TECHNICAL SUPPORT DOCUMENT

FIA-TSD-2000-4-2-3

OPTICAL FIBRE CABLING
-
TESTING OF INSTALLED CABLING
-
SPECIFICATION, PROCUREMENT AND USE OF TEST CORDS

Price: £150 (free to FIA members)

THE FIBREOPTIC INDUSTRY ASSOCIATION
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The Fibreoptic Industry Association - An Introduction

There has been a significant growth in optical fibre systems being installed in private data, entertainment and telecommunications networks which are separate from the national telephony and data carrier systems. This part of the industry is characterised by having a large number of relatively small company participants albeit supplying large corporate customers with products and services. The use of optical fibres in private, local area data and sensor networks has increased rapidly since the early 1990's. In order to support this rate of growth, an organizational focus is required for both suppliers and users in the industry in order to ensure the quality and reliability of network design, installation practice and methods of training.

The **Fibreoptic Industry Association** provides such a focus as a Trade Association to which companies, organizations and individuals involved with, or planning an involvement with, fibre optics can subscribe. In addition, by means of seminars, publications, newsletters, press promotion and similar activities, the **Fibreoptic Industry Association** is dedicated to raising the profile of the industry and highlighting its many benefits in order to increase its growth and thus provide direct benefits for members.

Our overall aims can be summarised as follows:

- to promote an awareness of the benefits and applications of fibre optic technology as an adjunct to - or as a replacement for - conventional copper communications technology;
- to promote an awareness of the existence of a professional fibre optics industry fully capable of meeting the needs of users or, so benefiting both suppliers and their customers;
- to promote and adopt standards to which professional participants within the fibre optic industry should be expected to adhere;
- **t**o provide a central source for information on wide ranging aspects of the fibre optic industry;
- to provide a single voice to promote and represent the interests of the industry obtained by consensus and debate amongst FIA members;
- to develop and promote codes of practice within the industry - both operational and ethical - to which members will be expected to adhere and thus offer an assurance that the highest quality of service will be provided.

FIA TECHNICAL SUPPORT DOCUMENTS

This document is one a series of FIA Technical Support Documents which adopt a common format as used throughout this document.

These documents are now **free** to **FIA members** via downloads from the FIA web-site (**www.fia-online.co.uk**). Non-members are also able to purchase these documents either by contacting the Secretariat (address shown below) or by on-line purchase.

Members and non-members unable to benefit from this service may receive the documents in hard-copy or .pdf format by contacting the FIA Secretariat (contact details are shown at the bottom of each text page in this document). However, the rapidly changing nature of our technology means that web-based documents can be amended and revised easily and it is the responsibility of the reader to ensure that the latest issue of a document is used.

The FIA web-site will indicate the issue status of each document and will have links to previous issues in order that changes made will be clear to readers.

The complete list of FIA Technical Support Guides is shown in the Table below.

TOPIC	FIA-TSD-	TITLE
DESIGN	2000-1-1	OPTICAL FIBRE CABLING: LAN APPLICATION SUPPORT GUIDE
COMPONENT SELECTION	2000-2-1	OPTICAL FIBRE CABLING: CABLE SELECTION GUIDE
OPERATION	2000-3-3	OPTICAL FIBRE CABLING: POLARITY MAINTENANCE
INSTALLATION	2000-4-1-1	OPTICAL FIBRE CABLING: INSTALLATION PRACTICE: SPLICING
	2000-4-2-1	OPTICAL FIBRE CABLING: TESTING OF INSTALLED CABLING: LSPM equipment
	2000-4-2-2	OPTICAL FIBRE CABLING: TESTING OF INSTALLED CABLING: OTDR equipment
	2000-4-2-3	OPTICAL FIBRE CABLING: TESTING: TESTING OF INSTALLED CABLING: Specification, Procurement and Use of Test Cords
SAFETY	2000-5-1	OPTICAL POWER: SAFETY LEVELS
	2000-5-2	OPTICAL FIBRE: HANDLING OF PROCESSING CHEMICALS
	2000-5-3	OPTICAL FIBRE: DISPOSAL OF WASTE

FOREWORD AND EXECUTIVE SUMMARY

This document has taken almost five years to produce - a timescale that reflects the complexity of the topic. During that period two international standards have been published which discuss the requirements for test cords to be used to undertake testing of installed optical fibre cabling. These standards promote slightly different interpretations for the test cords to be used.

Specifically:

- [BS EN] IEC 61280-4-1:2009 describes two types of test cord - one of those types having "reference grade terminations" (which shall be used for resolution of disputes, unless otherwise agreed) and are recommended to be used to reduce measurement uncertainty and the other type having "normal terminations".
- ISO/IEC 14763-3 Ed.1.1: 2011 including Technical Corrigendum 1 allows only one type of cord - terminated with "reference grade connectors"

The FIA, via its Project Team "Reference Grade Termination" (RGT), has been working for more than two years in order to identify an economically viable method to allow installers to obtain test cords having either "reference grade terminations" or "reference grade connectors". This project was deemed critical since if the correct test cords are not readily available then the complete approach to test methods becomes fundamentally flawed.

To date, it has only been found possible to specify and procure "reference grade terminations" for certain types of commonly used connecting hardware.

For this reason and others, the FIA Technical Support Documents describing test procedures using both light source/power meter (LSPM) and optical time domain reflectometer (OTDR) equipment have been re-issued to reflect the requirements of [BS EN] IEC 61280-4-1 for multimode (50/125 or 62,5/125 µm) optical fibre cabling and of [BS EN] IEC 61280-4-2* for singlemode optical fibre cabling rather than ISO/IEC 14763-3.

This document interprets the requirements of [BS EN] IEC 61280-4-1 and [BS EN] IEC 61280-4-2 in relation to the specification, procurement and use of test cords having both "normal" and "reference grade" terminations. It inter-relates with the other FIA TSDs that address testing of installed cabling.

* Edition 2 is in development at the time of publication of this document

By Paul Bateson, Chairman of the FIA

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INTRODUCTION

Both [BS EN] IEC 61280-4-1:2009 and ISO/IEC 14763-3 have identical objectives in relation to the testing of multimode optical fibre cabling. These can be summarised as reflecting the fact that the maximum channel lengths and insertion loss (globally termed “attenuation” in this document) limits for multimode networks have trended downwards, requiring the reduction of measurement uncertainty in any test applied to the cabling.

Part of that objective is served by the use of tightened tolerances for the terminations applied to the test cords used.

Specifically:

- [BS EN] IEC 61280-4-1:2009 describes two types of test cord - one of those types having “reference grade terminations” (which shall be used for resolution of disputes, unless otherwise agreed) and are recommended to be used to reduce measurement uncertainty and the other type having “normal terminations”.
- ISO/IEC 14763-3 allows only one type of cord - terminated with “reference grade connectors”

To date, it has only been found possible to specify and procure “reference grade terminations” for certain types of commonly used connecting hardware.

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This document interprets the requirements of [BS EN] IEC 61280-4-1 and [BS EN] IEC 61280-4-2 in relation to the specification, procurement and use of test cords having both “normal” and “reference grade” terminations. It inter-relates with the other FIA TSDs that address testing of installed cabling.

Background

As long ago as 2002, the FIA published two Technical Support Documents which provided installers of optical fibre cabling with a wide ranging review of test methods using both light source/power meter (LSPM) and optical time domain reflectometer (OTDR) equipment. Part of this review addressed the growing number of LSPM equipment which did not allow the existing international standard methods to be applied.

Both documents (TSD-2000-4-2-1 and TSD-2000-4-2-2) were submitted to the structured cabling standards committee (ISO/IEC JTC1 SC25 WG3) for their consideration in the development and/or revision of the relevant international standards.

Following this submission, the FIA presented further evidence which suggested that, for multimode optical fibre, additional controls were necessary to define the correct launch conditions at the point at which the test cords were attached to the cabling under test.

The implications of these two submissions were reviewed and further work done which resulted in the publication of two separate international standards:

- ISO/IEC 14763-3:2006 - *Implementation and operation of customer premises cabling - Part 3: Testing of optical fibre cabling*
- IEC 61280-4-1:2009 - *Fibre optic communication subsystem test procedures - Part 4-1: Installed cable plant - Multimode attenuation measurement*

ISO/IEC 14763-3 is produced by ISO/IEC JTC1 SC25 WG3 and specifies “systems and methods for the inspection and testing of optical fibre cabling designed in accordance with ISO/IEC 11801 or equivalent standards. The test methods refer to existing standards-based procedures where they exist.”

This document served to replace the requirements, for specific application to cabling in accordance with ISO/IEC 11801, of earlier more general standards IEC 61280-4-1:2003 (for multimode optical fibre cabling) and IEC 61280-4-2:1999 (for singlemode optical fibre cabling).

The publication of ISO/IEC 14763-3 re-energised IEC SC86C to revise IEC 61280-4-1 which, in the 2009 edition, has a wider scope being applicable to the “measurement of attenuation of installed multimode (50/125 or 62,5/125 µm) optical fibre cabling, typically in lengths of up to 2 000 m”, i.e. whether or not it complies with ISO/IEC 11801 or equivalent standards. IEC 61280-4-2 will also be revised in 2012.

In the UK, IEC 61280-4-1:2009 has been endorsed as a national standard with the reference [BS EN] IEC 61280-4-1.

1 SCOPE

This document interprets the requirements of [BS EN] IEC 61280-4-1 and [BS EN] IEC 61280-4-2 in relation to the specification, procurement and use of test cords having both “normal” and “reference grade” terminations.

It details the requirements for:

- multimode optical fibre test cords including those containing all types of mode controller assemblies that provide the correct encircled flux launch conditions;
- singlemode optical fibre test cords.

Clause 4 explains the interconnection performance requirements of “reference grade” and “normal” terminations.

Clause 5 explains the impact on test limits of using “reference grade” and “normal” terminations.

Clause 6 summarises the outcome of FIA Project Team work on the specification of test cords i.e. the pragmatic approach to their specification.

Clause 7 summarises the outcome of FIA Project Team work on the procurement of test cords.

Clause 8 describes the maintenance of test cords.

Clause 9 refers to the verification of test cord performance.

2 REFERENCES

2.1 Testing standards

[BS EN] IEC 61280-4-1:2009	*Fibre optic communication subsystem test procedures - Part 4-1: Installed cable plant - Multimode attenuation measurement*
[BS EN] IEC 61280-4-2:2000	*Fibre optic communication subsystem basic test procedures - Part 4-2: Fibre optic cable plant - Single-mode fibre optic cable plant attenuation*
[BS EN] IEC 61280-4-2:2012*	*Fibre optic communication subsystem basic test procedures - Part 4-2: Fibre optic cable plant - Single-mode fibre optic cable plant attenuation*
ISO/IEC 14763-3 Ed.1.1:2011 including Technical Corrigendum 1	*Implementation and operation of customer premises cabling - Part 3: Testing of optical fibre cabling*

* in development at the time of publication of this document

2.2 Other standards

BS EN 50377-4-4	*Connector sets and interconnect components to be used in optical fibre communication systems - Product specifications: Part 4-4: Type SC-PC simplex terminated on IEC 60793-2-50 category B1.1 and B1.3 singlemode fibre, with full zirconia ferrule category U*
[BS EN] IEC 60793-2-10	*Optical fibres - Product specifications - Sectional specification for category A1 multimode fibres*
[BS EN] IEC 60793-2-50	*Optical fibres - Product specifications - Sectional specification for class B single-mode fibres*
[BS EN] IEC 61300-3-35	*Fibre optic interconnecting devices and passive components - Basic test and measurement procedures - Examinations and measurements - Fibre optic connector endface visual and automated inspection*
[BS PD] IEC TR 62627-01	*Fibre optic interconnecting devices and passive components. Fibre optic connector cleaning methods*

3 DEFINITIONS, ABBREVIATIONS AND CONVENTIONS

3.1 Definitions

For the purpose of this Technical Support Document the following definitions apply:

Connection	mated device or combination of devices including terminations used to connect cables or cable elements to other cables, cable elements or application specific equipment (EN 50173-1)
Installed cable	cabling between two test interfaces which can comprise cable, splices (mechanical or fusion) and/or other connections deemed to be "permanent" for the purposes of the test being carried out
Test cord	a cord that is part of the test system
RGT test cord	a test cord having a reference grade termination at the end(s) intended to be connection to cabling under test or other test cords

3.2 Abbreviations

For the purpose of this Technical Support Document the following abbreviations apply:

RGT	Reference Grade Termination
LS	Light Source
MMF	Multimode optical Fibre
OTDR	Optical Time Domain Reflectometer
PM	Power Meter
SMF	Singlemode optical Fibre

3.3 Conventions

Within this Technical Support Document the term "attenuation" is used widely as a global replacement for other terms such as "insertion loss".

Within this Technical Support Document:
- IEC standards that are published, essentially unchanged, as European Norms (and then as British Standards) are designated [BS EN] IEC but are published by IEC as IEC xxxxx or by BSI as BS EN xxxxx;
- IEC Technical Reports that are published, essentially unchanged, as British Standards are designated [BS PD] IEC TR but are published by IEC as IEC TR xxxxx or by BSI as BS PD IEC TR xxxxx;
- ISO/IEC standards that are published, essentially unchanged, as British Standards are shown as [BS] ISO/IEC but are published by IEC as ISO/IEC xxxxx or by BSI as BS ISO/IEC xxxxx;
- European Norms that are published, essentially unchanged, as British Standards are designated [BS] EN];
- any documents shown with a BS prefix may be purchased from the BSI link via the FIA web-site home page (www.fia-online.co.uk);
- any documents not shown with a BS prefix are not endorsed by as a Bristish Standard and may be purchased via the IEC web-store (http://webstore.iec.ch/).

4 PERFORMANCE OF MATED CONNECTIONS

Two types of termination are considered within this Technical Support Document.

The first is a “normal” termination which meets the requirements of all current cabling standards such that when randomly mating two such terminations:

- 100% of all such random mated connections exhibit an attenuation of no greater than 0,75 dB;
- 95% of all such random mated connections exhibit an attenuation of no greater than 0,5 dB.

This requirement applies to both multimode (50/125 or 62,5/125 µm) and singlemode optical fibre cabling.

This general requirement is further emphasised in the standards for connecting hardware which state that for premises cabling applications (commonly referred to as Category C) for multimode:

- 100% of all such random mated connections exhibit an attenuation ≤ 0,75 dB;
- 97% of all such random mated connections exhibit an attenuation ≤ 0,5 dB;
- 50% of all such random mated connections exhibit an attenuation ≤ 0,35 dB.

and for singlemode:

- 100% of all such random mated connections exhibit an attenuation ≤ 0,75 dB;
- 97% of all such random mated connections exhibit an attenuation ≤ 0,5 dB.

These statistical requirements for “normal” to “normal” are shown in Figure 1 and Figure 2 for multimode and singlemode respectively. These requirements apply independent of the direction of the light passing through the connections.

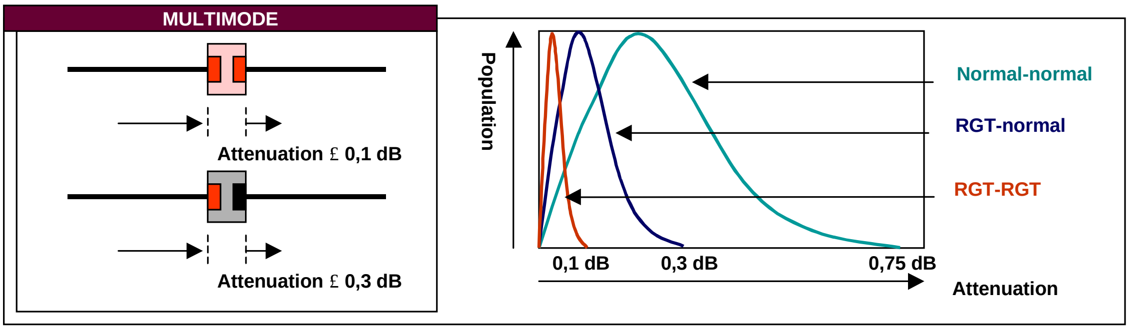

Figure 1 - Attenuation characteristic of multimode terminations

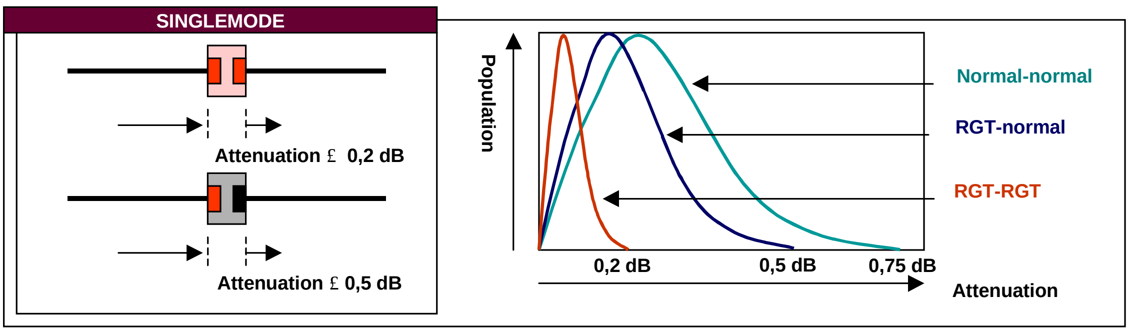

Figure 2 - Attenuation characteristic of singlemode terminations

The second type of termination is “reference grade” which is defined in:

- [BS EN] IEC 61280-4-1 as a “connector plug with tightened tolerances terminated onto an optical fibre with tightened tolerances such that the expected attenuation of a connection formed by mating two such assemblies is ≤ 0,1 dB”.
- [BS EN] IEC 61280-4-2:2012* as a “connector plug with tightened tolerances terminated onto an optical fibre with tightened tolerances such that the expected attenuation of a connection formed by mating two such assemblies is less ≤ 0,2 dB”.

* in development at the time of publication of this document

Both standards note that an adaptor which is required to achieve such attenuation values may be considered as part of the reference grade termination (RGT).
These statistical requirements for “RGT-RGT” are shown in Figure 1 and Figure 2 for multimode and singlemode respectively.

The connection of an RGT to a normal termination obviously delivers performance somewhere between the two statistical extremes as follows:

- [BS EN] IEC 61280-4-1 requires a normal-RGT connection to produce an attenuation ≤ 0,3 dB”.
- [BS EN] IEC 61280-4-2:2012* requires a normal-RGT connection to produce an attenuation ≤ 0,5 dB”.

* in development at the time of publication of this document.

These statistical requirements for “RGT-normal” are shown in Figure 1 and Figure 2 for multimode and singlemode respectively.

5 THE IMPLICATION OF USING REFERENCE GRADE TERMINATIONS

5.1 General

The LSPM test methods of [BS EN] IEC 61280-4-1 and [BS EN] IEC 61280-4-2 address three possible configurations of installed cabling as follows

- A - Adapters attached to plugs or sockets attached to both ends of the cabling
- B - Plugs on both ends
- C - Mixed, where one end of the cabling is terminated with an adapter and the other end is terminated with a plug

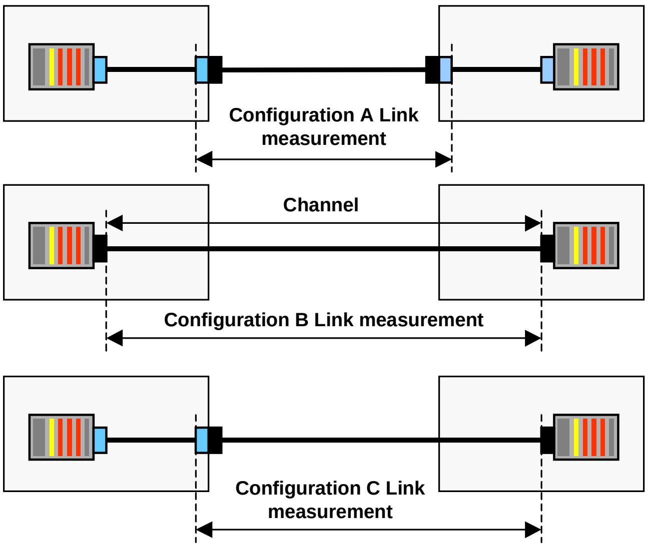

Figure 3 - Boundaries of measurement for channels and links

As shown graphically in Figure 3.

- cabling Configuration A measurements are intended to represent the installed cabling with the mated connections to the test cords;
- cabling Configuration B measurements are intended to represent the installed cabling without the mated connections to the test cords (as is equivalent to the channel definition of structured cabling standards);
- cabling Configuration C measurements are intended to represent the installed cabling with one of the mated connections to the test cords.

Each configuration has a test method within the referencing (normalisation) or "zero-ing out" of the test system and subsequent measurement is undertaken in a different way.

It should be noted that the term "installed cable" in the following sub-clauses includes the cable between the two interfaces (adapters or free plugs) together with any embedded connecting hardware between these interfaces i.e. **"installed cable" can include splices (mechanical or fusion) and/or other connections deemed to be "permanent" for the purposes of the test being carried out**.

5.2 Testing of multimode optical fibre cabling

5.2.1 "1-Cord Reference" method of [BS EN] IEC 61280-4-1

Figure 4 shows the referencing process and the test method that is preferred for cabling Configuration A.

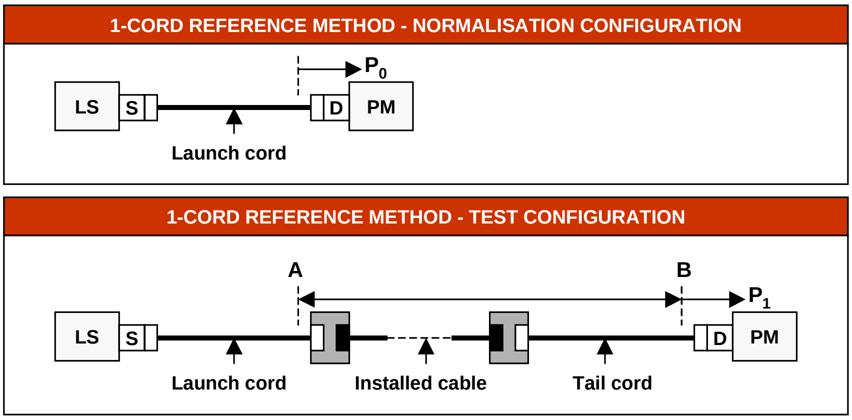

Figure 4 - 1-Cord Reference testing

It uses one cord to perform the referencing process (giving the value P_0 (dBm)). A tail cord is added to the cabling under test before the measurement is made which produces the measured value P_1 (dBm). The test result is P_1 - P_0 (dB).

The attenuation test limit is defined as the sum of the attenuation of the installed cable and the attenuation of the connections to the launch and tail cords (assuming the tail cord generates no appreciable attenuation due its short length).

Clearly if the launch and tail cords are terminated with an RGT then the test limit is different to that when the cords have a normal termination – the difference being as follows:

- RGT limit = 0,3 dB + installed cable + 0,3 dB = installed cable + 0,6 dB;
- Normal limit = 0,75 dB + installed cable + 0,75 dB = installed cable + 1,5 dB.

The use of RGTs on the test cords dramatically reduces the possible spread of results as shown in Figure 5

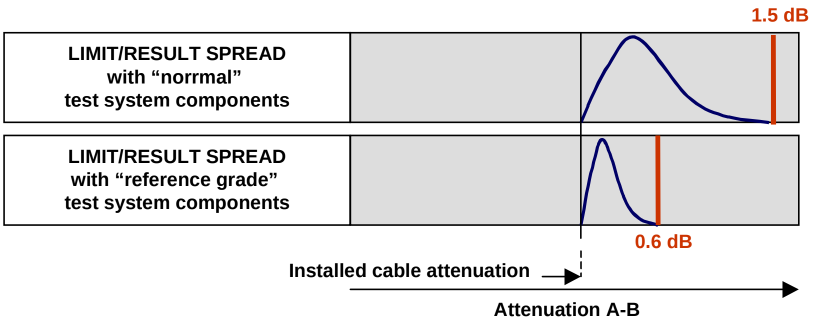

Figure 5 - Limits and spread of results using the 1-Cord Reference method (MMF)

NOTE Monte Carlo modelling of typical connection distributions suggests that in excess of 99.7% of results should be no greater than "installed cable + 0,5 dB" and "installed cable + 1,2 dB" for the RGT and normal test cords respectively.

5.2.2 "3-Cord Reference" method of [BS EN] IEC 61280-4-1

Figure 6 shows the referencing process and the test method applied to cabling Configuration B. It is also used for cabling Configuration A where the application of the one cord reference method cannot be implemented.

It uses a total of three cords to perform the referencing process (giving the value P_0 (dBm). The dummy cord is replaced by the cabling under test before the measurement is made which produces the measured value P_1 (dBm). The test result is P_1 - P_0 (dB).

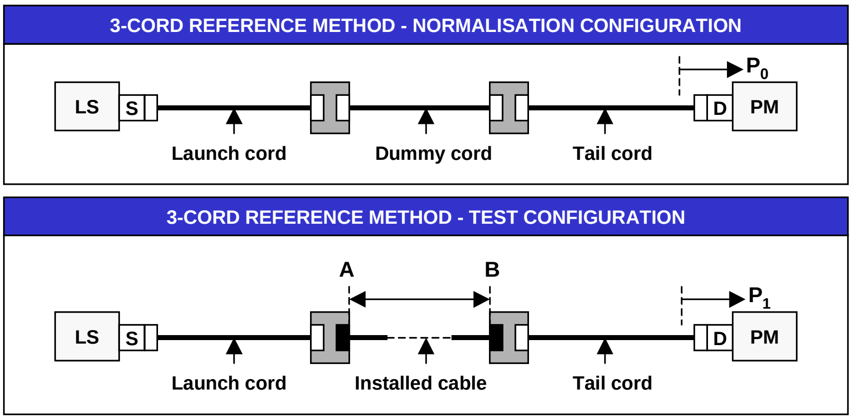

Figure 6 - 3-Cord Reference testing

The attenuation test limit is defined as the sum of the attenuation of the installed cable and the difference between the attenuation of the connections "zero-ed out" during the normalisation process and those of the to the launch and tail cord (assuming the tail cord generates no appreciable attenuation due its short length).

Clearly if the launch, dummy and tail cords are terminated with an RGT then the test limit is different to that when the these cords have "normal" terminations - the difference being as follows:

- Normal limit = (0,75 – 0,75) dB + installed cable + (0,75 – 0,75) dB = installed cable;
- RGT limit = (0,3 – 0,1 dB) + installed cable + (0,3 – 0,1) dB = installed cable + 0,4 dB.

The limits are shown in red on the schematic in Figure 7. Of greater concern is the possible spread of results.

A normal-normal connection has a given probability of delivering an attenuation of 0 dB and also one of 0,75 dB. If the two normalisation connections each have an attenuation of 0 dB but the two connections to the cabling under test each have an attenuation of 0,75 dB, then the result obtain is “installed cabling + 1,5 dB” (producing a result that is 1, 5dB above the calculated limit). Similarly if the reverse occurred the measured result would be 1,5 dB below the limit – potentially producing a negative attenuation for short cable lengths.

The role of the RGT is to restrict this variation. If the two RGT-RGT normalisation connections each have an attenuation of 0 dB but the two connections to the cabling under test (normal-RGT) each have an attenuation of 0,3 dB, then the result obtain is “installed cabling + 0,6 dB” (producing a result that is 0.2 dB above the calculated limit. If the two RGT-RGT normalisation connections each have an attenuation of 0,1 dB but the two connections to the cabling under test (normal-RGT) each have an attenuation of 0,0 dB, then the result obtain is “installed cabling - 0,2 dB” (producing a result that is 0.2 dB below the calculated limit). This dramatically reduces the risk of undesirable results.

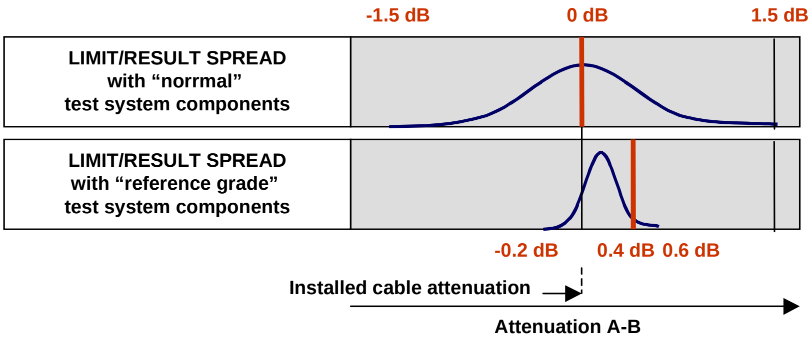

Figure 7 - Limits and spread of results using the 3-Cord Reference method (MMF)

NOTE Monte Carlo modelling of typical connection distributions suggests that in excess of 99.7% of results should be no greater than “installed cable -0,04 dB and installed cable + 0,4 dB” and “installed cable +/- 0,72 dB” for the RGT and normal test cords respectively.

Where the “1-Cord Reference” method cannot be implemented, [BS EN] IEC 61280-4-1 allows the “3-Cord Reference” method to be used but advises that the major disadvantage of this approach is the higher level of measurement uncertainty that results (comparing Figure 7 with Figure 5):

- if test cords with normal terminations are used, the result spread is 3,0 dB versus 1.5 dB;
- if test cords with RGTs are used, the result spread is 0,8 dB versus 0.6 dB.

NOTE Monte Carlo modelling of typical connection distributions suggests that this is only partially true since the result spread is much better:
- if test cords with RGTs are used, the result spread for 99.7% of results is 0,44 dB versus 0.5 dB (actually slightly better than the 1-Cord reference approach);
- if test cords with normal terminations are used, the result spread for 99.7% of results is 1,44 dB versus 1,2 dB.

5.2.3 “2-Cord Reference” method of [BS EN] IEC 61280-4-1

See Annex A for details as this method is only intended for cabling Configuration C. This is not a common cabling configuration and the test method produces conclusions which comprise features of both the 1- and 3-Cord Reference methods.

5.3 Testing of singlemode optical fibre cabling

5.3.1 “1-Cord Reference” method of [BS EN] IEC 61280-4-2

The method is as described in 5.2.1.

Clearly if the launch and tail cords are terminated with an RGT then the test limit is different to that when the cords have a normal termination. The use of test cords with RGT is not supported by [BS EN] IEC 61280-4-2:2000 but is expected to be in the revision of the document currently underway.

The limit difference is as follows:

- Normal limit = 0,75 dB + installed cable + 0,75 dB = installed cable + 1,5 dB;
- RGT limit = 0,5 dB + installed cable + 0,5 dB = installed cable + 1.0 dB.

The use of RGTs on the test cords significantly reduces the possible spread of results as shown in Figure 8.

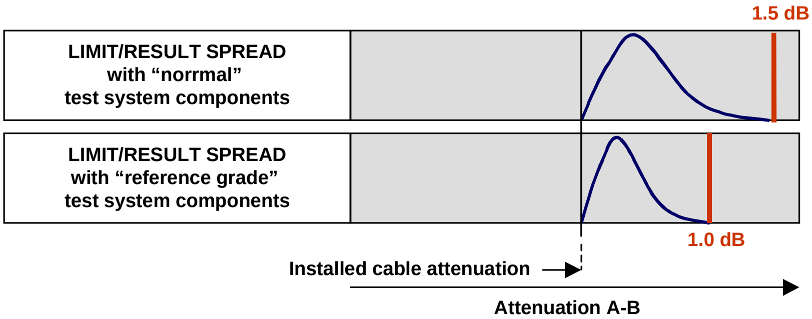

Figure 8 - Limits and spread of results using the 1-Cord Reference method (SMF)

5.3.2 "3-Cord Reference" method of [BS EN] IEC 61280-4-2

The method is as described in 5.2.2.

Clearly if the launch and tail cords are terminated with an RGT then the test limit is different to that when the cords have a normal termination. The use of test cords with RGT is not supported by [BS EN] IEC 61280-4-2:2000 but is expected to be in the revision of the document currently underway.

The limit difference is as follows:

- Normal limit = (0,75 – 0,75) dB + installed cable + (0,75 – 0,75) dB = installed cable;
- RGT limit = (0,5 – 0,2 dB) + installed cable + (0,5 – 0,2) dB = installed cable + 0,6 dB.

The limits are shown in red on the schematic in Figure 9. Of greater concern is the possible spread of results.

A normal-normal connection has a given probability of delivering an attenuation of 0 dB and also one of 0,75 dB. If the two normalisation connections each have an attenuation of 0 dB but the two connections to the cabling under test each have an attenuation of 0,75 dB, then the result obtain is "installed cabling + 1,5 dB" (producing a result that is 1, 5dB above the calculated limit). Similarly if the reverse occurred the measured result would be 1,5 dB below the limit – potentially producing a negative attenuation for short cable lengths.

The role of the RGT is to restrict this variation. If the two RGT-RGT normalisation connections each have an attenuation of 0 dB but the two connections to the cabling under test (normal-RGT) each have an attenuation of 0,5 dB, then the result obtain is "installed cabling + 1,0 dB" (producing a result that is 0.4 dB above the calculated limit. If the two RGT-RGT normalisation connections each have an attenuation of 0,2 dB but the two connections to the cabling under test (normal-RGT) each have an attenuation of 0,0 dB, then the result obtain is "installed cabling - 0,4 dB" (producing a result that is 0.4 dB below the calculated limit). This considerably reduces the risk of undesirable results.

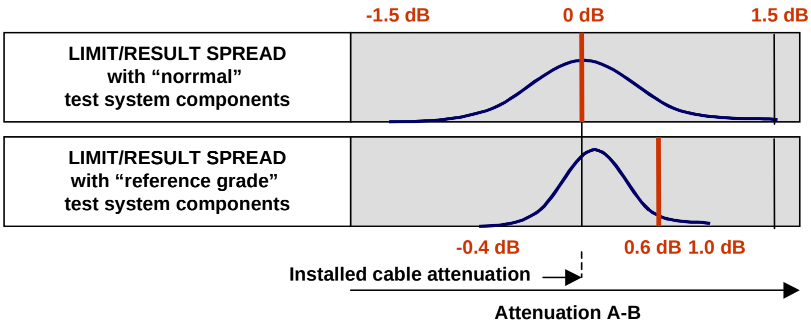

Figure 9 - Limits and spread of results using the 3-Cord Reference method (SMF)

Where the “1-Cord Reference” method cannot be implemented, [BS EN] IEC 61280-4-2 allows this method to be used but the major disadvantage of this approach is the higher level of measurement uncertainty that results (comparing Figure 9 with Figure 8):

- if test cords with normal terminations are used, the result spread is 3,0 dB versus 1.5 dB;
- if test cords with RGTs are used, the result spread is 1,4 dB versus 1.0 dB.

5.3.3 “2-Cord Reference” method of [BS EN] IEC 61280-4-2

See Annex A for details as this method is only intended for cabling Configuration C. This is not a common cabling configuration and the test method produces conclusions which comprise features of both the 1- and 3-Cord Reference methods.

5.4 Summary

It is clearly desirable to undertake tests using test cords with RGTs - independent of the cabling Configuration to be measured and the referencing technique to be applied.

6 SPECIFICATION OF TEST CORDS

6.1 General

The benefits of using RGT test cords are described in clause 5. Recognising these benefits and to reflect the publication of [BS EN] IEC 61280-4-1:2009, the FIA established a Project Team in March 2010 with the objective of determining how FIA members would be able to purchase and maintain such test cords.

The dual objectives, i.e. to purchase and maintain, are critical to the achievement of the improvements in measurement uncertainty which underpin both [BS EN] IEC 61280-4-1:2009 and ISO/IEC 14763-3 for the following reasons:

- if it is uneconomic to purchase RGT test cords, installers will not adopt them and test results will retain the normal range of results - which, when applied to short length of cabling under test, will result in an increasing number of non-compliant measurements even where the correct “normal” limits are applied;
- once purchased, if the performance of RGT test cords is not maintained, the application of test limits which assume the use of RGT test cords will result in substantial numbers of non-compliant measurements if the “RGT” limits are applied.

The work of the FIA Project Team RGT was restricted to circular, multimode, optical fibre connector styles. The reason for this is that:

- rectangular, multi-optical fibre (or array) connecting hardware does not yet lend itself to the test approaches defined in [BS EN] IEC 61280-4-1:2009 (or ISO/IEC 14763-3) since appropriate test equipment configurations are not available for 1-cord, 2-cord or 3-cord reference tests;
- the enhanced requirements for singlemode connecting hardware and optical fibre tolerances are under study by an IEC standards committee and pre-emptive work in this area would have been inappropriate.

The outcome of the work of the FIA Project Team RGT is that for **certain commonly used multimode connector styles, it is relatively straightforward to specify and procure RGT test cords**.

However, for **other commonly used connector styles it would appear that no obvious (and therefore economic) solution exists for the procurement of RGT test cords**. Moreover, the work of the FIA Project Team RGT suggests that this is a fundamental feature of the connecting hardware rather than being associated with the restriction of optical fibre parameters.

As a result the FIA cannot support the universal application of ISO/IEC 14763-3 and has to support a more pragmatic approach which recognises the value of RGT test cords while allowing the continued use of "normal terminations". This allows the FIA to support the solutions specified in [BS EN] IEC 61280-4-1:2009 (for multimode optical fibre cabling) and the revised [BS EN] IEC 61280-4-2 expected to be published in 2012.

6.2 "Normal" terminations

6.2.1 Multimode

A "normal" termination is considered to constitute the application of a plug of a given style, conforming to the dimensional requirements of the relevant multimode product standard to an optical fibre conforming to all the dimensional requirements of the relevant multimode optical fibre type.

6.2.2 Singlemode

A "normal" termination is considered to constitute the application of a plug of a given style, conforming to the dimensional requirements of the relevant singlemode product standard to an optical fibre:
- conforming to all the dimensional requirements of the relevant multimode optical fibre type;
- additionally conforming to the restricted dimensional requirements within that optical fibre type that are applied by the supplier of the optical fibre under test..

This latter additional requirement reflects the wide range of mode field diameters that may exist for a given optical fibre type within [BS EN] IEC 60793-2-50 and that some suppliers tend to manufacture products within a specific part of that range while others manufacture products within a different part of that range. It is not realistic to expect connection attenuation to "behave properly" when two optical fibres are from different parts of a given range - for example a mode field diameter of 8,0 µm mated with a mode field diameter of 10,1 µm as exemplified for Type B1.3 optical fibre shown in Figure 10.

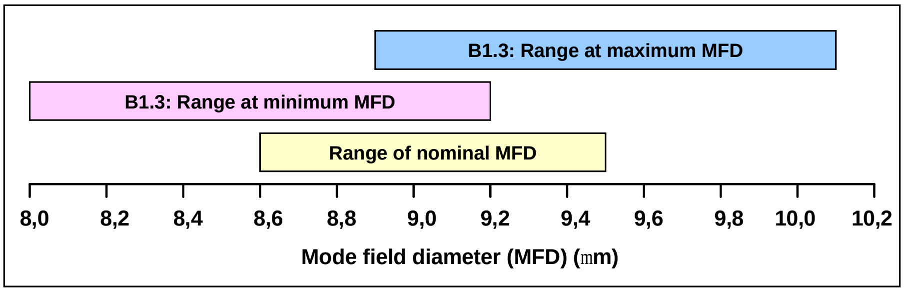

Figure 10 - Example spreads of mode field diameter (Type B1.3 SMF of [BS EN] IEC 60793-2-50:2008)

Further, detailed, information on this topic is provided in FIA-TSD-2000-4-1-1.

6.3 Multimode reference grade terminations

6.3.1 General

At a most basic level, most connections are a combination of two ferrules, containing optical fibre, and an alignment sleeve. Controls applied to the diameter and concentricity of the ferrule and hole within which the optical fibre is located together with the tolerance of the alignment sleeve provide a platform on which the attenuation of the connection is based. It is perhaps possible to improve the attenuation by further controls of the optical fibre parameters.

6.3.2 How standards define an RGT

[BS EN] IEC 61280-4-1 defines a RGT as follows:

> **connector plug** with tightened tolerances terminated onto an optical fibre with tightened tolerances such that the expected attenuation of a connection formed by mating two such assemblies is less than or equal to 0,1 dB
> EXAMPLE: as an example, the core diameter tolerance may need to be ≤ 0,7 micron (ffs). Other fibre tolerances are ffs.
> NOTE 1 An adapter, required to assure this performance, may be considered to be part of the reference grade termination where required by the test configuration
> NOTE 2 This definition remains as a point under study. When a more complete definition is available in another document, this definition will be replaced by a reference.

The connecting hardware specifications such as that for the multimode SC connector plug (IEC 60874-19-1) require that a reference plug has:

- a ferrule outer diameter is 2,499 mm +/- 0,000 5 mm (i.e. a singlemode ferrule);
- an eccentricity of the fibre core and the outer diameter of the ferrule is less than 1 μm;
- an eccentricity of a spherically polished ferrule end face is less than 30 μm.

The general principle applied by the optical fibre connector standards groups is that a multimode reference grade termination requires the use of singlemode connector piece parts and the control of certain optical fibre positional eccentricities.

However, the connector standards do not require the optical fibre beyond that of basic conformance to the relevant optical fibre Type specified in [BS EN] IEC 60793-2-10. This does not necessarily place them in conflict with the definition in [BS EN] IEC 61280-4-1 which clearly highlights that any tightening of basic optical fibre tolerances are for further study as designated by the "ffs".

6.3.3 The findings of FIA Project Team RGT

6.3.3.1 Summary

The work by the FIA Project Team RGT determined that for some connector styles, the use of singlemode piece parts and termination techniques were necessary – but that no further optical fibre controls were necessary to deliver the required attenuation of ≤0,1 dB.

However for other connector styles, neither the use of singlemode piece parts or improved optical fibre tolerances guaranteed to produce the required attenuation. This of course does not mean that it is impossible to create reference grade terminations for those connector styles but that the production yield and potential lack of interoperability of any products claiming to be reference grade terminations could have substantial impact of their cost and practicality.

6.3.3.2 2,5 mm ceramic ferrule connecting hardware

A wide number of connection styles use 2,5 mm ferrules including SC and ST.

The work by the FIA Project Team RGT produced results which suggested that all that was necessary to SC produce reference grade terminations for 2,5 mm ferrules was the use of singlemode connection components and singlemode termination techniques. In addition, performance was not connector supplier-specific providing excellent interoperability.

Where adaptors are used to join two RGTs during the referencing process, these should be singlemode adaptors using ceramic (rather than phosphor bronze) alignment sleeves.

This has resulted in a procurement specification to be developed as detailed in 7.2.2.

6.3.3.3 NTT FC connectors

Previous work as long ago as 2002 produced results which suggested that all that was necessary to produce reference grade terminations for NTT FC ferrules was the use of singlemode connection components and singlemode termination techniques but without optimisation processes being applied. In addition, it was found that performance was not connector supplier-specific providing excellent interoperability.

Where adaptors are used to join two RGTs during the referencing process, these should be singlemode adaptors using ceramic (rather than phosphor bronze) alignment sleeves.

6.3.3.4 1,25 mm ceramic ferrules

The work by the FIA Project Team RGT produced results which suggested that it was <u>not</u> possible to produce reference grade terminations for the most commonly used 1,25 mm ferrules connector style - the LC - simply by using singlemode connection components and singlemode termination techniques.

Furthermore, the application of tightened tolerance optical fibres did not materially improve the results obtained.

The FIA Project Team RGT is therefore unable to define a procurement route for LC connector reference grade terminations and it is recommended that "normal" terminations are used on test cords for the foreseeable future.

7 PROCUREMENT OF TEST CORDS

7.1 General

7.1.1 Connecting hardware

In general, it cannot be assumed that connectors from one supplier provide interoperability (i.e. defined maximum attenuation) with those from another. Exceptions to this rule are restricted to a comparatively small group of products. Therefore when testing an installation terminated with connector plugs from Supplier A, it is recommended to ensure that the correct adaptors (also from Suppler A) are used on any terminating panels in cabling Configurations A or C (see 5.1).

In such cases, it is recommended that the test cords be terminated with connector plugs from Supplier A and that any adaptors used in the referencing process are also from Supplier A.

Any deviation from this approach may, if non-compliant test results are obtained, result in claims and counter-claims by the suppliers of the various piece parts within the installation and on the test cords.

7.1.2 Multimode optical fibre

The test cords shall comprise the same type of optical fibre as that under test - i.e. either:
- 50/125 µm (Type A1a of [BS EN] IEC 60793-2-10) or
- 62,5/125 µm (Type A1b of [BS EN] IEC 60793-2-10)

There is no evidence that the optical fibre sub-Type in the fixed installation has to be matched by that of the test cords i.e. if the installation is Type A1a.2 (used to create Category OM3 cabled optical fibre) it is acceptable to have test cords containing optical fibre of Type A1a.1 (used to create Category OM2 cabled optical fibre) and vice-versa.

There is no evidence that the supplier of the optical fibre in the fixed installation has to be matched by that of the test cords.

However, the recent advent of so-called "less bend sensitive" multimode optical fibres (which are not subject to any sub-Type standard at the time of publication of this document) may create incompatibilities and it is recommended that where such products are used in the fixed installation, the optical fibre within the test cords should be from the same supplier.

7.1.3 Single optical fibre

The test cords shall comprise the same "type" of optical fibre as that under test - i.e. either:

- B1.1, B1.2 or B1.3 of [BS EN] IEC 60793-2-50 or
- B2_a or B2_b of [BS EN] IEC 60793-2-50 or
- B4c, B4d or B4e of [BS EN] IEC 60793-2-50 or
- B5 of [BS EN] IEC 60793-2-50 or
- B6_a1, B6_a2, B6_b1 or B6_b2 of [BS EN] IEC 60793-2-50.

In view of the comparatively large range of allowed mode field diameters within a given "type", it is recommended that the supplier of the optical fibre in the fixed installation is matched by that of the test cords.

7.1.4 Mechanical aspects

Test cords for LSPM testing solutions shall be between 2 m and 5 m in length and should adopt a cable construction consistent with the intended usage environment.

Test cords (both launch and tail cords) for OTDR testing solutions shall be of a length appropriate for the cabling under test and the OTDR to be used. The cord shall be at least 2 m in length, and should adopt a cable construction consistent with the intended usage environment. Annex D of [BS EN] 61280-4-1:2009 and the future [BS EN] 61280-4-2 requires that:

- the length of both launching and tail test cord shall be longer than the dead zone created by the pulse width selected for a particular length of optical fibre to be measured;
- these lengths shall be long enough for a reliable straight line fit of the backscatter trace that follows the dead zone;
- the suppliers of OTDR equipment should recommend lengths.

Each end of each test cord shall be labelled with a unique identifier. This allows the specific configuration of test cords to be recorded (cord at local end, cord at remote end etc) for each measurement.

7.1.5 "End-face" condition

In addition to the requirements and recommendations of 7.1, the optical fibre end faces shall be clean and free from defects in accordance with the relevant requirements of [BS EN] IEC 61300-3-35.

[BS PD] IEC TR 62627-01 provides further information of end-face cleaning of connecting hardware.

7.2 Multimode "RGT" terminations

7.2.1 General

This document only provides procurement solutions for test cords with RGTs with SC interfaces.

7.2.2 SC interfaces

In addition to the requirements and recommendations of 7.1.2 and 7.1.4, the following requirements apply.

Interface:	IEC 61754-04 Fibre Optic Connector Interfaces Part 4 Type SC connector family
Performance:	Suitable for IEC 61753-021-2 Ed. 2.0: Fibre optic interconnecting devices and passive components performance standard – Part 021-2: Grade C/3 single-mode fibre optic connectors for category C – Controlled environment

Colour:	Blue
Connector return loss:	≥ 20 dB achieved by termination
Optical fibre continuity:	Continuous from tip to tip (no splices).
Ferrule:	All zirconia ceramic (with fully glued termination)
End face after termination:	Radius - BS EN 50377-4-4:2011 Dome offset - BS EN 50377-4-4:2011 Undercut - BS EN 50377-4-4:2011 The optical fibre end faces shall be clean and free from defects in accordance with the relevant requirements of [BS EN] IEC 61300-3-35.

8 USE OF TEST CORDS

8.1 Contamination, inspection and cleaning

Test cords shall be inspected and, if necessary, cleaned immediately prior to any referencing procedure or connection to any optical interface under test.

Optical interfaces shall be inspected and, if necessary, cleaned before any testing is undertaken.

Inspection criteria are defined in [BS EN] IEC 61300-3-35.

Inspection equipment compatible with software assessment against the requirements of [BS EN] IEC 61300-3-35 should be used.

Failure to apply these requirements risks damage to the test cords together with instability and system degradation of any test results obtained.

9 VERIFICATION OF TEST CORD PERFORMANCE

9.1 LSPM test cords

See [BS EN] IEC 61280-4-1:2009 Annex H for multimode optical fibre test cords for LSPM testing. It is expected that the revision of [BS EN] IEC 61280-4-2 will contain similar information for singlemode optical fibre test cords for LSPM testing.

ANNEX A
2-CORD REFERENCE METHOD

A.1 Testing of multimode optical fibre cabling

A.1.1 "2-Cord Reference" method of [BS EN] IEC 61280-4-1

Figure A1 shows the referencing process and the test method that is intended for cabling Configuration C.

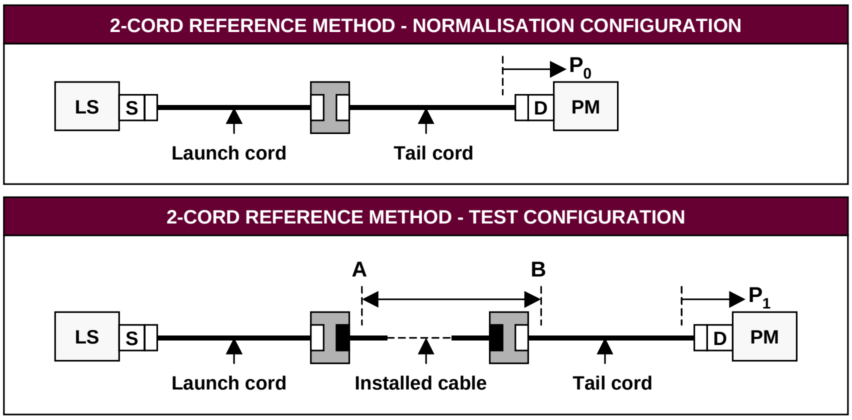

Figure A1 - 2-Cord Reference testing

It uses two cords to perform the referencing process (giving the value P_0 (dBm)). A the cabling under test is added between the cabling under test before the measurement is made which produces the measured value P_1 (dBm). The test result is P_1 - P_0 (dB).

The attenuation test limit is defined as the sum of the installed cable and the connection to the tail cord (assuming the tail cord generates no appreciable attenuation due its short length).

Clearly if the launch and tail cords are terminated with an RGT then the test limit is different to that when these cords have "normal" terminations - the difference being as follows:
- Normal limit = installed cable + 0,75 dB;
- RGT limit = (0,3 – 0,1) dB + installed cable + 0,3 dB = installed cable + 0,5 dB.

The limits are shown in red on the schematic in Figure A2. Of greater concern is the possible spread of results.

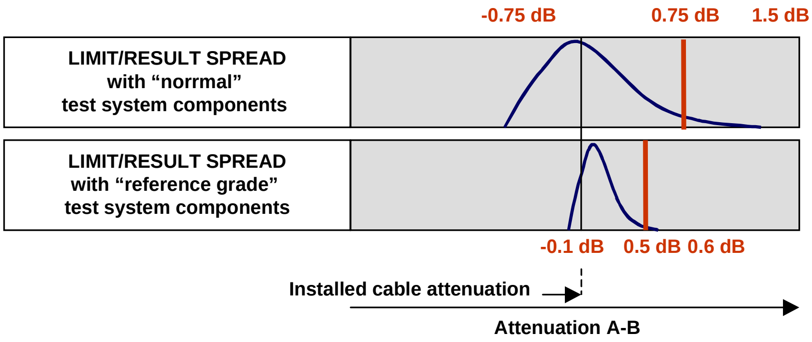

Figure A2 - Limits and spread of results using the 2-Cord Reference method (MMF)

NOTE Monte Carlo modelling of typical connection distributions suggests that in excess of 99.7% of results should be no greater than "installed cable + 0,03 dB to + installed cable + 0,45 dB" and "installed cable -0,28 dB and installed cable + 0,92 dB" for the RGT and normal test cords respectively.

A normal-normal connection has a given probability of delivering an attenuation of 0 dB and also one of 0,75 dB. If the normalisation connection has an attenuation of 0 dB but the two connections to the cabling under test each have an attenuation of 0,75 dB, then the result obtain is "installed cabling + 1,5 dB" (producing a result that is 0,75 dB above the calculated limit). Similarly if the reverse occurred the measured result would be 0,75 dB below the limit – potentially producing a negative attenuation for short cable lengths.

The role of the RGT is to restrict this variation. If the RGT-RGT normalisation connection has an attenuation of 0 dB but the two connections to the cabling under test (normal-RGT) each have an attenuation of 0,3 dB, then the result obtain is "installed cabling + 0,6 dB" (producing a result that is 0.1 dB above the calculated limit). If the RGT-RGT normalisation connection has an attenuation of 0,1 dB but the two connections to the cabling under test (normal-RGT) each have an attenuation of 0,0 dB, then the result obtain is "installed cabling - 0,1 dB" (producing a result that is 0.6 dB below the calculated limit). This considerably reduces the risk of undesirable results.

A.2 Testing of singlemode optical fibre cabling

A.2.1 "2-Cord Reference" method of [BS EN] IEC 61280-4-1

The method is as described in A.1.1.

Clearly if the launch and tail cords are terminated with an RGT then the test limit is different to that when the cords have a normal termination. The use of test cords with RGT is not supported by [BS EN] IEC 61280-4-2:2000 but is expected to be in the revision of the document currently underway.

The limit difference is as follows:

- Normal limit = installed cable + 0,75 dB;
- RGT limit = (0,5 – 0,2) dB + installed cable + 0,5 dB = installed cable + 0,8 dB.

The limits are shown in red on the schematic in Figure A2. Of greater concern is the possible spread of results.

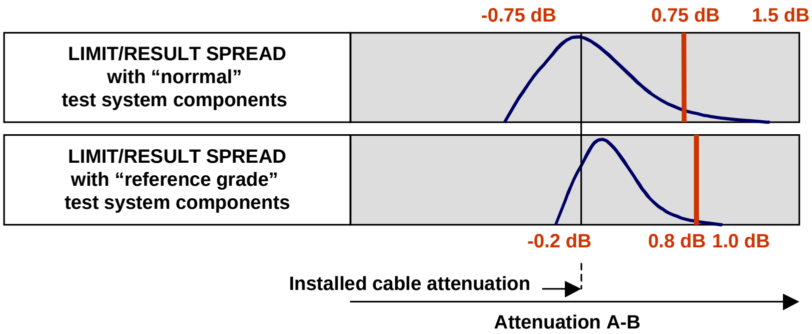

Figure A3 - Limits and spread of results using the 2-Cord Reference method (SMF)

A normal-normal connection has a given probability of delivering an attenuation of 0 dB and also one of 0,75 dB. If the normalisation connection has an attenuation of 0 dB but the two connections to the cabling under test each have an attenuation of 0,75 dB, then the result obtain is “installed cabling + 1,5 dB” (producing a result that is 0,75 dB above the calculated limit). Similarly if the reverse occurred the measured result would be 0,75 dB below the limit – potentially producing a negative attenuation for short cable lengths.

The role of the RGT is to restrict this variation. If the RGT-RGT normalisation connection has an attenuation of 0 dB but the two connections to the cabling under test (normal-RGT) each have an attenuation of 0,5 dB, then the result obtain is “installed cabling + 1,0 dB” (producing a result that is 0.2 dB above the calculated limit). If the RGT-RGT normalisation connection has an attenuation of 0,2 dB but the two connections to the cabling under test (normal-RGT) each have an attenuation of 0,0 dB, then the result obtain is “installed cabling - 0,2 dB” (producing a result that is 1,0 dB below the calculated limit). This considerably reduces the risk of undesirable results.

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