10GbE Link Budget Review

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Scope

- Compare 10GBASE-L with system requirements for achieving 10GbE over 300m of MMF.
- Pick-up the intersection of potentially usable parameters for transmitter, fiber and receiver in order to generate a new *ad-hoc* specification table.
- Making quantitative conclusions on link design feasibility for implementing 10GbE over 300m legacy MMF.

Transmitter – TAB.T1

Parameter	10GBASE-L	Unit
Center wavelength	1260 - 1355	nm
Laser cavity	SLM	-
RMS spectral width	NA	nm
Min. SMSR	30	dB
Min. average launch power	-8.2	dBm
Max. average launch power	+0.5	dBm
Min. OMA	-5.2	dBm
Min. extinction ratio	3.5 (2.24)	dB
RIN	-128	dB/Hz
Dispersion penalty	3.2	dB
Optical return loss	12	dB

Transmitter: Set-up – TAB.T2

Parameter	10G-300m-MMF Requirements
Center wavelength	**1260-1335 nm**
Laser cavity	Single Longitudinal mode in order to avoid MPN contribution.
RMS spectral width	**1nm to 4nm**. This is not a stringent requirement since chromatic dispersion coefficient is below 6ps/nm.km in the whole center wavelength range.
Min. SMSR	**30dB** guarantees single mode operation with negligible side mode degradation.
Min. average launch power (mod.)	**-3dBm**. The minimum guaranteed average launch power must be intended under modulated conditions, assuming minimum ER=3.5dB. Set: $P_{T,\min} = OMA_{\min} - 3dB + 4.2dB = -3dBm$
Max. average launch power (mod.)	**+0.5dBm**. The maximum average launch power is related to safety condition and receiver overload. Set: $P_{T,\max} = 0.5dBm$. Maximum OMA will be related consequently.
Min. OMA	Minimum OMA is related to BER, independently from Extinction Ratio. In order to extend link budget for EDC operation this parameter should be slightly increased up to -4.2dBm.
Max. OMA	Maximum OMA is related to maximum average launch power under infinite extinction ratio condition: $OMA_{\max} = P_{T,\max} + 3dB = +3.5dBm$
Min. extinction ratio	**3.5dB**. For DM laser there is a trade-off between ER and OMA. Since OMA should be increased for link improvement, the minimum Extinction Ratio can be kept at 3.5dB (2.24)
RIN	**-135dB/Hz** would be enough for negligible contribution on the receiver sensitivity.
Optical return loss	**12dB** as for 10GBASE specifications.

Transmitter: Proposal – TAB.T3

Parameter	10GBASE-L	10G-1310-MMF	Unit	Note
Center wavelength	1260 - 1355	1260 - 1355	nm	Related to MMF design
Laser cavity	SLM	SLM	-	To avoid MPN
Max. RMS spectral width (PRBS)	NA	2	nm	It is not a relevant parameter for 1310nm operation
Min. SMSR	30	30	dB	Almost standard for SLM laser
Min. average launch power	-8.2 (-4.2)* →	-3.0	dBm	Guarantees OMA_{min} with ER_{min}
Max. average launch power	+0.5	+0.5	dBm	Maximum receiver overload or safety requirements
Min. OMA	-5.2 →	-4.2	dBm	WC link sensitivity at 10^{-12} BER
Max. OMA	NA	+3.5	dBm	Related to maximum average launch power with ER→∞
Min. ext. ratio	3.5 (2.24)	3.5 (2.24)	dB	Modulation speed limited
RIN	-128 →	-135	dB/Hz	Small sensitivity improvement
Optical return loss	12	12	dB	Low cost LC connector

* According to 10GBASE-L, the value -8.2 dBm refers to infinite extinction ratio and it should be compared with -4.2dBm under 3.5dB extinction ratio.

Receiver: – TAB.R1

Parameter	10GBASE-L	Unit
Center wavelength	1260 - 1355	nm
Min. average receive power	-14.4	dBm
Max. average receive power	+0.5	dBm
Sensitivity OMA_{max}	-12.6	dBm
Max. reflectance	-12	dB
Electrical cut-off	12.3	GHz

Receiver: Set-up – TAB.R2

Parameter	10G-300m-MMF Requirements
Center wavelength	**1260-1355nm**
Min. average receive power	**-12.0dBm**. The minimum average received power which guarantees a given BER=10^{-12} performance assuming OMA sensitivity condition and a back-to-back reference transmitter with ER=3.5dB. $P_{sens} = OMA_{sens} - 3dB + 4.2dB = -12dBm$
Max. average receive power	**+0.5dBm**. This value is determined by receiver overload or safety conditions. It must be compliant with the maximum average launch power at transmitter end.
Sensitivity OMA_{sens}	**-13.2dBm**. This parameter specifies the minimum received OMA which guarantees a given BER=10^{-12} performance independently from extinction ratio and assuming back-to-back connection with the reference transmitter.
Overload OMA_{max}	**+3.5dBm**. This parameter is related to the maximum received average power assuming infinite extinction ratio: $OMA_{\max} = P_{R,\max} + 3dB = +3.5dBm$
Max. reflectance	**-12dB**. Standard for low cost LC connectors and butt coupling PIN technology.
Low frequency cut-off	**100kHz**. This lower cutoff frequency is related to the generation of long tails in the pulse response and should be lowered as much as possible in order to avoid ISI
High frequency cut-off	**7.8GHz**. This higher cutoff frequency is strictly related to receiver noise bandwidth and it should be minimized in order to maximize SNR and increase sensitivity.

Receiver: Proposal – TAB.R3

Parameter	10GBASE-L	10G-1310-MMF	Unit	Note
Center wavelength	1260 - 1355	1260 - 1355	nm	Related to MMF design
Min. average receive power sensitivity	-14.4 →	-12.0	dBm	Assuming OMA sensitivity at BER=10^{-12} with ER=3.5dB
Max. average receive power overload	+0.5	+0.5	dBm	Overload or safety
Sensitivity OMA_{sens}	-12.6 →	-13.2	dBm	Sensitivity at BER=10^{-12} and back-to-back connection with reference transmitter
Overload OMA_{max}	NA	+3.0	dBm	Overload with ER→∞
Max. reflectance	-12	-12	dB	Standard for low cost LC
Low frequency cut-off	NA	100	kHz	Max. low frequency cutoff
High frequency cut-off	12.3 →	7.8	GHz	High frequency cutoff for maximizing SNR

Link Budget: Proposal – TAB.L1

Parameter	10G-1310-MMF	Unit	Note
Center wavelength	1260 - 1355	nm	Related to MMF design
Multimode fiber BW	500	MHz.km	Minimum BW for 50µm and 62,5µm multimode fiber under OFL condition
OMA Power budget	-4.2-(-13.2) = 9	dB	Minimum transmitter OMA minus receiver sensitivity OMA
Average power budget	-3-(-12) = 9	dB	Minimum transmitter average launch power minus receiver average power sensitivity with ER=3.5dB
Connector loss	2	dB	4 connectors with 0.5dB loss each
Fiber loss	1	dB	Assumes α=2.5dB/km and up to 300m link length
Available Link Budget	6	dB	Difference between power budget and losses

Conclusion

- Transmitter and receiver specifications for **10G-1310-MMF** have been reported respectively in TAB.T3 and TAB.R3
- **Total link power budget is 9dB**, independently if using average power values or OMA specifications.
- Fiber and connector losses have been accounted for 3dB
- Available link budget for EDC operation and noise contributions (reflection noise and modal noise):

Available Link Budget for EDC : 6dB