TECHNICAL SUPPORT DOCUMENT

FIA-TSD-2000-4-2-1

OPTICAL FIBRE CABLING
-
TESTING OF INSTALLED CABLING
-
LIGHT SOURCE AND POWER METER (LSPM)

Price: £150 (free to FIA members)

THE FIBREOPTIC INDUSTRY ASSOCIATION
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The Fibreoptic Industry Association
-
An introduction for the new millennium

The past decade has been a time in which there has been a vast increase in the use of optical fibre - primarily driven by the need to provide a quality, high-speed transmission media for digital trunk telephony services. The specifications for these systems have typically been produced by large national telecommunications service providers. This has resulted in clear standards and specifications exist to which all suppliers to the WAN telecommunications industry must adhere.

In parallel 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 throughout the 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. During the year 2000 all the existing FIA documents will be re-written or re-published in the format used throughout this document.

More importantly, the way in which these Technical Support Documents is published has also changed.

These documents are now **free** to **FIA members** via downloads from the FIA web-site (www.fibreoptic.org.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 diskette/CD ROM 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 Documents 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 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

The past ten years have seen a reduction in the lengths in which optical fibre has been installed. In the early days of commercial applications for optical fibre the channels were long either in the form of singlemode telecommunications systems or campus-wide interconnection of buildings. As the data rates within local area networks have increased so has the use of multimode optical fibre within buildings as backbone distribution systems and data centres.

This reduction in link lengths has highlighted the problem of measurement error when undertaking testing of installed cabling attenuation. For this reason, the FIA has produced this document which focuses on the correct method, equipment and cords to be used.

The impact of measurement error becomes manifest as the link lengths fall.

Substantial standardisation effort has been applied to delivering which reinforce existing methods but with improved test systems and conditions. The FIA are pleased to provide this Technical Support Document in order to clarify our recommended approaches following this work.

In certain cases it is still possible to obtain misleading results, as is explained in this document, and we attempt to indicate the likely outcome of measurements in advance of the testing scheme being initiated. Where deviant test results are predicted, appropriate quality assurance practices are necessary in addition to simply supplying test results to customers.

Failure to follow the procedures recommended by this Technical Support Document will increases the probability of installers and their customers becoming embroiled in disputes which could have financial impact.

By Paul Bateson, Chairman of the FIA

Table of Contents

Table of Figures

Table of Tables

INTRODUCTION

There are a number of international, European and British standards that define the correct test procedures to be used to measure the attenuation of the different link configurations and channels. In addition there are United States standards that cover the same topics.

The first document to address the testing of installed cabling was the FIA/CCP/1/91 (completed by BSI in 1989 and first published by the FIA in 1991. This document was subsequently published by BSI as BS 7718 (1995).

NOTE: BS 7718 was withdrawn following the publication of BS 6701 in 2004 - although this decision was not related to testing.

The methods described in this document were followed within IEC in their publications of:

- IEC 61280-4-2 (for singlemode optical fibre) published as a British standard [BS EN] 61280-4-2 in 2000;
- IEC 61280-4-1 (for multimode optical fibre) published as a British standard [BS EN] 61280-4-1 in 2004.

However, all the above standards were written around specific types of test equipment and could not consider the implications of the subsequent developments of small form factor connectors, some of which feature asymmetric constructions. The original FIA TSD-2000-4-2-1 (2002) was written to extend the application of these standards to a wider range of test equipment and connecting hardware.

Following the publication of TSD-2000-4-2-1, additional factors were discovered that indicated that changes would be necessary to the light source - power meter test methods and test equipment specified in all the standards.

Work began to develop ISO/IEC 14763-3 which was published as a British Standard [BS] ISO/IEC 14763-3 in 2006. The international standards for generic cabling design refer to this standard. Similarly, the general testing document in Europe, [BS] EN 50346 also refers to the ISO/IEC 14763-3 for all fibre optic cabling.

NOTE: [BS] EN 50346 is scheduled for withdrawal.

ISO/IEC 14763-3 initiated fundamental changes to testing practices - the test methods are different, the test cords are different, the launch conditions (at least for multimode) are specified very carefully and the test limits have had to be modified accordingly.

Since the initial publication of ISO/IEC 14763-3 in 2006, the original international standard IEC 61280-4-1 for multimode cabling has been updated (published as [BS EN] 61280-4-1 in 2009). This document maintained its wider set of test procedures, applicable to different installed cabling configurations, while incorporating the basic improvements of ISO/IEC 14763-3. In 2014, IEC also updated IEC 61280-4-2 for singlemode cabling using the same philosophy.

Because the UK is not able to publish two British Standards covering the same territory (and because Euronorms take precedence), the BS endorsement of [BS] ISO/IEC 14763-3 was removed in 2010. This is a procedural matter and does not reflect any undermining of the ISO/IEC standard which will still be referenced in this document.

ISO/IEC 14763-3 was updated in 2014 and includes an additional method for the testing of certain channel configurations which provides improved measurement accuracy. This is now being included in the IEC 61280-4-1 and IEC 61280-4-2 standards.

In summary, the procedures for attenuation testing of installed fibre optic cabling have been updated and tightened to provide more accurate results - largely as a result of the issues raised in early issues of this document. However, the outcome is a little confusing due to the proliferation of apparently similar standards.

Issue 4.01 and onwards of this document seeks to clarify the FIA recommendations for testing by making direct reference to the latest standards both published and in development - rather than by redefining them.

1 SCOPE

Unlike earlier issues of this Technical Support Document, this issue does not contain detailed test methods. Instead, this document clarifies which of the latest standardised test methods provides the best practical testing solution to be applied to particular optical fibre cabling configurations in order to measure link and channel attenuation using light source and power meter test equipment.

In addition, the specific demands of the latest standards in relation to the selection of test equipment, referencing methods, the use of reference test cords (where available and/or appropriate) and the impact of all of this on test limits.

This document has to be considered in conjunction with TSD-2000-4-2-3: OPTICAL FIBRE CABLING: TESTING OF INSTALLED CABLING: Specification, procurement and use of test cords.

Clause 6 outlines the commonalities and differences between the approaches taken by the two primary referenced standards and why the FIA has decided to only promote the use of one of them in this Technical Support Document.

Clause 7 provides information of the inspection and cleaning of test system connecting hardware and the interfaces to the cabling under test.

Clause 8 describes the cabling configurations and the applicable referencing techniques and test methods.

Clause 9 explains the determination of test limits.

Clause 10 reviews the expected spread of test results

Clause 11 discusses how test result may be used and finally clause 12 provides a reminder of the need to produce appropriate quality plans which indicate the likely outcome of testing based upon the test methods to be applied.

2 CONFORMANCE

This Technical Support Document provides additional information enabling the more viable implementation of the requirements of published British, European and international standards in specific. Conformance to this Technical Support Document requires the application of those standards supported by the guidance provided in this document.

NOTE: Cabling system suppliers may choose to adopt other testing regimes than those outlined in this document. They are obviously free to do so and are free to ask the installer to use these regimes providing the customer accepts that approach. However, any audit work undertaken by the FIA Technical Directorate will apply the preferred methods and limits defined in this document.

In addition the testing shall be undertaken in accordance with the generic or installation-specific Quality Plan (see clause 12) produced by the installer and agreed with the customer as meeting the needs of the installation Specification. Readers are referred to [BS] EN 50174-1 for the requirements and contents of both Installation Specifications and Quality Plans.

3 RELATIONSHIP WITH PREVIOUS EDITIONS OF TSD-2000-4-2-1

From Issue 1 to Issue 3.02 of this Technical Support Document, all changes between one issue and the next were logged within a downloadable .pdf file from the FIA web-site.

With the publication of Issue 4.00 the changes were so substantial that the entire structure of the document has been changed and Issues 4.00 and above bear no direct relationship with Issue 3.02.

This version, 5.01, is a revision of 4,01, and addresses the impact of the additional method for the testing of certain channel configurations which provides improved measurement accuracy which is included in ISO/IEC 14763-3:2014 and being included in revisions of IEC 61280-4-1 and IEC 61280-4-2 standards beginning in 2015.

4 REFERENCES

4.1 Primary references

This document will primarily refer to five standards:

[BS EN] IEC 61280-4-1:2009	Fibre optic communication subsystem test procedures. Installed cable plant. Multimode attenuation measurement
[BS EN] IEC 61280-4-2:2014	Fibre optic communication subsystem basic test procedures. Installed cable plant- Single-mode attenuation and optical return loss measurement
[BS EN] IEC 61300-3-35:2015	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 62627-01:2015	Fibre optic interconnecting devices and passive components. Fibre optic connector cleaning methods
ISO/IEC 14763-3 Ed.1.1:2014 including Amendent 1:2016	Information technology - Implementation and operation of customer premises cabling - Testing of optical fibre cabling

4.2 Other testing references

[BS] EN 50174-1	Information technology - Cabling installation - Part 1: Installation specification and quality assurance
[BS] EN 50346:2002 + A2:2009	Information Technology - Testing of installed cabling (this is to be withdrawn in 2015/2016)
FIA-CCP-1/91	Code of Practice for the installation of fibre optic cabling (withdrawn when BS 7718 was published)

4.3 Other general references

BS 6701:2010	Telecommunications equipment and telecommunications cabling - Specification for installation, operation and maintenance (being revised 2016)
BS 7718:1996	Code of Practice for the installation of fibre optic cabling (withdrawn when BS 6701:2004 published)
[BS] EN 50173-1	Information technology - Generic cabling systems - Part 1: General requirements
[BS] EN 50173-2	Information technology - Generic cabling systems - Part 2: Office premises
[BS] EN 50173-3	Information technology - Generic cabling systems - Part 3: Industrial premises
[BS] EN 50173-5	Information technology - Generic cabling systems - Part 5: Data centres
[BS] EN 50173-5	Information technology - Generic cabling systems - Part 6: Distributed building services
ISO/IEC 11801	Information technology - Generic cabling for customer premises
ISO/IEC 24702	Information technology - Generic cabling - Industrial premises
ISO/IEC 24764	Information technology - Generic cabling - Data centres

4.4 Sourcing the primary standards

In order to understand the recommendations of this TSD, it is required that readers will have access to the published versions of the following documents. These are available as follows:

[BS EN] IEC 61280-4-1:2009	Online from the BSI link on the FIA web-site home page (www.fia-online.co.uk) Cost to BSI members: £110.00 Cost to non-BSI members: £220.00
[BS EN] IEC 61280-4-2:2014	Online from the BSI link on the FIA web-site home page (www.fia-online.co.uk) Cost to BSI members: £117.00 Cost to non-BSI members: £234.00
[BS EN] IEC 61300-3-35:2015	Online from the BSI link on the FIA web-site home page (www.fia-online.co.uk) Cost to BSI members: £76.00 Cost to non-BSI members: £152.00
[BS PD] IEC TR 62627-01:2015	Online from the BSI link on the FIA web-site home page (www.fia-online.co.uk) Cost to BSI members: £56.00 Cost to non-BSI members: £112.00

In order to understand the recommendations of this TSD, it is recommended that readers will have access to the published versions of the following documents. These are available as follows:

ISO/IEC 14763-3 Ed.1.1: 2014	http://webstore.iec.ch/ Cost: CHF178

5 DEFINITIONS AND ABBREVIATIONS

5.1 Definitions

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

Application	system, with its associated transmission method that is supported by telecommunications cabling ([BS] EN 50173-1)
Channel	any transmission path comprising passive cabling components between application-specific equipment ... ([BS] EN 50173-1)
Channel insertion loss	the maximum channel attenuation defined by an application standard e.g. 1000BASE-SX. This is not necessarily the same as optical power budget of the transmission equipment (see FIA-TSD-2000-2-1)
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 ([BS] EN 50173-1)
Equipment cord	A cord connecting a link to application-specific equipment
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
Link	transmission path that excludes work area cords, equipment cords, patch cords and jumpers but includes the connection at each end. It can include a CP link
Patch cord	a cord connecting a link to a link
Test cord	a cord that is part of the test system

5.2 Abbreviations

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

MMF	Multimode optical Fibre
SMF	Singlemode optical fibre
LS	Light Source
PM	Power Meter

5.3 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;
- 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;
- 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].

6 OBJECTIVES OF THE STANDARDS

6.1 The common features of the primary referenced standards

The main objectives of ISO/IEC 14763-3:2009 in relation to light source/power meter testing were to define:
- a single method of testing which could be applied to both adapter-to-adapter and to plug-to-plug configurations of generic cabling in accordance with the following standards:
  - ISO/IEC 11801 (or BS EN 50173-2);
  - ISO/IEC 24702 (or BS EN 50173-3);
  - ISO/IEC 24764 (or BS EN 50173-5);
- a launch condition to be used when undertaking the testing of multimode optical fibre cabling;
- the appropriate use of reference grade connectors on test cords to reduce measurement spread - together with an associated amendment of test limits.

[BS EN] IEC 61280-4-1 does, to some extent, take on board these changes but provides much greater flexibility as outlined in Table 1. Firstly, it adopts the same launch conditions based on encircled flux. Secondly, it supports the same method of testing described in ISO/IEC 14763-3 but not to the exclusion of more appropriate methods. Finally it supports the use of reference grade terminations where they can be provided.

As part of general improvements, ISO/IEC 14763-3:2014 introduced an additional test method termed "enhanced 3-cord" which is applicable to certain types of channel configuations which delivers substantially improved measurement accuracy (reduced measurement uncertainly).

This approach will be added to the IEC 61280-4-x standards (although not called "enhanced 3-cord") during revisions in 2016 and 2017. However, this has (possibly accidentally) removed the universal method of testing of links and channels.

As a result the main aspects of ISO/IEC 14763-3 are as listed in Table 1.

Table 1 - Mapping of the primary referenced testing standards

	ISO/IEC 14763-3:2014	[BS EN] IEC 61280-4-x	
	Multimode and singlemode	**-1: Multimode**	**-2: Singlemode**
Multimode launch conditions	Encircled flux	Encircled flux	Not applicable
Singlemode launch conditions	Not applicable	Not applicable	Not applicable
Reference grade connectors/terminations	Mandatory	Optional	Optional
Normalisation (referencing) test approaches			
- **Link measurements**			
1-cord reference method	Only	Preferred (adapter-adapter)	Adapter-to-adapter only
2-cord reference method	No	Adapter-to-plug only	Adapter-to-plug only
3-cord reference method	No	Plug-to-plug and Adapter-adapter (where necessary)	Plug-to-plug only
- **Channel measurements**			
3-cord reference method	No (see below)	Only	Only
"Enhanced" 3-cord reference method	Only	Concept to be added in a revision in 2016	Concept to be added in a revision in 2016/2017

6.2 The differences between the primary referenced standards

The main differences are that ISO/IEC 14763-3:2014:

- is written specifically to support both multimode and singlemode optical fibre generic cabling as detailed in 6.1;
- mandates the use of reference grade connectors on test cords;
- mandates a single test method for links (which is not universal) and a single "enhanced 3-cord" for channels (which is not universal) and has removed the universal link/channel method present in the 2009 edition.

For multimode optical fibre cabling, [BS EN] IEC 61280-4-1:

- is written specifically to support all 50/125 or 62,5/125 µm multimode optical fibre cabling (a maximum length of 2000 m is quoted but is not specifically relevant);
  NOTE: the methods are applicable to other multimode optical fibres but launch conditions are not specified
- allows the use of either normal or reference grade terminations on test cords;
- includes the three separate test methods (from earlier versions of all recognised standards) which are applicable to the configuration the cabling under test (although allows the universal method of ISO/IEC 14763-3:2009 where its use is unavoidable).
  NOTE: the revision of this standard is expected to include the concept of the enhanced 3-cord method of ISO/IEC 14763-3:2014

For singlemode optical fibre cabling, [BS EN] IEC 61280-4-2:

- is written specifically to support all singlemode optical fibre cabling;
- allows the use of either normal or reference grade terminations on test cords;
- includes the three separate test methods (from earlier versions of all recognised standards) which are applicable to the configuration the cabling under test (although allows the universal method of ISO/IEC 14763-3:2009 where its use is unavoidable).
  NOTE: the revision of this standard is expected to include the concept of the enhanced 3-cord method of ISO/IEC 14763-3:2014

ISO/IEC 14763-3 uses the term “reference grade connector” whereas [BS EN] IEC 61280-4-1 and [BS EN] IEC 61280-4-2 both use the term “reference grade termination”. The objective of the use of test cords with either reference grade connectors or terminations (in conjunction with reference grade adapters as appropriate to the test method) is to produce mated “connections” with reduced attenuation as a mean of reducing the measurement uncertainty and resulting spread of results obtained. An FIA Project Team has investigated the viability of obtaining such reduced attenuation connection systems (irrelevant of the actual terminology applied by the standards) and the outcome of their work is detailed in FIA-TSD-2000-4-2-3.

6.3 The FIA preference for the application of the standards

The FIA does not support the direct application of ISO/IEC 14763-3:2014 for the following reasons:

- **the work of the FIA Project Team investigating the specification and procurement of reference grade terminations found that there was no straightforward method by which test cords with reference grade terminations could be purchased that could be universally applied to all connector styles (this is documented in FIA-TSD-2000-4-2-3);**
  NOTE: for example, SC connectors had few problems but LC connectors did not lend themselves to the same approach
- **the chaos introduced by the removal of the universal test method for link and channel cabling configurations - replaced by separate, single, non-universal test methods for links and channels fails to provide adequate coverage for the generality of optical fibre cabling.**

These two specific technical issues are considered of major importance because they can directly lead to an installer obtaining sets of test results which become a source of technical debate and ultimately commercial conflict with their customers.

The greatest proportion of multimode optical fibre cabling links are of comparatively short length and which have low levels of attenuation. Equally importantly, the applications that are characterised to operate on such short lengths are likely to be of higher data rate and be more “mission critical” and therefore attract more attention. In addition, an increasing amount of singlemode optical fibre cabling is being installed for short links to support the delivery of applications where the multimode bandwidths become inadequate.

The focus on greater measurement accuracy and reduced measurement spread is most critical for these short lengths and the impact of customer dissatisfaction has greater commercial implications.

Taking these factors into account there are a number of specific issues which have directed the FIA position on test methods:

1. if reference grade terminations are not universally available it is not practical, or even possible, to apply a standard that universally requires their use;
2. there is a clear and present risk for installers that tightened limits that assume the use of reference grade terminations on the test cords will be breached if, for whatever the reason, the performance of the test cord terminations fails to meet the specified values for reference grade terminations;
3. there has to be a universal method for Configuration B2 cabling and certain types of Configuration A cabling.

It is not in the interest of the FIA to encourage installers or their customers to act in a way that risks the reputation of the FIA or the installer and it is certainly not in the interests of the FIA to encourage practices that could result in financial penalty for any of those involved.

In view of all the above factors, the FIA can only support the use of the following standards:

- **[BS EN] IEC 61280-4-1 for multimode optical fibre cabling;**
- **[BS EN] IEC 61280-4-2 for singlemode optical fibre cabling.**

The remainder of this document highlights specifics implementations of these two standards.

7 INSPECTION AND DE-CONTAMINATION OF CONNECTING HARDWARE

There is no value in undertaking any form of testing unless the optical fibre end-faces and any adapter components have not been inspected for contamination and cleaning, if contamination is found to be present.

A separate FIA Technical Support Document is planned to address this topic but the following provides some basic information.

An end-face inspection standard now exists in the form of [BS EN] IEC 61300-3-35. This allows automated inspection of end-faces using CCD microscopes of appropriate quality and with associated software-based assessment. These devices will become indispensible to installers and users alike.

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

Contamination on end-faces and within other connecting hardware components such as adapters can both cause permanent damage to mated components and can be passed via those components on to other end-faces. This is obviously a concern during testing and, if test cords are not maintained in a “de-contaminated” state, can potentially introduce a trend of worsening results as testing proceeds. This is particularly important if reference grade terminations are used on test cords since a failure to maintain their low attenuation characteristics will affect the results obtained on a systematic level.

In view of all the above factors, the FIA takes this opportunity to highlight that “**without inspection and cleaning, if necessary, of test cord end-faces and the end-faces of the cabling under test, there is no point in testing any cabling whatsoever.**”

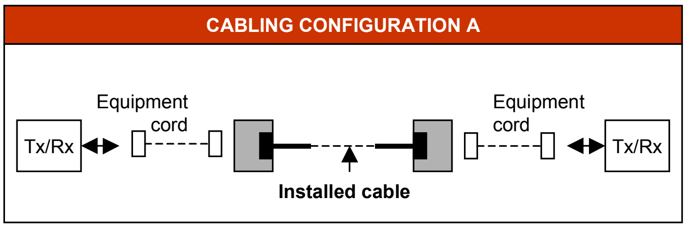
8 CABLING CONFIGURATIONS, REFERENCING TECHNIQUES AND TEST METHODS

8.1 Cabling configurations

Figure 1 shows the three possible link configurations described in [BS EN] 61280-4-1 and [BS EN] 61280-4-2.

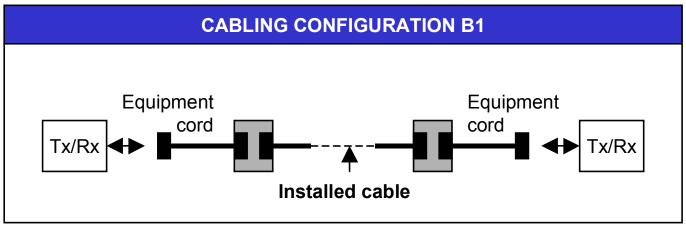
It should be noted that the term "installed cable" includes the cable between the two interfaces (adapters or free plugs) together with any embedded connecting hardware between these interfaces i.e. **"installed cable" can include splices (mechanical or fusion) and/or other connections deemed to be "permanent"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

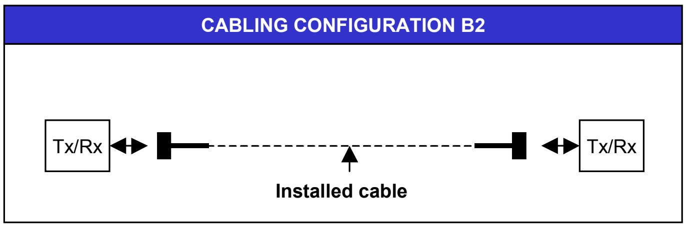
Configuration A is the conventional adapter-to-adapter (or "panel to panel") approach where the installed cable is terminated within closures requiring an equipment cord at each end to create the channel for connection to the transmission (Tx/Rx) equipment.



Configuration B has the installed cable is terminated in free plugs at each end. In such a situation either:

- the equipment cords are already attached to a Configuration A (or Configuration C) link - for the purposes of this document this is termed Configuration B1;
- no equipment cords are required to create the channel i.e. the link performance is identical to the channel performance - more common in singlemode systems where there panels are removed in order to reduce the light reflected back into the transmission equipment - for the purposes of this document this is termed Configuration B2.





Configuration C is a combination of Configuration A and Configuration B in which the installed cable is terminated within a closure at one end, requiring an equipment cord at that end to create the channel, but the other end is terminated in a free plug. This configuration may be found in specialist environments such as secure optical fibre telephone circuits where the exchange is the panel and the telephones are directly connected to the free plug.

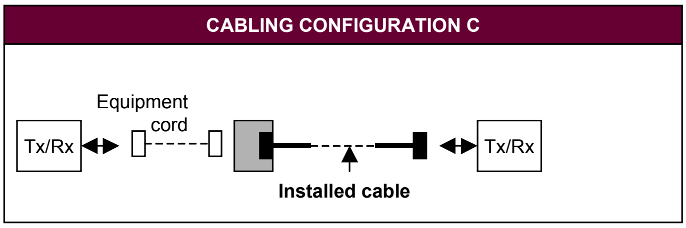
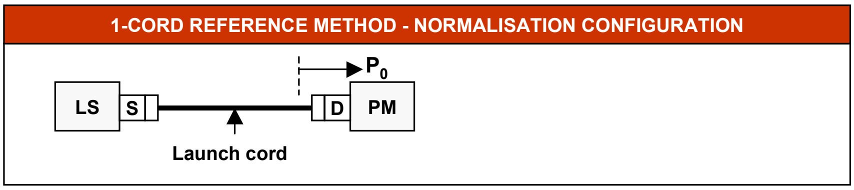


Figure 1 - The cabling configurations of [BS EN] 61280-4-x standards

8.2 Normalisation/referencing procedures

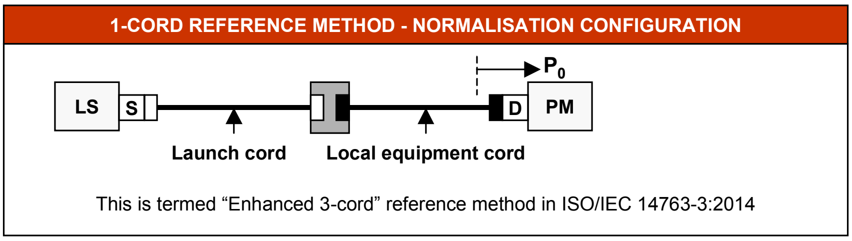
Figure 2 shows the referencing process for the different cabling configurations. This following text and Figure 2 is only intended to describe the outline of the procedures and it is required that the relevant procedures of [BS EN] IEC 61280-4-1 or [BS EN] IEC 61280-4-1 are applied in full.

The 1-Cord Reference method is the preferred approach for Configuration A cabling. If this is not possible (see NOTE 1) then a 3-Cord Reference method may be used (but with greater measurement uncertainty and the risk of negative loss results as discussed in 10.1).

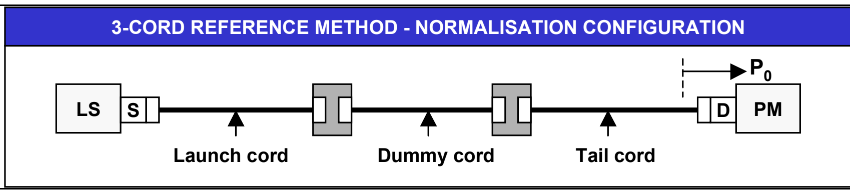


Configuration B1 shall adopt the 1-cord Reference method shown - which additionally uses the equipment cord local to the light source - provides the lowest measurement inaccuracy.

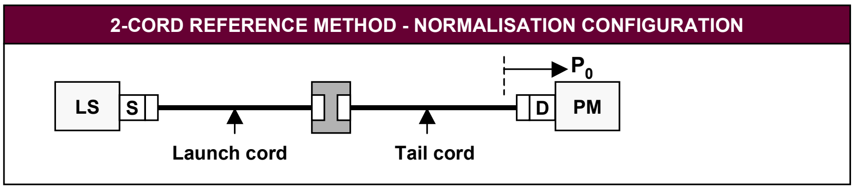
This is termed the “Enhanced 3-Cord” method of ISO/IEC 14763-3 but is not actually a 3-cord referencing procedure. It actually only uses 1 test cord but relies on the equipment cord for its process (hence 1-cord in this document).



Configuration B2 cabling terminated in fixed plugs or Configuration B1 which cannot physically be tested (see NOTE 2) using the 2-cord method above) shall adopt the 3-cord Reference method.



A 2-Cord Reference method shall only be applied to Configuration C cabling.



NOTE 1: there is at least one specific situation where it is not possible to apply a 1-Cord Reference method - where the power meter (PM) does not have an interchangeable adaptor, thereby restricting the choice of connector style on the launch cord that can be attached. In this situation the 1-cord method can only be used where the adapter at the local panel (or closure) is the same style as that of the power meter. In such cases a 2-cord referencing approach SHALL NOT be used – but a 3-cord referencing approach may be applied provided that the risk of greater measurement uncertainty and that of negative loss results (as discussed in 10.1) is acceptable.

NOTE 2: there is at least one specific situation where it is not possible to apply the modified 1-Cord Reference method which uses the local equipment cord as part of the reference measurement - where the power meter (PM) does not have an interchangeable adaptor, thereby restricting the choice of connector style on the local equipment cord that can be attached. In this situation the 1-cord method can only be used where the adapter at the local panel (or closure) is the same style as that of the power meter. In such cases a 1-cord referencing approach SHALL NOT be used – but a 3-cord referencing approach may be applied provided that the risk of greater measurement uncertainty and that of negative loss results (as discussed in 10.1) is acceptable.

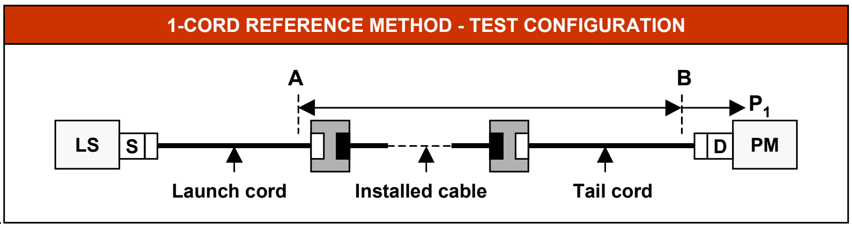
Figure 2 - Normalisation configurations of the n-Cord Reference methods

8.3 Test procedures

Figure 3 is only intended to describe the outline of the procedures and it is required that the relevant procedures of [BS EN] IEC 61280-4-1 or [BS EN] IEC 61280-4-1 are applied in full.

This test uses the adapters at the local and remote panels (or closures) and requires the use of a tail cord.

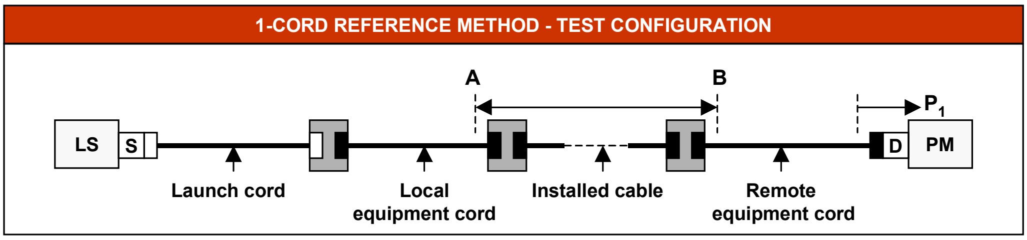
The attenuation is calculated as $P_1 – P_0$ (see Figure 2)



This test uses remote equipment cord as the tail cord.

This is termed the "Enhanced 3-Cord" method of ISO/IEC 14763-3 but is not a 3-cord referencing procedure. It only uses 1 test cord but relies on the use of the equipment cords

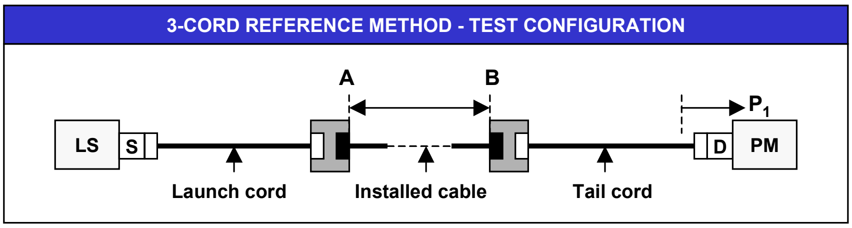
The attenuation is calculated as $P_1 – P_0$ (see Figure 2).



The installed cabling replaces the dummy cord shown in Figure 2.

For tests applied to Configuration B1 or B2 cabling, the adapters are part of the test system. For tests applied to Configuration A, the adapters are those on the local and remote panels (or closures).

The attenuation is calculated as $P_1 – P_0$ (see Figure 2).



The adapter of the referencing system is retained on either the launch or tail cord as appropriate and the other cord is plugged into the panel (or closure).

The attenuation is calculated as $P_1 – P_0$ (see Figure 2).

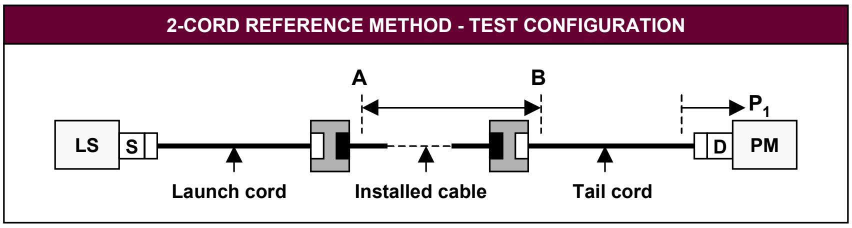


Figure 3 - Test configurations of the n-Cord Reference methods

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8.4 Summary

The 1-Cord Reference method is the preferred approach for Configuration A cabling and shall not be used for any other cabling Configuration.

The 1-Cord Reference method modified by the use of local equipment cord is the preferred approach for Configuration B1 cabling and shall not be used for any other cabling Configuration.

The 3-Cord Reference method is applicable to Configuration B2 cabling as described in Figure 2. It may be used for Configuration A or B1 cabling where there is no alternative (see NOTEs to Figure 2).

The 2-Cord Reference method is the only approach for Configuration C cabling and shall not be used for any other cabling Configuration.

9 DETERMINATION OF PASS-FAIL CRITERIA

9.1 1-Cord Reference Method for Configuration A cabling

Assuming the use of “normal” terminations on the test cords, the attenuation test limit for a 1-Cord Reference method is:

$P_1 – P_0$ (see Figure 2) $\leq$ installed cable $_{max}$ + 2 x connections (normal-normal) $_{max}$

Assuming the use of “reference grade” terminations on the test cords, the attenuation test limit for a 1-Cord Reference test method is:

$P_1 – P_0 \leq$ installed cable $_{max}$ + 2 x connections (normal-reference) $_{max}$

9.2 1-Cord Reference Method for Configuration B1 cabling

Assuming the use of “normal” terminations on the test cords, the attenuation test limit for a 1-Cord Reference method is:

$P_1 – P_0$ (see Figure 2) $\leq$ installed cable $_{max}$ + 2 x connections (normal-normal) $_{max}$

As the equipment cords are used as part of the referencing and test procedures there is no option fo rth euse of reference connections - on the equipment cords or on the launch cord.

9.3 2-Cord Reference method

Assuming the use of “normal” terminations on the test cords, the attenuation test limit for a 2-Cord Reference method is:

$P_1 – P_0$ (see Figure 2) $\leq$ installed cable $_{max}$ + 1 x connection (normal-normal) $_{max}$

Assuming the use of “reference grade” terminations on the test cords and the use of a reference grade adapter during the referencing and test method, the attenuation test limit for a 2-Cord Reference method is:

$P_1 – P_0 \leq$ installed cable $_{max}$ + 2 x connections (normal-reference) $_{max}$ – 1 x connection (reference-reference) $_{max}$

9.4 3-Cord Reference method

Assuming the use of “normal” terminations on the test cords, the attenuation test limit for a 3-Cord Reference method is:

$P_1 – P_0$ (see Figure 2) $\leq$ installed cable $_{max}$

When using a 3-Cord Reference method to test cabling Configuration B1 or B2 the adapters are part of the test cords whereas when using a 3-Cord Reference method to test Configuration A cabling the referencing adapters are replaced by those of the adapters on the panels (or closures) at each end.

It is not clear whether attenuation specification of a "connection (normal-reference) $_{max}$" assumes the use of a reference grade adapter but it is assumed, for the present, not to do so. Therefore, independent of the cabling Configuration under test and assuming the use of "reference grade" terminations on the test cords, the attenuation test limit for a 3-cord reference test method is:

$$P_1 - P_0 \le \text{installed cable}_{max} + 2 \times \text{connections (normal-reference)}_{max} - 2 \times \text{connections (reference-reference)}_{max}$$

9.5 The impact of test cords with reference grade terminations

9.5.1 Example performance values

Both [BS EN] IEC 61280-4-1 and ISO/IEC 14763-3 include the following specifications for multimode systems:
- connection (normal-normal) $_{max}$ = 0,75 dB;
- connection (normal-reference) $_{max}$ = 0,3 dB;
- connection (reference-reference) $_{max}$ = 0,1 dB.

Using these values, Table 2:
- indicates the impact on the PASS or FAIL criteria against which cabling under test is assessed.
- shows that the limits are dramatically affected by the use of reference grade test system components - the importance of this impact is amplified when the cable lengths are short (i.e. the attenuation of the installed cable is low).

Table 2 - Examples of multimode cabling attenuation test limits

	PASS/FAIL LIMIT		
Test system components	**1-Cord Reference method**	**2-Cord Reference method**	**3-Cord Reference method**
Normal	installed cable + 1,5 dB	installed cable + 0,75 dB	installed cable
Reference grade	installed cable + 0,6 dB (not applicable to Configuration B1)	installed cable + 0,5 dB	installed cable + 0,4 dB

ISO/IEC 14763-3 includes the following specifications for singlemode systems:
- connection (normal- normal) $_{max}$ = 0,75 dB;
- connection (normal-reference) $_{max}$ = 0,5 dB;
- connection (reference-reference) $_{max}$ = 0,2 dB.

Using these values, Table 3 indicates the impact on the PASS or FAIL criteria against which cabling under test is assessed.

Table 3 - Examples of singlemode cabling attenuation test limits

	PASS/FAIL LIMIT		
Test system components	**1-Cord Reference method**	**2-Cord Reference method**	**3-Cord Reference method**
Normal	installed cable + 1,5 dB	installed cable + 0,75 dB	installed cable
Reference grade	installed cable + 1,0 dB (not applicable to Configuration B1)	installed cable + 0,8 dB	installed cable + 0,6 dB

9.5.2 “Normal” limits

There is a great temptation to adopt the “connection (normal- normal) $_{max}$“ value of 9.5.1 for all cabling under test. This may not always be appropriate.

The “connection (normal- normal) $_{max}$“ value of 9.5.1 are certainly relevant to cabling in accordance with structured cabling in accordance with the international, European and British standards such as those detailed in 6.1. However, there are many other optical fibre connector styles installed in legacy systems that cannot conform to this specification and it is obviously unfair to apply a maximum attenuation specification of 0,75 dB to, for example, a FSMA 906 connector manufactured with a steel ferrule in 1983. It is therefore important to realise that the specification of 9.5.1 is widely but not universally applicable.

9.5.3 “Reference grade” limits

There is a great temptation to adopt the “connection (normal- reference) $_{max}$“ and “connection (reference- reference) $_{max}$“ of 9.5.1 for all cabling under test. This is far from appropriate in all cases.

The values of 9.5.1 are certainly relevant to SC and LC connecting hardware.

However, there are many other optical fibre connector styles (both new and installed in legacy systems) that either cannot conform to these values or do not have standardised values specified at this time.

In the absence of universally applicable specifications, it is not possible to mandatorily apply the use of the reference grade terminations or the modified limits.

Therefore the **FIA follow the recommendations of [BS EN] IEC 61280-4-1 regarding the optional use of reference grade products as part of the test system only where their impact is fully understood since**:

- it may be difficult to determine exactly what a reference grade test system component is for a given connector style;
- to assume that components are of reference grade and to apply the lower limits that such an assumption implies when in fact the test components are not of reference grade may produce test results that fail.

9.6 Failure to apply the correct procedures

A failure to apply to the correct approach and the associated test limits to the cabling Configuration under test is either:

- underestimating the attenuation of the cabling under test and obtaining some proportion of PASS results that should FAIL - **this is more colloquially known as cheating;**
- overestimating the attenuation of the cabling under test and obtaining some proportion of FAIL results that should PASS - **this is more colloquially known as “being an idiot”;**

The FIA only tend to hear about the latter situation when the Technical Directorate is asked to resolve conflicts between installers and customers. However, it fully recognised that the incorrect use of test methods is widespread - as much through ignorance as through a specific intent to mislead.

To be clear:

- **cabling Configuration A measurements are intended to represent the installed cabling with the mated connections to the test cords;**
- **cabling Configuration B1 measurements are intended to represent the installed cable with its mated connections to the equipment cords (as is equivalent to the channel definition of structured cabling standards);**
- **cabling Configuration B2 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.**

This is shown graphically in Figure 4.

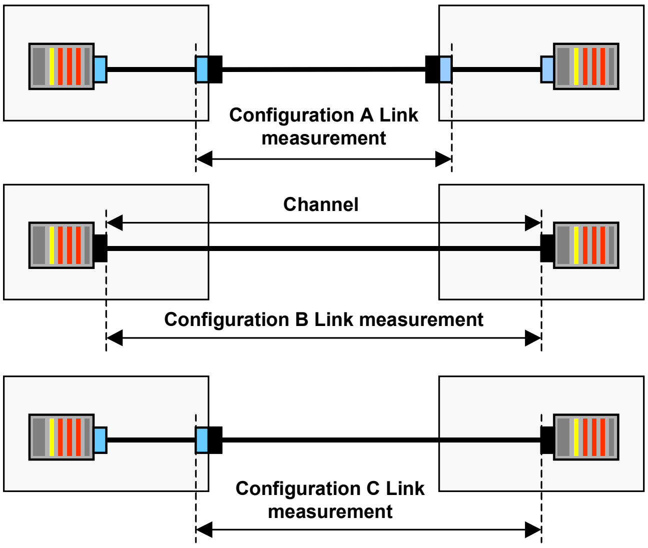

Figure 4 - Boundaries of measurement for channels and links

Table 4 provides a summary of the impact of using the different n-Cord Reference methods for the different cabling Configurations unless the limits against which the result as assessed are modified.

Table 4 - Impact of different n-Cord Reference methods unless limits are modified

Reference method	Cabling Configuration A	Cabling Configuration B1	Cabling Configuration B2	Cabling Configuration C
1-cord	**Correct**	**Correct** (using equipment cords)	**High by 2 connections** (shall not be used)	**High by 1 connection** (shall not be used)
3-cord	**Low by 2 connections** (allowed with modified limits)	**Correct** (but with greater measurement uncertainty than the 1-Cord approach)	Correct	**Low by 1 connection** (shall not be used)
2-cord	**Low by 1 connection** (shall not be used)	**High by 1 connection** (shall not be used)	**High by 1 connection** (shall not be used)	Correct

The combinations marked in red are the “cheats” and shall not be used although as previously stated the 3-cord reference method may be applied to cabling Configuration B if modified limits are applied.

The combinations marked in blue are those that will produce “high” results and shall not be used.

Any audit work undertaken by the FIA Technical Directorate will apply the correct methods and limits defined in this document.

10 TEST RESULT SPREAD

10.1 Multimode optical fibre cabling

10.1.1 General

This clause uses the example attenuation limits specified in 9.5.1 to indicate the spread of results that will be obtained during testing using the different cord reference methods and when using reference grade test system components. More information is provided in FIA-TSD-2000-4-2-3.

10.1.2 1-cord Reference Method for Configuration A

Figure 5 shows the theoretical range of results to be expected when a 1-Cord Reference method is applied. The limits are shown in red on the schematic. Using a 1-Cord Reference method, it is not possible to obtain a “negative” attenuation result even if the installed cable attenuation is low.

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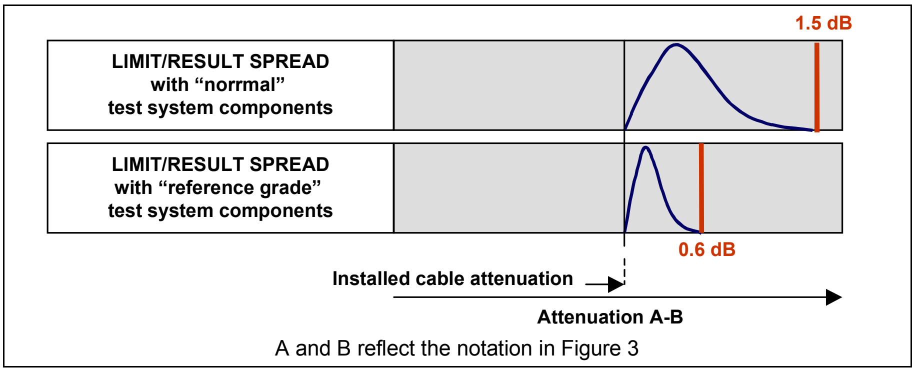

Figure 5 - Limits and spread of results using the 1-Cord Reference method (multimode)

It is also clear that the use of a launch cord with a reference grade termination not only reduces the range of worst case test results obtained but will also affect the distribution.

In fact, Monte Carlo modelling of typical connection distributions suggests that in excess of 99.7% of results should be:

- no greater than "installed cable + 1,2 dB" when using a launch cord with a "normal" termination;
- no greater than "installed cable + 0,5 dB" when using a launch cord with a "reference grade" termination.

This explains why, if it is possible, the 1-Cord Reference Method should be used and why reference grade termination provides substantial improvement in measurement reproducibility.

10.1.3 1-cord Reference Method for Configuration B1

Because this method employs the local equipment cords as part of the referencing technique, there is no cabling-related measurement inaccuracy other than the repeatability of the connections between the equipment cords and the termination of the installed cable.

10.1.4 2-cord Reference Method for Configuration C

Figure 6 shows the theoretical range of results to be expected when a 2-Cord Reference method is applied. The limits are shown in red on the schematic. Using a 2-Cord Reference method, it is possible to obtain a "negative" attenuation (or insertion loss) result if the installed cable attenuation is low.

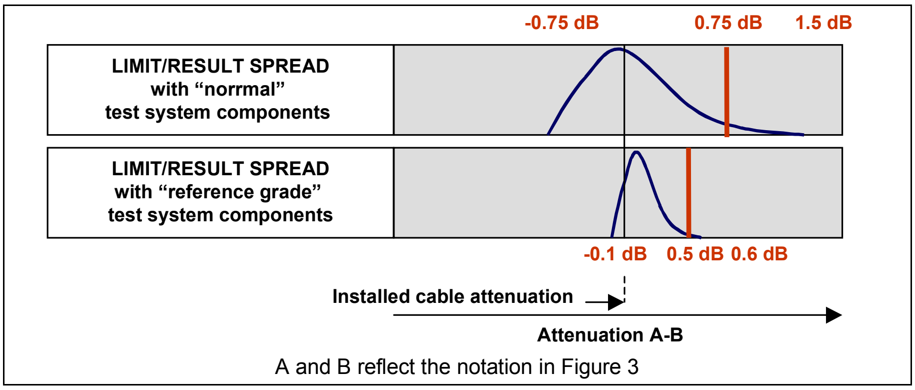

Figure 6 - Limits and spread of results using the 2-Cord Reference method (multimode)

It is also clear that the use of launch and tail cords with reference grade terminations (and a reference grade adapter) reduces the range of worst case test results obtained, affects the overall distribution and will limit the probability of obtaining a “negative” attenuation (or insertion loss) result. More detailed Monte Carlo modelling of typical connection distributions suggests that in excess of 99.7% of results should be within the range:

- “installed cable - 0,28 dB” and “installed cable + 0,92 dB”” when using a launch and tail cord with “normal” terminations;
- “installed cable + 0,03 dB” to “installed cable + 0,45 dB” when using a launch and tail cord with “reference grade” terminations.

This explains why reference grade terminations provide substantial improvement in measurement reproducibility. However, the almost unavoidable possibility of “negative” attenuation results generates a quality plan “red flag” and customers need to be aware of the possibility of such results if cabling of Configuration C is to be tested.

10.1.5 3-cord Reference Method for Configuration A and B2

Finally, Figure 7 shows the theoretical range of results to be expected when a 3-Cord Reference method is applied. The limits are shown in red on the schematic. Using a 3-Cord Reference method, it is possible to obtain a “negative” attenuation result if the installed cable attenuation is low.

It is also clear that the use of launch, dummy and tail cords with reference grade terminations (and reference grade adapters) reduces the range of worst case test results obtained, affects the overall distribution and will limit the probability of obtaining a “negative” attenuation result.

More detailed Monte Carlo modelling of typical connection distributions suggests that in excess of 99.7% of results should be within the range:

- “installed cable - 0,72 dB” to “installed cable + 0,72 dB” when using test cords with “normal” terminations;
- “installed cable - 0,04 dB” to “installed cable + 0,40 dB” when using test cords with “reference grade” terminations.

This data clearly explains why reference grade terminations provide substantial improvement in measurement reproducibility.

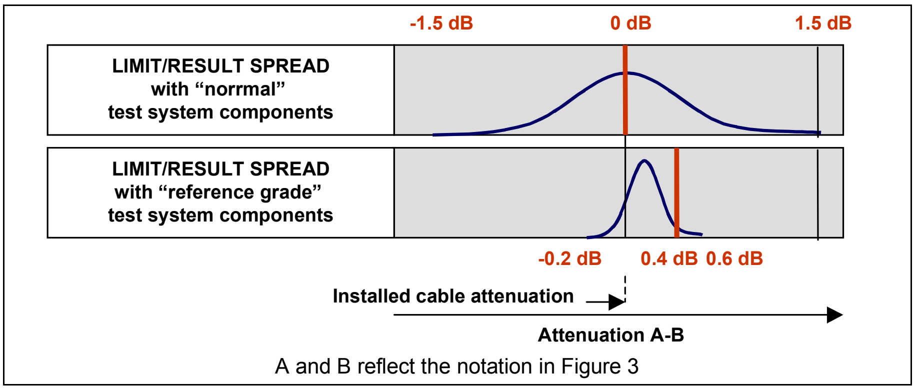

Figure 7 - Limits and spread of results using the 3-Cord Reference method (multimode)

There are some who suggest that the measurement inaccuracy of the 3-Cord Reference method is much greater than that of the 1-Cord Reference however the Monte Carlo modelling suggests that the range of “real world” results is only marginally worse (1,44 dB vs. 1,2 dB) for “normal” test system components and is actually better (0,5 dB vs. 0,44 dB) for “reference grade” test system components. As a result, the FIA is not persuaded by this particular argument..

However, the almost unavoidable possibility of “negative” attenuation results generates a quality plan “red flag” and customers need to be aware of the possibility of such results if cabling of Configuration A or B is to be tested using a 3-Cord Reference method and the FIA cannot support the universal use of the 3-Cord Reference method.

10.2 Singlemode optical fibre cabling

See Annex A for similar information to that of 10.1.

11 USE OF TEST RESULTS

11.1 Creation of channels

Figure 8 shows two links interconnected by a patch cord and the resulting channel created by addition of an equipment cord at each end.

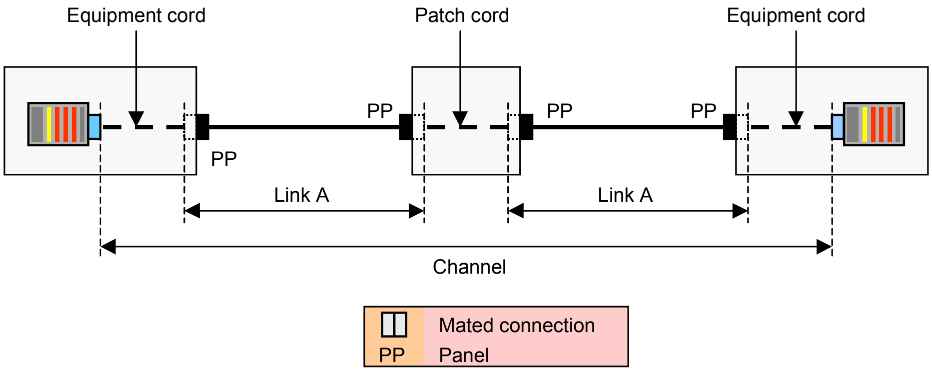

Figure 8 - Patch cord and equipment cord attenuation

From the schematics shown in Figure 4 it is clear that the impact of equipment cords on channel attenuation performance is purely the contribution of the cable of the cords and not their terminating connectors. The same is true of patch cords used to connect links.

Caution is required if any attempt is made to determine the total attenuation of the channel based on the sum of the attenuation of each link together with the cable content (if any) of the cords.

If the correct test method has been applied (i.e. the 1-, 2- or 3-Cord Reference method) using "normal" test cords then it is reasonable to consider that the total attenuation of the channel may approximate to the sum of the attenuation of each link together with the cable content (if any) of the cords. Clearly the cords have to be functioning properly for this assumption to be made. A working definition of a "properly functioning cord" is that the connector end-faces meet the inspection requirement of IEC 61300-3-35 and that the connector at each end of the cord performs according to its specification. Measurement of cord performance is discussed in TSD-2000-4-2-3.

However, if reference grade test system components have been used in the test methods for the individual links, the test results will not be applicable to the subsequent interconnection of the individual link with "normal" patch and equipment cords to create the channel.

11.2 Application-specific testing

Table 5 shows a list of applications (LAN-based) with their maximum channel insertion loss values (see FIA-TSD-2000-2-1 for further information). It is possible to measure a completed channel against the limits defined the application to be supported.

As a channel is of cabling Configuration B1, a 1-Cord Reference method shall be used where possible. Where this is not viable and for Configuration B2 the a 3-Cord Reference method shall be used.

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If “normal” components are used within the test system it is reasonable to compare results obtained with contain with the requirements of applications such as those shown in Table 5.

However, use of “reference grade” test system components within a 3-Cord Reference method test produces results that are based on the channel boundaries of Figure 4 but, as described in 9.4, will measure higher than a “channel” (i.e. that only contains “installed cable”. The results obtain will have to be modified in order to compare them directly with the requirements of applications such as those shown in Table 5.

Table 5 - Sample application-specific channel limits

		Channel insertion loss (attenuation)$_{max}$ (dB)			
λ (nm)	**Application**	**62,5/125 µm OM1**	**50/125 µm OM2**	**50/125 µm OM3**	**50/125 µm OM4**
850	IEEE 802.3: 1000BASE-SX	2.6	3.56	3.56	3.56
1300	IEEE 802.3: 1000BASE-LX	2.35	2.35	2.35	2.35
850	10GBASE-SR/SW	1.62	1.80	1.80	1.80
1270-1320	10GBASE-LX4	1.96	1.96	1.96	1.96
1310	10GBASE-LRM	1.96	1.96	1.96	1.96
850	40GBASE-SR4			1.90	1.90
850	100GBASE-SR10			1.53	1,90
NOTE: it should be noted that many applications have associated channel length limits in addition to the overall attenuation limits shown.					

Figure 9 - Application-specific channel testing

However, the use of application-specific testing shall not be used to verify the performance of links since the performance of links shall be consistent with their design.

12 QUALITY ASSURANCE

12.1 General

Testing is a means of verification that the performance of installed cabling channels and links (see Figure 4) meet the requirements of the relevant Installation Specification. Testing of installed cabling is not a substitute for the:

- proper inspection of installed cabling against the requirements recognised installation standards e.g. BS 6701 and the [BS] EN 50174 series;
- proper inspection of optical interfaces against the requirement of [BS EN] IEC 61300-3-35.

12.2 Quality Plan

It should be clear from the preceding clauses that:

- it is important to use the correct test method that is both matched to the configuration of the cabling under test and is appropriate to the Grade of test equipment used;
- even if the correct method is used there is a measurement error that cannot be reduced or ignored;
- on short links the impact of the measurement error is likely to produce results that lie both above and below the expected values.

In view of these factors the installer shall produce a Quality Plan in accordance with the BS EN 50174 series of standards. This may be in the form of a generic method statement.

The Quality Plan details the:

- test procedures to be used
- actions to be taken in the event of marginal results (i.e. results that lie within the measurement accuracy but outside the expected values.

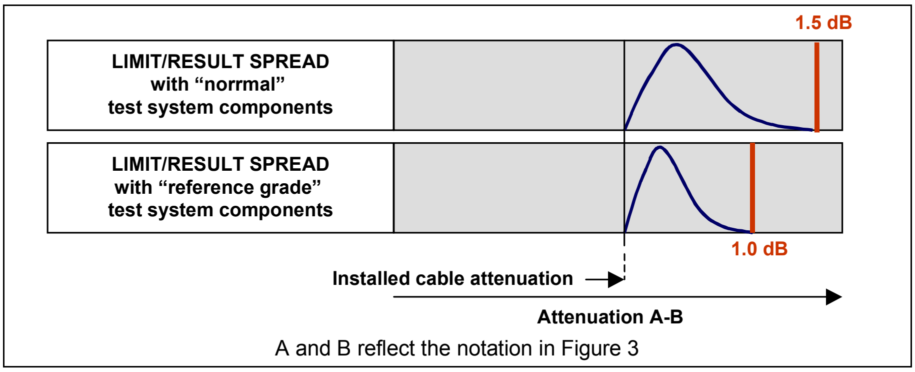
Specifically the Quality Plan shall contain information about the following:

- the test equipment and test cords to be used;
- the need for bi-directional testing:
- transmission wavelength:
  - the Installation Specification defines the wavelength(s) at which the cabling is to be tested. If the Installation Specification refers to external standards such as ISO/IEC 11801, EN 50173-1 or ANSI/TIA/EIA-568-C then these standards shall be consulted to determine their requirements;

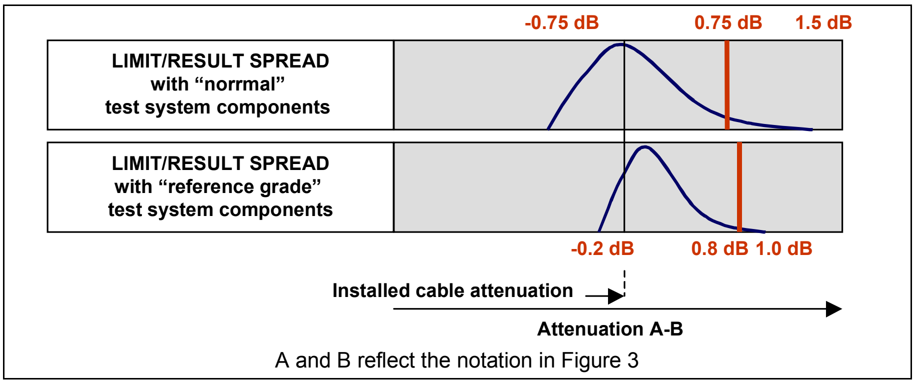
    NOTE: all these standards define limits at both 850 nm and 1300 nm for MMF and both 1310 nm and 1550 nm for SMF but this does not means that testing is required at all wavelengths
- the administration of the test;
  - detailing how each test is to be referenced/identified;
  - detailing how the test configuration is to be recorded;
- the treatment of marginal results;
  - proposals for re-testing with different test leads and the use of a statistical approach;
  - if the result continues to be marginal then it may be necessary to investigate the cause of the loss by means of an OTDR (see FIA-TSD-2000-4-2-2) to determine if the problem lies within the cable or the connections.

ANNEX A
TEST LIMITS AND RESULT FOR SINGLEMODE TEST METHODS

The figures below provide similar information as that of the multimode implementations in 10.1 assuming the component [performance values of 9.5.1 .



Limits and spread of results using the 1-Cord Reference method (singlemode)



Limits and spread of results using the 2-Cord Reference method (singlemode)

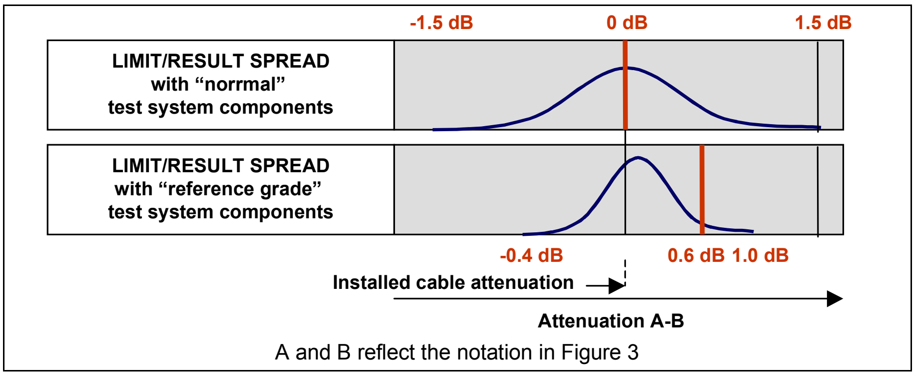


Figure 10 - Limits and spread of results using the 3-Cord Reference method (singlemode)