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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).

The content of this ETR was originally published in May 1992 as an internal Technical Committee document and is now published, with its technical content unchanged, as an ETR to make it publicly available. The original document which was not publicly available has now been withdrawn.

ETRs are informative documents resulting from ETSI studies which are not appropriate for European Telecommunication Standard (ETS) or Interim European Telecommunication Standard (I-ETS) status. An ETR may be used to publish material which is either of an informative nature, relating to the use or the application of ETSs or I-ETSs, or which is immature and not yet suitable for formal adoption as an ETS or an I-ETS.

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1 Scope

ITU-T Recommendation G.955 [1] contains minimum requirements for the performance between reference points S and R of the optical path, in terms of attenuation and dispersion, for a digital line system on single-mode optical fibre. When combined with ITU-T Recommendation G.652 [2] on the fibre characteristics, these figures can be used in a worst-case design for the maximum repeater section length. This approach employs worst-case values for all transmission parameters resulting in a repeater section design which guarantees attenuation and dispersion penalties between the S and R reference points which are lower the specified limits in 100 % of all cases.

Studies carried out in several countries, show that a worst-case design approach can lead to significant cost penalties for long-haul systems. Recently statistical and semi-statistical approaches have been considered in designing the maximum repeater section length, taking account of the expected statistical variations in the transmission parameters of equipment and cable (e.g. cable attenuation, splice attenuation, transmitted power, etc.). These approaches are based on designing the maximum repeater section length for a high probability (e.g. 99 %) of each repeater section having an adequate system margin over the lifetime of the system. Statistical and semi-statistical approaches achieve significant cost-saving through reductions in the number of the repeaters for a long-haul system, but admit a pre-determined probability of insufficient optical path allowances between reference points S and R. The cost savings are substantial for remote power feeding systems where local electrical power plant does not exist.

This ETR contains definitions of the different design approaches, statistical data forms and numerical examples for statistical design for fibre optics systems. The use of this ETR is at the discretion of the reader.

2 References

For the purposes of this ETR, the following references apply:

[1] ITU-T Recommendation G.955 (1993): "Digital line systems based on the 1544 kbit/s and the 2048 kbit/s hierarchy on optical fibre cables".

[2] ITU-T Recommendation G.652 (1993): "Characteristics of a single-mode optical fibre cable".

[3] ITU-T Recommendation G.951 (1988): "Digital line systems based on the 1544 kbit/s hierarchy on symmetric pair cables".

[4] ITU-T Recommendation G.952 (1988): "Digital line systems based on the 2048 kbit/s hierarchy on symmetric pair cables".

3 Definitions and abbreviations

3.1 Definitions

S (Send) reference point: A point on the optical fibre just after the Optical Line Terminal (OLT) optical connection point (i.e. optical connector or optical splice).

R (Receive) reference point: point on the optical fibre just before the Optical Line Terminal (OLT) optical connection point (i.e. optical connector or optical splice).

3.2 Abbreviations

3.2.1 Abbreviations used for system parameters

P_T	Transmitted power (dBm) at reference point S: transmitted power can be controlled to within the specified limits throughout its working life. Margin is accounted for in the standard deviation;
P_R	Input optical power (dBm) at reference point R that is necessary to achieve a specified bit error ratio;
k	Source operating central wavelength (nm);
P_D	Dispersion power penalty (dB) due to inter-simbol interference, mode partition noise and chirping;
Dk_{fwhm}	Source fwhm (full width half maximum) spectral width (nm);
a_{wdm}	All inclusive loss (dB) associated with Wavelength Division Multiplexing (WDM) equipment (at both ends), including all insertion and additional connector losses as well as other degradations. The allocations shall include the effects of temperature, humidity and ageing;
a_{con}	Single-mode to single-mode connector loss (dB);
R_p	Reflection power penalty (dB); this considers the additional power required by the receiver when optical reflections occur at the line side of the transmitter (or receiver) connector to achieve the same Bit Error Rate (BER) performance that is obtained without these reflections;
M	Unallocated margin (dB) for unpredicted penalties, to be determined by the system designer for a specific application;
N_{con}	Number of single-mode to single-mode connectors. This is the number recommended by the supplier for a typical point-to-point regenerator section;
l_{sm}	Total length (km), on both ends of a regenerator section, of single-mode regeneration station cable;
a_{sm}	Loss (dB/km) of single-mode regeneration station cable.

3.2.2 Abbreviations used for cable parameters

a_c	Cable loss (dB/km) (at 23 °C) at the end of cable lifetime and at the transmitter's nominal central wavelength;
a_{cT}	Effect of temperature on cable loss (dB/km) at worst case temperature conditions over the expected cable operating temperature range;
a_{S_k}	Increase in mean cable loss (dB/km) (at 23 °C) above α_C measured at the wavelength within the transmitter's central wavelength range at which the largest means-plus-two-sigma loss occurs;
l_t	Total sheath length (km) of spliced fibre cable. This value may include an allowance for cable repair purposes;
a_s	Splice loss (dB) at 23 °C;
a_{sT}	Effect of temperature on splice loss (dB) at worst case temperature conditions over the cable operating temperature range;

$\mathbf{N_s}$	Number of splices in multi-fibre cable of length l_t (including those at the fibre distributing frame at both ends of the regenerator section), plus any allowance for additional splices for cable repair purposes;
$\mathbf{l_r}$	Average installed reel length of fibre cable (km);
D	Chromatic dispersion of the fibre (ps/(nm km));
S	Zero-dispersion slope (ps/(nm^2 km)).

3.2.3 General abbreviations

BER	Bit Error Rate
OLT	Optical Line Terminal

4 Approaches for optical fibre system design

In general three possible approaches can be defined in the optical fibre system design:

- Worst case approach (purely deterministic);
- Statistical approach (all parameters are statistically defined);
- Semi-statistical approach (only some parameters are statistically defined).

4.1 Worst case approach

This approach consists of considering the worst possible values for all design parameters of the repeater span; this approach penalizes the achievable span length with respect to statistical or semi-statistical combination of design parameters, but guarantees in 100 % of cases, over the lifetime of the system, an attenuation and a dispersion between reference points S and R lower than the specified system values.

In this approach the regenerator section length can be calculated considering that for a specified application at the end of the optical path between reference points S and R (see figure 2 of ITU-T Recommendation G.955 [1]) the overall attenuation should not exceed the specified value and the overall bandwidth should be not less than the specified value.

Concerning the attenuation the power budget is evaluated according to:

$$A_{tot} = (\alpha_C + \alpha_M) l_t + (N_p - 1)\alpha_S + N_{con}\alpha_{con}$$

where:

α_C : cable attenuation (dB/km);

α_M : cable margin (dB/km);

l_t : total length of spliced fibre cable (km);

N_{con} : number of connectors;

N_p : number of cable factory length in the repeater section;

α_s : splice loss (dB);

α_{con} : single-mode to single-mode connectors loss (dB).

Concerning the bandwidth, in order to obtain the regenerator section length defined by the power budget and to respect the overall limit define in tables 1 and 2 of ITU-T Recommendation G.955 [1] the following condition has to be satisfied (see clause 3 of G.951 [3]):

$$B_t = [B_{MODAL}{}^{-2} + B_{CHROMATIC}{}^{-2}]^{-1/2}$$

For additional information on the calculation of bandwidth for elementary cable section, refers to ITU-T Recommendations G.951 [3] and G.952 [4].

4.2 Statistical approach

In this approach the statistic distributions of each parameters design, which influence the attenuation and dispersion of regenerator section length, are considered.

In general the parameters which can be considered statistical in nature are the following:

- cable attenuation;
- splice loss;
- connector loss;
- zero-dispersion wavelength;
- zero-dispersion slope;
- operating wavelength;
- optical power available at the transmitter;
- receiver sensitivity;
- equipment improvements.

With this approach the design, starting from the characteristics of statistical distribution, consists in defining a statistical confidence level (e.g. 99 %) by which it is possible to satisfy the attenuation and dispersion limits imposed in the regeneration section length.

When using the statistical approach, the subsystem parameters are expressed in terms of statistical distributions, which are assumed to be available from the manufacturers or from data obtained from equipment production facilities.

Such distributions can be handled either analytically (e.g. convolution functions or Gaussian averages and standard deviations) or numerically (e.g. by the Montecarlo method). Applying convolution functions, the probability density functions (pdf) distribution of all design parameters existing between the optical transmitter and the optical receiver have to be known.

This method requires more computation effort than the analytical one but will provide a more accurate estimation of the performance of real systems.

4.2.1 Convolution method design

Considering the probability density function (pdf) distribution p(x) of a budget parameter where the probability of having a certain loss between x_i and x_i+dx, where dx is small, is given by $p(x_i)$dx. The probability of having a certain additive loss A_{ij} to A_{ij}+dA due to a certain loss x_i to x_i+dx of pdf P(x) and loss y_j to y_j+dy of pdf P(y) is simply the multiplication of their associated probabilities:

$$p(A_{ij})dA = p(x_i)dx\ p(y_j)dy \qquad (1)$$

The total probability of having an additive loss A to A+dA is then:

$$P(A)dA = P(x_i)\ P(y_j)dx\,dy, \qquad A = x_i + y_j \qquad (2)$$

The method by which the combination or convolution may be carried out in practice is a numerical application of equations (1) and (2). The resolution used in the constituent loss distribution is 0,10 dB.

Further pdf can be similarly convoluted with P(A), one at a time, until all loss distributions are combined to give a final distribution of total available loss. This process may be carried out for all the budget parameters.

4.2.2 Gaussian statistical distribution design

If all parameters have Gaussian statistical distributions, a simple design process may be used, considering for each one mean values (μ) and standard deviation (σ).

In this situation the following formulas could be used (for an explanation of the symbols used, see clause 3).

Considering the mean and standard deviation of the system gain:

$$\mu_G = \mu_{P_T} - \mu_{P_R} - \mu_{P_D} - R_p - M - \mu_{\alpha_{wdm}} - l_{sm}\mu_{\alpha_{sm}} - N_{con}\mu_{\alpha_{con}}$$

$$\sigma_G = [\sigma^2{}_{P_T} + \sigma^2{}_{P_R} + \sigma^2{}_{P_D} + \sigma^2{}_{\alpha_{wdm}} + N^2{}_{con}\sigma^2{}_{\alpha_{con}}]^{1/2}$$

and the mean and standard deviation of the fibre cable loss:

$$\mu_L = l_t(\mu_{\alpha_c} + \mu_{\alpha_{cT}} l + \mu_{\alpha_{S\lambda}}) + N_S(\mu_{\alpha_S} + \mu_{\alpha_{sT}})$$

we can obtain:

$$\mu_{G-L} - 2\sigma_{G-L} \geq 0$$

where:

$$\mu_{G-L} = \mu_G - \mu_L$$

and:

$$\sigma^2{}_{G-L} = \sigma^2{}_G + \sigma^2{}_L$$

Some of the design parameters cannot be assumed to have Gaussian distributions (e.g.: splice attenuation). However, in these cases, if we consider the following hypotheses:

1) The mean values and standard deviations are representative of the parameters over time and sample sizes are sufficient to warrant the use of Gaussian statistical theory;

2) The parameter distributions are reasonably Gaussian in shape;

3) All connector and splice losses are un-correlated with fibre losses;

4) The loss allowance associated with transmitter wavelength drift is correlated in different reels;

5) Cable losses, except those associated with transmitter wavelength variation, are correlated over the mean reel length but are un-correlated from reel to reel;

6) All cables are represented by the same statistics.

Assuming that mean values plus two sigma (standard deviation) are less than the worst case values, it is possible to invoke a valid statistical method, with a simple analytic method, in 97,7 % of cases.

Nevertheless, in a very small percentage of cases, it is possible that attenuation or dispersion between reference points S and R is larger than specified system values. In these cases it will be necessary to sacrifice part of the system margin or selecting source and receiver to overcome power budget and/or dispersion limit problems. However these remedies produce several problems of logistic and operating nature.

4.3 Semi-statistical approach

Considering the previous statistical approach the parameters relating to fibres and passive devices can confidently be considered statistical; on the other hand, parameters such as optical transmitter power and receiver sensitivity should not be considered on a statistical basis, because of the deterministic values of these parameters are set in the factory and because the ITU-T Recommendation G.955 [1] specifications are recommended in terms of allowable attenuation and dispersion between reference points S and R. However, statistical data could be generated from production measurements.

In this situation, the semi-statistical approach considers some parameters in a deterministic way (worst-case), as for example operating wavelength, optical power available at the transmitter and receiver sensitivity. For other parameters (as fibre attenuation, splice loss, etc.), statistical distributions are considered, with suitable statistical parameters (e.g. mean value, standard deviation, skewness).

The parameters which can be considered to have statistical distribution (in this case it has been assumed that all parameters have Gaussian distribution) are the following:

- cable attenuation;
- splice loss;
- connector loss;
- zero-dispersion wavelength;
- zero-dispersion slope.

For example a semi-statistical method can use a set of values distributed according to Gaussian distribution generated through a Montecarlo algorithm starting from the factory statistical values (e.g. mean value, standard deviation, skewness) relating to the parameters previously shown. This set of values is used to evaluate the total dispersion and the total attenuation over the repeater section. The calculation is iterated N number of times. A number of iterations equal to 100 gives a statistical confidence level better than 99 % relating to the largest regenerator section length at which the allowable attenuation and dispersion limits between reference points S and R are not exceeded. A three-term Sellmeier equation is used to calculate the total dispersion, at the wavelength of interest, over the regenerator section.

As regards total attenuation the power budget is calculated taking into account the relationship reported in the worst case approach (see subclause 4.1).

5 Statistical Data Forms

Two forms are shown in tables 1 and 2 below, which may be used for record statistical data. In these forms, besides the parameter mean values and standard deviations, the distribution type is required where possible, for further information.

Tables, proposed by several Administrations, showing values for the statistical and semi-statistical approaches can be found in annex A.

Table 1: Form for recording statistical data (system)

SYSTEM					
Parameter	Unit	worst case approach	Statistical approach		
			μ	σ	distribution type
P_T	dBm				
P_R	dBm				
P_D	dB				
λ	nm				
$\Delta\lambda_{fwhm}$	nm				
α_{wdm}	dB				
α_{con}	dB				
α_{sm}	db/km				

Table 2: Form for recording statistical data (cable)

CABLE					
Parameter	Unit	worst case approach	Statistical approach		
			μ	σ	distribution type
α_c	dB/km				
α_{cT}	dB/km				
$\alpha_{S\lambda}$	dB/km				
α_s	dB				
α_{sT}	dB				
D	ps/(nm.km)				
S	ps/(nm.km)				

6 Examples

In this paragraph examples for "worst case", "statistical" and "semi-statistical" approaches are given.

6.1 Worst case design

An example of a regenerator section length design for 4 x 140 Mbit/s single-mode optical system operating in the 1300 nm region is shown in table 3 below:

Table 3: Example of regenerator section length design for worst case approach and 4 x 140 Mbit/s single-mode systems

Attenuation		Dispersion	
System gain	24,00 dB	Maximum dispersion	120 ps/nm
Distribution frame connectors	1,00 dB each	Cable dispersion (1 285 to1 330 nm range)	3,50 ps/nm.km
Cable attenuation	0,40 dB/km		
Splice attenuation	0,15 dB/km		
Cable margin	0,10 dB/km		
$Length_{(max)} = \frac{24-2(1)}{0,40+0,15+0,10} = 33,80\ km$		$Length_{(max)} = \frac{120}{3,50} = 34,30\ km$	

From this example, the resulting maximum span length is limited to about 34 km.

6.2 Statistical design (Convolution method)

This example gives optical power budget for a hypothetical system. Rather than manipulating mean and standard deviation values of the individual budget components, all parameters are represented as frequency - histogram base on a common 0,10 dB magnitude increment. The overall result is then obtained by direct convolution of these components.

Table 4 below shows the budget for the hypothetical (DEMO) system including the worst case (extreme) and typical (mean) values taken from the eleven systems parameter distributions shown. Direct arithmetic summation of these values gives the worst case and typical system margin of 39,05 dB and 41,80 dB respectively.

Table 4: Power budget for the hypothetical (DEMO) system including the Worst Case (extreme) and Typical (mean) values

		Worst case	Typical case
1	Laser mean output power at the chip-fibre interface	- 2,95 dBm	- 2,65 dBm
2	Receiver sensitivity	- 50,05 dBm	- 50,50 dBm
	Available power ratio	47,10 dB	47,85 dB
	System impairments		
3	Source mean power variation due to temperature and time	0,95 dB	0,74 dB
4	Receiver mean sensitivity variation due to temperature and time	2,45 dB	2,04 dB
5	Reflection effects	0,05 dB	0,05 dB
6	Pattern jitter imperfect equalization	0,95 dB	0,85 dB
7	Imperfect Transmit pulse	0,45 dB	0,39 dB
8	Others; extinction ratio dispersion	0,65 dB	0,54 dB
9	Error rate adjustment	0,65 dB	0,65 dB
10	Optical connector attenuation for single mode fibre (Transmit)	0,95 dB	0,40 dB
11	Optical connector attenuation for single mode fibre (Receive)	0,95 dB	0,40 dB
	Total impairments	8,05 dB	6,05 dB
	System margin	39,05 dB	41,80 dB
NOTE 1:	Difference of best case Transmit (2,30 dB) and Receive values (51,20 dB) is 48,90 dB.		
NOTE 2:	Margin will exceed 40,35 dB for 999 cases in 1000.		

Figure 1 shows the result of the statistical analysis; in particular, figure 1 gives the system margin as a function of probability of occurrence.

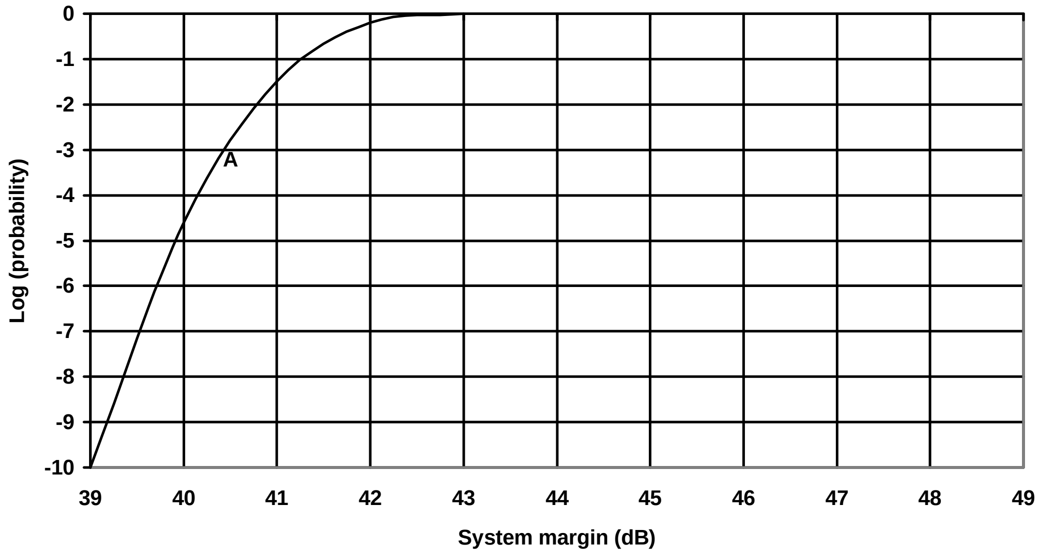

Figure 1: Cumulative distribution for system margin

For example, point "A" in figure 1 shows that a system margin of 40.4 dB will be achieved with a probability of 999 cases in 1000.

Note that the form of the overall system margin probability distribution is nearly Gaussian despite the non-Gaussian form of the individual parameter distributions as shown in figure 2.

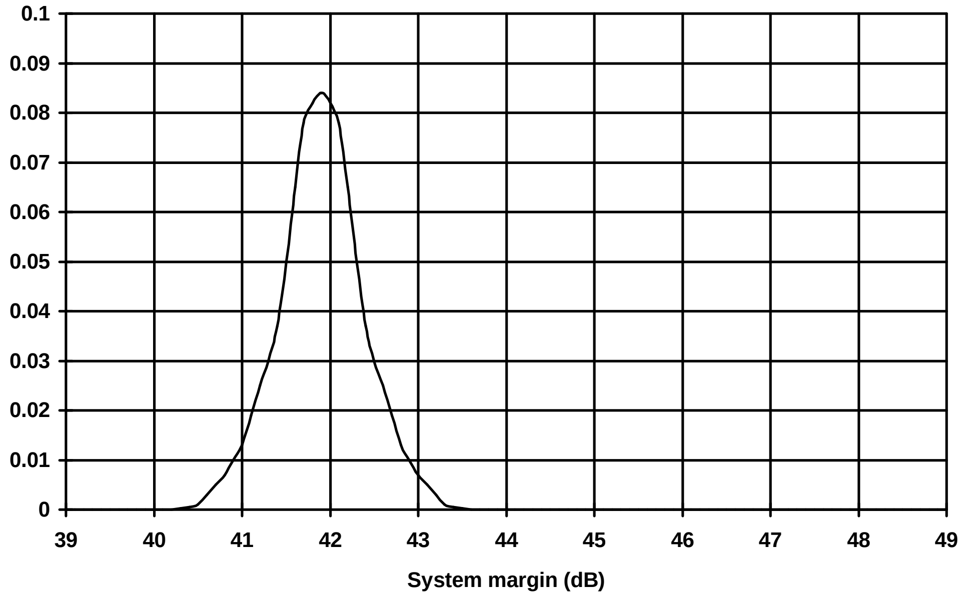

Figure 2: Probability density function for system margin

Any deterministic parameter, such as the "Error-rate adjustment" (item 9 in table 4), is represented in the distribution table as a single-column histogram 0,10 dB wide.

6.3 Semi-statistical design

This example assumes the following deterministic parameters:

- **operating wavelength**: set at the extremes of the allowable range, in order to take into account the least favourable cases (e.g. 1 285 nm and 1 330 nm for high bit-rate optical system);

- **power budget and allowable dispersion between reference points S and R**: set at the values specified in the relevant specifications (e.g. ITU-T Recommendation G.955 [1]) and/or in the customer/supplier specifications.

For the other parameters, factory statistical distributions have been considered, with suitable statistical parameters (e.g. mean value, standard deviation, skewness) characterizing the distribution.

From the input data distributions, a Montecarlo algorithm generates a set of fibre and device parameters which is used for calculating the longest regenerator section length at which the allowable attenuation and dispersion limits between reference points S and R are not exceeded.

This calculation is iterated N number of times (100 in this case), which gives the statistical confidence level of the extrapolations (better than 99 %).

The total dispersion is calculated, at the wavelength of interest, by combining the three-term Sellmeier equation of the single fibre factory lengths; the power budget is calculated according to:

$$A_{tot} = \left(A_f + A_m + \frac{A_g}{L_p}\right) N_p L_p + 2A_C$$

where:

A_f = cable attenuation (dB/km);

A_m = cable margin (dB/km);

A_g = splice attenuation (dB);

N_p = number of cable factory lengths in the repeater section;

L_p = length of each cable factory length (2 km in the present simulation);

A_c = connector attenuation (assuming 2 connectors per link).

The basic result of the algorithm is the longest repeater section length at which, at the assumed operating wavelength, the limits set for the attenuation and dispersion between reference points S and R are not exceeded (with the pre-determined confidence level). As a by-product, statistical distribution of attenuation and dispersions for the fibres considered, as well as the cumulative distribution of section lengths outside the specified limits between reference points S and R can be obtained. Some examples of the results are reported in table 5.

Table 5: Example of results

Attenuation between reference points S and R (dB)	Attenuation limited length (km)		Dispersion between reference points S and R (ps/nm)	Dispersion limited length(km)
	with cable margin	without cable margin		
21	40	52	100	40
23	44	56	110	44
24	44	58	120	48
			130	52
			140	56

An example of cumulative length distribution for attenuation (full line) and dispersion (dashed line) is reported in figure 3. The fibre and device parameters have been chosen according to actual factory and field distributions.

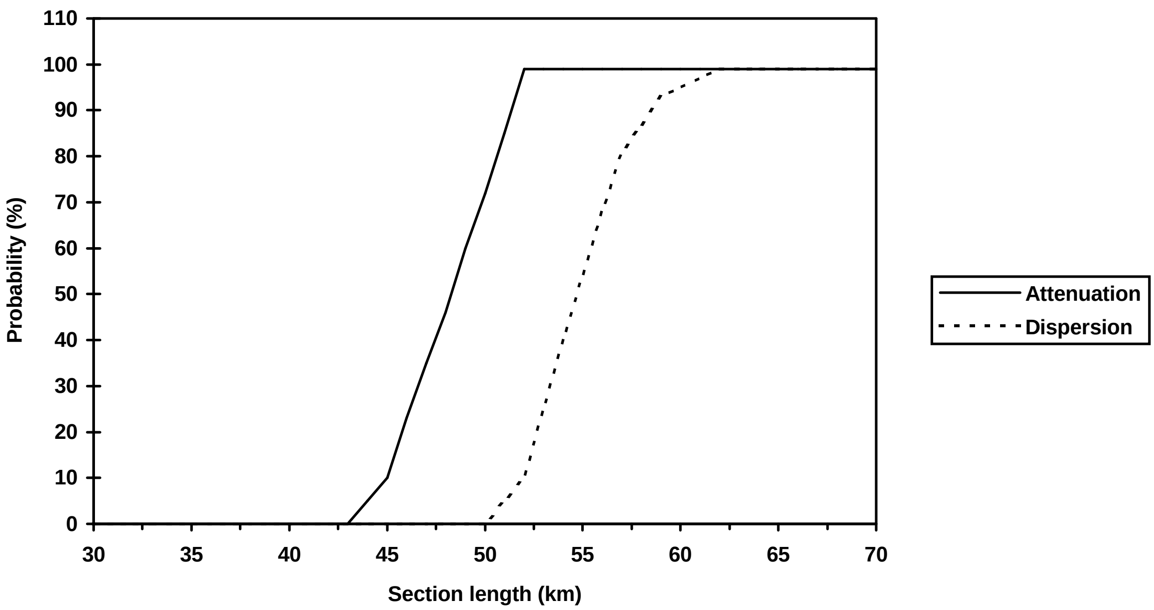

Figure 3: Cumulative distributions for attenuation and dispersion for 24 dB and 120 ps/nm limits between reference points S and R

It should be noted from table 5 that the values of achievable span length are substantially lower than the ones proposed for statistical approach. This is due to the semi-statistical design approach used.

Moreover, table 5 shows that the cable margin introduces a substantial penalty in the repeater section length. Nevertheless, the achievable span lengths result substantially higher than the ones obtained with the worst case design (see table 3).

Annex A (informative): Proposed values for the statistical and semi-statistical approaches

A.1 Introduction

This annex shows tables 1 and 2 (as defined in clause 5 of this ETR) as completed by a number of administrations.

A.2 Tables from Australia

Table A.1: Statistical system data

SYSTEM					
Parameter	**Unit**	**worst case approach**	**Statistical approach**		
			μ	**σ**	**distribution type**
P_T	~~dBm~~ dB		41 140 (1,30 μm)		
P_R	~~dBm~~ dB				
P_D	dB				
λ	nm				
$\Delta\lambda_{fwhm}$	nm				
α_{wdm}	dB				
α_{con}	dB				
α_{sm}	db/km				

Table A.2: Statistical cable data

CABLE					
Parameter	**Unit**	**worst case approach**	**Statistical approach**		
			μ	**σ**	**distribution type**
α_c	dB/km		0,37 (1,30 μm) 0,24 (1,55 μm)		
α_{cT}	dB/km				
α_{S_λ}	dB/km				
α_s	dB		0,077	0,073	
α_{sT}	dB				
D	ps/(nm.km)				
S	ps/(nm.km)				

A.3 Tables from Eire

Table A.3: Statistical system data

SYSTEM					
Parameter	Unit	worst case approach	Statistical approach		
			μ	σ	distribution type
P_T	dBm	- 5			
P_R	dBm	- 38			
P_D	dB	0,163			
λ	nm	1300			
$\Delta\lambda_{fwhm}$	nm	5			
α_{wdm}	dB				
α_{con}	dB	0,5			
α_{sm}	db/km	0,38			

Table A.4: Statistical cable data

CABLE					
Parameter	Unit	worst case approach	Statistical approach		
			μ	σ	distribution type
α_c	dB/km	0,38	0,354	0,015	
α_{cT}	dB/km				
α_{S_λ}	dB/km				
α_s	dB	0,1	0,07	0,06	
α_{sT}	dB				
D	ps/(nm.km)	3,5			
S	ps/(nm.km)				

A.4 Tables from France

Table A.5: Statistical system data

SYSTEM					
Parameter	**Unit**	**worst case approach**	**Statistical approach**		
			μ	**σ**	**distribution type**
P_T	~~dBm~~ dB	29 140 (1,30 μm) 24 565 (1,30 μm) 1g			
P_R	~~dBm~~ dB	26 565 (1,30 μm) 2g 25 565 (1,55 μm) 2g			
P_D	dB				
λ	nm				
$\Delta\lambda_{fwhm}$	nm				
α_{wdm}	dB				
α_{con}	dB		0,36 (1,30 μm) 0,33 (1,55 μm)	0,23 (1,30 μm) 0.23 (1,55 μm)	
α_{sm}	db/km				

Table A.6: Statistical cable data

CABLE					
Parameter	**Unit**	**worst case approach**	**Statistical approach**		
			μ	**σ**	**distribution type**
α_c	dB/km		0,35 (1,30 μm) 0,21 (1,55 μm)	0,03 (1,30 μm) 0,02 (1,55 μm)	
α_{cT}	dB/km				
α_{S_λ}	dB/km				
α_s	dB		0,07 (1,30 μm) 0,07 (1,55 μm)	0,05 (1,30 μm) 0,05 (1,55 μm)	
α_{sT}	dB				
D (see note)	ps/(nm.km)		2,494 (1,30 μm) 16,993 (1,55 μm)		
S	ps/(nm.km)				
NOTE: Maximum values of D are 3,297 ps/(nm.km) at 1,3 μm and 16,993 ps/(nm.km) at 1,55 μm.					

A.5 Tables from Germany

Table A.7: Statistical cable data

CABLE					
Parameter	**Unit**	**worst case approach**	**Statistical approach**		
			μ	σ	**distribution type**
α_c (see note)	dB/km		0,41	0,04	
α_{cT}	dB/km				
$\alpha_{S\lambda}$	dB/km				
α_s	dB				
α_{sT}	dB				
D	ps/(nm.km)				
S	ps/(nm.km)				
NOTE: (α_c + α_s) at 1.3 µm has a maximum value of 0,69 dB.					

Annex B (informative): Bibliography

The following documents were used by the author as source material for this ETR:

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History

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