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Technical Report

Transmission and Multiplexing (TM);
Spectral management on metallic access networks;
Part 2: Technical methods for performance evaluations

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Contents

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Transmission and Multiplexing (TM).

The present document is part 2 of a multi-part deliverable covering Transmission and Multiplexing (TM); Acces networks; Spectral management on metallic access networks, as identified below:

Part 1: "Definitions and signal library".

Part 2: "Technical methods for performance evaluations”.

NOTE: Further parts are under preparation.

1 Scope

The present document gives guidance on a common methodology for studying the impact on xDSL performance (maximum reach, noise margin, maximum bitrate) in noisy cables when changing parameters within various Spectral Management scenarios. These methods enable reproducible results and a consistent presentation of the assumed conditions (characteristics of cables and xDSL equipment) and configuration (choosen technology mixture and cable fill) of each scenario.

The technical methods include computer models for calculating:

- xDSL receiver capability of detecting signals under nois y conditions;
- xDSL transmitter characteristics;
- cable characteristics
- crosstalk cumulation in cables, originating from a mix of xDSL disturbers;

The *objective* is to provide the technical means for evaluating the performance of xDSL equipment within a chosen scenario, such as calculations and measurements. This includes the description of *performance properties* of equipment. Another objective is to assist the reader with applying this methodology by providing examples on how to specify the *configuration* and the *conditions* of a scenario in an unambiguous way. The distinction is that a configuration of a scenario can be controlled by access rules while the conditions of a scenario cannot.

Possible applications of this document include:

- Studying access rules, for the purpose of bounding the crosstalk in unbundled networks.
- Studying deployment rules, for the various systems present in the access network.
- Studying the impact of crosstalk on various technologies within different scenarios

The scope of this Spectral Management document is explicitly restricted to the methodology for defining scenarios and quantifying the performance of equipment within such a scenario. All judgement on what access rules are required, what performance is acceptable, or what combinations are spectral compatible, is explicitly beyond the scope of this document. The same applies for how realistic the example scenarios are.

2 References

For the purposes of this Technical Report (TR) the following references apply:

SpM

[1] ETSI TR 101 830-1 " Transmission and Multiplexing (TM); Spectral Management on metallic access networks; Part 1: Definitions and signal library" V1.2.1 (2001-08), august 2001.

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

ISDN

[3] ETSI TS 102 080 (V1.3.2): "Transmission and Multiplexing (TM); Integrated Services Digital Network (ISDN) basic rate access; Digital transmission system on metallic local lines".

HDSL

[4] 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".

SDSL

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

[6] ITU-T Recommendation G.991.2: "Single-Pair High-Speed Digital Subscriber Line (SHDSL) transceivers".

ADSL

[7] ETSI TS 101 388 (V1.1.1): "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 [ANSI T1.413 - 1998, modified]".

[8] ANSI T1.413 (1998): "Network to Customer Installation Interfaces - Asymmetric Digital Subscriber Line (ADSL) Metallic Interface".

[9] ITU-T Recommendation G.992.1 (1999): "Asymmetric digital subscriber line (ADSL) transceivers".

VDSL

[10] ETSI TS 101 270-1 (V1.2.1): "Transmission and Multiplexing (TM); Access transmission systems on metallic access cables; Very high speed Digital Subscriber Line (VDSL); Part 1: Functional requirements".

[11] ANSI T1E1.4/2000-009R3 (February 2001): "Very high bit-rate Digital Subscriber Lines (VDSL) Metallic Interface; Part 1: Functional Requirements and Common Specification".

[12] ANSI T1E1.4/2000-011R3 (February 2001): "Very high bit-rate Digital Subscriber Lines (VDSL) Metallic Interface; Part 2: Technical Specification for a Single-Carrier Modulation (SCM) Transceiver".

[13] ANSI T1E1.4/2000-013R4 (November 2000): "Very high bit-rate Digital Subscriber Lines (VDSL) Metallic Interface; Part 3: Technical Specification of a Multi-Carrier Modulation Transceiver".

3 Definitions and abbreviations

3.1 Definitions

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

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

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

Noise margin: the ratio by which the received noise may increase until the recovered signal does not meet the predefined quality criteria. This ratio is commonly expressed in dB.

Signal margin: the ratio by which the received signal may decrease until the recovered signal does not meet the predefined quality criteria. This ratio is commonly expressed in dB.

Max datarate: the maximum data rate that can be recovered according to predefined quality criteria, when the received noise is increased with a choosen noise margin (or the received signal is decreased with a choosen signal margin).

PSD: A signal characteristic in the frequency domain, equal to the Fourier transform of the autocorrelation of that signal. Due to the mathematical nature of this definition, a direct measurement of this quantity (according to the definition) is often impractical. PSD values can be estimated, however, from narrow band signal power measurements within a known resolution bandwidth (Wiener Khintchine theorem). These spectral measurements are only *approximations* of the PSD, unless the PSD is frequency independent within that resolution bandwidth. The definition of a PSD is independent of any resolution bandwidth, while spectral measurements require a specification of the resolution band being used.

Peak mask of a PSD: This is the absolute upper bound of a PSD, measured within a specified but relatively *narrow* resolution bandwidths; for instance 10 kHz for signals up to 1 MHz. The purpose of peak masks is often to specify spectrum management compliance, since it enables bounding of "worst case" values of a (single sided) PSD.

Nominal mask of a PSD: This is the absolute upper bound of a PSD, measured within a specified but relatively *wide* resolution bandwidth; for instance 100 kHz for signals up to 1 MHz. The purpose of peak masks is often to specify spectrum management compliance, since it enables bounding of "average" values of a (single sided) PSD. On the edges of PSDs, however, the nominal mask tend to be more capacious, due to the wider nature of the resolution band, and the meaning of their values becomes often limited within these frequency bands.

Template of a PSD: These levels represent nominal signal characteristics in the frequency domain, not related to any resolution bandwidth. It is intended to be a fair replica of a (single sided) PSD for modeling crosstalk and calculating noise margin. Template levels are often close to the levels of a nominal mask in frequency bands with flat PSD, but may deviate significantly from that nominal mask near the edges of PSDs.

Loop provider: company facilitating access to the local loop wiring. (In several cases the loop provider is historically connected to the incumbent network operator, but other companies may serve as loop provider as well)

Network operator: company that makes use of a local loop wiring for transporting telecommunication services. This definition covers *incumbent* as well as *competitive* network operators.

(Spectral) Access Rule: Mandatory rule for achieving access to the local loop wiring, equal for all *network operators* that make use of the same network cable, that bounds the crosstalk in that network cable.

(Spectral) Deployment Rule: Voluntary rule, irrelevant for achieving access to the local loop wiring and proprietary for individual *network operators*. Deployment rules reflect the private view of the network operator about what maximum length or maximum bitrate he prefers for offering his transmission service to ensure a chosen minimum quality of service.

(Spectral) Purity Rule: Voluntary rule, irrelevant for achieving access to the local loop wiring and proprietary for individual *loop providers*. Purity rules reflect the private view of the loop provider about additional prepatory activities for facilitating access to the local loop wiring (such as wire pair selection or manipulation) in order to keep the crosstalk in the cable as low as possible.

3.2 Abbreviations

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

ADSL	Asymmetrical Digital Subscriber Line
BER	Bit Error Ratio
CAP	Carrier Amplitude/Phase modulation
DMT	Discrete Multitone modulation
FDD	Frequency Division Duplexing
HDSL	High bitrate Digital Subscriber Line
ISDN	Integrated Services Digital Network
LT-port	Line Termination port
NT-port	Network Termination port
PAM	Pulse Amplitude modulation
PSD	Power Spectral Density (single sided)
QAM	Quadrature Amplitude modulation

SDSL	Symmetrical (single pair high bitrate) Digital Subscriber Line
VDSL	Very high bit rate Digital Subscriber Line
xDSL	(all systems) Digital Subscriber Line
2B1Q	Special variant of a 4-level PAM linecode

4 Transmitter models for xDSL

A transmitter model in this clause is mainly a PSD description of the transmitted signal under matched conditions, plus an output impedance description to cover mis-matched conditions as well.

PSD masks of transmitted xDSL signals are specified in several documents for various purposes, for instance in Part 1 of Spectral Management [*]. These PSD masks, however, cannot be applied directly to the description of a transmitter model. This is caused by the fact that the definition of the real PSD of a time limited signal requires no resolution bandwidth at all (it is defined by means of an autocorrelation, followed by a Fourier transform) while PSD *masks* do rely on some resolution bandwidth. They describe values that are (a slightly) different from the real PSD, and for modeling purposes this difference is sometimes very relevant.

To illustrate the difference between several PSD descriptions, *masks* and *templates* of a PSD are given a different meaning. The distinction between *peak* and *nominal* masks gives further details about masks in general.

The transmitter models in this clause are not based on (nominal) masks but on templates of PSDs. In many simulations this difference is irrelevant, but in case of equipment using FDD without echo-cancelation (non-overlapping spectra for signals in opposite directions, as used for some ADSL variant and for VDSL) this distinction becomes quite relevant. In the guardband between up and downstream spectra, nominal masks can have a signific remaining overlap while the real PSDs have hardly any overlap. As a result, using nominal masks for modeling transmitted PSDs would deteriorate the performance modeling of FDD systems significantly.

This clause summarizes various xDSL transmitter models, mainly by defining template spectra of output signals.

4.1 Generic transmitter model

A generic model of an xDSL transmitter is essentially a linear signal source. The Thevenin equivalent of such a source equals an ideal voltage source U_s having a real resistor R_s in series. The output voltage of this source is random in nature (as a function of the time), is uncorrelated with any other transmitter signal, and occupies a relatively broad spectrum.

This generic model can be made specific by defining:

- The output impedance R_s of the transmitter
- The template of the PSD, measured at the output port, when terminated with an external impedance equal to R_s. This is identified as the "matched condition", and under these conditions the output power equals the maximum power that is available from this source. Under all other (mis-matched) termination conditions the output power will be lower.

4.2 Cluster 2 transmitter models

4.2.1 transmitter model for "ISDN.2B1Q"

4.2.2 transmitter model for "ISDN.MMS.43"

4.2.3 transmitter model for "Proprietary.SymDSL.CAP.QAM"

4.3 Cluster 3 transmitter models

4.3.1 Transmitter model for "HDSL.2B1Q"

4.3.2 Transmitter model for "HDSL.CAP"

4.3.3 Transmitter model for "SDSL"

4.3.4 Transmitter model for "Proprietary.SymDSL.CAP.A::Fn"

4.3.5 Transmitter model for "Proprietary.SymDSL.CAP.B::Fn"

4.3.6 Transmitter model for "Proprietary.SymDSL.CAP.C::Fn"

4.3.7 Transmitter model for "Proprietary.SymDSL.PAM::Fn"

4.3.8 Transmitter model for "Proprietary.SymDSL.2B1Q::Fn"

4.3.9 Transmitter model for "Proprietary.PCM.HDB3.2M.SR"

4.3.10 Transmitter model for "Proprietary.PCM.HDB3.2M.SQ"

4.4 Cluster 4 transmitter models

4.4.1 Transmitter model for "ADSL over POTS"

4.4.2 Transmitter model for "ADSL over ISDN"

4.4.3 Transmitter model for "ADSL.FDD over POTS"

4.4.4 Transmitter model for "ADSL.FDD over ISDN"

4.5 Cluster 5 transmitter models

4.5.1 Transmitter model for "VDSL"

5 Generic performance models for xDSL

A performance model is capable of predicting up to what performance a data stream can be recovered from a noisy signal. In all cases it assumes that this recovery meets predefined quality criteria such as a maximum BER (Bit Error Ratio). Values like BER<10^{-7}, during a time interval of several minutes, are not uncommon.

The word performance refers within this context to a variety of quantities, including noise margin, signal margin and max datarate. When the internal receiver noise is zero and the echo cancellation is infinite, quantities like noise margin and signal margin become equal.

Performance models are implementation and linecode specific. Performance modeling becomes more convenient when broken down into smaller submodels, such as a linecode independent *input* (sub)model that is cascaded by a linecode dependent *detection* (sub)model. This clause describes a basic input model, as well as a variety of detection models.

Generic models are defined with various parameters, to express various receiver properties. They include parameters to express the amount of echo suppression, receiver noise level, and SNR gap. This clause is dedicated to *generic* performance models only. The succeeding clause is dedicated to *specific* models by assigning values to all parameters of a generic model.

5.1 Basic model for the input block (effective SNR)

This clause summarizes a linear *sub*model for xDSL receivers, that enables the description of their linecode independent behavior. It enables the evaluation of the effective SNR, from various input quantities, as interim result. When combined with a (linecode dependent) detection model a complete performance model can be formed (see succeeding subclauses).
When modeling non-linear behavior is relevant, such as for gain controlled analog frontends, more advanced modeling is required.

> ED NOTE: This clause provides a model for evaluating the Signal to Noise Ratio (SNR) from received signal, noise and echo levels. This SNR is intermediate result, commonly used in many detection models such as for PAM, CAP/QAM or DMT

<for further study>

5.2 Generic Shannon detection model

<for further study>

5.3 Generic PAM detection model

<for further study> (model similar to the model described in the ANSI SpM report)

5.4 Generic CAP/QAM detection model

<for further study> (model similar to the model described in the ANSI SpM report)

5.5 Generic DMT detection model

<for further study> (model similar to the model described in the ANSI SpM report)

6 Specific performance models for xDSL

This clause defines parameter values for the generic performance models of the previous clause, to provide specific models for various xDSL modems.

> ED NOTE This will be the main portion of the document. The validity of each model that get the predicate “ETSI compliant” must be demonstrated by showing how close it can predict the ETSI performance requirements specified in the associated ETSI xDSL standard.
> For instance SDSL: Gap=6.6 dB, Echo=-50dB, Noise=-110 dBm, BitDensity=3 bits/symbol, Overhead= …, etc.

6.1 Performance model for "HDSL.2B1Q"

6.2 Performance model for "HDSL.CAP"

6.3 Performance model for "SDSL"

6.4 Performance model for "ADSL over POTS"

6.5 Performance model for "ADSL.FDD over POTS"

6.6 Performance model for "ADSL over ISDN"

6.7 Performance model for "ADSL.FDD over ISDN

6.8 Performance model for "VDSL"

7 Transmission and reflection models

7.1 Summary of test loop models

> ED NOTE This clause refers to various testloops for ADSL, SDSL, VDSL, as defined in published documents like standards.
> If required references to additional cable models can be added, but when possible we should try to keep this clause as short as possible. In practice, each country will favor its own cable models, and they are too numerous (and too proprietary) to mention them all here.

7.2 Echo loss model

ED NOTE This clause contains a simple model, how much transmitted signal (into the opposite direction) echoes back into the receivers when a hybrid of an xDSL transceiver is brought out of balance by impedance mismatch. This can be a simple Wheatstone bridge approach, that is in equilibrium when the medem is terminated with its own esign impedance (e.g. 135 ohm for SDSL), and that is out of balance when terminated with the impedance of a real cable.

8 Crosstalk models

Crosstalk models account for the fact that the transmission is impaired by crosstalk originated from discrete disturbers distributed over the local loop wiring. In practice this is not restricted to a lineair cable topology, since wires may fan out into different directions to connect for instance different customers to a central office

The most simple topology models assume that all disturbers are co-located at only two locations; one at each end of a cable. These approximations may be adequate for situations above for instance 1 km in which the fan out of the wires can be ignored.

More advanced topology models require a multi-node co-location approach. An example is the insertion of repeaters, that introduces co-located disturbers in-between. Another example is deploying VDSL from the cabinet for the situation that all customers are distributed along the cable.

This clause summarizes different crosstalk models for different topologies, sorted by complexity.

8.1 Overview of network topologies

8.2 Validity limitations of modeling

8.3 Generic crosstalk models for two-node co-location

ED NOTE This clause provides the common calculation approach for deployment of SDSL, HDSL, ADSL and ISDN. For these calculations, the access network is simplified as if is a single cable with only two ends, and all disturbers are collocated at these two ends.

8.3.1 Basic diagram for two-node topologies

ED NOTE This clause provides a flow diagram of all building blocks to evaluate the noise level at the receiver of the modem undertest.

<for further study>

8.3.2 Models for crosstalk cumulation

ED NOTE Explaination on how to evaluate the equivalent disturber for each node of a two-node or multi-node topology. In principle only the FSAN cumulation model is commonly adopted, but other cumulation models are not excluded here.

<for further study>

8.3.2.1 FSAN sum for crosstalk cumulation

ED NOTE Description on the FSAN power sum, to evaluate the crosstalk cumulation for co-located disturbers. The factor Kn should be left undefined here, although ETSI uses Kn=0.6, because this is cable dependent and should be defined in the scenario

<for further study>

8.3.3 Models for crosstalk coupling

8.3.3.1 Basic models for equivalent NEXT and FEXT

ED NOTE Classic formulas for NEXT and FEXT, as described in various ETSI xDSL standards. The parameters K_{xn} and K_{xf} should left undefined here because this is cable dependent and should be defined in the scenario

<for further study>

8.3.4 Models for crosstalk injection

ED NOTE These models account for the impedance mismatch between cable and xDSL modem under test, that modifies the crosstalk levels as well.

8.3.4.1 Forced noise injection

ED NOTE This “model” represent the classical approach of ignoring mismatch completely

<for further study>

8.3.4.2 Current noise injection

ED NOTE This “model” represent the current injection (plus associated calibration) as is commonly used for ADSL that accounts for mismatch in a pragmatic way.

<for further study>

8.4 Generic crosstalk models for multi-node co-location

ED NOTE This clause provides the common calculation approach for deploying xDSL from subloop location (like HDSL repeaters and VDSL). For these calculations, the access network is simplified as if is a single cable but with multiple LT and NT-nodes distributed along the cable.

<for further study>

9 Measurement methods

ED NOTE This clause has been included here on explicit request, as a placeholder for using measurements instead of calculations. Currently, there is no detailed guidance for this approach, so this will be contribution driven.

10 Examples of defining various reference scenarios

ED NOTE This section should demonstrate how to define a full scenario in less that one page of paper, be referring as much as possible to the described reference models

These scenario's are examples only, and enable for each scenario to calculate the performance of each involved system. If, for a specific purpose, one of these scenarios is labeled as "reference" and another one as "modified" then the change in performance is a nice demonstration of what the consequences are of changing for instance the technology mix. This can be a basis in what context (= specific scenario) the word "spectral compatibility" has got a meaning.

10.1 Example scenario A

ED NOTE (this example is FSAN noise model B for ADSL)

10.1.1 Assumed configuration

Disturber assumptions

Technology mix	Number of wire pairs	Transmitters/disturbers model
ISDN.2B1Q	10	ETSI default model "ISDN.2B1Q"
HDSL.2B1Q (2-pair)	2×2	ETSI default model "HDSL.2B1Q/2"
ADSL over ISDN (E.C.)	15	ETSI default model "ADSL over ISDN"
SDSL (2.3 Mb/s; sym)	15	ETSI default model "SDSL"

Performance assumptions

Technology	Target noise margin	Performance model
ISDN.2B1Q	6 dB	ETSI default model "ISDN.2B1Q"
HDSL.2B1Q (2-pair)	6 dB	ETSI default model "HDSL.2B1Q/2"
ADSL over ISDN (E.C.)	6 dB	ETSI default model "ADSL over ISDN"
SDSL (2.3 Mb/s; sym)	6 dB	ETSI default model "SDSL"

10.1.2 Assumed conditions

property	Model name	Parameter values
Transmision models	ETSI testloop model “ADSL#2”	-
	ETSI default echo-loss model	Rv=135 (HDSL/SDSL/ISDN) Rv=100 (ADSL)
Crosstalk models	Basic two-node topology model	-
	FSAN cumulation model	K_n=0.6
	Basic NEXT & FEXT model	K_{xn}=–50 dB @ 1 MHz K_{xn}=–45 dB @ 1 MHz, 1 km
	Current injection model (real)	Z_{line}= 135 ohm Rv=135 (HDSL/SDSL/ISDN) Rv=100 (ADSL)

10.1.3 Evaluated performance for scenario A

ED NOTE:

Margin of technology “HDSL.2B1Q” as a function of cable length
Margin (or bitrate) of technology “ADSL over ISDN” as a function of cable length
Margin (or bitrate) of technology “SDSL” as a function of cable length

10.2 Example scenario B

<for further study>

10.3 Example scenario C

<for further study>

10.4 Example scenario D

<for further study>

Annex A: Bibliography

- 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 (970p02r3).

History

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