TITLE **Spectral Management approach in the Netherlands**

PROJECTS SpM – part 2

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STATUS For information

ABSTRACT This contribution describes some topics of the Spectral management approach in the Netherlands.

1. Current status of MDF-access

In order to make unbundling happen, specialists from competitive operators within the Netherlands, are working together in the Dutch forum “FIST”. One of the goals of this cooperation is to enable optimal broadband usage of the available copper resources in the Netherlands.
For optimal broadband usage “access rules” have been set that are mandatory for all operators that share the same access network. By limiting the signal level that is allowed for injection into an access network, the total spectral pollution is bounded. This enables each involved operator to design its own deployment rules/guidelines.

The access rules for the *MDF access service*[1] in the Netherlands are based on the signal descriptions provided by the ETSI Spectral Management report, part 1. These descriptions are copied into the *technical manual*. Currently the following *XTL Transmission Line Services* have been identified:

PTL-service:	for signals compliant to the “POTS” signal category
ITL-service:	for signals compliant to the “ISDN.2B1Q” signal category
HTL-service:	for signals compliant to the “HDSL.CAP/2” signal category
ATL.P-service:	for signals compliant to the “ADSL over POTS” signal category
ATL.I-service:	for signals compliant to the “ADSL over ISDN” signal category
STL-service:	for signals compliant to the “SDSL::Fn” signal category (symmetrical)

2. Effort in improving the current access rules

These current access rules work for the time being, since the spectral pollution is bounded. However, it is believed that this kind of bounding provides only moderate utilization of the available copper resources. A more sophisticated (tighter) bounding will probably enable an improved commercial utilization of the copper for all involved operators.

Take for instance the following example. Due to the large number of wire pairs that are packed into commonly used Dutch cables (900”) the economic value of the access network may be extended by (1) restricting the number of the more polluting xTL services, or (2) by restricting the number of wire pairs that made available for broadband “xTL” access.
It will be clear that such a decision will be a commercial trade-off between (a) selling basic services to more customers (at the cost of reduced maximum bitrate) and (b) selling improved services with higher bitrates (at the cost of reduced coverage). In case the market demand within some “X” years is close to 100% then option “a” is favourable. When in practice, however, less then e.g. 30% of the potential customers are demanding for broadband services it would be a waist not to take advantage of option “b”, even at the disadvantage of tighter “access rules”.

To enable such a commercially biased discussion and decision among the involved operators in the Netherlands, it is desired/required to quantify how much advantage can be achieved by adopting more

[1] For more details, see www.kpn-telecom.nl\carrierservices, and select “standard documents”

tighter access rules. For this reasons an approach is being developed that enable all involved parties to check (and agree) on the calculation method, so that all discussions within the Netherlands can fully focus on the commercial impact of that.

The approach of bringing all assumptions together, is referred to as “the Dutch reference scenario”. The only purpose of it is to see (quantify) how much will change (compared to this initial “reference”) when people “play” with various spectral management parameters. For instance changing the technology mix, to see if it makes sense to limit one technology in favor of others.

The definition and description of this so called “Dutch reference scenario” is still under construction. The purpose of this ETSI-TM6 contribution is to show in what direction we are looking at, and to inspire others to follow a similar approach in other countries.

The text below has been extracted from the originating Dutch document “reference scenario for the Netherlands”, to enable spectral management calculations

3 Purpose and terminology

To enable a consistent interpretation of results while studying the impact of changing various Spectral Management Parameters, such as restrictions on technology mix and wire pair limitations. Due to the fact that a broad range of different xDSL systems are to be studied, the most consistent observation will be the *relative* change in performance[2] for a particular xDSL technology of interest. This is the difference in performance for the scenario under study and for a chosen *reference scenario*.

This document defines the *reference scenario* that has been chosen for Spectral Management studies in the Dutch access network. It defines various network characteristics in two distinct groups:

- The *reference configuration* that can be controlled by spectral management. Examples are the range of technologies that are allowed for deployment and the maximum number of wire pairs that is allowed for transporting signals from xDSL systems.
- The *reference conditions* that covers intrinsic network characteristics that cannot be controlled by spectral management. Examples are cable characteristics (insertion loss, crosstalk coupling), and modem characteristics (like transmit spectra or receiver immunity for noise).

4 Reference configuration

This section describes the technology mix, that has been selected by specialists of competitive operators within the Netherlands, that work together to make unbundling happen in practise.
This choice is market driven, and provides a first average estimate on what deployment may happen on the Dutch copper access network within several years.

4.1 The reference technology mixture

number of wire pairs	**Broadband Technologies** *(occupying 250 wire pairs, or 28% cable fill)*
38	"ADSL over POTS" (full spectrum)
37	"ADSL.FDD over POTS" (reduced spectrum)
13	"ADSL over ISDN" (full spectrum)
12	"ADSL.FDD over ISDN" (reduced spectrum)
2×25	"HDSL.CAP/2" (1Mb/s per wire pair, causing a 2 Mb/s system over 2 pairs)
75	"SDSL.1024" (1024 kb/s, symmetrical spectrum; Fn=344 kHz)
25	"SDSL.2304" (2304 kb/s, symmetrical spectrum; Fn=771 kHz)
number of wire pairs	**Legacy systems**
150	"ISDN.2B1Q"

250 wire pairs in total for xDSL systems: 100 for ADSL, 100 for SDSL, 50 for HDSL

[2] The word "performance" is a generic term that may refer to numbers like maximum reach, maximum bitrate or maximum customer penetration.

The symbolic names in this table are kept the same as the associated names used for the signal descriptions in the ETSI Spectral Management Report [3]. Mark that the above HDSL system transports 1 Mb/s per wire pair, so that 50 wire pairs can cover 25 2-pair HDSL systems.

5 Reference conditions

5.1 The reference cable topology

The reference topology is based on a single 900" cable, that is represented by various cable characteristic. All LT systems in the technology mixture are intended for downstream transmission and are co-located at the LT side of this reference topology. All NT systems in the technology mixture are intended for upstream transmission and are co-located at the NT side of this reference topology.
The methods for calculating the cumulated noise level in the wire pair under study follows the FSAN methods that are commonly used within ETSI [1], ANSI and ITU. Unless specified otherwise, all power levels are specified in dBm when signals are terminated into 135Ω.

All LT-disturbers of the technology mix can be virtually replaced by a single *equivalent* LT-disturber, as if all LT-disturbers that couple into the wire pair under study is originated by that equivalent disturber. The same applies for all NT-disturbers, as illustrated in figure 1.
The cumulated noise spectrum of each equivalent disturber can be evaluated by summing all powers from the individual disturbers using a reference crosstalk cumulation model.
Due to the nature of crosstalk coupling, the cumulated noise that can be observed at the ends of the wire pair under study varies with the length of the cable.

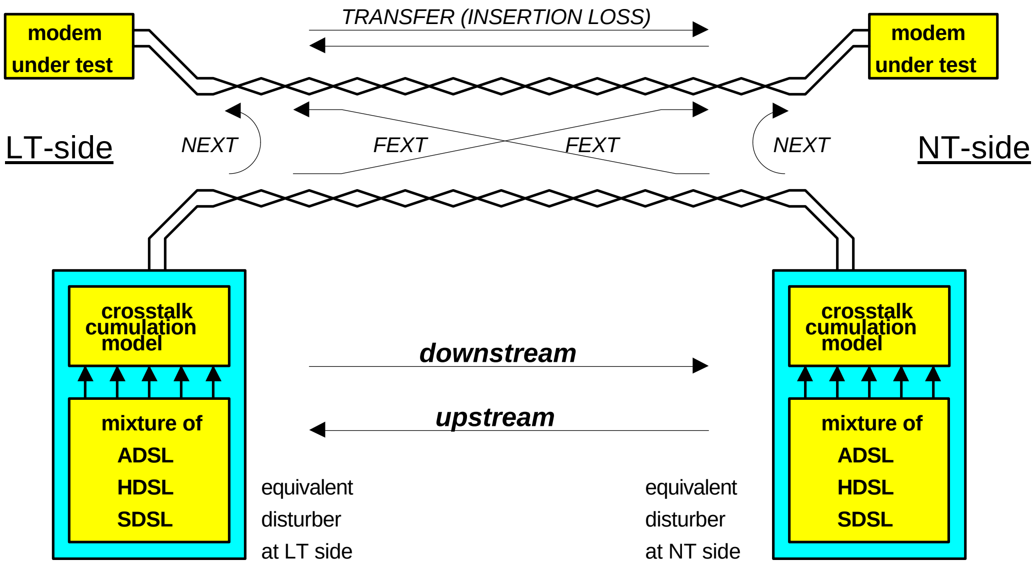

Figure 1: The reference topology

5.2 The reference model for insertion loss in wire pairs

The KPN cable model "KPN_L1", as specified in [2], is used to compute insertion loss (and return loss) as a function of the frequency and cable length. This equals cable model "TP150" as specified in the ETSI document for testing [1] (and also in the ETSI-VDSL standard)
This cable is constructed of multiple quads (4 wires or 2 wire pairs), 0.5 mm solid copper conductors with paper insulation. The cables are constructed in concentric layers, and each layer consists of a number of twisted quads. A shield of lead (connected to earth) provides mechanical protection for the bundle of quads. This cable is predominantly used for underground distribution in the Netherlands, and can be organized as cables of the type 900" (450 quads), 300" (150 quads), 100" (50 quads) or lower.

5.3 The reference model for crosstalk between wires

5.3.1. coupling between wire pairs

The crosstalk coupling functions are identical to the formulas of the cable cross-talk models used by ETSI in [1] , with an exception for the parameters K_{xn} (for NEXT) and K_{xf} (for FEXT). These generic formula's account for the frequency and length dependency of the crosstalk coupling.
To enable a closer match to Dutch cables, the reference cable model used the following parameter values:

NEXT:	K_{xn} = –49.5 dB @ 1 MHz
EL-FEXT:	K_{xf} = –37.4 dB @ 1 MHz, 1 km

It is currently assumed that the generic ETSI formulas predict the "99%" noise level in Dutch cables when the above parameter values are used. This means that in only 1% of the cases the crosstalk level is higher (worse) than predicted by this formula.
This 99% approach is commonly used and the preferred approach within FSAN, ETSI, ANSI, and ITU.

5.3.2 crosstalk cumulation

The cumulated crosstalk power of 250 identical xDSL disturbers is lower then 250 times the power of the individual disturbers. This is caused by the fact that the amount of crosstalk coupling to *individual* wire pairs is very random in nature, and from 250 systems only one system can occupy the worst-case wire pair, and only one another system can occupy the next to worst case wire pair.
To account for this effect the FSAN crosstalk sum [1] shall be used. When $P_{x,i}$ is the spectral power of each individual disturber, the cumulated spectral power P_x is defined as follows:

$$P_x = \left(S_i\, P_{x,i}^{\;Kn}\right)^{1/Kn}; \qquad \text{where } K_n=0.6$$

The by this way cumulated spectral power of all LT-disturbers represents the spectrum of the *equivalent* LT-disturber as described in figure 1. The same applies for the NT-side.

5.3.3 crosstalk level at victim modem

To overall crosstalk level is to be evaluated in the following steps:

- Evaluate the spectral power of the two equivalent disturbers (at NT and LT side), being the “crosstalk cumulation” of all colocated modems. Ignore all impedances in this calculation
- Evaluate the spectral power of the overall crosstalk (at NT and LT side), by adding the spectral power of the near-end (collocated) equivalent disturber multiplied by the NEXT coupling, to the spectral power of the far-end equivalent disturber multiplied by the FEXT coupling. Ignore all impedances in this calculation
- Calculate the spectral voltage of the overall crosstalk as the crosstalk voltage that results when the evaluated crosstalk power is dissipated by the input impedance of the victim modem (100Ω for ADSL, 135Ω for SDSL, etc)

5.4 The reference transmitter model for each individual xDSL technology

The cumulated crosstalk noise that is coupled into the wire pair under study is random in nature and commonly gaussian distributed. To evaluate this level, the output signal of each individual disturber is therefore modeled by means of gaussian distributed random noise Their spectral levels are lower than the spectral limits defined by the ETSI Spectral Management report [3], since these limits are based on worst case levels, while *nominal* values are more likely for an adequate transmitter model.

The reference modem transmitter models follows the FSAN assumptions [1] on these nominal PSD values, and defines dedicated assumptions when FSAN assumptions are lacking or inadequate. The individual systems in this technology mix are described by simplified PSD masks, in tabular or formula format.

5.4.1 Reference termination Impedance for output level.

The output level of the each transmitter depends on the value of its load impedance, which is dominated by cable impedance. This impedance is cable and frequency dependent.
To simplify matters, and to harmonize test equipment and test methods, it is preferred to *approximate* all cable impedances to be identical and to be frequency independent. A value of 145-150 Ω would favor many Dutch cables, but a value of 135 Ω is commonly taken within ETSI as an average of European cables.
So, for evaluating the output level of a (100Ω) ADSL system in the reference scenario, its output shall be terminated with the reference impedance of 135 Ω, while its power is specified (below) when it is terminated into 100Ω. This complicates the computation for ADSL, but simplifies it for SDSL and HDSL that are both 135Ω systems.

5.4.2 Nominal transmit spectrum for "ADSL over POTS"

The PSD of the "ADSL over POTS" spectrum is defined in terms of break frequencies, as summarized below. The associated PSD masks are constructed with straight lines between these break frequencies, when plotted against a *logarithmic* frequency scale and a *linear* dBm scale.
This definition is identical to what is assumed by FSAN, as summarized in the ETSI report on testing [1].

ADSL over POTS full version	***Up 100 W***
[Hz]	**[dBm/Hz]**
1	-97.5
3.99k	-97.5
4k	-92.5
25.875k	-37.5
138k	-37.5
307k	-90
1.221M	-90
1.630M	-110
30M	-110

ADSL over POTS full version	***Down 100 W***
[Hz]	**[dBm/Hz]**
1	-97.5
3.99k	-97.5
4k	-92.5
25.875k	-39.5
1.104M	-39.5
3.093M	-90
4.545M	-110
30M	-110

5.4.3 Nominal transmit spectrum for "ADSL.FDD over POTS"

The PSD of the "ADSL.FDD over POTS" spectrum is defined in terms of break frequencies, as summarized below. The associated PSD masks are constructed with straight lines between these break frequencies, when plotted against a *logarithmic* frequency scale and a *linear* dBm scale.
An internationally agreed assumption on the FDD variant of ADSL is lacking, and this variant is currently not covered by ETSI standards.
This definition is therefor in line with the rationales behind the FSAN assumptions, as summarized in the ETSI report on testing [1], but modified on the basis of an educated guess. Until ETSI or FSAN has solved this issue in future, the numbers below are used as reference.

ADSL over POTS FDD version	***Up 100 W***
[Hz]	**[dBm/Hz]**
1	-97.5
3.99k	-97.5
4k	-92.5
25.875k	-37.5
138k	-37.5
307k	-90
1.221M	-90
1.630M	-110
30M	-110

ADSL over POTS FDD version	***Down 100 W***
[Hz]	**[dBm/Hz]**
1	-97.5
3.99 k	-97.5
4 k	-92.5
80 k	-72.5
138.0 k	-44.2
138.1 k	-39.5
1.104 M	-39.5
3.093 M	-90
4.545 M	-110
30 M	-110

5.4.4 Nominal transmit spectrum for "ADSL over ISDN"

The PSD of the "ADSL over ISDN" spectrum is defined in terms of break frequencies, as summarized below. The associated PSD masks are constructed with straight lines between these break frequencies, when plotted against a *logarithmic* frequency scale and a *linear* dBm scale.
This definition is identical to what is assumed by FSAN, as summarized in the ETSI report on testing [1].

ADSL over ISDN full version	***Up 100 W***
[Hz]	**[dBm/Hz]**
1	-90
50k	-90
80k	-81.9
138k	-37.5
276k	-37.5
614k	-90
1.221M	-90
1.630M	-110
30M	-110

ADSL over ISDN full version	***Down 100 W***
[Hz]	**[dBm/Hz]**
1	-90
50k	-90
80k	-81.9
138k	-39.5
1.104M	-39.5
3.093M	-90
4.545M	-110
30M	-110

5.4.5 Nominal transmit spectrum for "ADSL.FDD over ISDN"

The PSD of the "ADSL.FDD over ISDN" spectrum is defined in terms of break frequencies, as summarized below. The associated PSD masks are constructed with straight lines between these break frequencies, when plotted against a *logarithmic* frequency scale and a *linear* dBm scale.
An internationally agreed assumption on the FDD variant of ADSL is lacking, and this variant is currently not covered by ETSI standards.
This definition is therefor in line with the rationales behind the FSAN assumptions, as summarized in the ETSI report on testing [1], but modified on the basis of an educated guess. Until ETSI or FSAN has solved this issue in future, the numbers below are used as reference.

ADSL over ISDN FDD version	***Up 100 W***
[Hz]	**[dBm/Hz]**
1	-90
50k	-90
80k	-81.9
138k	-37.5
276k	-37.5
614k	-90
1.221M	-90
1.630M	-110
30M	-110

ADSL over ISDN FDD version	***Down 100 W***
[Hz]	**[dBm/Hz]**
1	-90
50k	-90
80k	-81.9
91.3k	-68
138k	-68
207k	-65
241k	-62
276k	-39.5
1.104M	-39.5
3.093M	-90
4.545M	-110
30M	-110

5.4.6 Nominal transmit spectrum for "HDSL.CAP/2"

The PSD of the "HDSL.CAP/2" spectrum is defined in terms of break frequencies, as summarized below. The associated PSD masks are constructed with straight lines between these break frequencies, when plotted against a *logarithmic* frequency scale and a *linear* dBm scale.
This definition is identical to the FSAN assumptions, as summarized in the ETSI report on testing [1].

HDSL.CAP/2	***2 pair*** ***135*** *W*
[Hz]	**[dBm/Hz]**
1	-57
3.98k	-57
21.5k	-43
39.02k	-40
237.58k	-40
255.10k	-43
272.62k	-60
297.00k	-90
1.188M	-120
30M	-120

5.4.7 Nominal transmit spectrum for "SDSL"

The PSD of the "SDSL" spectrum is defined in three distinct frequency bands, as described below. The break frequency f_{int} is the frequency where the curves for $P_1(f)$ and $P_2(f)$ intersect. This definition is identical to the *nominal* PSD value, as specified in the ETSI- SDSL standards [5].

$f<f_{int}$	$P_1(f) = \frac{K_{SDSL}}{R_s} \times \frac{2 \cdot f_0}{f_{sym}} \times \mathrm{sinc}^2(f/f_{sym}) \times \frac{1}{1+(f/f_H)^{2 \cdot N}} \times \frac{1}{1+(f_L/f)^2}$	[W/Hz]
$f_{int} \le f \le 1.5$ MHz	$P_2(f) = K_X \times (f/f_0)^{1.5}$	[W/Hz]
f> 1.5 MHz	$P_3(f) = -110$	[dBm/Hz]
	$R_s=135\ \Omega$; $\mathrm{sinc}(x) = \sin(\pi \cdot x) / (\pi \cdot x)$	

Data Rate R	**SymbolRate f_{sym}**	**K_{SDSL}**	**K_X**	**N**	**f_H**	**f_L**	**f_0**
R < 2.024 Mb/s	(R+ 8 kbit/s)/3	7.86 V^2	$0.5683 \cdot 10^{-4}$ W	6	$f_{sym}/2$	5 kHz	1 Hz
R ≥ 2.024 Mb/s	(R+ 8 kbit/s)/3	9.90 V^2	$0.5683 \cdot 10^{-4}$ W	6	$f_{sym}/2$	5 kHz	1 Hz

5.5 The reference receiver model for each individual xDSL technology

The receiver model shall predict what bitrate is achievable or what noise margin is left when the modem receives a noisy data signal that is attenuated by the cable insertion loss and impaired by crosstalk noise that couples into the wire pair. These formula's are different for different xDSL technologies (line codes) and xDSL implementations. Some generic formulas are given in the (draft) ANSI Spectral Management document [4], while the associated parameter values are to be found by fitting the parameters of the generic formula on the observed (measured) performance curves.
For the purpose of a reference scenario, these receiver models are not specified in terms of mathematical formulas but it terms of *reference* performance curves that are verifiable by laboratory experiments. Many of these curves are specified as "performance objectives" in ETSI xDSL standards, under well defined and realistic test scenarios (noise level, cable loss, etc). These curves may have the appearance shown in figure 2.

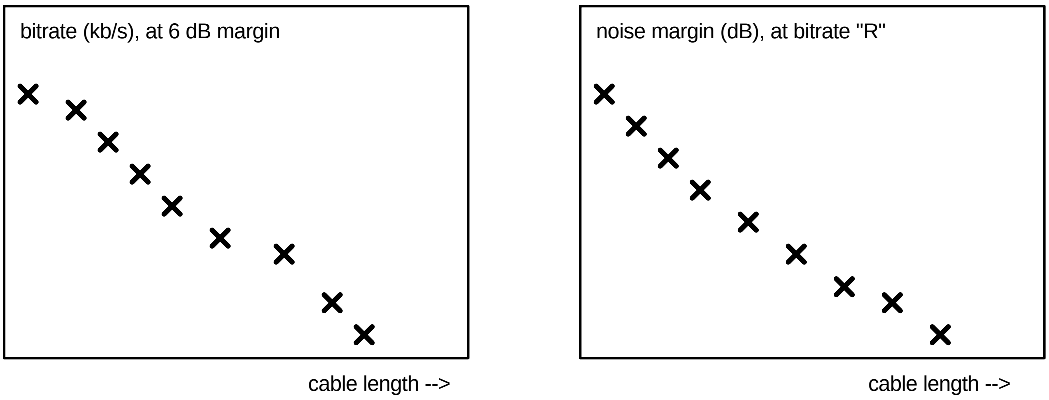

Figure 2: Generic appearance of performance objectives

A dedicated mathematical receiver model, similar or better than those given in the ANSI document [4], which can predict the reference performance objectives for a particular xDSL technology, is considered to be valid for the reference scenario.

- Performance objectives of ETSI standards are mandatory, provided that the test scenarios are considered as realistic. This holds for the ETSI SDSL and VDSL standards, and for the draft ADSL report that is currently under preparation within ETSI-TM6. See ETSI document [1] on testing.
- If adequate performance objectives are lacking in standards, measured performance curves (or specified performance curves from vendors) can be considered for inclusion in this document, provided that the test scenario is *realistic* (like one of the scenario's from the ETSI document [1] on testing, or the reference scenario of this document)

5.5.1 Reference performance objectives for "ADSL over POTS"

Test scenario:	The ADSL over POTS test scenario, specified in the ETSI ADSL standard [7]
performance objectives	<**for further study**> This issue hasn't been solved yet within ETSI-TM6
performance conditions	available DMT tones: Up=[7:15,17:31]; Down=[7:63,65:255];

5.5.2 Reference performance objectives for "ADSL.FDD over POTS"

Test scenario:	The ADSL.FDD over POTS test scenario, specified in the ETSI ETSI ADSL standard [7]
performance objectives	<**for further study**> This issue hasn't been solved yet within ETSI-TM6
performance conditions	available DMT tones: Up=[8:15,17:29]; Down=[45:63,65:255] alternative: Up=[8:15,17:28]; Down=[40:63,65:255] <**for further study**> This issue hasn't been solved yet within ETSI-TM6

5.5.3 Reference performance objectives for "ADSL over ISDN"

Test scenario:	The ADSL over ISDN test scenario, specified in the ETSI ADSL standard [7]
performance objectives	<**for further study**> This issue hasn't been solved yet within ETSI-TM6
performance conditions	available DMT tones: Up=[21:63]; Down=[32:95,97:255]; <**for further study**>

5.5.4 Reference performance objectives for "ADSL.FDD over ISDN"

Test scenario:	The ADSL.FDD over ISDN test scenario, specified in the ETSI ADSL standard [7]
performance objectives	<**for further study**> This issue hasn't been solved yet within ETSI-TM6
performance conditions	available DMT tones: Up=[29:48]; Down=[63:95,97:255]; <**for further study**> This issue hasn't been solved yet within ETSI-TM6

5.5.5 Reference performance objectives for "HDSL.CAP/2"

Test scenario:	The SDSL test scenario, specified in the ETSI document on testing [1] and the ETSI SDSL standard [5] The original HDSL test scenario, specified in the ETSI HDSL document [6] is considered as unrealistic because the noise levels are too low. Extrapolation from these old performance objectives into a realistic test scenario will probably be too inaccurate.
performance objectives	<**for further study**>

5.5.6 Reference performance objectives for "SDSL"

Test scenario:	The SDSL test scenario, specified in the ETSI document on testing [1] and the ETSI SDSL standard [5]
performance objectives	The SDSL performance objectives, specified in the ETSI document on testing [1] and the update of the ETSI SDSL standard [5]

6 Bibliography

TESTING & CABLES

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[2] 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.

SPECTRAL MANAGEMENT

[3] ETSI TR 101 830-1 (V.1.2.1) "Transmission and Multiplexing (TM); Spectral management on metallic access networks; Part 1: Definitions and signal library; aug 2001

[4] ANSI T1E1.4/2000-002R6 "Spectrum Management for loop transmission systems" draft; revision 6, November 2000. (or a more recent version)

SDSL

[5] ETSI TS 101 524 (V1.1.2): "Transmission and Multiplexing (TM); Access transmission system on metallic access cables; Symmetrical single pair high bit rate Digital Subscriber Line (SDSL); aug 2001.

HDSL

[6] ETSI TS 101 135 (V1.5.3): "Transmission and Multiplexing (TM); High bit-rate Digital Subscriber Line (HDSL) transmission systems on metallic local lines; HDSL core specification and applications for combined ISDN-BA and 2 048 kbit/s transmission".

ADSL

[7] ETSI- TS 101 388 (1.2.1): " Transmission and Multiplexing (TM); Access transmission systems on metallic access cables; Asymmetric Digital Subscriber Line (ADSL) - European specific requirements [ITU-T G.992.1 modified]", oct 2001