ACIF C559:2003

PART 2

SPECTRAL COMPATIBILITY DETERMINATION PROCESS

CONTENTS

1. INTRODUCTION AND OVERVIEW

1.1 Introduction

Part 2 describes the ACIF Spectral Compatibility Determination Process together with the assumptions and analytical techniques required to assess system spectral compatibility.

The ACIF Spectral Compatibility Determination Process is the process that determines matters pertaining to spectral compatibility of Disturbing and Disturbed Systems used on distinct unconditioned Communications Wires. Elements of the process include determining the Spectral Compatibility Benchmarks of Basis Systems, Unacceptable Interference into a Basis System, and Unacceptable Excess Power.

Part 1 of this Code requires that carriers and carriage service providers that propose to deploy a system that is not within a Deployment Class use the ACIF Spectral Compatibility Determination Process to determine whether or not the proposed system causes either Unacceptable Interference into a Basis System or Unacceptable Excess Power. A computer model based on this process is being developed by Telstra and will be made available to affected parties.

The Spectral Compatibility Benchmarks for Basis Systems are set out in Clauses 4.1.1 and 4.2.1, Unacceptable Interference into a Basis System is addressed in Clause 2.3, and Unacceptable Excess Power is addressed in Clause 2.4.

1.2 Overview

It is well known that in the unshielded twisted pair cable used to provide local loops, xDSL signals on one twisted pair cause interference to signals on other twisted pairs in the same cable. This interference, called crosstalk, is caused by electromagnetic coupling between the unshielded twisted pairs and has the potential to unacceptably degrade the performance of services/systems sharing the same cable, thereby compromising network integrity.

In an unbundled loop environment, where an Access Provider's local loop cable is being shared by other carriers and carriage service providers (ie Access Seekers who are being supplied with ULLS) inter-system crosstalk must be controlled to ensure an acceptable level of protection of network integrity. Therefore, in order to ensure effective exploitation of the unbundled local loop, there is a requirement for Access Seekers and Access Providers to abide by a set of agreed performance requirements by suitable selection of the type, quantity and disposition of xDSL systems to ensure their spectral compatibility.

Crosstalk depends on pair-to-pair exposure, signal frequency and signal strength.

Pair-to-pair exposure depends on the length variation of proximity of pairs in a cable and crosstalk coupling increases with increasing proximity and cable length. Unavoidable variability in cable manufacturing processes leads to unavoidable variability in exposure between cable pairs and it is impossible to specify/predict the exact amount of crosstalk between pairs in a cable. In addition, the level of interference is increased by any imbalance in the equipment and this is controlled by appropriate specification of equipment longitudinal balance similar to the intrinsic cable pair longitudinal balance.

Crosstalk coupling is very sensitive to exposure and the variability/unpredictability of crosstalk interference dominates all other system variability, and an extreme worst-case design cannot be economically justified.

This leads to the unavoidable use of statistical measures and techniques to determine performance requirements for the operation of systems that use ULLS. The statistical techniques are based on the underlying assumption that the Access Provider makes available to the Access Seeker cable pairs chosen at random from a population of cable pairs that exhibit no unusual or 'faulty' performance. In other words, it is assumed that cable pairs exhibit typical transmission and crosstalk performance variability consistent with typical cable manufacturing and installation processes. As mentioned above, an extreme worst case design which ensures that all such typical pairs can be used for Unconditioned Local Loop Service cannot be economically justified, and so the performance requirements for operation of systems using ULLS are based on assuming that less than 1% of typical pairs offered to an Access Seeker exhibit excessive crosstalk.

With the expectation that less than 1% of offered pairs prove unsuitable, there is little benefit in requiring any pre-qualification of offered pairs. Rather, offered pairs need only be tested when excessive crosstalk is suspected.

High frequency energy has higher coupling than lower frequency energy because crosstalk increases with frequency. Thus the higher the speed/capacity of the xDSL system, the greater the potential for inter-system interference. Crosstalk is directly proportional to signal strength, so limiting transmit power lessens inter-service interference. Hence, controlling the spectral content and balance of xDSL signals through specifying transmit signal spectral masks and equipment longitudinal balance, and controlling the number and disposition of xDSL systems in a cable are effective means of limiting crosstalk interference between systems.

2. ACIF SPECTRAL COMPATIBILITY DETERMINATION PROCESS

2.1 Definition of ACIF Spectral Compatibility Determination Process

The **ACIF Spectral Compatibility Determination Process** is the process that determines matters pertaining to spectral compatibility of Disturbing and Disturbed Systems used on ULLS. Elements of the process include the determination of Unacceptable Interference into a Basis System,the determination of Unacceptable Excess Power, and the process for determination of Spectral Compatibility Benchmarks for Basis Systems and Deployment Rules for Deployment Class Systems.

2.2 Definition of Spectral Compatibility Benchmark and Basis System

A **Spectral Compatibility Benchmark** is the determined relationship between system bit rates achievable by a Basis System in each direction and system deployment range (expressed as a single deployment range for a fixed rate system) for a system error rate of 10^{-7} with margin of 6dB in the 1% worst-case crosstalk environment.

Note 1: The 1% worst case-crosstalk environment is defined in Clause 5.2.

Note 2: The Spectral Compatibility Benchmark includes the rates in each direction of transmission. For a fixed rate system, the Spectral Compatibility Benchmark is the system range which achieves the required rate in both directions with at least 6 dB margin.

A **Basis System** is a system type that has one or more determined Spectral Compatibility Benchmarks.

The Basis Systems used in this Code are set out in Table 2-1 and their Spectral Compatibility Benchmarks are given in Clauses 4.1.1 and 4.2.1.

Note 1: Both transmitter and receiver performance of a Basis System are required to determine its Spectral Compatibility Benchmark.

Note 2: Some, but not all, Legacy Systems are Basis Systems.

Note 3: Basis Systems and the associated Spectral Compatibility Benchmarks for different network topologies provide the basis for ensuring network integrity.

Name	Description	Relevant Standard
Voiceband		
ISDN-BR	2B1Q	ITU-T G.961
HDSL-784	2B1Q	ITU-T G.991.1
HDSL-1168	2B1Q	ITU-T G.991.1
HDSL-2320	2B1Q	ITU-T G.991.1
E1-HDB3	2048 kbit/s	ITU-T G.703
ADSL	Reduced NEXT option	ITU-T G.992.1
ADSL-Lite	Non-overlapped spectrum	ITU-T G.992.2

Table 2-1:
Basis Systems

Transceiver models for the Basis Systems are given in Clause 5.3.

2.3 Unacceptable Interference into a Basis System

Unacceptable Interference into a Basis System is defined in Clause 8.2.2 of Part 1 of this Code. The concept of Unacceptable Interference into a Basis System requires determination of the impact on Basis Systems of crosstalk interference caused by disturbing systems. The impact on Basis Systems is determined as follows:

1. The determination of crosstalk interference is based on a representative cable sub-unit consisting of 10 twisted pairs, 4 of which carry the disturbing system type and 5 of which carry the disturbed system type. Hence each disturbed system is subject to interference from 4 systems of the disturbing type and 4 of the same type as itself.
2. The method of calculation of the 1% worst-case crosstalk from the disturbing systems is given in Clause 5.
3. The transmit and receive characteristics of the Basis Systems are given in Clause 5.3.
4. The topologies considered in the determination must include all those permissible within the deployment restrictions for the disturbing system.
5. The level of interference depends on the relative disposition of disturbing and disturbed systems, and in particular, to represent system performance differences between Deployment State A and Deployment State B, two Spectral Compatibility Benchmarks are defined for each Spectrally Asymmetric Basis System. Spectral Compatibility Benchmark I applies to Basis Systems fed from the Highest NRP in Deployment State A and from the Nominated Lower NRP in Deployment State B, whilst Spectral Compatibility Benchmark II applies to Basis Systems fed from the Highest NRP in Deployment State B.

2.3.1 Test for Crosstalk Interference

For all configurations listed below, the performance of all Basis System types as defined in Clause 5.3 must be no worse than the applicable Spectral Compatibility Benchmarks of those Basis Systems as given in Clauses 4.1.1 and 4.2.1.

The spectral compatibility calculations specified in this clause are based on the assumptions of Clause 2.3 and the method of calculation of Basis System performance given in Clause 5 with the following configurations of the proposed system interfering into each Basis System type in turn.

Note 1: Different configurations are required for each direction of the Spectral Compatibility Benchmark I;

Note2: In each direction the Spectral Compatibility Benchmark is a function of the range of the disturbed Basis System from its Deployment Reference Point (usually at the Highest NRP).

The process for determining proposed deployment rules based on the requirement of Unacceptable Interference into a Basis System is given in Clause 3 for Non-Deployment Class Systems and in Clause 4 for Deployment Class Systems.

(a) Spectral Compatibility Benchmark I configuration.

The configurations in Figures 2-1 and 2-2 for determination of the downstream Spectral Compatibility Benchmark I consist of 4 interferers of the proposed type fed from the proposed Lowest Asymmetric System Feed Point and with the customer end at the higher (or shorter range from the highest NRP) of:

(i) the same location as the disturbed Basis System, or

(ii) a point at the proposed Deployment Limit below the Deployment Reference Point.

and 4 interferers of the same type and the same Deployment Class Group A PSD as the Basis System, with both ends colocated with the disturbed Basis System, interfering into the Basis System fed from the Highest NRP.

The configuration in Figure 2-3 for determination of the upstream Spectral Compatibility Benchmark I consists of 4 interferers of the proposed type and 4 interferers of the same type and the same Deployment Class Group A PSD, as the disturbed Basis System, both with ends colocated with the disturbed Basis System, interfering into the Basis System fed from the Highest NRP.

In both of these configurations the performance must be equal to or better than the corresponding Spectral Compatibility Benchmark I in Clause 4.1.1 for the relevant direction.

(b) Spectral Compatibility Benchmark II configuration (Deployment State B - only for Spectrally Asymmetric Basis Systems)

Spectral Compatibility Benchmark II is defined only for the downstream direction and only for Basis System range beyond the specified range to the Nominated Lower NRP.

The configuration in Figure 2-4 for determination of the downstream Spectral Compatibility Benchmark I consists of 4 interferers of the proposed type fed from the proposed Lowest Asymmetric System Feed Point and with the customer end at the higher of:

(i) the same location as the disturbed Basis System, or

(ii) a point at the proposed Deployment Limit below the Deployment Reference Point.

and 4 interferers of the same type and same Deployment Class Group A PSD as the Basis System fed from the Nominated Lower NRP, interfering into the Basis System fed from the Highest NRP. This should be repeated for 0.5 km intervals between 0.5 km and 3 km of the range from the Highest NRP to the Nominated Lower NRP.

In this configuration the performance must be equal to or better than the corresponding Spectral Compatibility Benchmarks II in Clause 4.2.1 with the specified range parameter.

Note: Lowest Asymmetric System Feed Point is the point nominated as per Clause 8.4.4(6) in Part 1.

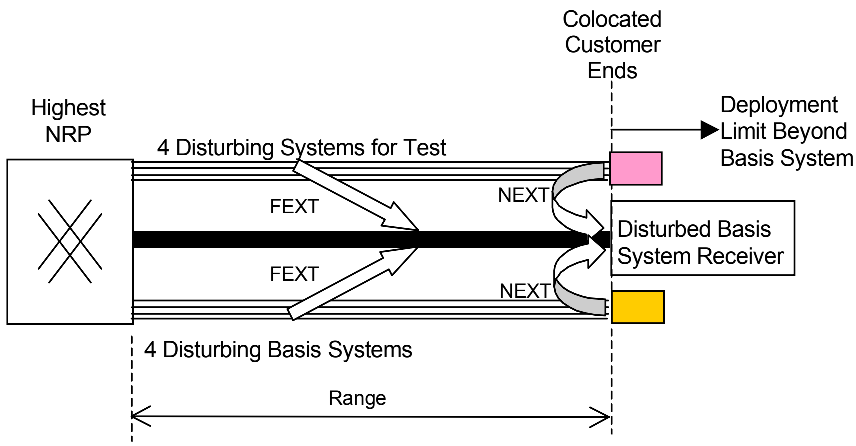

Figure 2-1
Configuration for Downstream Benchmark I for Basis System ranges up to the proposed Deployment Limit

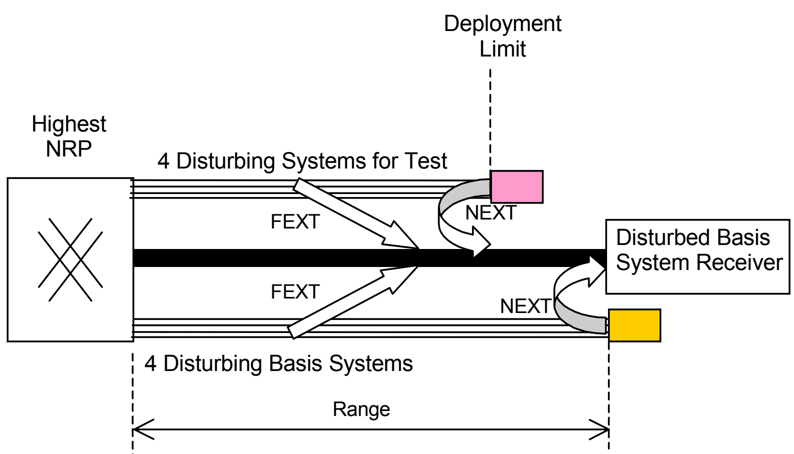

Figure 2-2
Configuration for Downstream Benchmark I for Basis System ranges beyond the proposed Deployment Limit

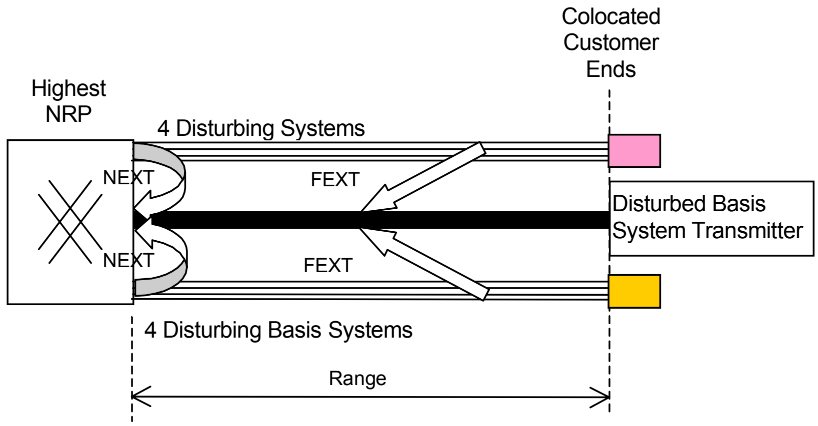

Figure 2-3
Configuration for Upstream Benchmark I

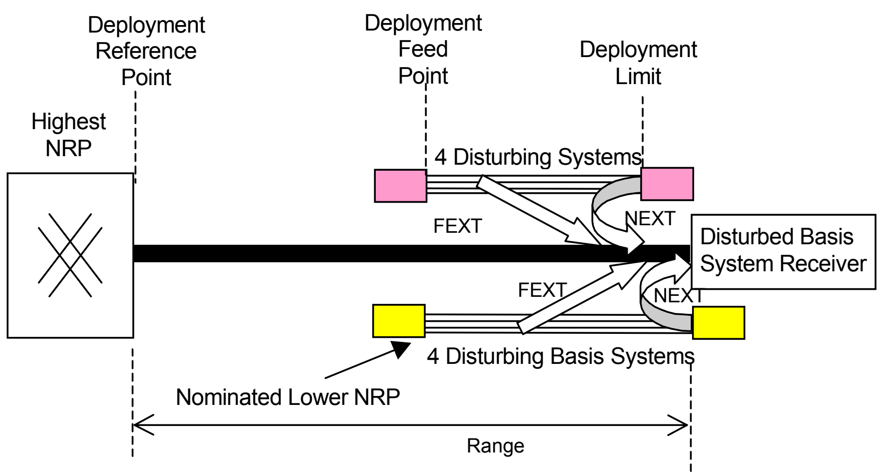

Figure 2-4
Configuration for Benchmark II (Downstream only) for Asymmetric Basis Systems (Note that the Deployment Reference Point and Lowest Asymmetric Feed Point may be nominated by the AS; the Deployment Limit shown is based on the limit for Deployment State A and is measured from the proposed Deployment Reference Point). Note that this diagram only shows the case in (b) (ii).

2.3.2 Tests for Longitudinal Balance and Signal Levels

For Non-Deployment Class Systems, the longitudinal output voltage masks of Clause 8.4.4(7) and the longitudinal balance masks specified of Clause 8.4.4(8) are required to be within the limits below at all frequencies in the specified frequency ranges.

(a) Longitudinal output voltage limit:

-50dBV in any 4kHz band over a frequency range of 10kHz to 12040kHz

(b) Longitudinal balance limit:

40dB from 20kHz to f kHz with a slope 20dB/decade below 20kHz and –20dB/decade above f.

The value of f is the highest frequency in kHz at which the PSD mask is 20dB below its peak .

Where the system uses a different PSD in each direction, the frequency of the upper breakpoint for longitudinal balance is the same for both ends of the system and is the maximum determined from either end PSD.

For Deployment Class Systems, the longitudinal output voltage and balance masks are referenced in Part 3 of this code.

2.4 Unacceptable Excess Power

Clause 8.2.1 of Part 1 requires a Non Deployment Class System to not cause **Unacceptable Excess Power.** Excess power is a measure of the amount by which the system transmit PSD exceeds the maximum PSD of all Deployment Class Systems in Part 3 of this code, as shown in Clause 2.4.1.

2.4.1 Define the Unacceptable Excess Power Template U(f) as the maximum over all of the transmit PSD templates in mW/Hz of all Deployment Class Systems.

U(f) = Max {Pi(f)}

where Pi(f) are the transmit PSD templates (Group A requirements) of the Deployment Class systems in both directions.

The function 10 $\log_{10}$(U(f)) in dBm/Hz is given in Table 2-2 and plotted in Figure 2-5.

Define the function:

$$POS(X) = \begin{vmatrix} X, X \geq 0 \\ 0, X < 0 \end{vmatrix}$$

For a proposed system with transmit PSD S(f) mW/Hz, the excess power is given by:

$$Excess\ \ power = \int_0^\infty POS\big(S(f) - U(f)\big)df$$

2.4.2 The system does not cause Unacceptable Excess Power if Excess power ≤0.05 mW.

Frequency, kHz	Template $10\log_{10}\{U(f)\}$
4.3125	-30.48
8.625	-30.67
12.9375	-31.00
17.25	-31.48
21.5625	-32.14
25.875	-32.50
30.1875	-32.87
34.5	-33.05
38.8125	-33.17
43.125	-33.34
47.4375	-33.70
51.75	-34.15
56.0625	-34.60
60.375	-35.05
64.6875	-35.33
69	-35.45
73.3125	-35.66
77.625	-35.81
81.9375	-36.11
86.25	-36.28
90.5625	-36.58
94.875	-36.73
99.1875	-37.03
103.5	-37.18
107.8125	-37.48
112.125	-37.63
116.4375	-37.88
120.75	-37.94
$125 < f < 276$	-38
280.3125	-39.07
$284.63 < f < 1104$	-40
$1104 < f < 2891.12$	$-40-36\log_2(f/1104)$
$f \geq 2891.12$	-90

Table 2.2
Unacceptable Excess Power Template

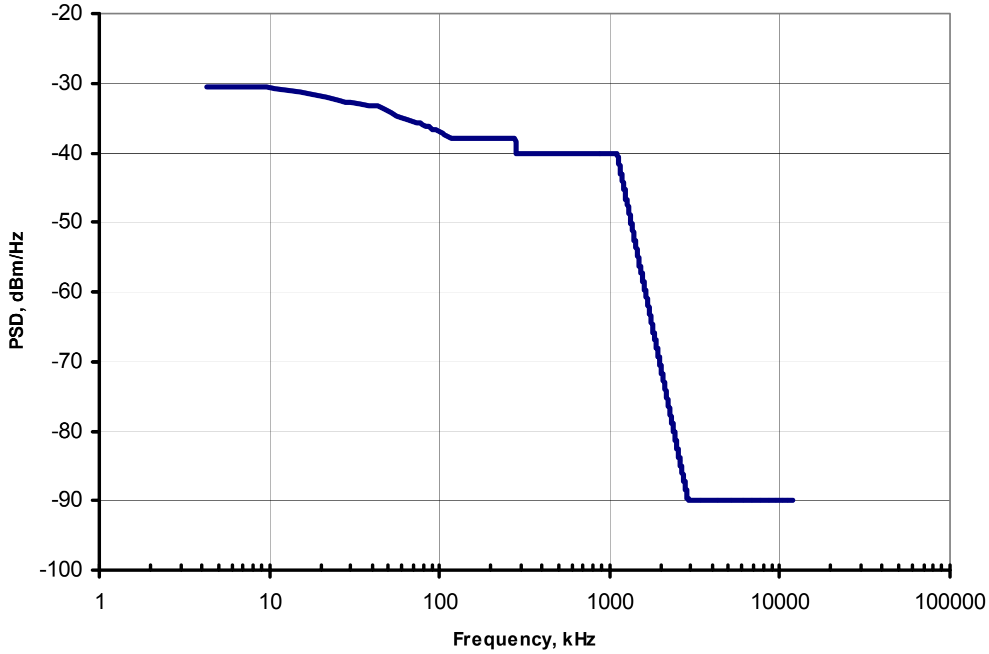

Figure 2.5
Unacceptable Excess Power Template

3. Process for Assessment of Non-Deployment Class Systems

All systems operated using ULLS must not cause Unacceptable Interference into a Basis System. Clause 8.4 of Part 1 requires a carrier or carriage service provider proposing to operate a Non-Deployment Class system to use the ACIF Spectral Compatibility Determination Process described below to determine whether the system will cause Unacceptable Interference into a Basis System.

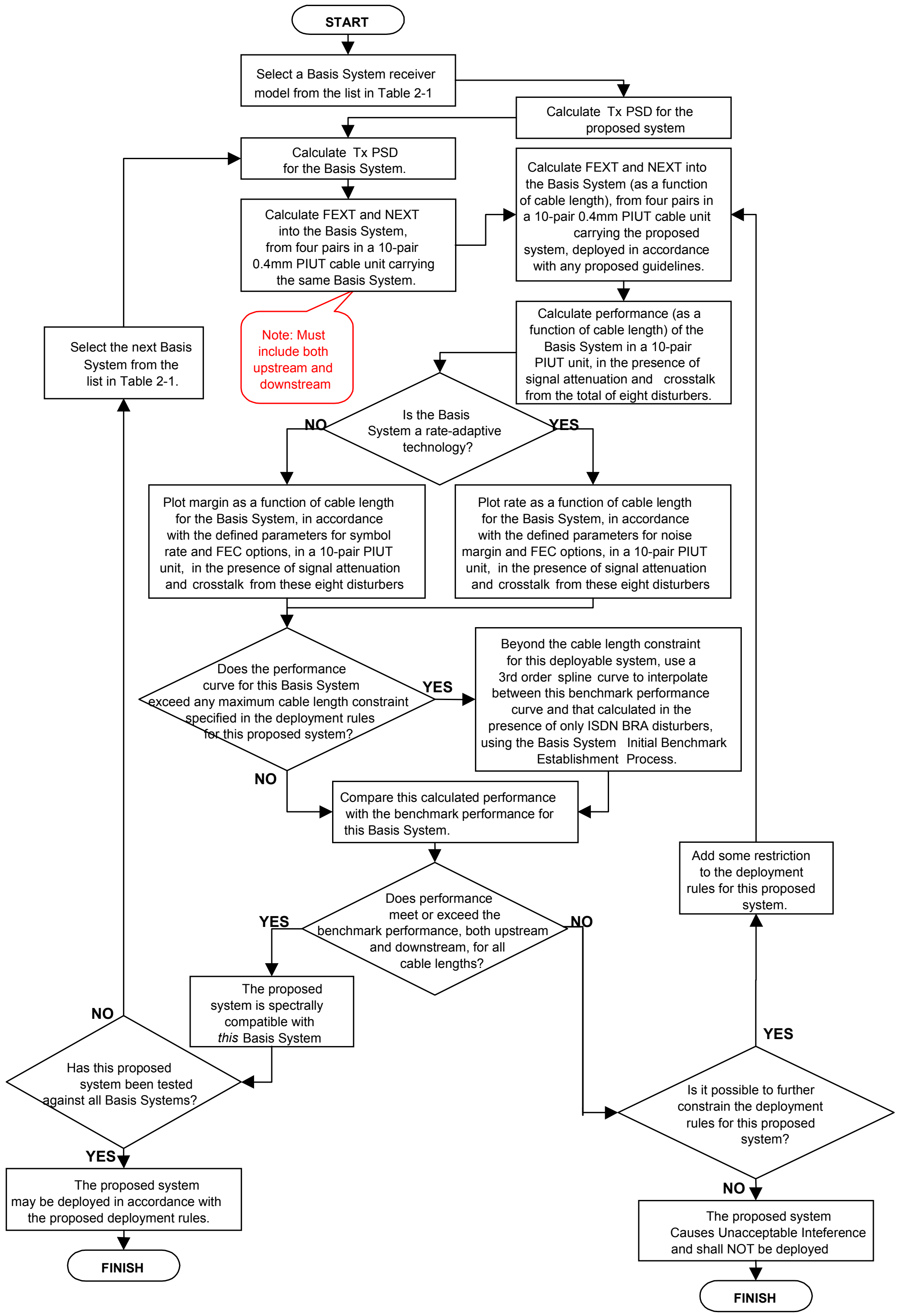

Figure 3-1
Process for Assessment of Non-Deployment Class Systems

4. Process for Determination of Spectral Compatibility Benchmarks for Basis Systems and Deployment Rules for Deployment Class Systems.

The Spectral Compatibility Benchmarks have been determined for a set of idealised Basis Systems that are representative of the system types used on the ULLS. The Spectral Compatibility Benchmarks provide a metric against which the interference generated by proposed deployments is assessed. The crosstalk from 4 systems from a Deployment Class, together with 4 systems of the same type as the Basis System, must not degrade the performance of the Basis System below its Spectral Compatibility Benchmark.

A consistent set of Deployment Classes and Spectral Compatibility Benchmarks is achieved by taking into account the trade-off between suitable Deployment Rules for each Deployment Class and realistic Spectral Compatibility Benchmarks.

Because this Code defines two Deployment States A and B for a DA, two Spectral Compatibility Benchmarks and multiple configurations must be considered in determining whether the operation of a system will cause Unacceptable Interference into a Basis System. These configurations are given in Clause 2.3.1.

Spectral Compatibility Benchmark I is used to determine the Deployment Rules in Deployment State A.

In Deployment State B, any above derived State A Deployment Limits apply, but the Deployment Reference Point from which each limit is measured may differ. For Basis Systems deployed from the Nominated Lower NRP in Deployment State B, the Spectral Compatibility Benchmark I performance is used. However for Basis Systems deployed from any higher NRP in Deployment State B, the Spectral Compatibility Benchmark is degraded by an amount dependent on the range from that higher NRP to the Nominated Lower NRP. Spectral Compatibility Benchmark II gives that performance with the range as a parameter.

4.1 Spectral Compatibility Benchmark I Determination

This process and the resulting Spectral Compatibility Benchmark I applies to Basis Systems originating from the Highest NRP when the DA is in Deployment State A, and to Basis Systems originating from the Nominated Lower NRP when the DA is in Deployment State B. In these situations the Basis Systems achieve their best possible Spectral Compatibility Benchmark in the presence of other systems. (Note that in Deployment State B, a Spectrally Asymmetric Basis System deployed from the Highest NRP will suffer degraded performance compared with Spectral Compatibility Benchmark I; an additional Spectral Compatibility Benchmark II for these cases is included in Clause 4.2.)

The process for determining whether or not a system is deployable is shown in Figure 4-1 and the process for reviewing the Spectral Compatibility Benchmark I of a Basis System is shown in Figure 4-2 and Figure 4-3.

Analysis techniques, assumptions and transceiver models for Basis Systems are shown in Clause 5.

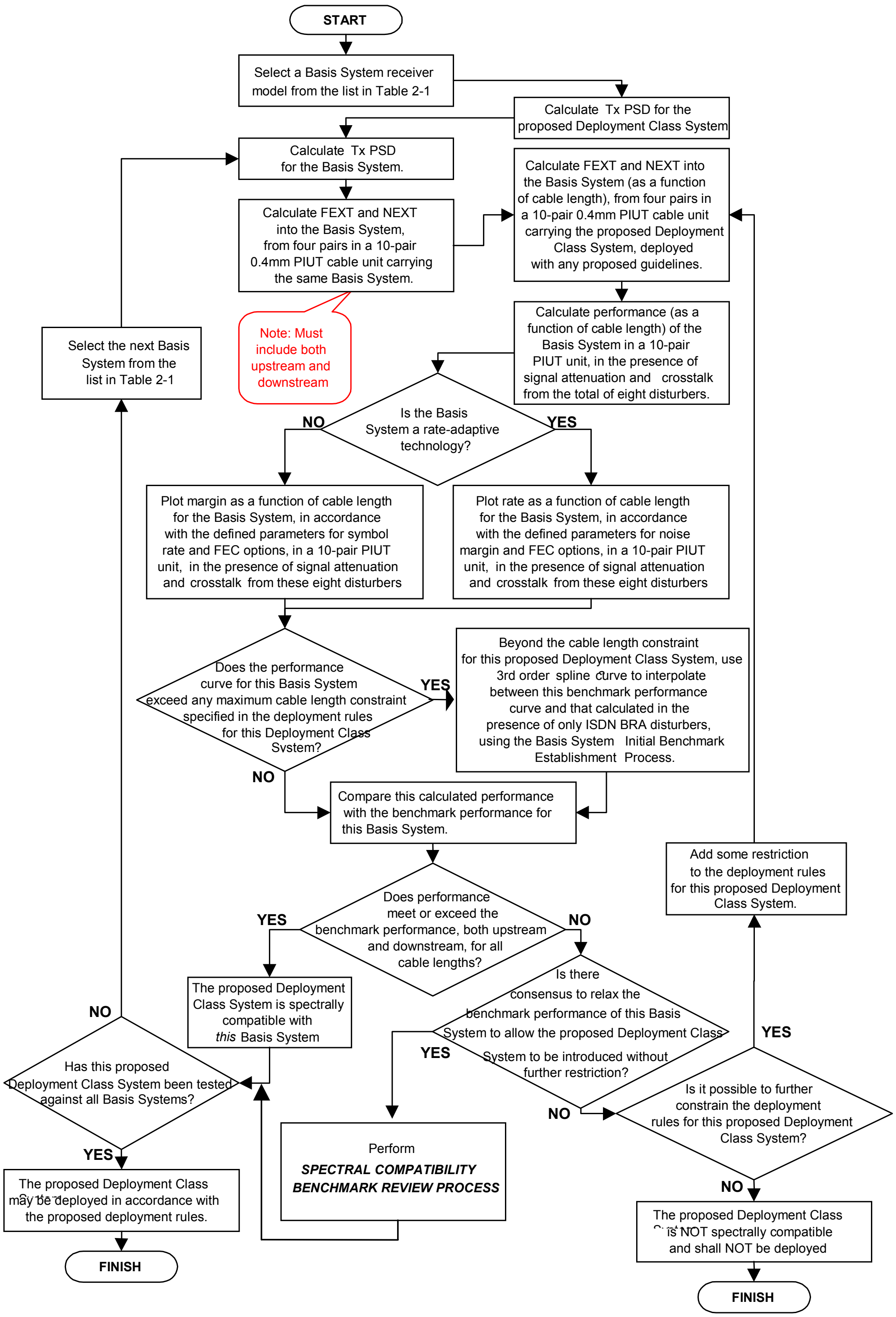

Figure 4-1
Deployment Class System Deployment Rule Determination

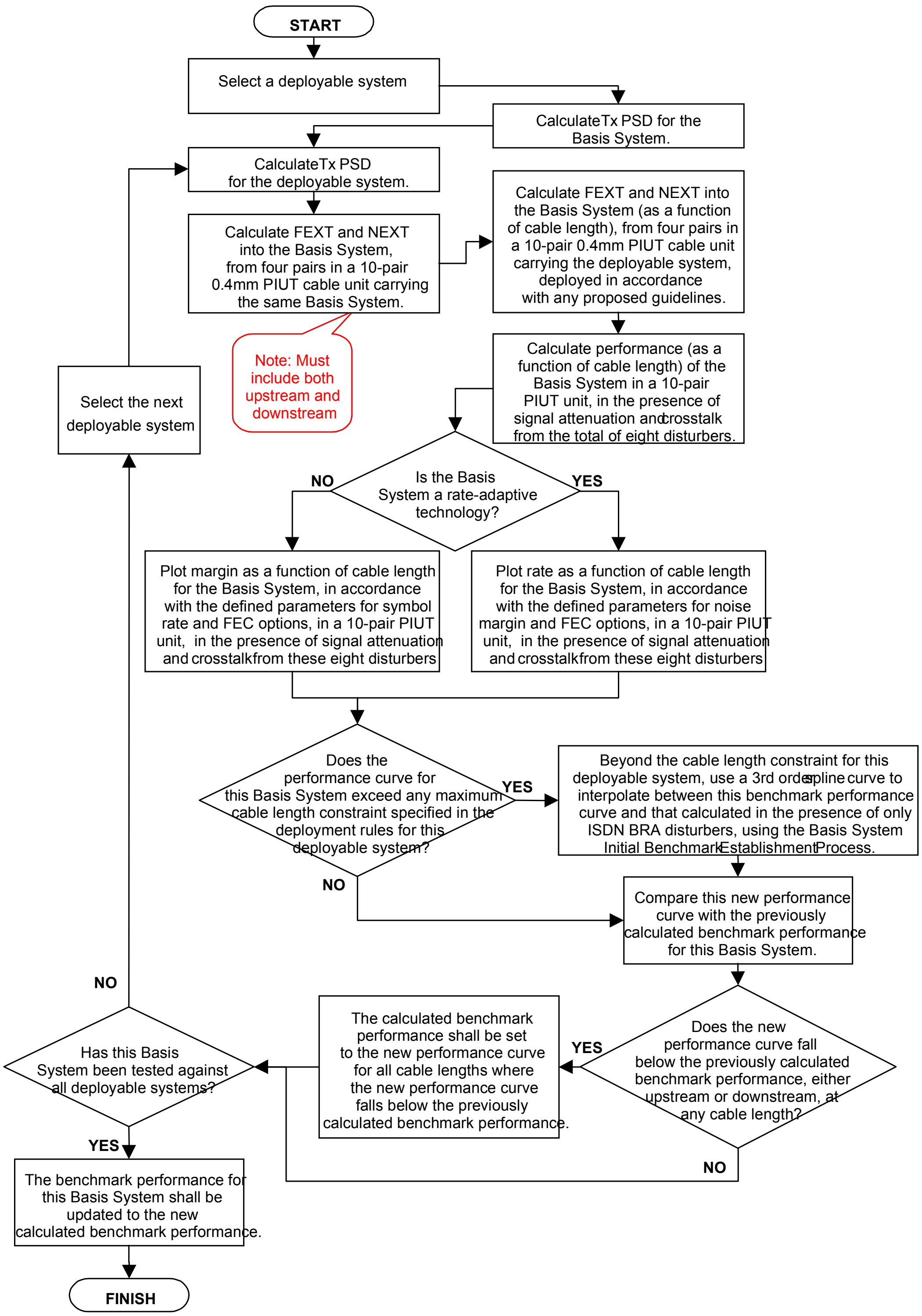

Figure 4-2
Spectral Compatibility Benchmark Review

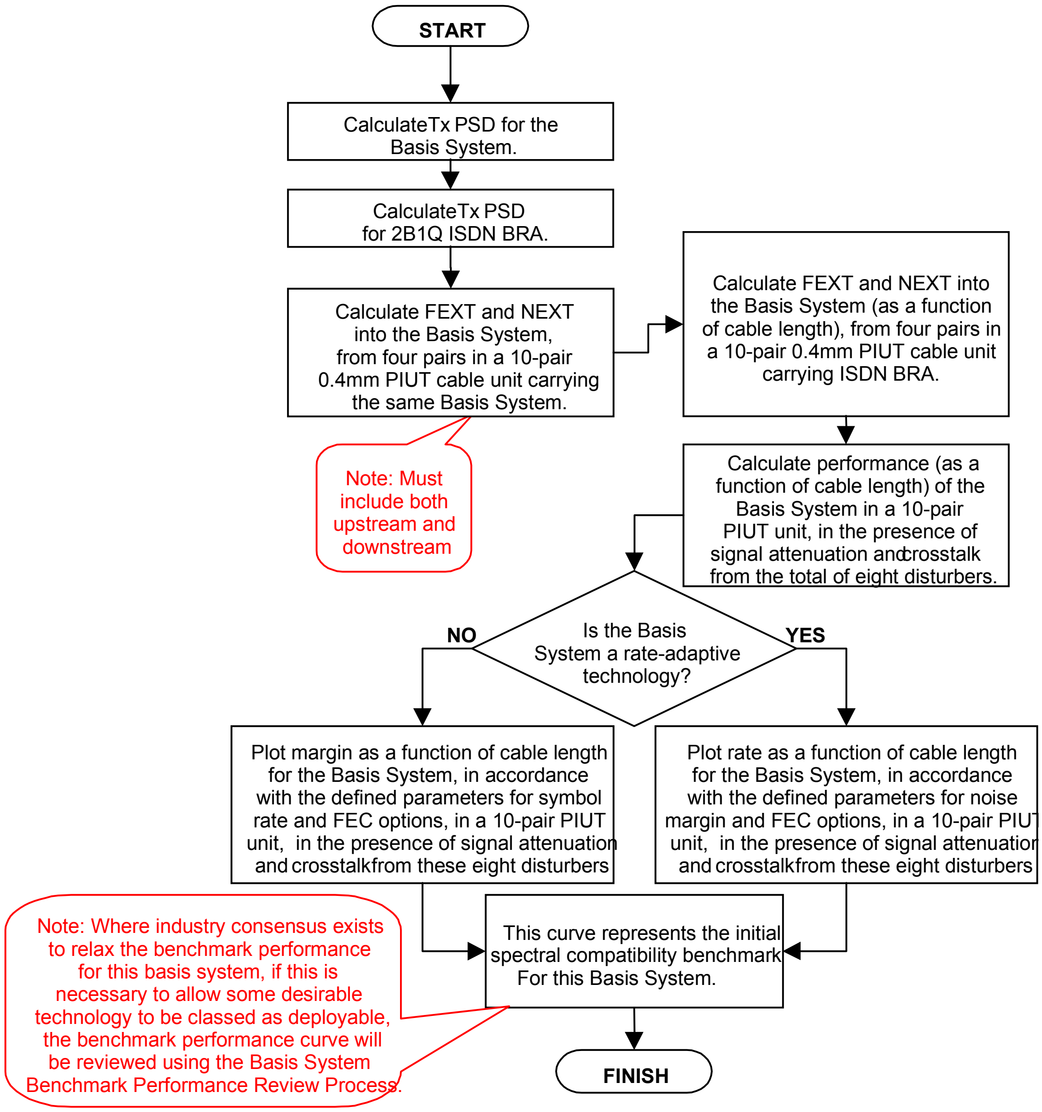

Figure 4-3
Initial Spectral Compatibility Benchmark Establishment

4.1.1 Spectral Compatibility Benchmark I

Spectral Compatibility Benchmarks I have been determined for the Basis Systems described in Clause 5.3.

The Spectral Compatibility Benchmark I for the Voiceband Basis System is the requirement that the total power of any disturbing system in the frequency band $0 < f < 4$kHz shall be less than −10dBm (600Ω).

The Spectral Compatibility Benchmarks I for the fixed rate Basis Systems are given in Table 4-1 both as ranges and as attenuations at the relevant reference frequency (half of the baud rate) in each case.

	Range (km of 0.4mm PIUT)	Reference (kHz)	Attenuation (dB at Reference)
HDSL-784	2.36	196	27.94
HDSL-1168	1.85	292	25.25
HDSL-2320	0.99	580	18.83
E1-HDB3	1.00	1024	26.20
ISDN-BR	5.46	40	44.68

Table 4-1

Spectral Compatibility Benchmark I for Fixed Rate Systems, operating on 0.4mm PIUT cable

The Spectral Compatibility Benchmarks I of the variable rate systems are given in Table 4-2 and in Figure 4-4 as the net payload rate with 6 dB margin versus attenuation at 300 kHz. Note that these Spectral Compatibility Benchmarks have been determined for transceivers operating on well-matched and well-balanced lines; i.e. with no impact from splitters.

		ADSL		ADSL-lite				ADSL		ADSL-lite	
Range	Atten(dB)	Rate (kbit/s)		Rate (kbit/s)		Range	Atten(dB)	Rate (kbit/s)		Rate (kbit/s)	
(km)	at 300kHz	down	up	down	up	(km)	at 300kHz	down	up	down	up
0.1	1.38	6648	1000	2584	1000	2.6	35.91	4777	548	1948	548
0.2	2.76	6648	1000	2584	1000	2.7	37.29	4579	520	1948	520
0.3	4.14	6648	1000	2584	1000	2.8	38.67	4377	499	1948	499
0.4	5.52	6648	1000	2584	1000	2.9	40.05	4179	484	1948	484
0.5	6.91	6648	1000	2584	1000	3	41.43	3984	472	1948	472
0.6	8.29	6648	1000	2584	1000	3.1	42.81	3788	463	1948	463
0.7	9.67	6648	1000	2584	1000	3.2	44.19	3586	454	1948	454
0.8	11.05	6648	1000	2584	1000	3.3	45.57	3373	434	1948	434
0.9	12.43	6648	1000	2584	1000	3.4	46.95	3128	412	1948	412
1	13.81	6648	1000	2584	1000	3.5	48.34	2880	392	1948	392
1.1	15.19	6648	1000	2584	1000	3.6	49.72	2617	368	1948	368
1.2	16.57	6564	1000	2584	1000	3.7	51.10	2333	312	1899	312
1.3	17.95	6424	964	2552	964	3.8	52.48	2060	284	1748	284
1.4	19.33	6272	936	2376	936	3.9	53.86	1848	264	1636	268
1.5	20.72	6116	916	2252	916	4	55.24	1552	212	1412	212
1.6	22.10	5916	868	2064	868	4.1	56.62	1380	180	1300	180
1.7	23.48	5780	840	1952	840	4.2	58.00	1172	156	1140	156
1.8	24.86	5732	804	1948	804	4.3	59.38	936	136	936	136
1.9	26.24	5696	772	1948	772	4.4	60.76	776	96	776	96
2	27.62	5691	740	1948	740	4.5	62.15	548	48	548	48
2.1	29.00	5691	712	1948	712	4.6	63.53	408	8	408	8
2.2	30.38	5678	668	1948	668	4.7	64.91	248	0	248	0
2.3	31.76	5528	640	1948	640	4.8	66.29	168	0	168	0
2.4	33.14	5300	608	1948	608	4.9	67.67	64	0	64	0
2.5	34.53	4984	572	1948	572	5	69.05	0	0	0	0

Table 4-2

Spectral Compatibility Benchmark I values for Variable Rate Systems, operating on 0.4mm PIUT cable.

Note: At short ranges the actual calculated net transmission rates exhibit step fluctuations caused by the mandatory power cut-back provisions for ADSL and ADSL-lite systems. These fluctuations have been removed by setting constant rates (equal to the lowest local minima) across this region of the table.

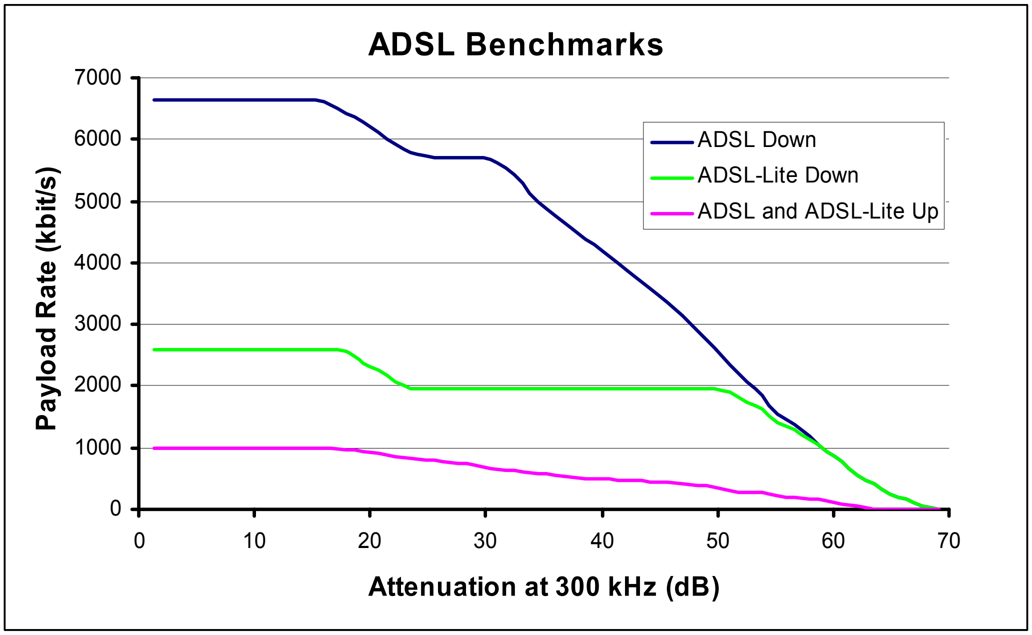

Figure 4-4
Spectral Compatibility Benchmark I values for Variable Rate Systems, operating on 0.4mm PIUT cable

4.2 Spectral Compatibility Benchmark II Determination

Spectral Compatibility Benchmark II applies to Spectrally Asymmetric Basis Systems originating from any NRP higher than the Nominated Lower NRP when the DA is in Deployment State B. Those Basis systems unavoidably suffer degraded performance as a result of unequal level FEXT from other Spectrally Asymmetric systems which may be deployed from lower NRPs in Deployment State B. These Spectral Compatibility Benchmarks II have been generated in order to determine which systems may be deployed from the Nominated Lower NRP in Deployment State B, without further degrading the performance of Spectrally Asymmetric Basis Systems originating from the Highest NRP. Because the use of symmetric systems from the Highest NRP does not result in failure to achieve the Spectral Compatibility Benchmarks I performance of those systems, these Spectral Compatibility Benchmarks II apply only to Spectrally Asymmetric Basis Systems.

The process of determination of the Spectral Compatibility Benchmark II uses the processes in Figs 4-1 to 4-3 with the following modifications:

(a) Only the performance of Spectrally Asymmetric Basis Systems operating from the Highest NRP in Deployment State B are considered.

(b) A separate Spectral Compatibility Benchmark II performance is established for each of a range of lengths on 0.4mm PIUT cable from the Highest NRP to the Nominated Lower NRP at which the disturbing systems are fed.

(c) The process of establishing the Spectral Compatibility Benchmark II curves must not result in any change to the Deployment Limits, but may result in a change in the location of the Lowest Asymmetric Feed Point and the Deployment Reference Point for some Deployment Classes in Deployment State B.

4.2.1 Spectral Compatibility Benchmark II

The Spectral Compatibility Benchmarks II of the Spectrally Asymmetric Basis Systems when fed from the Highest NRP in Deployment State B are given in Figure 4-5 and Table 4-3 for ADSL and Figure 4-6 and Table 4-4 for ADSL-Lite. In each case the Spectral Compatibility Benchmark II is a function of the range from the Highest NRP to the Nominated Lower NRP for Deployment State B.

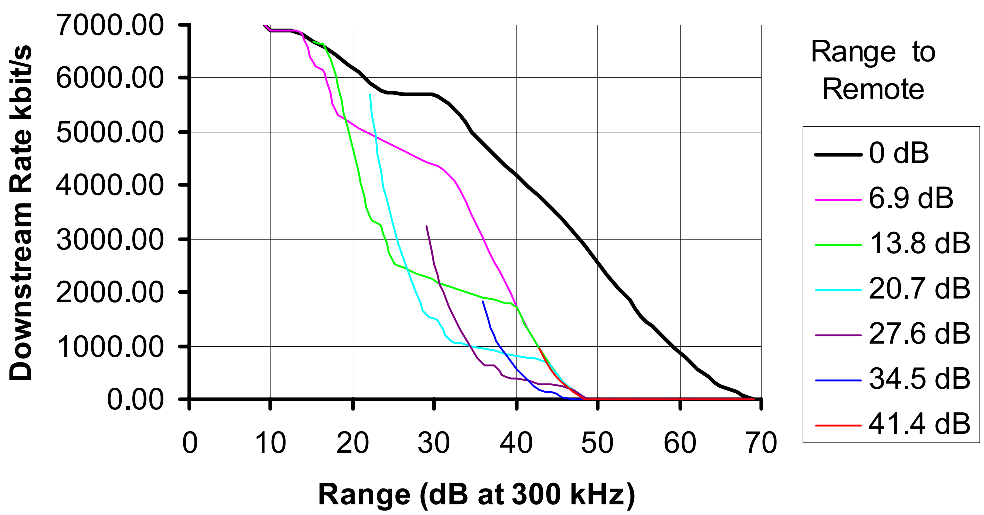

Figure 4-5
Spectral Compatibility Benchmark II values for ADSL as a function of range from the Highest NRP, with range from the Highest NRP to the Nominated Lower NRP as a parameter.

Range		Attenuation at 300 kHz to remote feed						
km .4PIUT	dB at 300 kHz	0 dB	6.9 dB	13.8 dB	20.7 dB	27.6 dB	34.5 dB	41.4 dB
0.10	1.38	9600						
0.20	2.76	8864						
0.30	4.14	8488						
0.40	5.52	8000						
0.50	6.9	7736						
0.60	8.28	7308	7308					
0.70	9.66	6920	6920					
0.80	11.04	6896	6896					
0.90	12.42	6886	6886					
1.00	13.8	6820	6820					
1.10	15.18	6680	6300	6680				
1.20	16.56	6564	6092	6564				
1.30	17.94	6424	5384	6040				
1.40	19.32	6272	5216	5092				
1.50	20.7	6116	5080	4252				
1.60	22.08	5916	4972	3428	5692			
1.70	23.46	5780	4860	3240	4248			
1.80	24.84	5732	4744	2604	3320			
1.90	26.22	5695	4636	2476	2612			
2.00	27.6	5691	4528	2360	2052			
2.10	28.98	5704	4428	2272	1592	3236		
2.20	30.36	5677	4352	2188	1488	2312		
2.30	31.74	5528	4192	2116	1132	1736		
2.40	33.12	5300	3916	2052	1064	1292		
2.50	34.5	4984	3460	1976	1000	960		
2.60	35.88	4792	3032	1904	944	676	1812	
2.70	37.26	4579	2572	1856	900	620	1212	
2.80	38.64	4376	2164	1808	860	408	844	
2.90	40.02	4179	1716	1716	820	372	564	
3.00	41.4	3984	1296	1296	780	336	356	
3.10	42.78	3787	952	952	732	296	180	952
3.20	44.16	3586	628	628	628	264	148	548
3.30	45.54	3376	348	348	348	248	28	312
3.40	46.92	3145	168	168	168	168	8	140
3.50	48.3	2880	24	24	24	24	0	16
3.60	49.68	2616	0	0	0	0	0	0
3.70	51.06	2332	0	0	0	0	0	0
3.80	52.44	2060	0	0	0	0	0	0
3.90	53.82	1848	0	0	0	0	0	0
4.00	55.2	1552	0	0	0	0	0	0

Table 4-3

Spectral Compatibility Benchmark II values for ADSL in kbit/s as a function of range from the Highest NRP, with range from the Highest NRP to the Nominated Lower NRP as a parameter.

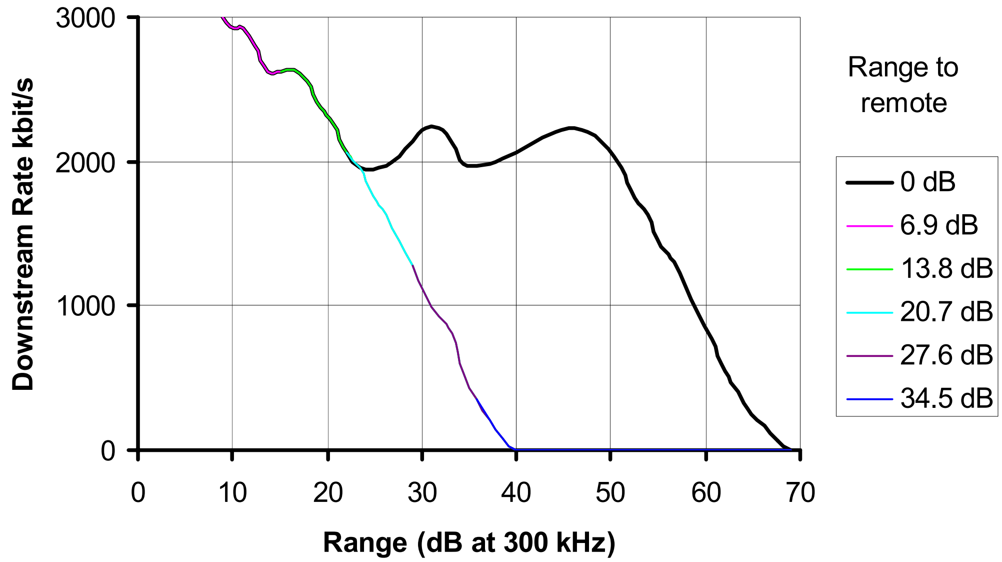

Figure 4-6
Spectral Compatibility Benchmark II values for ADSL-Lite as a function of range from the Highest NRP, with range from the Highest NRP to the Nominated Lower NRP as a parameter.

Range		Attenuation at 300 kHz to remote feed						
km .4 PIUT	dB at 300 kHz	0 dB	6.9 dB	13.8 dB	20.7 dB	27.6 dB	34.5 dB	41.4 dB
0.1	1.38	3968						
0.2	2.76	3744						
0.3	4.14	3600						
0.4	5.52	3392						
0.5	6.9	3260						
0.6	8.28	3080	3080					
0.7	9.66	2932	2932					
0.8	11.04	2920	2920					
0.9	12.42	2804	2804					
1	13.8	2616	2616					
1.1	15.18	2616	2616	2616				
1.2	16.56	2630	2630	2630				
1.3	17.94	2552	2552	2552				
1.4	19.32	2376	2376	2376				
1.5	20.7	2252	2252	2252				
1.6	22.08	2064	2064	2064	2064			
1.7	23.46	1952	1952	1952	1952			
1.8	24.84	1948	1760	1760	1760			
1.9	26.22	1969	1628	1628	1628			
2	27.6	2035	1444	1444	1444			
2.1	28.98	2134	1284	1284	1284	1284		
2.2	30.36	2226	1076	1076	1076	1076		
2.3	31.74	2236	928	928	928	928		
2.4	33.12	2124	808	808	808	808		
2.5	34.5	1980	532	532	532	532		
2.6	35.88	1976	352	352	352	352	352	
2.7	37.26	1986	204	204	204	204	204	
2.8	38.64	2019	84	84	84	84	84	
2.9	40.02	2066	0	0	0	0	0	
3	41.4	2119	0	0	0	0	0	
3.1	42.78	2170	0	0	0	0	0	0
3.2	44.16	2210	0	0	0	0	0	0
3.3	45.54	2230	0	0	0	0	0	0
3.4	46.92	2224	0	0	0	0	0	0
3.5	48.3	2172	0	0	0	0	0	0

Table 4-4

Spectral Compatibility Benchmark II values for ADSL-Lite in kbit/s as a function of range from the Highest NRP, with range from the Highest NRP to the Nominated Lower NRP as a parameter.

5 CALCULATION OF BASIS SYSTEM PERFORMANCE

For a given disturbing system type, the Basis System performance is calculated for each of the configurations in Clause 2.3.1 using the cable attenuation models and parameters of Clause 5.1, the crosstalk noise environment of Clause 5.2 and the Basis System transceiver models of Clause 5.3. This calculation is implemented in a software tool which will be available to Carriers and Carriage Service Providers.

Basis System performance is the achievable rate versus range (or just the range for a fixed rate system) for that Basis System when the 1% worst case error rate equals 10^{-7} with a 6dB margin.

5.1 Cable Environment

The multiplicity of cable types and gauges found in the Australian customer access network, and indeed in any one customer loop, cannot all be modelled separately. To simplify matters, the most common type of Communications Wire, viz., 0.4mm Paper Insulated Unit Twin (PIUT) copper pair cable, is taken to be representative of the behaviour of customer access loops.

The fundamental parameters of this cable are (for *f* in kHz):

$$R = \left(r_0^{\,4} + r_1 f^{\,2}\right)^{\frac{1}{4}} \qquad \Omega / km \text{ where}$$

$$r_0 = 2.71793 \times 10^2; \qquad r_1 = 1.24169 \times 10^5 \qquad (1)$$

$$L = \frac{l_0 + l_1 \left(\frac{f}{f_m}\right)^{\beta}}{1 + \left(\frac{f}{f_m}\right)^{\beta}} \qquad mH / km \text{ where}$$

$$l_0 = 6.43631 \times 10^{-1}; \quad l_1 = 4.28481 \times 10^{-1}; \quad f_m = 1.17408 \times 10^3; \quad \beta = 8.67987 \times 10^{-1} \qquad (2)$$

$$G = g_0 f^{\alpha} \qquad S / km \text{ where}$$

$$\text{where } g_0 = 1.01848 \times 10^{-6}; \qquad \alpha = 1.24621 \qquad (3)$$

$$C = c_0 + c_1 f^{-\chi} \qquad mF / km \text{ where}$$

$$c_0 = 3.46262 \times 10^{-5}; \quad c_1 = 1.08788 \times 10^{-5}; \quad \chi = 3.89154 \times 10^{-2} \ (4)$$

Studies of system spectral compatibility are performed as if the whole access network were made up of 0.4mm PIUT. The resulting deployment range limits for deployable systems are then converted, at a suitable frequency for the system under study, to Calculated Attenuation Deployment Limits for application to mixed cable types and gauges.

The layout and make-up of the access network has a significant influence on spectral compatibility in that pairs serving customers that are widely separated geographically have a low probability of being in the same cable unit. This leads to the assumption in the study of zero probability of pairs being in the same unit for customers separated by more than 1.2 km.

5.2 The Noise Environment

The types of noise considered in the analysis include:

(a) Background white Gaussian noise at a PSD of –140 dBm/Hz (assumed the same and added into all cases – as per T1E1.4)

(b) Self crosstalk noise from other systems of the same type as the Disturbed System; and

(c) Compatibility crosstalk noise from transmission systems of different type from the Disturbed System.

5.2.1 Crosstalk Noise

The crosstalk noise at the input to the disturbed receiver may be via NEXT and/or FEXT paths from other pairs in the same cable.

The NEXT or FEXT path is modelled using the 1% worst case (or 99th percentile) of the power sum crosstalk noise from n disturbers. For Australian cables with 10-pair subunits (other cables may have different unit size but still give approximately the same worst case noise for the same % of disturber fill in the unit), the worst case power sum crosstalk formulas are:

NEXT Power Sum Attenuation (NEXTPSA) is the ratio in dB of one of the n identical disturbing PSDs to the total NEXT noise from those disturbers at the NEAR end of the disturbed pair.

$$NEXTPSA = 40.5 - 6\log\left(\frac{n}{4}\right) - 15\log(f) \qquad (5)$$

FEXT Power Sum Ratio (FEXTPSR) is the ratio in dB of the far end received PSD of the n identical disturbing systems to the total FEXT noise from those disturbers at the FAR end of the disturbed pair.

$$FEXTPSR = 36 - 6\log\left(\frac{n}{4}\right) - 10\log\left(f^2 l\right) \qquad (6)$$

where n is the number of disturbers from a 10-pair subunit, l is the length of 0.4mm PIUT cable in km, and f is in MHz.

NEXTPSA is known to remain about the same for all gauges of access network cables, due to the compensating effects of pair separation and cable attenuation. Hence it is assumed to be the same for all cables, including mixed gauge cables.

The variation of FEXT with cable gauge is less well understood, but FEXTPSR is known to increase (ie FEXT noise decreases for the same length) significantly with increasing gauge of the cable. However, the $-10\log(l)$ dependence on length results in a corresponding decrease in FEXTPSR for a heavier gauge cable run with the same attenuation. Hence FEXTPSR is assumed to be the same for all cables, including mixed gauge cables, with the same attenuation.

Category 5 cable may be used in buildings and in future broadband access networks. Its NEXTPSA and FEXTPSR are given by:

$$NEXTPSA_5 = 61.5 - 6\log\left(\frac{n}{4}\right) - 15\log(f) \qquad (7)$$

$$FEXTPSR_5 = 55 - 6\log\left(\frac{n}{4}\right) - 10\log\left(f^2 l\right) \qquad (8)$$

For NEXT, the NEXTPSA in dB is subtracted from the PSD in dBm/Hz transmitted by the Disturbing System to obtain the PSD of the NEXT noise at the receiver input. With PSD in dBm/Hz, the noise PSD N_i at the receiver input is:

$$N_i = PSD_i\left(f\right) - NEXTPSA(f) \qquad (9)$$

For FEXT, the FEXTPSA Ratio in dB and the line attenuation in dB are both subtracted from the PSD in dBm/Hz transmitted by the disturbing system. The FEXT noise PSD F_i at the receiver input is:

$$F_i = PSD_i\left(f\right) - FEXTPSR(f) - A(f) \qquad (10)$$

where A(f) is the line attenuation in dB.

5.2.2 Transmit Power Spectral Densities of Disturbing Systems

The transmit Power Spectral Density (PSD) of the Disturbing Systems are modelled as templates which have been obtained from the relevant standards and system descriptions as follows. The key requirement is that, for a standard which has a line code and PSD mask defined, the template provides a close approximation to the real transmit PSDs of systems which meet the standard. Hence the following approach:

(a) The midband PSD in the template is taken to be the nominal value specified in the relevant standard; and

(b) The remainder of the template, in the regions of high and low frequency rolloff, should be less than or equal to the mask in the standard, and attempt to more closely follow the actual ideal PSD dictated by the line code. Several such templates have been drawn from the T1E1.4 Draft Spectrum Management Standard. Others such as those for SHDSL (ITU G.991.2) are drawn directly from the relevant standard.

For systems which are in common use but are not standards or draft standards, templates have been based on ideal transmit PSDs (E1) or on obvious extensions from similar standard systems.

Note that all noise models must include an additional –140 dBm/Hz of white Gaussian noise.

Appendix A summarizes the types and origins of transmit PSD models and masks used for the Disturbing Systems in the analysis. The table also gives the relevant frequency at which any range restrictions for each technology are to be converted to attenuation in dB for application to cable types other than the 0.4mm PIUT cable analysed.

5.2.3 Noise Power Summation Method

The FSAN model is adopted by ACIF for the summation of crosstalk noise. T1E1.4/98-189 provides a detailed description and justification of that model.

The model states that when summing multiple NEXT disturbers (or multiple FEXT, but not NEXT and FEXT together), the NEXT noise powers N_i in dB must be added as follows to give the total noise power N.

$$N = 6\log_{10}\left[\sum_i 10^{N_i/6}\right] \qquad (11)$$

When adding NEXT to FEXT and other noise, the noises are added directly in mW/Hz, where N and F are in dB, viz.

$$TotalNoise(dB) = 10\log_{10}\left[10^{N/10} + 10^{F/10}\right] \quad (12)$$

5.3 Transceiver Models for Basis Systems

A transceiver model has been developed for each Basis System. For each Basis System transceiver model it is important to ensure insofar as possible that the computed transmission performances are representative of those achievable with real equipment operating in the real network.

The underlying aim is to develop models that are representative of the majority of equipment likely to be deployed for each potential basis xDSL type. Consequently each model has been first developed in an ideal form, and then adjusted to account for the non-idealization effects of real equipment. The adjustments have been made either against the transmission performance specifications of an appropriate international Standard or draft Standard, or against the known measured performances of relevant commercially available equipment. The adjustment in dB which must be applied to the ideal receiver performance is quoted for each of the Basis Systems in Clauses 5.3.1 to 5.3.4.

It is important to note here, that for each technology the degree of adjustment has been chosen so as to align the model performances with those achievable with well engineered equipment, but not with the highest attainable by unrepresentative very high state-of-the-art systems.

The process just referred to for aligning model performances with those of actual equipment inherently incorporates with it one means of assessing the veracity of the models in question. In addition, the majority of assessments reported here have been obtained using two independently developed computer programs for each basis transceiver. Thus the estimates of each program have been verified against those of the other.

Trellis coding is used in several types of DSL transceivers, and a coding gain in dB is applied to account for the advantage thereby obtained. Generally, the trellis coder adds additional redundant bits to the data symbols, and then uses the redundant information to make more accurate decisions in a noisy environment.

A Decision Feedback Equaliser (DFE) is used in several DSL receivers to optimize the SNR at the decision point of the receiver. Because the performance is dependent on the number of taps and other design features of the digital signal processing used, it has been decided to use ideal (infinite tap count) DFEs for these studies, and then to degrade all DFE-based receivers by an amount to account for practical realisation. Based on computer simulations and measurements of practical systems, this degradation amounts to 4-5 dB.

5.3.1 ADSL Transceiver Model

The ADSL DMT transceiver is based on an ideal model similar to that due to Cioffi (Ref. 1) with parameters according with the G.992.1 Standard. Specifically:

(a) Bit allocation is based on transmit PSD of –38dBm/Hz up and –40 dBm/Hz down for all allocated subchannels (or –3.65dB per 4.3125kHz sub-channel) together with up to +/- 1.5 dB power adjustment to achieve equal signal to noise ratio in all subchannels;

(b) Sub-channels used are determined from the standard PSD masks. The downstream mask for FDD operation employs the reduced NEXT option (i.e. non-overlapped spectra). The subchannels used for upstream are 6 to 31 and for downstream 38 to 256 with subchannel 64 reserved for the pilot tone.

(c) Max bits per sub-channel =14 (up and down);

(d) Minimum bits per sub-channel = 2 (up and down);

(e) Assumed coding gain of combined Reed-Solomon FEC and Trellis coding = 3 dB;

(f) Overhead rate (with fast and slow buffers) = 192 kbit/s down, and 128 kbit/s up; and

(g) No additional overhead FEC.

To just meet the requirements of G.992.1 Region A test loops and test noise conditions, the receiver model used for this Basis System is assumed to be the ideal model.

5.3.2 ADSL-Lite Transceiver Model

The ADSL-Lite DMT transceiver is based on an ideal model similar to that due to Cioffi (Ref. 1) though with parameters according with the G.992.2 Standard. Specifically:

(a) Bit allocation is based on transmit psd of –38dBm/Hz up and –40 dBm/Hz down for all allocated subchannels (or –3.65dB per 4.3125kHz sub-channel) together with up to +/- 1.5 dB power adjustment to achieve equal signal to noise ratio in all subchannels;

(b) Sub-channels used are determined from the Standard PSD masks. The downstream mask for FDD operation employs the reduced NEXT option (i.e. non-overlapped spectra) The subchannels used for upstream are 6 to 31 and for downstream 38 to 128 with subchannel 64 reserved for the pilot tone;

(c) Max bits per sub-channel =14 (up and down);

(d) Minimum bits per sub-channel = 2 (up and down);

(e) Assumed coding gain of combined Reed-Solomon FEC and Trellis coding = 3 dB;

(f) Overhead rate (with fast and slow buffers) = 192 kbit/s down, and 128 kbit/s up; and

(g) No additional overhead for trellis coding or FEC.

To just meet the requirements of G.992.2 Region A test loops and test noise conditions, the receiver model used for this Basis System is assumed to be the ideal model.

5.3.3 ISDN-BR or HDSL Transceiver Models

The 2B1Q transceiver model employs an ideal DFE-based representation that is adjusted to account for the limitations of representative actual systems. The ideal DFE-based representation is that set out in the draft ANSI Spectrum Management Standard (Ref. 2). The representation has been developed from the optimal mean-square error formulation due to Salz (Ref. 3). The transmit PSD is assumed to be ideal –

- For HDSL, 2B1Q line coded full width rectangular pulses, filtered by a 4^{th} order Butterworth filter at half of the baud rate.
- For Basic Rate ISDN, 2B1Q line coded full width rectangular pulses, filtered by a 2^{nd} order Butterworth filter at the baud rate.

- For both the Basic Rate ISDN and the three HDSL Basis Systems, the total transmitted power integrated over the frequency range from 0 to the baud rate shall be exactly +14 dBm

To just meet the requirements of G.961 or G.991.1 test loops, the receiver models for these Basis Systems are assumed to have 5 dB worse performance than the ideal receivers.

5.3.4 E1-HDB3 Transceiver Model

The E1-HDB3 receiver is modelled as an ideal linear equaliser with the following characteristics (some from G.703):

(a) Assumed 100% raised cosine (frequency domain) pulse shape at receiver eye;

(b) Half-width rectangular transmit pulse shape, with peak amplitude = 3.3V; and

(c) Baud rate = 2048 kbaud.

The difference between this ideal equaliser and well designed practical receivers is 1-2 dB. Hence the receiver model for this Basis System is assumed to have 2 dB worse performance than the ideal receiver.

5.3.5 Voiceband

This code does not directly specify a benchmark performance for voiceband systems but instead controls the interference into voiceband systems by limiting the transmit PSD of all disturbing systems within the voiceband.

The total power of any disturbing system in the frequency band $0 < f < 4$kHz shall be less than −10dBm (600Ω).

6 EXPECTED WORST CASE WIDEBAND NOISE MASK ON ULLS

6.1 This section describes the development and definition of an indicative Wideband noise test for an ULLS. The specification accounts for crosstalk noise from disturbing systems belonging to Deployment Classes and deployed according to Deployment Rules . However, it should be noted that it excludes all other possible noise components, such as impulsive noise, and RFI from AM broadcast stations, which are likely to be encountered on actual lines. The expected worst case noise PSD has been calculated for all possible Disturbing Systems when deployed from a ULLS-NRP at a single location. This model applies to both Deployment States A and B as described in Part 1. The process for determination of this worst case noise is as follows:

(a) Determine the 1% worst case crosstalk noise PSD at each end of the cable for 9 disturbers of the given Deployment Class at each end within a 10-pair cable unit;

(b) Repeat for all Deployment Classes at a given line length;

(c) Find the maximum of the 1% worst case crosstalk noise PSD over all classes at the given length;

(d) Repeat at several lengths up to 5 km of 0.4mm PIUT cable, to obtain a length dependent set of noise PSDs at the customer end; and

(e) Fit a mask consisting of straight lines on a plot of dBm in 3 kHz versus log (frequency) to just fit above the 1% worst case noise plots.

(f) Convert the range parameter on the curves to dB at 300 kHz to allow reference to cable types other than 0.4mm PIUT.

6.2 The worst case noise mask of power in 3 kHz at the Deployment Reference Point for an asymmetric Deployment Class is described in Fig. 6-1 and Table 6-1. The worst case noise PSD masks at the ULLS-EURP in Fig 6-2 and Table 6-2 are plotted with the attenuation at 300 kHz as a parameter.

6.3 In Deployment State A, the worst case noise mask applies with the attenuation parameter based on the range from the Highest NRP.

6.4 In Deployment State B;

(1) the network end noise mask in Fig. 6-1 applies to all NRPs between the Highest NRP and the Nominated Lower NRP.

(2) the customer end noise mask in Fig. 6-2 applies where the attenuation parameter is measured from the Nominated Lower NRP. Note that this corresponds to more severe customer end noise for systems fed from the exchange in Deployment State B, compared with Deployment State A.

6.5 The worst case wideband noise masks represent the 1% worst case noise PSD due to crosstalk from all Deployment Class Systems on the reference 0.4mm PIUT cable. These masks are expected to be exceeded in less than 1% of cases on unit cables, but may be exceeded in a larger percentage of cases on quad cable.

6.6 The effect of radio frequency interference on ULLS noise is to introduce large spikes associated with AM radio broadcasts; these spikes are tolerated by most DSL systems and they should not be considered exceedances.

6.7 Exceedance of the mask does not necessarily result in system failure because the frequency bands used by the systems may not align with the frequencies at which exceedance occurs. System failures may occur even when the mask is not exceeded because of wideband interference due to combinations of multiple crosstalk and external noise sources. Therefore the mask is only indicative of a more severe noise environment.

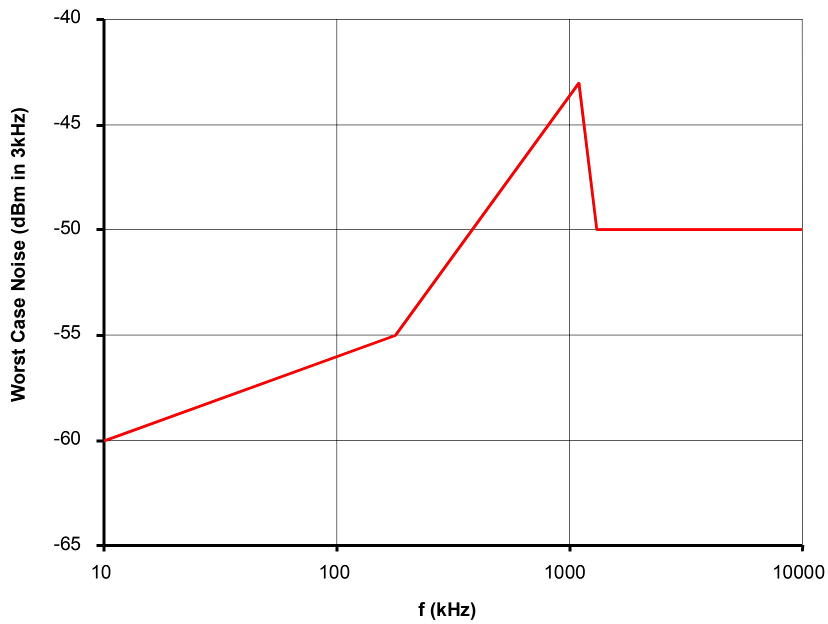

Figure 6-1
Worst case noise power in 3 kHz at the Highest NRP in Deployment State A, and at any location between the Highest NRP and the Nominated Lower NRP in Deployment State B.

Frequency (kHz)	Noise in 3 kHz (dBm)
10	-60
180	-55
1100	-43
1300	-50
10000	-50

Table 6-1
Break points of mask for worst case noise at the Highest NRP in Deployment State A, and at any location between the Highest NRP and the Nominated Lower NRP in Deployment State B.

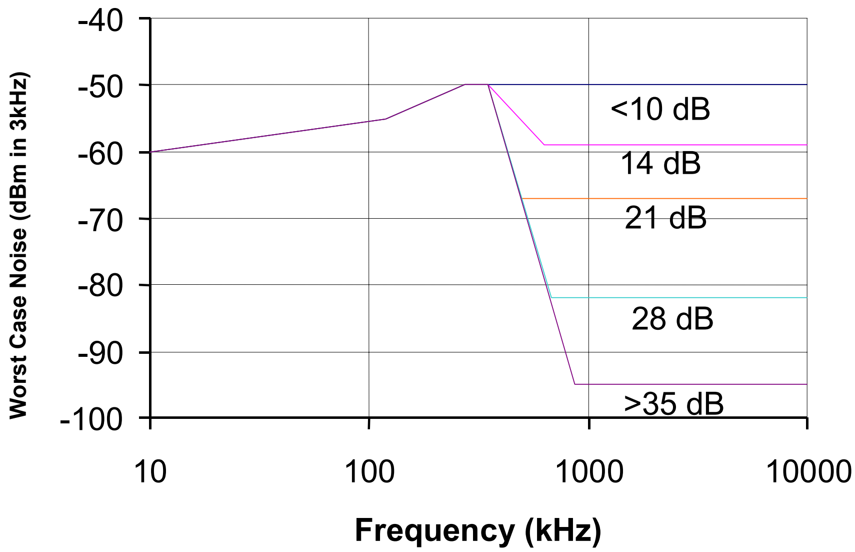

Figure 6-2
Worst case noise power in 3 kHz at the Network Boundary Point as a function of the cable attenuation at 300 kHz from the Highest NRP in Deployment State A, and from the Nominated Lower NRP in Deployment State B.

Line attenuation < 10 dB		Line attenuation 14 dB		Line attenuation 21 dB		Line attenuation 28 dB		Line attenuation > 35 dB	
f (kHz)	dBm	f (kHz)	dBm	f (kHz)	dBm	f (kHz)	dBm	f (kHz)	dBm
10	-60	10	-60	10	-60	10	-60	10	-60
120	-55	120	-55	120	-55	120	-55	120	-55
276	-50	276	-50	276	-50	276	-50	276	-50
50	-50	350	-50	350	-50	350	-50	350	-50
10000	-50	635	-59	495	-67	680	-82	870	-95
		10000	-59	10000	-67	10000	-82	10000	-95

Table 6-2
Break points for masks for worst case noise at the Network Boundary Point as a function of the cable attenuation at 300 kHz from the Highest NRP in Deployment State A, and from the Nominated Lower NRP in Deployment State B..

7 REFERENCES

1. Cioffi, J. "A Multicarrier Primer". ANSI Standards Committee T1 Submission, T1E1.4/91-157, 11th November 1991.

2. Alliance for Telecommunications Industry Solutions. "Spectrum Management for Loop Transmission Systems". ANSI draft Standard; T1E1.4/99-002R4 (DRAFT T1.XXX-1999).

3. Salz, J. "Optimum Mean-Square Decision Feedback Equalization". BSTJ, October 1973, pp1341-1373.

4. FSAN VDSL working group " A new analytical method for NEXT and FEXT noise calculation", T1.E1.4 contribution 98-189, 28 May 1998.

5 ITU-T Recommendation G.991.2 " SHDSL"

APPENDIX A - TRANSMIT PSD TEMPLATES FOR DEPLOYMENT CLASS SYSTEMS

This Appendix gives the transmit PSD templates for the Deployment Class Systems which are used to define the disturbing systems in the calculation of Basis System performance. These templates correspond to the Group A requirements referenced in Part 3 for the Deployment Classes.

Deploy-ment Class	Reference to source of Transmit PSD Template	Midband PSD or other parameter	Typical Technology (informative)	Reference frequency for class (kHz)
1a	Ideal based on G. 703	V_{peak} = 3.1V	E1 HDB3 ≤ 0.7 km	1024
1b	Ideal based on G.703	V_{peak} = 3.1V	Reserved (E1 HDB3 > 0.7 km)	1024
2a	Reserved			
3a	Systems complying with class 3a shall comply with the requirements of [--]AS/ACIF S043.3, AS/ACIF S002 or AS/ACIF S003 or AS/ACIF S006	Used ISDN mask from 4a for high frequency content	Low Band	-
4a	ANSI SM Class 1 Template	-32 dBm/Hz	ISDN BR 2B1Q	40
5a	Modified G.991.2	Based on Formula in equation (14)	Modified Rolloff SHDSL to 570 kbit/s	95
5b	Modified G.991.2	Based on Formula in equation (14)	Modified Rolloff SHDSL with reduced power to 784 kbit/s	130.67
6a	G.992.1 with reduced NEXT	Up –38 dBm/Hz Down –40 dBm/Hz	ADSL FD	300
6b	G.992.2	Up –38 dBm/Hz Down –40 dBm/Hz	ADSL Lite	300
6c	G.992.1 Annex	Up –38 dBm/Hz Down –40 dBm/Hz	ADSL over ISDN	300
6d	G.992.1	Up –38 dBm/Hz Down –40 dBm/Hz	ADSL EC	300
6e	Modified G.992.1	Up –38 dBm/Hz Down –50 dBm/Hz	ADSL FD Low Power	300
6f	Modified G.992.1	Up –38 dBm/Hz Down –40 dBm/Hz	ADSL FD Limited carriers	300
7a	Frequency scaled ANSI SM Class 3 template.	Based on Formula in equation (13)	SDSL (≤ 272 kbit/s)	68
7b	Frequency scaled ANSI SM Class 3 template.	Based on Formula in equation (13) reduced by 3.5 dB	SDSL (≤ 528 kbit/s, reduced power)	132
7c	Frequency scaled ANSI SM Class 3 template.	Based on Formula in equation (13)	SDSL (≤ 528 kbit/s)	132
7d	Frequency scaled ANSI SM Class 3 template.	Based on Formula in equation (13)	SDSL (≤ 784 kbit/s)	196
7e	Frequency scaled ANSI SM Class 3 template.	Based on Formula in equation (13)	SDSL (≤ 1168 kbit/s)	292
7f	Frequency scaled ANSI SM Class 3 template.	Based on Formula in equation (13)	SDSL (≤ 1552 kbit/s)	388
7g,i	Frequency scaled ANSI SM Class 3 template.	Based on Formula in equation (13)	SDSL (≤ 2064 kbit/s)	516
7h,j	Frequency scaled ANSI SM Class 3 template.	Based on Formula in equation (13)	SDSL (≤ 2320 kbit/s)	580

8a	Frequency scaled ANSI SM Class 3 template.	-37 dBm/Hz	HDSL 2B1Q 784 kbit/s	196
8b	Frequency scaled ANSI SM Class 3 template.	-39 dBm/Hz	HDSL 2B1Q 1168 kbit/s	292
8c,d	Frequency scaled ANSI SM Class 3 template.	-41.5 dBm/Hz	HDSL 2B1Q 2320 kbit/s	580
9a	G.991.2 Template	Based on Formula in equation (14)	SHDSL (up to 584 kbit/s)	95
9b	G.991.2 Template	Based on Formula in equation (14) reduced by 3.5 dB	SHDSL (up to 784 kbit/s, reduced power)	130.67
9c	G.991.2 Template	Based on Formula in equation (14)	SHDSL (up to 784 kbit/s)	130.67
9d	G.991.2 Template	Based on Formula in equation (14)	SHDSL (up to 1168 kbit/s)	194.67
9e	G.991.2 Template	Based on Formula in equation (14)	SHDSL (up to 1552 kbit/s)	258.67
9f	G.991.2 Template	Based on Formula in equation (14)	SHDSL (up to 2064 kbit/s)	344
9g	G.991.2 Template	Based on Formula in equation (14)	SHDSL (up to 2320 kbit/s)	386.67

Table A-1
List of PSD Templates for Deployment Classes: for use in determining Unacceptable Interference into a Basis System

Midband PSDs and templates for the SDSL and SHDSL systems with variable rate in Table A1 above are based on formulae which scale the PSD while retaining the same total transmit power for all rates.

SDSL

For SDSL the total power under the transmit PSD template is retained at +15.5 dBm by frequency- and amplitude-scaling the ANSI Spectrum Management Class 3 template so that the midband PSD and the baud rate are related by:

$$Midband\_PSD(dBm/Hz) = 10\log_{10}\left(\frac{K}{135B}\right) \qquad (13)$$

where the baud rate B (kbaud) for SDSL is half of the bit rate in kHz, and for SDSL K=10.6.

SHDSL

For SHDSL the transmit PSD template is defined in G.991.2. In this case, the midband PSD and the baud rate are also related (by equation 13), but the baud rate B (kbaud) is here equal to the bit rate (kbit/s) divided by the number of bits per symbol (usually 3), and the constant K is given by:

if $B<2056/3$, K=7.86,

if $B\geq 2056/3$, K=9.9. (14)

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