

# Comparison of Monte Carlo & Spreadsheet Models

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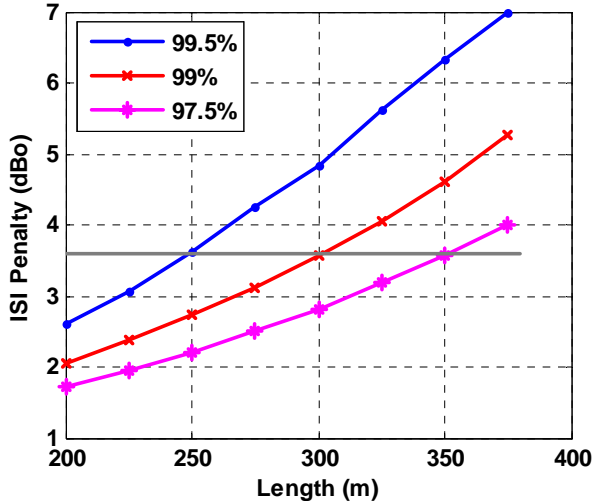
# Simulation Parameters



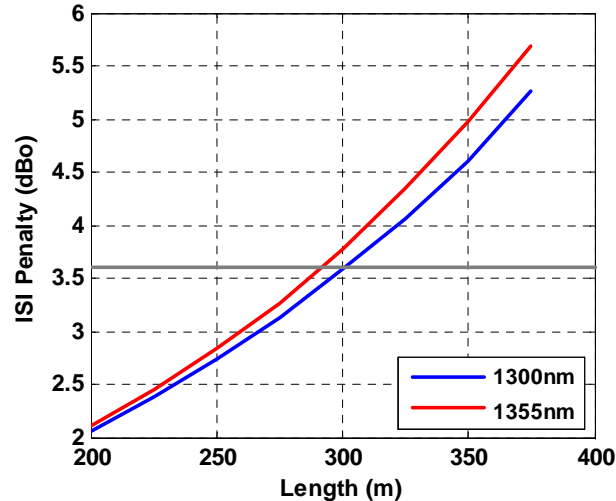
- Delay Sets
  - MC67 ( $\geq 500$  MHz·km, 18 mode-groups)
  - MC50 ( $\geq 500$  MHz·km, 10 mode-groups)
  - OM3 (passing fibers, 10 mode-groups)
- Single-mode launch
  - center launch (CL):  $0\mu\text{m} \rightarrow 3\mu\text{m}$
  - offset launch (OSL):
    - $17\mu\text{m} \rightarrow 23\mu\text{m}$  for  $62.5\mu\text{m}$  fiber
    - $10\mu\text{m} \rightarrow 16\mu\text{m}$  for  $50\mu\text{m}$  fiber
  - joint launch: best chosen for each pair-wise combination of launches
- Link Configuration
  - fibers randomly chosen from set
  - 1-1-Lx-1
    - Vary Lx over range of distances
- Connectors
  - Random offset from Rayleigh distribution
    - mean =  $3.58\mu\text{m}$ , truncated at  $7\mu\text{m}$
  - Total loss  $\leq 1.5$  dB
    - loss computed with OFL launch
- 10GBASE-LX4
  - 3.268 Gb/s (effective rate)
  - 120 ps Tx filter, 2.34 GHz Rx filter
  - Pisi  $\sim 3.6$ dB at 300m
  - Offset launch
- 1000BASE-LX10 ( $62.5\mu\text{m}$  MMF)
  - 1.389 Gb/s (effective rate)
  - 300 ps Tx filter, 0.9375 GHz Rx filter
  - Pisi  $\sim 2.8$ dB at 550m
  - Offset launch

# 10GBASE-LX4: MC67 vs. Spreadsheet

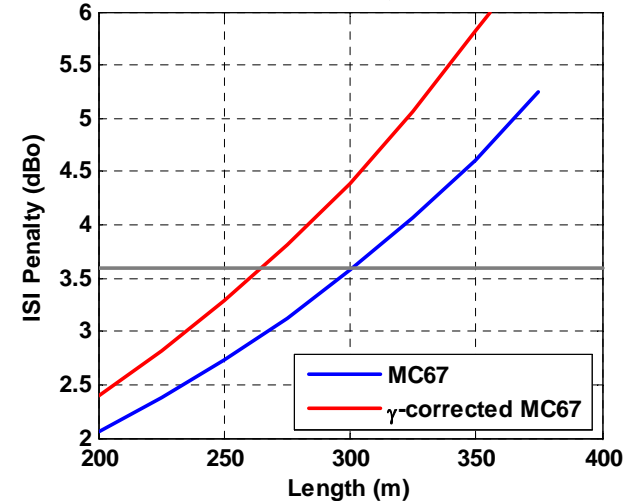
MC67, 10GBASE-LX4, 3.125Gb/s, 1-1-Lx-1, simplex link



LX4 99%-tiles: MC67, 1300nm vs. 1355nm



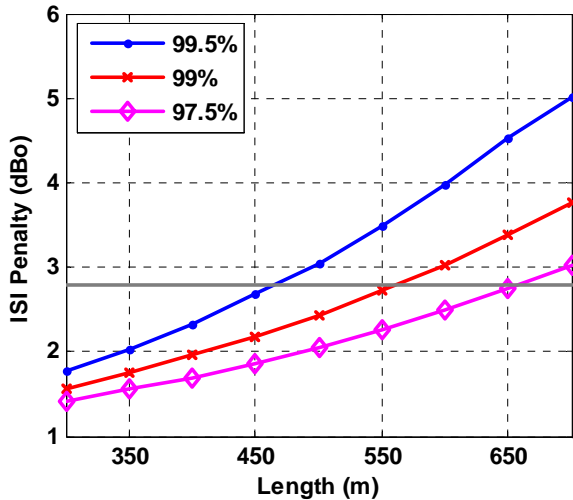
LX4 99%-tiles: MC67 vs.  $\gamma$ -corrected MC67



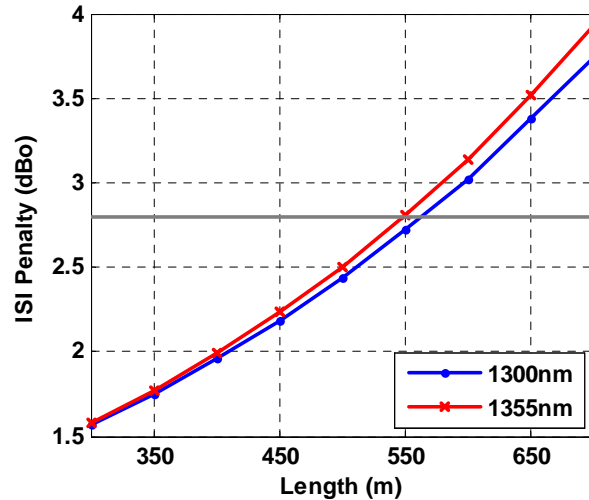
- Spreadsheet model ISI limit ~3.6 dB
- MC67 predicts equivalent ISI penalty at
  - 99 %-tile, 1-1-300-1 configuration, simplex link, 1300nm
  - Additional 0.2dB penalty for 1355nm
- $\gamma$ -corrected MC67 predicts equivalent ISI penalty at
  - 99 %-tile, 1-1-265-1 configuration, simplex link
  - 98.2 %-tile, 1-1-300-1 configuration, simplex link

# 1000BASE-LX10: MC67 vs. Spreadsheet

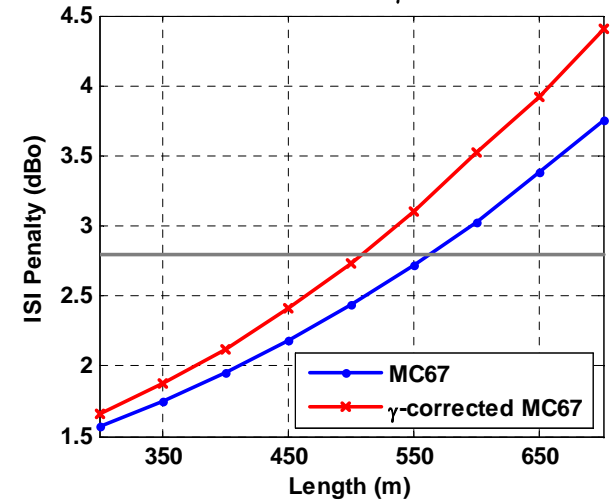
MC67, 1000BASE-LX10, 1.25Gb/s, 1-1-Lx-1, simplex link



LX10 99%-tiles: MC67 1300nm vs. 1355nm



LX10 99%-tiles: MC67 vs.  $\gamma$ -corrected MC67



- Spreadsheet model ISI limit ~2.8 dB
- MC67 predicts equivalent ISI penalty at
  - 99 %-tile, 1-1-563-1 configuration, simplex link, 1300nm
  - Additional 0.08dB penalty for 1355nm
- $\gamma$ -corrected MC67 predicts equivalent ISI penalty at
  - 99 %-tile, 1-1-510-1 configuration, simplex link
  - 98.5 %-tile, 1-1-550-1 configuration, simplex link

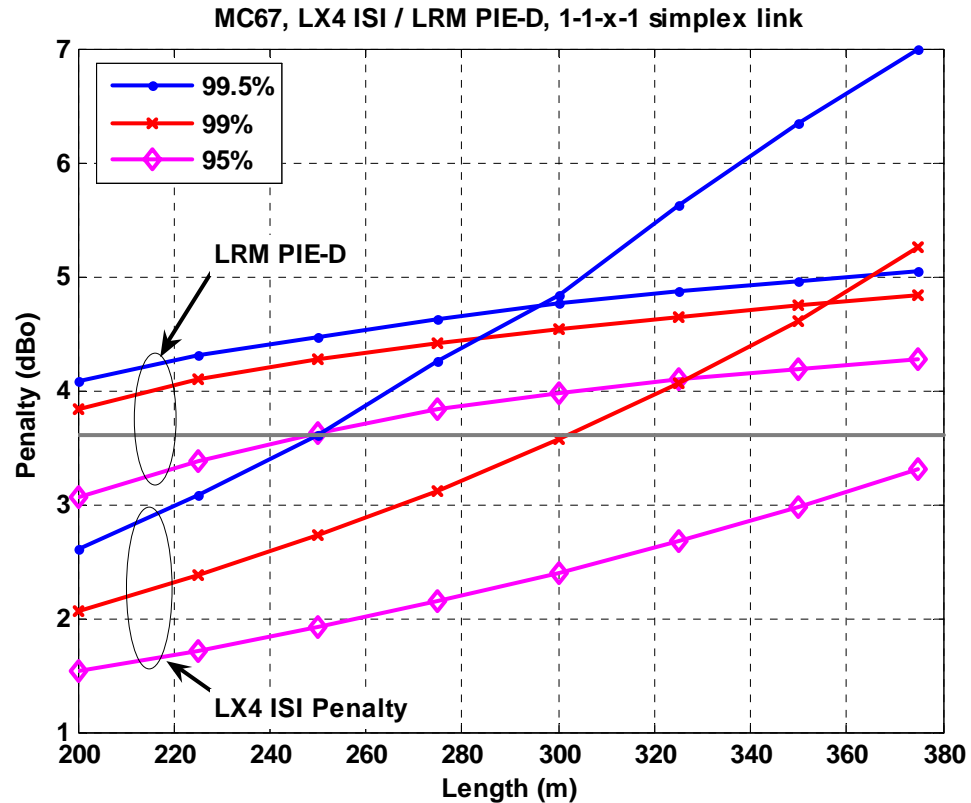
# Observations

- Spreadsheet model is only used where it is valid
  - Not attempting to predict 10Gb/s performance at 300m
  - Only analyzing links without EQ
- MC67 model should be equally valid independent of EQ in Rx
- MC67 & 802.3 spreadsheet model agree well
  - Both for 10GBASE-LX4 and 1000BASE-LX10
  - Agreement best assuming
    - 99%-tile
    - 1-1-300-1 link configuration (LX4) or 1-1-550-1 (LX10)
    - simplex link
    - total OFL connector loss  $\leq 1.5\text{dB}$
- $\gamma$ -corrected model more pessimistic than the spreadsheet model

# Discussion

- Determining actual coverage, *with reasonable confidence*, is impossible
  - The measurement sample size is too small
- However, some %-tile is required to interpret the results of any Monte Carlo model
- Compare the spreadsheet model with the MC67 %-tile and link configuration
  - Consider links without EQ, i.e. where both the spreadsheet and MC67 models are considered valid
- Result
  - Distinguish MC %-tile vs. link coverage in our discussions
  - Ensure –LRM will be as robust, and with the same level of confidence, as previous 1G and 10G Ethernet standards
  - This is the best we can do...

# MC67 Percentiles vs. Distance

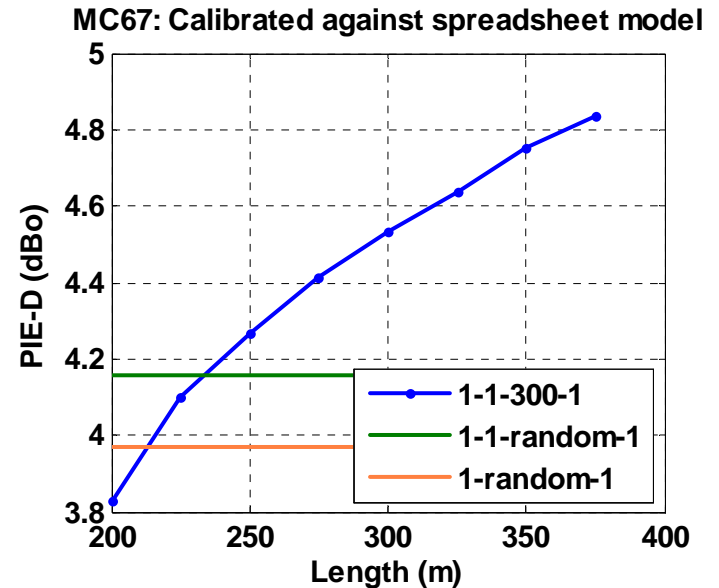


- LX4: ISI ~ 3.6dB at 300m at 99%-tile
- LRM: PIE-D ~ 4.0dB at 220m at 99%-tile

# Conclusions (OM1): 10GBASE-LRM

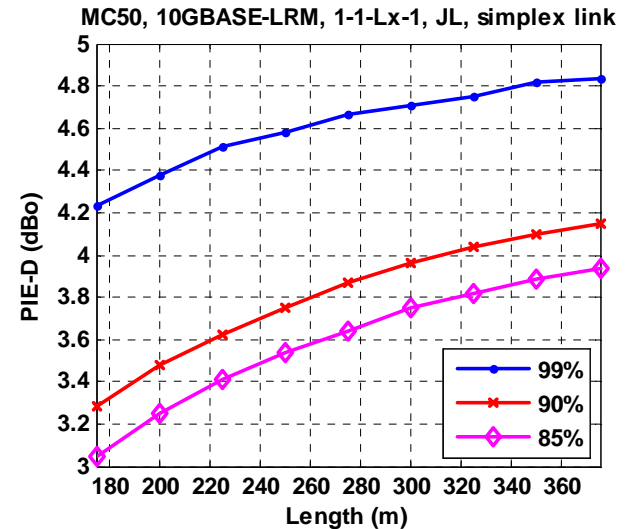
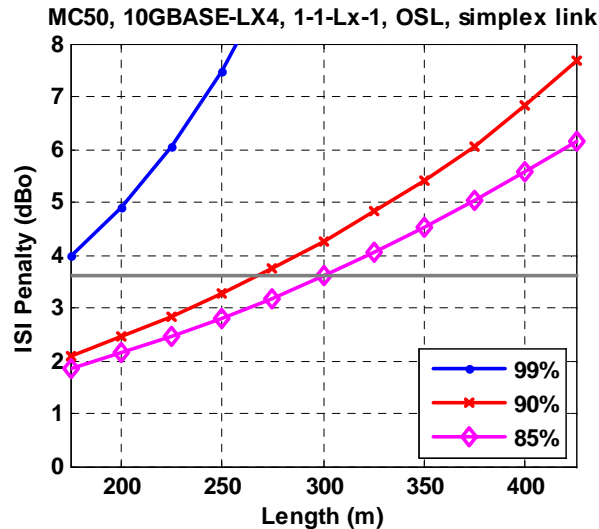
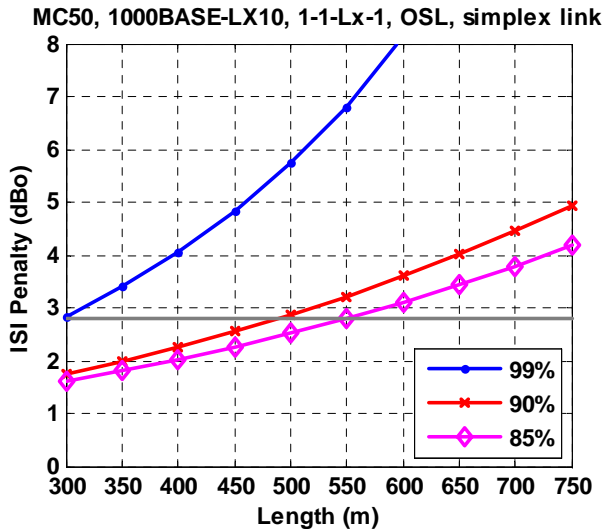
- Same link assumptions used as for previous -LX4 & -LX10 simulations
- PIE-D ~ 4.5dB
  - 300m “worst case” link
- PIE-D ~ 4.0dB
  - Will support the installed base (range of link lengths)
  - 220m “worst case” link

*(“worst case” as used in 802.3z and 802.3ae)*



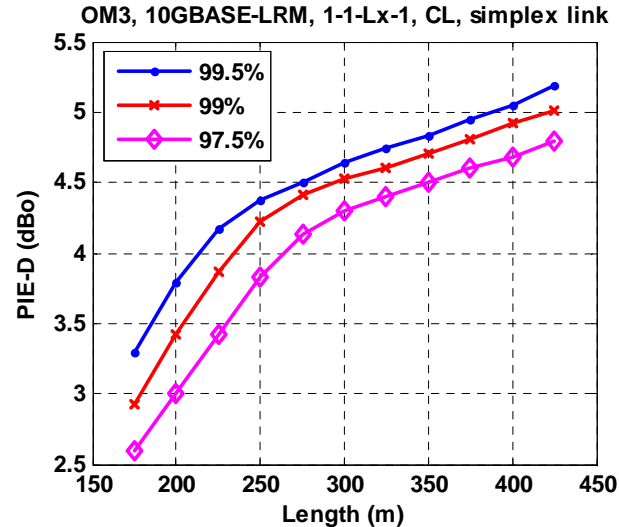
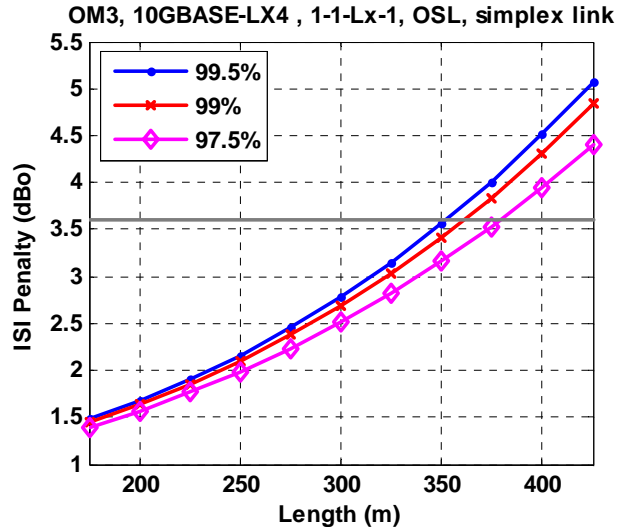


# MC50 (OM2) vs. Spreadsheet



- For no EQ, MC50 more pessimistic than MC67 relative to spreadsheet
- MC50 predicts equivalent ISI penalty at
  - 85 %-tile, 1-1-300-1 configuration (LX4), simplex link
  - 1000BASE-LX10 and 10GBASE-LX4 give same results
- 10GBASE-LRM
  - PIE-D ~ 3.4dB at 220m at 85%-tile
  - PIE-D ~ 3.8dB at 300m at 85%-tile

# OM3 vs. Spreadsheet



- Compare against 10GBASE-LX4
  - Assume 500MHz·km OFL BW for OM3 at 1300nm
- For no EQ, OM3 Monte Carlo is optimistic relative to spreadsheet
  - 100% of links pass 3.6dB ISI penalty criteria at 300m
  - OM3 designed for 850nm – is comparison at 1300nm appropriate?
- 10GBASE-LRM
  - PIE-D ~ 4.5dB at 300m at 99%-tile
  - ~230m at PIE-D ~4.0dB at 99%-tile

# Summary

- OM1:
  - MC67 & spreadsheet models agree well for non-EQ links
  - Simulations support 220m distance with ~4.0dB stressors
- OM2:
  - MC50 appears very pessimistic relative to spreadsheet for no EQ
  - Assuming a target %-tile where both models agree
    - 220m appears conservative with 4.0dB stressors
    - ~3.8dB stressors consistent with 300m distance
- OM3
  - Monte Carlo simulations appear optimistic relative to spreadsheet for no EQ
  - 220m distance consistent with ~4.0dB stressors