ETSI WG TM6

(ACCESS TRANSMISSION SYSTEMS ON METALLIC CABLES)

Permanent Document

TM6(01)21 – rev 4 (a4)

Living List for Spectral Management SpM - part 2 creation of TR 101 830-2

This document is the living list of current issues connected with ETSI's spectral management report TR 101 830, part 2 (*Technical methods for performance evaluations*).
This work item is focussed on the creation of "Part 2", dedicated to calculation and measurement methods for evaluating what the performance of xDSL systems will be for various scenarios.
The target is to achieve working group approval by the end of the ETSI-TM6 meeting in march 2003. This means that the first version of SpM part 2 can be published by ETSI before summer 2003. Issues that are (still) unsolved by that time, may be scheduled for a succeeding revision.
The issues related to the revision of "Part 1", or to the creation of "Part 3", are beyond the scope of this living list.

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2. STUDY POINTS PART 2 (TECHNICAL METHODS FOR PERFORMANCE EVALUATIONS)

SP	Title	Owner	Status
2-1	~~Spectral management aspects of non-stationary signals.~~	~~Reuven Franco (Tioga)~~	Deleted
2-2	Basic model of input block	Ragnar Jonsson (Conexant)	Agreed
2-3	Basic model of 2-node cross talk	Rob van den Brink (KPN)	Agreed
2-4	Generic detection models	Rob van den Brink (KPN)	Prov Agreed
2-5	Transmitter/Disturber models - ADSL	Rosaria Persico (TI-labs)	Under Study
2-6	Transmitter/Disturber models - SDSL	Rob van den Brink (KPN)	Agreed
2-7	Transmitter/Disturber models - HDSL-CAP/2	Rob van den Brink (KPN)	Agreed
2-8	Transmitter/Disturber models - HDSL-2B1Q	Rob van den Brink (KPN)	Under Study
2-9	Performance model for ETSI compliant SDSL	Marc Kimpe (Adtran)	Prov Agreed
2-10	Performance model for ETSI compliant HDSL-CAP	Rob van den Brink (KPN)	Prov Agreed
2-11	Transmitter/Disturber models - ISDN-2B1Q	Rob van den Brink (KPN)	Under Study
2-12	Implementation loss values for PAM, CAP and DMT	Marc Kimpe (Adtran)	US
2-13	Method/Model for Crosstalk Cumulative Distribution, etc.	Jack Douglass (Paradyne)	US
2-14	Method/Model for Impairment Combination for multiple disturbers	Jack Douglass (Paradyne)	US
2-15	Method/Model for Loop Cumulative Distribution + Occurance	Jack Douglass (Paradyne)	US
2-16	Method/Model for Network Model Coverage Score	Jack Douglass (Paradyne)	US
2-17			
2-18			
2-19			
2-20			
2-21			
2-22			
2-23			

The current agreed procedure for changing the status of living list items is in Annex A of TM6 working methods.

Part 2 study points

SP 2-1. Spectral management rules for non-stationary signals.
It was observed that the combined impairment from modems that are rapidly switching on and off over a period of time is much more destructive to ADSL then when these modems are continuously transmitting their signals. This is identified as "non stationary noise". The effect of non-stationary transmission in general on ADSL modems has not been fully understood. Is it a performance issue, related to the way a victim xDSL modem is implemented, or is it a spectral management issue that requires a way to bound the amount of non-stationary behaviour of signals that are injected into the Local Loop Wiring.
This study point is dedicated to the analysis of the impact of non-stationary cross talkers on legacy systems, and to find a way to model and bound the amount of non stationary noise.
Status: Deleted
Related Contributions:

- *002t24, Helsinki 2000, Impact of non-stationary cross talk on legacy ADSL modems - Orckit*
- *003t52, Vienna - Alcatel*
- *003t53, Vienna 2000, Stationarity requirements for spectral compatibility - Tioga*
- *004t25, TD26,TD35,TD53, Montreux 2000 - Alcatel*

SP 2-2. Basic model of input block.
Part 2 of SpM requires a range of calculation blocks, to enable performance evaluations. One of them is the evaluation of SNR, as interim result of an xDSL performance model (receiver). This study point explores possible improvements to the calculation blocks proposed in TD35 (021t35) of the Torino meeting, dedicated to the input block and the associated echo loss model.
Related Contributions:

- *021t35, Torino 2002 - Model of basic input block, within xDSL receivers - KPN*

SP 2-3. Basic model of 2-node cross talk.
Part 2 of SpM requires a range of calculation blocks, to enable performance evaluations. One of them is the evaluation of cross talk noise levels in a scenario, in the special case that all disturbers are virtually co-located at no more than 2 nodes. This study point explores possible improvements to the calculation block proposed in TD36 (021t36) of the Torino meeting.
Related Contributions:

- *021t36, Torino 2002 - Generic cross talk models for two-node co-location - KPN*

SP 2-4. Generic Detection models.
Part 2 of SpM requires a range of calculation blocks, to enable performance evaluations. One of them is the evaluation of the performance (in terms of noise margin or max bitrate) when a received signal is deteriorated by noise. Models for PAM and CAP/QAM and a linecode independent ("Shifted Shannon") model have been proposed. This study point explores possible improvements of the proposed models, and to study additional models dedicated to DMT.
Related Contributions:

- *022t35, Sophia 2002 - Generic detection models for performance modelling - KPN*

SP 2-5. Transmitter/Disturber models for ADSL
Part 2 of SpM requires a range of calculation blocks, to enable performance evaluations. One of them is the evaluation of the expected signal levels of the "modem under study" as well as modems acting as disturber for the "modem under study". The PSD ***masks*** from "part 1" cover worst *case values* and are too pessimistic for this purpose and related to some resolution bandwidth. Performance modelling requires the definition of PSD ***templates*** representing *expected* values, being independent from any resolution bandwidth.
Related Contributions:

- *991t20, Villach 1999 - Revised noise models for SDSL - KPN*
- *993t22, Edinburgh 1999 - Update of SDSL noise models, as requested by ETSI-TM6 - KPN*
- *022t36, Sophia 2002 - Transmitter models for performance evaluations - KPN*
- *022t22, Sophia 2002 - FSAN noise models are too pessimistic for SpM - Alcatel*
- *022t23, Sophia 2002 - PSD of ADSL is too pessimistic in FSAN noise models - Alcatel*
- *023t43, Praha 2002 - Defining Xtalk noise models by measuring ADSL transceivers - Alcatel*

SP 2-6. Transmitter/Disturber models for SDSL
Similar to SP 2-5, but dedicated to SDSL systems

- *991t20, Villach 1999 - Revised noise models for SDSL - KPN*
- *993t22, Edinburgh 1999 - Update of SDSL noise models, as requested by ETSI-TM6 - KPN*
- *022t36, Sophia 2002 - Transmitter models for performance evaluations - KPN*

SP 2-7. Transmitter/Disturber models for HDSL-CAP/2
Similar to SP 2-5, but dedicated to two-pair HDSL-CAP systems

- *991t20, Villach 1999 - Revised noise models for SDSL - KPN*
- *993t22, Edinburgh 1999 - Update of SDSL noise models, as requested by ETSI-TM6 - KPN*
- *022t36, Sophia 2002 - Transmitter models for performance evaluations - KPN*

SP 2-8. Transmitter/Disturber models for HDSL-2B1Q
Similar to SP 2-5, but dedicated to HDSL-2B1Q systems

- *991t20, Villach 1999 - Revised noise models for SDSL - KPN*
- *993t22, Edinburgh 1999 - Update of SDSL noise models, as requested by ETSI-TM6 - KPN*
- *022t36, Sophia 2002 - Transmitter models for performance evaluations - KPN*

SP 2-9. Performance model for ETSI compliant SDSL
Part 2 of SpM requires a range of calculation blocks, to enable performance evaluations. Among them are models that predict the performance (noise margin, or bitrate) of xDSL receivers, when the received signal is disturbed by noise. This study point is dedicated to models that predict 6 dB noise margin under all stress conditions specified by the ETSI SDSL standard, for various bitrates, noise

models and testloops. Models of SDSL modems that outperform (or underperform) the ETSI standard requirements are beyond the scope of this study point.

- *023t32, Praha 2002 - Receiver performance model for ETSI compliant SDSL - KPN*
- *024t37, Darmstadt 2002 - Parameters for SDSL performance model - Conexant / Adtran*

SP 2-10. Performance model for ETSI compliant HDSL-CAP
Similar to SP 2-9, but dedicated to HDSL-CAP systems. This means predicting 0 dB noise margin under all stress conditions specified by the ETSI HDSL standard.

- *023t33, Praha 2002 - Receiver performance model for ETSI compliant HDSL/CAP - KPN*

SP 2-11. Transmitter/Disturber models for ISDN-2B1Q
Similar to SP 2-5, but dedicated to ISDN-2B1Q systems

- *991t20, Villach 1999 - Revised noise models for SDSL - KPN*
- *993t22, Edinburgh 1999 - Update of SDSL noise models, as requested by ETSI-TM6 - KPN*
- *022t36, Sophia 2002 - Transmitter models for performance evaluations - KPN*

SP 2-12. Implementation loss values for PAM, CAP and DMT
The SNR gap Γ, being used in various receiver performance models for xDSL modems, is a combination of various effects. This Γ parameter is usually split-up into the following three parts:

- Its theoretical value $\Gamma_{linecode}$, usually in the order of 9.8 dB, for the chosen line code (e.g. Γ_{PAM}, Γ_{CAP} or Γ_{DMT}).
- A theoretical coding gain $\Delta\Gamma_{coding}$, usually in the order of 3-5 dB, to indicate how much additional improvement is achieved by the chosen coding mechanism.
- The empirical implementation losses $\Delta\Gamma_{impl}$, usually 1.6 dB or more), indicating how much overall deterioration is caused by implementation dependent imperfections in echo cancellation, equalization, etc.

For SDSL this can be expressed as:

SNR gap (linear): $\Gamma_{SDSL} = \Gamma_{PAM} \;/\; \Delta\Gamma_{coding} \times \Delta\Gamma_{impl}$

SNR gap (in dB): $\Gamma_{SDSL\_dB} = \Gamma_{PAM\_dB} - \Delta\Gamma_{coding\_dB} + \Delta\Gamma_{impl\_dB}$

This study point is dedicated to split-up the SNR gap into the above mentioned components for all relevant xDSL modems (HDSL, ADSL, SDSL, VDSL, etc) by deriving the first two theoretical values, and by reconstructing the third empirical values. The resulting SNR gap shall be such that the receiver performance model can predict the performance values required by ETSI, under ETSI test conditions.

- *024t37, Darmstadt 2002 - Parameters for SDSL performance model - Conexant / Adtran*

SP 2-13. Method/model for crosstalk cumulative distribution, etc
To extend current performance evaluation methods (based on scenarios with a fixed set of disturbers) to statistical network modelling (based on scenarios with likelihood of occurrence), various additional parametric models are to be developed. These models are *generic* models only, because the inclusion of empirical values for these parameters and/or the inclusion of other statistical data is beyond the scope op SpM-2.
This study point defines the measurement methods, procedures and calculations required to determine (a) the cross talk cumulative distribution, (b) the likelihood of occurrence (LOO) and (c) severity levels for *cross talk*.
Related Contributions

- *023t56, Praha 2002 - Suggested starting point for NMC Cross talk Models - Paradyne*
- *024t39, Darmstadt 2002 - Calculating the probability of interferers … - Paradyne*

SP 2-14 Methods for Impairment Combinations for multiple disturbers
The objective of this study point is the same as described for SP 2-13, but this one is focussed on how to determine the Impairment Combinations (IC) for multiple types of cross talk.

SP 2-15 Methods for determining Loop Cumulative Distribution
To extend the interpretation of straight-forward reach calculation to the consequences of how many customers are enabled to demand for some service, various additional parametric models are to be

developed that account for what percentage of customers live within a certain range. These models are country/region/cable specific, and therefore the models being studied are *generic* models only. This is because the inclusion of empirical values for these parameters and/or the inclusion of other statistical data is beyond the scope op SpM-2.
This study point is focussed on how to determine (a) the cumulative distribution, (b) the likelihood of occurrence (LOO) and (c) severity levels for *Loops*.

- *024t40, Darmstadt 2002 - A simple method of estimating the LOO of loop lengths - Paradyne*

SP 2-16 Methods for Determining Network Model Coverage (NMC) Score based on IC LOO and Loop LOO
The study point defines the measurement methods, procedures and calculations required to determine the Network model coverage score(NMC-score) based on IC LOO and Loop LOO

Text proposals, being candidate for inclusion into the Draft .

The text fragments below have been proposed for inclusion in the draft version of SpM part 2, but are still in the "under study" status. If agreement is achieved, they will be moved into the Draft

2 References

[1] 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".

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

Text portion proposed for inclusion into clause 4

4.2 Cluster 2 Transmitter signal models

4.2.1 Transmitter signal model for "ISDN.2B1Q"

< TO BE REPLACED BY A FORMULA USING THE SINC-FUNCTION>
The PSD template for modeling the "ISDN.2B1Q" transmit spectrum is defined in terms of break frequencies, as summarized in table 1. The associated values are constructed with straight lines between these break frequencies, when plotted against a *logarithmic* frequency scale and a *linear* dBm scale. The source impedance equals R_s=135Ω.

ISDN.2B1Q	***135 Ω***
[Hz]	**[dBm/Hz]**
1	-31.8
15k	-31.8
30k	-33.5
45k	-36.6
60k	-42.2
75k	-55
85k	-55
100k	-48
114k	-48
300k	-69
301k	-79
500k	-90
1.4M	-90
3.637M	-120
30M	-120

Table 1 PSD template values at break frequencies for modeling "ISDN.2B1Q"

NOTE: This PSD template is constructed for in-band frequencies from a piece-wise approximation of a (theoretical) sync-shape of 2B1Q encoded signals. For out-of-band frequency the PSD template is guided by the PSD mask. The resulting envelope power of that PSD-template is close to the maximum power is allowed by the ISDN standard.

4.2.2 Transmitter signal model for "ISDN.MMS.43"

<This model is left for further study>

4.2.3 Transmitter signal model for "Proprietary.SymDSL.CAP.QAM"

<This model is left for further study>

4.3 Cluster 3 Transmitter signal models

4.3.1 Transmitter signal models for "HDSL.2B1Q"

< TO BE REPLACED BY A FORMULA USING THE SINC-FUNCTION>

The PSD template for modeling the "HDSL.2B1Q/2" transmit spectrum is defined in terms of break frequencies, as summarized in table 2. The associated values are constructed with straight lines between these break frequencies, when plotted against a logarithmic frequency scale and a linear dBm scale. The source impedance equals R_s=135Ω.

HDSL.2B1Q/2 2 pair	***135 Ω***
[Hz]	**[dBm/Hz]**
1	-40.2
100k	-40.2
200k	-41.6
300k	-44.2
400k	-49.7
500k	-61.5
570k	-80
600k	-80
650k	-72
755k	-72
2.92M	-119
30M	-119

Table 2 PSD template values at break frequencies for modeling "HDSL.2B1Q/2"

NOTE: This PSD template is constructed for in-band frequencies from a piece-wise approximation of a (theoretical) sync-shape of 2B1Q encoded signals. For out-of-band frequency the PSD template is guided by the PSD mask. The resulting envelope power of that PSD-template is close to the maximum power is allowed by the HDSL standard.

4.3.2 Transmitter signal model for "HDSL.CAP"

<A model for HDSL.CAP/1 is stull under study; only HDSL.CAP/2 has been agreed>

4.3.3 Transmitter signal model for "SDSL"

<This model has been agreed>

4.3.7 Transmitter signal model for "Proprietary.XXXXX"

<all proprietary models are left for further study>

4.4 Cluster 4 Transmitter signal models

4.4.1 Transmitter signal model for "ADSL over POTS" (EC)

The PSD template for modeling the (echo cancelled) "ADSL over POTS" transmit spectrum is defined in terms of break frequencies, as summarized in table 3. The associated values are constructed with straight lines between these break frequencies, when plotted against a *logarithmic* frequency scale and a *linear* dBm scale. The source impedance equals R_s=100Ω.

ADSL over POTS	*Up 100 Ω*
[Hz]	[dBm/Hz]
1	-97.5
3.99k	-97.5
4k	-92.5
25.875k	-38
138k	-38
307k	-90
1.221M	-90
1.630M	-110
30M	-110

ADSL over POTS	*Down 100 Ω*
[Hz]	[dBm/Hz]
1	-97.5
3.99k	-97.5
4k	-92.5
25.875k	-40
1.104M	-40
3.093M	-90
4.545M	-110
30M	-110

Table 3. PSD template values at break frequencies for modeling "ADSL over POTS"

NOTE: This PSD template is based on a combination of the nominal PSD value for in-band frequencies, and the PSD mask for out-of-band frequencies, as specified in the ETSI ADSL standard.

4.4.2 Transmitter signal model for "ADSL.FDD over POTS"

The PSD template for modeling the "ADSL.FDD over POTS" transmit spectrum is defined in terms of break frequencies, as summarized in table 4. The associated values are constructed with straight lines between these break frequencies, when plotted against a *logarithmic* frequency scale and a *linear* dBm scale. The source impedance equals R_s=100Ω.

ADSL.FDD over POTS	*Up 100 Ω*
[Hz]	[dBm/Hz]
1	-97.5
3.99k	-97.5
4k	-92.5
25.875k	-38
138k	-38
307k	-90
1.221M	-90
1.630M	-110
30M	-110

ADSL.FDD over POTS	*Down 100 Ω*
[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	-40
1.104 M	-40
3.093 M	-90
4.545 M	-110
30 M	-110

Table 4. PSD template values at break frequencies for modelling "ADSL.FDD over POTS"

NOTE: This PSD template is based on a combination of the nominal PSD value for in-band frequencies, and the PSD mask for out-of-band frequencies, as specified in the ETSI ADSL standard.

4.4.3 Transmitter signal model for "ADSL over ISDN" (EC)

The PSD template for modelling the (echo cancelled) "ADSL over ISDN" transmit spectrum is defined in terms of break frequencies, as summarized in table 5. The associated values are constructed with straight lines between these break frequencies, when plotted against a *logarithmic* frequency scale and a *linear* dBm scale. The source impedance equals R_s=100Ω.

ADSL over ISDN	*Up 100 Ω*
[Hz]	**[dBm/Hz]**
1	-90
50k	-90
80k	-81.8
138k	-38
276k	-38
614k	-90
1.221M	-90
1.630M	-110
30M	-110

ADSL over ISDN	*Down 100 Ω*
[Hz]	**[dBm/Hz]**
1	-90
50k	-90
80k	-81.8
138k	-40
1.104M	-40
3.093M	-90
4.545M	-110
30M	-110

Table 5. PSD template values at break frequencies for modeling "ADSL over ISDN"

NOTE: This PSD template is based on a combination of the nominal PSD value for in-band frequencies, and the PSD mask for out-of-band frequencies, as specified in the ETSI ADSL standard.

4.4.4 Transmitter signal model for "ADSL.FDD over ISDN"

The PSD template for modelling the "ADSL.FDD over ISDN" transmit spectrum is defined in terms of break frequencies, as summarized in table 6. The associated values are constructed with straight lines between these break frequencies, when plotted against a logarithmic frequency scale and a linear dBm scale. The source impedance equals R_s=100Ω.

ADSL.FDD over ISDN	*Up 100 Ω*
[Hz]	**[dBm/Hz]**
0.001	-90
50 k	-90
80 k	-81.8
120 k	-38
276 k	-38
614 k	-90
1.221 M	-90
1.630 M	-110
30 M	-110

ADSL.FDD over ISDN	*Down 100 Ω*
[Hz]	**[dBm/Hz]**
0.001	-90
93.1	-90
209	-62
253.99	-48.5
254	-40
1104	-40
3093	-90
4545	-110
30000	-110

Table 6. PSD template values at break frequencies for modeling "ADSL.FDD over ISDN"

NOTE: This PSD template is based on a combination of the nominal PSD value for in-band frequencies, and the PSD mask for out-of-band frequencies, as specified in the ETSI ADSL standard.

Text portion proposed for inclusion into clause 5

5.2 Generic detection models

This clause identifies several generic (sub) models for the detection block: one line code independent model derived from the Shannon capacity limit, and various line code dependent models dedicated to PAM, CAP/QAM or DMT line coding.
Table 7 summarizes the naming convention for input and output quantities.

INPUT QUANTITIES	*linear*	*In dB*	*remarks*
Signal to Noise Ratio	SNR	$10\times\log_{10}(SNR)$	Ratio of powers (frequency dependent)
Output quantities			
Noise margin	m_n	$10\times\log_{10}(m_n)$	Ratio of noise powers
Signal margin	m_s	$10\times\log_{10}(m_s)$	Ratio of signal powers

Table 7. Symbols used for input and output quantities of detection models

On input, the detection block requires an effective SNR, as provided by the input block. This SNR is a function of the frequency *f*. When the offset format is used for describing the SNR (see expression **[*]**), it will also be a function of the offset parameter *m.*

On output, the detection block evaluates a signal margin m_n (or a noise margin m_s when more appropriated). This margin parameter is a dominant measure for the transport quality that is achieved under noisy conditions.

- The *Noise Margin* m_n indicates how much the received noise power can increase before the transmission becomes unreliable.
- The *Signal Margin* m_s indicates how much the received signal power can decrease before the transmission becomes unreliable.

Unless explicitly specified otherwise, the word *margin* refers in this document to *noise margin*.

NOTE From an xDSL deployment point of view, analyzing the noise margin is preferred over signal margin, since the (cross talk) noise is the quantity that may increase when more systems are connected to the same cable. Many xDSL implementations, however, do report margin numbers that are not exactly equal to this noise margin, since the detection circuitry cannot make a distinction between external noise (due to cross talk) and internal noise (due to imperfect electronics). These margins are often an estimate closer in value to the signal margin then the noise margin.

5.2.1 Generic Shifted Shannon detection model

The calculation of the margin *m* using the generic Shifted Shannon detection model, is equivalent with solving the equation in expression 1. It has been derived from Shannon's capacity theorem, by reducing the effective SNR ("shifting" on a dB scale) by a factor Γ, to account for the imperfections of practical detectors. The associated parameters are summarized in table 8. Depending on what offset format is used for the SNR expression (see expression **[*]**), the calculated margin *m* will represent the noise margin m_n or the signal margin m_s.

$$f_b = \int_{f_c - B/2}^{f_c + B/2} \log_2\left(1 + \frac{SNR_{ofs}(m, f)}{\Gamma}\right) \cdot df$$

Expression 1: Equation of the Shifted Shannon detection model, for solving the margin m.

Model Parameters	***linear***	***In dB***	***remarks***
SNR gap	Γ	$10\times\log_{10}(\Gamma)$	
Data rate	f_d		all payload bits that are transported in 1 sec
Line rate	f_b		= DateRate + overhead bitrate
Bandwidth	B		Width of most relevant spectrum

Table 8. Parameters used for Shifted Shannon detection models.

The various parameters used within this generic detection model are summarized in table 8. The model can be made specific by assigning values to all these model parameters.

- The SNR-gap (Γ) is a performance parameter that indicates how close the detection approaches the Shannon capacity limit.
- The linerate is usually higher then the data rate (0…30%) to transport overhead bits for error correction, signaling and framing.
- The Bandwidth is a parameter that indicates what portion of the received spectrum is relevant for data transport. The model assumes that this portion passes the receive filters.

5.2.2 Generic PAM detection model

The calculation of the margin *m* using the generic PAM detection model is equivalent with solving the equation in expression 2. The associated parameters are summarized in table 9. Depending on what offset format is used for the SNR expression (see expression **[*]**), the calculated margin *m* will represent the noise margin m_n or the signal margin m_s.
This model assumes optimal decision feedback equalizer (DFE) margin calculations.

$$SNR_{req} = \Gamma \times \left(2^{2\cdot b} - 1\right) = \exp\left(\frac{1}{f_s} \times \int_0^{f_s} \ln\left(1 + \sum_{n=N_L}^{N_H} SNR_{ofs}\left(m, f + nf_s\right) \right) \cdot df \right)$$

Expression 2: Equation of the PAM-detection model, for solving the margin m.

The (effective) SNR gap Γ, being used in the above expression 2, is a combination of various effects. This Γ parameter is often split-up into the following three parts:

- Its theoretical value Γ_{PAM} (usually in the order of 9.75 dB)
- A theoretical coding gain $\Delta\Gamma_{coding}$ (usually in the order of 3-5 dB), to indicate how much additional improvement is achieved by the chosen coding mechanism.
- An empirical implementation loss $\Delta\Gamma_{impl}$ (usually 1.6 dB or more), indicating how much overall deterioration is caused by implementation dependent imperfections in echo cancellation, equalization, etc.

When Γ is split-up into the above three parts, its value shall be evaluated as follows:

SNR gap (linear): $\Gamma = \Gamma_{PAM} \;/\; \Delta\Gamma_{coding} \times \Delta\Gamma_{impl}$
SNR gap (in dB): $\Gamma_{\_dB} = \Gamma_{PAM\_dB} - \Delta\Gamma_{coding\_dB} + \Delta\Gamma_{impl\_dB}$

Model Parameters	***linear***	***In dB***	***remarks***
SNR gap (effective)	Γ	$10\times\log_{10}(\Gamma)$	$= SNR_{req} / (2^{2\cdot b}-1)$
SNR gap in parts:	Γ_{PAM} $\Delta\Gamma_{coding}$ $\Delta\Gamma_{impl}$	$10\times\log_{10}(\Gamma_{PAM})$ $10\times\log_{10}(\Delta\Gamma_{coding})$ $10\times\log_{10}(\Delta\Gamma_{impl})$	*Theoretical linecode value* *Coding gain* *Implementation loss*
Required SNR	SNR_{req}	$10\times\log_{10}(SNR_{req})$	$= \Gamma\times(2^{2\cdot b}-1)$
Data rate	f_d		all payload bits that are transported in 1 sec
Line rate	f_b		= DateRate + overhead bitrate
Symbol rate	f_s		$= f_b / b$
Bits per symbol	b		$= f_b / f_s$ (can be non-integer)
Summation range	N_L, N_H		On default: N_L=–2 and N_H=+1

Table 9. Parameters used for PAM detection models.

The various parameters in table 9 used within this generic detection model have the following meaning:

- The SNR-gap (Γ) and required SNR (SNR_{req}) are similar parameters and can be converted into each other. The advantage of using Γ over SNR_{req} is that Γ can be defined with similar meaning for all theoretical models in the frequency domain (Shifted Shannon, CAP, PAM, DMT). The advantage of using SNR_{req} over Γ is that this quantity is closer related to the SNR observed at the decision point of the detection circuitry.
- The line rate is usually higher then the data rate (0…30%) to transport overhead bits for error correction, signaling and framing. The symbol rate is usually significantly lower when multiple bits are packed together in a single symbol.
- The summation range for *n* is from $n=N_L$ to $n=N_H$, and this range has to be defined to make this generic model specific. Commonly used values for PAM, using over sampling, are N_L=–2 and N_H=+1, but wider ranges are not excluded.

5.2.3 Generic CAP/QAM detection model

The calculation of the margin *m* using the generic CAP/QAM detection model is equivalent with solving the equation in expression 3. The associated parameters are summarized in table 10. Depending on what offset format is used for the SNR expression (see expression **[*]**), the calculated margin *m* will represent the noise margin m_n or the signal margin m_s.
This model assumes optimal decision feedback equalizer (DFE) margin calculations.

$$SNR_{req} \equiv \Gamma \times \left(2^{b} - 1\right) = \exp\left(\frac{1}{f_s} \times \int_0^{f_s} \ln\left(1 + \sum_{n=N_L}^{N_H} SNR_{ofs}\left(m, f + nf_s\right) \right) \cdot df \right)$$

Expression 3: Equation of the CAP/QAM-detection model, for solving the margin m.

The (effective) SNR gap Γ, being used in the above expression 3, is a combination of various effects. This Γ parameter is often split-up into the following three parts:

- Its theoretical value Γ_{CAP} (usually in the order of 9.8 dB)
- A theoretical coding gain $\Delta\Gamma_{coding}$ (usually in the order of 3-5 dB), to indicate how much additional improvement is achieved by the chosen coding mechanism.
- An empirical implementation loss $\Delta\Gamma_{impl}$ (usually 1.6 dB or more), indicating how much overall deterioration is caused by implementation dependent imperfections in echo cancellation, equalization, etc.

When Γ is split-up into the above three parts, its value shall be evaluated as follows:

SNR gap (linear): $\Gamma = \Gamma_{CAP} \;/\; \Delta\Gamma_{coding} \times \Delta\Gamma_{impl}$

SNR gap (in dB): $\Gamma_{\_dB} = \Gamma_{CAP\_dB} - \Delta\Gamma_{coding\_dB} + \Delta\Gamma_{impl\_dB}$

Model Parameters	***linear***	***In dB***	***remarks***
SNR gap (effective)	Γ	$10\times\log_{10}(\Gamma)$	= $SNR_{req} / (2^{b}-1)$
SNR gap in parts:	Γ_{CAP} $\Delta\Gamma_{coding}$ $\Delta\Gamma_{impl}$	$10\times\log_{10}(\Gamma_{PAM})$ $10\times\log_{10}(\Delta\Gamma_{coding})$ $10\times\log_{10}(\Delta\Gamma_{impl})$	*Theoretical linecode value* *Coding gain* *Implementation loss*
Required SNR	SNR_{req}	$10\times\log_{10}(SNR_{req})$	= $\Gamma\times(2^{b}-1)$
Data rate	f_d		all payload bits that are transported in 1 sec
Line rate	f_b		= DateRate + overhead bitrate
Symbol rate	f_s		= f_b / *b*
Bits per symbol	*b*		= f_b / f_s (can be non-integer)
Summation range	N_L, N_H		On default: N_L=0 and N_H=+3

Table 10. Parameters used for CAP/QAM detection models.

The various parameters in table 10 used within this generic detection model have the following meaning:

- The SNR-gap (Γ) and required SNR (SNR_{req}) are similar parameters and can be converted into each other. The advantage of using Γ over SNR_{req} is that Γ can be defined with similar meaning for all theoretical models in the frequency domain (Shannon, CAP, PAM, DMT). The advantage of using SNR_{req} over Γ is that this quantity is closer related to the SNR observed at the decision point of the detection circuitry.
- The line rate is usually higher then the data rate (0..30%), to transport overhead bits for error correction, signaling and framing. The symbol rate is usually significantly lower when multiple bits are packed together in a single symbol.
- The summation range for *n* is from $n=N_L$ to $n=N_H$, Commonly used values for CAP/QAM systems using over sampling are N_L=0 and N_H=+3. This holds when the carrier frequency positions the spectrum low in the frequency band (e.g. CAP-based HDSL). Other values may be more appropriated when the carrier frequency moves the spectrum to higher frequencies (e.g CAP based VDSL).

5.2.4 Generic DMT detection model
<left for further study>

Text portion proposed for inclusion into clause 6

6 Specific receiver performance models for xDSL

6.1 Receiver performance model for "HDSL.2B1Q"
<left for further study>

6.2 Receiver performance model for "HDSL-CAP"
This calculation model is capable for predicting the performance of an ETSI compliant HDSL-CAP modem [1]. The validity of the model has been demonstrated for stress conditions (loss, noise) equal to the ETSI stress conditions described in the ETSI HDSL specification [1].

6.2.1 Building blocks of the receiver performance model.
The receiver performance model for ETSI compliant HDSL-CAP is build-up from the following building blocks:

- The echo-loss model, specified in clause 7.2
- The basic model for the input block, specified in clause 5.1
- The generic CAP/QAM detection model, specified in clause 5.2.3
- The parameter values specified in the succeeding clause 6.2.2 and 6.2.3.

6.2.2 Parameters, of the receiver performance model.
The parameter values, used in the receiver performance model for ETSI compliant HDSL-CAP, are summarized in table 12. Parts of them are directly based on HDSL specifications. The remaining values are based on theory, followed by an iterative fit of the model to meet the ETSI reach requirements for HDSL-CAP under the associated stress conditions.
Various parameters are derived directly from the above-mentioned parameters. Their purpose is to simplify the required expression of the used CAP/QAM-detection model.

Model Parameter		**HDSL.CAP/2**	**HDSL.CAP/1**
SNR-Gap (effective)	Γ	6.8 dB	6.8 dB
SNR-Gap in parts	Γ_{CAP} $\Delta\Gamma_{coding}$ $\Delta\Gamma_{impl}$	**<TBD>** **<TBD>** **<TBD>**	**<TBD>** **<TBD>** **<TBD>**
Echo suppression	η_e	60 dB	60 dB
Receiver noise	P_{RN0}	–105 dBm @ 135 Ω	–105 dBm @ 135 Ω
Data rate	f_d	2×1024 kb/s	1×2048 kb/s
Line rate	f_b	1168 kb/s	2330 kb/s
Carrier frequency	f_c	138.30 kHz	226.33 kHz
bits per symbol	b	5	6
Summation bounds in the CAP/QAM model	N_H N_L	+3 0	+3 0
Derived Parameter			
Symbol rate	f_s	f_b/b = 233.6 kbaud	f_b/b = 388.3 kbaud
Required SNR	SNR_{req}	$\Gamma\times(2^b-1)$ =21.7 dB	$\Gamma\times(2^b-1)$ =24.8 dB

Table 11. Values for the parameters of the performance model, obtained from ETSI requirements for HDSL-CAP [1].

6.3 Receiver performance model for "SDSL"

This calculation model is capable for predicting the performance of an ETSI compliant SDSL modem [2]. The validity of the model has been demonstrated for stress conditions (loss, noise) equal to the ETSI stress conditions described in the ETSI SDSL specification [2]. Reach predictions under these stress conditions are valid within about 4.5% in reach, and less then 125m. The validity of the predicted performance holds for a wider range of stress conditions.

6.3.1 Building blocks of the receiver performance model.

The receiver performance model for ETSI compliant SDSL is build-up from the following building blocks:

- The echo-loss model, specified in clause 7.2
- The basic model for the input block, specified in clause 5.1
- The generic PAM detection model, specified in clause 5.2.2
- The parameter values specified in table 11 of the succeeding clause.

6.3.2 Parameters, of the receiver performance model.

The parameter values, used in the receiver performance model for ETSI compliant SDSL, are summarized in table 11. Part of them are directly based on SDSL specifications. The remaining values are based on theory, followed by an iterative fit of the model to meet the ETSI reach requirements for SDSL under the associated stress conditions.
Various parameters are derived from the above-mentioned parameters. Their purpose is to simplify the required expression of the used PAM-detection model.

First proposal (see 023t32)

Model parameter		***PAM model***
SNR-Gap (effective)	Γ	6.5 dB
SNR-Gap in parts	Γ_{PAM} $\Delta\Gamma_{coding}$ $\Delta\Gamma_{impl}$	9.75 dB **<TBD>** **<TBD>**
Echo suppression	η_e	70 dB
Receiver noise	P_{RN0}	–120 dBm @ 135 Ω
Data rate	f_d	192 … 2304 kb/s
Line rate	f_b	f_d + 8 kb/s
bits per symbol	B	3
Summation bounds in PAM model	N_H N_L	+1 –2
Derived Parameter		
Required SNR	SNR_{req}	$\Gamma\times(2^{2b}-1)$ =24.5 dB
Symbol rate	f_s	f_b / 3

Second proposal (see 024t37)

Model parameter		***PAM model***	
		≤ 256 kb/s	***> 256 kb/s***
SNR-Gap (effective)	Γ	6.95 dB	6.25 dB
SNR-Gap in parts	Γ_{PAM} $\Delta\Gamma_{coding}$ $\Delta\Gamma_{impl}$	*9.75 dB* *4.4 dB* *1.6 dB*	*9.75 dB* *5.1 dB* *1.6 dB*
Echo suppression	η_e	∞ (no echo)	
Receiver noise	P_{RN0}	–140 dBm @ 135 Ω	
Data rate	f_d	192 … 2304 kb/s	
Line rate	f_b	f_d + 8 kb/s	
bits per symbol	b	3	
Summation bounds in PAM model	N_H N_L	+1 –2	
Derived Parameter			
Required SNR	SNR_{req}	$\Gamma\times(2^{2b}-1) = \Gamma + 18$ dB	
Symbol rate	f_s	f_b / 3	

Table 12. Values for the parameters of the performance model, obtained from ETSI requirements for SDSL [2]

End of literal text proposals

Hidden definitions: