ETSI TECHNICAL REPORT

ETR 328

November 1996

Source: TC/TM

Reference: DTR/TM-06001

ICS: 33.020

Key words: ADSL, digital, access, transmission, multimedia, subscriber

Transmission and Multiplexing (TM); Asymmetric Digital Subscriber Line (ADSL); Requirements and performance

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Foreword

This ETSI Technical Report (ETR) has been produced by the Transmission and Multiplexing (TM) Technical Committee of the European Telecommunications Standards Institute (ETSI).

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1 Scope

This ETR describes a transmission technique called Asymmetric Digital Subscriber Line (ADSL). The requirements for the ADSL transmission system and the transmission performance are defined in this report.

ADSL allows the provision of a variety of digital channels on the same, single subscriber line as the analogue telephone service. An ADSL system contains several digital channels. Some of them are full duplex low-speed channels and the others are simplex high-speed channels. The high-speed channels are transported only in the direction to the customer premises.

This ETR is based on ANSI T1.413 [1] provided by the ANSI committee T1E1.4 and contains only specific European topics not covered by ANSI T1.413 [1]. These are, for example, the test requirements including test noise and test loops for transportation of n x 2 048 Mbit/s (n = 1,2,3) and the so-called POTS splitter, which separates the analogue telephone band from that used by the ADSL transmission system (where POTS is Plain Old Telephony Service).

2 References

[1] ANSI T1.413-1995: "Telecommunications - Network and Customer Installation Interfaces - Asymmetric Digital Subscriber Line (ADSL) Metallic Interface.“

3 Definitions, symbols and abbreviations

3.1 Definitions

2M1: Classification of an ADSL system capable of transporting 6 144 kbit/s downstream towards the ADSL Network Termination (ANT).

2M2: Classification of an ADSL system capable of transporting 4 096 kbit/s downstream towards the ANT.

2M3: Classification of an ADSL system capable of transporting 2 048 kbit/s downstream towards the ANT.

3.2 Symbols

C’	capacitance nanoFarads per km (nF/km)
G’	leakance Siemens per km (S/km)
L’	inductance microHenries per km (µH/km)
R’	resistance Ohms per km (Ω/km)

3.3 Abbreviations

ADSL	Asymmetric Digital Subscriber Line
ALT	ADSL Line Termination (in [1] referred to as ATU-C)
ANSI	American National Standards Institute
ANT	ADSL Network Termination (in [1] referred to as ATU-R)
ATU-C	ADSL Transmission Unit - Central Office
ATU-R	ADSL Transmission Unit - Remote
BRA	Basic Rate Access
dBm	deciBel referred to 1 milliwatt
ETR	ETSI Technical Report
FDM	Frequency Division Multiplexing
FEC	Forward Error Correction
HDB3	High Density Bipolar 3
ISDN	Integrated Services Digital Network
PE	PolyEthylene
POTS	Plain Old Telephony Service
PSD	Power Spectral Density
TC	Trellis Coding

4 Bearer channel allocations

The transport class and configuration of those which are appropriate for 2 048 kbit/s applications are shown in table 1. The noise models and test loops presented in this ETR are for bearer channel allocations as shown in table 1.

Table 1: Bearer channel allocations

Transport class	Configuration	Simplex downstream rate [kbit/s]	Duplex rate(s) [kbit/s]
2M1	-	6 144	160 (note1) 64 (C) (note2)
2M2	1	4 096	160 (note1) 64 (C) (note2)
2M2	2	4 096	64 (C) (note2)
2M3	1	2 048	160 (note1) 16 (C) (note2)
2M3	2	2 048	16 (C) (note2)

NOTE 1: This rate is designed to accommodate Integrated Services Digital Network (ISDN) Basic Rate Access (BRA) (2B + D + overhead). Some carriers use a concatenated concept of V reference points (e.g. concatenation of V1 + V5). Therefore it might be desirable to limit the latency to a value of 1,25 ms per digital section and per ADSL system.

NOTE 2: This duplex channel is reserved for control purposes of the application.

5 Noise models

Two noise sources are described for the testing of ADSL systems. These are frequency-domain sources that model the steady state operating environment caused by crosstalk from adjacent wire pairs due to differing transmission systems. The two models differ due to the need to cater to countries that may or may not have High Density Bipolar 3 (HDB3) based primary rate systems operating at 2 048 kbit/s in their access networks. Model A is for the case where no such interferers exist while model B includes the crosstalk coupling effects of these types of systems. The need for amateur radio interferers was specially expressed by the countries supporting noise model A and is therefore included only there.

5.1 Injection method

The injection circuit should have a Thevenin impedance of at least 4 kΩ. The spectral density of the crosstalk noise sources should be measured at the output of the injection circuit, replacing the test loop by a 50 Ω resistor and with no terminal equipment connected.

5.2 Crosstalk noise sources

The Power Spectral Density (PSD) of the crosstalk noise sources used for performance testing is given in figure 1 for model A and in figure 2 for model B. Model A includes discrete tones, which represent radio frequency interference that is commonly observed, especially on wire pairs routed over-ground. Further details of the specification of these noise models are shown in tables 2 to 4.

The resulting wideband noise power over the frequency range 1 kHz to 1,5 MHz for model A is -49,4 dBm ± 0,5 dBm and for model B is -43,0 dBm ± 0,5 dBm.

The noise probability density function should be approximately Gaussian with a crest factor greater than or equal 5.

The accuracy of the power spectral density should be ± 1 dB over the frequency range 1 kHz to 1,5 MHz, when measured with a resolution bandwidth of 1 kHz.

NOTE: For the ADSL Line Termination (ALT) transmitter mask it is assumed that the slope from the pass band to the upper stop band is -80 dB/decade due to the 4th order low pass filtering as it is assumed in annex B.4 of [1].

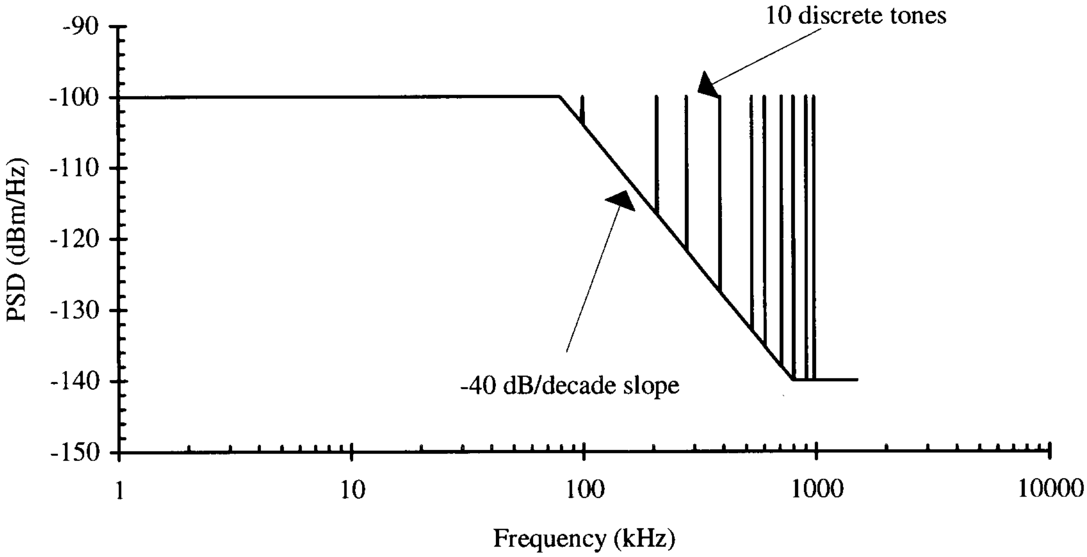

Figure 1: Single sided noise Power Spectral Density (PSD) into 50 Ω for model A

Table 2: Co-ordinates for noise model A

Frequency (kHz)	PSD (dBm/Hz)	PSD (μV/√Hz)
1	-100	3,16
79,5	-100	3,16
795	-140	0,03
1 500	-140	0,03

Table 3: Tone frequencies and powers for noise model A

Frequency (kHz)	Power (dBm)
99	-70
207	-70
333	-70
387	-70
531	-70
603	-70
711	-70
801	-70
909	-70
981	-70

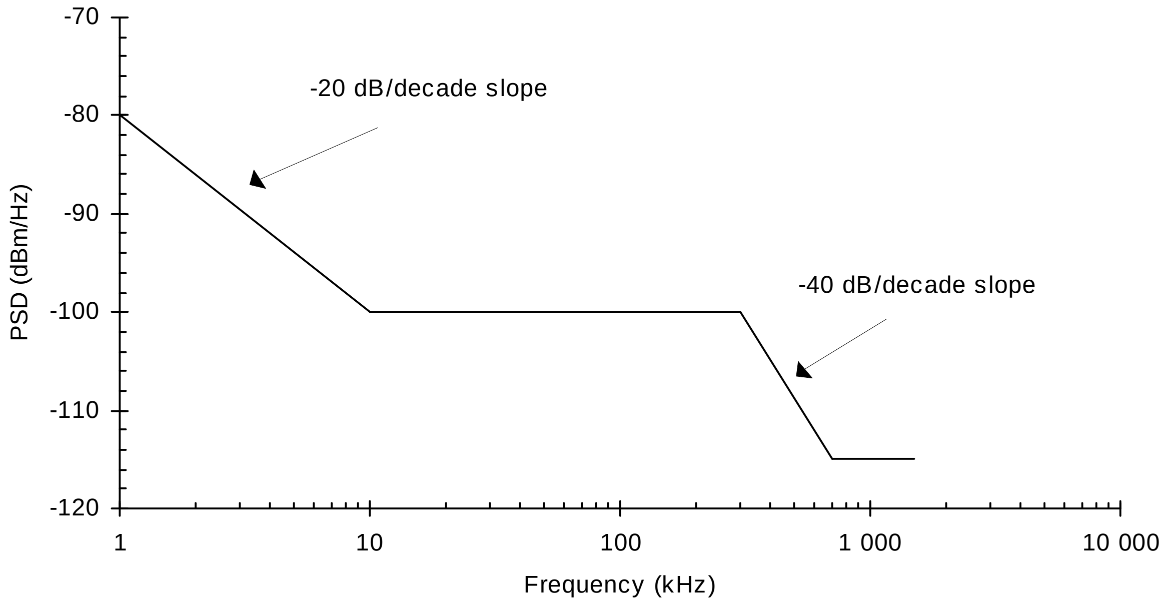

Figure 2: Single sided noise PSD into 50 Ω for model B

Table 4: Co-ordinates for noise model B

Frequency (kHz)	PSD (dBm/Hz)	PSD (μV/√Hz)
1	-80	31,62
10	-100	3,16
300	-100	3,16
711	-115	0,56
1 500	-115	0,56

6 Test loops

For the purposes of testing the performance of the ADSL system incorporating the bearer channel capabilities outlined in clause 4, the test loops specified in figure 3 should be used. The power spectral density of the ADSL downstream transmission is as described in subclause 6.13 of ANSI T1.413 [1] with the proviso that the power boost option in ANSI T1.413 [1] is not used for test purposes.

The primary line constants (R', L' & C') variation with frequency for the different reference cable types are given in tables 19 to 23. Note that G' is assumed to be zero. The R'L'C' values are quoted on a per kilometre basis at a temperature of 20°C and are smoothed measured values.

Note also that there are adjustable sections (marked 'X') in figure 3. The nominal lengths of these sections are shown in tables 5 to 12. The lengths of the sections are based on the reference R'L'C' values for each cable type given in this ETR. For repeatability of measurement, results the adjustable section length should be adjusted to give the overall insertion loss given in tables 5 to 12. Insertion loss is measured with 100 Ω (balanced resistive) source and termination impedances at 300 kHz.

Tables 5 to 12 show ADSL performance for the downstream channel. The results are referred to the values of following specific parameters:

- channel separation technique: Frequency Division Multiplexing (FDM);
- coding gain: 3 dB (only FEC);
- lower cut off frequency: 88 kHz.

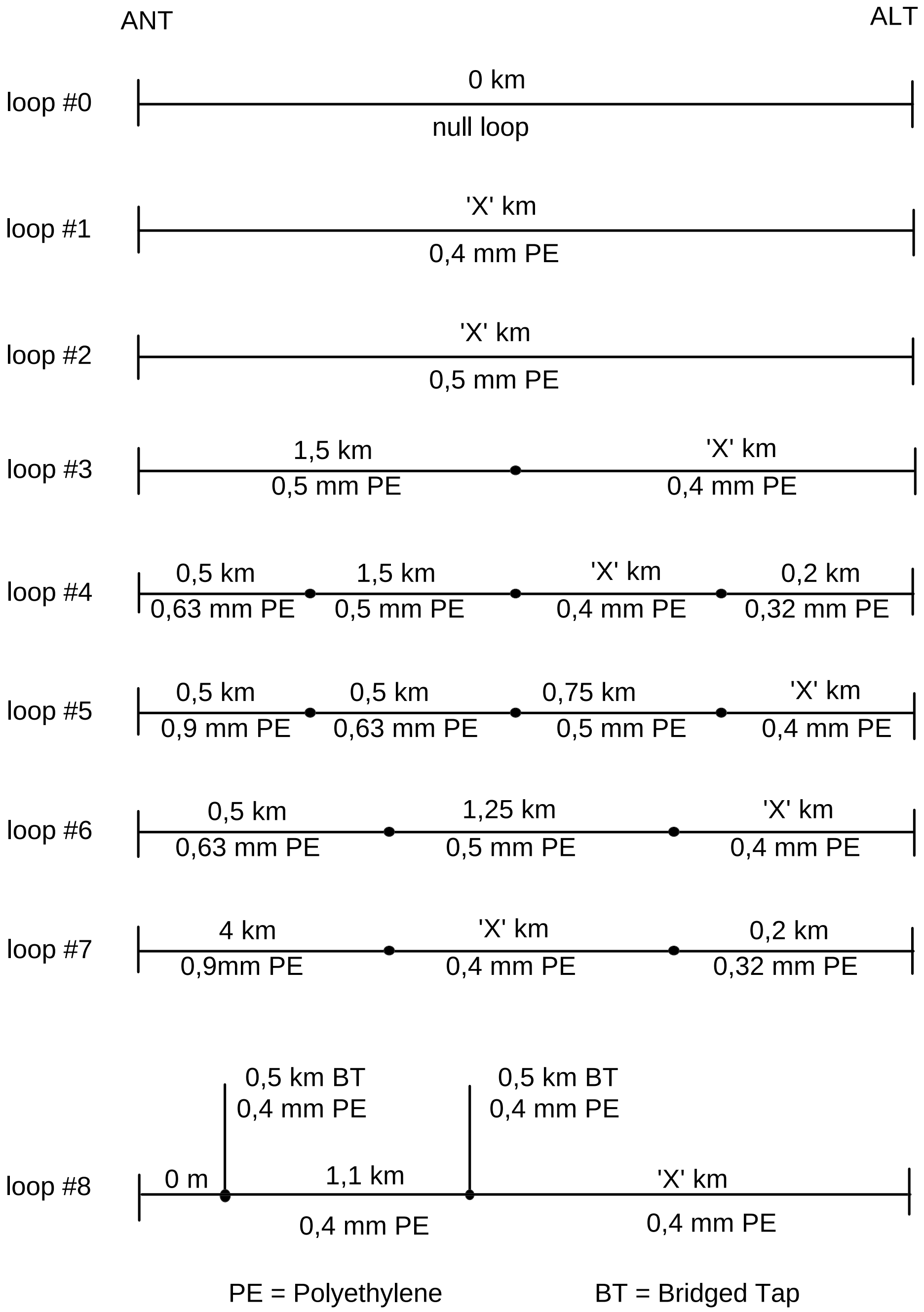

Figure 3: Test loop set for transport classes 2M1, 2M2, and 2M3 with noise model A or B

Table 5: Loop-set insertion loss and nominal lengths for 2M1 (noise model A)

Loop #	Nominal value of adjustable length 'X' (km)	Loop insertion loss at 300 kHz (dB)
1	2,90	41,0
2	3,85	41,0
3	1,80	41,0
4	1,25	41,0
5	1,85	41,0
6	1,70	41,0
7	0,85	41,0
8	1,45	42,0

Table 6: Loop-set insertion loss and nominal lengths for 2M1 (noise model B)

Loop #	Nominal value of adjustable length 'X' (km)	Loop insertion loss at 300 kHz (dB)
1	1,80	25
2	2,35	25
3	0,60	25
4	0,15	25
5	0,70	25
6	0,60	25
7	0,00	25
8	0,35	26

Table 7: Loop-set insertion loss and nominal lengths for 2M2 (noise model A)

Loop #	Nominal value of adjustable length 'X' (km)	Loop insertion loss at 300 kHz (dB)
1	3,30	47
2	4,30	46
3	2,10	46
4	1,65	47
5	2,20	46
6	2,10	47
7	1,20	47
8	1,85	47

Table 8: Loop-set insertion loss and nominal lengths for 2M2 (noise model B)

Loop #	Nominal value of adjustable length 'X' (km)	Loop insertion loss at 300 kHz (dB)
1	2,15	30
2	2,80	30
3	0,95	30
4	0,50	30
5	1,10	30
6	0,95	30
7	0,10	30
8	0,70	31

Table 9: Loop-set insertion loss and nominal lengths for 2M3 configuration 1 (noise model A)

Loop #	Nominal value of adjustable length 'X' (km)	Loop insertion loss at 300 kHz (dB)
1	3,45	49
2	4,60	49
3	2,30	49
4	1,80	49
5	2,35	49
6	2,20	49
7	1,50	49
8	1,25	43

Table 10: Loop-set insertion loss and nominal lengths for 2M3 configuration 2 (noise model A)

Loop #	Nominal value of adjustable length 'X' (km)	Loop insertion loss at 300 kHz (dB)
1	3,60	51
2	4,80	51
3	2,45	51
4	1,90	51
5	2,50	51
6	2,35	51
7	1,60	51
8	1,80	51

Table 11: Loop-set insertion loss and nominal lengths 2M3 configuration 1 (noise model B)

Loop #	Nominal value of adjustable length 'X' (km)	Loop insertion loss at 300 kHz (dB)
1	2,45	35
2	3,20	34
3	1,30	35
4	0,80	35
5	1,40	35
6	1,25	35
7	0,50	35
8	0,70	35

Table 12: Loop-set insertion loss and nominal lengths 2M3 configuration 2 (noise model B)

Loop #	Nominal value of adjustable length 'X' (km)	Loop insertion loss at 300 kHz (dB)
1	2,55	36
2	3,40	36
3	1,40	36
4	0,90	36
5	1,45	36
6	1,30	36
7	0,60	36
8	0,75	36

Tables 13 to 18 show ADSL performance for the downstream channel. The results are referred to the values of following specific parameters:

- channel separation technique: echo cancellation;
- coding gain: 5 dB (FEC and TC);
- configuration 1 (where distinguished).

Table 13: Loop-set insertion loss and nominal lengths for 2M1 (noise model A)

Loop #	Nominal value of adjustable length 'X' (km)	Loop insertion loss at 300 kHz (dB)
1	2,80	40
2	3,60	38
3	1,75	40
4	1,05	38
5	1,65	38
6	1,50	38
7	0,70	37
8	1,20	38

Table 14: Loop-set insertion loss and nominal lengths for 2M1 (noise model B)

Loop #	Nominal value of adjustable length 'X' (km)	Loop insertion loss at 300 kHz (dB)
1	1,90	27
2	2,55	27
3	0,70	30
4	0,15	25
5	0,80	26
6	0,60	25
7	0,00	25
8	0,35	26

Table 15: Loop-set insertion loss and nominal lengths for 2M2 (noise model A)

Loop #	Nominal value of adjustable length 'X' (km)	Loop insertion loss at 300 kHz (dB)
1	3,70	45
2	4,20	44
3	2,00	45
4	1,45	44
5	2,05	44
6	1,90	44
7	1,15	46
8	1,60	43

Table 16: Loop-set insertion loss and nominal lengths for 2M2 (noise model B)

Loop #	Nominal value of adjustable length 'X' (km)	Loop insertion loss at 300 kHz (dB)
1	2,25	32
2	3,00	32
3	1,15	34
4	0,55	31
5	1,15	31
6	0,95	30
7	0,25	32
8	0,75	32

Table 17: Loop-set insertion loss and nominal lengths for 2M3 (noise model A)

Loop #	Nominal value of adjustable length 'X' (km)	Loop insertion loss at 300 kHz (dB)
1	3,80	54
2	4,90	52
3	2,65	53
4	2,10	52
5	2,70	53
6	2,55	53
7	1,75	54
8	2,00	50

Table 18: Loop-set insertion loss and nominal lengths for 2M3 (noise model B)

Loop #	Nominal value of adjustable length 'X' (km)	Loop insertion loss at 300 kHz (dB)
1	2,60	37
2	3,50	37
3	1,55	38
4	1,00	37
5	1,65	38
6	1,40	37
7	0,70	37
8	1,20	37

Table 19: R'L'C' values for 0,32 mm PE cable

Frequency (kHz)	R' (Ω/km)	L' (μH/km)	C' (nF/km)
0,00	409,000	607,639	40,00
2,50	409,009	607,639	40,00
10,00	409,140	607,639	40,00
20,00	409,557	607,639	40,00
30,00	410,251	607,639	40,00
40,00	411,216	607,639	40,00
50,00	412,447	607,639	40,00
100,00	422,302	607,631	40,00
150,00	437,337	607,570	40,00
200,00	456,086	607,327	40,00
250,00	477,229	606,639	40,00
300,00	499,757	605,074	40,00
350,00	522,967	602,046	40,00
400,00	546,395	596,934	40,00
450,00	569,748	589,337	40,00
500,00	592,843	579,376	40,00
550,00	615,576	567,822	40,00
600,00	637,885	555,867	40,00
650,00	659,743	544,657	40,00
700,00	681,138	534,942	40,00
750,00	702,072	526,991	40,00
800,00	722,556	520,732	40,00
850,00	742,601	515,919	40,00
900,00	762,224	512,264	40,00
950,00	781,442	509,503	40,00
1 000,00	800,272	507,415	40,00
1 050,00	818,731	505,831	40,00
1 100,00	836,837	504,623	40,00

Table 20: R'L'C' values for 0,4 mm PE cable

Frequency (kHz)	R' (Ω/km)	L' (μH/km)	C' (nF/km)
0,00	280,000	587,132	50,00
2,50	280,007	587,075	50,00
10,00	280,110	586,738	50,00
20,00	280,440	586,099	50,00
30,00	280,988	585,322	50,00
40,00	281,748	584,443	50,00
50,00	282,718	583,483	50,00
100,00	290,433	577,878	50,00
150,00	302,070	571,525	50,00
200,00	316,393	564,889	50,00
250,00	332,348	558,233	50,00
300,00	349,167	551,714	50,00
350,00	366,345	545,431	50,00
400,00	383,562	539,437	50,00
450,00	400,626	533,759	50,00
500,00	417,427	528,409	50,00
550,00	433,904	523,385	50,00
600,00	450,027	518,677	50,00
650,00	465,785	514,272	50,00
700,00	481,180	510,153	50,00
750,00	496,218	506,304	50,00
800,00	510,912	502,707	50,00
850,00	525,274	499,343	50,00
900,00	539,320	496,197	50,00
950,00	553,064	493,252	50,00
1 000,00	566,521	490,494	50,00
1 050,00	579,705	487,908	50,00
1 100,00	592,628	485,481	50,00

Table 21: R'L'C' values for 0,5 mm PE cable

Frequency (kHz)	R' (Ω/km)	L' (μH/km)	C' (nF/km)
0,00	179,000	673,574	50,00
2,50	179,015	673,466	50,00
10,00	179,244	672,923	50,00
20,00	179,970	671,980	50,00
30,00	181,161	670,896	50,00
40,00	182,790	669,716	50,00
50,00	184,822	668,468	50,00
100,00	199,608	661,677	50,00
150,00	218,721	654,622	50,00
200,00	239,132	647,735	50,00
250,00	259,461	641,208	50,00
300,00	279,173	635,119	50,00
350,00	298,103	629,489	50,00
400,00	316,230	624,309	50,00
450,00	333,591	619,557	50,00
500,00	350,243	615,202	50,00
550,00	366,246	611,211	50,00
600,00	381,657	607,552	50,00
650,00	396,528	604,192	50,00
700,00	410,907	601,104	50,00
750,00	424,835	598,261	50,00
800,00	438,348	595,639	50,00
850,00	451,480	593,217	50,00
900,00	464,258	590,975	50,00
950,00	476,710	588,896	50,00
1 000,00	488,857	586,966	50,00
1 050,00	500,720	585,169	50,00
1 100,00	512,317	583,495	50,00

Table 22: R'L'C' values for 0,63 mm PE cable

Frequency (kHz)	R' (Ω/km)	L' (μH/km)	C' (nF/km)
0,00	113,000	699,258	45,00
2,50	113,028	697,943	45,00
10,00	113,442	693,361	45,00
20,00	114,737	687,008	45,00
30,00	116,803	680,714	45,00
40,00	119,523	674,593	45,00
50,00	122,768	668,690	45,00
100,00	143,115	642,718	45,00
150,00	164,938	622,050	45,00
200,00	185,689	605,496	45,00
250,00	204,996	592,048	45,00
300,00	222,961	580,960	45,00
350,00	239,764	571,691	45,00
400,00	255,575	563,845	45,00
450,00	270,533	557,129	45,00
500,00	284,753	551,323	45,00
550,00	298,330	546,260	45,00
600,00	311,339	541,809	45,00
650,00	323,844	537,868	45,00
700,00	335,897	534,358	45,00
750,00	347,542	531,212	45,00
800,00	358,819	528,378	45,00
850,00	369,758	525,813	45,00
900,00	380,388	523,480	45,00
950,00	390,734	521,352	45,00
1 000,00	400,816	519,402	45,00
1 050,00	410,654	517,609	45,00
1 100,00	420,264	515,956	45,00

Table 23: R'L'C' values for 0,9 mm PE cable

Frequency (kHz)	R' (Ω/km)	L' (μH/km)	C' (nF/km)
0,00	55,000	750,796	40,00
2,50	55,088	745,504	40,00
10,00	56,361	731,961	40,00
20,00	59,941	716,775	40,00
30,00	64,777	703,875	40,00
40,00	70,127	692,707	40,00
50,00	75,586	682,914	40,00
100,00	100,769	647,496	40,00
150,00	121,866	625,140	40,00
200,00	140,075	609,652	40,00
250,00	156,273	598,256	40,00
300,00	170,987	589,504	40,00
350,00	184,556	582,563	40,00
400,00	197,208	576,919	40,00
450,00	209,104	572,237	40,00
500,00	220,365	568,287	40,00
550,00	231,081	564,910	40,00
600,00	241,326	561,988	40,00
650,00	251,155	559,435	40,00
700,00	260,615	557,183	40,00
750,00	269,745	555,183	40,00
800,00	278,577	553,394	40,00
850,00	287,138	551,784	40,00
900,00	295,452	550,327	40,00
950,00	303,538	549,002	40,00
1 000,00	311,416	547,793	40,00
1 050,00	319,099	546,683	40,00
1 100,00	326,602	545,663	40,00

7 ADSL/POTS splitter impedances

The design impedance for the POTS port of the splitter is application specific and therefore outside the scope of this ETR. Of particular importance are return loss and consequential sidetone levels. It is expected that some n x 2 048 kbit/s applications will require that the splitter matches to a complex telephony impedance.

NOTE: Significant differences may exist between particular applications; examples are:

- telephony impedances;
- telephony return loss;
- out of (POTS) band signalling systems (e.g. subscriber private metering at 11 to 50 kHz);
- low frequency telemetry.

8 Testing

Performance testing is outlined in clause 15 of ANSI T1.413 [1].

NOTE: Differences exist here with respect to the crosstalk noise sources (see subclause 5.2 of this ETR) and the test loops (see clause 6 of this ETR), and the addition of a maximum stress linearity test (see subclause 8.1 of this ETR). Further details appropriate for testing are given in ANSI T1.413 [1].

8.1 Maximum stress linearity test

This test is intended to be used to stress the ADSL system to ensure that adequate linearity is achieved in implementations. A modified loop #1 from the loop-set given in figure 3 is used for the purpose of this test. The modification is detailed in table 24. An additive white Gaussian noise source with a power spectral density of -140 dBm/Hz ± 1 dBm/Hz over the frequency range 1 kHz to 1,5 MHz is applied at the ADSL Network Termination (ANT) in place of the crosstalk source. A resolution bandwidth of 1 kHz is used for calibration of the power spectral density.

Table 24: Insertion loss (and nominal length) for Loop #1

Transport class 2M3 configuration	Nominal value of adjustable length 'X' of Loop #1 (km)	Loop insertion loss at 300 kHz (dB)
1	4,35	62,0
2	4,70	67,0

History

Document history	
November 1996	First Edition

ISBN 2-7437-1168-X
Dépôt légal : Novembre 1996