Testing Optical Fibre Infrastructures

Prepared and delivered for

FIA
The Fibreoptic Industry Association

Bisham Abbey
20th March 2001

www.it-cabling.com www.e-readybuilding.com
P. O. Box MT65, LEEDS, LS17 8YD. United Kingdom Tel: +44 (0) 113 232 3721 Fax: +44 (0) 113 232 3724

AGENDA

- Introduction
- OF: Testing Philosophies
- Test Methods
- Break
- Quality Planning
- Close

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Mike Gilmore

The Cabling Partnership
www.it-cabling.com
***e*-Ready Building**
www.e-readybuilding.com
PO Box MT65, LEEDS, LS17 8YD, United Kingdom
Tel: +44 (0) 113 232 3721 Fax: +44 (0) 113 232 3724

Mike Gilmore

ISO/IEC JTC1 SC25
Secretary: WG3: Generic Cabling
Member: Project Team: SOHO

CENELEC
50173 Ed.2 (2002)
Convenor: TC215 WG1: IT Cabling

BSI
Chairman TCT7/-/1: IT Cabling
Chairman TCT7/-/3: IT Cabling

Fibreoptic Industry Association
Standards Director
Technical Director

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FIA Documentation Update

DESIGN		
FIA-TSD-2000-1-1	OPTICAL FIBRE CABLING: LAN APPLICATION SUPPORT GUIDE	JANUARY 2001
	Revision to include mode conditioning cords and 10GBASE-xyz	JANUARY 2002
INSTALLATION		
FIA-TSD-2000-4-2-1	TESTING OF INSTALLED CABLING: ATTENUATION USING LSPM EQUIPMENT	JANUARY 2002
SAFETY		
FIA-TSD-2000-5-1	OPTICAL POWER: SAFETY LEVELS	DECEMBER 2001
FIA-TSD-2000-5-2	OPTICAL FIBRE: HANDLING OF PROCESSING CHEMICALS	
FIA-TSD-2000-5-3	OPTICAL FIBRE: DISPOSAL OF WASTE	

MODELLING TOOLS	
CABLING STRUCTURES COST MODEL	DECEMBER 2001

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OF - Testing Philosophies

AGENDA

- Introduction
- OF: Testing Philosophies
  - Reference Points
  - General Implementations
  - The Alternative Approaches
  - Testing Regimes
  - Light Source - Power Meters
    - Equipment Grades (FIA)
  - Test Cords
    - Launch conditions
    - MMF Mandrel Wrap
    - The Importance of Cords
  - LSPM Measurement Accuracy
  - Measurement Error
  - Typical Results
  - Cabling Configurations
  - Impact of Incorrect Methods
- Test Methods
- Break
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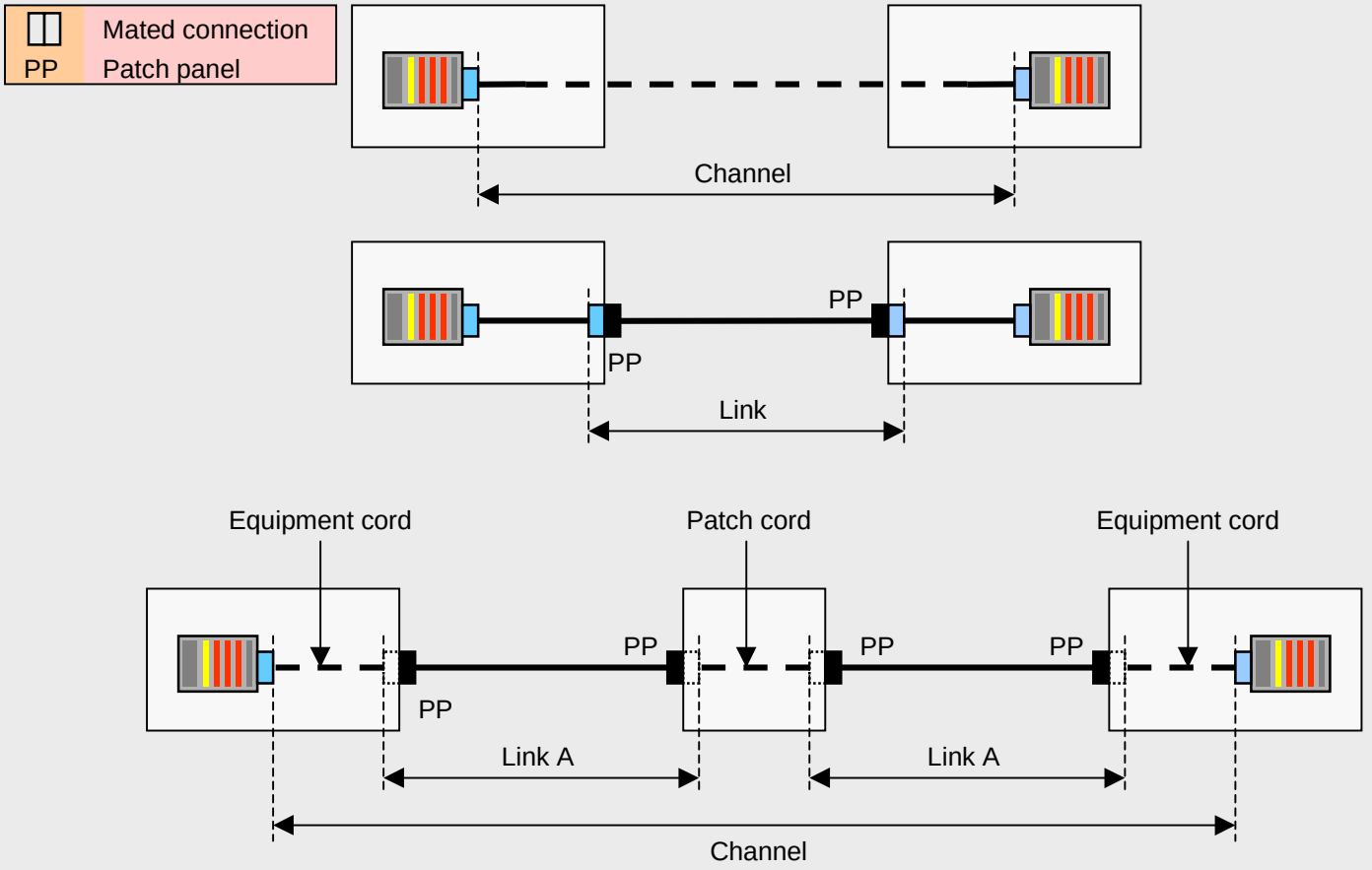
Reference Points



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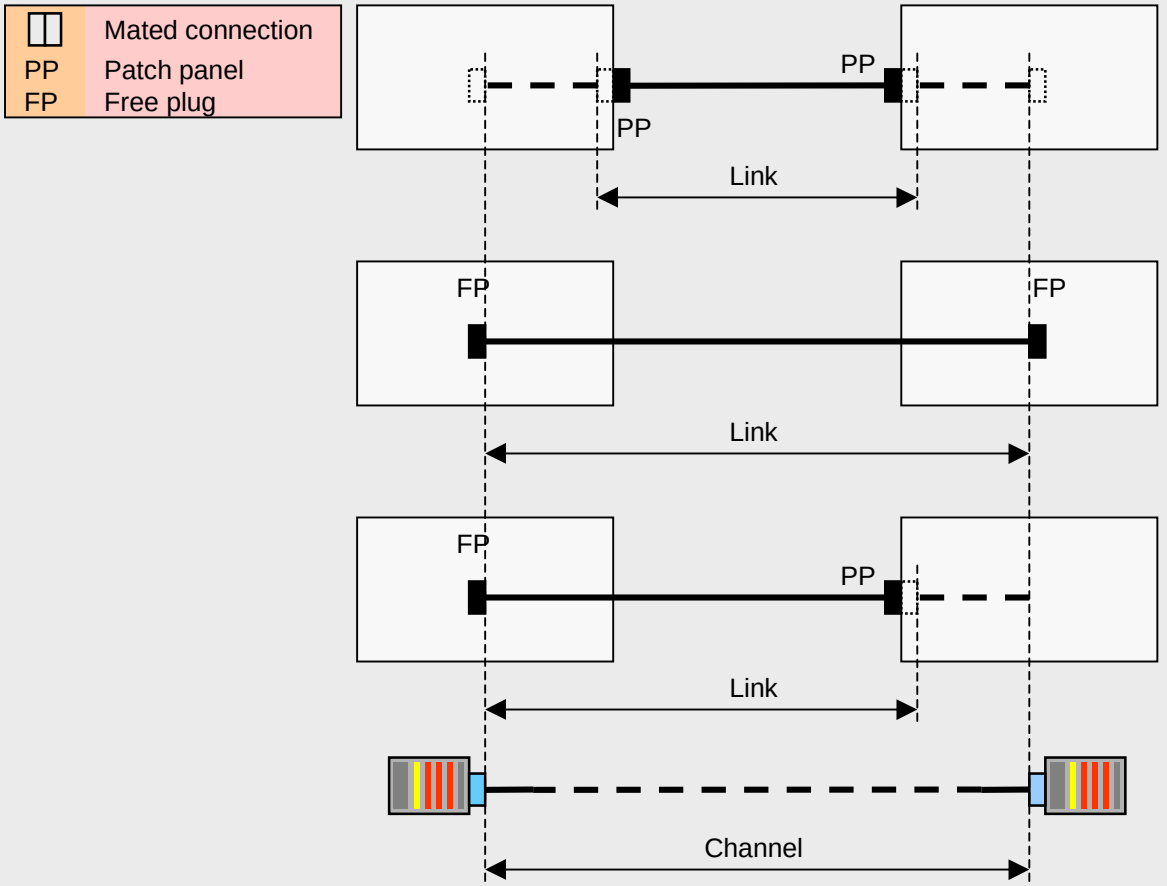
General Implementations



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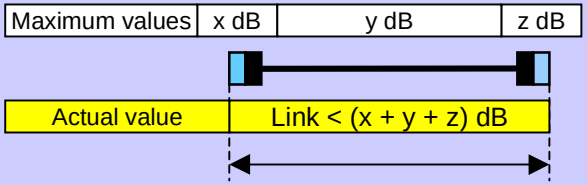
The Alternative Approaches

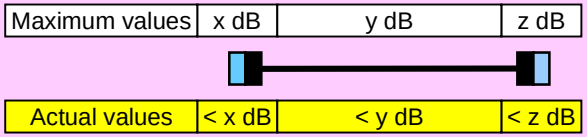
"Channel" approach

APPLICATION	Optical power budget (dB) MMF 850nm	MMF 1300nm	SMF 1310nm
ISO/IEC 8802-3: 10BASE-FL/FB	12,5 (6,8)		
ISO/IEC 8802-5: TR 4/16 Mbit/s	13,0 (8,0)		
ISO/IEC 9314-3 FDDI		11,0 (6,0)	
ISO/IEC DIS 9314-4 FDDI			10,0
ISO/IEC 8802-3: 100BASE-FX		11,0 (6,0)	
TR 100 Mbit/s		11,0 (6,0)	
CD 14165-1: Fibre Channel-1062	4,0		6,0
IEEE 802-3: 1000BASE-SX	2,6 (3,56)		
IEEE 802-3: 1000BASE-LX		2,35	5,0

"Overall loss" approach



"Component loss" approach



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Testing Regimes

TEST REGIME	ITEMS UNDER TEST	TESTING APPROACH	TEST TOOL
Component Acceptance	Cables	Component loss	OTDR
	Cords	Overall loss	LSPM
		Component loss	LSPM
Legacy Cabling Acceptance	Links and channels	Overall loss	LSPM
		Component loss	OTDR
Partial Completion Tests	Links	Component loss	OTDR
Installed Cabling Acceptance	Links and channels	Overall loss	LSPM
		Component loss	OTDR
Fault Diagnosis	Links and channels	Component loss	OTDR

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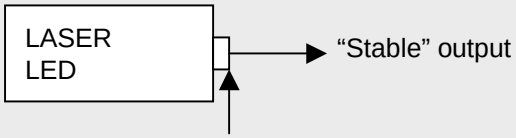
Light Source - Power Meters

LSPM = Light Source - Power Meter

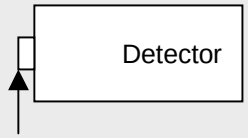
Light Source



Connector independent of cabling under test

Multimode	
λ (nm)	Δλ (nm)
820-880	30-60
1280-1320	30-60

Power Meter



Connector dependent on cabling under test
• interchangeable

Measurement
• absolute power (W or dBm)
• relative power (dB)

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Equipment Grades (FIA)

Grade 1 • simplex • single wavelength	Light source → λ_1 → Power meter	Component- based
Grade 2 • simplex • dual wavelength	Light source → λ_1, λ_2 → Power meter (λ_1/λ_2)	Component- based
Grade 3 • simplex • auto dual wavelength	Light source → λ_1/λ_2 → Power meter	System-based
Grade 4 • duplex • dual wavelength	Light source / Power meter ↔ λ_1, λ_2 ↔ Power meter / Light source	System-based
Grade 5 • duplex • auto dual wavelength	Light source / Power meter ↔ λ_1/λ_2 ↔ Power meter / Light source	System-based

Includes single location Grade 3

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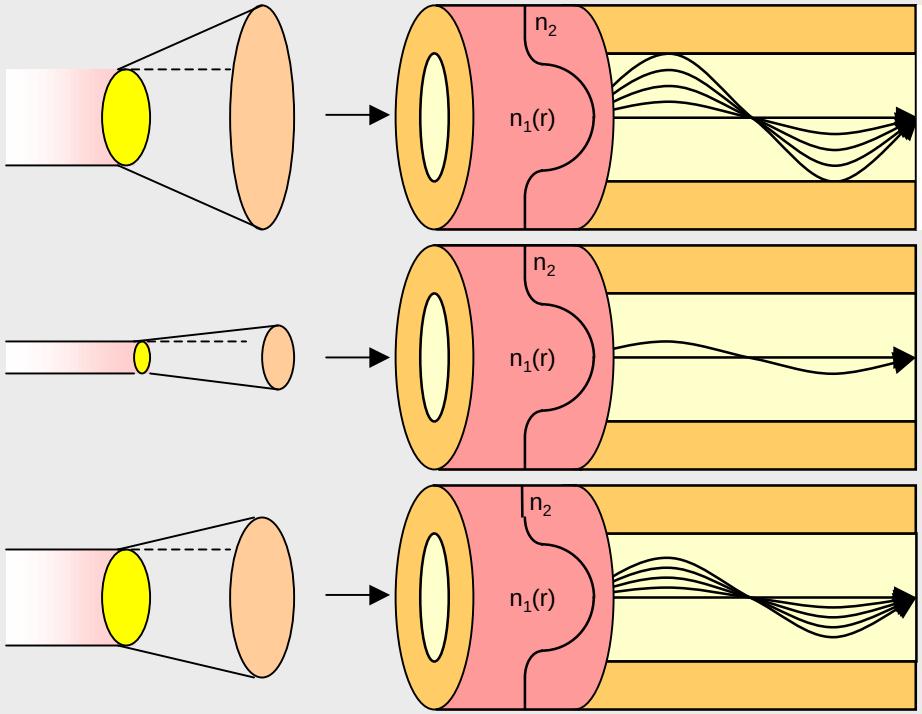
Test Cord Launch Conditions



Reference measurement contains unwanted high order modes.

Test measurement reads HIGH.

Reference measurement does not contain all modes.

Test measurement reads LOW.

Reference measurement does not contain cladding modes but does contain all modes.
Test measurement reads CORRECTLY.

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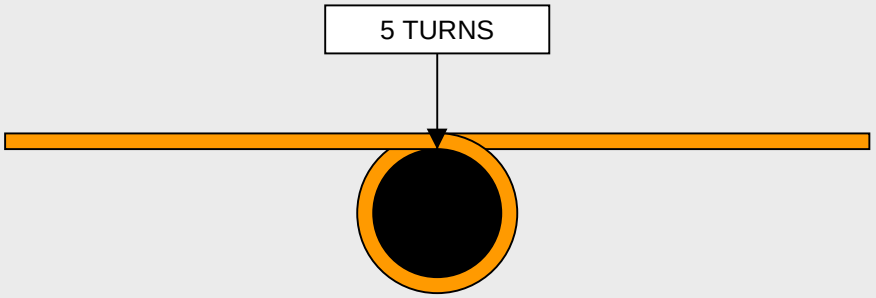
MMF Mandrel Wrap



MMF: not applicable

MMF: EN 50346 6MP

		Mandrel Diameter
50/125	Cable	18
50/125	SCOF	15
62.5/125	Cable	20
62.5/125	SCOF	17

MMF: ANSI/TIA/EIA B.1

		Mandrel Diameter
50/125	Cable	25
50/125	SCOF	22
62.5/125	Cable	20
62.5/125	SCOF	17

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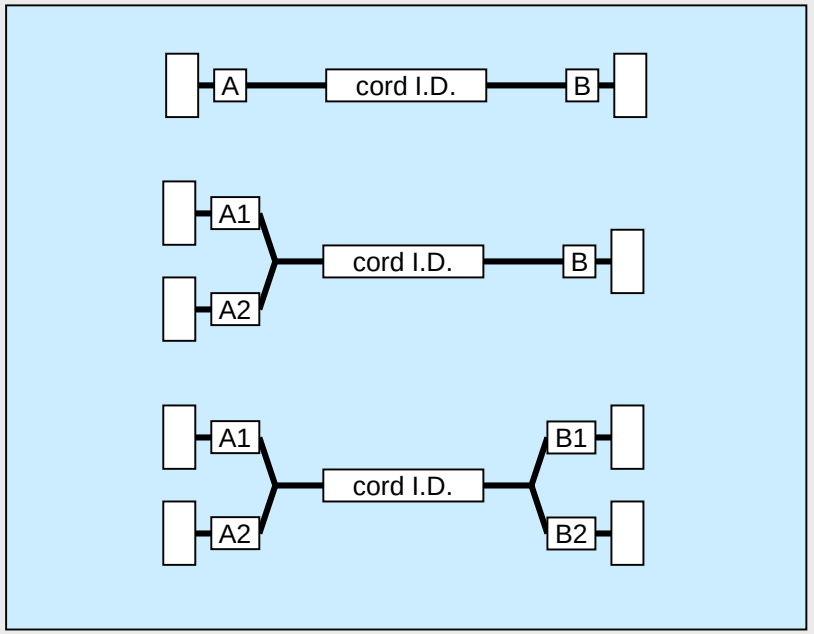
The Importance of Cords



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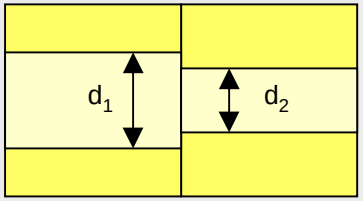
LSPM Measurement Accuracy

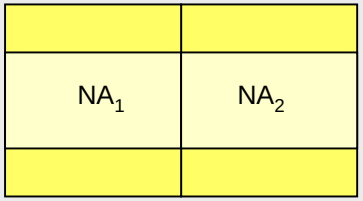
CORE



$$Loss = -10\log_{10}\left[\left(\frac{d_2}{d_1}\right)^2\right]$$

dB from large core to small core
(0 dB from small to large)

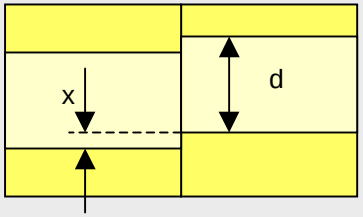
CORE



$$Loss = -10\log_{10}\left[\left(\frac{NA_2}{NA_1}\right)^2\right]$$

dB from large NA to small NA
(0 dB from small to large)

CORE



$$Loss = -10\log_{10}\left[\frac{1}{90}\tan^{-1}\left(\frac{de}{x}\right) - \frac{2xe}{\pi d}\right]$$

dB in both directions

$$e = \left[1 - \left(\frac{x}{d}\right)^2\right]^{0.5}$$

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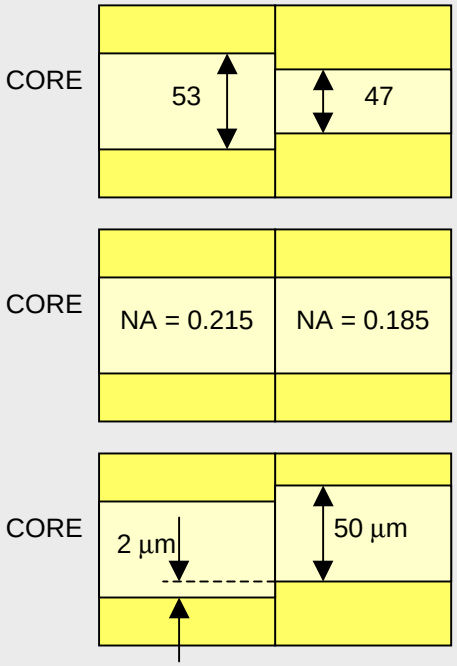
LSPM Measurement Accuracy



$$Loss = -10\log_{10}\left[\left(\frac{47}{53}\right)^2\right]$$

= -1.04 dB

$$Loss = -10\log_{10}\left[\left(\frac{0.185}{0.215}\right)^2\right]$$

= -1.30 dB

Loss

= -0.47 dB

Applied statistics and real manufacturing tolerances suggest combined value

< -0.35 dB per joint

Measurement accuracy of LSPM systems = 0.7 dB plus other mismatches

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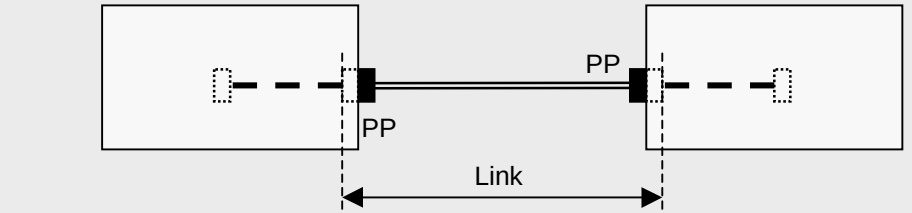
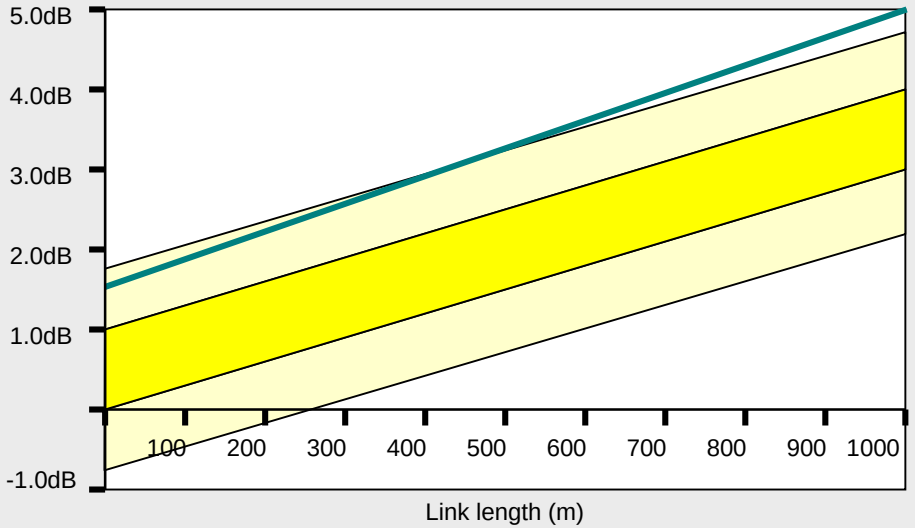
Measurement Error



Configuration A



Optical loss budget

99.75% spread + ME

99.75% spread
(2 x 0.5dB + 3.0dBkm^{-1} x L)

99.75% spread - ME

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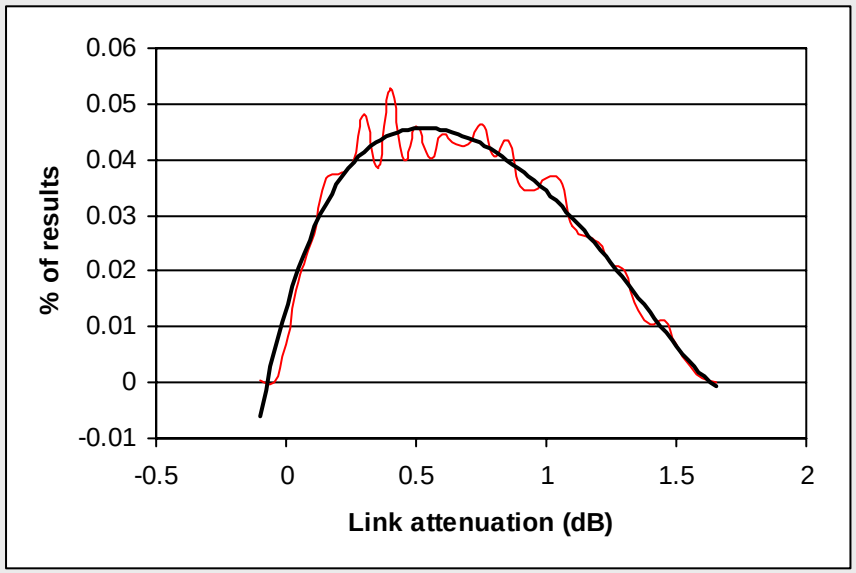
Typical Results



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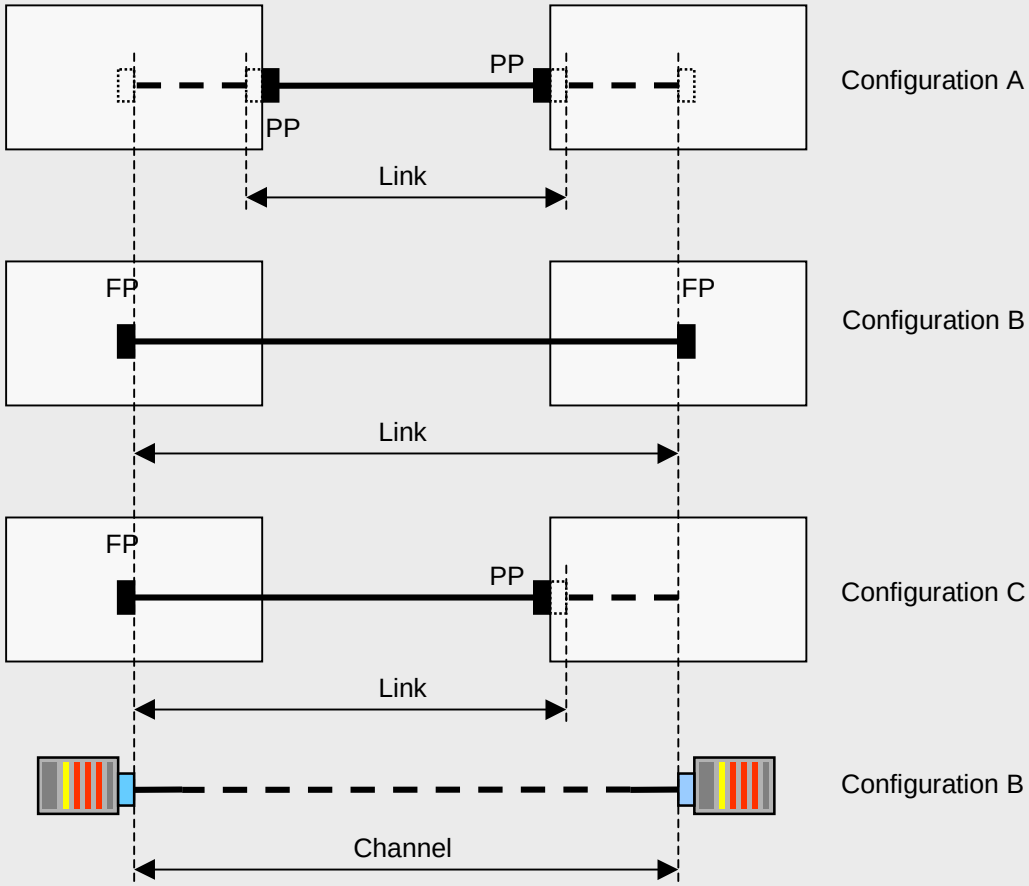
Cabling Configurations



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Impact of Incorrect Methods

INSTALLED LINK	METHOD APPLIED	RESULT
CONFIGURATION A	CONFIGURATION A	CORRECT
	CONFIGURATION B	LOW BY 2 CONNECTIONS
	CONFIGURATION C	LOW BY 1 CONNECTION
CONFIGURATION B	CONFIGURATION A	HIGH BY 2 CONNECTIONS
	CONFIGURATION B	CORRECT
	CONFIGURATION C	HIGH BY 1 CONNECTION
CONFIGURATION C	CONFIGURATION A	HIGH BY 1 CONNECTION
	CONFIGURATION B	LOW BY 1 CONNECTION
	CONFIGURATION C	CORRECT

INSTALLED CHANNEL	METHOD APPLIED	RESULT
CONFIGURATION B	CONFIGURATION A	HIGH BY 2 CONNECTIONS
	CONFIGURATION B	CORRECT
	CONFIGURATION C	HIGH BY 1 CONNECTION

All measurements are subject to the fundamental accuracy of the technique

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Test Methods

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  - LSPM Test Methods
    - Configuration A
    - Configuration B
    - Configuration C
  - Duplex Cabling
  - Link Configuration A
    - Equipment Grade 2
    - Equipment Grades 4,5
- Break
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LSPM Test Methods

INTERNATIONAL STANDARDS

ISO/IEC **11801 Ed.2 (2002)**

Multimode	Singlemode
IEC **61280-4-1**	IEC **61280-4-2**

US STANDARDS

ANSI/TIA/EIA **568B.1 (2001)**

Multimode	Singlemode
ANSI/TIA/EIA **526-14-A**	ANSI/TIA/EIA **526-7-A**

EUROPEAN STANDARDS

EN (future BS EN) **50173 Ed.2 (2002)**

EN (future BS EN) **50346 (2002)**

Multimode	Singlemode
	IEC **61280-4-2**

BRITISH STANDARDS

BS **7718 (1996)**

Multimode	Singlemode

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LSPM Test Method Glossary

ARENA	REFERENCE	TITLE
IEC	61280-4-1	Fibre optic communication subsystem basic test procedures - Part 4-1: Fibre optic cable plant - Multimode fibre optic cable plant attenuation
IEC	61280-4-2	Fibre optic communication subsystem basic test procedures - Part 4-2: Fibre optic cable plant - Single-mode fibre optic cable plant attenuation
EN	50346	Information Technology - Testing of installed cabling
TIA/EIA	526-14-A	OFSTP-14A Optical Power Loss Measurement of Installed Multimode Fiber Cable Plant (ANSI/TIA/EIA-526-14A-98)
TIA/EIA	526-7	OFSTP-7 Measurement of Optical Power Loss of Installed Single-Mode Fiber Cable Plant (ANSI/TIA/EIA-526-7-98)

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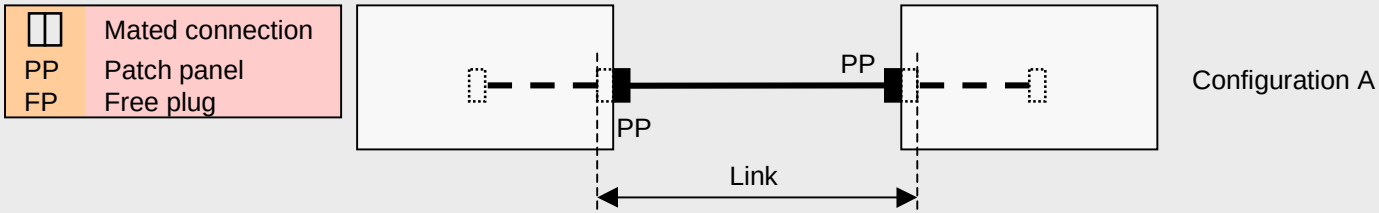
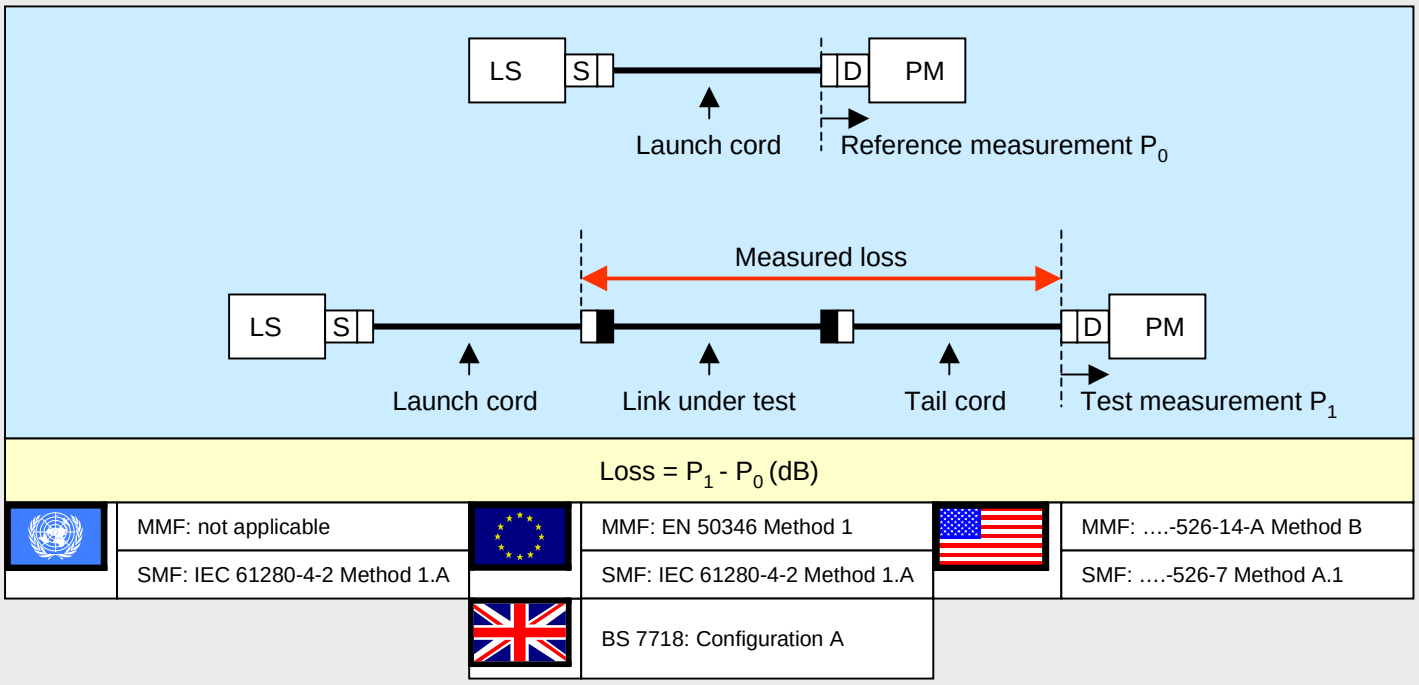
Configuration A Test Method





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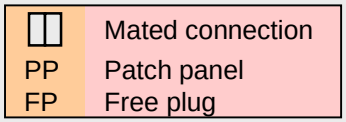
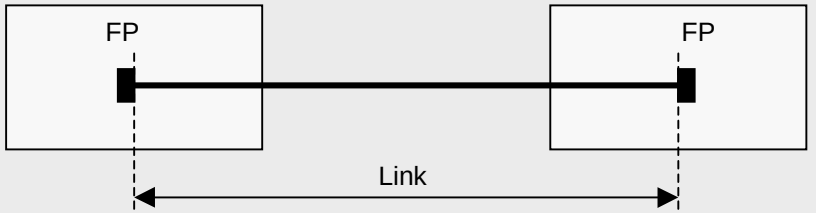
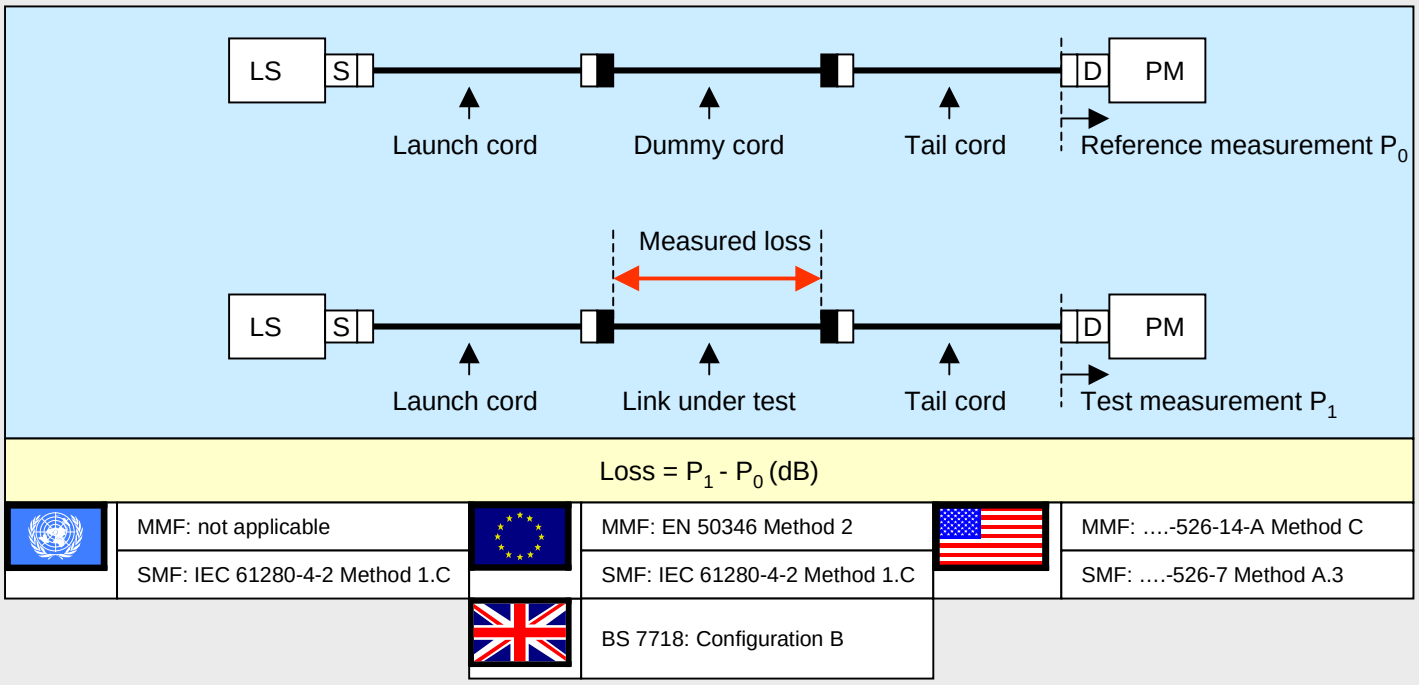
Configuration B Test Method





Configuration B



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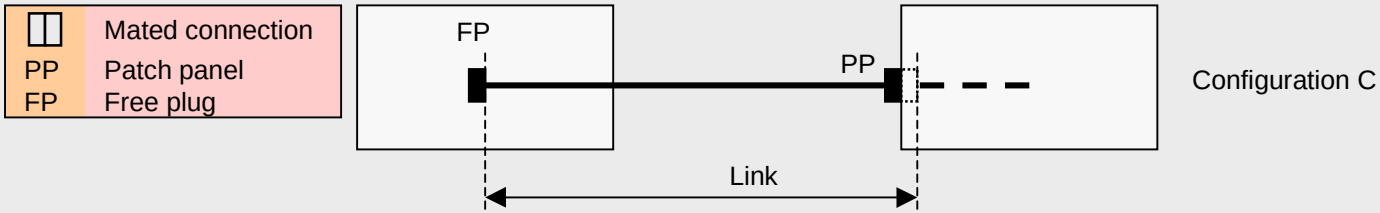
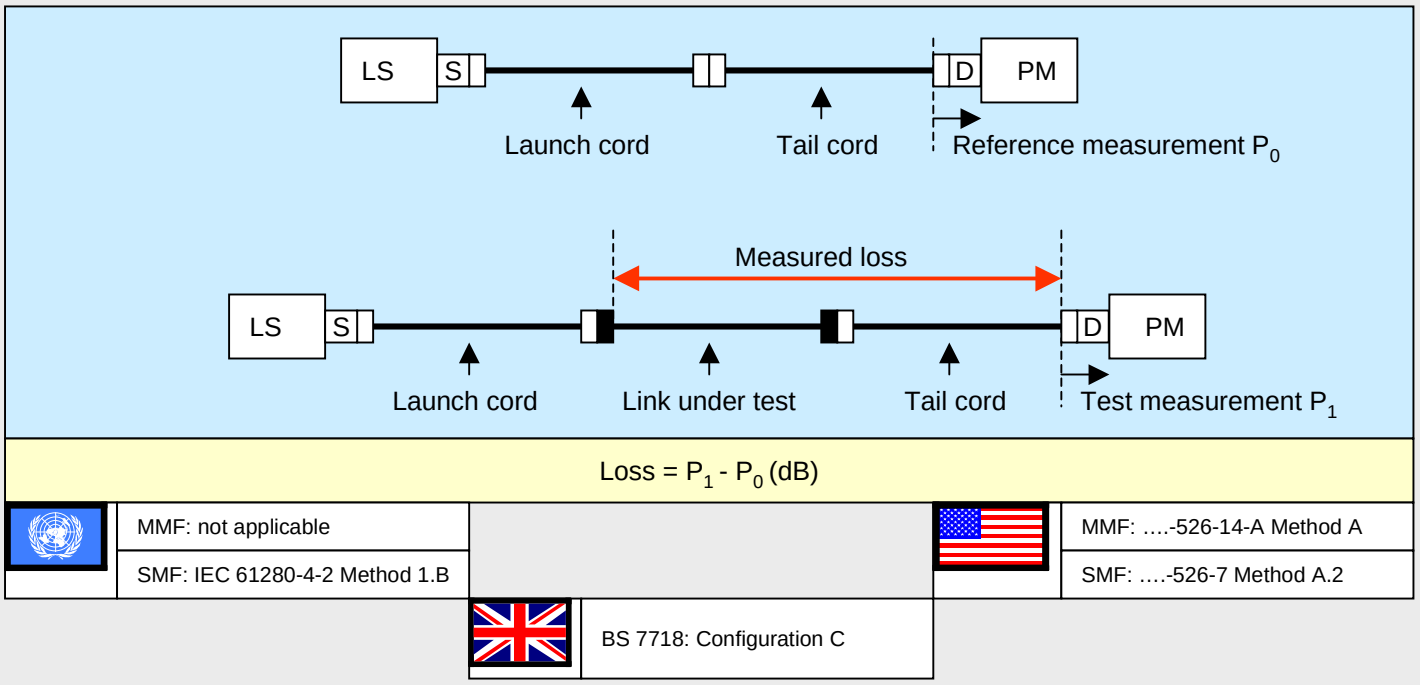
Configuration C Test Method





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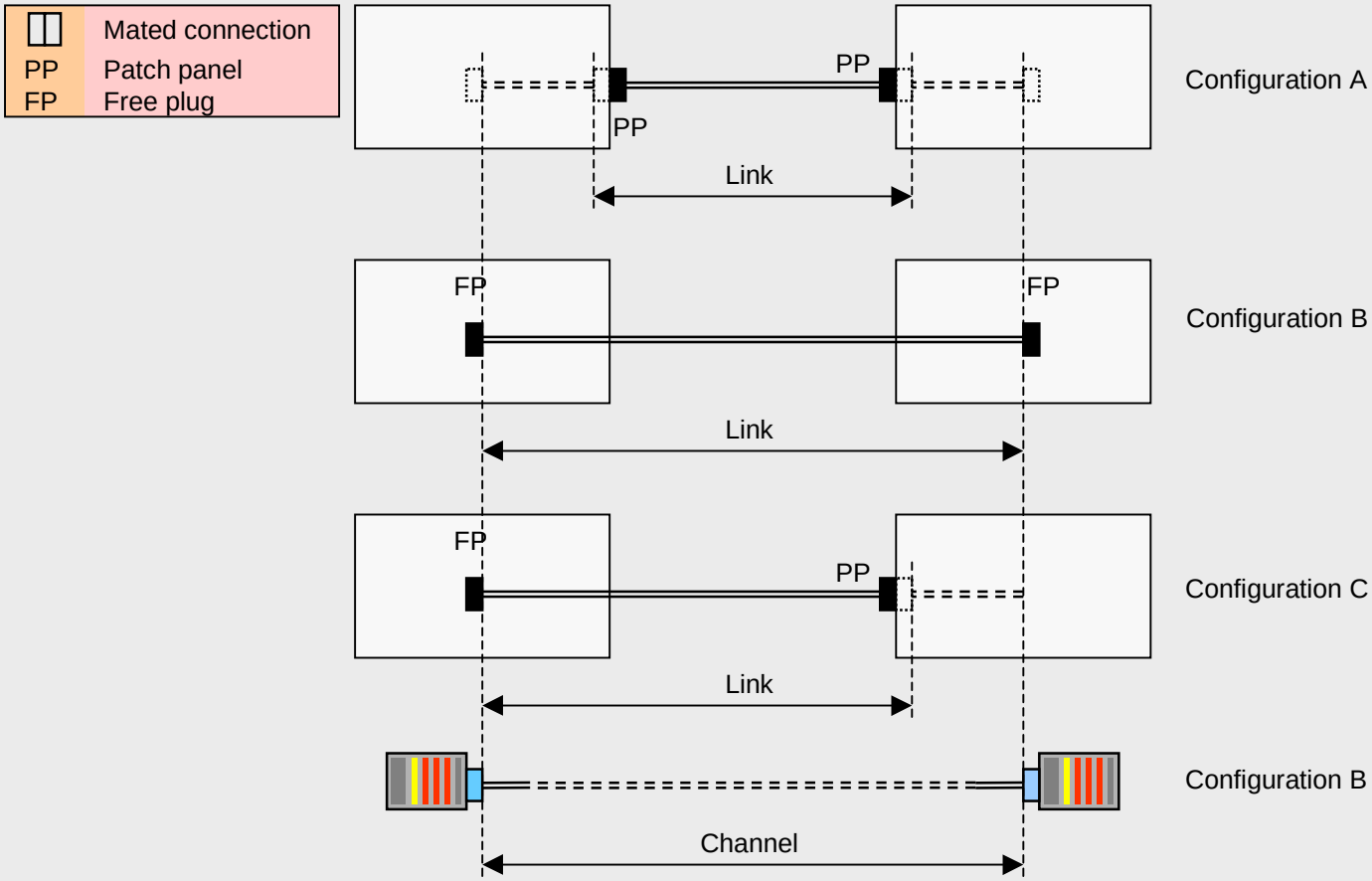
Duplex Cabling



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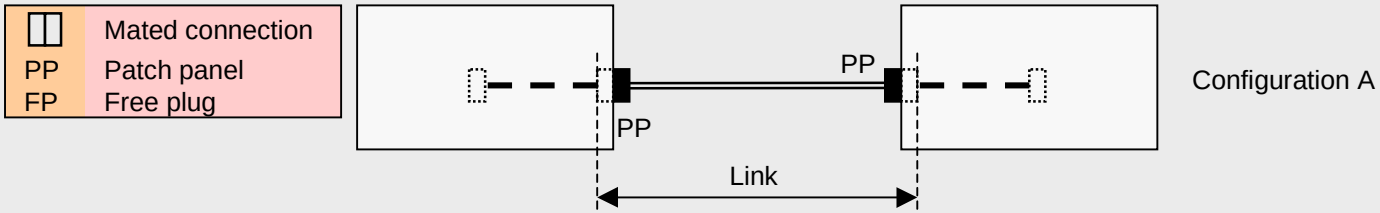
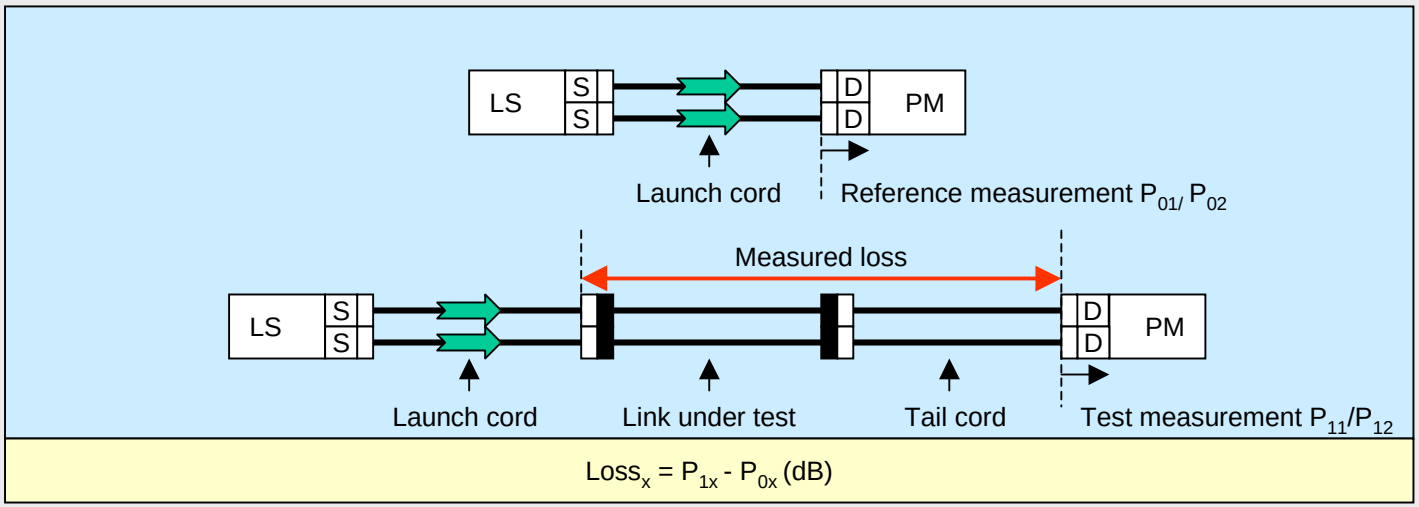
Link Configuration A - Grade 2





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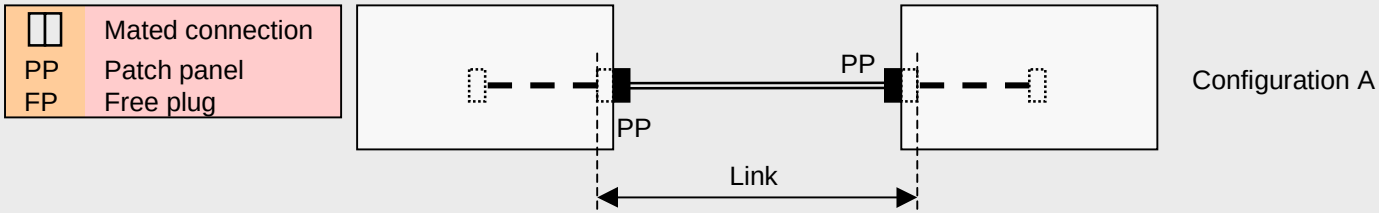
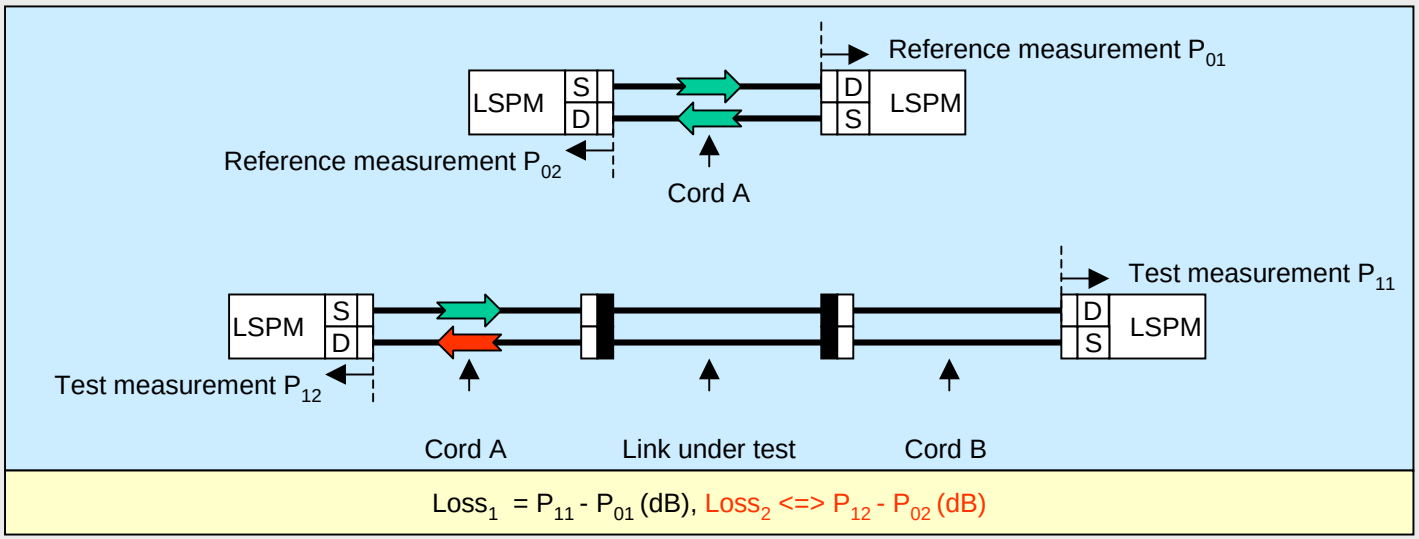
Link Configuration A - Grade 4,5





$Loss_1 = P_{11} - P_{01}$ (dB), $Loss_2 <=> P_{12} - P_{02}$ (dB)

Test measurement P_{12} will be influenced by removal of Cord A from RH LSPM
Unless LSPM guarantees that coupled power into Cord B is the same as Cord A, measurement error may occur

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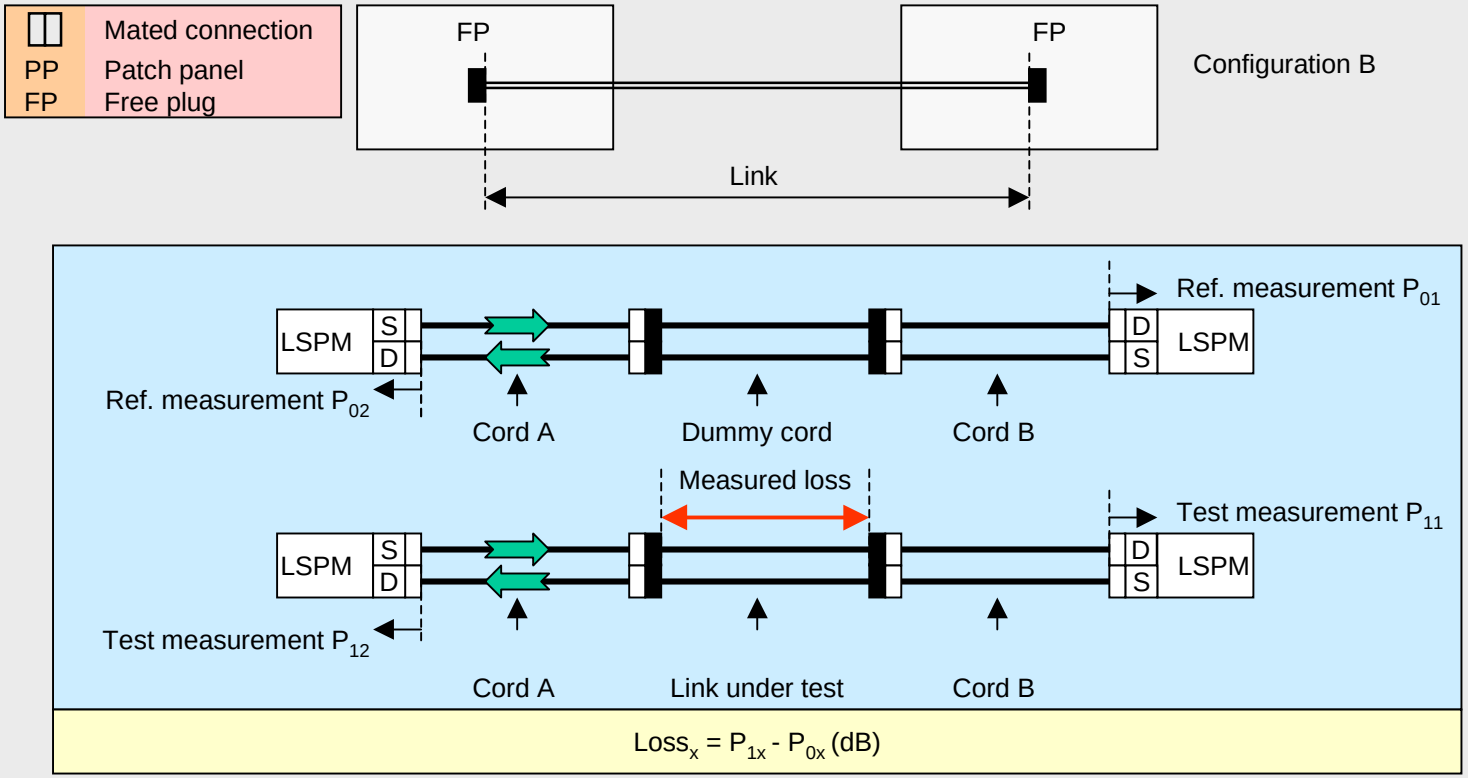
Channel Test - Grade 4,5



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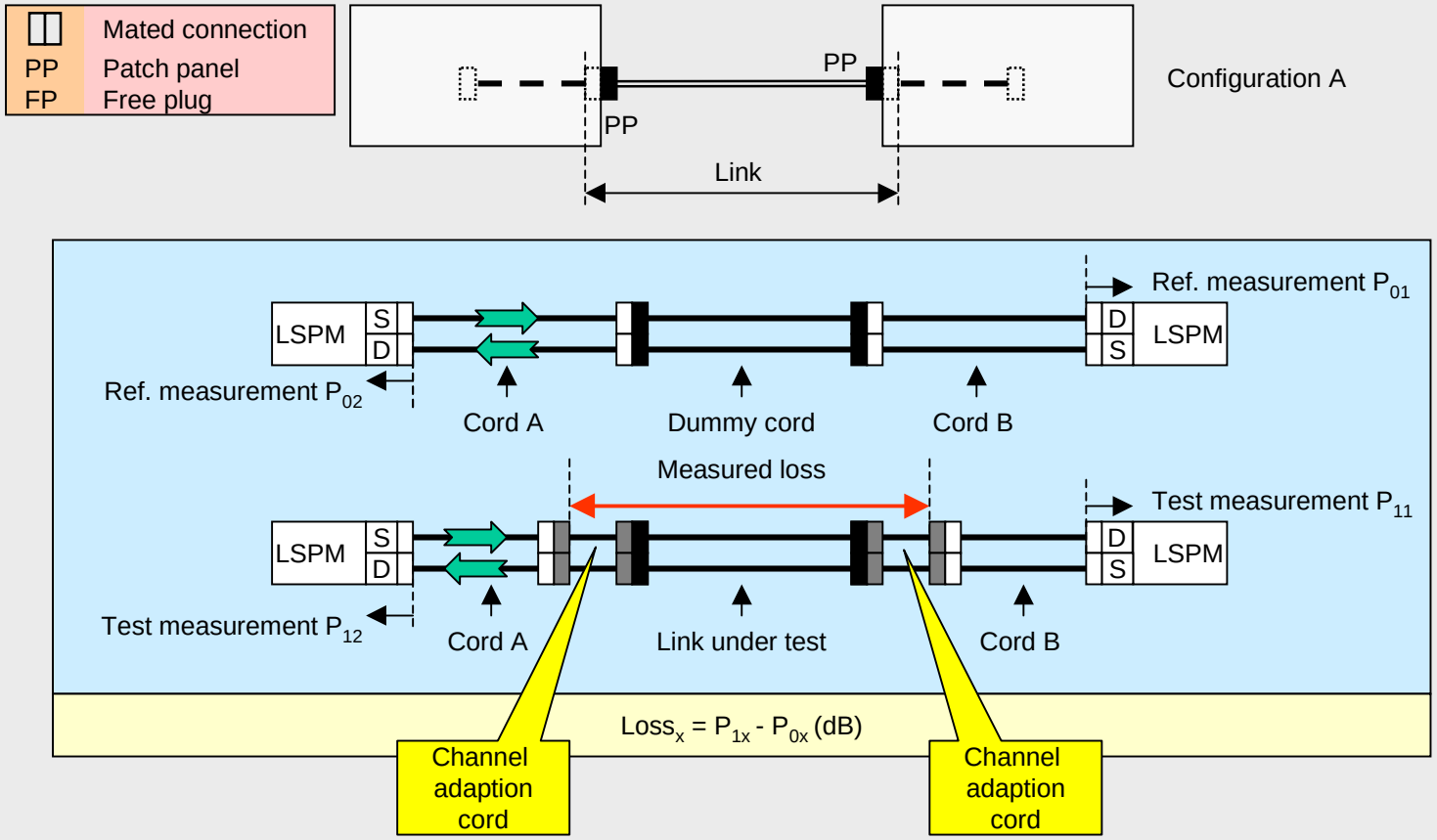
Link Configuration A - Grade 4,5



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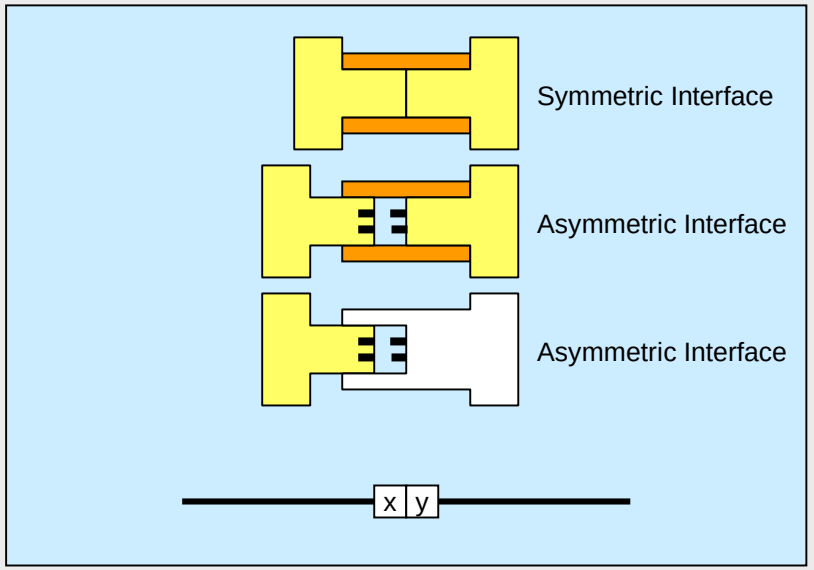
Symmetric and Asymmetric



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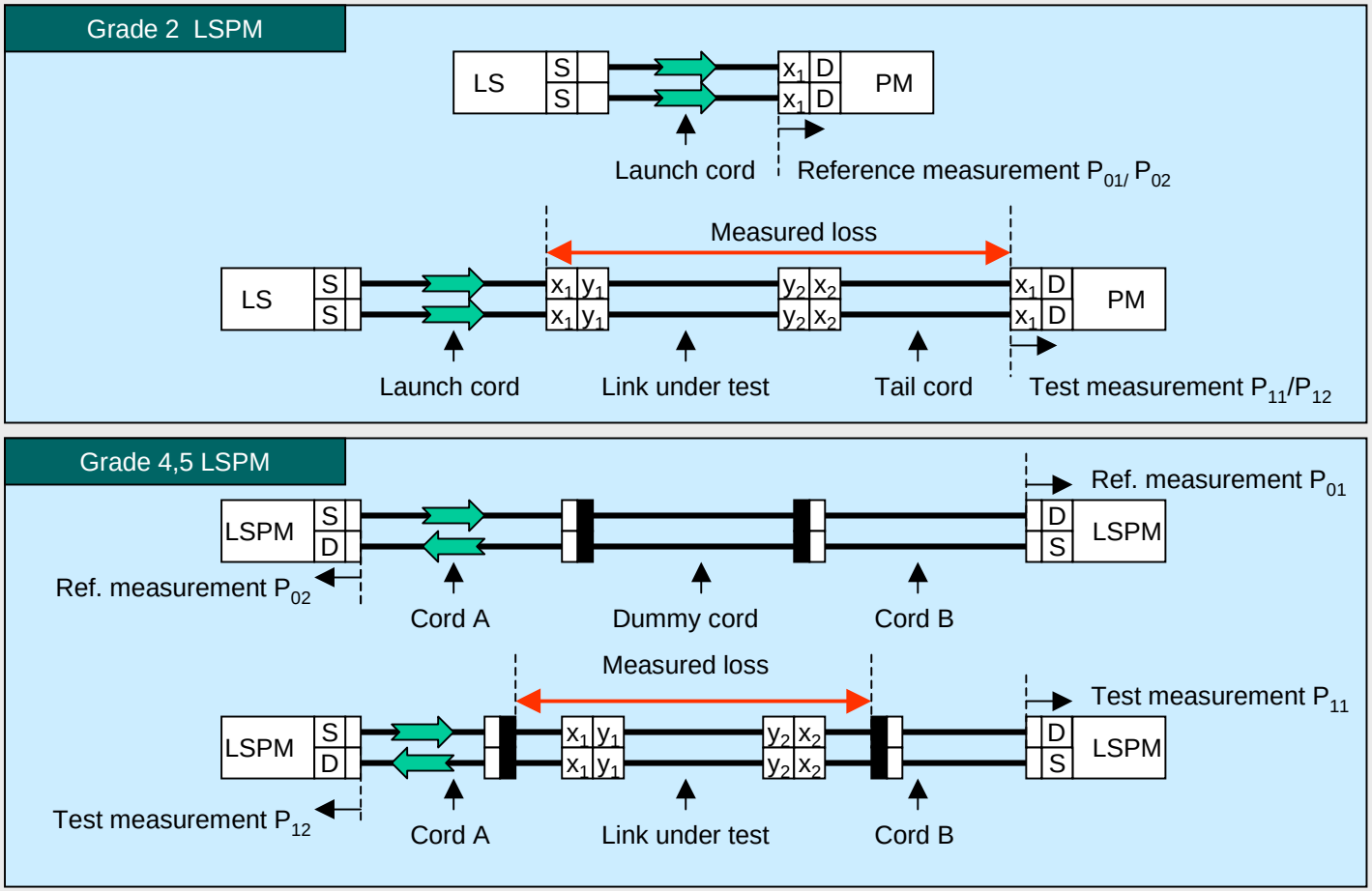
Configuration A Link Testing



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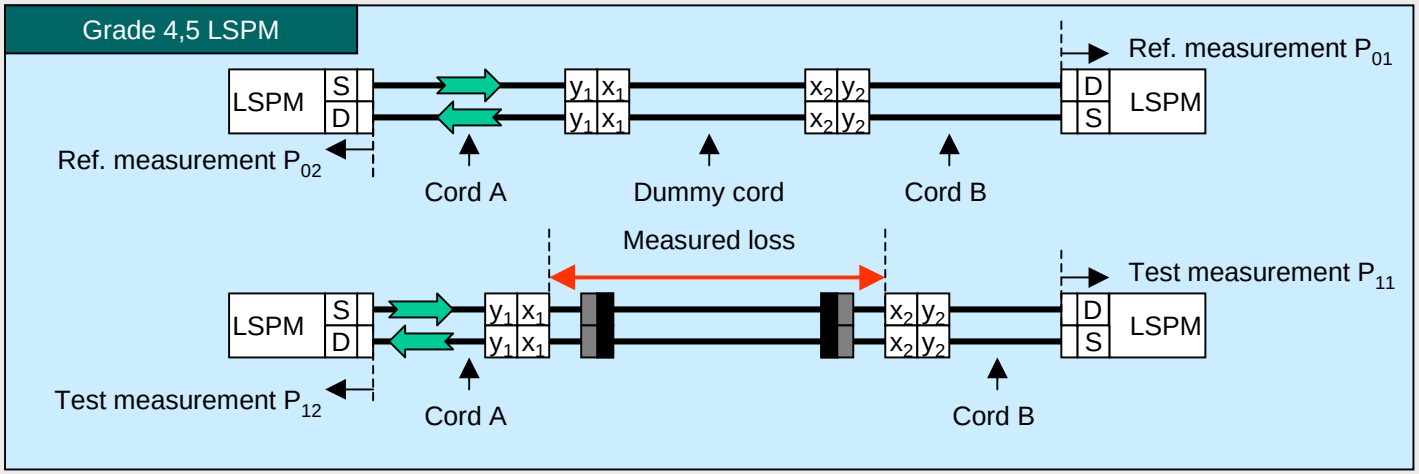
Channel Testing



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AGENDA

Break

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Quality Planning

AGENDA

- Introduction
- OF: Testing Philosophies
- Test Methods
- Break
- Quality Planning
  - Optical Power Budget/CIL
  - Optical Fibre Cabling Classes
  - Quality Plan
  - Pass/Fail Indicators
  - LASER LSPM Equipment
  - OTDR vs. LSPM
- Close

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AGENDA

Optical Power Budget/CIL

Application			Optical Fibre			
			50/125 (OM2)		62.5/125 (OM1)	
Mb/s	Network	λ	Max. length (m)	OPB max. (dB)	Max. length (m)	OPB max. (dB)
4	Token Ring	850 nm	1857[1]	8.0	2000	13.0
10	Ethernet		1514[1]	6.8	2000	12.5
16	Token Ring		1857[1]	8.0	2000	13.0
100	Ethernet	1300 nm	2000	6.0	2000	11.0
1000	Ethernet	850 nm	550	3.56	275	2.6
1000	Ethernet	1300 nm	550	2.35	550	2.35
10000	Ethernet	850 nm	82	1.80	33	1.60
10000	Ethernet	CWDM/850	300	1.96	300	1.96
			50/125 (OM3)			
10000	Ethernet	850 nm	300	2.59		

[1] Calculated values using 1.5dB of connecting hardware losses

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AGENDA

Optical Fibre Cabling Classes

Parameter	Optical fibre channel class		
	OF-300	OF-500	OF-2000
Attenuation	CLC/IS	CLC/IS	CLC/IS

Class		Maximum attenuation (dB)			
		Multimode		Singlemode	
		850nm	1300nm	1310nm	1550nm
	OF-300	2,55	1,95	1,80	1,80
	OF-500	3,25	2,25	2,00	2,00
	OF-2000	8,50	4,50	3,50	3,50

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Quality Plan

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:
  This may be a specific customer requirement but there is no need for bi-directional testing providing that the correct methods and cords are used
- 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 or ANSI/TIA/EIA-568B then these standards shall be consulted to determine their requirements;
- 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.

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AGENDA

Pass/Fail Indicators

Test equipment that
not only
measures
but also
ADJUDICATES

Application support based upon:
- length (requiring the modal bandwidth of the optical fibre to be input);
- measured link/channel loss.

Cabling performance against calculation of optical loss budget based upon:
- number and type of joints
- length;
- measured link/channel loss.

PASS/FAIL INDICATORS ARE VERY SUSCEPTIBLE
TO SHORT LENGTH SYNDROME
(measurement error)

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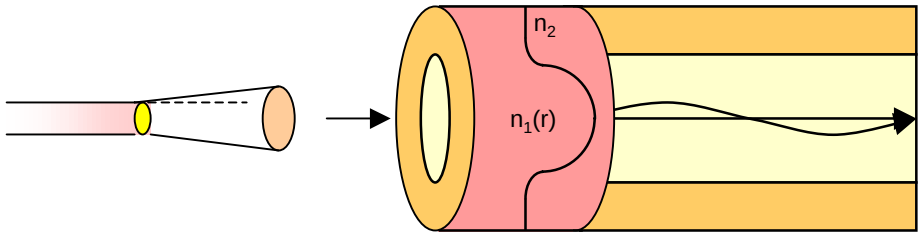
LASER LSPM Equipment

There is an argument to suggest that MMF cabling to support LASER-based applications should be tested with LASER sources



Reference measurement does not contain all modes.

Test measurement reads LOW.

Test results can vary with test lead handling.

Unless explicitly allowed and documented such equipment should not be used

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OTDR vs. LSPM

SHORT LENGTH SYNDROME
calls LSPM measurements into question

(unless measurement error is “allowed for” in adjudication)

OTDRs can be used to assess and measure individual components
(subject to appropriate techniques)

COMPONENT UP VERIFICATION MAY BECOME MORE COMMON

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AGENDA

Conclusions

READ THE CABLING SPECIFICATION

KNOW YOUR LIMITS
- which standard?
- which issue?

UNDERSTAND THE MARGINS
- undertake a channel design review
- make sure the client understands it

PLAN FOR FAILURE
- can “FAIL”s be expected?
- under which conditions?
- what happens next?
- agree process with client

TEST CORDS - TEST CORDS
TEST CORDS - TEST CORDS

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Testing Multimode Optical Fibre Infrastructures

Prepared and delivered for

FIA
The Fibreoptic Industry Association

Bisham Abbey
20th March 2002

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