

Testing Optical Fibre Infrastructures

Prepared and delivered for



Bisham Abbey
20th March 2002

AGENDA

Introduction

OF: Testing Philosophies
Test Methods

Break

Quality Planning

Close

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Member: Project Team: SOHO**



BSI

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



CENELEC

50173 Ed.2 (2002)

Convenor: TC215 WG1: IT Cabling

**Fibreoptic Industry Association
Standards Director
Technical Director**

FIA

The Fibreoptic Industry Association

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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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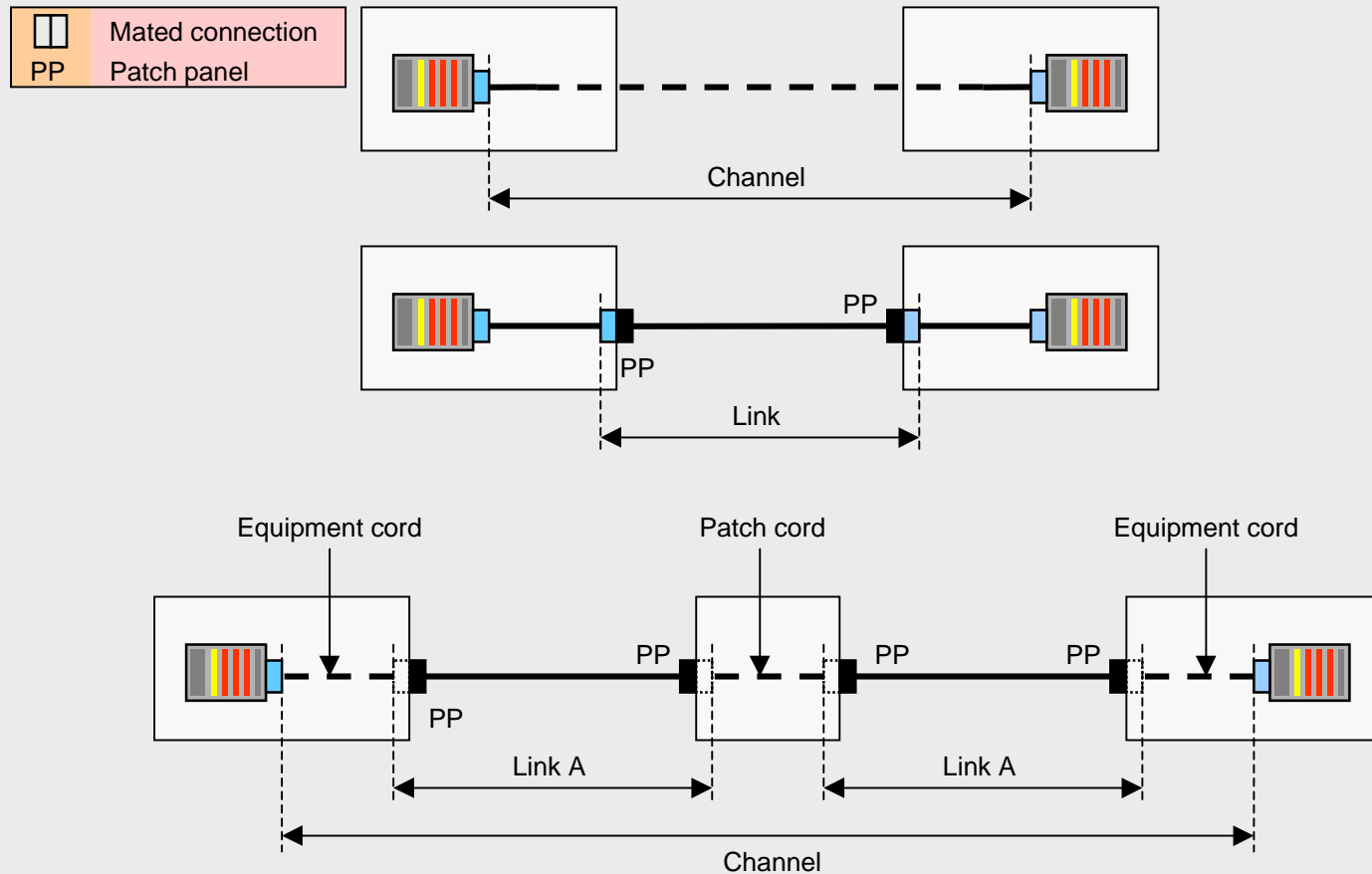
OF - Testing Philosophies

- 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

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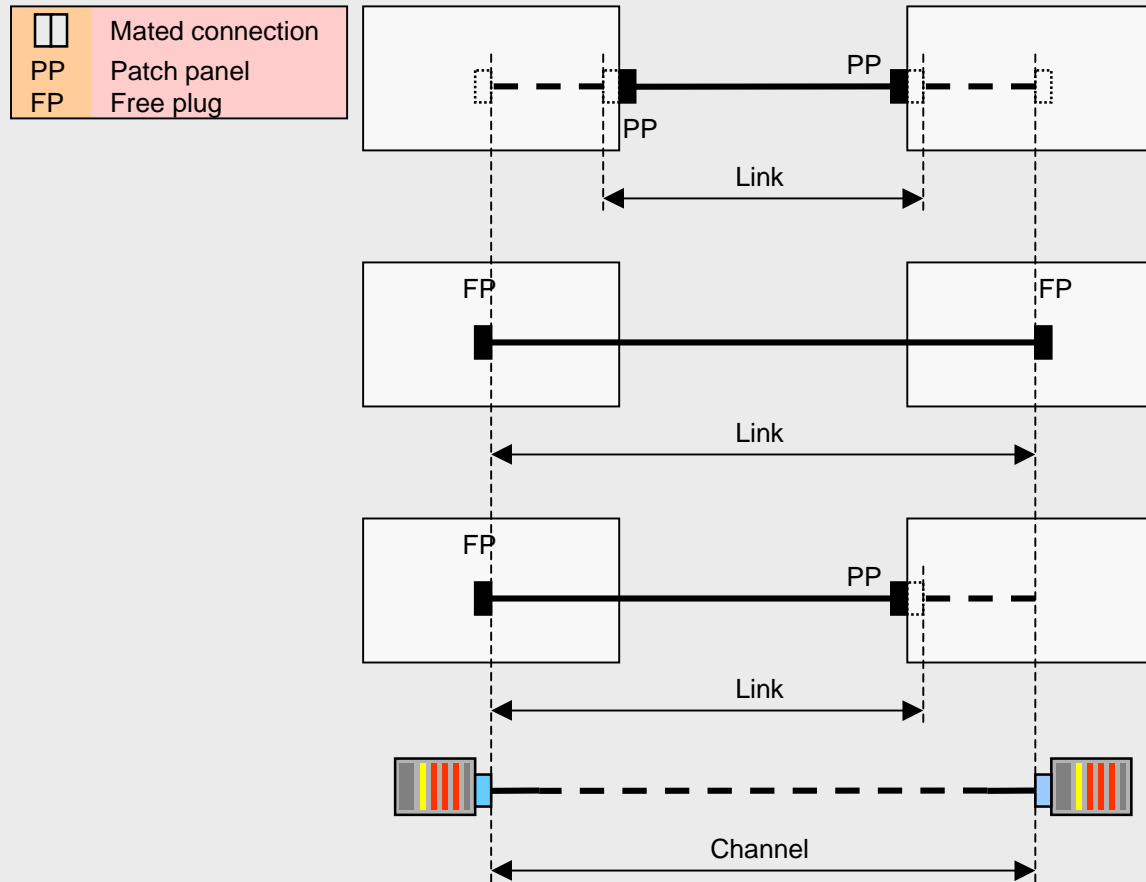
Reference Points



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General Implementations



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The Alternative Approaches

| | Optical power budget (dB) | | | |
|---------------------------|--|------------|------------|-----|
| | MMF | | SMF | |
| | 850nm | 1300nm | 1310nm | |
| "Channel" approach | APPLICATION | | | |
| | 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 | Maximum values x dB y dB z dB | | | |
| | Actual value Link < (x + y + z) dB | | | |
| "Component loss" approach | Maximum values x dB y dB z dB | | | |
| | Actual values < x dB < y dB < z dB | | | |



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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 |

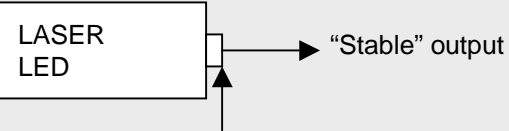
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Light Source - Power Meters

LSPM = Light Source - Power Meter

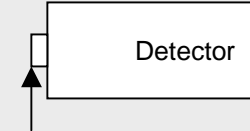
Light Source



Connector independent of cabling under test

| Multimode | |
|----------------|----------------------|
| λ (nm) | $\Delta\lambda$ (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 | | Component- based |
| Grade 2 • simplex • dual wavelength | | Component- based |
| Grade 3 • simplex • auto dual wavelength | | System-based |
| Grade 4 • duplex • dual wavelength | | System-based |
| Grade 5 • duplex • auto dual wavelength | | System-based |

Includes single location Grade 3



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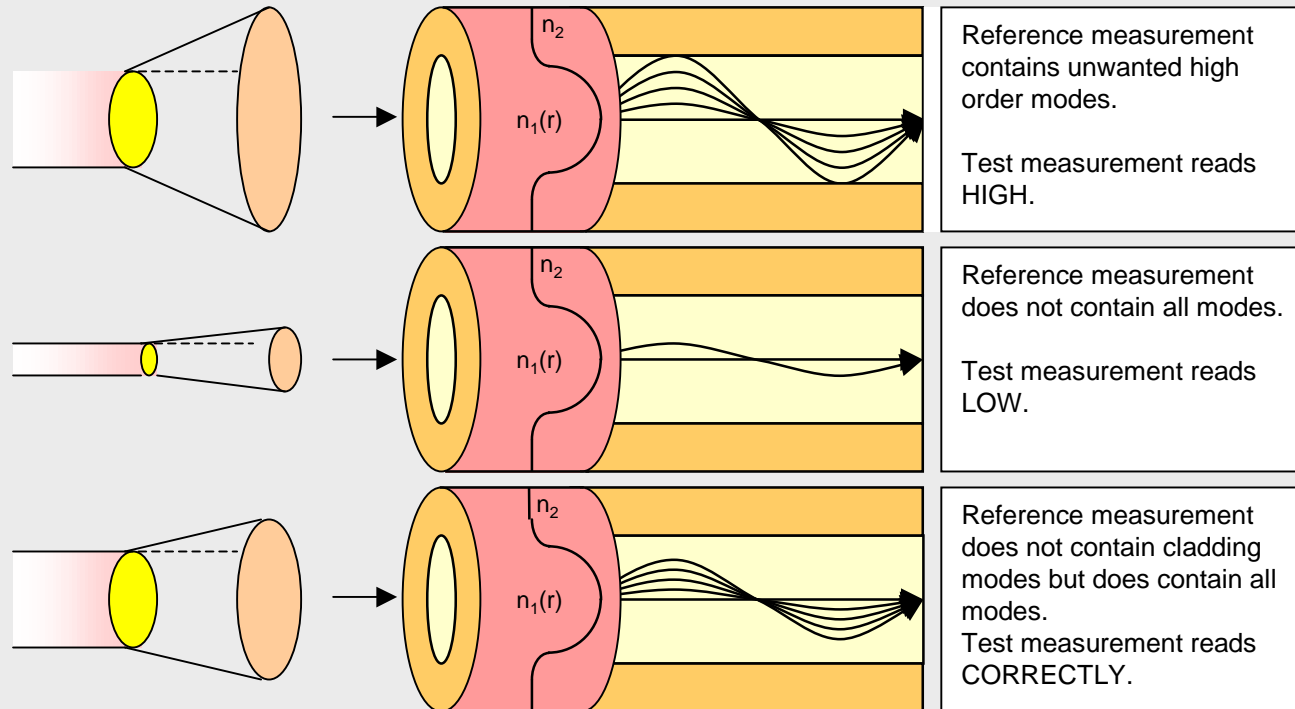
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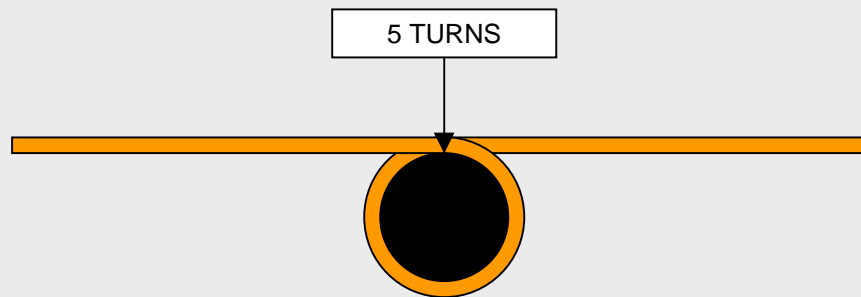
Test Cord Launch Conditions



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MMF Mandrel Wrap



| | MMF: not applicable | | MMF: EN 50346 6MP | | | | MMF: ANSI/TIA/EIA B.1 | | |
|--|---------------------|--|-------------------|-------|------------------|--|-----------------------|-------|------------------|
| | | | | | Mandrel Diameter | | | | Mandrel Diameter |
| | | | 50/125 | Cable | 18 | | 50/125 | Cable | 25 |
| | | | 50/125 | SCOF | 15 | | 50/125 | SCOF | 22 |
| | | | 62.5/125 | Cable | 20 | | 62.5/125 | Cable | 20 |
| | | | 62.5/125 | SCOF | 17 | | 62.5/125 | SCOF | 17 |



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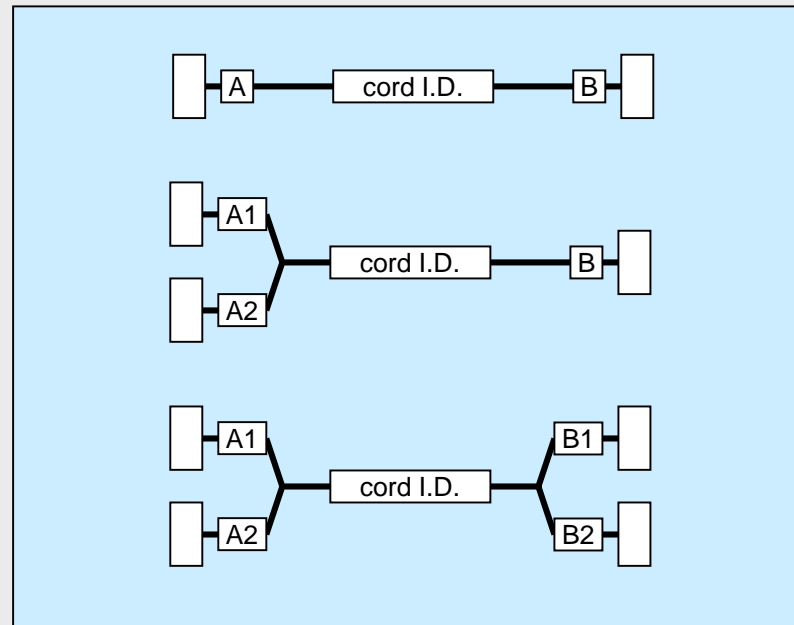
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The Importance of Cords



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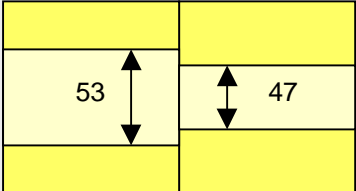
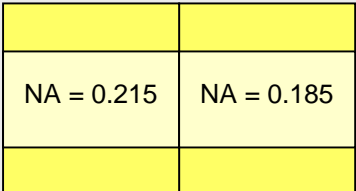
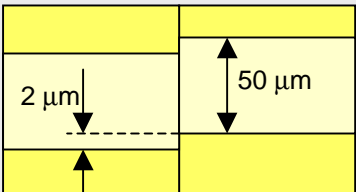
LSPM Measurement Accuracy

| | | |
|------|--|---|
| CORE | | $Loss = -10 \log_{10} \left[\left(\frac{d_2}{d_1} \right)^2 \right]$ <p>dB from large core to small core (0 dB from small to large)</p> |
| CORE | | $Loss = -10 \log_{10} \left[\left(\frac{NA_2}{NA_1} \right)^2 \right]$ <p>dB from large NA to small NA (0 dB from small to large)</p> |
| CORE | | $Loss = -10 \log_{10} \left[\frac{1}{90} \tan^{-1} \left(\frac{de}{x} \right) - \frac{2xe}{\pi d} \right]$ <p>dB in both directions</p> $e = \left[1 - \left(\frac{x}{d} \right)^2 \right]^{0.5}$ |

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LSPM Measurement Accuracy

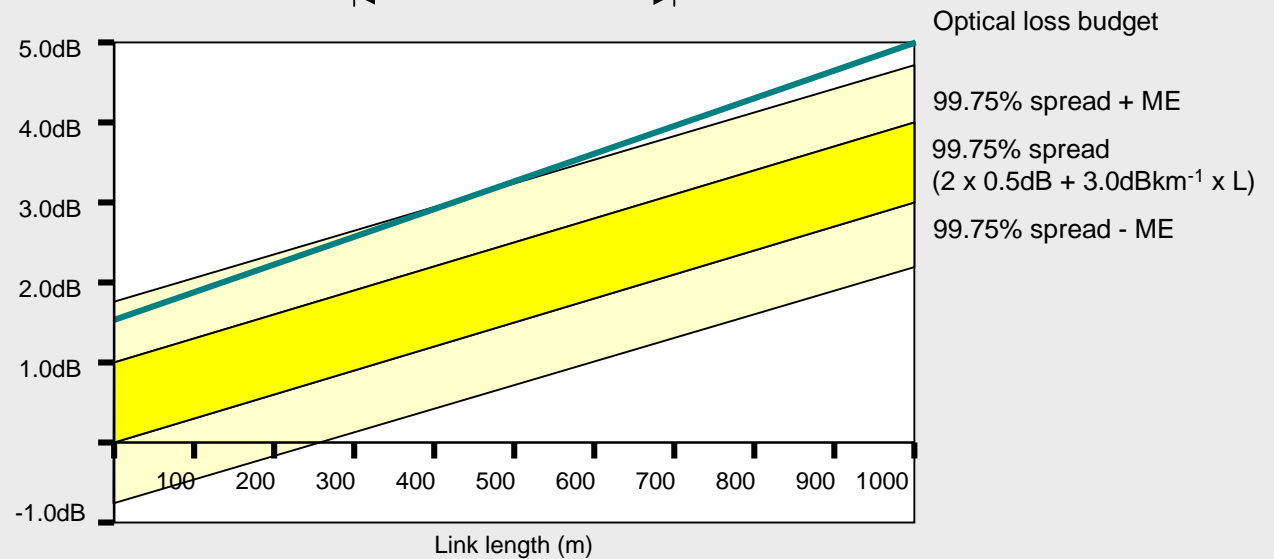
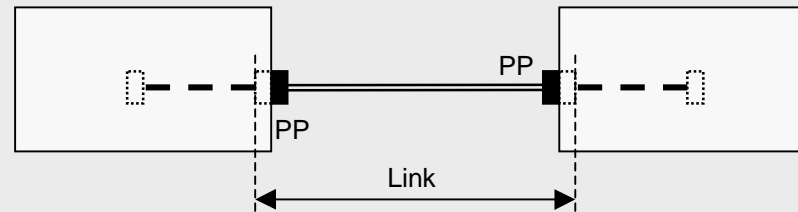
| | | | | |
|------|---|--|------------|--|
| CORE |  | $Loss = -10 \log_{10} \left[\left(\frac{47}{53} \right)^2 \right]$ | = -1.04 dB | Applied statistics and real manufacturing tolerances suggest combined value < -0.35 dB per joint |
| CORE |  | $Loss = -10 \log_{10} \left[\left(\frac{0.185}{0.215} \right)^2 \right]$ | = -1.30 dB | |
| CORE |  | <i>Loss</i> | = -0.47 dB | |

Measurement accuracy of LSPM systems = 0.7 dB plus other mismatches

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Measurement Error



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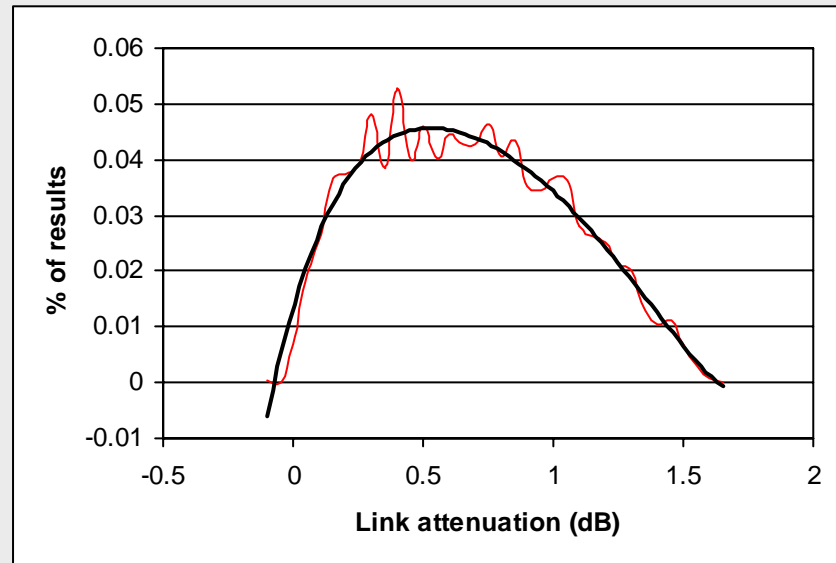
Test Methods

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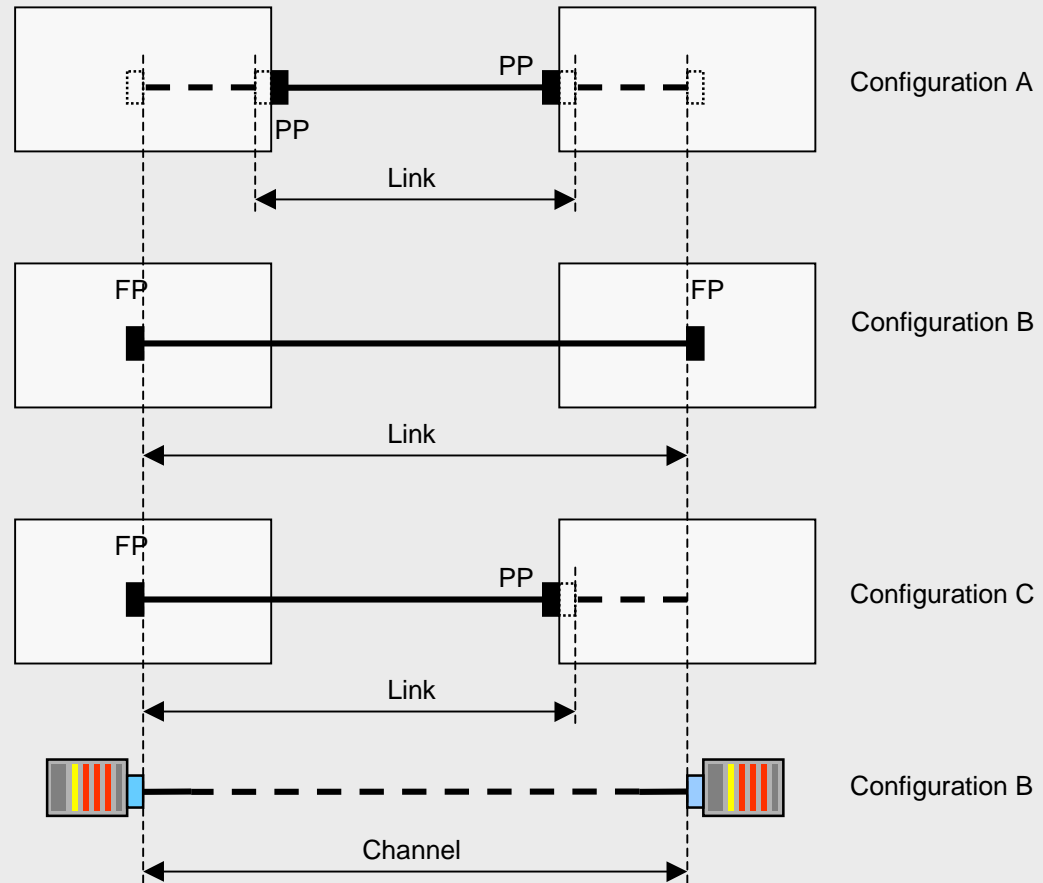
Typical Results



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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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LSPM Test Methods

Configuration A

Configuration B

Configuration C

Duplex Cabling

Link Configuration A

Equipment Grade 2

Equipment Grades 4,5

FIA

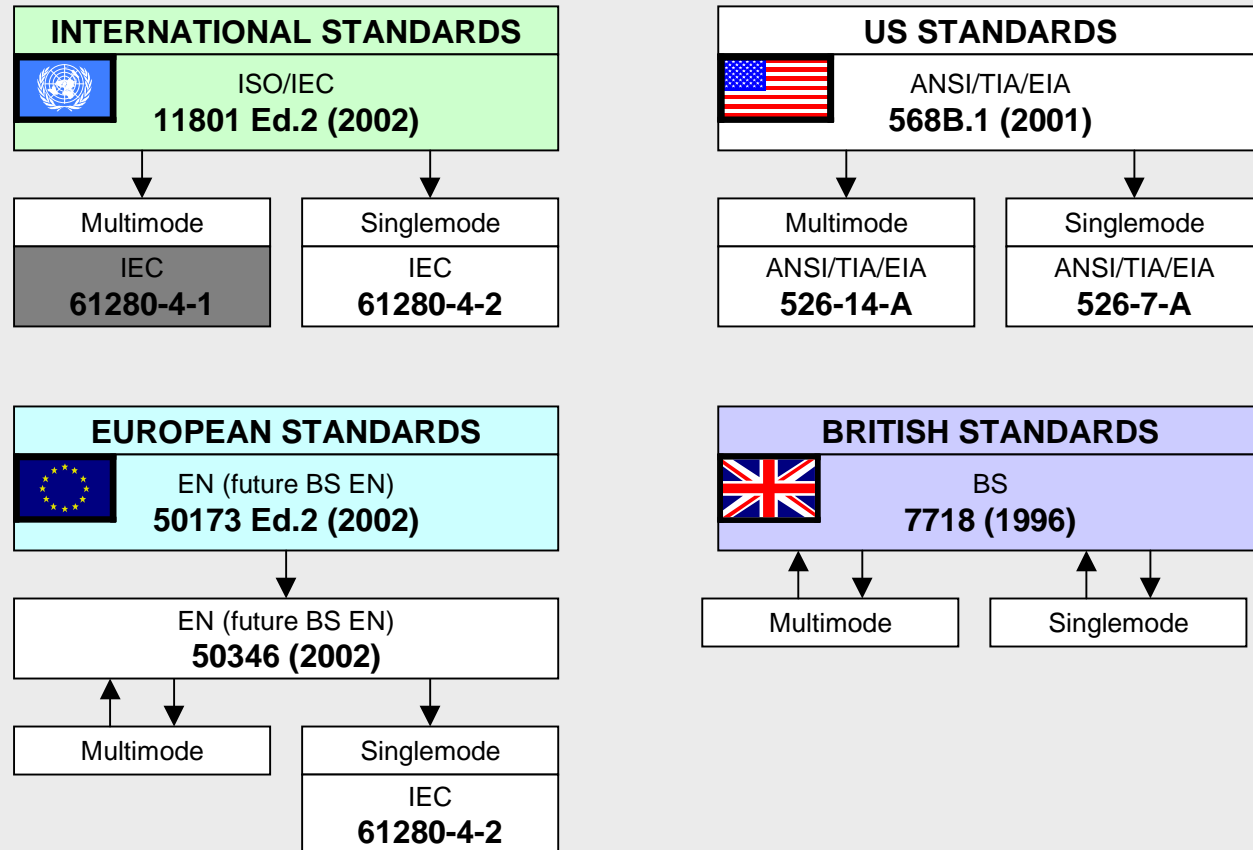
The Fibreoptic Industry Association



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LSPM Test Methods



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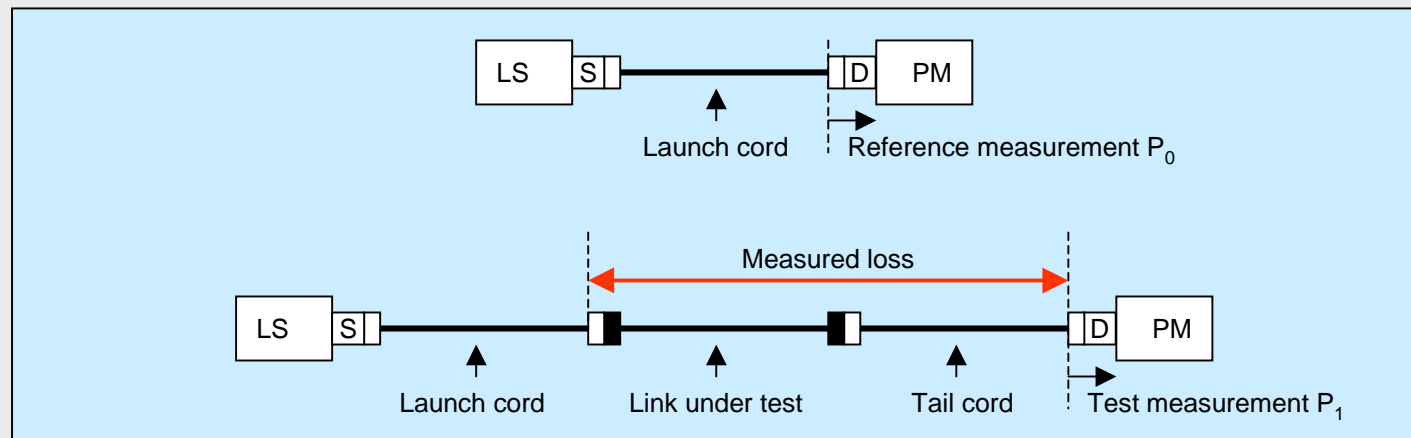
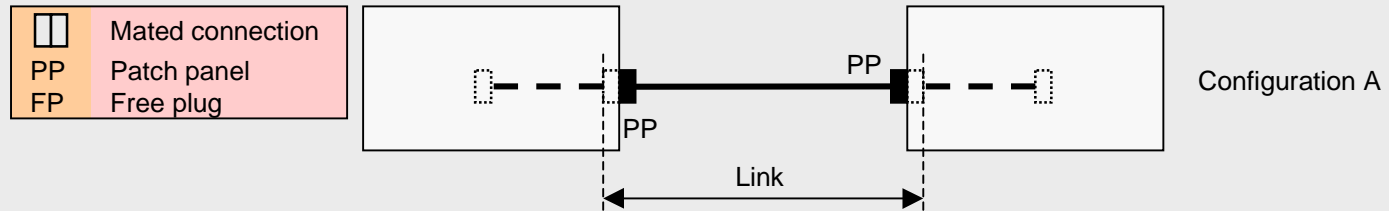
LSPM Test Method Glossary

| 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



Loss = $P_1 - P_0$ (dB)

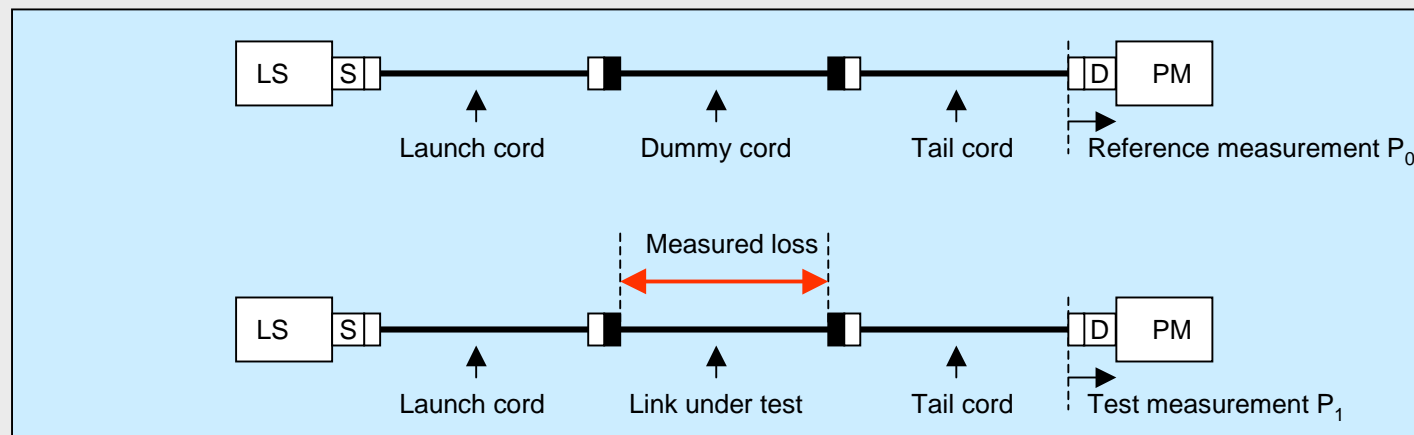
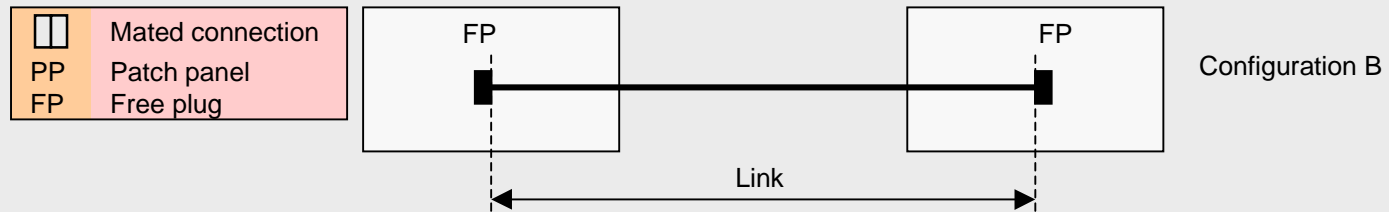
| | | | | | |
|---|-------------------------------|---|-------------------------------|---|-----------------------------|
|  | MMF: not applicable |  | MMF: EN 50346 Method 1 |  | MMF:-526-14-A Method B |
| | SMF: IEC 61280-4-2 Method 1.A | | SMF: IEC 61280-4-2 Method 1.A | | SMF:-526-7 Method A.1 |
| | |  | BS 7718: Configuration A | | |







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Configuration B Test Method



Loss = $P_1 - P_0$ (dB)

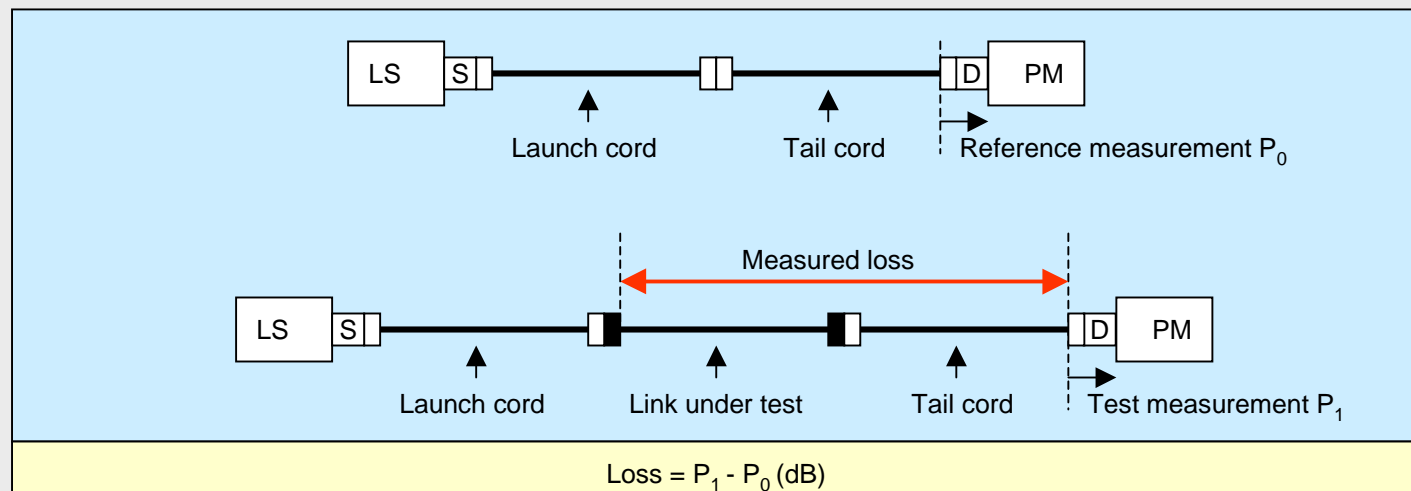
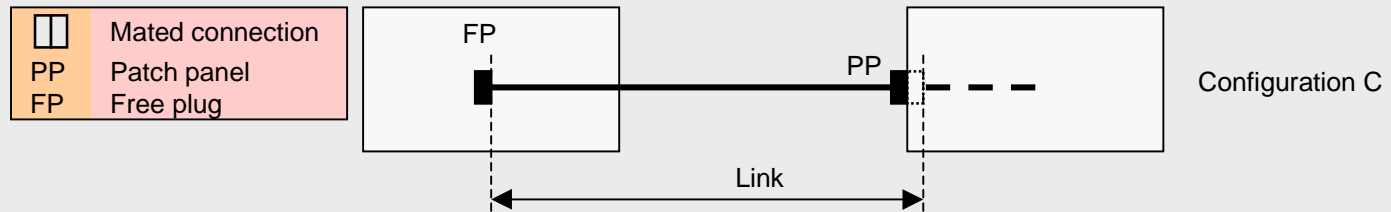
| | | | | | |
|---|-------------------------------|---|-------------------------------|---|-----------------------------|
|  | MMF: not applicable |  | MMF: EN 50346 Method 2 |  | MMF:-526-14-A Method C |
| | SMF: IEC 61280-4-2 Method 1.C | | SMF: IEC 61280-4-2 Method 1.C | | SMF:-526-7 Method A.3 |
| | |  | BS 7718: Configuration B | | |



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Configuration C Test Method



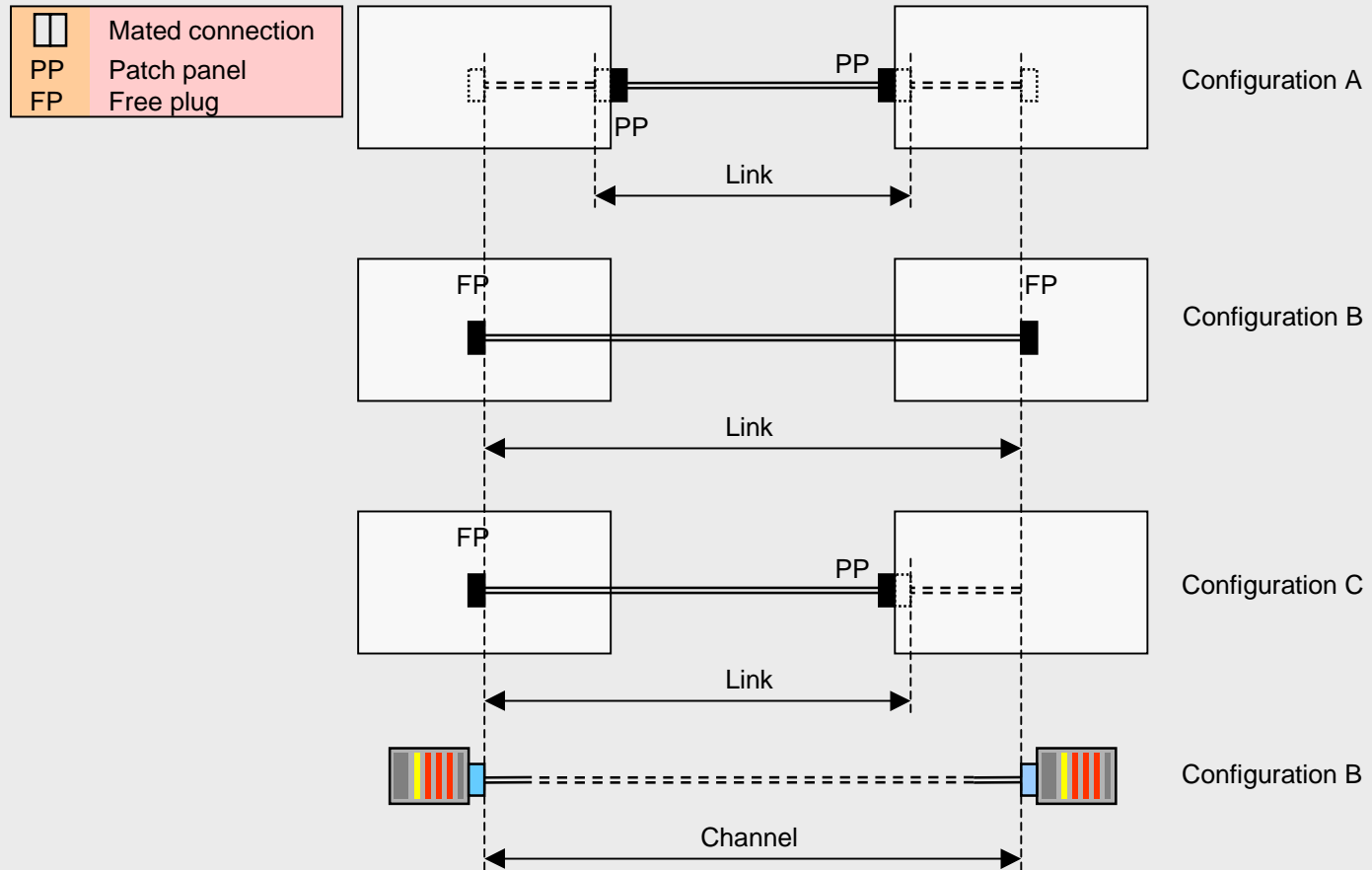
| | | | |
|--|-------------------------------|--|-----------------------------|
| | MMF: not applicable | | MMF:-526-14-A Method A |
| | SMF: IEC 61280-4-2 Method 1.B | | SMF:-526-7 Method A.2 |
| | BS 7718: Configuration C | | |



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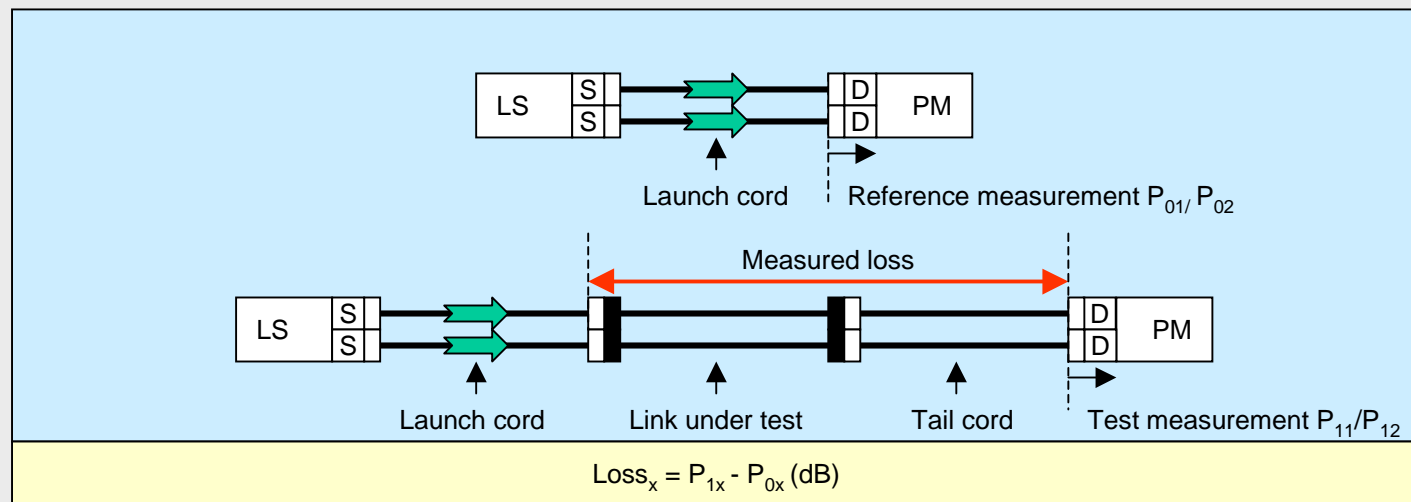
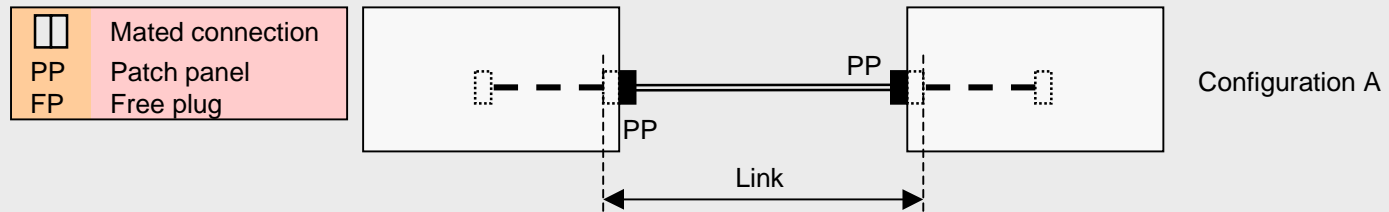
Duplex Cabling



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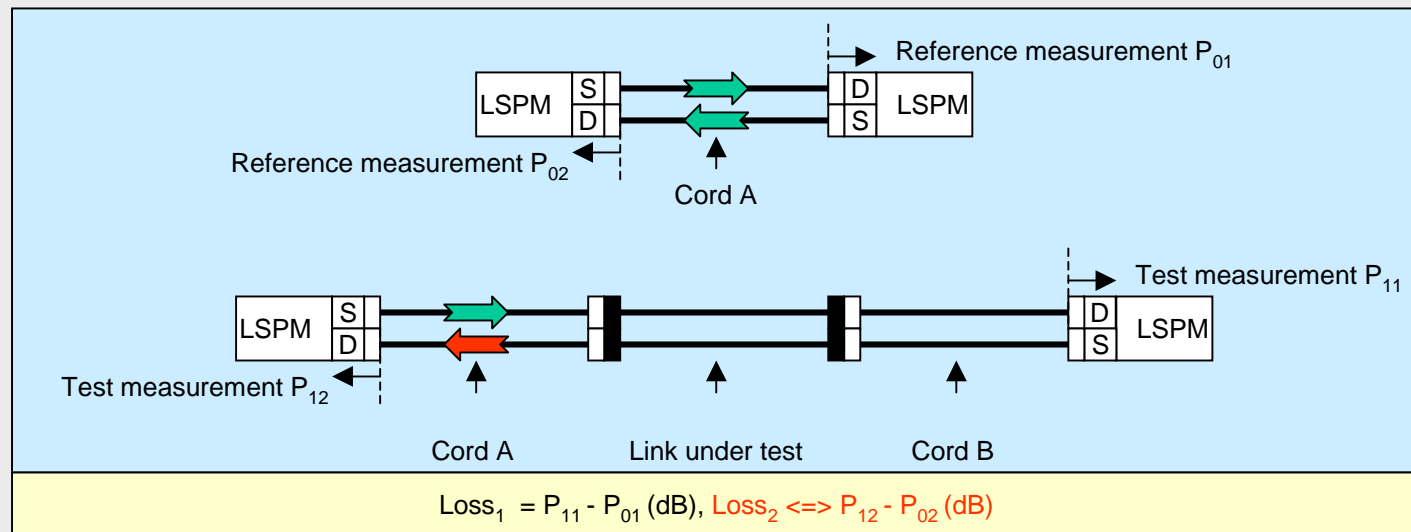
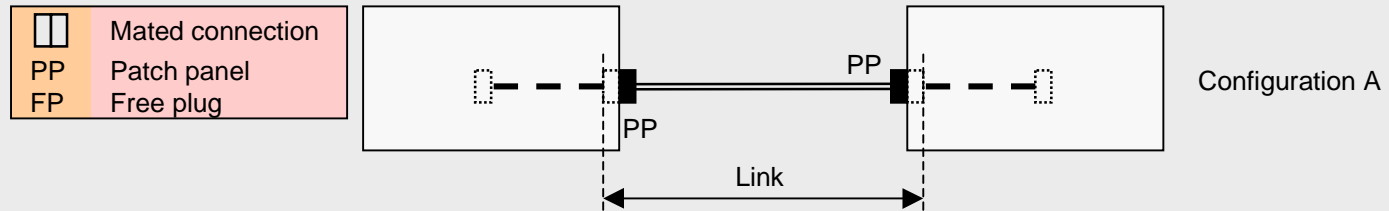
Link Configuration A - Grade 2



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Link Configuration A - Grade 4,5

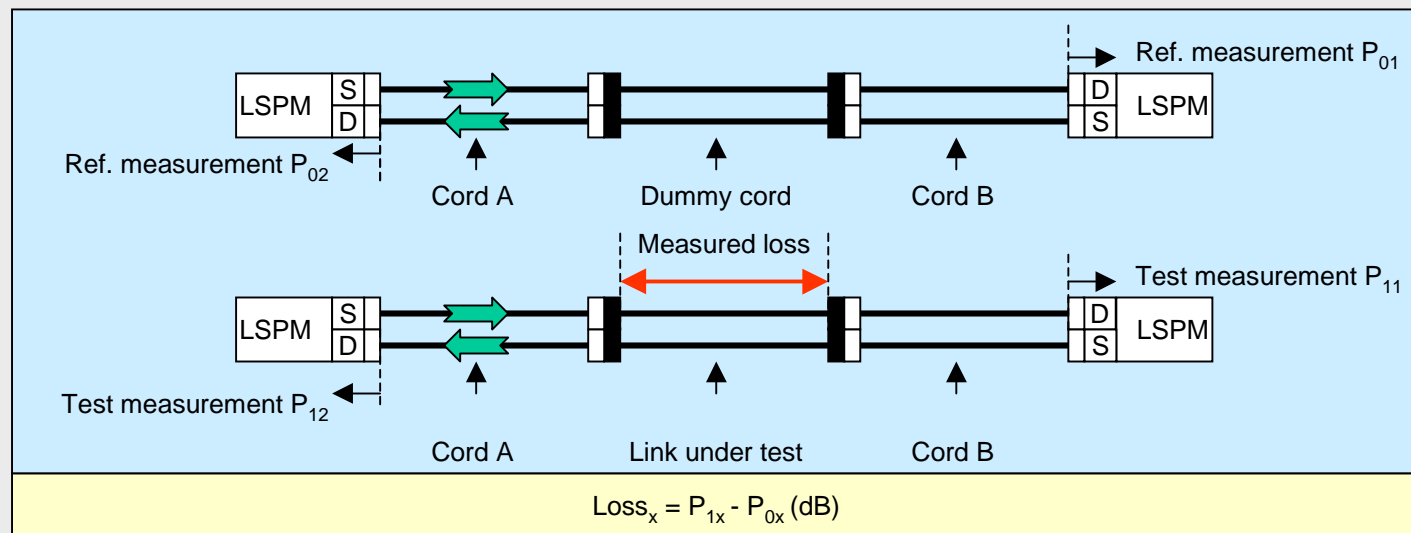
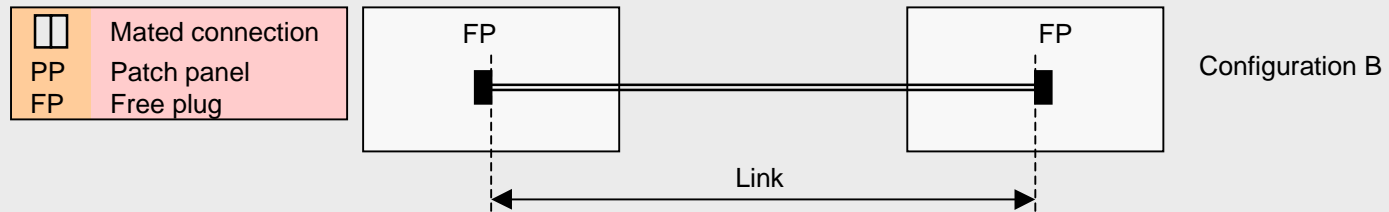


Test measurement P_{12} will be influenced by removal of Cord A from RH LSPM
Unless LSPM guarantees that coupled power into Cord B is the same as Cord A, measurement error may occur

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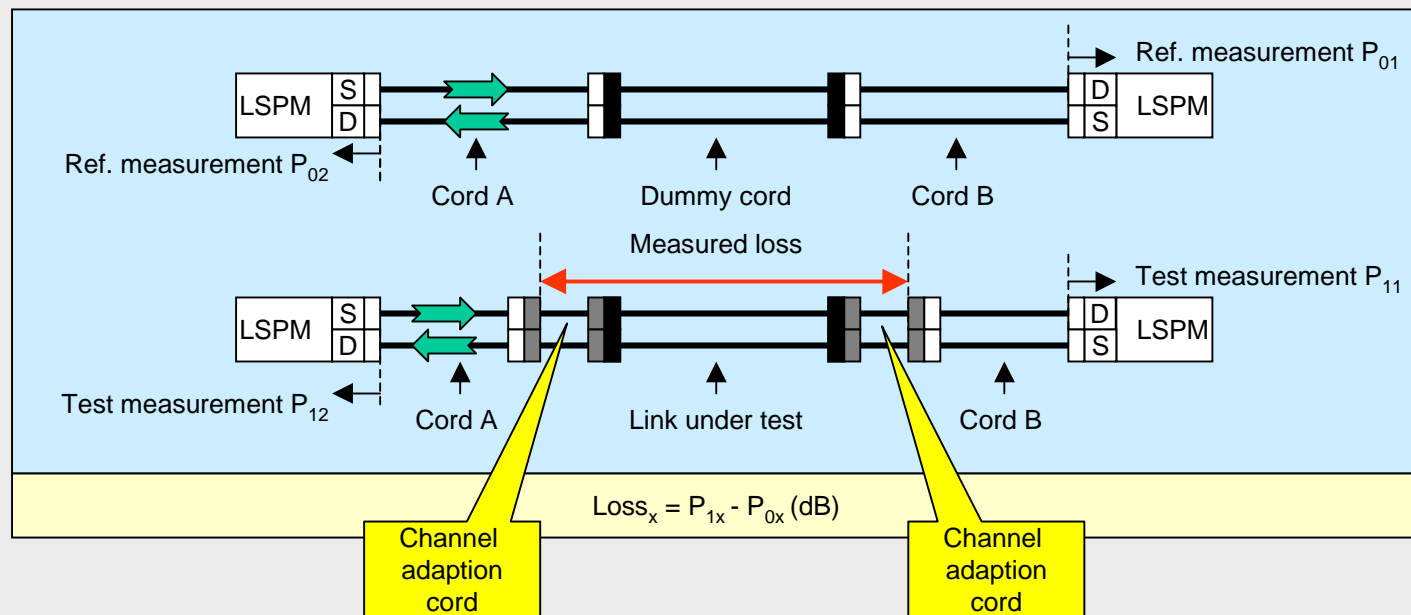
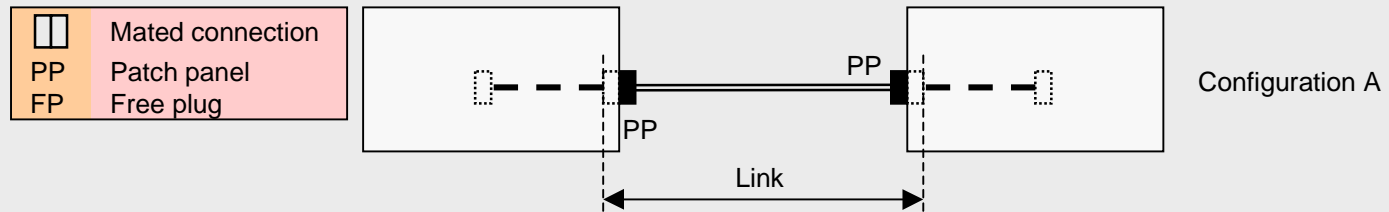
Channel Test - Grade 4,5



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Link Configuration A - Grade 4,5



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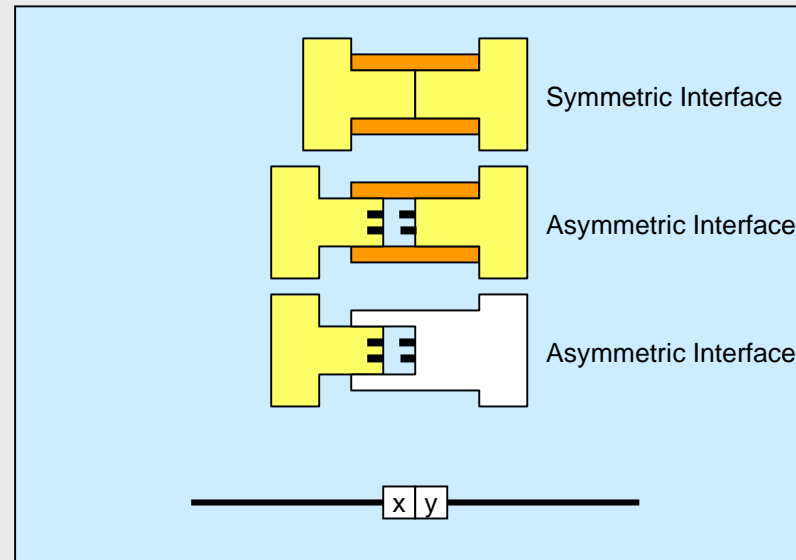
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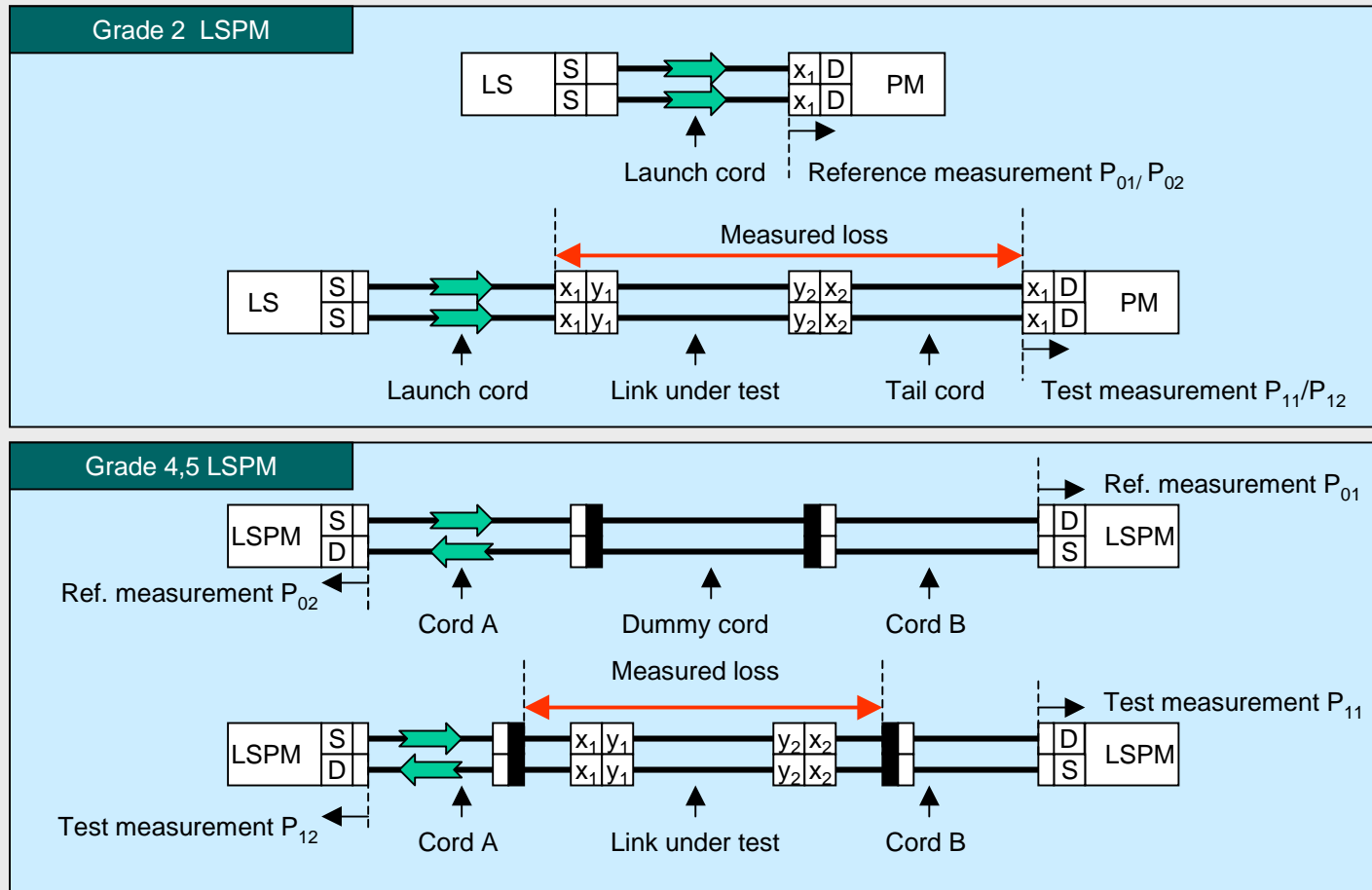
Symmetric and Asymmetric



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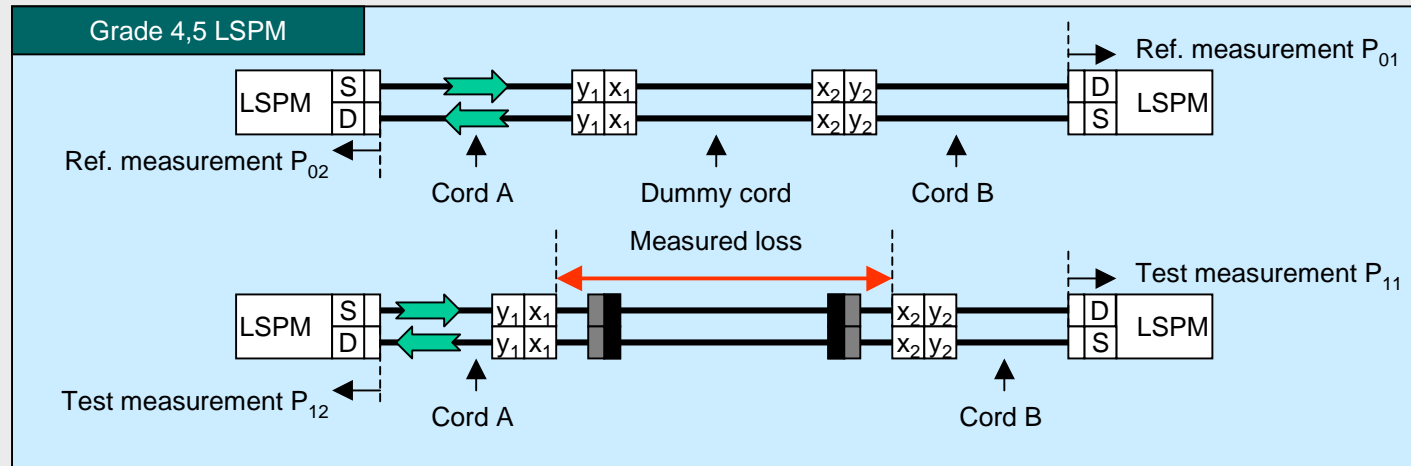
Configuration A Link Testing



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Channel Testing



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Optical Power Budget/CIL
Optical Fibre Cabling Classes
Quality Plan
Pass/Fail Indicators
LASER LSPM Equipment
OTDR vs. LSPM

Quality Planning

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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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Optical Fibre Cabling Classes

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

| | | Maximum attenuation (dB) | | | |
|-------|---------|--------------------------|--------|------------|--------|
| | | Multimode | | Singlemode | |
| | | 850nm | 1300nm | 1310nm | 1550nm |
| Class | 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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OF: Testing Philosophies
Test Methods

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Quality Planning

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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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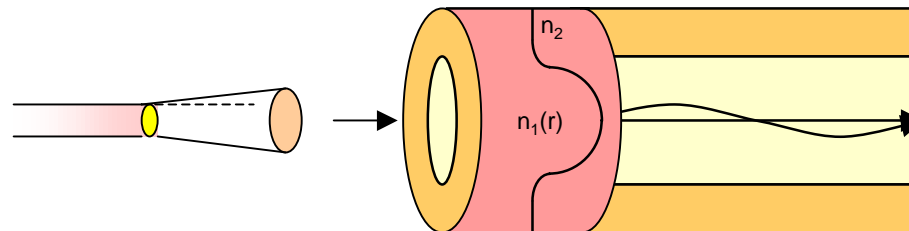
Break

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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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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

Testing Multimode Optical Fibre Infrastructures

Prepared and delivered for



Bisham Abbey
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