ETSI WG TM6
(ACCESS TRANSMISSION SYSTEMS ON METALLIC CABLES)

Permanent Document
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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 June 2004. This means that the first version of SpM part 2 can be published by ETSI in the summer of 2004. 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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Mark the changes, valid from nov 24, 2003

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 (*PAM, CAP/QAM, shifted-shannon*)	Rob van den Brink (KPN)	Agreed
2-5	Transmitter/Disturber models - ADSL	Rosaria Persico (TI-labs)	prov agreed
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)	Prov Agreed
2-9	Performance model for ETSI compliant SDSL	Marc Kimpe (Adtran)	Agreed
2-10	Performance model for ETSI compliant HDSL-CAP	Rob van den Brink (KPN)	Agreed
2-11	Transmitter/Disturber models - ISDN-2B1Q	Rob van den Brink (KPN)	Agreed
2-12	Implementation loss values for PAM, CAP and DMT	Ragnar Jonsson (Conexant)	US
2-13	Method/Model for Cross talk 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 + Occurrence	Jack Douglass (Paradyne)	US
2-16	Method/Model for Network Model Coverage Score	Jack Douglass (Paradyne)	US
2-17	Transmitter/Disturber models - ISDN-MMS43 (4B3T)	Marko Löffelholz (DTAG)	US
2-18	Generic detection model for DMT	Tomas Nordstrom (FTW)	Prov Agreed
2-19	Performance model for ETSI compliant ADSL (EC-variant)	Ragnar Jonsson (Conexant)	Prov Agreed
2-20	Disturber model for line shared ISDN noise	Marko Loeffelholz (DTAG)	US
2-21	Data collection of PSD measurements	Marcus Jonsson (TeliaSonera)	US
2-22	Improving the validity of receiver performance models	Krista Jacobsen (TI)	US
2-23	Performance model for ETSI compliant ADSL.FDD over POTS	Krista Jacobsen (TI)	US
2-24	Performance model for ETSI compliant ADSL.FDD over ISDN	Sigurd Schelstraete (ALC)	US
2-25			
2-26			
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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. (PAM, CAP/QAM, Shifted Shannon)

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.

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*
- *031t11, Sophia 2003 - Realistic noise model of ADSL for spectral management - Alcatel*
- *031t23, Sophia 2003 - Transmitter models for ADSL modems - KPN/TNO*
- *031w19, Sophia 2003 - Measurement of actual ADSL products - various vendors*

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*
- *032t14, Reykjavik 2003 - Example of 2B1Q HDSL and SDSL PSDs - Siemens*

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*
- *031t20, Sophia 2003 - Example 2B1Q HDSL PSDs - Keymile*
- *031t21, Sophia 2003 - Proposal on HDSL.2B1q/2 Transmitter signal models - KE*
- *031t22, Sophia 2003 - Transmitter models for ISDN & HDSL-2B1Q modems - KPN/TNO*
- *032t14, Reykjavik 2003 - Example of 2B1Q HDSL and SDSL PSDs - Siemens*
- *033t05, Sophia 2003 - Realistic template of HDSL.2B1Q/2 in out of band range - Swisscom*
- *033t06, Sophia 2003 - Measurements and model for HDSL.2B1Q/2 transceivers - Siemens*

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. ***Measurements are invited !!!!***

- *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*
- *031t22, Sophia 2003 - Transmitter models for ISDN & HDSL-2B1Q modems - KPN/TNO*

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 ETSImating the LOO of loop lengths - Paradyne*
- *031t40, Sophia 2003 - Updated European crosstalk CDFs & example procedure - Paradyne*
- *031t41, Sophia 2003 - Example for approximating European loop distribution - Paradyne*

A proposed generic model for how many customers are located within distance L is based on (a) the knowledge of the distance that encloses 63% of the customers, (b) the knowledge on the slope of this customer count, around this 63% distance, and (c) the assumption that this curve follows a Weibull distribution at all other distances. This model for loop length L, has therefore 2 scenario dependent constants (L_0 and q_0), and equals:

Cumulative distribution function: $F(L;L_0,q_0)=\left(1-\exp\left(-\left(\frac{L}{L_0}\right)^{q_0}\right)\right)$

Probability density function: $f(L;L_0,q_0)=\left(\frac{q_0}{L_0}\right)\times\left(\left(\frac{L}{L_0}\right)^{q_0}\times\exp\left(-\left(\frac{L}{L_0}\right)^{q_0}\right)\right)=\frac{\partial F}{\partial L}$

Constant L_0 represent the length covering 63% of all subscribers: $F(L_0)=(1-1/e)$. Constant q_0 represents the slope of $F(L)$ at that length and equals $q_0= e\cdot L\cdot(\mathrm{d}F/\mathrm{d}L)$ at $L=L_0$.

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

SP 2-17. Transmitter/Disturber models for ISDN-MMS43 (4B3T)

Similar to SP 2-11, but dedicated to ISDN-MMS43 systems. These systems are widely deployed in Germany. The current proposal addresses in-band frequencies. Out of band values, above 400 kHz are left for further study. Measurements are invited.

- *014t13, Sophia 2001 - Proposal for same pair ISDN template (4B3T) - DTAG*
- *033t17, Sophia 2003 - Proposal for an ISDN-MMS43 (4B3T) in-band template - T-Systems*

SP 2-18. Generic Detection model for DMT.

Part 2 of SpM requires a range of calculation blocks, including one (or more) detection model(s) dedicated to DMT in general. This study point explores possible improvements of the proposed model.

Related Contributions:

- *032t09, Reykjavik 2003 - Generic DMT detection model - KPN*

SP 2-19. Performance models for ETSI compliant ADSL (EC-variant).

Part 2 of SpM requires a range of calculation blocks, including performance models that are specific for the EC variants of ADSL, including "ADSL over POTS" and "ADSL over ISDN". These specific models are based on generic models for DMT detection and the receiver input. This study point explores possible improvements of the proposed models.

Related Contributions:

- *032t10, Reykjavik 2003 - Receiver performance model for "ADSL over POTS" (EC) - KPN*
- *032t11, Reykjavik 2003 - Receiver performance model for "ADSL over ISDN" (EC) - KPN*

SP 2-20 Disturber model for line shared ISDN noise

A model is required that enhance ADSL performance simulations by accounting for the additional noise generated by the ISDN system that share the same line. A simple approach may be a PSD description of line shared ISDN noise, but more advanced models (including splitter models) are not excluded from being studied.

Related Contributions:

- *014t13, Sophia 2001 - Proposal for same pair ISDN template (4B3T) - DTAG*
- *033t18, Sophia 2003 - Disturber model for the line shared ISDN.4B3T noise - T-Systems*

SP 2-21 Data collection of PSD measurements

Various contributions have provided PSD measurements on signals transmitted by modems. They indicate how good the various transmitter model can represent these modems. This study point is to collect this data in a computer readable format and to store this data on the ETSI server at some TM6 subdirectory (*ftp://docbase.etsi.org/tm/tm6/Inbox/PSD_data*). This is to enable all delegates to compare this data with possibly improved models.

The format shall be some tabular ascii format, and easily loadable by programs such as Matlab. The format is:

filename.psd → an **ascii data file** with numbers only, and without additional text
each line contains two numbers, separated by one ore more <tabs>
the first number is the frequency in [**Hz**] (so no [kHz] or [MHz] !!!)
the second number is the PSD value in [**dBm/Hz**]
the frequency increases with the line number,
each frequecny vallue occurs only once
filename.txt → an **ascii text file** describing all relevant details about the data file

SP 2-22 Improving the validity of receiver performance models

The validity of the current generic models for receivers is too limited to be usable for scenarios with high SNR. This limitation is highly relevant when simulating FDD modems (some ADSL variants or VDSL) because FDD modems are designed to maximize the SNR values due to the lack of spectral overlap. The high SNR aspect requires to model the imperfection of the equalization (causing inter symbol/carrier interference).

Another aspect of improvement is to add the need for a guard band between upstream and downstream by modelling the imperfections of the case echo cancellation (if any). A guard band of 7 DMT tones is quite common for the FDD variants of ADSL, and spectral management studies will

become too optimistic when the model (incorrectly) predicts an improvement of the performance when DMT tones in the guard band are activated.
This guard-band aspect may be too implementation-dependent and therefore undesirable to model. A possible way forward is leaving all echo cancellation out of the modelling, to accept a restricted validity of the ADSL model, and to make the tones in the guard band unavailable by explicit warning in the SpM standard
Related Contributions:

- *033t13, Sophia 2003 - Extending the validity of receiver performance models - KPN*

SP 2-23 Performance model for ETSI compliant ADSL.FDD over POTS
Same as SP-2-19, but dedicated to the FDD variant of ADSL over POTS. The model should predict the performance that can be guaranteed by the performance requirements in the ADSL standard.
Related Contributions:

- *033t14, Sophia 2003 - Receiver performance model for "ADSL.FDD over POTS" - KPN*

SP 2-24 Performance model for ETSI compliant ADSL.FDD over ISDN
Same as SP-2-19, but dedicated to the FDD variant of ADSL over ISDN. The model should predict the performance that can be guaranteed by the performance requirements in the ADSL standard.
Related Contributions:

- *033t15, Sophia 2003 - Receiver performance model for "ADSL.FDD over ISDN" - KPN*

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 102 080 (V1.3.2): "Transmission and Multiplexing (TM); Integrated Services Digital Network (ISDN) basic rate access; Digital transmission system on metallic local lines".
[2]	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".
[3]	ETSI TS 101 524: "Transmission and Multiplexing (TM); Access transmission system on metallic access cables; Symmetrical single pair high bitrate Digital Subscriber Line (SDSL)".
[4]	ETSI TS 101 388, v1.3.1, (2002-05): "Transmission and Multiplexing (TM); Access transmission systems on metallic access cables; Asymmetric Digital Subscriber Line (ADSL) - European specific requirements", may 2002.

Text portion proposed for inclusion into clause 4

4.2 Cluster 2 Transmitter signal models

4.2.2 Transmitter signal model for "ISDN.MMS.43" (4B3T)

The PSD template for modeling the "ISDN.MMS.43" transmit spectrum (also known as ISDN.4B3T) is defined in terms of break frequencies, as summarized in table 1. The values are based on measurements on these modems. The associated values are constructed with straight lines between these break frequencies, when plotted against a *logarithmic* frequency scale and a *linear* dBm scale.

ISDN.MMS.43 (150 Ω)	
f [Hz]	**P [dBm/Hz]**
0	**<TBD>**
5 k	-40
22,5 k	-36
40 k	-37
65 k	-40
80 k	-43
100 k	-50
122,5 k	-62
154,5 k	-60
170 k	-61
185 k	-65
200 k	-69
215 k	-74
250 k	-82
300 k	-78
400 k	-67
<TBD>	**<TBD>**
30 M	**<TBD>**

Table 1: PSD template for modeling "ISDN.MMS.43" signals.

ED. NOTE. Due to the lack of measurements, the frequencies above 400 kHz are left for further study. The same applies for frequenies below 5 kHz. A way forward is to apply –40 dBm for the lower band, and to follow the PSD mask specification from ETSI TS 102 080 V1.3.2 (2000-05). In other words:

0,	–40
5 k	–40
…	…
400 k	-67
1 M	-67
5 M	-120
30 M	-120

4.2.3 Line-shared signal model for "ISDN.2B1Q"

<This model is left for further study>

4.2.4 Line-shared signal model for "ISDN.MMS.43" (4B3T)

The PSD template for modeling the filtered signal from an ISDN.MMS.43 transmitter, that has passed a low-pass splitter/filter for sharing the line with ADSL signals, is defined in table 2 in terms of break frequencies. It has been constructed from the transmitter PSD template, filtered by the low-pass transfer function representing the splitter/filter.

The values are based on measurements on these modems. The associated values are constructed with straight lines between these break frequencies, when plotted against a *logarithmic* frequency scale and a *linear* dBm scale.

Line-shared ISDN.MMS.43 (150 Ω)	
f [Hz]	**P [dBm/Hz]**
0	**<TBD>**
5 k	-48,7
22,5 k	-44,7
40 k	-45,3
65 k	-47,4
80 k	-50,1
100 k	-59,5
122,5 k	-108,5
154,5 k	-126,1
170 k	-127
185 k	-131
200 k	-135
215 k	-140
250 k	-148
300 k	-144
400 k	-133
1000 k	-133
5000 k	-186

Table 2: PSD template for modeling line shared "ISDN.MMS.43" signals.

4.3 Cluster 3 Transmitter signal models

4.3.1 Transmitter signal models for "HDSL.2B1Q"

The PSD templates for modeling the spectra of various "HDSL.2B1Q" transmitters is defined by the theoretical sinc-shape of PAM encoded signals, with additional filtering and a noise floor. The PSD template is the maximum of both power density curves, as summarized in table 3.
The coefficient q_N scales the total signal power of $P_1(f)$ to a value that equals P_0. This value is dedicated to the used filter characteristics, but equals q_N=1 when no filtering is applied ($f_L \rightarrow 0$, $f_H \rightarrow \infty$), The source impedance equals 135Ω.

$$P_1(f) = P_{HDSL} \times \frac{2 \times q_N}{f_X} \times \mathrm{sinc}^2\left(\frac{f}{f_X}\right) \times \frac{1}{1+\left(f_L / f\right)^2} \times \frac{1}{1+\left(f / f_{H1}\right)^{2 \cdot N_{H1}}} \times \frac{1}{1+\left(f / f_{H2}\right)^{2 \cdot N_{H2}}} \qquad [W/Hz]$$

$$P_2(f) = \frac{10^{(P_{floor\_dBm}/10)}}{1000} \qquad [W/Hz]$$

$$P(f) = \max\left(P_1(f), P_2(f)\right) \qquad [W/Hz]$$

Where:

$P_{HDSL} = \left(10^{P_{HDSL\_dBm}/10}\right) / 1000$ [W]

$R_S = 135$ [Ω]

$\mathrm{sinc}(x) = \sin(\pi \cdot x) / (\pi \cdot x)$

Default values for remaining parameters are summarized in table 3.

Expression 1: PSD template for modeling "HDSL.2B1Q" signals.

Different HDSL implementations, may use different filter characteristics, and noise floor values. Table 3 summarizes *default* values for modeling HDSL transmitters, and *alternative* values in case higher order Butterworth filtering has been applied to dedicated implementations. It is recommended to use the default values for spectral management studies, unless motivated why alternative values are more appropriated.
The default power level P_{HDSL} equals the maximum power allowed by the HDSL standard [2], since a nominal specification does not exist. The default noise floor P_{floor} equals a value observed for various

implementations. When these measurements were not available, the maximum PSD level was chosen here that meets the out-of-band specification of the HDSL standard [2].

Default

	Type	f_X kHz	f_L kHz	f_{H1}	N_{H1}	f_{H2}	N_{H2}	q_N	P_{HDSL_dBm} dBm	P_{floor_dBm} dBm/Hz
	HDSL.2B1Q/1	1160	3	$0.42 \times f_X$	3	N/A	N/A	1.4662	14	-121.5
	HDSL.2B1Q/2	584	3	$0.50 \times f_X$	3	N/A	N/A	1.3501	14	-133
	HDSL.2B1Q/3	392	3	$0.50 \times f_X$	3	N/A	N/A	1.3642	14	-117

Alternatives

	Type	f_X kHz	f_L kHz	f_{H1}	N_{H1}	f_{H2}	N_{H2}	q_N	P_{HDSL_dBm} dBm	P_{floor_dBm} dBm/Hz
H2.1	HDSL.2B1Q/2	584	3	$0.68 \times f_X$	4	N/A	N/A	1.1915	14	-133
H2.2	HDSL.2B1Q/2	584	3	$0.68 \times f_X$	4	$1.50 \times f_X$	2	1.1965	14	-133

Table 3: Default parameter values for the HDSL.2B1Q templates, as defined in expression 1. The alternative values are based on higher order Butterworth filtering. Choose $f_{H2}=\infty$ and $N_{H2}=1$ when not applicable (N/A).

ED. NOTE. Is the alternative model "H2.1" still of any relevance, or has it become obsolete due to the inclusion of the alternative model "H2.2" ???

4.4 Cluster 4 Transmitter signal models

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

The PSD template for modeling the "ADSL over POTS" transmit spectrum (EC variant) 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 break frequencies, (f_1 and f_2) and (f_3 and f_4), are dependent on the used DMT tones, (k_1 to k_2) and (k_3 to k_4), and they are to be specified first when using this PSD template. Default values are given for guidance only. The source impedance equals 100Ω.

NOTE: The FSAN Legacy 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.

FSAN LEGACY

ADSL over POTS	***Up 100 Ω***
[Hz]	**[dBm/Hz]**
0	-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]**
0	-97.5
3.99k	-97.5
4k	-92.5
25.875k	-40
1.104M	-40
3.093M	-90
4.545M	-110
30M	-110

KPN PROPOSAL

ADSL over POTS (EC) DMT carriers [k_1:k_2]	Up [k_1:k_2]
f [Hz]	**P [dBm/Hz]**
0	-97.5
3.99k	-97.5
4 k	-92.5
f_1 -20k	-92.5
f_1	-38
f_2	-38
f_2 +40k	-90
1.221M	-90
1.630M	-110
30M	-110
$f_1 = (k_1–½) \times f_c$ $f_2 = (k_2+½) \times f_c$ $f_c = \Delta f = 4.3125$ kHz	

Default values: [k_1 : k_2] = [7:31]

ADSL over POTS (EC) DMT carriers [k_3:k_4]	Down [k_3:k_4]
f [Hz]	**P [dBm/Hz]**
0	-97.5
3.99 k	-97.5
4 k	-92.5
f_3 -20k	-92.5
f_3	-40
f_4	-40
f_4 +100k	-90
3.093M	-90
4.545M	-110
30M	-110
$f_3 = (k_3–½) \times f_c$ $f_4 = (k_4+½) \times f_c$ $f_c = \Delta f = 4.3125$ kHz	

Default values: [k_3 : k_4] = [7:255]

ALCATEL PROPOSAL

ADSL over POTS Spec overlap	*Up 100 Ω*
[Hz]	**[dBm/Hz]**
0	-101
3.99k	-101
4k	-96
25.875k	-38
138k	-38
229.6k	-92.9
686k	-100
1.411M	-100
1.630M	-110
30M	-110

ADSL over POTS Spec overlap	*Down 100 Ω*
[Hz]	**[dBm/Hz]**
0	-101
3.99k	-101
4k	-96
25.875k	-40
1.104M	-40
3.093M	?
4.545M	?
30M	?

RAPPORTEURS PROPOSAL: ALCATEL/KPN MIXTURE

ADSL over POTS (EC) DMT carriers [k_1:k_2]	Up [k_1:k_2]
f [Hz]	**P [dBm/Hz]**
0	-101
3.99k	-101
4 k	-96
$f_1 - 5.5 \times f_c$	-96
f_1	-38
f_2	-38
$f_2 + 21.5 \times f_c$	-90
686 k	-100
1.411M	-100
1.630M	-110
5.275M	-112
30M	-112
$f_1 = (k_1–½) \times f_c$ $f_2 = (k_2+½) \times f_c$ $f_c = \Delta f = 4.3125$ kHz	

Default values: [k_1 : k_2] = [7:31]

ADSL over POTS (EC) DMT carriers [k_3:k_4]	Down [k_3:k_4]
f [Hz]	**P [dBm/Hz]**
0	-101
3.99 k	-101
4 k	-96
$f_3 - 5.5 \times f_c$	-96
f_3	-40
f_4	-40
$f_4 + 23 \times f_c$	-90
3.093M	-90
4.545M	-112
30M	-112
$f_3 = (k_3–½) \times f_c$ $f_4 = (k_4+½) \times f_c$ $f_c = \Delta f = 4.3125$ kHz	

Default values: [k_3 : k_4] = [7:255]

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

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 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 break frequencies, (f_1 and f_2) and (f_3 and f_4), are dependent on the used DMT tones, (k_1 to k_2) and (k_3 to k_4), and they are to be specified first when using this PSD template. Default values are given for guidance only. The source impedance equals 100Ω.

NOTE: The FSAN legacy 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.

FSAN LEGACY

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

KPN PROPOSAL

ADSL.FDD over POTS DMT carriers [k_1:k_2]	***Up [k_1:k_2]***
f [Hz]	***P [dBm/Hz]***
1	-97.5
3.99 k	-97.5
4 k	-92.5
f_1 -20k	-92.5
f_1	-38
f_2	-38
f_2 +40k	-90
1.221M	-90
1.630M	-110
30M	-110
$f_1 = (k_1-\frac{1}{2}) \times f_c$ $f_2 = (k_2+\frac{1}{2}) \times f_c$ $f_c = \Delta f = 4.3125$ kHz	

ADSL.FDD over POTS DMT carriers [k_3:k_4]	***Down [k_3:k_4]***
f [Hz]	***P [dBm/Hz]***
1	-97.5
3.99 k	-97.5
4 k	-92.5
f_3 -40k	-92.5
f_3	-40
f_4	-40
f_4 +100k	-90
3.093M	-90
4.545M	-110
30M	-110
$f_3 = (k_3-\frac{1}{2}) \times f_c$ $f_4 = (k_4+\frac{1}{2}) \times f_c$ $f_c = \Delta f = 4.3125$ kHz	

Default values: [k_1 : k_2] = [7:30]

Default values: [k_3 : k_4] = [38:255]

ALCATEL PROPOSAL

ADSL over POTS Spec nonoverlap	***Up 100 Ω***
[Hz]	**[dBm/Hz]**
0	-101
3.99k	-101
4k	-96
25.875k	-38
138k	-38
229.6k	-92.9
686k	-100
1.411M	-100
1.630M	-110
30M	-110

ADSL over POTS Spec nonoverlap	***Down 100 Ω***
[Hz]	**[dBm/Hz]**
0	-101
3.99k	-101
4k	-96
80k	-76
138	-47.7
138	-40
1.104M	-40
3.093M	?
4.545M	?
30M	?

RAPPORTEURS PROPOSAL: ALCATEL/KPN MIXTURE

ADSL.FDD over POTS DMT carriers [k_1:k_2]	*Up [k_1:k_2]*
f [Hz]	*P [dBm/Hz]*
0	-101
3.99k	-101
4 k	-96
f_1 - 5.5×f_c	-96
f_1	-38
f_2	-38
f_2 + 10×f_c	-90
686 k	-100
1.411M	-100
1.630M	-110
5.275M	-112
30M	-112
$f_1 = (k_1–½) × f_c$ $f_2 = (k_2+½) × f_c$ $f_c = \Delta f = 4.3125$ kHz	

ADSL.FDD over POTS DMT carriers [k_3:k_4]	*Down [k_3:k_4]*
f [Hz]	*P [dBm/Hz]*
0	-101
3.99 k	-101
4 k	-96
f_3 - 10×f_c	-96
f_3 - 0.5×f_c	-47.7
f_3	-40
f_4	-40
f_4 + 23×f_c	-90
3.093M	-90
4.545M	-112
30M	-112
$f_3 = (k_3–½) × f_c$ $f_4 = (k_4+½) × f_c$ $f_c = \Delta f = 4.3125$ kHz	

Default values: [k_1 : k_2] = [7:30]

Default values: [k_3 : k_4] = [38:255]

Table 5. PSD template values at break frequencies for modelling "ADSL.FDD over POTS". The default tone set enable a guard band between upstream and downstream PSD of 7 unused tones.

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

The PSD template for modeling the "ADSL over ISDN" transmit spectrum (EC variant) 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 break frequencies, (f_1 and f_2) and (f_3 and f_4), are dependent on the used DMT tones, (k_1 to k_2) and (k_3 to k_4), and they are to be specified first when using this PSD template. Default values are given for guidance only. The source impedance equals 100Ω.

NOTE: The FSAN legacy 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.

FSAN LEGACY

ADSL over ISDN	*Up 100 Ω*
[Hz]	**[dBm/Hz]**
0	-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]**
0	-90
50k	-90
80k	-81.8
138k	-40
1.104M	-40
3.093M	-90
4.545M	-110
30M	-110

KPN PROPOSAL

ADSL over ISDN (EC) DMT carriers $[k_1:k_2]$	***Up $[k_1:k_2]$***
f [Hz]	***P [dBm/Hz]***
0	-90
f_1 -40k	-90
f_1	-38
f_2	-38
f_2 +40k	-90
1.221M	-90
1.630M	-110
30M	-110
$f_1 = (k_1–½) \times f_c$ $f_2 = (k_2+½) \times f_c$ $f_c = \Delta f$ = 4.3125 kHz	

Default values: $[k_1 : k_2]$ = [33:63]

ADSL over ISDN (EC) DMT carriers $[k_3:k_4]$	***Down $[k_3:k_4]$***
f [Hz]	***P [dBm/Hz]***
0	-90
f_3 -40k	-90
f_3	-40
f_4	-40
f_4 +100k	-90
3.093M	-90
4.545M	-110
30M	-110
$f_3 = (k_3–½) \times f_c$ $f_4 = (k_4+½) \times f_c$ $f_c = \Delta f$ = 4.3125 kHz	

Default values: $[k_3 : k_4]$ = [33:255]

ALCATEL PROPOSAL

ADSL over ISDN Spec overlap	***Up 100 Ω***
[Hz]	**[dBm/Hz]**
0	-90
50k	-90
80k	-85.3
120k	-38
276k	-38
491k	-97.8
686k	-100
1.411M	-100
1.630M	-110
5.275M	-112
30M	-112

ADSL over ISDN Spec overlap	***Down 100 Ω***
[Hz]	**[dBm/Hz]**
0	-90
50k	-90
80k	-85.3
120k	-40
1.104M	-40
3.093M	?
4.545M	?
30M	?

RAPPORTEURS PROPOSAL: ALCATEL/KPN MIXTURE

ADSL over ISDN (EC) DMT carriers $[k_1:k_2]$	***Up $[k_1:k_2]$***
f [Hz]	***P [dBm/Hz]***
0	-90
50	-90
$f_1 - 10 \times f_c$	-85.3
f_1	-38
f_2	-38
$f_2 + 4 \times f_c$	-55
$f_2 + 11 \times f_c$	-60
$f_2 + 17 \times f_c$	-97.8
686	-100
1.411M	-100
1.630M	-110
5.275M	-112
30M	-112
$f_1 = (k_1–½) \times f_c$ $f_2 = (k_2+½) \times f_c$ $f_c = \Delta f$ = 4.3125 kHz	

Default values: $[k_1 : k_2]$ = [33:63]

ADSL over ISDN (EC) DMT carriers $[k_3:k_4]$	***Down $[k_3:k_4]$***
f [Hz]	***P [dBm/Hz]***
0	-90
50 k	-90
$f_3 - 10 \times f_c$	-85.3
f_3	-40
f_4	-40
$f_4 + 23 \times f_c$	-90
3.093M	-90
4.545M	-112
30M	-112
$f_3 = (k_3–½) \times f_c$ $f_4 = (k_4+½) \times f_c$ $f_c = \Delta f$ = 4.3125 kHz	

Default values: $[k_3 : k_4]$ = [33:255]

Table 6. PSD template values at break frequencies for modeling "ADSL over ISDN (EC)"

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

The PSD template for modeling the "ADSL.FDD over ISDN" transmit spectrum is defined in terms of break frequencies, as summarized in table 7. 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 break frequencies, (f_1 and f_2) and (f_3 and f_4), are dependent on the used DMT tones, (k_1 to k_2) and (k_3 to k_4), and they are to be specified first when using this PSD template. Default values are given for guidance only. The source impedance equals 100Ω.

NOTE: The FSAN legacy 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.

FSAN LEGACY

ADSL.FDD over ISDN	***Up 100 Ω***
[Hz]	**[dBm/Hz]**
0	-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	-90
93.1	-90
209	-62
253.99	-48.5
254	-40
1104	-40
3093	-90
4545	-110
30000	-110

KPN PROPOSAL

ADSL.FDD over ISDN DMT carriers [k_1:k_2] f [Hz]	***Up [k_1:k_2] P [dBm/Hz]***
0	-90
f_1 -40k	-90
f_1	-38
f_2	-38
f_2 +40k	-90
1.221M	-90
1.630M	-110
30M	-110
$f_1 = (k_1 - ½) \times f_c$ $f_2 = (k_2 + ½) \times f_c$ $f_c = \Delta f = 4.3125$ kHz	

Default values: [k_1 : k_2] = [33:56]

ADSL.FDD over ISDN DMT carriers [k_3:k_4] f [Hz]	***Down [k_3:k_4] P [dBm/Hz]***
0	-90
f_3 -40k	-90
f_3	-40
f_4	-40
f_4 +100k	-90
3.093M	-90
4.545M	-110
30M	-110
$f_3 = (k_3 - ½) \times f_c$ $f_4 = (k_4 + ½) \times f_c$ $f_c = \Delta f = 4.3125$ kHz	

Default values: [k_3 : k_4] = [64:255]

ALCATEL PROPOSAL

ADSL over ISDN Spec nonoverlap	***Up 100 Ω***
[Hz]	**[dBm/Hz]**
0	-90
50k	-90
80k	-85.3
120k	-38
276k	-38
491k	-97.8
686k	-100
1.411M	-100
1.630M	-110
5.275M	-112
30M	-112

ADSL over ISDN Spec nonoverlap	***Down 100 Ω***
[Hz]	**[dBm/Hz]**
0	-90
93.1k	-90
209k	-65.5
253.99	-52
254k	-40
1.104M	-40
3.093M	?
4.545M	?
30M	?

RAPPORTEURS PROPOSAL: ALCATEL/KPN MIXTURE

ADSL.FDD over ISDN DMT carriers [k_1:k_2]	*Up [k_1:k_2]*
f [Hz]	*P [dBm/Hz]*
0	-90
50	-90
f_1 - 10×f_c	-85.3
f_1	-38
f_2	-38
f_2 + 4×f_c	-55
f_2 + 11×f_c	-60
f_2 + 17×f_c	-97.8
686	-100
1.411M	-100
1.630M	-110
5.275M	-112
30M	-112
$f_1 = (k_1–½) × f_c$ $f_2 = (k_2+½) × f_c$ $f_c = \Delta f = 4.3125$ kHz	

Default values: [k_1 : k_2] = [33:56]

ADSL.FDD over ISDN DMT carriers [k_3:k_4]	*Down [k_3:k_4]*
f [Hz]	*P [dBm/Hz]*
0	-90
f_3 - 10×f_c	-90
f_3 - 0.5×f_c	-52
f_3	-40
f_4	-40
f_4 +23×f_c	-90
3.093M	-90
4.545M	-112
30M	-112
$f_3 = (k_3–½) × f_c$ $f_4 = (k_4+½) × f_c$ $f_c = \Delta f = 4.3125$ kHz	

Default values: [k_3 : k_4] = [64:255]

Table 7. PSD template values at break frequencies for modeling "ADSL.FDD over ISDN". The default tone set enable a guard band between upstream and downstream PSD of 7 unused tones.

Text portions proposed for inclusion into clause 5

5 Generic receiver performance models for xDSL

A receiver 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 receiver is ideal (zero internal receiver noise, infinite echo cancellation, etc), 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 a cascade of smaller submodels:

- a line code independent *input* (sub)model that evaluates the effective SNR from received signal, received noise, and various receiver imperfections. Details are described in clause 5.1.
- a line code dependent *detection* (sub)model that evaluates the performance (e.g. the noise margin at specified bit rate) from the effective SNR. Details are described in clause 5.2.
- a *echo coupling* (sub)model that evaluates what portion of the transmitted signal flows into the receiver. Details are described in clause 5.3.

This clause details all the above mentioned sub models, being used for evaluating the performance of receivers under noise conditions. This clause 5 is dedicated to *generic* performance models only. Clause 6 is dedicated to *specific* models by assigning values to all parameters of a generic model.

5.1 Generic input models for effective SNR

An input (sub) model describes how to evaluate the effective SNR, as intermediate result (see figure 1), from various input quantities and imperfections.

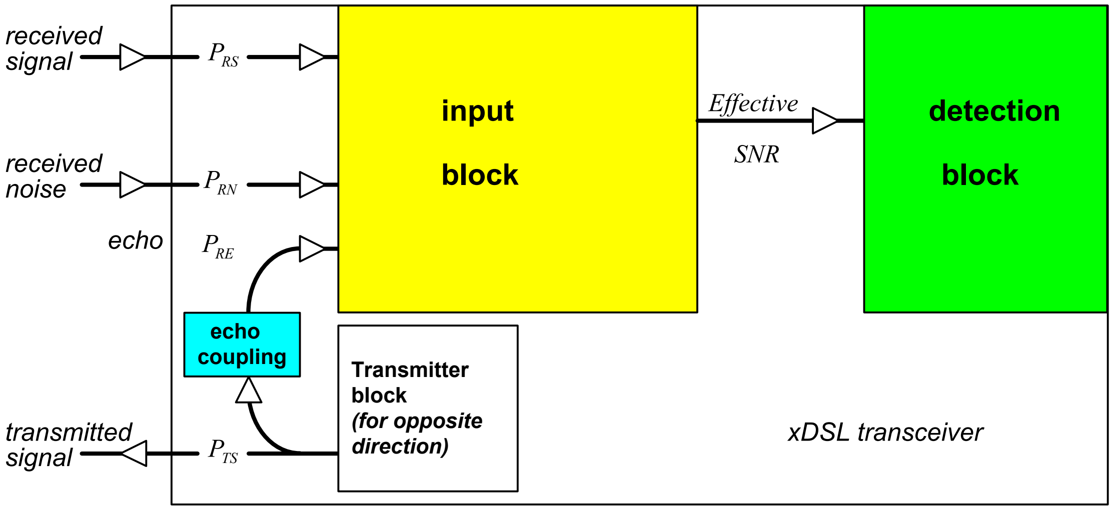


Figure 1: Flow diagram of a transceiver model, build up from individual submodels.

On input, the input model for effective SNR requires values for *signal*, *noise* and *echo*. The flow diagram in figure 1 illustrates this for an xDSL transceiver that is connected via a common wire pair to another transceiver (not shown).

- The received *signal* power P_{RS} carries the data that is to be recovered. This signal originates from the transmitter at the other side of the wire pair, and its level is attenuated by cable loss.
- The received *noise* power P_{RN} is all that is received when the transmitters at both sides of the link under study are silent. The origin of this noise is mainly cross talk from internal disturbers connected to the same cable (cross talk noise), and partly from external disturbers (ingress noise).
- The received *echo* power P_{RE} is all that is received when the transmitter at the other end of the wire pair is silent, as well as all internal and external disturbers. It is a residue that will be received when a transmitter and a receiver are combined into a transceiver en co-connected via a hybrid to the same wire pairs. When the hybrid of that transceiver is unbalanced due to mismatched termination impedances (of the cable), then a portion (P_{RE}) of the transmitted signal (P_{TS}) will leak into the receiver and is identified as echo. Models for echo coupling are specified in clause 5.3.

On output, the input model evaluates a quantity called effective SNR (Signal to noise Ratio) that indicates to what degree the received signal is deteriorated by noise, residual echo and all kinds of implementation imperfections. Due to signal processing in the receiver, the *input* SNR (the ratio between signal power, and the power-sum of noise and echo) will change into the *effective* SNR at some virtual internal point at the receiver. The effective SNR can be better or worse then the input SNR. Receivers with build-in echo cancellation can take advantage of a-priori knowledge on the echo, and can suppress most of this echo and thus improving the effective SNR. On the other hand, all analog receiver electronics produce shot noise and thermal noise, the A/D-converter produces quantization noise, and the equalization has its limitations as well. The combination of all these individual imperfections deteriorates the effective SNR.

In principle all parameters of the effective SNR can be assumed as frequency dependent, but this dependency has often been omitted here for reasons of simplicity. In addition, external change of signal and noise levels will modify the value of this effective SNR.

Effective SNR, in offset format for margin evaluations

To simplify further analysis of performance quantities like *noise margin* and *signal margin*, the effective SNR is often expressed in its offset format, characterized by an additional parameter *m*. With this parameter *m* the external noise level can be increased (for noise margin calculations) or the external signal level can be decreased (for signal margin calculations). The convention is that when *m*=1 (equals zero dB) the effective *offset* SNR equals the effective SNR itself. When the value of parameter *m* increases, the effective offset SNR decreases.

5.1.1. First order input model

This input model is quite a simplified model that assumes that the SNR of the input signal is internally modified by internal receiver noise (P_{RN0}). Most imperfections of the receiver (such as imperfect echo suppression, imperfect equalization and quantization noise) are assumed to be concentrated in a single virtual internal noise source (P_{RN0}). Figure 2 shows the flow diagram of an xDSL transceiver model that incorporates a linear first order model for effective SNR evaluation.

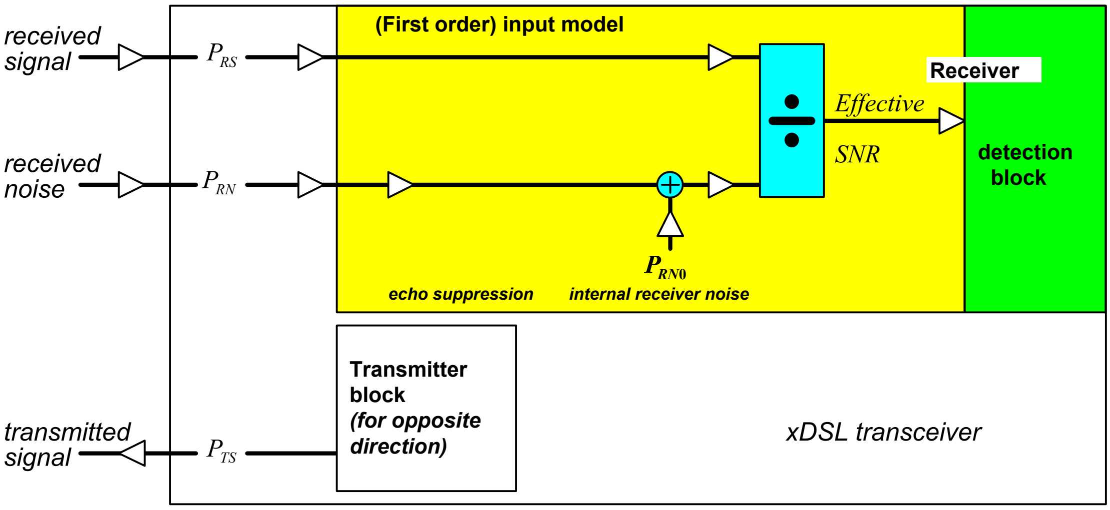


Figure 2: Flow diagram of a transceiver model that incorporates a linear first order input model for the determination of the effective SNR.

Expression 2 summarizes how to evaluate the effective SNR for this model, and it has been specified in plain and offset formats. Table 8 summarizes the involved parameters.

Plain format: $SNR(f) = \dfrac{P_{RS}}{P_{RN} + P_{RN0}}$

Noise offset format: $SNR_{\text{ofs,N}}(m, f) = \dfrac{P_{RS}}{P_{RN} \times m + P_{RN0}}$

Signal offset format: $SNR_{\text{ofs,S}}(m, f) = \dfrac{P_{RS} / m}{P_{RN} + P_{RN0}}$

Expression 2: Effective SNR, in various formats, for a first order input model

INPUT QUANTITIES	*linear*	*In dB*	*remarks*
Received signal power	P_{RS}	$10\times\log_{10}(P_{RS})$	*Frequency dependent*
Received crosstalk noise	P_{RN}	$10\times\log_{10}(P_{RN})$	*External noise*
Model Parameters			
Receiver noise power	P_{RN0}	$10\times\log_{10}(P_{RN0})$	*Internal noise*
Output quantities			
Signal to noise ratio (effective)	SNR	$10\times\log_{10}(SNR)$	*Frequency dependent*

Table 8: Involved parameters and quantities for a first order input model.

5.1.2. Second order input model (with residual distortion)

This input model assumes that the SNR of the input signal is internally modified by two effects:

- an equivalent *receiver noise power* P_{RN0} that indicates how much noise is added by the receiver electronics.
- a *distortion suppression factor* η_d that indicates how effective equalization has been implemented. It represents the difference between transmitted signal and equalized received signal, and any non-zero difference behaves like noise.

Figure 3 shows the flow diagram of this model.

The importance of including distortion suppression in this input model is mainly to extend the validity of the model to scenarios with relatively high SNR values. This is of particular interest when studying scenarios for FDD modems.

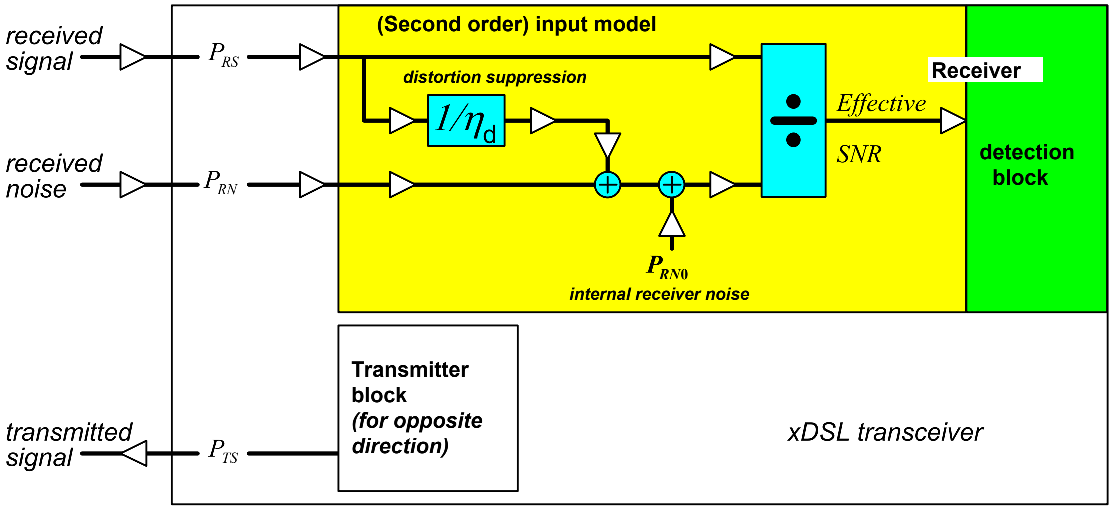


Figure 3: Flow diagram of a transceiver model that incorporates a linear second order input model for the determination of the effective SNR.

Expression 3 summarizes how to evaluate the effective SNR for this model, and it has been specified in plain and offset formats. Table 9 summarizes the involved parameters.

Plain format: $SNR(f) = \dfrac{P_{RS}}{P_{RN} + P_{RN0} + P_{RS} / \eta_d^2}$

Noise offset format: $SNR_{\text{ofs,N}}(m, f) = \dfrac{P_{RS}}{P_{RN} \times m + P_{RN0} + P_{RS} / \eta_d^2}$

Signal offset format: $SNR_{\text{ofs,S}}(m, f) = \dfrac{P_{RS} / m}{P_{RN} + P_{RN0} + P_{RS} / (\eta_d^2 \times m)}$

Expression 3: Effective SNR, in various formats for a second order input model accounting for residual distortion

INPUT QUANTITIES	linear	In dB	remarks
Received signal power	P_{RS}	$10\times\log_{10}(P_{RS})$	*Frequency dependent*
Received crosstalk noise	P_{RN}	$10\times\log_{10}(P_{RN})$	*External noise*
Received reflected power	P_{RE}	$10\times\log_{10}(P_{RE})$	*External noise*
Model Parameters			
Receiver noise power	P_{RN0}	$10\times\log_{10}(P_{RN0})$	*Internal noise*
Distortion suppression	η_d	$20\times\log_{10}(\eta_d)$	*Quality of equalizer*
Output quantities			
Signal to noise ratio (effective)	SNR	$10\times\log_{10}(SNR)$	*Frequency dependent*

Table 9: Involved parameters and quantities for a second order input model, accounting for residual distortion.

5.1.3. Second order input model (with residual echo)

This input model assumes that the SNR of the input signal is internally modified by two effects:

- an equivalent *receiver noise power* P_{RN0} that indicates how much noise is added by the receiver electronics.
- an *echo suppression factor* η_e that indicates how effective echo cancellation is implemented.

Therefore this input model is enhanced with a simple but effective model of echo coupling as specified in clause 5.3. It models the echo coupling caused by the analogue hybrid used for “isolating” received and transmitted signal in a transceiver. When echo cancelation is on board, the echo can be suppressed additionally by a parameter η_e. Figure 4 shows the flow diagram of this model.

The importance of including echo cancellation in this input model is mainly to cover the case that *lacks* echo cancellation, such as for FDD systems like ADSL and VDSL. Residual frequency overlap in the guard bands between up and downstream spectra may cause some deterioration of performance. By tweaking the value for echo suppression η_e, the amount of additional echo cancellation can be controlled.

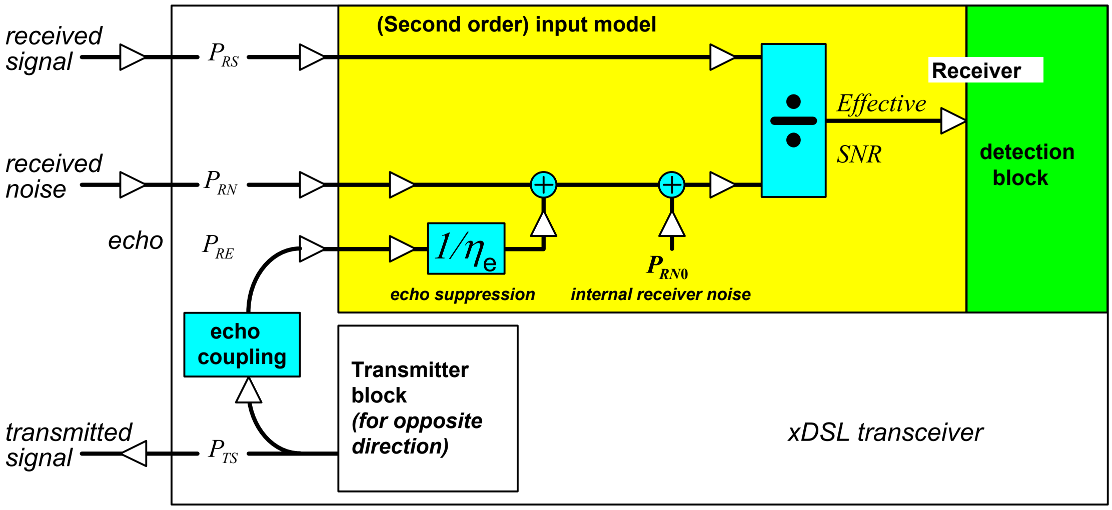


Figure 4: Flow diagram of a transceiver model that incorporates a linear second order input model for the determination of the effective SNR.

Expression 4 summarizes how to evaluate the effective SNR for this model, and it has been specified in plain and offset formats. Table 10 summarizes the involved parameters.

Plain format: $SNR(f) = \dfrac{P_{RS}}{P_{RN} + P_{RN0} + P_{RE} / \eta_e^2}$

Noise offset format: $SNR_{\text{ofs,N}}(m, f) = \dfrac{P_{RS}}{P_{RN} \times m + P_{RN0} + P_{RE} / \eta_e^2}$

Signal offset format: $SNR_{\text{ofs,S}}(m, f) = \dfrac{P_{RS} / m}{P_{RN} + P_{RN0} + P_{RE} / \eta_e^2}$

Expression 4: Effective SNR, in various formats, for a second order input model accounting for residual echo

INPUT QUANTITIES	***linear***	***In dB***	***remarks***
Received signal power	P_{RS}	$10\times\log_{10}(P_{RS})$	*Frequency dependent*
Received crosstalk noise	P_{RN}	$10\times\log_{10}(P_{RN})$	*External noise*
Received reflected power	P_{RE}	$10\times\log_{10}(P_{RE})$	*External noise*
Model Parameters			
Receiver noise power	P_{RN0}	$10\times\log_{10}(P_{RN0})$	*Internal noise*
Echo suppression	η_e	$20\times\log_{10}(\eta_e)$	*Quality of echo canceller*
Output quantities			
Signal to noise ratio (effective)	SNR	$10\times\log_{10}(\text{SNR})$	*Frequency dependent*

Table 10: Involved parameters and quantities for a second order input model accounting for residual echo

5.1.4. Third order input model (with residual distortion and echo)

This input model assumes that the SNR of the input signal is internally modified by three effects:

- an equivalent *receiver noise power* P_{RN0} that indicates how much noise is added by the receiver electronics.
- an *echo suppression factor* η_{e} that indicates how effective echo cancellation is implemented.
- a *distortion suppression factor* η_{d} that indicates how effective equalization has been implemented. It represents the difference between transmitted signal and equalized received signal, and any non-zero difference behaves like noise.

This model is essentially the combination of the two previous (second order) models, and is shown in figure 5.

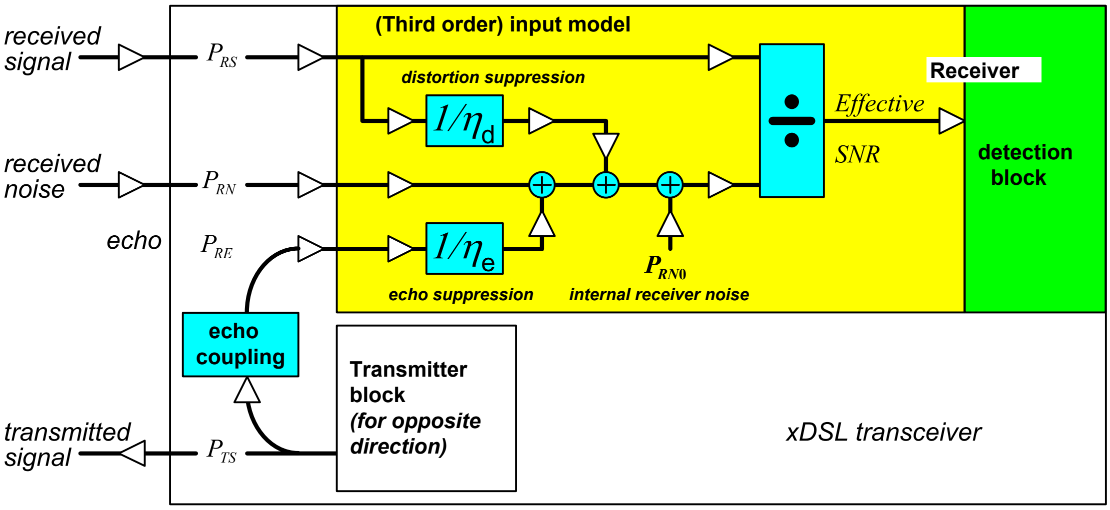


Figure 5: Flow diagram of a transceiver model that incorporates a linear third order input model for the determination of the effective SNR.

Expression 5 summarizes how to evaluate the effective SNR for this model, and it has been specified in plain and offset formats. Table 11 summarizes the involved parameters.

Plain format: $SNR(f) = \dfrac{P_{RS}}{P_{RN} + P_{RN0} + P_{RE}/\eta_e^2 + P_{RS}/\eta_d^2}$

Noise offset format: $SNR_{\mathrm{ofs,N}}(m, f) = \dfrac{P_{RS}}{P_{RN} \times m + P_{RN0} + P_{RE}/\eta_e^2 + P_{RS}/\eta_d^2}$

Signal offset format: $SNR_{\mathrm{ofs,S}}(m, f) = \dfrac{P_{RS}/m}{P_{RN} + P_{RN0} + P_{RE}/\eta_e^2 + P_{RS}/(\eta_d^2 \times m)}$

Expression 5: Effective SNR, in various formats for a third order input model

INPUT QUANTITIES	**linear**	**In dB**	**remarks**
Received signal power	P_{RS}	$10\times\log_{10}(P_{RS})$	*Frequency dependent*
Received crosstalk noise	P_{RN}	$10\times\log_{10}(P_{RN})$	*External noise*
Received reflected power	P_{RE}	$10\times\log_{10}(P_{RE})$	*External noise*
Model Parameters			
Receiver noise power	P_{RN0}	$10\times\log_{10}(P_{RN0})$	*Internal noise*
Echo suppression	η_e	$20\times\log_{10}(\eta_e)$	*Quality of echo canceller*
Distortion suppression	η_d	$20\times\log_{10}(\eta_d)$	*Quality of equalizer*
Output quantities			
Signal to noise ratio (effective)	SNR	$10\times\log_{10}(\text{SNR})$	*Frequency dependent*

Table 11: Involved parameters and quantities for a third order input model.

5.2 Generic detection models

5.2.4 Generic DMT detection model

The calculation of the margin *m* using the generic DMT detection model is equivalent with solving the equations in expression 6, for a given line rate f_b. The associated parameters are summarized in table 12, and function *bitload* is specified by the chosen bit-loading algorithm. The effective SNR is to be evaluated by using one of the input models described in clause 5.1. Depending on what offset format is used for the SNR expression, the calculated margin *m* will represent the noise margin m_n or the signal margin m_s.

$$\Delta b_k = \int_{(k-½)\bullet f_c}^{(k+½)\bullet f_c} \log_2\left(1+\frac{SNR_{ofs}(m,f)}{\Gamma}\right)\cdot df$$
$$f_b = f_s \times b = f_s \times \sum_{k\in tones} bitload(\Delta b_k)$$

Expression 6: Equation of the DMT-detection model,
for solving the margin m for a given line rate f_b.

Bit-loading algorithm

The DMT carriers are all positioned at a multiple of the carrier frequency f_c, and each carrier may carry a fraction of the symbol by means of a few bits. The way this bit space is used to load each carrier with bits is implementation dependent.

Bit-loading algorithms do commonly use masking. Masking means skipping carriers for bit-loading when their bit space Δb_k is below some predefined minimum value Δb_{min}, and limiting the bit-loading to some pre-defined maximum when the bit space Δb_k exceeds some predefined maximum Δb_{max}. When data transport has been pushed to its limits (zero margin), the following bit-loading algorithms may apply, in addition to masking:

- *Fractional bit-loading* is a pure theoretical approach enabling to load even (non-integer) fractions of the bit space Δb_k on carrier *k*. This maximizes the use of the available capacity, but is unpractical to implement.

$(\Delta b_k < \Delta b_{min})$	$\Rightarrow$	$bitload(\Delta b_k) \equiv 0$
$(\Delta b_k \geq \Delta b_{min})$ and $(\Delta b_k < \Delta b_{max})$	$\Rightarrow$	$bitload(\Delta b_k) \equiv \Delta b_k$
$(\Delta b_k > \Delta b_{max})$	$\Rightarrow$	$bitload(\Delta b_k) \equiv \Delta b_{max}$

- *Truncated bit-loading* is a more feasible in practice, and loads each carrier *k* to a number of bits equal to the largest non-negative integer *below* the bit space Δb_k.
- *Rounded bit-loading* is also feasible in practice, and loads each carrier *k* to a number of bits equal to the nearest non-negative integer of bit space Δb_k.

- *Gain adjusted bit-loading* is a sophisticated combination of rounded bit-loading and adjustment of powers to each of the tones, so that each individual bit space Δb_k approaches a rounded value (minimizes the loss of capacity), while the total transmit power is kept unchanged on average.

In various applications, it may be assumed that the capacity of well-designed *gain adjusted* bit-loading algorithms closely match those achieved by *fractional* bit-loading. For reasons of simplicity, and for making capacity calculations in this document less implementation dependent, the fractional bit-loading algorithm is used as default for DMT calculations all over this document, unless specified explicitly otherwise.

SNR-Gap

The (effective) SNR gap Γ, being used in the above expression 6, is a combination of various effects. This Γ parameter is often split-up into the following three parts:

- Its theoretical value Γ_{DMT} (in the order of 9.75 dB at BER = 10^{-7})
- 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 adjustment for all *unidentified* implementation losses $\Delta\Gamma_{impl}$ (usually a few dB as well), indicating how much overall performance degradation is caused by implementation dependent imperfections (e.g. echo cancellation and equalization).

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

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

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

Involved parameters

Input quantities	linear	In dB	remarks
Signal to Noise Ratio	SNR	$10\times\log_{10}(SNR)$	Frequency dependent ratio of powers
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_{DMT} $\Delta\Gamma_{coding}$ $\Delta\Gamma_{impl}$	$10\times\log_{10}(\Gamma_{DMT})$ $10\times\log_{10}(\Delta\Gamma_{coding})$ $10\times\log_{10}(\Delta\Gamma_{impl})$	Theoretical linecode value Coding gain Implementation loss
Symbol rate	f_s		The DMT symbol rate
Data rate	f_d		All payload bits that are to be transported in 1 sec
Line rate	f_b		= Date rate + overhead bitrate
Available set of tones	tones		Can be a subset of all possible tones. (e.g. tones = [7:255])
Carrier frequency (of tone k); k $\in$ tones	$k\times f_c$		
Bits per symbol	b		= f_b / f_s Bits of each symbol are spread out over all used carriers.
Bit-loading algorithm	<specify>		Can be one of: • Fractional • Truncated • Rounded • Gain adjusted
Minimum bit-loading	Δb_{min}		
Maximum bit-loading	Δb_{max}		
Output quantities			
Noise margin	m_n	$10\times\log_{10}(m_n)$	
Signal margin	m_s	$10\times\log_{10}(m_s)$	

Table 12: Parameters used for DMT detection models.

The various parameters in table 12, used within this generic detection model, have the following meaning:

- The SNR-gap (Γ) is a parameter indicative for how close the Shannon capacity limit can be approached.
- 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 then the line rate since multiple bits per symbol are packed together, and spread-out over many carriers.
- The available tones are a list of integers that indicate what frequency band can be occupied by individual carriers. For instance all tones from tone 7 to tone 255.
- The carrier frequency is the frequency of the first non-zero carrier.
- The minimum and maximum bit-loading specify in what range the bit space of each carrier is loaded. Bit loading is skipped when the bit space is below Δb_{min}, and limited when the bitspace exceeds Δb_{max}.

5.3 Generic model for echo coupling

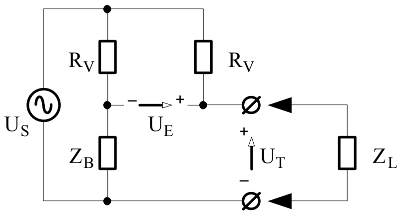
5.3.1 Linear echo coupling model

ED NOTE: clause 7.2 from the draft will be moved to this section, because it is more appropriate. It is proposed to rephrase it as follows:

This model describes a property of linear hybrids in transceivers, and models what portion of the transmitted signal reflects directly into the receiver. The hybrid is characterized by two parameters:

- R_V, representing the output impedance of the transceiver. Commonly used values are the design impedances of the modems under test, including as 100Ω for ADSL and 135Ω for SDSL.
- Z_B, representing the termination impedance that causes that the hybrid is perfectly balanced. This means that when the hybrid is terminated with this "balance impedance", no echo will flow into the receiver. For well-designed hybrids, this balance impedance is a "best guess" approximation of the "average" impedance of cables being used.

Figure 6 shows an equivalent circuit diagram of the above hybrid, represented as a Wheatstone bridge. The associated transfer function $H_E(j\omega)$ expresses what portion of the transmit signal will appear as echo.



$$H_E(j\omega) = \frac{U_E}{U_T} = 1 - \frac{Z_B}{R_V + Z_B} \times \frac{U_S}{U_T} = \frac{(Z_L - Z_B) \times R_V}{(R_V - Z_B) \times Z_L}$$

$$\frac{P_{RE}}{P_{TS}} = \left| H_E(j\omega) \right|^2$$

Figure 6: Flow diagram of the basic model for echo loss The identifiers P_{RE} and P_{TS} refer to power flow values used in figure 1.

When using this basic model for echo loss in a full simulation, value R_V can be made equal to the design impedance of the modem under test, and value Z_B can be made equal to the complex and frequency dependent input impedance of the cable, terminated at the other cable end with a load impedance equal to R_V. Values for R_V and Z_B are implementation specific.

Text portions proposed for inclusion into clause 6

6 Specific receiver performance models for xDSL

6.4 Receiver performance model for “ADSL over POTS” (EC)

This calculation model is capable for predicting the minimum ***guaranteed*** performance of an ETSI compliant “ADSL over POTS” modem. The *typical* performance of individual modem implementations may exceed the performance predicted by this model, but cannot be guaranteed by mandatory requirements.

The reach predictions of this model are close to the ETSI reach requirements under the ETSI stress conditions as specified in the ETSI ADSL specification [4]. Deviations between the predictions and requirements are less then 100m. The validity of the predicted performance holds for a wider range of stress conditions.

6.4.1 Building blocks of the receiver performance model

The receiver performance model for ETSI compliant “ADSL over POTS” is build-up from the following building blocks:

- A first order (linear) input model for the input block (without echo and equalization imperfections), specified in clause 5.1.1.
- The generic DMT detection model, specified in clause 5.2.4.
- The parameter values specified in table 13 of the succeeding clause.

6.4.2 Parameters of the receiver performance model

The parameter values, used in the receiver performance model for ETSI compliant “ADSL over POTS” modems, are summarized in table 13. Part of them are directly based on ADSL specifications. The remaining values are based on theory.

Model parameter		DMT	model	
		Upstream	Downstream	Remarks
SNR-Gap (effective)	Γ_{dB}	7.5 dB	7.5 dB	
SNR-Gap in parts	Γ_{DMT_dB} $\Delta\Gamma_{coding\_dB}$ $\Delta\Gamma_{impl\_dB}$	9.75 dB 4.25 dB 2.0 dB	9.75 dB 4.25 dB 2.0 dB	
Receiver noise	P_{RN0_dB}	*(–135 dBm)* **–120 dBm**	–135 dBm	
Symbol rate	f_s	4000 baud	4000 baud	
Data rate	f_d	64 … 640 kb/s	64 … 6144 kb/s	
Line rate	f_b	$f_{bl} = f_d + 16 \cdot f_s$ $f_{bh} = (f_d + 8 \cdot f_s) \cdot 1.13$ $f_b = \max(f_{bl}, f_{bh})$	$f_{bl} = f_d + 16 \cdot f_s$ $f_{bh} = (f_d + 8 \cdot f_s) \cdot 1.13$ $f_b = \max(f_{bl}, f_{bh})$	
Bits per symbol	b	f_b / b	f_b / b	
Available set of tones	tones	[7:31] $= [k_1 : k_2]$	[7:63 , 65:255] $= [k_1 : k_2 , k_3 : k_4]$ Tone 64 = pilot tone	DMT tone k = 64 does not convey any bits because it is reserved as pilot tone.
Carrier frequency of tone 1	f_c	4.3125 kHz	4.3125 kHz	
Bit-loading algorithm		Fractional	Fractional	See (clause 5.2.4)
Minimum bit-loading	Δb_{min}	2	2	Bits per carrier
Maximum bit-loading	Δb_{max}	15	15	Bits per carrier

Table 13: Values for the performance parameters extracted from the ETSI performance requirements under ETSI stress conditions.

6.5 Receiver performance model for "ADSL.FDD over POTS"

> ED NOTE: The text below is a first proposal, and has raised the discussion of echo suppression should be included in the model or not. Echo becomes highly relevant when FDD modems (without echo suppression) need a guard band to separate upstream and downstream spectra.
>
> The advantage of modeling echo is that the range of scenarios for which the model is valid may increase. The drawback is that the differences between various implementations are too significant to represent it by a single model.
>
> A possible way forward is remove all echo cancellation form the model, and to accept that the validity of the model will decrease as well. The consequence is that the ***default*** model excludes tone 31-37 explicitly from being used for data transport. This was the basic assumption from vendors when the ADSL performance requirements were set.

This calculation model is capable for predicting the minimum ***guaranteed*** performance of an ETSI compliant "ADSL.FDD over POTS" modem. The *typical* performance of individual modem implementations may exceed the performance predicted by this model, but cannot be guaranteed by mandatory requirements.
The reach predictions of this model are close to the ETSI reach requirements under the ETSI stress conditions as specified in the ETSI ADSL specification [4]. Deviations between the predictions and requirements in most cases within 150m. The validity of the predicted performance holds for a wider range of stress conditions.

6.5.1 Building blocks of the downstream receiver performance model

The downstream receiver performance model for ETSI compliant "ADSL.FDD over POTS" is build-up from the following building blocks:

- The generic linear input model, specified in clause 5.1.2. This is a second order model that accounts for two imperfections: internal receiver noise (P_{RN0}) and echo suppression (η_e).
- The generic DMT detection model, specified in clause 5.2.4.
- The echo-coupling model, specified in clause 5.3.1. This is a linear hybrid, which has R_V=100Ω as output impedance and Z_B = (120Ω) + (150Ω//47nF) + (750Ω//150nF) as balance impedance.
- The parameter values specified in table 14.

6.5.2 Building blocks of the upstream receiver performance model

The upstream receiver performance model for ETSI compliant "ADSL.FDD over POTS" is build-up from the following building blocks:

- The generic linear input model, specified in clause 5.1.4. This is a third order model that accounts for three imperfections: internal receiver noise (P_{RN0}), echo suppression (η_e) and distortion suppression (η_e).
- The generic DMT detection model, specified in clause 5.2.4.
- The echo-coupling model, specified in clause 5.3.1. This is a linear hybrid, which has R_V=100Ω as output impedance and Z_B = (120Ω) + (150Ω//47nF) + (750Ω//150nF) as balance impedance.
- The parameter values specified in table 14.

6.5.3 Parameters of the receiver performance model

The parameter values, used in the receiver performance model for ETSI compliant "ADSL.FDD over POTS" modems, are summarized in table 14. Parts of them are directly based on ADSL specifications. The remaining values are extracted from the ADSL performance requirements [4] or based on theory.

Model parameter		***DMT model***		
		Upstream	***Downstream***	***Remarks***
SNR-Gap (effective)	Γ_{dB}	9.3 dB	8.9 dB	
SNR-Gap in parts	Γ_{DMT_dB} $\Delta\Gamma_{coding\_dB}$ $\Delta\Gamma_{impl\_dB}$	9.75 dB 4.25 dB 4.3 dB	9.75 dB 4.25 dB 3.9 dB	
Receiver noise	P_{RN0_dB}	–135 dBm **-120 dBm?**	–140 dBm	
Distortion suppression	η_d	35 dB	N/A	*See clause 5.1.4*
Echo suppression	η_e	0 dB	0 dB	*See clause 5.1.4*
Echo model		Linear hybrid (see text)	Linear hybrid (see text)	*See clause 5.1.4*
Symbol rate	f_s	4000 baud	4000 baud	
Data rate	f_d	64 … 640 kb/s	64 … 6144 kb/s	
Line rate	f_b	$f_{bl} = f_d + 16 \times f_s$ $f_{bh} = (f_d + 8 \times f_s) \times 1.13$ $f_b = \max(f_{bl}, f_{bh})$	$f_{bl} = f_d + 16 \times f_s$ $f_{bh} = (f_d + 8 \times f_s) \times 1.13$ $f_b = \max(f_{bl}, f_{bh})$	
Bits per symbol	*b*	f_b / b	f_b / b	
Available set of tones	*tones*	[7:30] = [k_1 : k_2] *Tone 31-37 are used as guard band*	[38:63, 65:255] = [k_1 : k_2 , k_3 : k_4] Tone 64 = pilot tone	*DMT tone k = 64 does not convey any bits because it is reserved as pilot tone.*
Carrier frequency of tone 1	f_c	4.3125 kHz	4.3125 kHz	
Bit-loading algorithm		Fractional	Fractional	*See clause 5.3.4*
Minimum bit-loading	Δb_{min}	2	2	*Bits per carrier*
Maximum bit-loading	Δb_{max}	15	15	*Bits per carrier*

Table 14: Values for the performance parameters extracted from the ETSI performance requirements under ETSI stress conditions.

6.6 Receiver performance model for “ADSL over ISDN” (EC)

This calculation model is capable for predicting the minimum ***guaranteed*** performance of an ETSI compliant “ADSL over ISDN” modem. The *typical* performance of individual modem implementations may exceed the performance predicted by this model, but cannot be guaranteed by mandatory requirements.
The reach predictions of this model are close to the ETSI reach requirements under the ETSI stress conditions as specified in the ETSI ADSL specification [4]. Deviations between the predictions and requirements are less then 80m. The validity of the predicted performance holds for a wider range of stress conditions.

6.6.1 Building blocks of the receiver performance model

The receiver performance model for ETSI compliant “ADSL over ISDN” is build-up from the following building blocks:

- A first order (linear) input model for the input block (without echo and equalization imperfections), specified in clause 5.1.1.
- The generic DMT detection model, specified in clause 5.2.4.
- The parameter values specified in table 15 of the succeeding clause.

6.6.2 Parameters of the receiver performance model

The parameter values, used in the receiver performance model for ETSI compliant “ADSL over ISDN” modems, are summarized in table 15. Part of them are directly based on ADSL specifications. The remaining values are based on theory.

Model parameter		**DMT**	**model**	
		Upstream	**Downstream**	**Remarks**
SNR-Gap (effective)	Γ_{dB}	7.8 dB	7.5 dB	
SNR-Gap in parts	Γ_{DMT_dB} $\Delta\Gamma_{coding\_dB}$ $\Delta\Gamma_{impl\_dB}$	9.75 dB 4.25 dB 2.3 dB	9.75 dB 4.25 dB 2.0 dB	
Receiver noise	P_{RN0_dB}	*(–135 dBm)* **–120 dBm**	–135 dBm	
Symbol rate	f_s	4000 baud	4000 baud	
Data rate	f_d	64 … 640 kb/s	64 … 6144 kb/s	
Line rate	f_b	$f_{bl} = f_d + 16 \cdot f_s$ $f_{bh} = (f_d + 8 \cdot f_s) \cdot 1.13$ $f_b = \max(f_{bl}, f_{bh})$	$f_{bl} = f_d + 16 \cdot f_s$ $f_{bh} = (f_d + 8 \cdot f_s) \cdot 1.13$ $f_b = \max(f_{bl}, f_{bh})$	
Bits per symbol	b	f_b /b	f_b /b	
Available set of tones	tones	[33:63] $= [k_1 : k_2]$	[33:95 , 97:255] $= [k_1 : k_2 , k_3 : k_4]$ Tone 96 = pilot tone	DMT tone k = 96 does not convey any bits because it is reserved as pilot tone.
Carrier frequency of tone 1	f_c	4.3125 kHz	4.3125 kHz	
Bit-loading algorithm		Fractional	Fractional	See (clause 5.2.4)
Minimum bit-loading	Δb_{min}	2	2	Bits per carrier
Maximum bit-loading	Δb_{max}	15	15	Bits per carrier

Table 15: Values for the performance parameters extracted from the ETSI performance requirements under ETSI stress conditions.

6.7 Receiver performance model for “ADSL over ISDN" (FDD)

> ED NOTE: The text below is a first proposal, and has raised the discussion of echo suppression should be included in the model or not. Echo becomes highly relevant when FDD modems (without echo suppression) need a guard band to separate upstream and downstream spectra.
>
> The advantage of modeling echo is that the range of scenarios for which the model is valid may increase. The drawback is that the differences between various implementations are too significant to represent it by a single model.
>
> A possible way forward is remove all echo cancellation form the model, and to accept that the validity of the model will decrease as well. The consequence is that the ***default*** model excludes tone 57-63 explicitly from being used for data transport. This was the basic assumption from vendors when the ADSL performance requirements were set.

This calculation model is capable for predicting the minimum ***guaranteed*** performance of an ETSI compliant “ADSL.FDD over ISDN” modem. The *typical* performance of individual modem implementations may exceed the performance predicted by this model, but cannot be guaranteed by mandatory requirements.

The reach predictions of this model are close to the ETSI reach requirements under the ETSI stress conditions as specified in the ETSI ADSL specification [4]. Deviations between the predictions and requirements are less then 200m and in most cases within 100m. The validity of the predicted performance holds for a wider range of stress conditions.

6.7.1 Building blocks of the downstream receiver performance model

The downstream receiver performance model for ETSI compliant “ADSL.FDD over ISDN” is build-up from the following building blocks:

- The generic linear input model, specified in clause 5.1.2. This is a second order model that accounts for two imperfections: internal receiver noise (P_{RN0}) and echo suppression (η_e).
- The generic DMT detection model, specified in clause 5.2.4.
- The echo-coupling model, specified in clause 5.3.1. This is a linear hybrid, which has R_V=100Ω as output impedance and Z_B = (120Ω) + (150Ω//47nF) + (750Ω//150nF) as balance impedance.
- The parameter values specified in table 16.

6.7.2 Building blocks of the upstream receiver performance model

The upstream receiver performance model for ETSI compliant “ADSL.FDD over ISDN” is build-up from the following building blocks:

- The generic linear input model, specified in clause 5.1.4. This is a third order model that accounts for three imperfections: internal receiver noise (P_{RN0}), echo suppression (η_e) and distortion suppression (η_e).
- The generic DMT detection model, specified in clause 5.2.4.
- The echo-coupling model, specified in clause 5.3.1. This is a linear hybrid, which has R_V=100Ω as output impedance and Z_B = (120Ω) + (150Ω//47nF) + (750Ω//150nF) as balance impedance.
- The parameter values specified in table 16.

6.7.3 Parameters of the receiver performance model

The parameter values, used in the receiver performance model for ETSI compliant “ADSL.FDD over ISDN” modems, are summarized in table 16. Parts of them are directly based on ADSL specifications. The remaining values are extracted from the ADSL performance requirements [4] or based on theory.

Model parameter		***DMT model***		
		Upstream	***Downstream***	***Remarks***
SNR-Gap (effective)	Γ_{dB}	9.6 dB	9.0 dB	
SNR-Gap in parts	Γ_{DMT_dB} $\Delta\Gamma_{coding\_dB}$ $\Delta\Gamma_{impl\_dB}$	9.75 dB 4.25 dB 4.6 dB	9.75 dB 4.25 dB 4.0 dB	
Receiver noise	P_{RN0_dB}	–135 dBm **–120 dBm (?)**	–140 dBm	
Distortion suppression	η_d	34 dB	N/A	*See clause 5.1.4*
Echo suppression	η_e	0 dB	0 dB	*See clause 5.1.4*
Echo model		Linear hybrid	Linear hybrid	*See clause 5.1.4*
Symbol rate	f_s	4000 baud	4000 baud	
Data rate	f_d	64 … 640 kb/s	64 … 6144 kb/s	
Line rate	f_b	$f_{bl} = f_d + 16 \times f_s$ $f_{bh} = (f_d + 8 \times f_s) \times 1.13$ $f_b = \max(f_{bl}, f_{bh})$	$f_{bl} = f_d + 16 \times f_s$ $f_{bh} = (f_d + 8 \times f_s) \times 1.13$ $f_b = \max(f_{bl}, f_{bh})$	
Bits per symbol	b	f_b/b	f_b/b	
Available set of tones	*tones*	[33:56] = [k_1 : k_2] *Tone 57-63 are used as guard band*	[64:95 , 97:255] = [k_1 : k_2 , k_3 : k_4] *Tone 96 = pilot tone*	*DMT tone k = 96 does not convey any bits because it is reserved as pilot tone.*
Carrier frequency of tone 1	f_c	4.3125 kHz	4.3125 kHz	
Bit-loading algorithm		Fractional	Fractional	*See clause 5.2.4*
Minimum bit-loading	Δb_{min}	2	2	*Bits per carrier*
Maximum bit-loading	Δb_{max}	15	15	*Bits per carrier*

Table 16: Values for the performance parameters extracted from the ETSI performance requirements under ETSI stress conditions.

End of literal text proposals

Hidden definitions: