Bandwidth Requirements for 30m 100G SR

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100Gb/s 30m on OM3 is Technically Feasible

- Build on work in 802.3cm using BW_eff and TDECQ

- The starting points for EMB requirements for a 100Gb/s 30m link at 850nm are:
  - 1470 MHz.km based on 400GbE SR8 transceivers
  - 1070 MHz.km based on 400GbE SR4.2 transceivers

Compared to OM3 minimum EMB of 2000MHz.km at 850nm, this provides sufficient headroom for actual transceivers, for full technical feasibility/practicality and cost reduction

Outline

1. Summary
2. Full Table with all EMBs
3. Full Table with annotations

BACKUP

4. References
5. Methodology for BW_eff (king_3cm_adhoc_01_062818.pdf) –850nm agrees
6. Methodology for TDECQ (ingham_3cm_02a_0918.pdf) – use correct CD
7. Reference for OM1/OM2-OM3-OM4/OM5 CD
8. Reference for IEC BW guidance

Summary of Technical Feasibility

- Build on methodology in 802.3cm using BW_eff and TDECQ
- 50Gb/s 30m 400G SR8 and 400G SR4.2 require EMBs of
  - 735 MHz.km (SR8)
  - 535 MHz.km (SR4.2)
- Starting point for 100Gb/s is 2x these:
  - 1470 MHz.km (SR8 TDECQ)
  - 1070 MHz.km (SR4.2 TDECQ)

- OM3 EMB of 2000MHz.km allows scale-up to 100Gb/s to be practical while allowing room for cost reduction (for example spectral width)
- Methodology can be used for other lengths (i.e. OM4)

EMBs needed for 50Gb/s 30m implementation near 850nm

SR8 implementation needs 735MHz.km at 850nm, 680MHz.km at 840nm
SR4.2 implementation needs 535MHz.km at 850nm, 504MHz.km at 844nm

For 100Gb/s we double the values in last column and compare to OM3.
Plenty of head-room to meet 100Gb/s with OM3 (1826-2000 MHz.km 840-850nm)

			Based on	Δlambda	CD	BW_CD GHz.km	IEC EMB GHz.km	Bweff GHz.km	BWeff GHz	30mEMB requires MHz.km
1	SR8	850nm	100mOM4	0.6nm	-103.62	3.014	4.7000	2.537	25.37174	786.6
2	SR8	850nm	70m OM3	0.6nm	-103.62	3.014	2.0000	1.666	23.80699	735.1
3	SR8	840nm	100m OM4	0.6nm	-108.41	2.881	3.8400	2.304	23.04432	712.2
4	SR8	840nm	70m OM3	0.6nm	-108.41	2.881	1.8260	1.542	22.03264	680.0
5	SR4.2	850nm	150m OM5	0.6nm	-98.49	3.171	4.7000	2.629	17.52467	534.7
6	SR4.2	844nm	150m OM5	0.6nm	-101.17	3.087	4.1840	2.484	16.56040	504.4

Annotated Table for Clarity

SR8 implementation needs 735MHz.km at 850nm, 680MHz.km at 840nm
SR4.2 implementation needs 535MHz.km at 850nm, 504MHz.km at 844nm

Plenty of head-room to meet 100Gb/s with OM3 (1826-2000 MHz.km)

850nm is included for reference. 840nm(SR8) or 844nm(SR4.2) is real constraint

These CDs are the design assumptions for TDECQ

Agree with king_3cm_adhoc_01_062818.pdf

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Real requirements are 680MHz.km at 840 (SR8) or 504MHz.km at 844 (SR4.2)

SR4.2 844nm determined by 150m OM5 requirement

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References

[1] Nowell, Cunningham, et al., “Evaluation of Gb/s laser based fibre LAN links: Review of the Gigabit Ethernet model”, ***Opt. Quant. Elect.*** 32 (2000) pp. 169-192. Also the Cunningham Book ***Gigabit Ethernet Networking***.

[2] Bottacchi, Stefano, ***Multi-Gigabit Transmission Over Multimode Optical Fibre: Theory and Design Methods for 10GbE Systems***. New York: John Wiley & Sons, 2006. See p. 297 equation (6.29)

[3] King, Jonathan, “Channel wavelength ranges for 400GBASE-4.2: OM3 and OM4 effective bandwidth, modal and chromatic dispersion included”. IEEE 802.3 **king_3cm_adhoc_01_062818.pdf** http://www.ieee802.org/3/cm/public/adhoc/index.shtml

[4] Ingham, Jonathan, “TDECQ and SECQ methodology for 400GBASE-SR4.2”, http://www.ieee802.org/3/cm/public/September18/ingham_3cm_02a_0918.pdf

[5] http://www.ieee802.org/3/ae/public/adhoc/serial_pmd/documents/index.html (IEEE 10GbE link spreadsheet **10GEPBud3_1_16a.xls**) NOTE this was mid-project and predates the improved OM3/OM4 and OM5 CD values…

[6] http://www.ieee802.org/3/bm/public/may13/index.html (IEEE 100GbE SR4 link spreadsheet (4x25GbE) **ExampleMMF Link Model 20130503.xlsx)**

Methodology for BW_eff

$$\frac{1}{\left(BW_{eff}\right)^2} = \frac{1}{EMB^2} + \frac{1}{BW_{CD}^2}$$

As explained in king_3cm_adhoc_01_062818.pdf and other references, the consensus approximation is to combined EMB and chromatic dispersion effects in quadrature corresponding to Gaussian pulse-spreading.

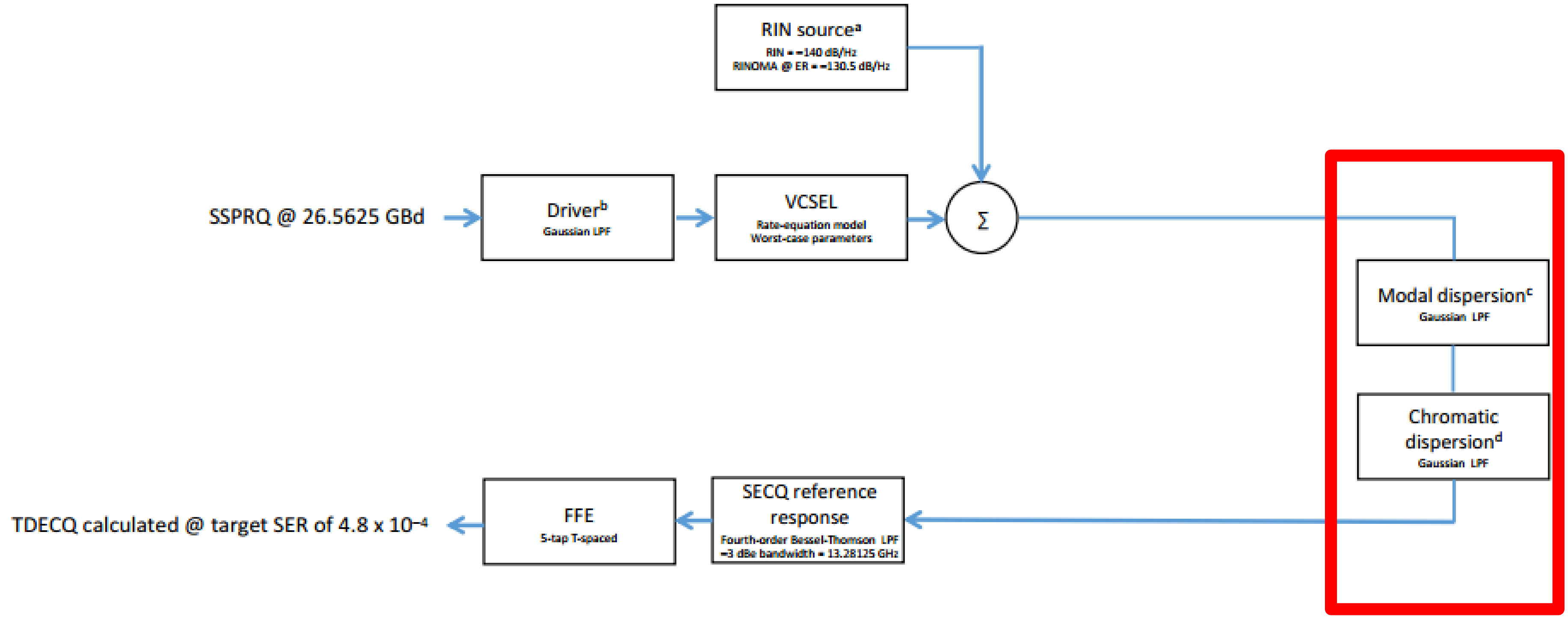
If the transceiver is designed for a certain length, wavelength, and fiber type, the BW_eff corresponds to a first length L0, and an EMBo and BW_CD corresponding to that fiber type (for example OM4 at 100nm at 844nm).

The EMB required at some shorter distance L1 would have a reduced contribution of chromatic dispersion and hence typically has a somewhat lower EMB requirement than a simple L1/L0 scaling.

$$\frac{{L_0}^2}{\left(BW_{eff}\right)^2} = \frac{{L_0}^2}{EMB_0^2} + \frac{{L_0}^2}{BW_{CD}^2} = \frac{{L_1}^2}{EMB_1^2} + \frac{{L_1}^2}{BW_{CD}^2}$$

Methodology for TDECQ (ingham_3cm_02a_0918.pdf)

Simulation



The combination of these two components is exactly ‘BW_eff” in GHz, and the point is that the transceiver to handle a BW_eff which depends on length, fiber type, and assumed chromatic dispersion.

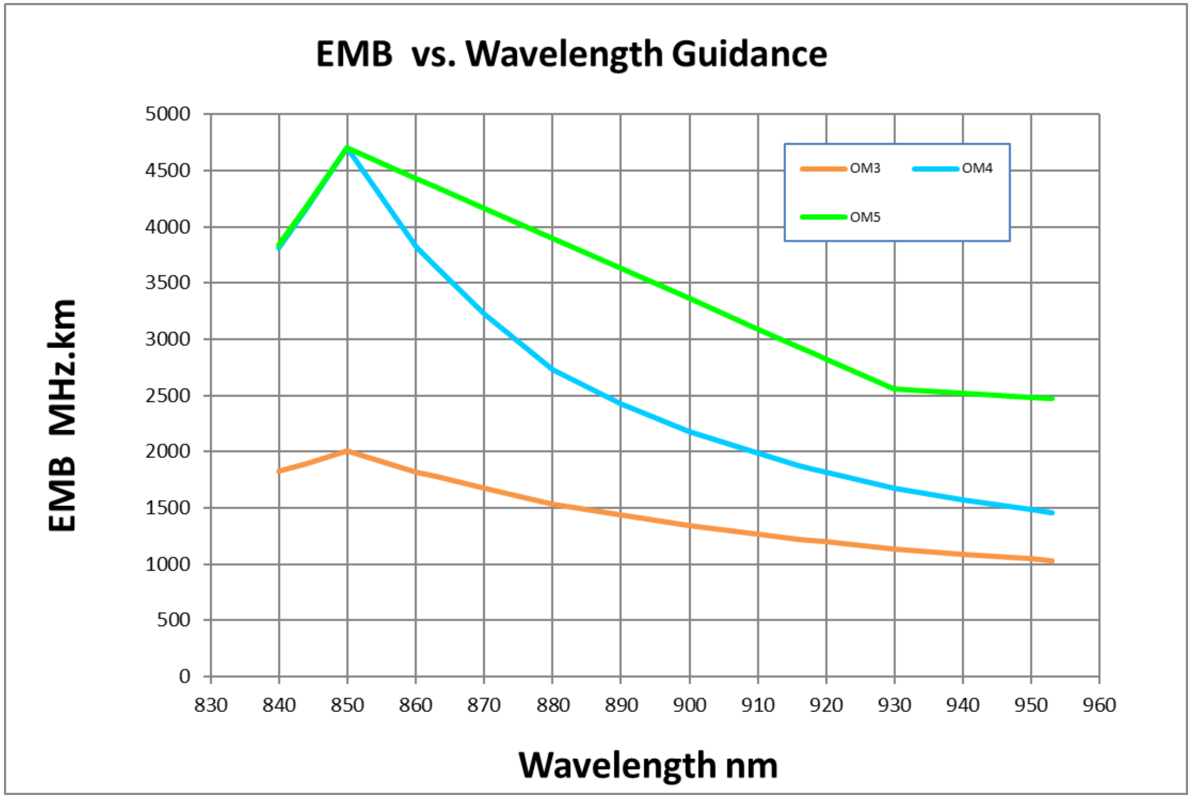
Reference for chromatic dispersion

The worst-case chromatic dispersion for MM types (for link models) is given by

OM1(62.5um)	So = 0.11	Uo = 1320nm	CD(850)= -112.57
OM2/OM3/OM4	So = 0.102750	Uo = 1316nm	CD(850)= -103.62
OM5	So =0.093477	Uo = 1228nm	CD(850)= -98.49

1. See IEEE 802.3 clause 138 table 138-15 for the spec ranges for So, Uo for OM3/OM4 and OM5. Units for So are ps/nm^2-km
2. See equations in J. King reference.
3. The So =0.11, Uo =1320nm values were used in1GbE and early 10GbE development for OM1, OM2, OM3. They should now only by used for the high-delta OM1 fiber.
4. The OM4 CD values were determined by a round robin at the time of introducing OM4. This represented a better measurement and was applied to the 50um fibers OM2, OM3, OM4.
5. The OM5 CD values were determined by a 2nd round robin of OM3 and OM4 fiber during OM5 development and represent improved measurements rather than an evolution in the fiber. The OM5 numbers are the most accurate estimate for OM3/OM4/OM5, but the IEC standard (and hence table 138-15) has not yet been updated.
6. Ingham_3cm_02a_0918.pdf says OM3/OM4 chromatic dispersion (and hence BW_eff) calculated using So=0.11,Uo=1320nm which is incorrect. Note the SR4.2 design is determined by 150m OM5 requirement so this is a moot point but it may cause confusion.

IEC BW guidance (see kolesar_NGMMF_01_jan18.pdf)



lambda	OM3	OM4	OM5
840	1826	3809	3840
844	1896.4	4166	4184
850	2002	4701	4700
860	1820	3817	4432
863	1778	3643	4351.6
870	1676	3226	4164
880	1533	2729	3896
890	1435	2428	3628
900	1345	2179	3360
910	1269	1984	3092
916	1222	1878	2931.2
918	1208	1846	2877.6
920	1200	1819	2824
930	1136	1675	2556
940	1085	1566	2519
950	1046	1486	2481
953	1033	1459	2470

OM5 guidance was agreed to during TIA OM5 development:

(1) $3840+(4700-3840)*(\lambda-840)/(850-840)$

(2) $4700+(2556-4700)*(\lambda-850)/(930-850)$

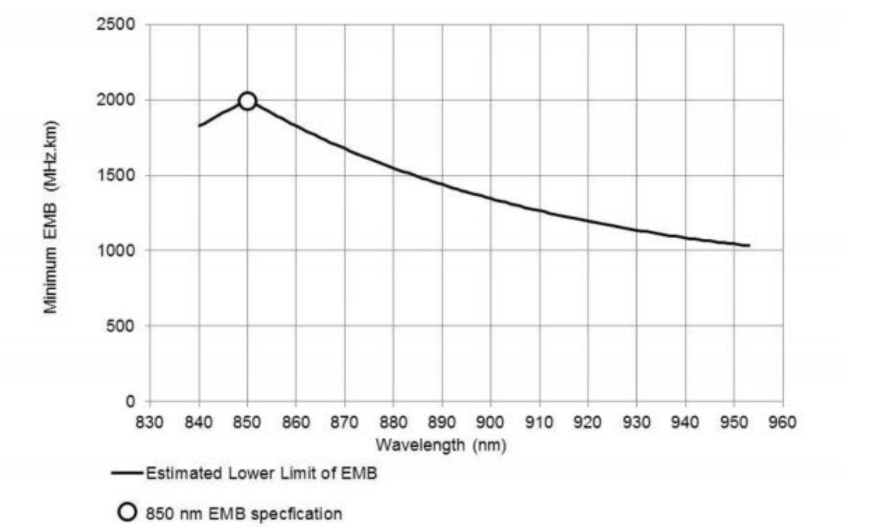
(3) $2556+(2470-2556)*(\lambda-930)/(953-930)$

IEC BW guidance (see kolesar_NGMMF_01_jan18.pdf)

$$\text{EMB} \geq 1826 + (2000 - 1826) \times (\lambda_c - 840)/(850 - 840) \text{ for } 840 \text{ nm} \leq \lambda_c \leq 850 \text{ nm} \quad \text{(E.3)}$$

$$\text{EMB} \geq 2000 \times (1.0010 - 0.9809x + 0.8073x^2 - 0.4304x^3 + 0.1194x^4) \text{ for } 850 \text{ nm} \leq \lambda_c \leq 953 \text{ nm} \quad \text{(E.4)}$$

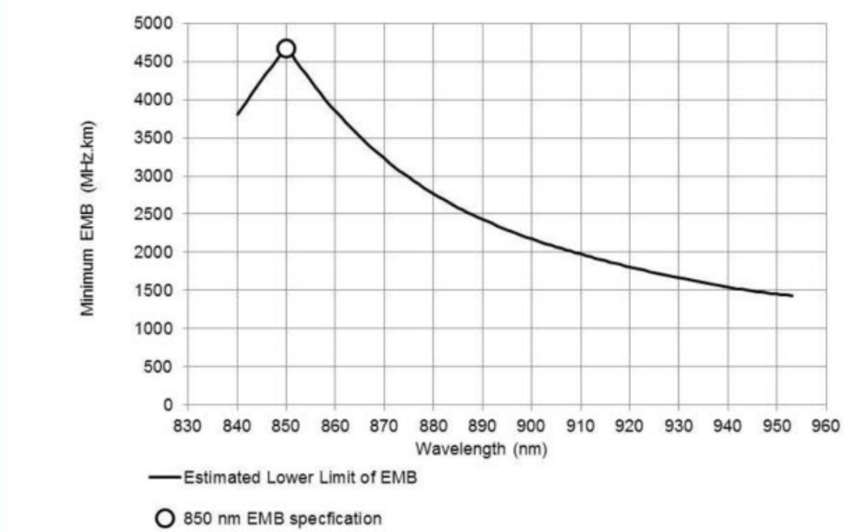
Where $x = (\lambda_c - 850)/(953 - 850)$



$$\text{EMB} \geq 3840 + (4700 - 3840) \times (\lambda_c - 840)/(850 - 840) \text{for } 840 \text{ nm} \leq \lambda_c \leq 850 \text{ nm} \quad \text{(E.5)}$$

$$\text{EMB} \geq 4700 \times (1.0002 - 2.1549x + 03.2700x^2 - 2.7328x^3 + 0.9280x^4) \text{ for } 850 \text{ nm} \leq \lambda_c \leq 953 \text{ nm} \quad \text{(E.6)}$$

Where $x = (\lambda_c - 850)/(953 - 850)$



OM5 guidance was agreed to during TIA OM5 development.
OM3/OM4 guidance was developed by fiber makers/suppliers based on actual measurements and modeling at different companies.

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