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G.996.1

Amendment 1
(03/2003)

SERIES G: TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

Digital sections and digital line system – Access networks

Test procedures for digital subscriber line (DSL) transceivers

Amendment 1: New Annex B

ITU-T Recommendation G.996.1 (2001) – Amendment 1

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ITU-T Recommendation G.996.1

Test procedures for digital subscriber line (DSL) transceivers

Amendment 1

New Annex B

Summary

The amendment adds a new Annex B to ITU-T Rec. G.996.1 that contains primary constants and disturbers for test loops for use in ADSL+ in an environment coexisting with TCM-ISDN DSL.

Source

Amendment 1 to ITU-T Recommendation G.996.1 (2001) was prepared by ITU-T Study Group 15 (2001-2004) and approved under the WTSA Resolution 1 procedure on 16 March 2003.

FOREWORD

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

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ITU-T Recommendation G.996.1

Test procedures for digital subscriber line (DSL) transceivers

Amendment 1

New Annex B

1) New Annex B

Add the following Annex B to ITU-T Rec. G.996.1:

Annex B

Test loops and crosstalk disturbers of ADSL transceivers with extended bandwidth for environment coexisting with TCM-ISDN DSL as defined in ITU-T Rec. G.961 Appendix III

B.1 Test loops

B.1.1 Loop configurations

To test the performance of ADSL transceivers with extended bandwidth, the test loops in Figure 11 and the associate loop lengths in Table 10 shall be used.

B.1.2 Primary line constants

The primary line constants are R, L, C, and G. The equations below give the values of R in ohm/m, L in H/m, G in mho/m, C in F/m, and f (frequency) in Hz. The equation of G only is modified to that defined in 6.1.3. The coefficient values are shown in Table B.1. The values of the exponent "ge" contained in the equation of G are added in Table B.1, and the other coefficient values are the same as those shown in Table 11.

$$R = 2(Ri + Rn + Rns) \qquad \text{[ohm/m]}$$

$$L = 2(La + Li + Ln + Lns) \qquad \text{[H/m]}$$

$$C = C_i \qquad \text{[F/m]}$$

$$G = 2\pi f^{ge} C \tan\delta \qquad \text{[mho/m]}$$

$$Ri = \frac{1}{\pi r_i^2 \sigma_i} \mathrm{Re}\left[\frac{\lambda}{2}\frac{J_0(\lambda)}{J_1(\lambda)}\right]; \qquad \text{skin effect}$$

$$Rn = \frac{1}{\pi d_i^2 \sigma_i} \mathrm{Re}\left[-\lambda\frac{J_1(\lambda)}{J_0(\lambda)}\right]; \qquad \text{intra-pair eddy current effect}$$

$$Rns = \frac{1}{\pi d_i^2 \sigma_i} 4\,\mathrm{Re}\left[-\lambda\frac{J_1(\lambda)}{J_0(\lambda)}\right]; \qquad \text{intra-quad eddy current effect}$$

$$La = \frac{\mu_0}{2\pi}\ln\left(\frac{d_i}{r_i}\right); \qquad \text{external inductance}$$

$$Li = \frac{\mu_i}{2\pi}\mathrm{Re}\left[-\frac{1}{\lambda}\frac{J_0(\lambda)}{J_1(\lambda)}\right]; \qquad \text{skin effect}$$

$$Ln = -\frac{\mu_0}{2\pi}\left(\frac{r_i}{d_i}\right)^2 \mathrm{Re}\left[-\frac{J_2(\lambda)}{J_0(\lambda)}\right]; \qquad \text{intra-pair eddy current effect}$$

$$Lns = -\frac{\mu_0}{2\pi}\left(\frac{r_i}{d_i}\right)^2 4\,\mathrm{Re}\left[-\frac{J_2(\lambda)}{J_0(\lambda)}\right]; \qquad \text{intra-quad eddy current effect}$$

where:

J_0, J_1, J_2 : zero-, first-, and second-order Bessel functions

$\mathrm{Re}[\ ]$: real part in [ ]

$$\lambda \equiv (1+j)\frac{r_i}{\delta_i}$$

r_i : radius of conductor [m]

$\delta_i = \sqrt{\frac{2}{\omega\sigma_i\mu_i}}$: skin depth [m]

σ_i : conductivity of copper (conductor) [mho/m]

μ_0 : permeability of vacuum [H/m]

μ_i : permeability of copper (conductor) [H/m]; $= \mu_r\ \mu_0$

μ_r : relative permeability of copper (conductor)

ω : angular frequency [rad/m]

d_i : distance between wire (conductor) centers of a pair [m]

: $d_i = 2\sqrt{2}(r_i + CO_i)$

CO_i : thickness of insulator for wire (conductor) [m]

Table B.1/G.996.1 – Coefficient values

Coefficient	Paper				Polyethylene				
	0.4 mm	**0.5 mm**	**0.65 mm**	**0.9 mm**	**0.32 mm**	**0.4 mm**	**0.5 mm**	**0.65 mm**	**0.9 mm**
r_i [m]	0.2×10^{-3}	0.25×10^{-3}	0.325×10^{-3}	0.45×10^{-3}	0.16×10^{-3}	0.2×10^{-3}	0.25×10^{-3}	0.325×10^{-3}	0.45×10^{-3}
CO_i [m]	0.09×10^{-3}	0.11×10^{-3}	0.17×10^{-3}	0.24×10^{-3}	0.05×10^{-3}	0.13×10^{-3}	0.15×10^{-3}	0.20×10^{-3}	0.27×10^{-3}
ge	0.996	0.993	0.998	0.998	1.21	1.16	1.05	1.02	1.02
$\tan\delta$	2.5×10^{-2}				4.0×10^{-4}	5.0×10^{-4}			
C_i [F/m]	50×10^{-12}								
σ_i [mho/m]	5.8×10^{7}								
μ_0 [H/m]	$4\pi \times 10^{-7}$								
μ_r	1								

B.1.3 Line transfer function and test loop characteristics

The line transfer function (of voltage) based on the propagation constant is given below. The transfer function assumes no impedance mismatch and perfect terminations by characteristic impedances at both ends, and is a simplified approximation.

$$H(f) = e^{-\gamma d}$$

$$\gamma = \sqrt{(R + j\omega L)(G + j\omega C)}$$

where:

d : loop length [m]

γ : propagation constant

The test loop characteristics for reference are presented in Tables B.2, B.3 and B.4 as results of calculation using the above line transfer function and the coefficient values.

NOTE – The insertion loss with a source impedance of R = 100 Ω and a terminal impedance of R = 100 Ω should be calculated by using the loop ABCD parameters, and the result is loop length and composition dependent.

Table B.2/G.996.1 – Test loop image attenuation in dB for reference

Cable type [Loop length 1 km]		Frequency [kHz]								
		20	**40**	**100**	**160**	**260**	**550**	**1100**	**2195**	**3750**
Paper	0.4 mm	7.07 dB	8.82	11.0	12.6	15.3	22.7	33.9	50.4	69.0
	0.5 mm	5.26 dB	6.31	7.99	9.63	12.3	18.8	28.0	41.9	57.6
	0.65 mm	3.55 dB	4.15	5.66	7.16	9.39	14.4	21.6	32.8	45.8
	0.9 mm	2.14 dB	2.63	4.10	5.36	7.08	10.9	16.6	25.6	36.4
Polyethylene	0.32 mm	9.23 dB	12.0	15.5	17.4	20.2	28.7	42.5	63.0	85.2
	0.4 mm	6.89 dB	8.47	10.2	11.3	13.3	18.9	27.2	39.2	52.3
	0.5 mm	5.09 dB	6.00	7.26	8.47	10.5	15.4	22.1	31.4	41.3
	0.65 mm	3.42 dB	3.91	5.09	6.27	8.02	11.8	16.8	23.9	31.4
	0.9 mm	2.03 dB	2.42	3.61	4.60	5.92	8.68	12.4	17.6	23.1

Table B.3/G.996.1 – Test loop group delay in µs for reference

Cable type [Loop length 1 km]		Frequency [kHz]								
		20	**40**	**100**	**160**	**260**	**550**	**1100**	**2195**	**3750**
Paper	0.4 mm	5.53 µs	5.31	5.49	5.48	5.36	5.13	4.99	4.91	4.86
	0.5 mm	5.32 µs	5.38	5.47	5.35	5.19	5.01	4.91	4.85	4.81
	0.65 mm	5.44 µs	5.59	5.47	5.33	5.21	5.10	5.03	4.99	4.96
	0.9 mm	5.60 µs	5.56	5.30	5.20	5.13	5.06	5.01	4.98	4.96
Polyethylene	0.32 mm	5.97 µs	5.27	5.23	5.30	5.26	4.98	4.76	4.63	4.57
	0.4 mm	5.70 µs	5.52	5.74	5.75	5.66	5.47	5.35	5.28	5.24
	0.5 mm	5.48 µs	5.57	5.69	5.60	5.47	5.30	5.22	5.16	5.13
	0.65 mm	5.55 µs	5.71	5.61	5.49	5.37	5.26	5.20	5.16	5.14
	0.9 mm	5.69 µs	5.65	5.42	5.31	5.25	5.18	5.13	5.10	5.09

Table B.4/G.996.1 – Test loop characteristic impedance in Ω for reference

Cable type		Frequency [kHz]								
		20	40	100	160	260	550	1100	2195	3750
Paper	0.4 mm	214 Ω	161	127	120	115	110	105	102	100
	0.5 mm	176 Ω	140	120	116	112	106	103	100	98.7
	0.65 mm	147 Ω	127	117	114	110	106	104	102	101
	0.9 mm	128 Ω	119	113	110	107	104	102	101	100
Polyethylene	0.32 mm	264 Ω	191	137	124	117	109	103	98.5	95.8
	0.4 mm	215 Ω	162	130	124	120	115	112	109	107
	0.5 mm	177 Ω	142	123	119	116	111	108	106	105
	0.65 mm	148 Ω	129	119	116	113	109	107	105	104
	0.9 mm	129 Ω	121	114	112	109	107	105	104	103

B.2 Crosstalk disturbers

B.2.1 Disturber types

Crosstalk margin measurements are performed with several types of disturbers, extended-bandwidth-ADSL self, TCM-ISDN DSL (Appendix III/G.961) and VDSL (ITU-T Rec. G.993.1).

Two kinds of noise models are defined as follows. Noise A and Noise B_j (j = 1-3). Noise A only or Noise A + each Noise B_j (j = 1 or 2) shall be injected at each central office or customer premises side end. Noise A + Noise B_3 shall be injected at the only customer premises side end. The test should be performed several (3-4) times. A combination Noise B_j and B_k (j<>k) is not used for performance test. Also, simultaneous injection at both central office and customer premises side ends is not used.

Noise A = –140 dBm/Hz AWGN (Additive White Gaussian Noise)

Noise B_1 = 24 extended-bandwidth-ADSL self NEXT and FEXT

Noise B_2 = 24 TCM-ISDN DSL (Appendix III/G.961) alternate NEXT and FEXT
(see ITU-T Rec. G.996.1 as for the disturber PSD)

Noise B_3 = 9 VDSL (ITU-T Rec. G.993.1) NEXT and in-equal level coupled FEXT
(see Annex F/G.993.1 as for the disturber PSD)

TCM-ISDN DSL NEXT and FEXT appear alternately in the same frequency band, and are cyclostationary. Annex B adopts cyclostationary crosstalk injection of NEXT and FEXT as defined in 7.9.3.

The loop length of VDSL disturbers shall be fixed at 150 m and shall not be adjustable, drawing upward to a central office side from a customer premises side end. Namely, an in-equal level coupling of FEXT from VDSL to extended-bandwidth-ADSL is considered, and the only 0.4 mm polyethylene-insulated cable is considered as the coupling path. The disturber loop length of 150 m is determined as a typical length of the most significant interference.

NOTE – Extended-bandwidth-ADSL NEXT and VDSL NEXT injection is for testing input signal dynamic range of an extended-bandwidth-ADSL receiver.

B.2.2 Power sum loss of crosstalk

NEXT and FEXT PSL values for 24 disturbers with 1% worst case are shown in Table 25, which are used for generating the simulated Noise B_1 and B_2. NEXT and FEXT PSL values for 9 disturbers with 1% worst case are shown in Table B.5, which are used for generating the simulated Noise B_3, where only a polyethylene-insulated cable is considered because an in-equal level FEXT coupling from VDSL to ADSL arises mostly within intra- user-building cables and all of them are polyethylene-insulated.

Table B.5/G.996.1 – Power sum loss values for 9 disturbers with 1% worst case

NEXT/FEXT power sum loss	Insulation material of pair conductor	Condition
	Polyethylene-insulated	
$NPSL_9$ [dB]	49.5 dB	At $f_{NEXT} = 160 \times 10^3$ [Hz]
$FPSL_9$ [dB]	51.5 dB	At $f_{FEXT} = 160 \times 10^3$ [Hz] At $d_{FEXT} = 1 \times 10^3$ [m]

B.2.3 Power spectral density of disturbers

The single-sided power spectral density (PSD) functions in watts/Hz are abbreviated by $PSD_{xDSL\text{-}DS}(f)$ and $PSD_{xDSL\text{-}US}(f)$ in watts/Hz below for downstream and upstream, respectively.

$PSD_{xDSL\text{-}DS}(f)$ and $PSD_{xDSL\text{-}US}(f)$ for TCM-ISDN DSL disturber are defined in 7.9.3.1, and those for VDSL are defined in F.3.2.2.1/G.993.1. As for extended-bandwidth-ADSL, they are specified in the related ITU-T Recommendations.

B.2.4 Power spectral density of crosstalk

XT (crosstalk) PSD for each xDSL disturber is given by multiplying the xDSL disturber PSD and the XT power coupling function.

B.2.4.1 Crosstalk power coupling function

XT (crosstalk) power coupling functions XT(f) are given below for cases of NEXT and FEXT.

NEXT power coupling function for use of Noise B_1, B_2 and B_3 is as follows.

$$XT_{NEXT}(f) = \left(\frac{Z_{disturbed}}{Z_{disturber}}\right) 10^{-\frac{NPSL_n}{10}} \left(\frac{f}{f_{NEXT}}\right)^{\frac{3}{2}}$$

FEXT power coupling function for use of Noise B_1 and B_2 is as follows. The bridged taps (BTs) shall not be incorporated in the simulated FEXT disturber PSD as a part of the FEXT coupling path.

$$XT_{FEXT}(f) = \left(\frac{Z_{disturbed}}{Z_{disturber}}\right) \mathop{\Pi}_{k} \left| e^{-2\gamma_k d_k} \right| \sum_{k} \left[10^{-\frac{FPSL_{24}[k]}{10}} \left(\frac{d_k}{d_{FEXT}}\right) \right] \left(\frac{f}{f_{FEXT}}\right)^2$$

FEXT power coupling function for use of Noise B_3 is as follows. The bridged taps (BTs) shall not be incorporated in the simulated FEXT disturber PSD as a part of the FEXT coupling path.

$$XT_{FEXT}(f) = \left(\frac{Z_{disturbed}}{Z_{disturber}}\right) \left| e^{-2\gamma_x d_x} \right| 10^{-\frac{FPSL_9}{10}} \left(\frac{f}{f_{FEXT}}\right)^2 \left(\frac{d_x}{d_{FEXT}}\right)$$

where:

f	: frequency in Hz
$NPSL_n$	: NEXT PSL value with n disturbers
$FPSL_{24}[k]$	: FEXT PSL value with 24 disturbers for each segment [*k*] consisting test loop
γ_k	: the propagation constant of each segment [*k*] consisting test loop
d_k	: length of each segment [*k*] consisting test loop in m
	$f_{FEXT} = 160 \times 10^3$ Hz
	$d_{FEXT} = 1 \times 10^3$ m
$Z_{disturbed}$	: termination impedance of disturbed extended-bandwidth-ADSL (= 100 Ω)
$Z_{disturber}$	: termination impedance of disturbing xDSL
	100 Ω : for extended-bandwidth-ADSL and VDSL
	110 Ω : for TCM-ISDN
γ_x	: the propagation constant of the 0.4 mm polyethylene-insulated cable
d_x = 150 m	
$FPSL_9$	: FEXT PSL value with 9 disturbers for the polyethylene-insulated cable

NOTE 1 – The NEXT power coupling function of $XT_{NEXT}(f)$ is a function of a coupling path length, to be exact, as expressed below. However, Annex B does not adopt the equation below so as to reduce test parameters.

$$XT_{NEXT}(f) = \left(\frac{Z_{disturbed}}{Z_{disturber}}\right) 10^{-\frac{NPSL_n}{10}} \left(\frac{f}{f_{NEXT}}\right)^{\frac{2}{3}} \left(1 - \left|e^{-4\gamma d}\right|\right)$$

NOTE 2 – FEXT of Noise B_1 and B_2 assume equal level coupling, i.e., the loop length of a disturbed extended-bandwidth-ADSL is the same as that of a disturbing xDSL so as to reduce test parameters.

NOTE 3 – FEXT of Noise B_3 assumes in-equal level coupling, and the FEXT coupling path length d_x of 150 m only is tested so as to reduce test parameters.

B.2.4.2 Disturber crosstalk PSD

The single-sided XTPSDs (crosstalk PSD) for each xDSL disturber are given by the equations below for the cases NEXT/FEXT and downstream/upstream.

$XTPSD_{xDSL\text{-}DS\text{-}NEXT}(f) = PSD_{xDSL\text{-}DS}(f)\ XT_{NEXT}(f)$ watts/Hz

$XTPSD_{xDSL\text{-}DS\text{-}FEXT}(f) = PSD_{xDSL\text{-}DS}(f)\ XT_{FEXT}(f)$ watts/Hz

$XTPSD_{xDSL\text{-}US\text{-}NEXT}(f) = PSD_{xDSL\text{-}US}(f)\ XT_{NEXT}(f)$ watts/Hz

$XTPSD_{xDSL\text{-}US\text{-}FEXT}(f) = PSD_{xDSL\text{-}US}(f)\ XT_{FEXT}(f)$ watts/Hz

XTPSDs injected at each central office or customer premises side end are as follows.

$XTPSD_{xDSL\text{-}CO}(f) = XTPSD_{xDSL\text{-}DS\text{-}NEXT}(f) + XTPSD_{xDSL\text{-}US\text{-}FEXT}(f)$ watts/Hz

$XTPSD_{xDSL\text{-}CPE}(f) = XTPSD_{xDSL\text{-}US\text{-}NEXT}(f) + XTPSD_{xDSL\text{-}DS\text{-}FEXT}(f)$ watts/Hz

As for TCM-ISDN DSL NEXT and FEXT, cyclostationary crosstalk injection of NEXT and FEXT as defined in 7.9.3 is adopted. Cyclostationary NEXT and FEXT injection timing is shown in Figure B.1, which is reproduced from Figure 31.

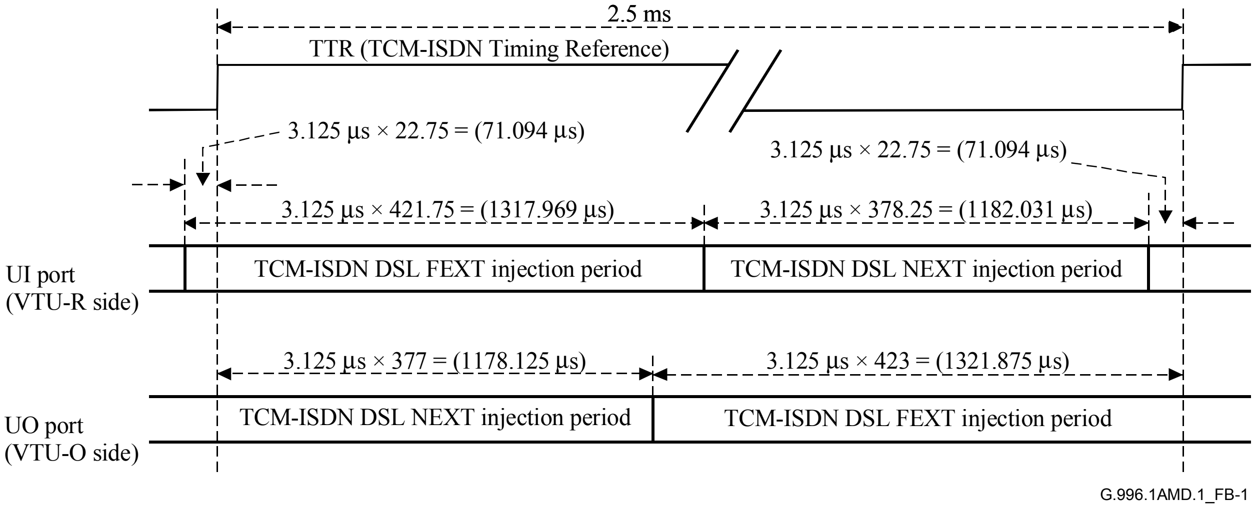

Figure B.1/G.996.1 – TCM-ISDN DSL alternate NEXT and FEXT injection timing

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