Achieving Gigabit 20 km Transmission - Case Study for Statistical Point-Point Transmission

Y. Lisa Peng

Corning Incorporated

5/07/02

CORNING

Discovering Beyond Imagination

Objective

- Demonstrate an alternative method of PMD specification for EFM to possibly enable:
  - longer reach
  - lower cost
  - fewer PMDs

Background

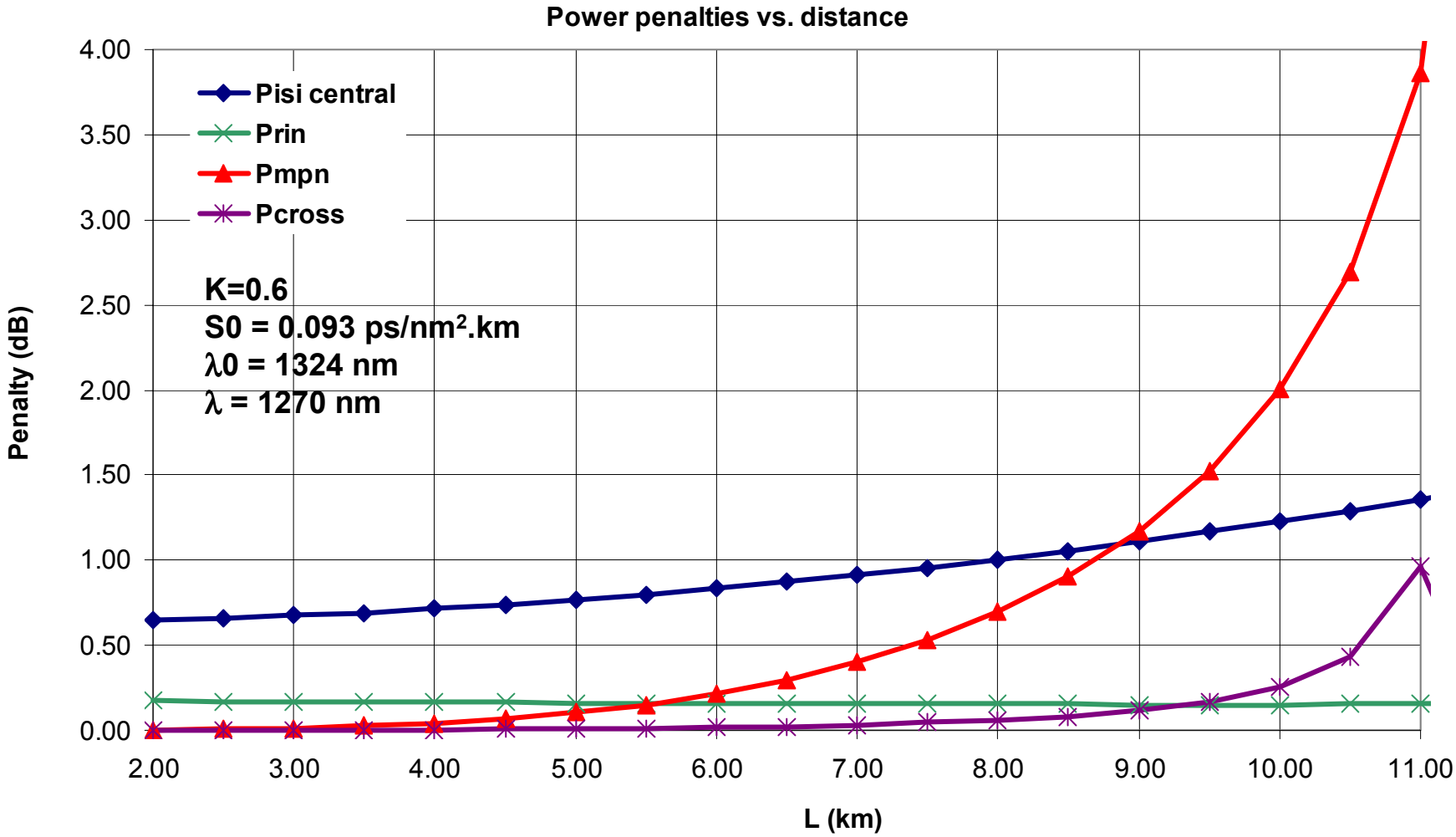
- Point-point system is defined using worst case scenarios from EFM link budget spread sheet
- System can be dispersion limited for transmission at 20km

Statistical design to combat worst case?

Example: Bi- directional P2P PMD proposed

Description	ONU/OLT Module	Unit
Transmitter Type	Bi-directional, 1 fibre	
Signaling speed	1.25	GBd
Link length (range)	0.5 to 10,000	m
Power Budget	10	dB
Wavelength (range)	1270 to 1360	nm
T_{rise}/T_{fall} (Max, 20%-80% response time)	0.26	ns
RMS spectral width (max)	2.4	nm
Average launch power (min)	-9	dBm
Average launch power (max)	-4	dBm
Extinction ratio (min)	9	dB
RIN (max)	-120	dB/Hz
Receiver sensitivity (min)	-19	dBm
Return loss of ODN (min)	20	dB
Return Loss of module (min)	18	dB

Major Power Penalties Under Worst Case Assumption - Output from Link Budget Model



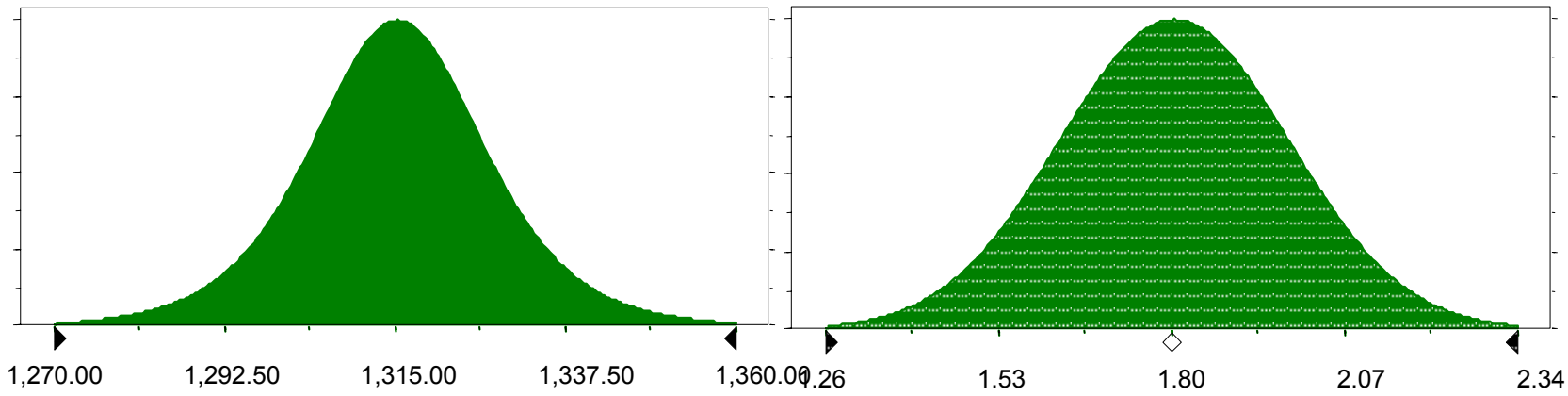
Statistical Implementations to the Link Budget Model

- Assume statistical distribution of major parameters that affect dispersion and leave the other link variables as worst case as defined in the link budget model
- Loss due to fiber and connector, etc. can be implemented later using the same principle

Statistically Defined Parameters

- Single mode fiber: Corning SMF-28™ 20km as one segment
  - dispersion slope
  - zero dispersion wavelength
- Laser distribution assumption
  - central wavelength defined in two ways, see later
  - spectral width

Statistical Inputs and Assumptions for Lasers with Inexplicit Temperature Assumptions



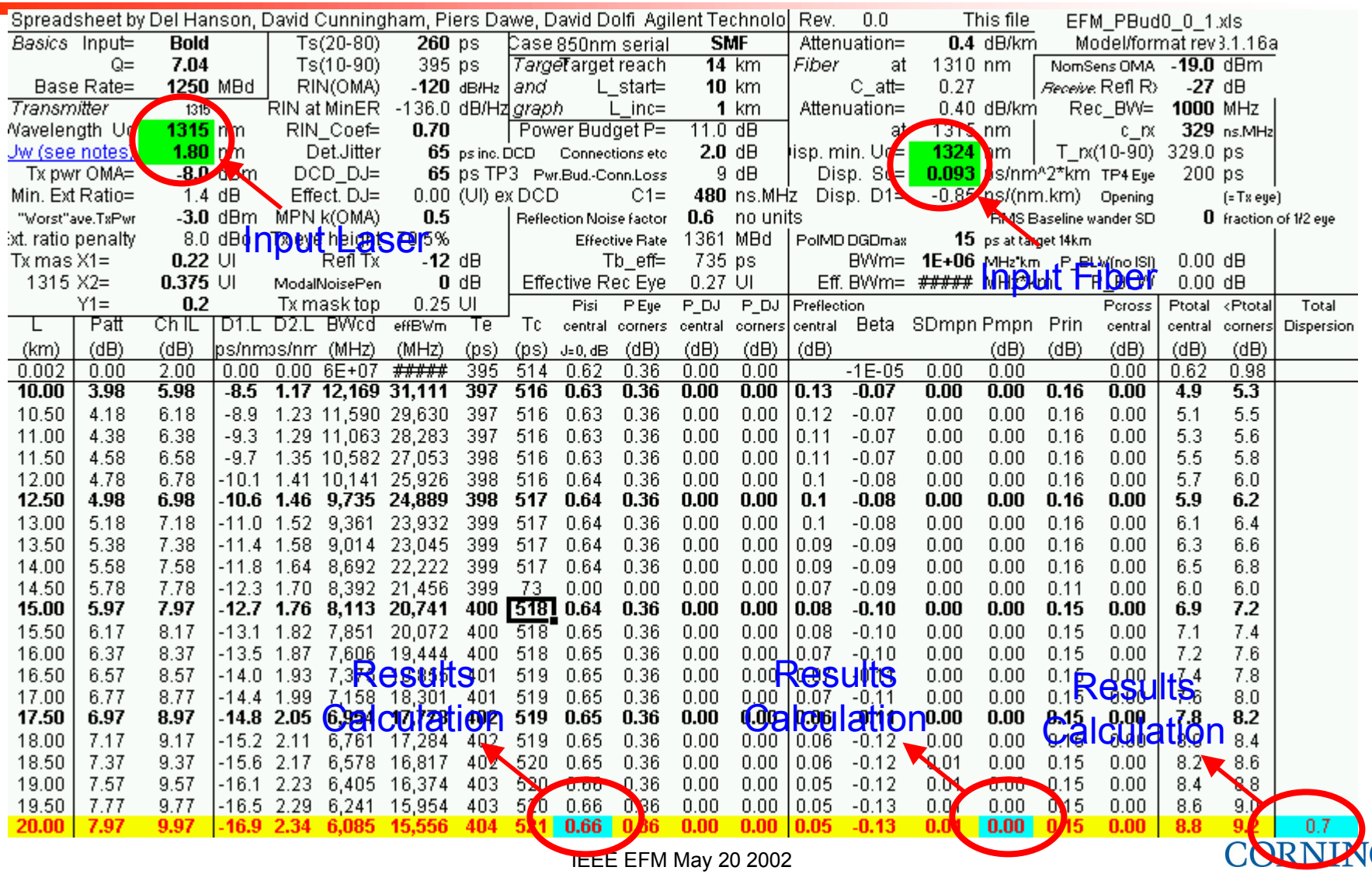
Logistical Distribution
Mean 1315nm
Scale 5.0nm
~ 0.06% wavelength fell outside the specified 1270 - 1360nm range

Normal Distribution
Mean 1.8nm
Stdev 0.18nm

Advantages of Statistical Overlay on Link Model

- Link model widely accepted as a tool
- Combining worst case parameters and statistical parameters to form a reasonably worst case scenario
- In an output friendly fashion - examine multiple output distributions (forecast) simultaneously - see next page

Spreadsheet Inputs and Outputs - Example



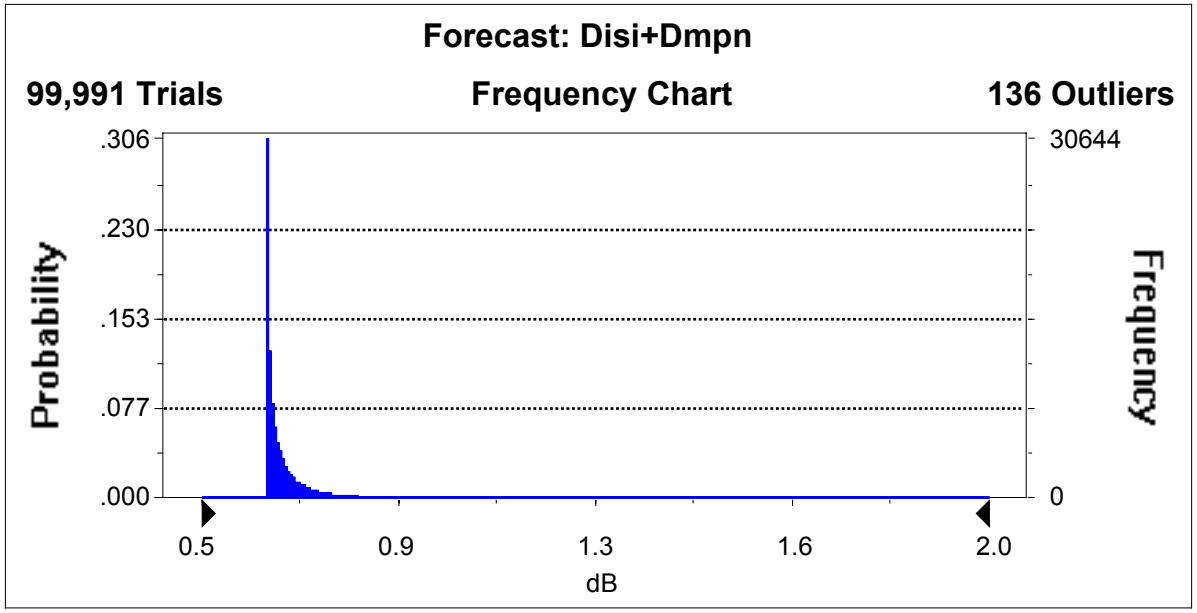
L (km)	Patt (dB)	Ch IL (dB)	D1.L ps/nm	D2.L ps/nm	BWcd (MHz)	effBWm (MHz)	Te (ps)	Tc (ps)	Pisi central J=0, dB	P Eye corners (dB)	P_DJ central (dB)	P_DJ corners (dB)	Preflection central (dB)	Beta	SDmpn	Pmpn (dB)	Prin (dB)	Pcross central (dB)	Ptotal central (dB)	<Ptotal corners (dB)	Total Dispersion
0.002	0.00	2.00	0.00	0.00	6E+07	#####	395	514	0.62	0.36	0.00	0.00		-1E-05	0.00	0.00		0.00	0.62	0.98	
10.00	**3.98**	**5.98**	**-8.5**	**1.17**	**12,169**	**31,111**	**397**	**516**	**0.63**	**0.36**	**0.00**	**0.00**	**0.13**	**-0.07**	**0.00**	**0.00**	**0.16**	**0.00**	**4.9**	**5.3**	
10.50	4.18	6.18	-8.9	1.23	11,590	29,630	397	516	0.63	0.36	0.00	0.00	0.12	-0.07	0.00	0.00	0.16	0.00	5.1	5.5	
11.00	4.38	6.38	-9.3	1.29	11,063	28,283	397	516	0.63	0.36	0.00	0.00	0.11	-0.07	0.00	0.00	0.16	0.00	5.3	5.6	
11.50	4.58	6.58	-9.7	1.35	10,582	27,053	398	516	0.63	0.36	0.00	0.00	0.11	-0.07	0.00	0.00	0.16	0.00	5.5	5.8	
12.00	4.78	6.78	-10.1	1.41	10,141	25,926	398	516	0.64	0.36	0.00	0.00	0.1	-0.08	0.00	0.00	0.16	0.00	5.7	6.0	
12.50	**4.98**	**6.98**	**-10.6**	**1.46**	**9,735**	**24,889**	**398**	**517**	**0.64**	**0.36**	**0.00**	**0.00**	**0.1**	**-0.08**	**0.00**	**0.00**	**0.16**	**0.00**	**5.9**	**6.2**	
13.00	5.18	7.18	-11.0	1.52	9,361	23,932	399	517	0.64	0.36	0.00	0.00	0.1	-0.08	0.00	0.00	0.16	0.00	6.1	6.4	
13.50	5.38	7.38	-11.4	1.58	9,014	23,045	399	517	0.64	0.36	0.00	0.00	0.09	-0.09	0.00	0.00	0.16	0.00	6.3	6.6	
14.00	5.58	7.58	-11.8	1.64	8,692	22,222	399	517	0.64	0.36	0.00	0.00	0.09	-0.09	0.00	0.00	0.16	0.00	6.5	6.8	
14.50	5.78	7.78	-12.3	1.70	8,392	21,456	399	73	0.00	0.00	0.00	0.00	0.07	-0.09	0.00	0.00	0.11	0.00	6.0	6.0	
15.00	**5.97**	**7.97**	**-12.7**	**1.76**	**8,113**	**20,741**	**400**	**518**	**0.64**	**0.36**	**0.00**	**0.00**	**0.08**	**-0.10**	**0.00**	**0.00**	**0.15**	**0.00**	**6.9**	**7.2**	
15.50	6.17	8.17	-13.1	1.82	7,851	20,072	400	518	0.65	0.36	0.00	0.00	0.08	-0.10	0.00	0.00	0.15	0.00	7.1	7.4	
16.00	6.37	8.37	-13.5	1.87	7,606	19,444	400	518	0.65	0.36	0.00	0.00	0.07	-0.10	0.00	0.00	0.15	0.00	7.2	7.6	
16.50	6.57	8.57	-14.0	1.93	7,3[illegible]	[illegible]401	519	0.65	0.36	0.00	0.00	[illegible]			0.00	0.00	0.15	0.00	7.4	7.8	
17.00	6.77	8.77	-14.4	1.99	7,158	18,301	401	519	0.65	0.36	0.00	0.00	0.07	-0.11	0.00	0.00	0.15	0.00	7.6	8.0	
17.50	**6.97**	**8.97**	**-14.8**	**2.05**	**6,9[illegible]**	**17,[illegible]**	**402**	**519**	**0.65**	**0.36**	**0.00**	**0.00**	**0.06**	**-0.11**	**0.00**	**0.00**	**0.15**	**0.00**	**7.8**	**8.2**	
18.00	7.17	9.17	-15.2	2.11	6,761	17,284	402	519	0.65	0.36	0.00	0.00	0.06	-0.12	0.00	0.00	0.15	0.00	8.0	8.4	
18.50	7.37	9.37	-15.6	2.17	6,578	16,817	402	520	0.65	0.36	0.00	0.00	0.06	-0.12	0.01	0.00	0.15	0.00	8.2	8.6	
19.00	7.57	9.57	-16.1	2.23	6,405	16,374	403	520	0.66	0.36	0.00	0.00	0.05	-0.12	0.01	0.00	0.15	0.00	8.4	8.8	
19.50	7.77	9.77	-16.5	2.29	6,241	15,954	403	520	0.66	0.36	0.00	0.00	0.05	-0.13	0.01	0.00	0.15	0.00	8.6	9.0	
20.00	**7.97**	**9.97**	**-16.9**	**2.34**	**6,085**	**15,556**	**404**	**521**	**0.66**	**0.36**	**0.00**	**0.00**	**0.05**	**-0.13**	**0.01**	**0.00**	**0.15**	**0.00**	**8.8**	**9.2**	**0.7**

System Reliability Assumption

- **Total dispersion penalty** less than 2 dB
  - total dispersion is defined as Pisi + Pmpn;
  - small MPN penalty;

  (2dB total dispersion is a stringent criteria - build guard band in reliability);
- ~ 99% Reliability requirement assumed - 99% of chance for success transmission or 99% of link does not exceed 2dB total dispersion penalty

Monte Carlo Simulation Results - 100,000 Trials



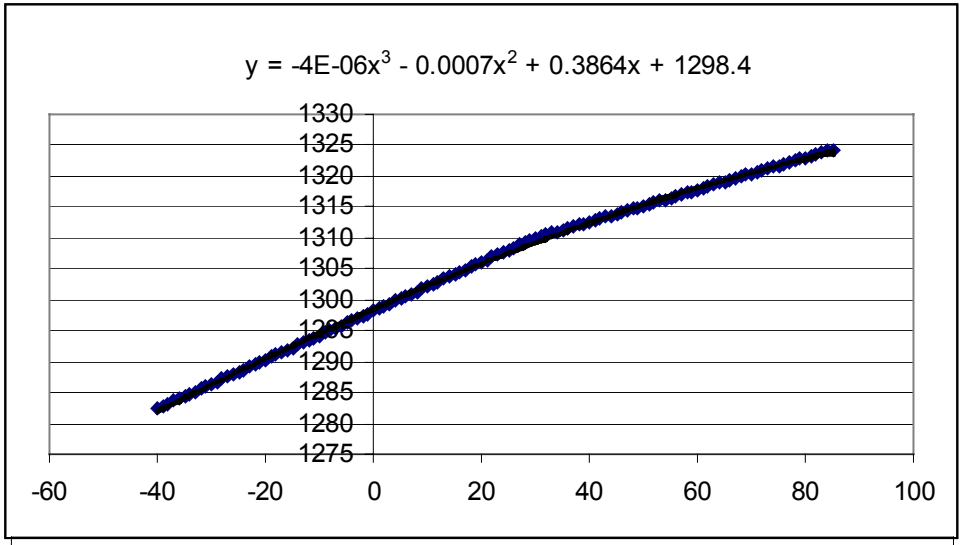
Reliability: ~99.86% when k=0.5

More Scenarios with Explicit Temperature Assumptions

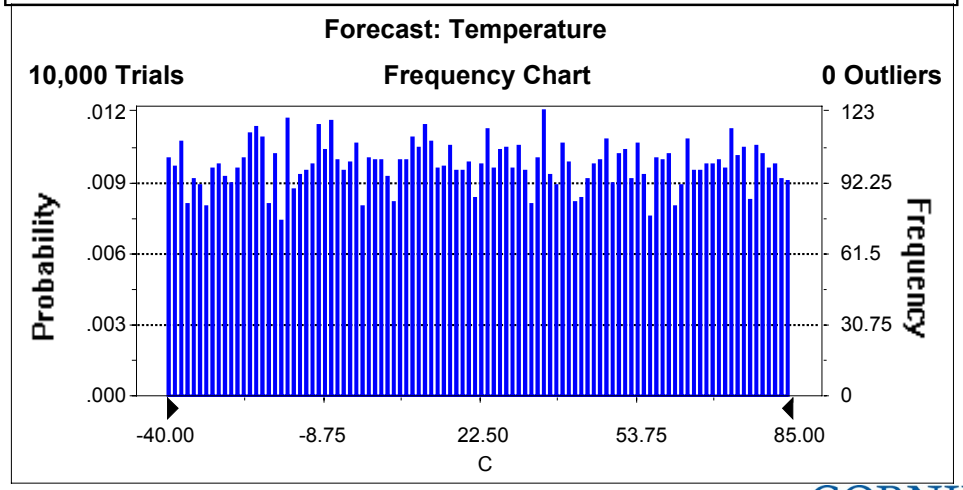
- Adding temperature assumptions
  - Uniform distribution across -40 - +85ºC See next page
- Using a laser with 1298±5nm at 0ºC and spectral width of 1.8±0.18nm (according info from one supplier)
- Assuming laser-temperature variation See next page

Temperatures

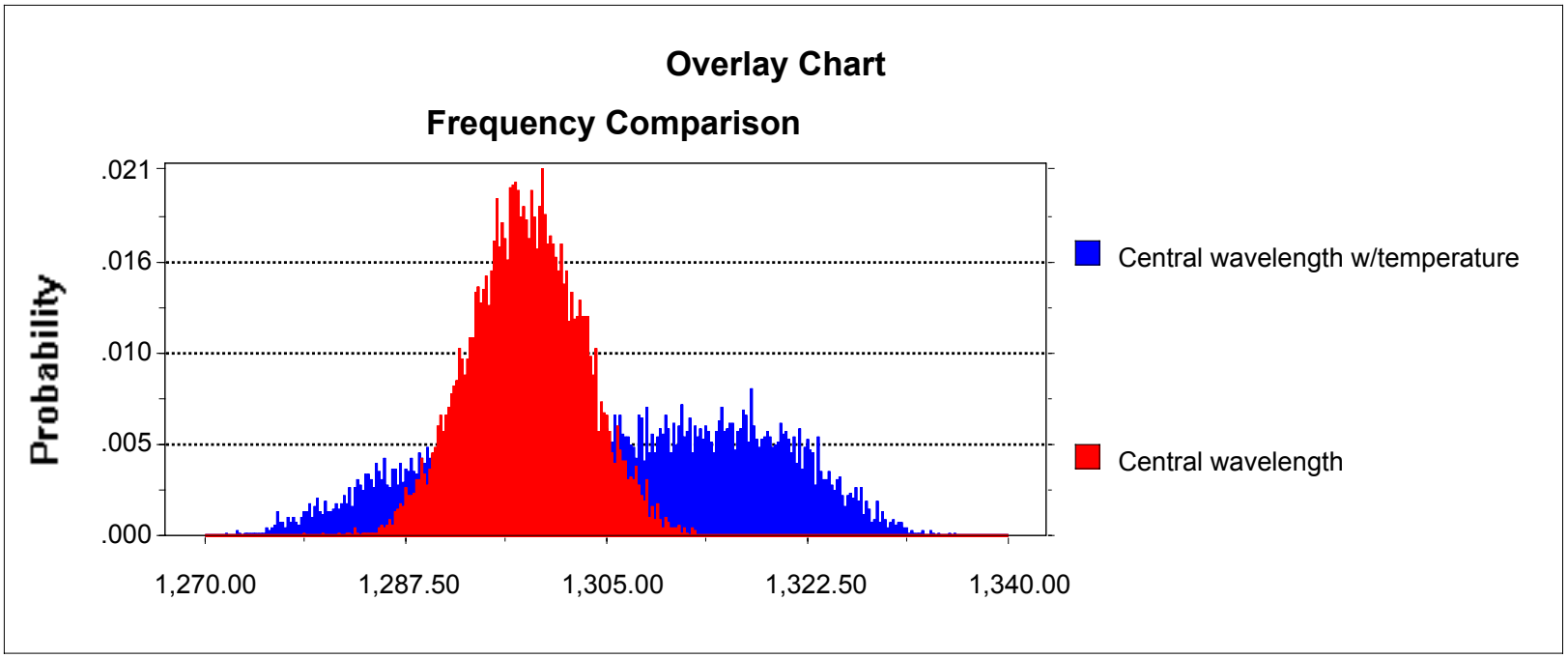
Temperature variation of laser



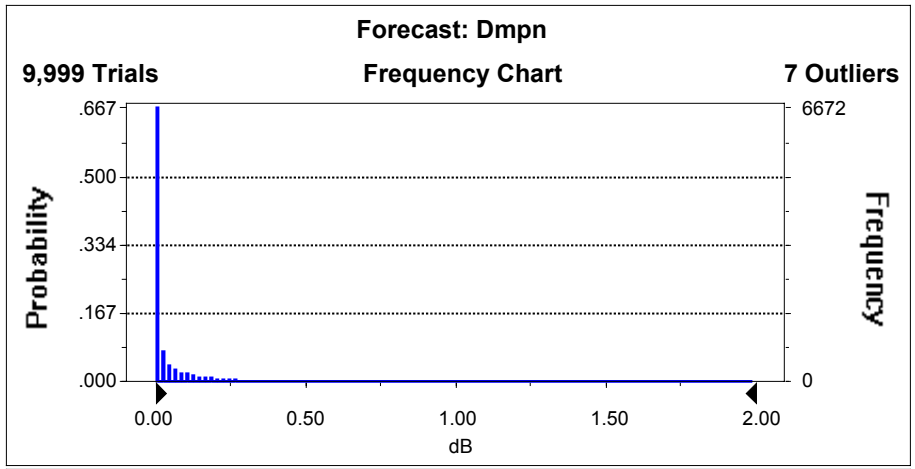
Assumed temperature distribution

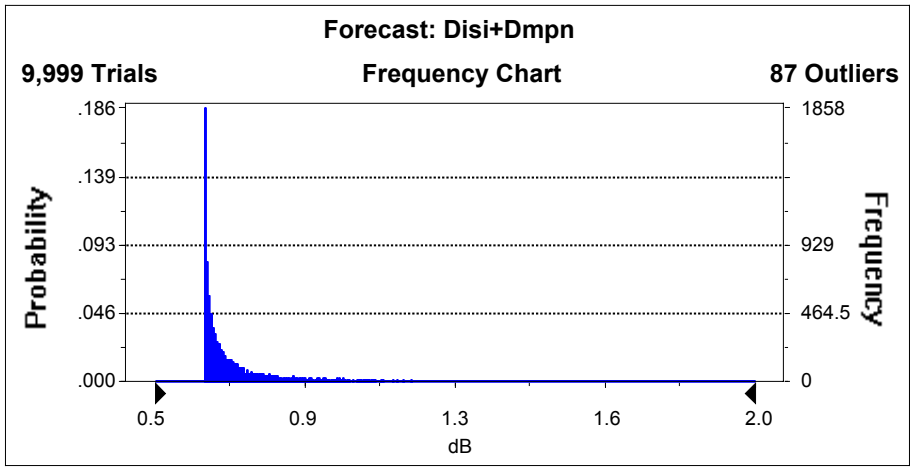


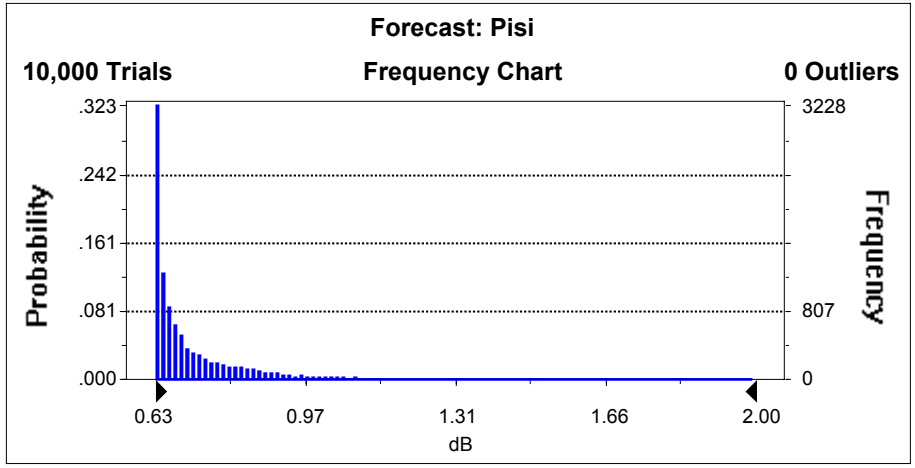
Central Wavelength Changes Due to Adding Temperature Impact



Simulation Results - 10,000 trials







Reliability: ~99.13% when k=0.5

Conclusion - 20km Transmission Feasible Statistically

- Lasers and following property will allow 20km transmission, assuming k = 0.5 and at least 99% success rate:
  - Central wavelength of 1315±5 nm (logistical) and spectral width of 1.8±0.18 nm (normal), covering 1270-1360nm for extended temperature assumption
  - Central wavelength of 1298±5 (normal at 0ºC) and spectral width 1.8± 0.18 nm (normal) under uniform temperature assumption from -40 - +85ºC
- The current G.652 fiber as specified should support the above laser specs.
- Assumed total dispersion penalty should provide design guard banding
  - Using MPN of 2dB would produce a lot looser requirements
- The case applies to P2MP since same dispersion issue present