40 Gbps and Plus

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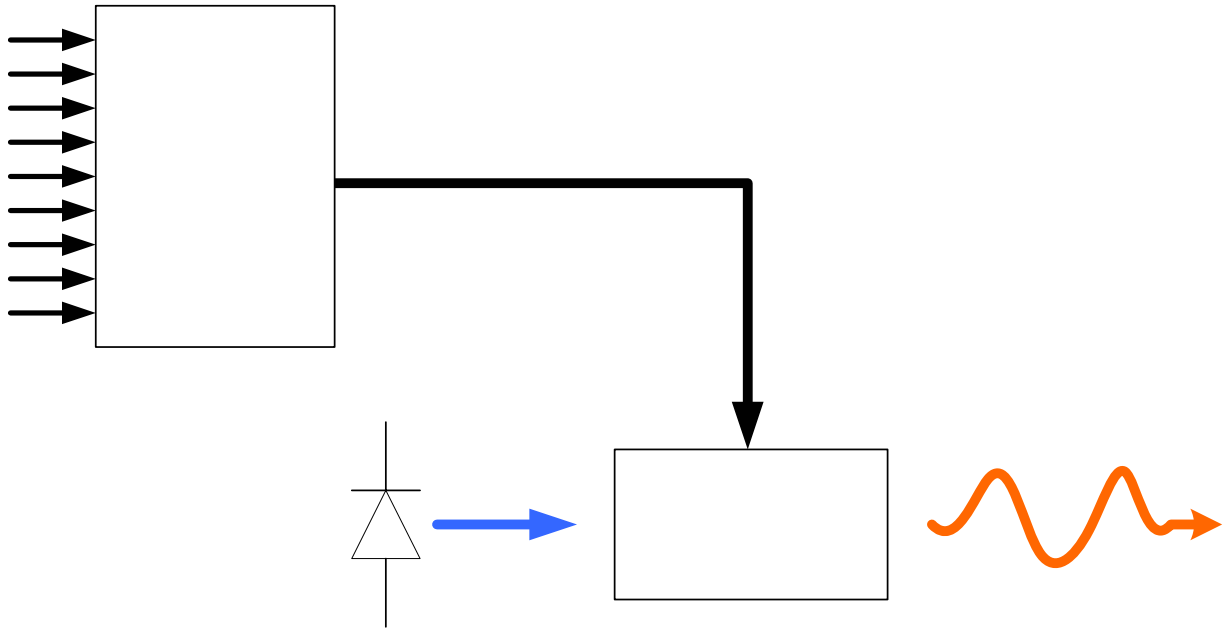
Introduction

High speed transmission – is sensitively technologies

- Transmitters and Receivers
- Modulation Scheme
- Fiber Impairments and Non-linearity
  - Attenuation
  - CMD
  - PMD

Modulator

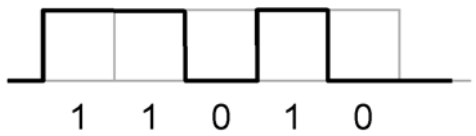
- The modulator changes the laser signal by either pulsing it off and on or by changing the phase of the signal so that it carries information.
- DWDM systems typically use phase modulation. Each variation represents a 1 or a 0.



Modulations Technologies

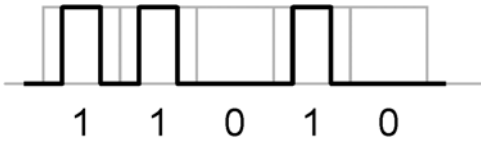
Non-Return to Zero (NRZ)

- Signal does not return to zero between bits
  - A one represents light signal present for a complete bit period
  - A zero is no light for a complete bit period
  - NRZ is more tolerant to dispersion effects



Return to Zero (RZ)

- Signal does return to zero between bits
  - A one results from the presence of light for one-half a bit period
  - A zero is no light for a complete bit period
  - Less tolerant to dispersion
  - Fiber loss are reduced



Modulations Technologies Continued..

Optical Duobinary is a pseudo binary-coded signal

- The bit period is the same for all bits
- The zero bit is represented by a one-half power level optical signal
- The one bit is represented by:
  - A full power optical signal, if the quantity of 0 bits since the last 1 bit is even
  - By a 0 power level optical signal if the quantity of 0 bits since the last 1 bit is odd
- Require less bandwidth than NRZ
- Permits the detection of some errors without the addition of error-checking bits.

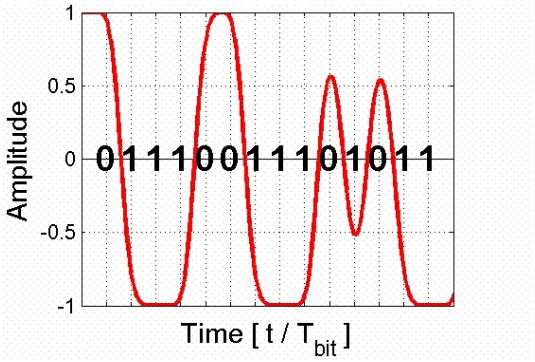
Carrier-suppressed return-to-zero (CS-RZ)

- Modulation has recently become commercially available
- Increase the spectral efficiency maintaining good transmission performance
- Modified RZ formats with less spectral width and larger tolerance of optical power

Modulations Technologies Continued..

PSBT - Phase Shaped Binary Transmission

- It is most commonly used in optical systems (WDM and OTDM) because of its increased tolerance to chromatic dispersion
- Reduced bandwidth occupation, with respect to the typically used NRZ scheme



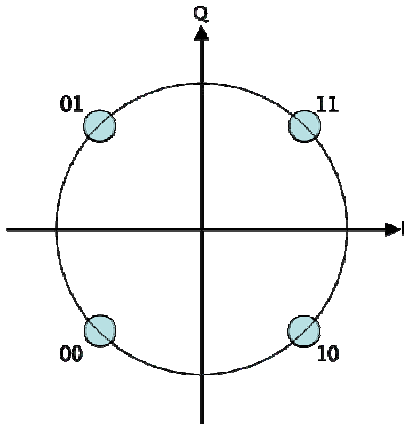
DPSK Differential Phase Shift Keying

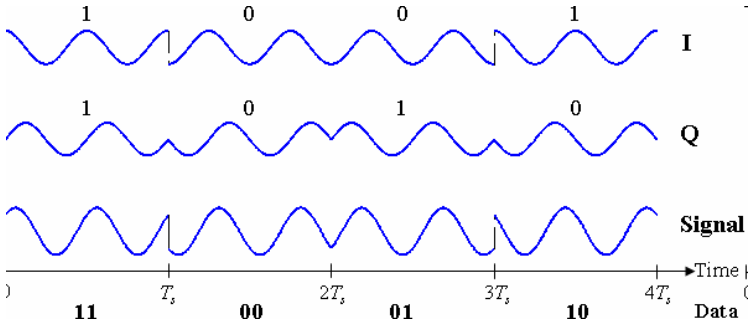
- Is a simple coding
- The modulating signal is not the binary code itself, but a code that records changes in the binary code
- This way, the demodulator only needs to determine changes in the incoming signal phase

Modulations Technologies Continued..

QPSK - Quadrature Phase Shift Keying Modulation

- The term "quadrature" implies that there are four possible phases (4-PSK)
- In QPSK modulation, a cosine carrier is varied in phase while keeping a constant amplitude and frequency
- In QPSK, information in conveyed through phase variations
- In each time period, the phase can change once. Since there are four possible phases, there are 2 bits of information conveyed within each time slot.





ITU-T's Recommendations for Max. PMD

- Recommendations specify for long-haul or high bit rate transmission applications of 10-40 Gbps, including 10 GbE, a **maximum PMD coefficient of 0,20 ps/√km**

- Some recommendations mention **"common typical values"**, particularly for 40 Gbps intermediate and long reach applications, of **0,10 ps/ √km**

PMD Limited Reach – Various Bit Rate

Calculation based on PMD 0,10 ps√km fiber PMD coefficient

	NRZ	50% RZ (OOK or DPSK)	50% RZ DQPSK
10 Gbps	14,000-15,700 km	20,600-23,100 km	
12 Gbps	9,700-10,900 km	14,300-16,000 km	
20 Gbps	3,500-3,900 km	5,100-5,800 km	
25 Gbps	2,200-2,500 km	3,300-3,700 km	
40 Gbps	870-980 km	1,290-1,450 km	5,800-6,500 km
80 Gbps	220-245 km	320-360 km	1,450-1,620 km
100 Gbps	140-160 km	205-230 km	925-1040 km
120 Gbps	100-110 km	140-160 km	640-720 km

- Modern fiberes have a much lower PMD
  - Trial - 107 Gbps DQPSK => 2950 – 4520 Km PMD limit reach @ 0,04 ps√km
- Most prominent formats highlighted in grey

Source Alcatel-Lucent Research & Innovation

40G - Technical Solutions

No "one-size-fits-all" format

- CD tolerance and grid compatibility require multi-level (PSBT, DQPSK)
- OSNR sensitivity requires balanced detection (DPSK)
- PMD tolerance requires low duty-cycle RZ-DPSK or DQPSK
- Non-linear effects (dispersion map) tolerance requires DPSK
- Cost-competitiveness (complexity) is an issue for all except PSBT
- 40G solution needs to follow technology maturity

Performance vs. NRZ	DPSK	RZ-DPSK	DQPSK	RZ-DQPSK	PSBT
OSNR sensitivity	+3dB	+4dB	+1dB	+2dB	Equiv.
CD Tolerance	20%	-20%	400%	300%	400%
TDCM	Mandatory	Mandatory	-	Mandatory	-
PMD Tolerance	20%	<200%	200%	<200%	400%
Non-linear Tolerance	Better	Much Better	Equiv.	Equiv.	Equiv.
Cost/Complexity/Size	+	++	+++	+++	Equiv.

The Preferred Format

Available 40G format (PSBT or DuoBinary) covers LH distances

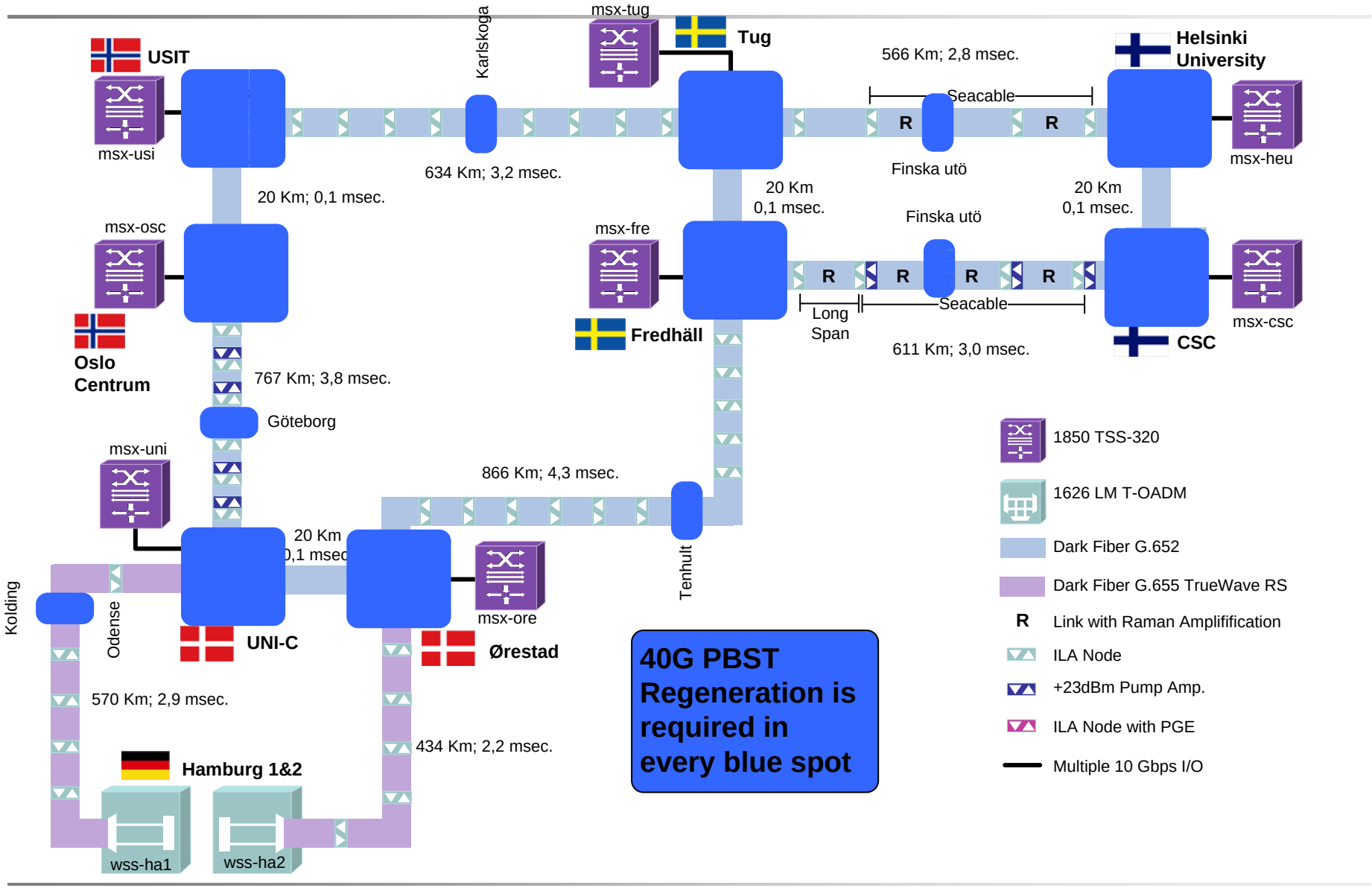
- Typically a few 100s of kilometers
- Tolerant to chromatic dispersion
- Fits on a 50 GHz grid
- 1000 km is not reachable in the field

40Gbps platform can be used for different formats

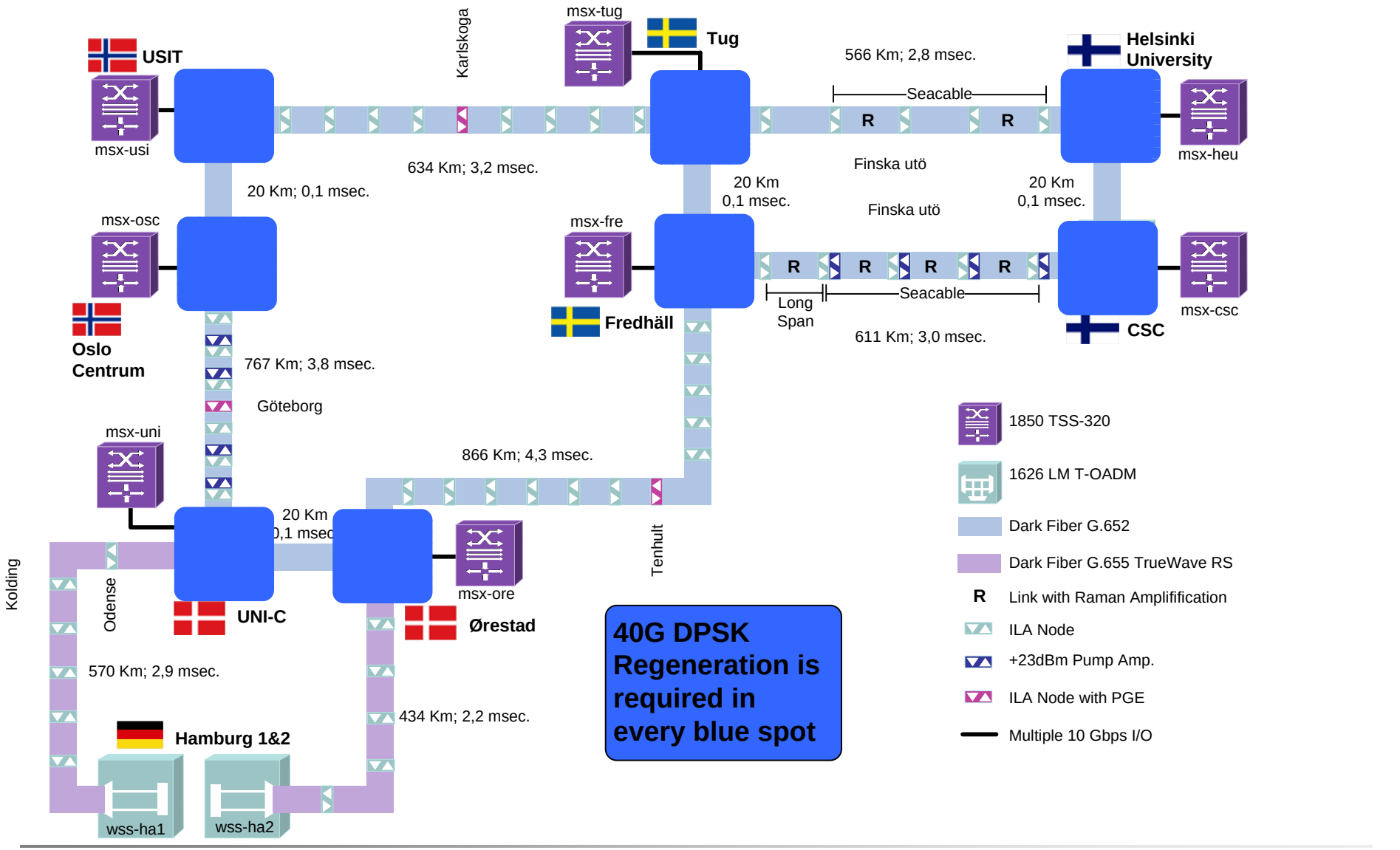
What format can be used for ULH transmission at 40G ?

- CS-RZ format, on a 100 GHz grid
  - Over 1000 km transmission distance
  - Mature format and components
- DPSK format, on a 100 GHz grid , or a 50 GHz grid with limitations
  - 2 adjacent 40G channels are not permitted using 50 GHz
  - More complicated and costly to generate (balanced receiver)
  - Longer distance than CS-RZ
  - Better margins than CS-RZ (about 3 dB)

40G based on PSBT
Extender shelf or integrated solution



40G Based on DPSK



100G

100-Gbps Ethernet is inching towards reality

- In Q4 2006, the IEEE 802.3 Higher Speed Study Group (HSSG) officially voted to make 100 Gbps Ethernet the subject of its standards work

- The challenges for realizing 100 GE are related to Ethernet switching and not to Ethernet transport

10x 107 Gbps WDM transmission Trial

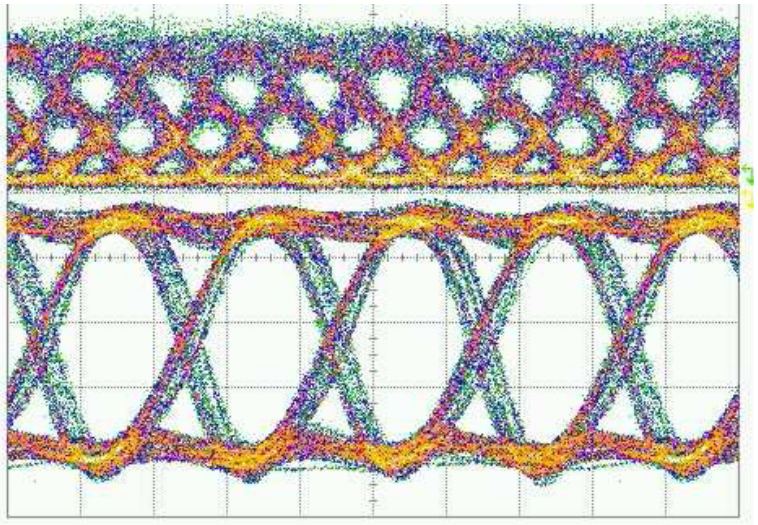
- Coding NRZ at 0.7 bits/s/Hz
- 10 x 107 Gbps electronically multiplexed NRZ transmission
- Distance 1000 km non-zero dispersion fiber
- 300 GHz Channel Spacing

Source: Alcatel-Lucent Research & Innovation
Former Bell Labs, Lucent Technologies

100G Continued…

100 Gbps ETDM system

- Pure electronic multiplexing / de-multiplexing transmitter and receiver
- Coding NRZ
- 300 GHz Channel Spacing
    - *Source Alcatel-Lucent Research & Innovation*



Optical 100 Gbit/s NRZ eye diagram. (10 ps/div) and electrical 50 Gbit/s eye diagram of the de-multiplexed signal (100 mV/div, 10 ps/div)

170G

8x 170 Gbps WDM Trail

- 8x170 Gbps WDM field transmission experiment over 430 km in field installed fiber using adaptive PMD compensation
- Transmission of 1.28 Terabits per second over a standard (ITU-T G.652) single mode fiber link in France Telecom's network in the Marseille area
- Carrying a record bit rate of 170 Gbps (160 Gbps plus an overhead so as to allow bit error detection and correction).
- As an example, each 160 Gbps transmission channel could transport the content of 4 DVDs in about 1 second
    - *Source Alcatel-Lucent Research & Innovation; France Telecom and Deutsche Telekom*

Papers

100 Gigabit Ethernet –
Applications, Features, Challenges

Marcus Duelk and Martin Zirngibl
Data Optical Networks Research
Bell Labs / Lucent Technologies

10 x 107 Gb/s electronically multiplexed NRZ transmission at 0.7 bits/s/Hz over 1000 km non-zero dispersion fiber

P. J. Winzer, G. Raybon, and C. R. Doerr
Bell Labs, Lucent Technologies, 791 Holmdel-Keyport Rd., Holmdel, NJ 07733, USA,

8x170 Gbit/s DWDM field transmission experiment over 430 km SSMF using adaptive PMD compensation

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3 : T-Systems Nova GmbH, Technologiezentrum Darmstadt, Am Kavalleriesand 3, D-64295 Darmstadt

End Of Presentation
&
Workshop

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