10G EDC For SMF

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- Adapted from OFC'06 Paper OTuE3 slide deck
  - EDC_Interop_OFC_Mar06.ppt
  - Here is the link to the paper

    http://www.asipinc.com/pdf/OFC06_EDC10c.pdf
- Highlight multi-vendor EDC interop results within the scope of OIF/ITU project
  - Help generate ITU G.959.1 120km SMF apps code for 2400 ps/nm.
- Need liaison to OIF/ITU for further details or other EDC SMF activities.
  - Also other EDC activities in T11/SFP+, backplane, LRM, etc.

Experimental Results of EDC Based Receiver for 2400 ps/nm at 10.7 Gb/s for Emerging Telecom Standards

Keith Conroy, Shaw Yuan and Oswin Schreiber

AMCC

Ali Ghiasi, Adil Dastur and Afshin Momtaz

Connecting everything™ BROADCOM

Abhijit Shanbhag and Edem Ibragimov

Scintera NETWORKS

Frank Chang, Badri Gomatam and George Noh

VITESSE

Jerry Wood

ESSEX

Ram Jambunathan

Apogee PHOTONICS

OFC 2006

Paper OTuE3

http://www.asipinc.com/pdf/OFC06_EDC10c.pdf

Multi-Vendor EDC Testing: Objectives

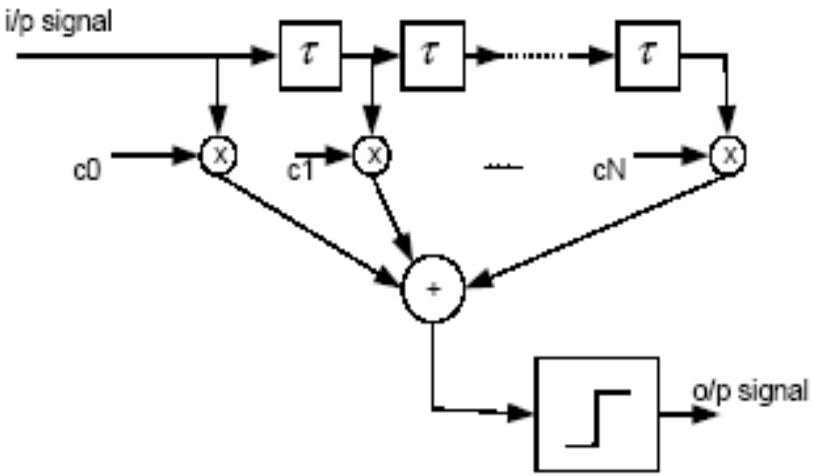
- Demonstrate Transverse Compatibility: For each application code, a transmitter source type and more than one EDC receiver will meets 2400 ps/nm application code.
- Focus on high OSNR applications “booster configuration”.
- Extend the link to 2400 ps/nm using 1600-2000 ps/nm transmitters with EDC.
- Specify for Transmitter Compliance: Identify parameter(s) that distinguishes a transmitter passing/failing the application code.
- Demonstrate multi-vendor Interoperability.

EDC Interop

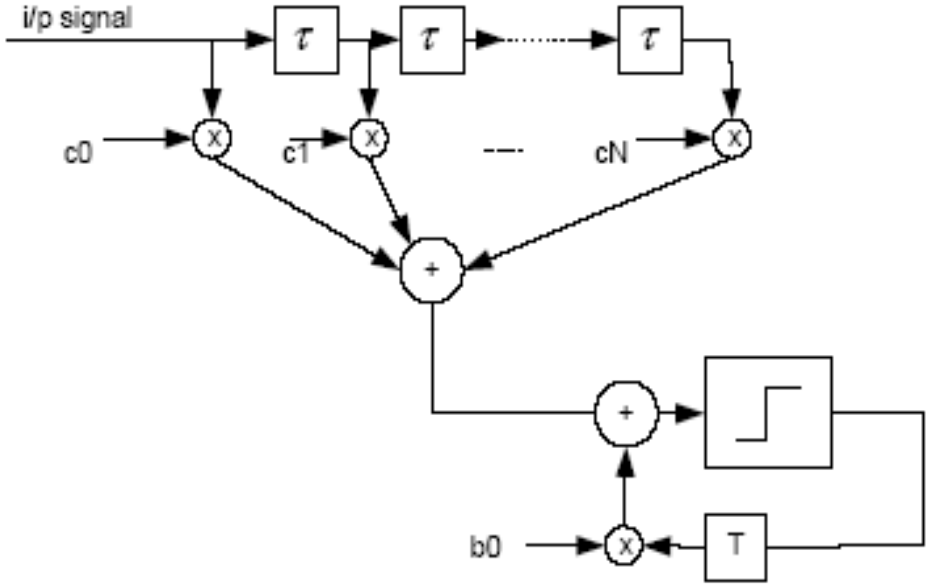
- Sponsored and facilitated by OIF
- Interop output to support ITU SG-15 EDC application code incorporated in to G.959.1 for 2400 ps/nm
- Seven companies participated
  - EDC supplier
    - AMCC
    - Broadcom
    - Scintera/Vitesse
  - Optics / Module Provider
    - Apogee Photonics
    - Avanex
    - Azna
    - Essex

Well Known Classical EDC Implementations

- FIR – Analog or Digital Implementation
- DFE – Analog or Digital Implementation
- MLSE – Digital Implementation is only practical



Linear Feedforward Equalizer (FIR)



Decision Feedback Equalizer

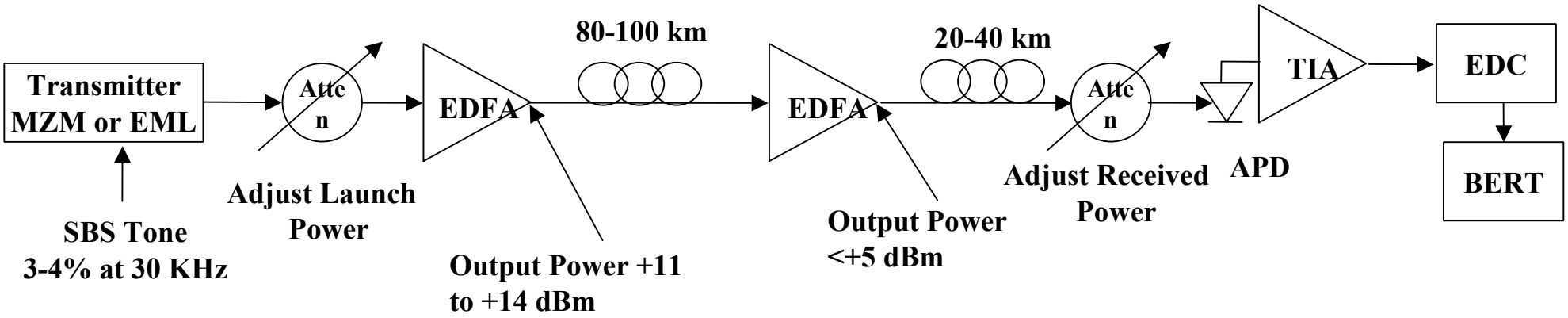
OIF OPTICAL INTERNETWORKING FORUM

Underlying Reason to use EDC

- Extend the reach to greater than 2400 ps/nm without optical compensation.
- Simplify network deployment
- Relaxes network reconfiguration
- Lower the cost
- Low power
- Allow cheaper optics and help power budgets
- Silicon CMOS driven market economy and scaling

Booster Configuration (P)1V1-2B2(F)E

- The main challenge here is due to high power and SPM



Tx baseline characteristics

	ER	Launch power Into fiber	Path lengths
Value	> 8.2dB	+10 to +14 dBm	0ps/nm – 2400 ps/nm

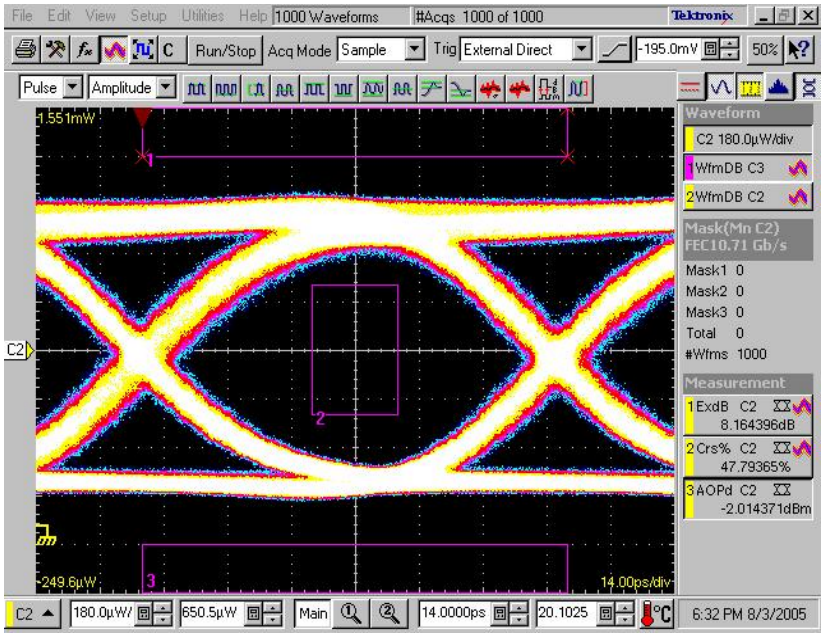
Booster-based Application Code for P1V1-2B2E and 1V1-2B2FE

Parameter	Units	P1V1-2B2E	1V1-2B2FE
G.691 Application Code		-	-
General Information			
Maximum Number of Channels	-	1	1
Bit rate/line coding of optical tributary signals	-	NRZ 10G	NRZ OTU2
Maximum bit error ratio	-	10^{-12}	10^{-12}
Fibre type	-	G.652	G.652
Interface at point MPI-S			
Operating wavelength range	nm	1530-1565	1530-1565
Source Type	-	SLM	SLM
Maximum spectral power density	mW/10MHz	ffs	ffs
Minimum SMSR	dB	30	30
Maximum mean output power	dBm	14	14
Minimum mean output power	dBm	11	11
Minimum extinction ratio	dB	8.2	8.2
Eye Mask	-	NRZ 10G 1550 nm	NRZ 10G 1550 nm
Optical path from point MPI-S to MPI-R			
Maximum Attenuation	dB	33	33
Minimum Attenuation	dB	21	21
Maximum chromatic dispersion	ps/nm	+2400	+2400
Minimum optical return loss at MPI-S	dB	24	24
Maximum discrete reflectance between MPI-S and MPI-R	dB	27	27
Maximum differential group delay	ps	30	30
Interface at point MPI-R			
Maximum mean input power	dBm	-7	-7
Minimum sensitivity	dBm	-24	-24
Maximum optical path penalty	dB	2	2
Maximum optical path penalty with EDC bypass at receiver	dB	10	7

Chirped MZM Baseline Link Performance

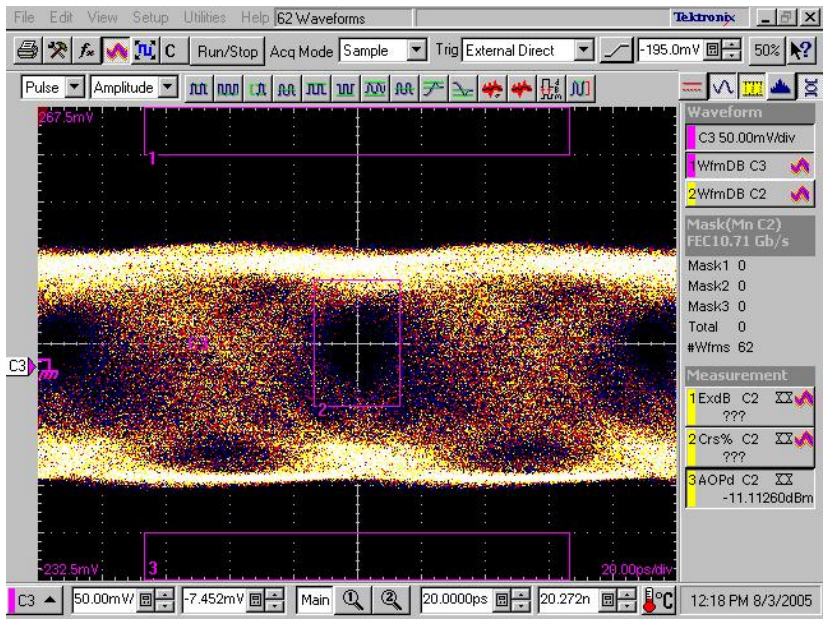
- Eye diagrams for Chirped MZM at B2B and 140km

B2B (filtered)



ER=8.5dB

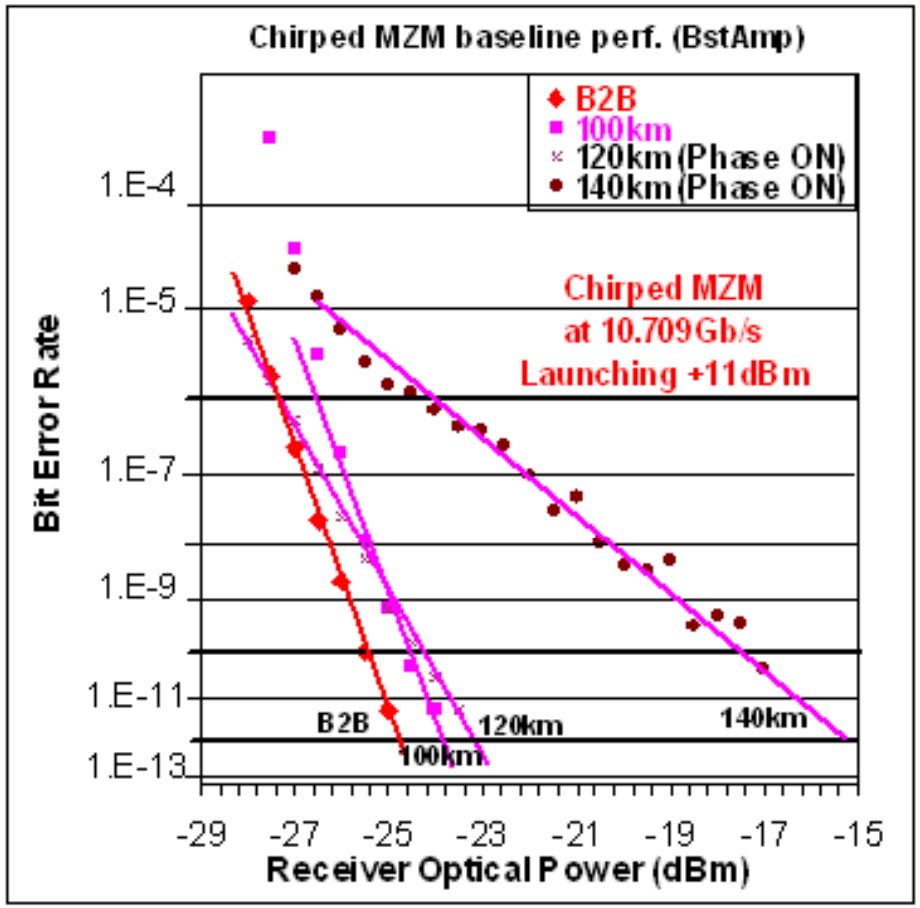
140 km



Relax ER from 9 dB to 8.2 dB to allow chirped x-cut $LiNbO_3$ MZM to be compliant transmitter.

Chirped MZM Baseline Link Performance

- Chirped MZM optimized for 120 km (2000 ps/nm) (with EDC bypass)

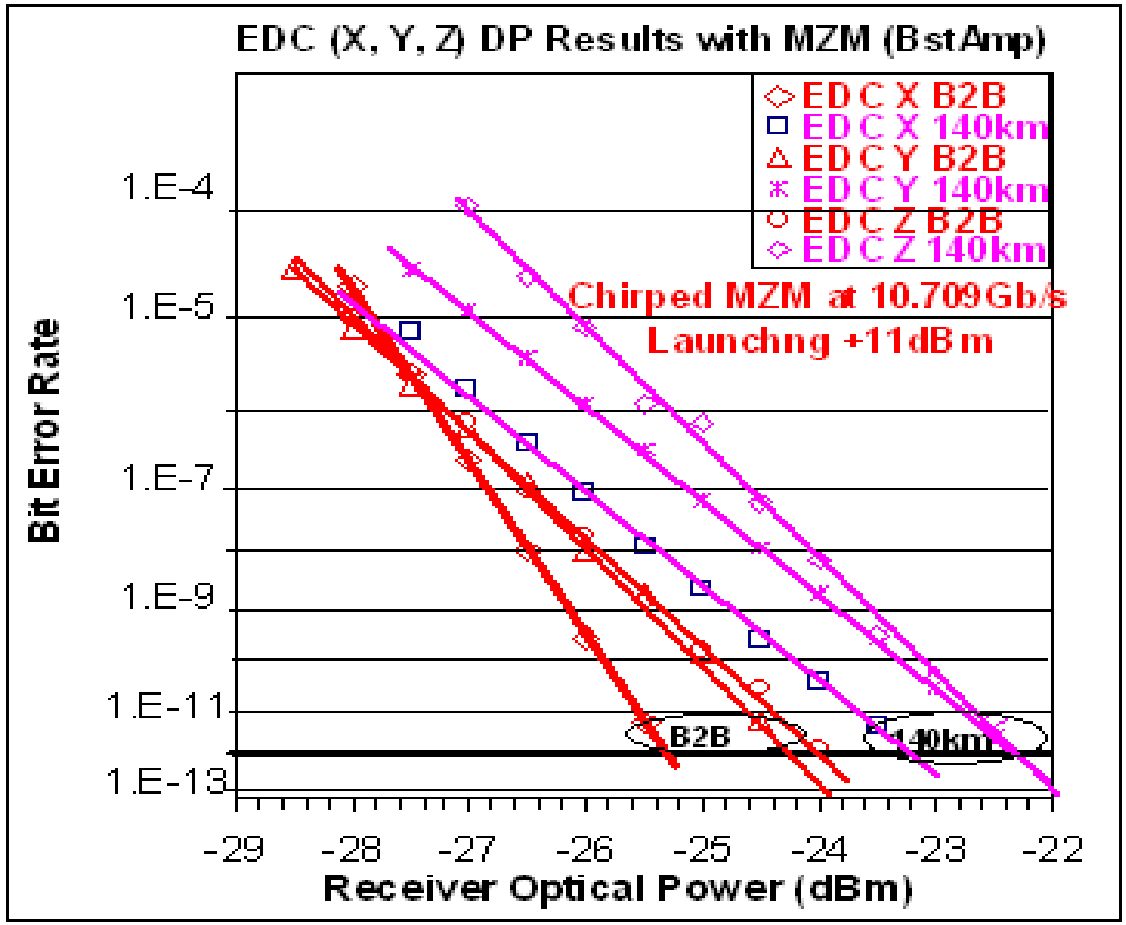


Notes: Disp. penalty ~1.5 dB for 120 km; 9.2 dB for 140 km

Not much improvement from SPM or launch power at 140 Km.

Chirped MZM+EDC Link Performance

- Multi-vendor EDC for 140 km (~2400 ps/nm)

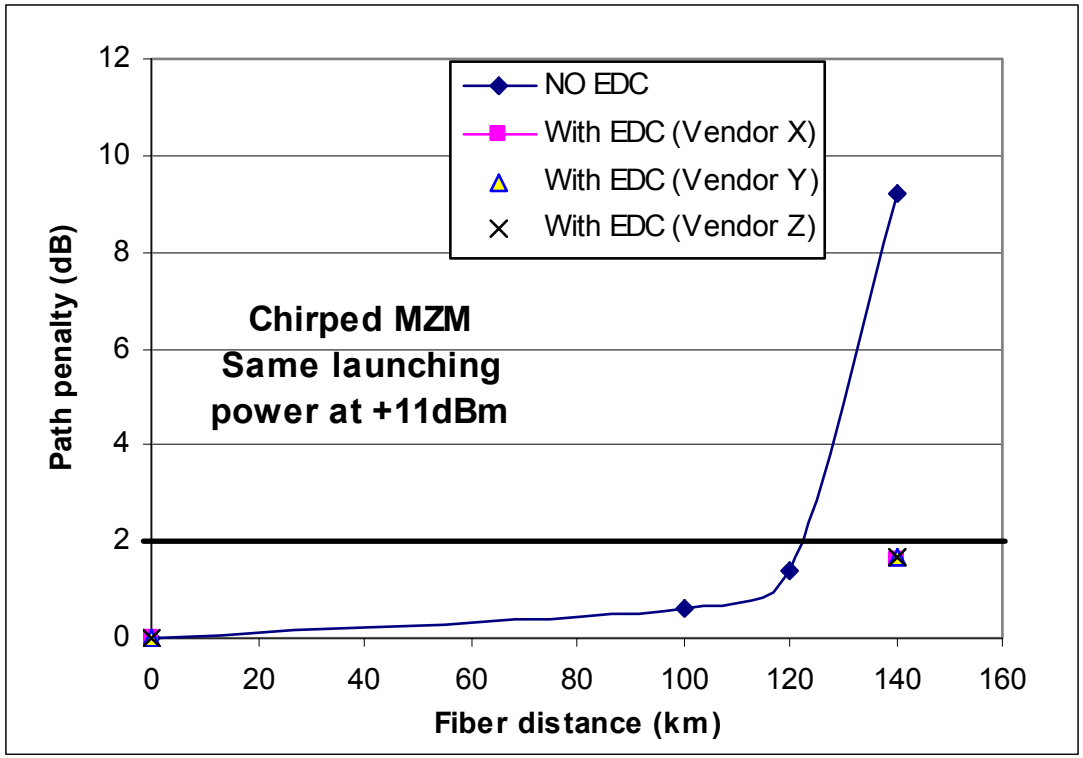


Launch Power +11 dBm

Confirm NO BER flooring for BER at 10^{-12} (Error free for at least 3min for Rx power greater than -22 dBm)

Path Penalty for multi-vendor EDC with chirped MZM

- Summary for chirped MZM for BER 1E-12



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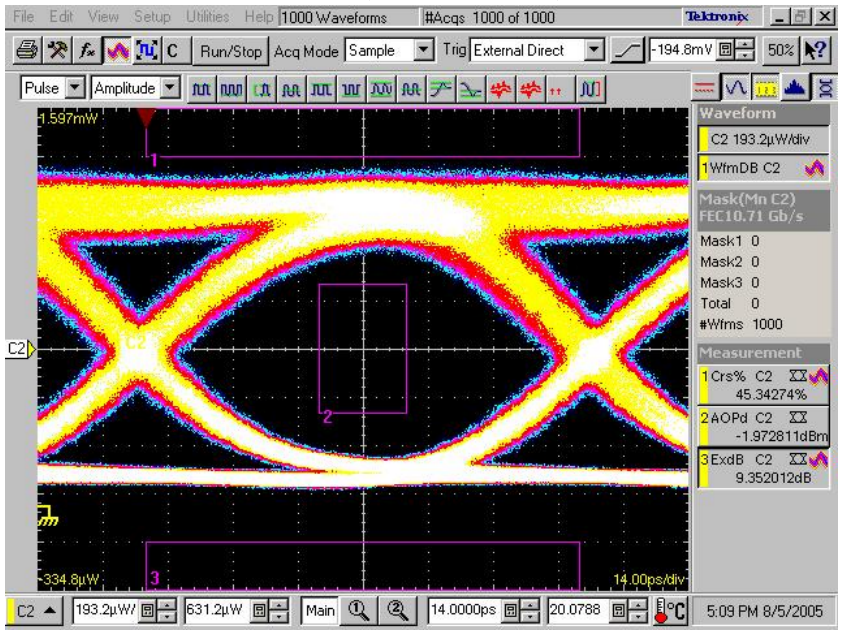
Chirped EML Baseline Link Performance

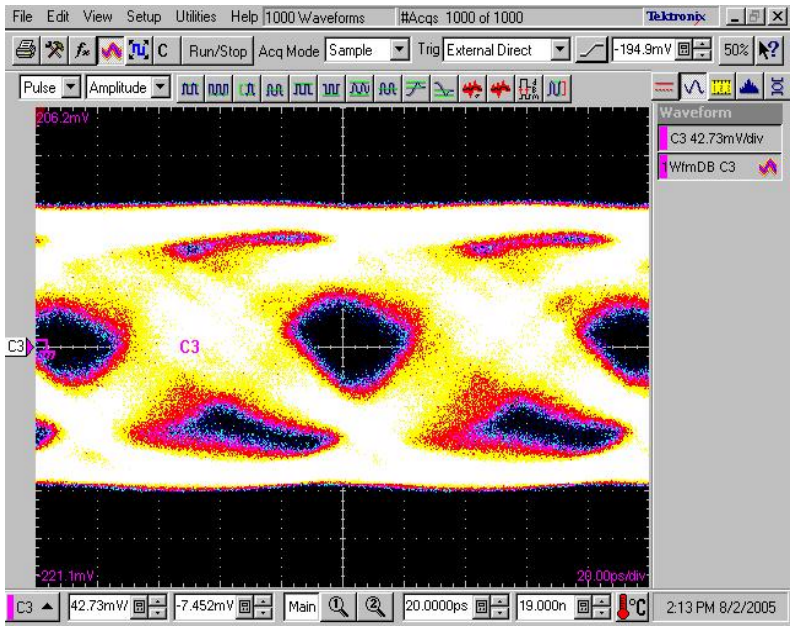
- Eye diagrams for Chirped EML at B2B and 140 km (EDC bypass)

B2B (filtered)



ER=9.4 dB

140 km

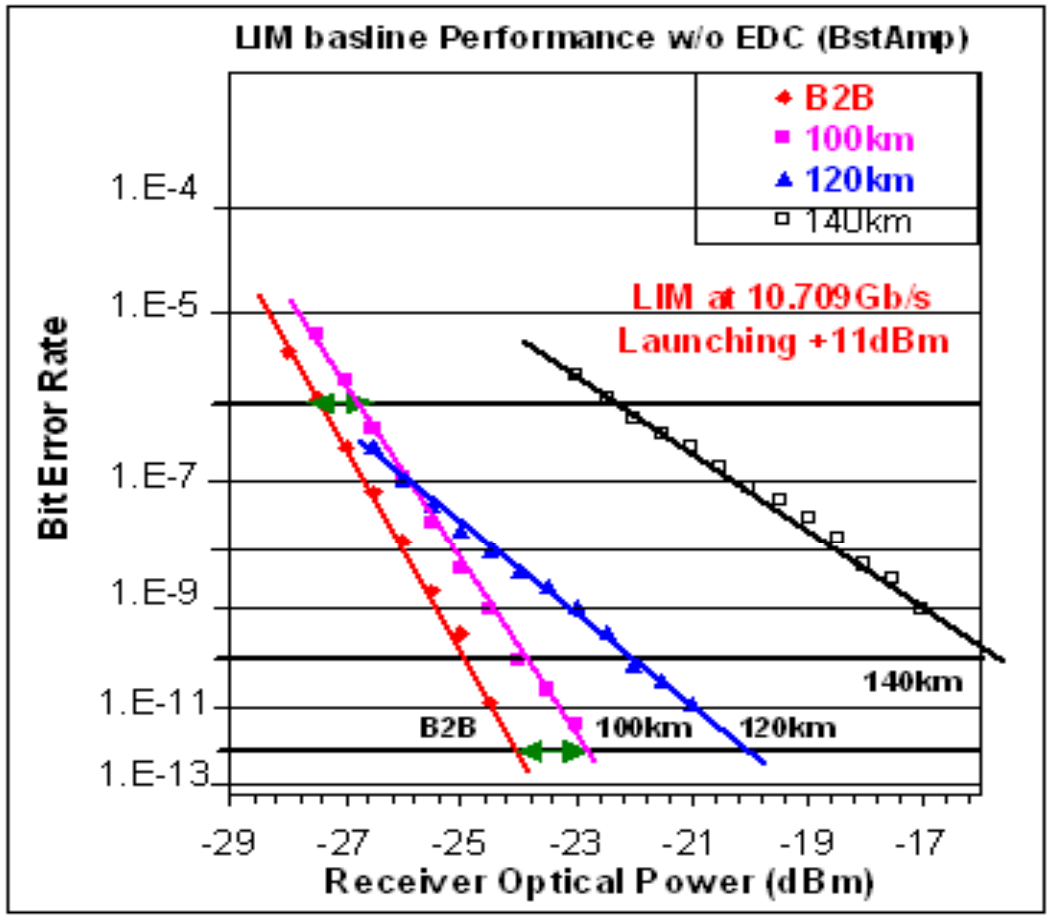


(Without SBS tone)

OIF OPTICAL INTERNETWORKING FORUM

Chirped EML Baseline Link Performance

- Chirped EML optimized (EDC bypass)



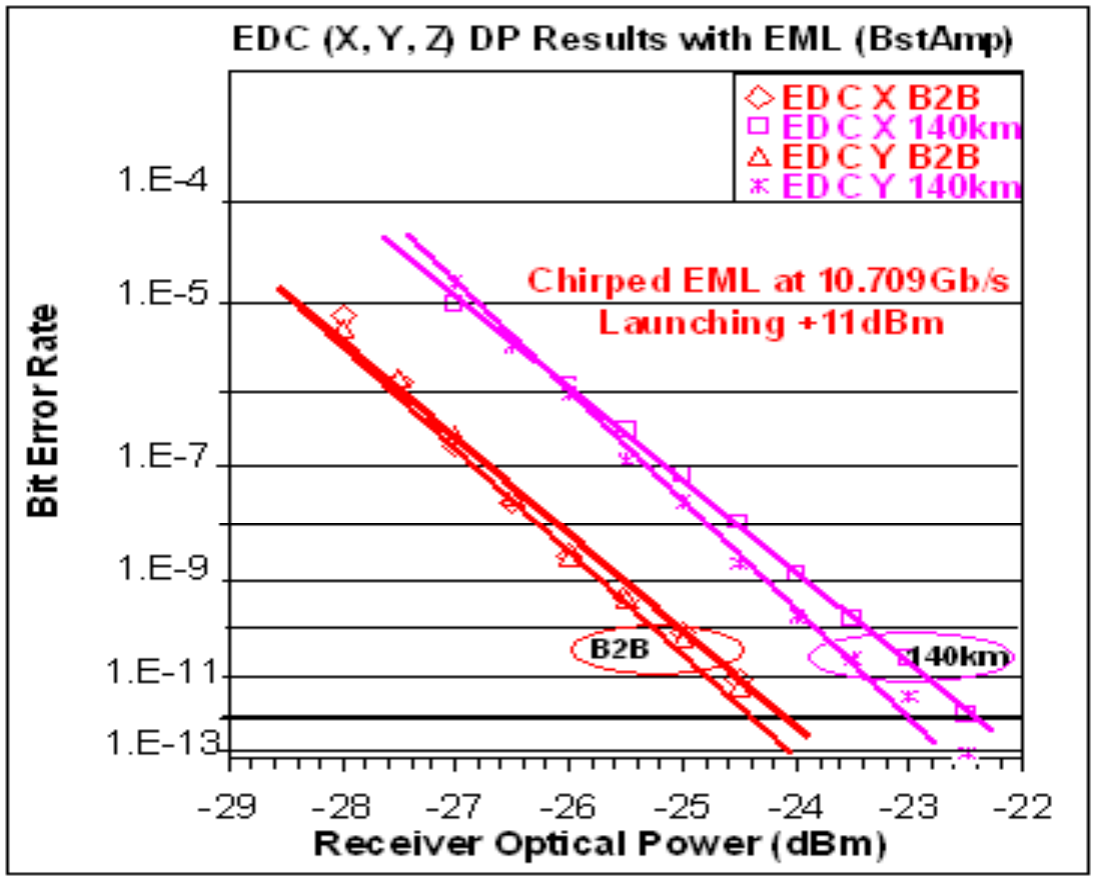
Launch Power 11 dBm

Disp. penalty ~1.2 dB for 100 km and 11.2 dB at 140 km.

OIF OPTICAL INTERNETWORKING FORUM

Chirped EML+EDC Link Performance

- Multi-vendor EDC for 140 km (~2400 ps/nm)



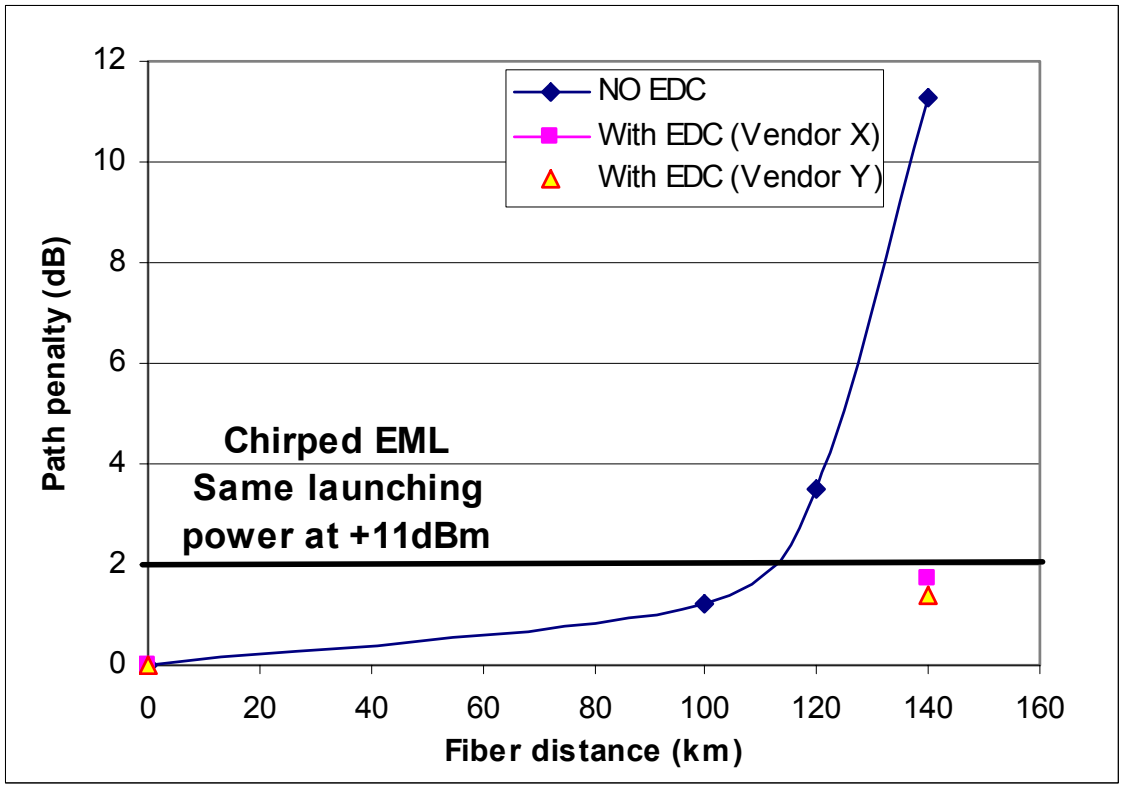
Launch Power 11 dBm

Confirm NO BER flooring for BER at 10^{-12} (Error free for at least 3min for Rx power greater than -22dBm)

OIF OPTICAL INTERNETWORKING FORUM

Path Penalty for multi-vendor EDC with Chirped EML

- Summary for Chirped EML for BER 1E-12



OIF OPTICAL INTERNETWORKING FORUM

Correlation Parameter for Transmitter Compliance

- Recommended to use: “Maximum Optical Path penalty with EDC bypassed at receiver” for transmitter with exponentially growing penalty at 2400 ps/nm.
  - Parameter to be set to 10 dB for P1V1-2B2E.
  - Parameter to be set to 7 dB for 1V1-2B2FE.
- Alternative parameter: BER measured with EDC bypassed at receiver as measured at reach.
  - Parameter to be set between 10^{-6} and 10^{-7}.

Summary

- Feasibility of Booster-based application codes (P1V1-2B2E, 1V1-2B2FE) demonstrated
  - A transmitter source type and more than one EDC supplier meets the application code.
- To guarantee 2 dB path penalty at 2400 ps/nm “Optical path penalty with EDC-bypassed at receiver” is introduced
- Multi-vendor Interoperability demonstrated
  - Multi-vendor EDC receivers interoperable with more than one type of transmitter demonstrated.
- Addressed issues relating to sensitivity and link parameters for booster configuration at 2400 ps/nm.

Backup

Chirp MZM Summary Results with EDC

- BER 1E-6 Summary

Vendor	B2B	140Km	Dispersion Penalty
X	-27.3 dBm	-26.8 dBm	0.5 dB
Y	-27.2 dBm	-26 dBm	1.2 dB
Z	-27.2 dBm	-25.4 dBm	1.8 dB

- BER 1E-12 Summary

Vendor	B2B	140Km	Dispersion Penalty
X	-25.1 dBm	-23.5 dBm	1.6 dB
Y	-24.1 dBm	-22.4 dBm	1.7 dB
Z	-24.0 dBm	-22.3 dBm	1.7 dB

EML Summary Results with EDC

- BER 1E-6 Summary

Vendor	B2B	140Km	Dispersion Penalty
X	-27.5	-26.0 dBm	1.5 dB
Y	-27.5	-26.3 dBm	1.2 dB
Z	*	*	*

- BER 1E-12 Summary

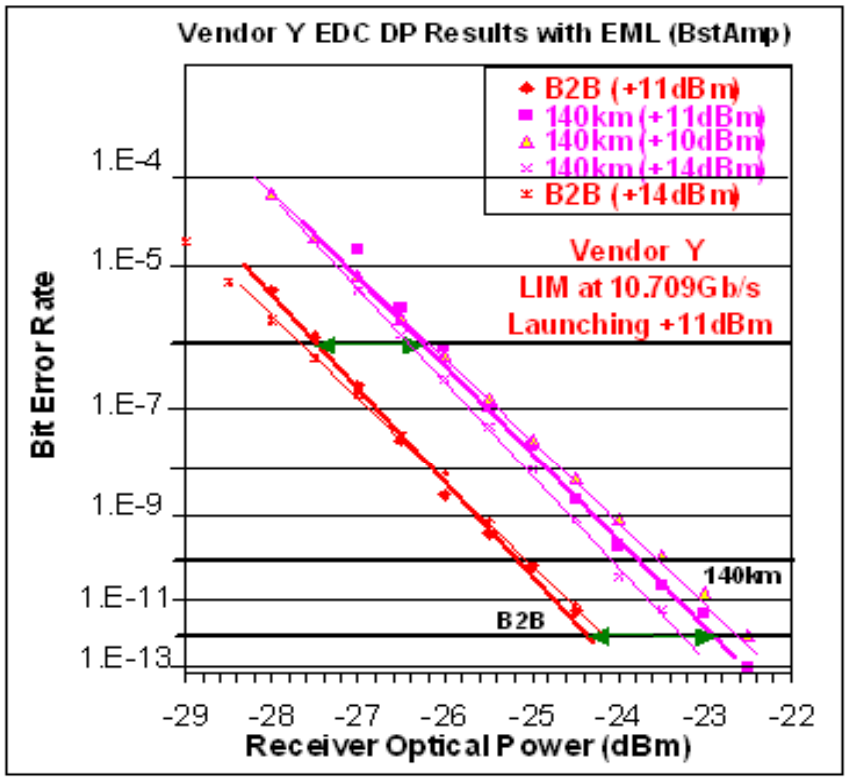
Vendor	B2B	140Km	Dispersion Penalty
X	-24.2 dBm	-22.5 dBm	1.7 dB
Y	-24.3 dBm	-22.9 dBm	1.4 dB
Z	*	*	*

* Due to time constrain Vendor Z was not tested in this configuration.

Effect of Transmit Launch Power on Link Performance

- Take one EDC as example to show the impact of varying the transmitter powers

Vendor Y	B2B (+11dBm)	B2B (+14dBm)	140km (+11dBm)	140km (+10dBm)	140km (+14dBm)
BER=10^{-6}:	-27.5dBm	-27.7dBm	-26.3dBm	-26.2dBm	-26.4dBm
BER=10^{-12}:	-24.3dBm	-24.2dBm	-22.9dBm	-22.7dBm	-23.2dBm



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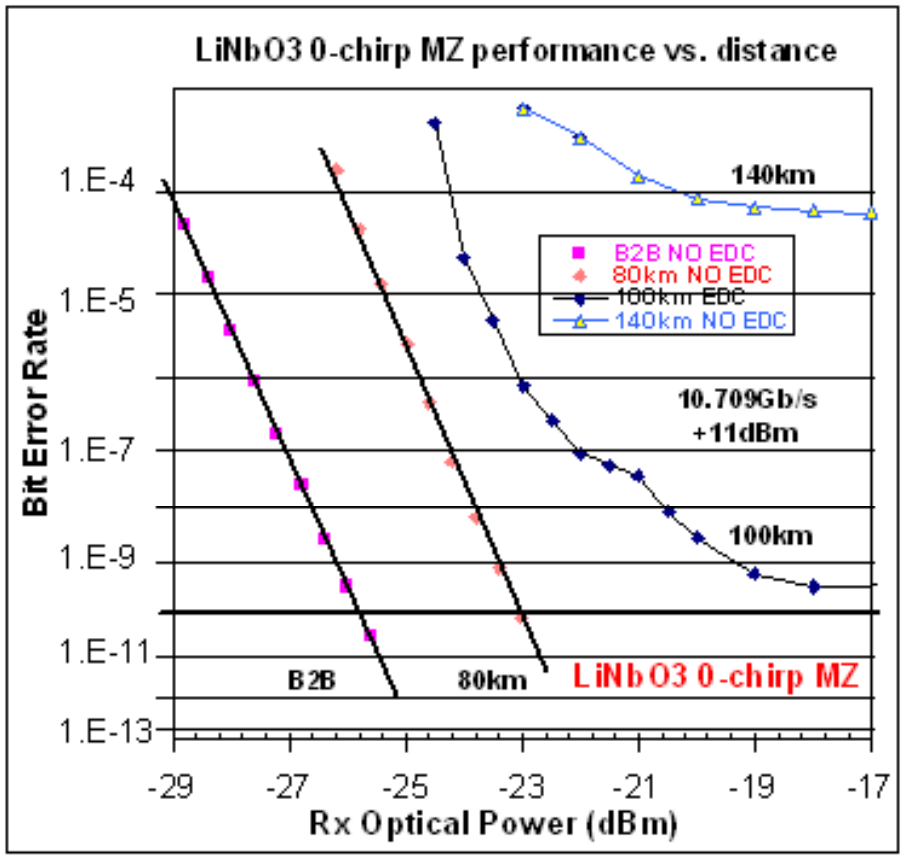
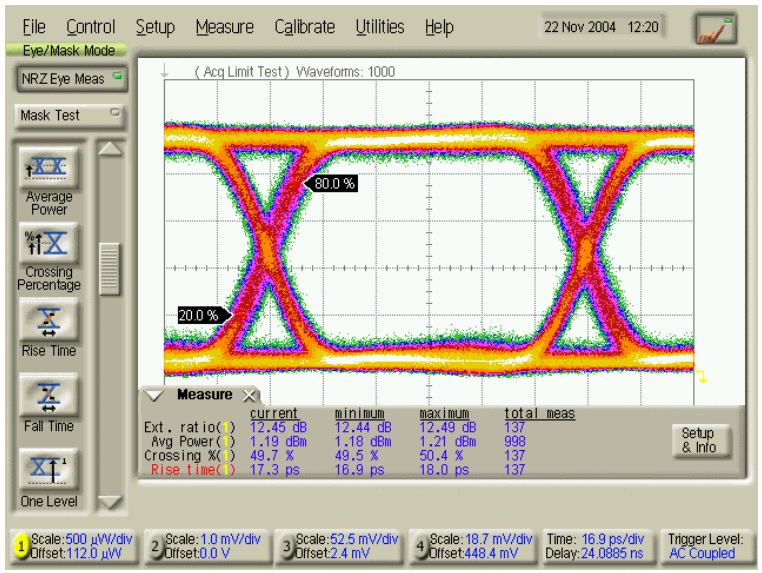
0-Chirp MZM Link Performance

- 0-chirp MZM optimized for 60km(1200ps/nm) with EDC bypass

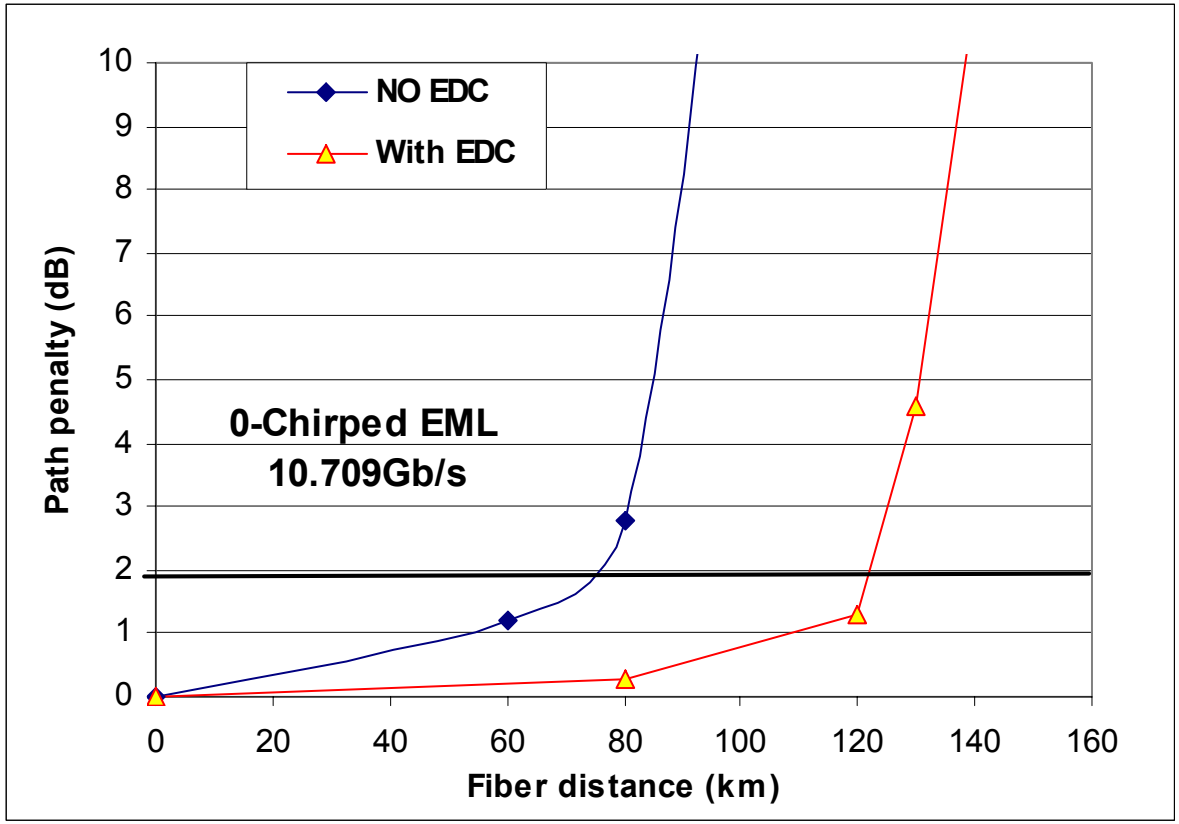




ER=12.5 dB

0-Chirp MZM Link Performance

- Disp. penalty with and w/o EDC



Disp. penalty >2 dB for 130 km or higher with EDC; not compliant to application code.