Skew and Dispersion Calculations

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Multi-lane skew

It is likely that the first implementations of the next rate of Ethernet will utilise multiple lanes

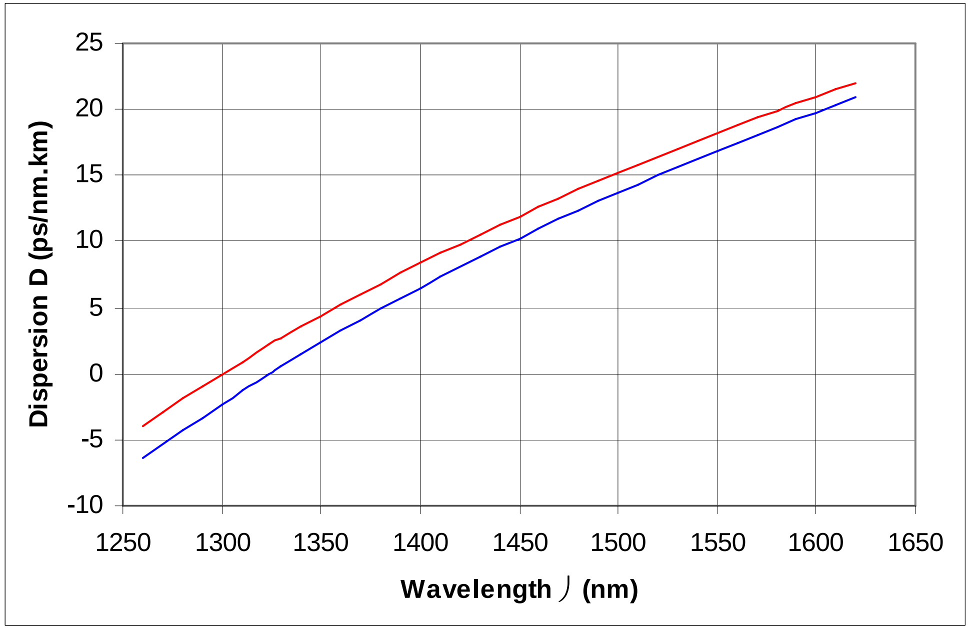
This document provides analysis of the skew generated in the case where these lanes are carried over separate wavelengths on a single fibre

G.652 Fibre dispersion spec

G.652 defines equations for the minimum and maximum dispersion coefficients (same for B.1 & B.3 fibres)

$$D_{max} = \frac{0.093\lambda}{4}\left[1-\left(\frac{1300}{\lambda}\right)^4\right]$$

$$D_{min} = \frac{0.093\lambda}{4}\left[1-\left(\frac{1324}{\lambda}\right)^4\right]$$

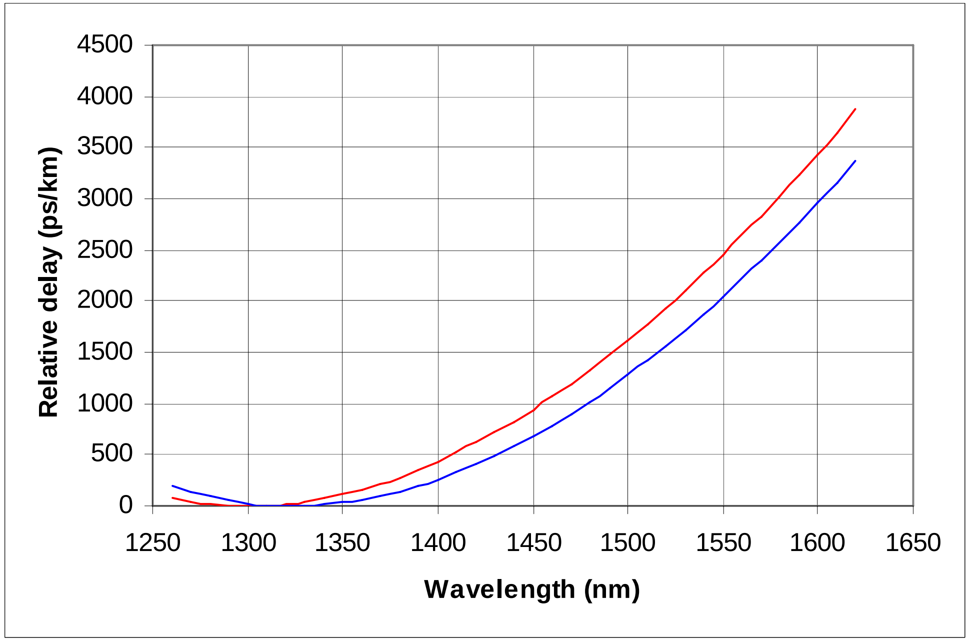


Delay equations

Integrating these gives equations for the minimum and maximum relative delay coefficients

$$\text{Delay}_{max} = A + \frac{0.093\lambda^2}{8}\left[1 + \left(\frac{1300}{\lambda}\right)^4\right]$$

$$\text{Delay}_{min} = A + \frac{0.093\lambda^2}{8}\left[1 + \left(\frac{1324}{\lambda}\right)^4\right]$$



Skew and dispersion calculation examples

The following slides give the result of applying these equations to some of the possible implementation options for 100 Gbit/s Ethernet

10 lane CWDM solution near 1550 nm

A 10 lane solution has been proposed using 20 nm spaced CWDM at 1550 nm

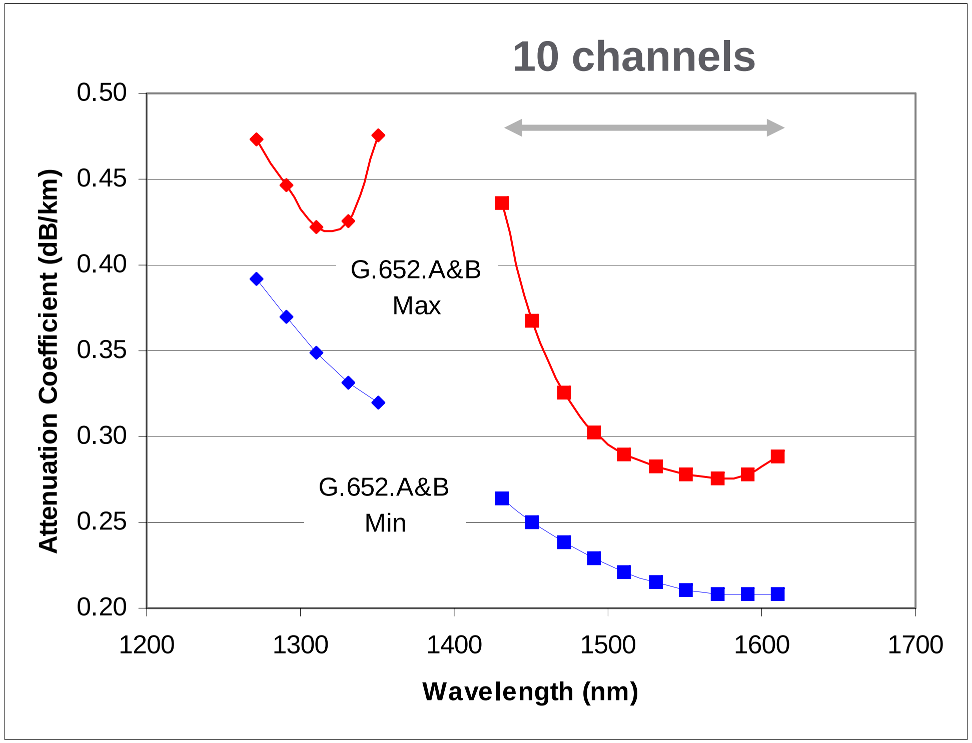
Operation on G.652 A or B (not low water peak) fibre seems possible

λmin = 1431 - 6.5 = 1424.5 nm

λmax = 1611 + 6.5 = 1617.5 nm

Max dispersion = 21.9 ps/nm·km
Max skew = 3.15 ns / km

Max skew for 10 km = 31.5 ns



Fibre loss data from [Appendix I/G.695]

10 lane DWDM solution near 1550 nm

A 10 lane solution has also been proposed using DWDM at 1550 nm

The highest skew solution in the C band would be 400 GHz spacing (from 191.9 to 195.5 THz)

λmin (195.5 + 0.08 THz) = 1532.84 nm

λmax (191.9 - 0.08 THz) = 1562.88 nm

Max skew = 0.543 ns / km

Max dispersion = 18.94 ps/nm·km

Max skew for 10 km = 5.43 ns

Max dispersion for 40 km = 758 ps/nm

Max skew for 40 km = 21.7 ns

5 lane CWDM solution near 1300 nm

A 5 lane solution has been proposed using 20 nm spaced CWDM at 1300 nm

λmin = 1271 - 6.5 = 1264.5 nm

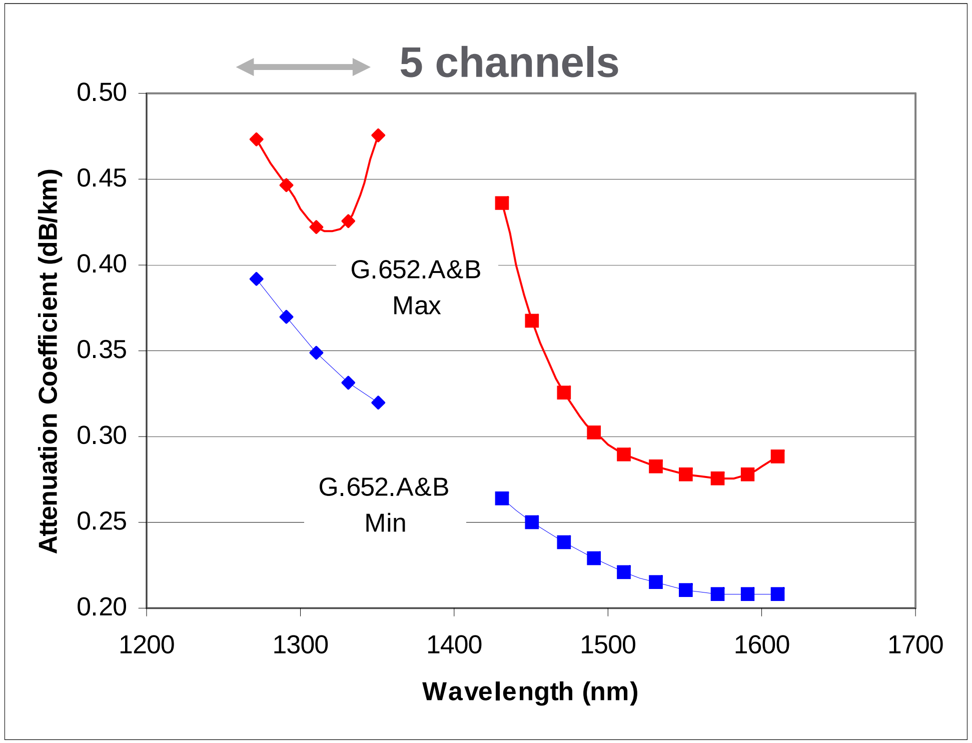
λmax = 1351 + 6.5 = 1357.5 nm

Max disp. = -5.94 to 5.02 ps/nm·km

Max skew = 0.172 ns / km

Max disp. 10 km = -59.4 to 50.2 ps/nm

Max skew 10 km = 1.72 ns



Fibre loss data from [Appendix I/G.695]

5 lane CWDM solution near 1550

A 5 lane solution has also been proposed using 20 nm spaced CWDM at 1550 nm

λmin = 1511 - 6.5 = 1504.5 nm

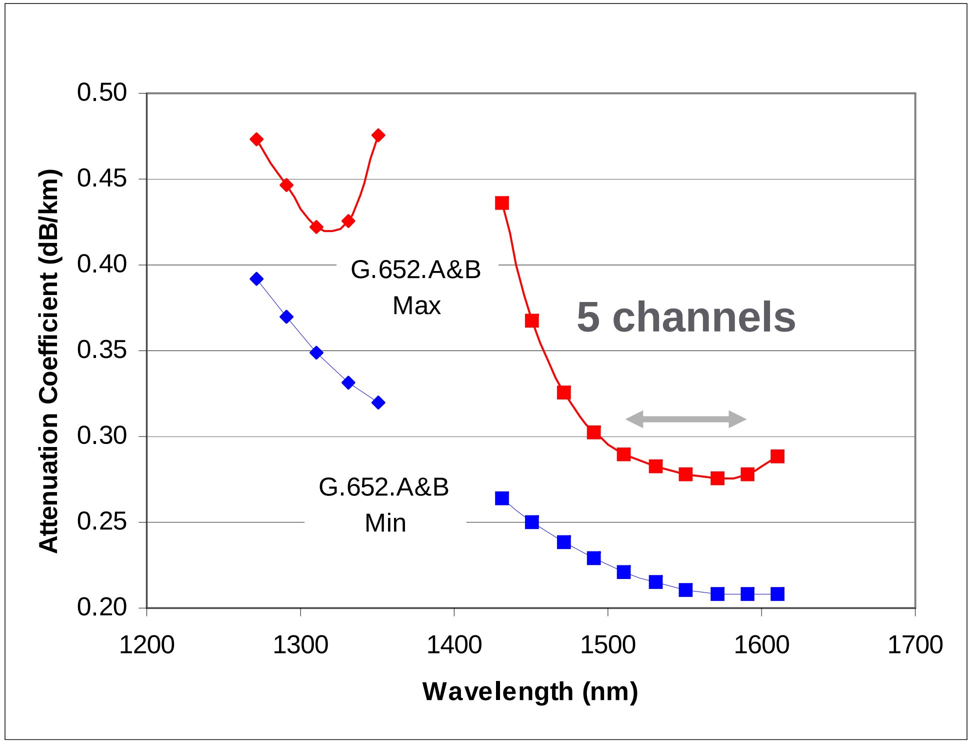
λmax = 1591 + 6.5 = 1597.5 nm

Max dispersion = 20.9 ps/nm/km

Max skew = 1.70 ns / km

Max disp. for 10 km = 209 ps/nm

Max skew for 10 km = 17.0 ns



Fibre loss data from Appendix I/G.695

Summary

Lanes	Spacing	Region nm	Lower nm	Upper nm	Disp ps/nm·km	Skew ns/km
10	20 nm	1550	1424.5	1617.5	21.9	3.15
10	400 GHz	1550	1532.8	1562.9	18.9	0.543
5	20 nm	1300	1264.5	1357.5	-5.94, 5.02	0.172
5	20 nm	1550	1504.5	1597.5	20.9	1.70
4	25 nm	1300	1269	1355.9	-5.46, 4.89	0.147

Appendix I
Equations for G.655 fibre

The following slides give the equivalent dispersion and delay equations for G.655 “non-zero dispersion shifted” fibres

G.655 Fibre dispersion spec

G.655 (NZDSF) defines equations for the minimum and maximum dispersion coefficients of G.655.D and E

1460 to 1550 nm

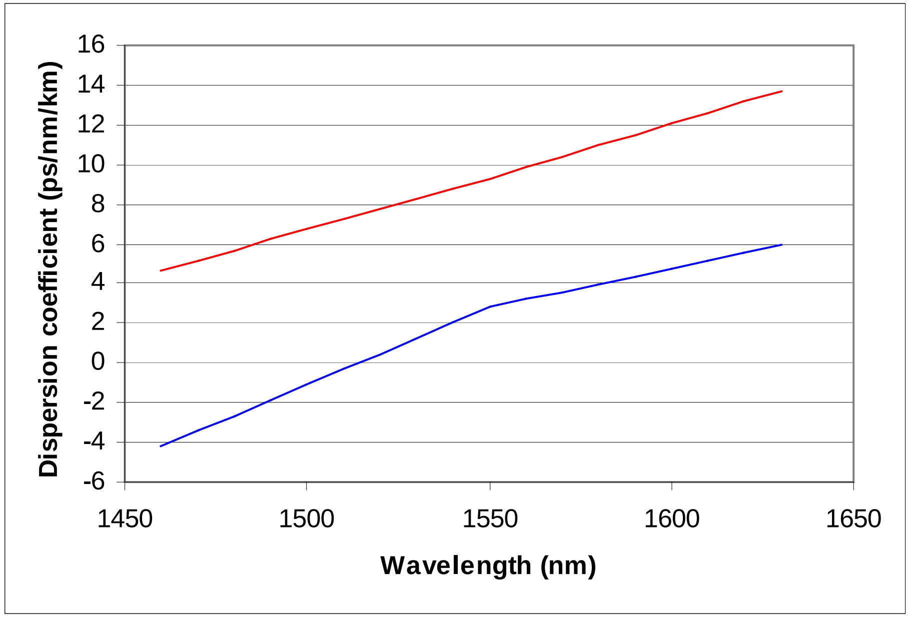
$$D_{max} = \frac{4.65}{90}(\lambda - 1460) + 4.66$$

$$D_{min} = \frac{7.00}{90}(\lambda - 1460) - 4.20$$

1550 to 1625 nm

$$D_{max} = \frac{4.12}{75}(\lambda - 1550) + 9.31$$

$$D_{min} = \frac{2.97}{75}(\lambda - 1550) + 2.80$$



G.655 Delay equations

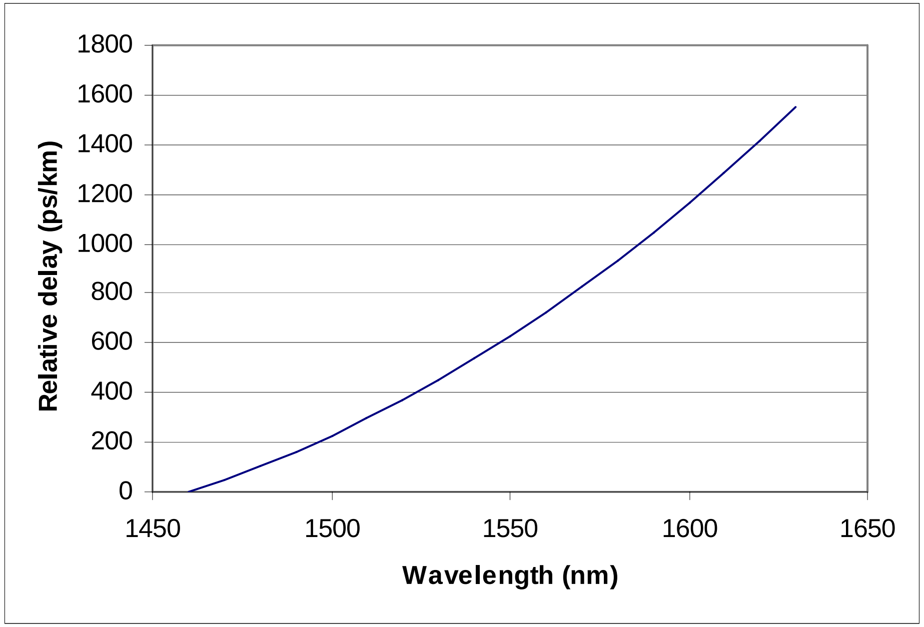
Integrating gives equations for the maximum relative delay coefficient

1460 to 1550 nm

$$\text{Delay}_{max} = \frac{4.65\lambda^2}{180} + \left(4.66 - \frac{4.65 \text{ x } 1460}{90}\right)\lambda + A$$

1550 to 1625 nm

$$\text{Delay}_{max} = \frac{4.12\lambda^2}{150} + \left(9.31 - \frac{4.12 \text{ x } 1550}{75}\right)\lambda + A$$



Thanks!

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