	–50.0 dBm	10 kHz	–90 dBm/Hz
F2	80 kHz	100Ω	–41.5 dBm	10 kHz	–81.8 dBm/Hz
F2	80 kHz	100Ω	See	10 kHz	See
F3	138 kHz	100Ω	Note	10 kHz	Note
F3	138 kHz	100Ω	+5.5 dBm	10 kHz	–34.5 dBm/Hz
F4	276 kHz	100Ω	+5.5 dBm	10 kHz	–34.5 dBm/Hz
F5	614 kHz	100Ω	–50 dBm	10 kHz	–90 dBm/Hz
F6	1.221 MHz	100Ω	–50 dBm	10 kHz	–90 dBm/Hz
F6	1.221 MHz	100Ω	–30 dBm	1 MHz	–90 dBm/Hz
F7	1.630 MHz	100Ω	–50 dBm	1 MHz	–110 dBm/Hz
F8	11.040 MHz	100Ω	–50 dBm	1 MHz	–110 dBm/Hz
F9	30 MHz	100Ω	–50 dBm	1 MHz	–110 dBm/Hz

***Table 25**: Upstream narrow band signal powers. The power in a 1 MHz sliding window is measured in 1 MHz bandwidth, starting at the measurement frequency, (F4) and in the [f, f+1MHz] window.*
***NOTE**: The narrow band power between 80 and 138 kHz is an area of further study and will be addressed by ETSI-TM6.*

6.4.3. Category 4c: “ADSL-lite” (with POTS window)

This category covers ADSL transmission equipment on a single wire-pair, that do not necessary requires the installation of a splitter filter at the customer.

ADSL-lite is a placeholder name for a class of ADSL look-alike modems. Compatibility with other categories cannot be predicted at this moment because of the rapid changing descriptions of this category.

6.4.3.1. Downstream unbalance about earth
<For further study>

6.4.3.2. Downstream total signal power
<For further study>

6.4.3.3. Downstream peak amplitude
<For further study>

6.4.3.4. Downstream power spectral density (PSD)
<For further study>

6.4.3.5. Downstream narrow-band signal power
<For further study>

6.4.3.6. Upstream unbalance about earth
<For further study>

6.4.3.7. Upstream total signal power
<For further study>

6.4.3.8. Upstream peak amplitude
<For further study>

6.4.3.9. Upstream power spectral density (PSD)
<For further study>

6.4.3.10. Upstream narrow-band signal power
<For further study>

6.4.4. Category 4d: "ADSL.FDM over POTS" (without echo cancellation)
Transmitter PSD masks that reduce the spectral overlap between upstream and downstream signals are ***for further study***. There purpose is to reduce the NEXT.
*Reference [9]: [**ANSI-T1.413, issue 2]** Annex F.*

6.4.5. Category 4e: "ADSL.FDM over ISDN" (without echo cancellation)
Transmitter PSD masks that reduce the spectral overlap between upstream and downstream signals are ***for further study***. There purpose is to reduce the NEXT.

6.4.6. Category 4f: "RADSL.CAP"
Reference: **ANSI-T1.RADSL** [10].

6.5. Cluster 5 transmission equipment (broadband 0.3..30MHz)
This category is intended for future transmission equipment up to tens of Mb/s on a single wirepair. VDSL is a technology that can be combined with POTS or ISDN services on the same wire-pair. The service is expected to be asymmetrically or symmetrically and can cover only relatively short ranges.

VDSL is currently under study for standardisation within ETSI [7] and ANSI. It has reached the phase that ETSI will publish the first functional requirements in the beginning of 1998. An update of that ETSI document is expected in the beginning of 1999. Other essential aspects are just in the beginning of standardisation. The feasibility of VDSL in an operational network relies on the spectral pollution generated by the installed base. Future updates of these Technical Requirements shall be in line with the expected requirements for category 5 equipment.

It is expected that most impairment noise that will harm VDSL signals is generated from coexistent ADSL and VDSL systems. Impairment by category 4 signals up to 1.2 MHz is currently expected to be the upper limit for VDSL, because VDSL will probably be equipped with the ability to leave VDSL spectra below 1.2MHz unused. In addition, it is expected that symmetrical and asymmetrical VDSL systems do not coexist in the same binder or cable bundle. It is also expected that EMC aspects, such as egress of VDSL signals, will play an important role in the acceptance of new categories. The metallic shield of most underground cables will prevent most of this egress, but this shield is lacking in the central office and customer end of the network. VDSL will have the ability to notch the transmitted spectrum at (programmable) frequencies. This can avoid that VDSL interferes with dedicated radio frequencies, so the rules about these notches might become an essential part of these Technical Requirements.

6.5.1. Category 5a: Asymmetrical VDSL

This category covers VDSL transmission equipment on a single wire-pair. The service is expected to be asymmetrically, which means a higher bitrate in the downstream direction and a significantly lower bitrate (e.g. 20%) in the upstream direction. Downstream is from central office to customer. ETSI [7] has targeted the following downstream/upstream bitrates for VDSL: 6/2, 12/2 and 24/4 Mb/s

The use of this type of equipment in upstream direction (i.e. the main bit stream in upstream direction) is definitely excluded from these Technical Requirements. That application is incompatible with similar category 5 equipment installed in downstream direction.
It is expected that category 5a equipment do not coexist with category 5b equipment in the same binder or cable bundle.

Reference [19]: ***ETSI-TS 101 270-1 V1.1.1 (1998-04)*** *Part 1: Functional requirements*

6.5.2. Category 5b: Symmetrical VDSL

It is expected that category 5b equipment do not coexist with category 5a equipment in the same binder or cable bundle. ETSI [7] has targeted the following downstream/upstream bitrates for VDSL: 6/6, 12/22, 24/24 and 36/36 Mb/s

Reference [19]: ***ETSI-TS 101 270-1 V1.1.1 (1998-04)*** *Part 1: Functional requirements*

7. References

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[2] **ETSI-ETR 80: "**Transmission and Multiplexing (TM); Integrated Services Digital Network (**ISDN**) basic rate access; Digital transmission system on metallic local lines", ETSI Technical Report ETR80, Edition 2, Nov 1996.

[3] **ETSI-TS 101 080: "**Transmission and Multiplexing (TM); Integrated Services Digital Network (**ISDN**) basic rate access; Digital transmission system on metallic local lines", ETSI Technical Report ETR80, Edition 3, January 1998, and the Living list (revision 8) for amendment No. 4 960p04 revision 8. (See also Working Document WD3, "Changes made in TS 101 080", ISDN-Rapporteur, ETSI-TM6 meeting, Lulea, Sweden, June 1998, [983W03]

[4] **ETSI-ETR 152:** "Transmission and Multiplexing (TM); High bit rate Digital Subscriber Line (**HDSL**) transmission system on metallic local lines; HDSL core specification and applications for 2 048 kbit/s based access digital sections", ETSI, European Telecommunication Standard, Edition 3, December 1996

[5] **ETSI-TS 152:** "Transmission and Multiplexing (TM); High bitrate digital subscriber line (**HDSL**) transmission system on metallic local lines; HDSL core specification and applications for 2048 kbit/s based access digital sections", ETSI, European Telecommunication Standard, draft Edition 4, November 1997

[6] **ETSI-ETR 328:** "Transmission and Multiplexing (TM); Asymmetric Digital Subscriber Line (**ADSL**); Requirements and performance", ETSI, European Telecommunication Standard, November 1996

[7] **ETSI-DTS/TM-06003:** "Transmission and Multiplexing (TM); Access transmission systems on metallic access cables; Very high speed Digital Subscriber Line (**VDSL**); Part 1: Functional requirements". ETSI, European Telecommunication Standard, draft Edition 1 revision 7, February 1998

[8] **ANSI-T1.413, issue 1:** "Network and customer installation interfaces - Asymmetrical Digital Subscriber Line (**ADSL**) Metallic Interface", ANSI, American National Standardization Institute, Issue 1, August 1995.

[9] **ANSI-T1.413, issue 2:** "Standards Project for Interfaces Relating to Carrier to Customer Connection of Asymmetrical Digital Subscriber Line (**ADSL**) Equipment", ANSI, American National Standardization Institute, draft specification issue 2, T1E1.4/97-007R6, Sept 1997. (ADSL_98R5)

[10] **ANSI-T1.RADSL**: "Draft Physical Layer Specification for CAP/QAM-Based Rate Adaptive Digital Subscriber Line (**RADSL**)" ANSI, American National Standardisation Institute, draft specification, T1E1/97-104R2a, September 1997.

[11] **ANSI-T1.VDSL**: "Very high-speed Digital Subscriber Lines (**VDSL**)", ANSI, Draft Technical report, revision 12 T1E1.4/97-131R3, may 1997.

[12] **ETSI-TM6(97)02**. "Cable reference models for simulating metallic access networks", R.F.M. van den Brink, ETSI-TM6, Permanent document TM6(97)02, revision 3, Luleå, Sweden, June 1998.

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[20] **ETSI/TC TM WG TM6(97)5** Transmission and Multiplexing (TM); Access transmission systems on metallic access cables; Asymmetric Digital Subscriber Line (ADSL) -Coexistence of ADSL and ISDN- BA on the same pair DTS/TM-06006 (Draft) V 1.0.1 (1998-9)

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