Task 2 update: Time variation and modal noise study

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Outline of task 2 goals

- Study the impact of time varying effects on the LRM draft spec
  - Provide input to the TP3 time varying component of the receiver compliance test
    - Set a frequency below which EDC should track (TP3 test rate) and/or
    - Define tracking 'mask' - size vs frequency of perturbation
  - Define spectrum and extent of time variation effects
    - What is a real life environment like? what's already out there ?
    - Measure effect of environment on channel performance
  - Modeling of extent of time variance of links
    - Effect of temperature on link components
  - Study of modal noise of the MMF channel
    - Assess modal noise penalty for different laser types

Task 2 planned activities

1) 'Standard link' for modeling and experiment
2) Real environments: review existing standards describing in-building environments
3) Mechanisms: identify key time varying components and determine mechanical vibration rates and amplitudes for each
4) Experiment: relationship of perturbation spectrum to modal noise spectrum for each mechanism
5) Model: effect of temperature (link and source) over 'standard link'
6) Modal noise: calculate penalty for different laser types over 'standard link'

Task 2 Progress

To date:

- 'Standard link' for modeling and experiments agreed
  - 4 connectors, with 2 connectors at 7micron offset (worst case consistent with preceding standards and existing link specs)
- Referencing GR-63-CORE for operational vibration testing
  - describes vibration tests for in-building environment at constant acceleration, (0.1g & 1g) from 5-100 Hz (vibration amplitude ~$1/f^2$)

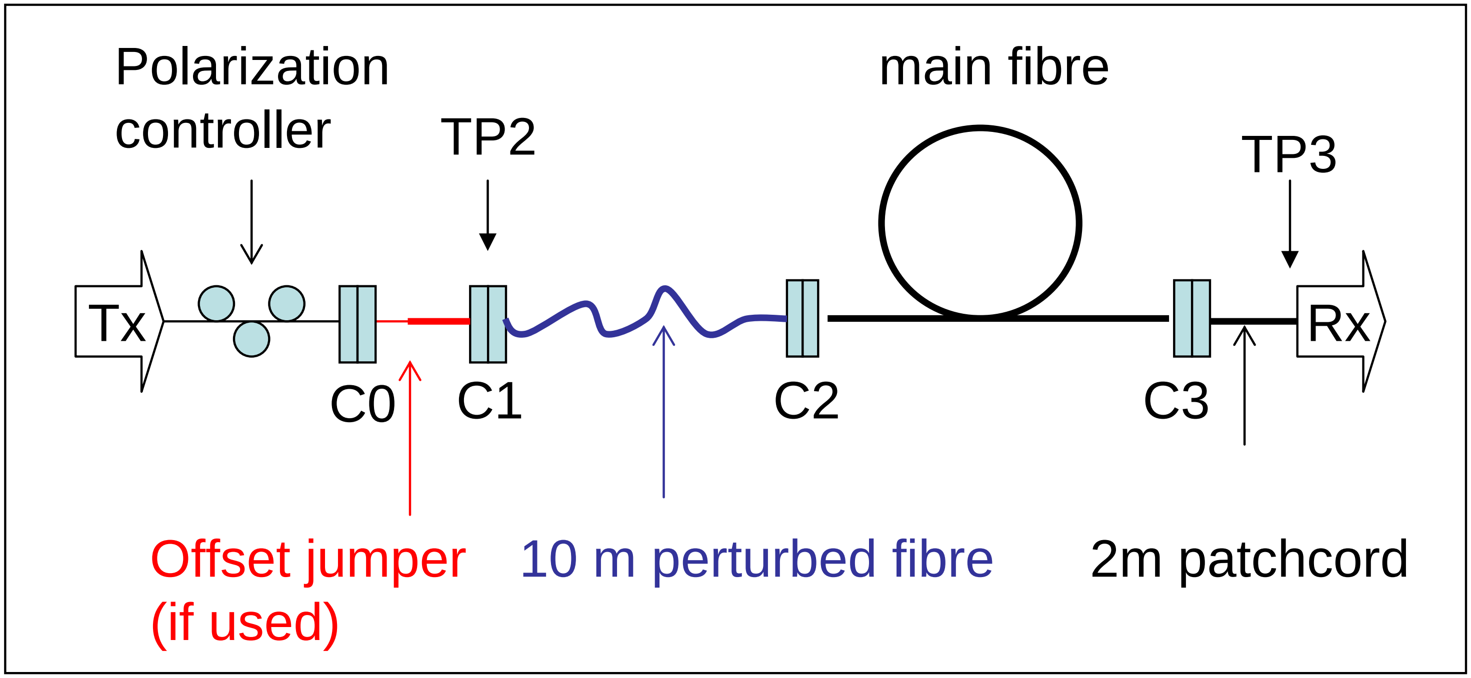
Active:

- Experiments to determine relationship of mechanical perturbation spectrum to modal noise spectrum have just started.
  - First experiments at 10-100Hz, 3-5mm movement (~4x GR-63-CORE spec)
  - Up to 3x frequency multiplication observed to date
  - Greatest effects seen at low frequencies
- Study of temperature effects in progress
  - Comprehensive list of mechanisms compiled and size of each effect determined Most temperature effects are not an issue; remaining significant effects will be subject of further study
- Modal Noise calculations planned
  - Modal noise calculations may need to be adapted to for equalized links in order to include noise enhancement

Standard link

- 'Standard link' for LRM modal noise and time variation testing
- Worst case connector offset :   7 microns
- Comments on testing with standard link
- Comparison of task 2 'standard link' and Legacy MMF link
- Modal power distribution issue

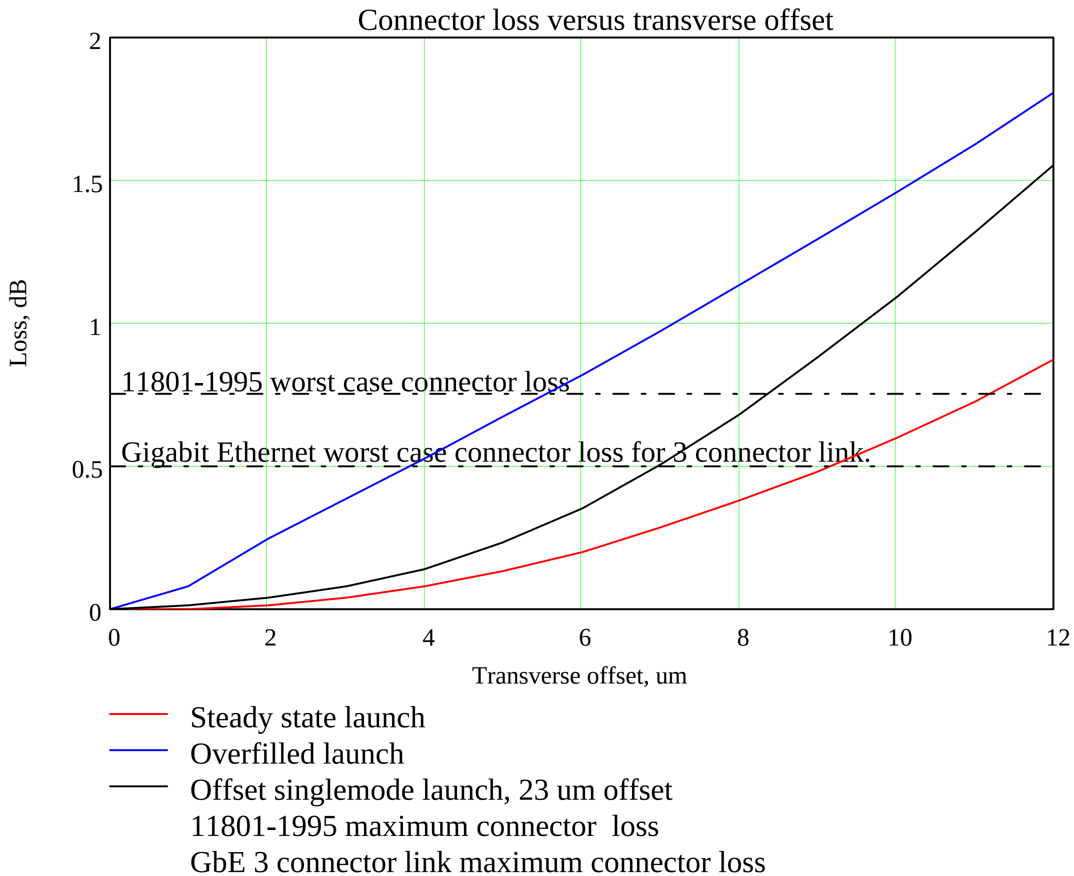
Agreed worst-case TEST configuration for channel variation measurements



Connectors	Offset, um	Notes
C0	N/A	SMF
C1	7	Worst case
C2	7	Worst case
C3	4	Low loss to keep within loss budget
main fibre	length, m	
62.5 um	220/300	tbd
50 um	220/300	tbd

- **This configuration was designed to give largest modal noise signal for testing purposes.**
- **It may not be suitable for link modeling.**

Loss versus transverse offset for 62 MMF connections



- The loss graph was calculated using overlap integrals between the modes of nominal 62.5/125 multimode fibre. Connectors are assumed to be physical contact therefore no reflection loss.

Comments on legacy links:

- The ISO 11801-1995 cabling standard specified a worst case, individual connector loss (OFL) of 0.75 dB for MMF links.
- Allowing 0.5 dB of the loss for lateral offset this is approximately equivalent to offsets in the range (4-9) um depending on launch.
- OM3 group proposed 7 um for maximum offset.
- Total connector loss allocation is 1.5 dB
- Gigabit Ethernet assumed two 0.75 dB connectors for its worst-case cable model.
- The Gigabit Ethernet standard also stated that if the link contained three connectors then the worst case loss must be reduced to 0.5 dB per connector.

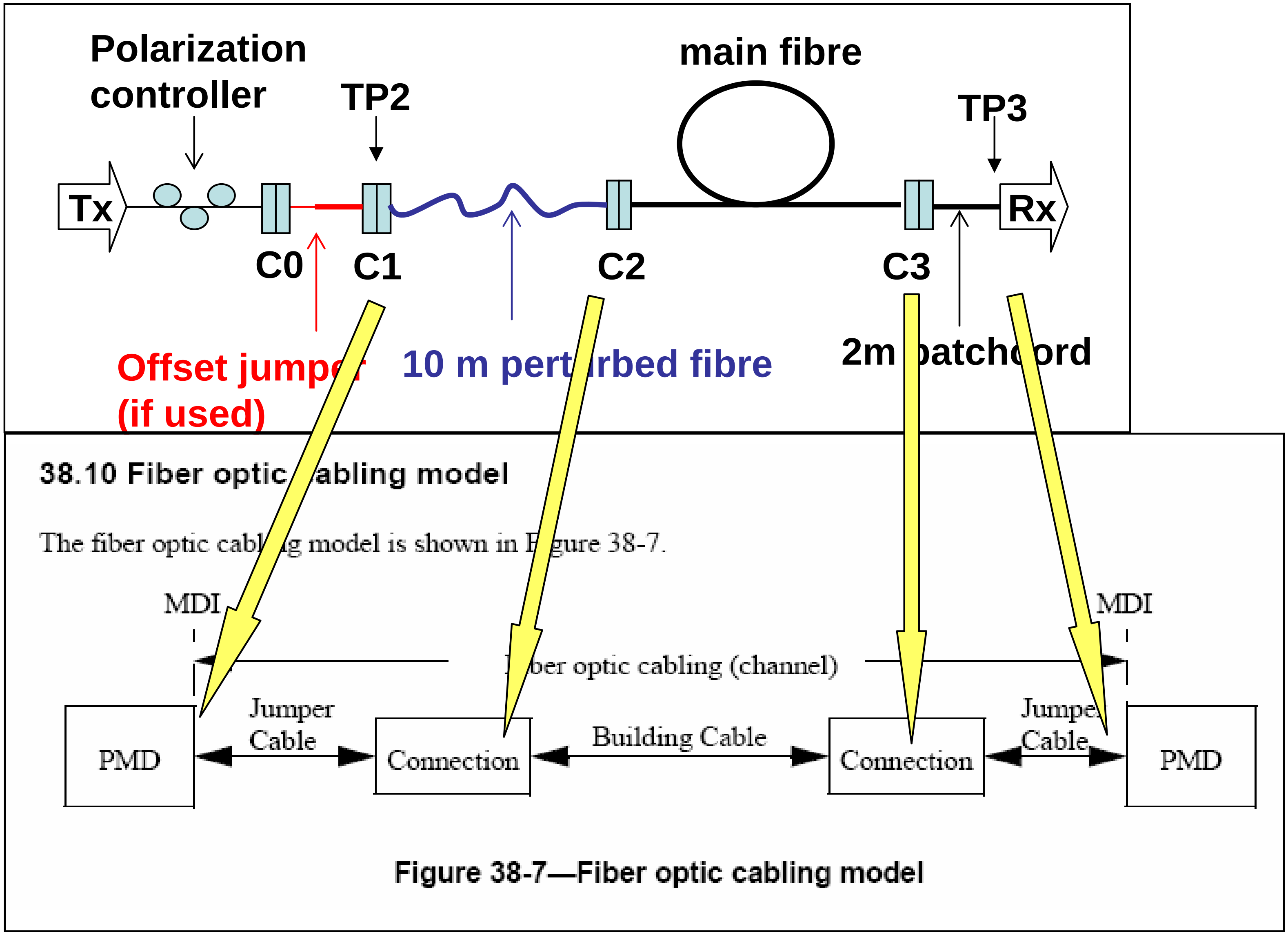
Worst case connector offset discussion

- The lateral offset that produces a specific loss depends on launch mode power distribution in the fibre
- Legacy link loss is in terms of OFL loss, which has highest loss/lateral offset (4um for 0.5dB loss)
- Steady state launch has lowest loss/offset (9um for 0.5dB loss)
- 23micron OSL agreed as justifiable 'reference' launch
- **leads to worst case figure of 7 micron offset**
  - 7 microns was value adopted by OM3 group
  - Independent calculations by Joerg Kropp for '70/70' power distribution also supported 7 micron offset as a worst case (0.63dB loss due to lateral offset at 7micron)

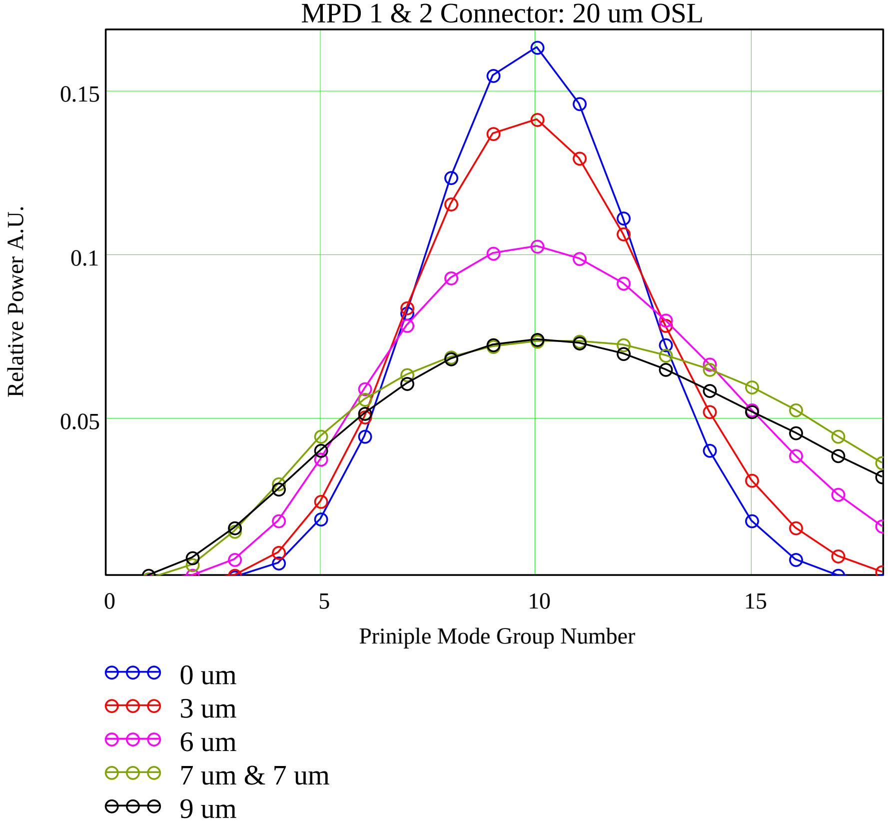
Comments/Considerations

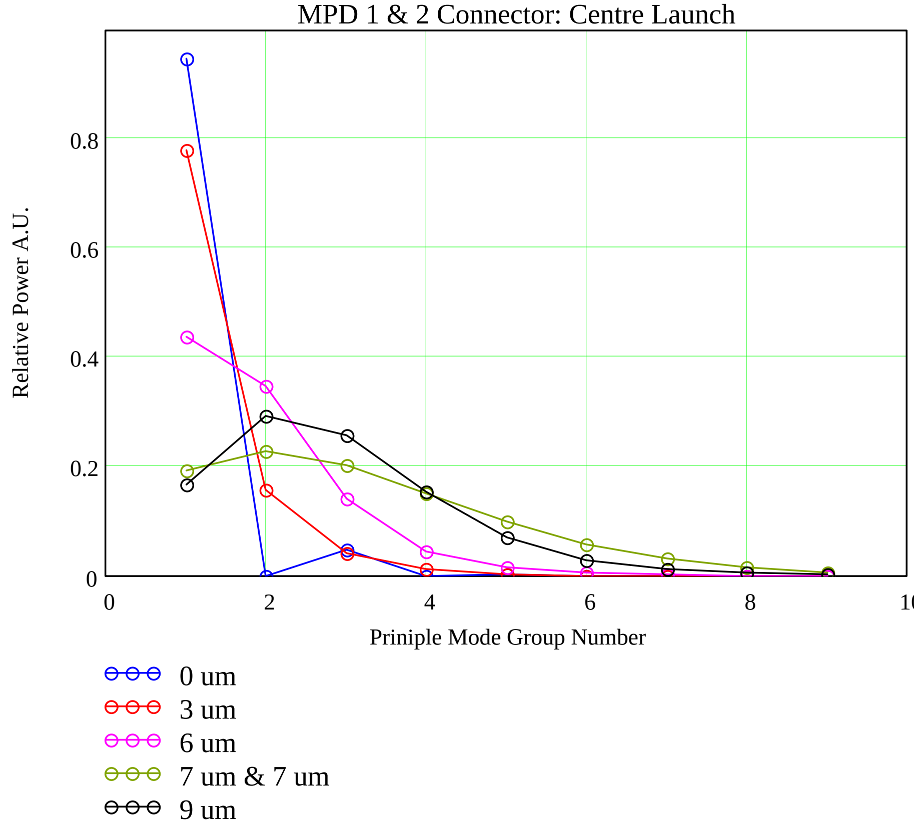
- To maximize modal effects, the two multimode connectors close to the transmitter have been chosen to have the maximum offset.
  - Speckle visibility decreases with increasing fiber length.
- C3 connection set to a lower loss condition so as not to exceed connector loss budget.
- Vibration of connectors is not expected to change offsets enough to cause significant variation of the channel.
- It is only required that the first length of fibre between C1 and C2 is shaken.

Comparison of 'Standard link' for test vs Legacy MMF link



Diffusion of Mode Power Distribution (MPD) at offset connectors





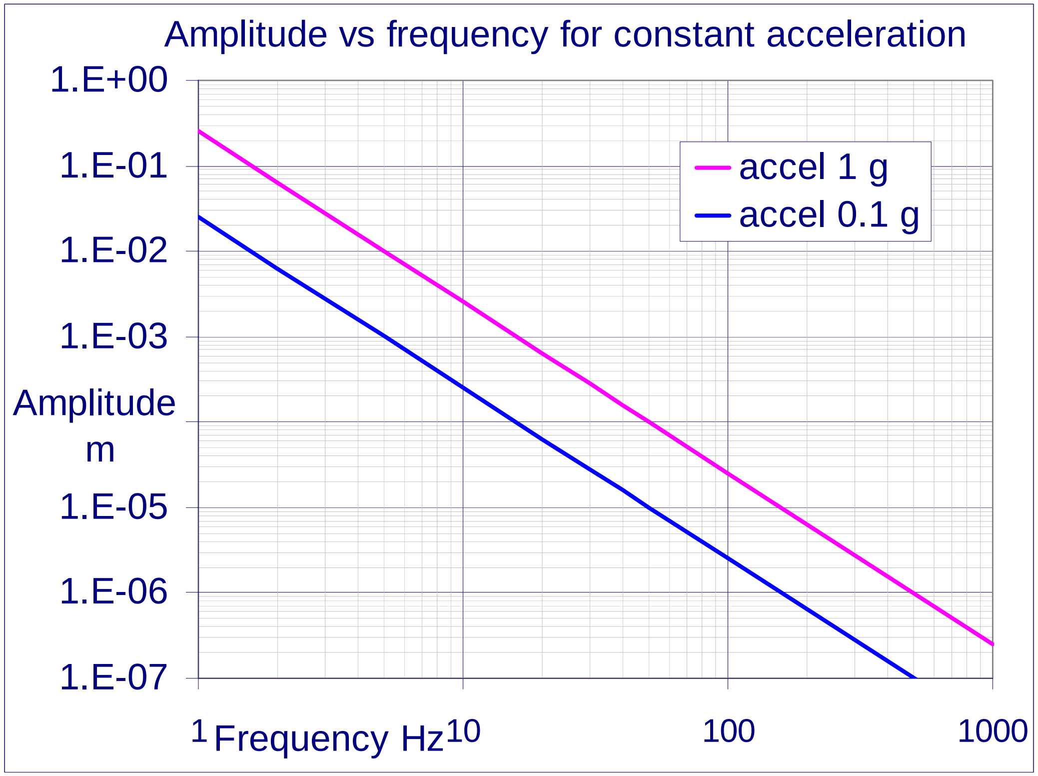
- **Two 7 um offset connectors equivalent to a single offset of about 9 um.**
- **Controlled launched will be destroyed by two 7 um offset connectors.**
- **Is this a reasonable worse-case for link modeling? Seems severe.**

Vibration Testing

Vibration tests representing office environment

Referencing GR-63-CORE

- Bellcore standard describing test conditions for telecomm central office equipment in a controlled indoor environment
- Describes vibration tests at constant acceleration (0.1g & 1g) from 5-100 Hz



- Vibration amplitude ~ **$1/f^2$**
  - 0.1g acceleration at 1Hz corresponds to a 25mm perturbation amplitude this is similar to TIA/EIA-455-203 fibre shaker
  - 1g acceleration at 1Hz corresponds to 250mm amplitude - similar to vigorous manual shaking of a fibre coil
  - 1g acceleration at 1kHz corresponds to 0.25micron amplitude - very small !

Suggests that low frequency range will be the test case of interest - supported by initial experiments

Summary

- Agreed basis for experiments on mechanical perturbation and modal noise calculations
  - standard link with multiple worst case connectors for modal noise and time variation measurements
- Description of mechanical perturbation environment
  - referencing GR-63-CORE, which describes operational vibration tests
  - strong relationship suggests test case of interest is at low frequencies
  - initial experiments support this
- Study of temperature effects
  - most temperature effects are not an issue
  - more detail in Popescu_02_0904

Tasks for further work

- Modal noise calculations
- Continuing vibration testing

Back up

Legacy MMF installations & standards: Gigabit Ethernet cable model (taken from the standard)

38.10 Fiber optic cabling model

The fiber optic cabling model is shown in Figure 38-7.

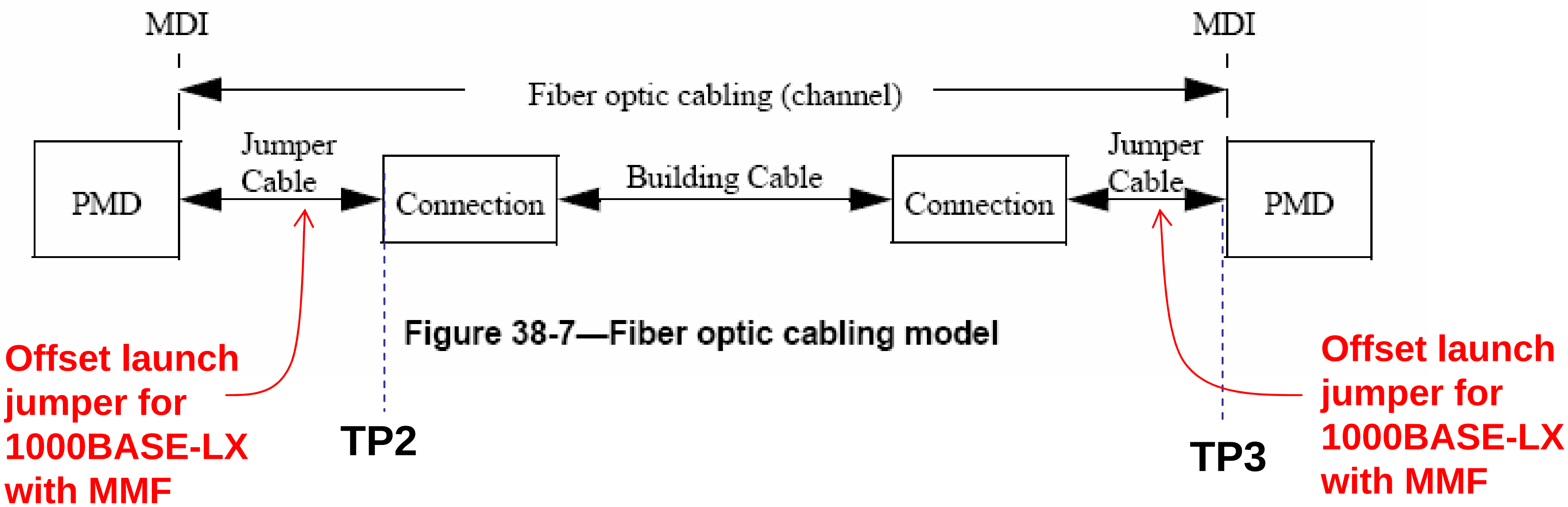


Figure 38-7—Fiber optic cabling model

38.11.2.1 Connection insertion loss

The insertion loss is specified for a connection, which consists of a mated pair of optical connectors. The maximum link distances for multimode fiber are calculated based on an allocation of 1.5 dB total connection and splice loss. For example, this allocation supports three connections with an average insertion loss equal to 0.5 dB (or less) per connection, or two connections (as shown in Figure 38-7) with a maximum insertion loss of 0.75 dB. Connections with different loss characteristics may be used provided the requirements of Table 38-11 and Table 38-12 are met.