Choose Line Codes for 100G EPON to Mitigate the Impacts of Chromatic Dispersion

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Outline

- Impacts of Chromatic dispersion on 25Gb/s/ch 100G EPON
- Muti-level modulation and NRZ
- Simulation studies on duobinary and NRZ modulations (line codes)
- Choose line codes for 100G EPON channels
  - The 25Gb/s channel in O band
  - Other channels in C band and/or L band

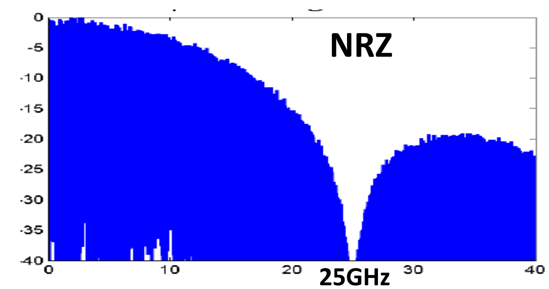
Motivation

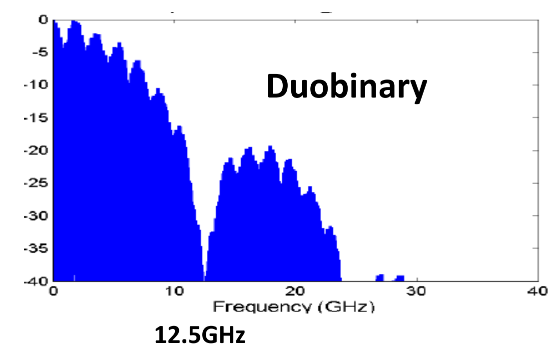
- Chromatic dispersion (CD) has significant impacts on 25Gb/s optical signal propagation at the PON ODN distances
- Chromatic dispersion has different impacts on O band, C band and L band, and 100G EPON channels may use 2 bands or 3 bands
- Extended reach for 100G EPON may be considered in the future
- How to compensate CD for a WDM based 100G EPON system across multiple bands is challenging
- This contribution explores mitigating the impacts of CD with duobinary modulation

Duobiary modulation in a nut shell

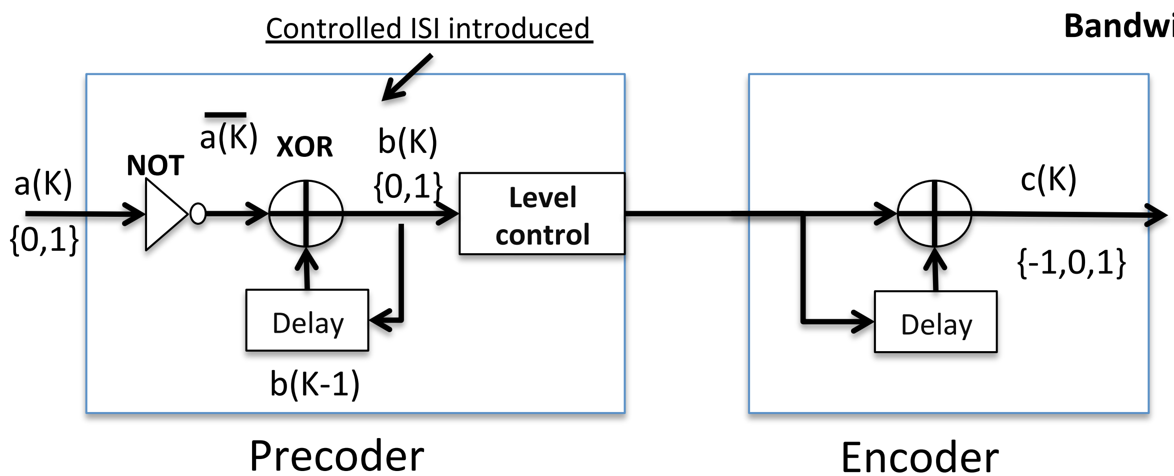
Duobinary modulation transmit B bit/s using B/2 Hz bandwidth that results in more efficiently using spectrum bandwidth

- Nyquist theorem indicates the minimum bandwidth required to transmits B bit/s data is B/2 Hz if ISI is zero.
- Duobinary signal will have by ISI, but a in controlled manner at TX side and can be equalized at RX side.





Bandwidth needed to transmit 25Gb/s



Duobinary, PAM4 and NRZ

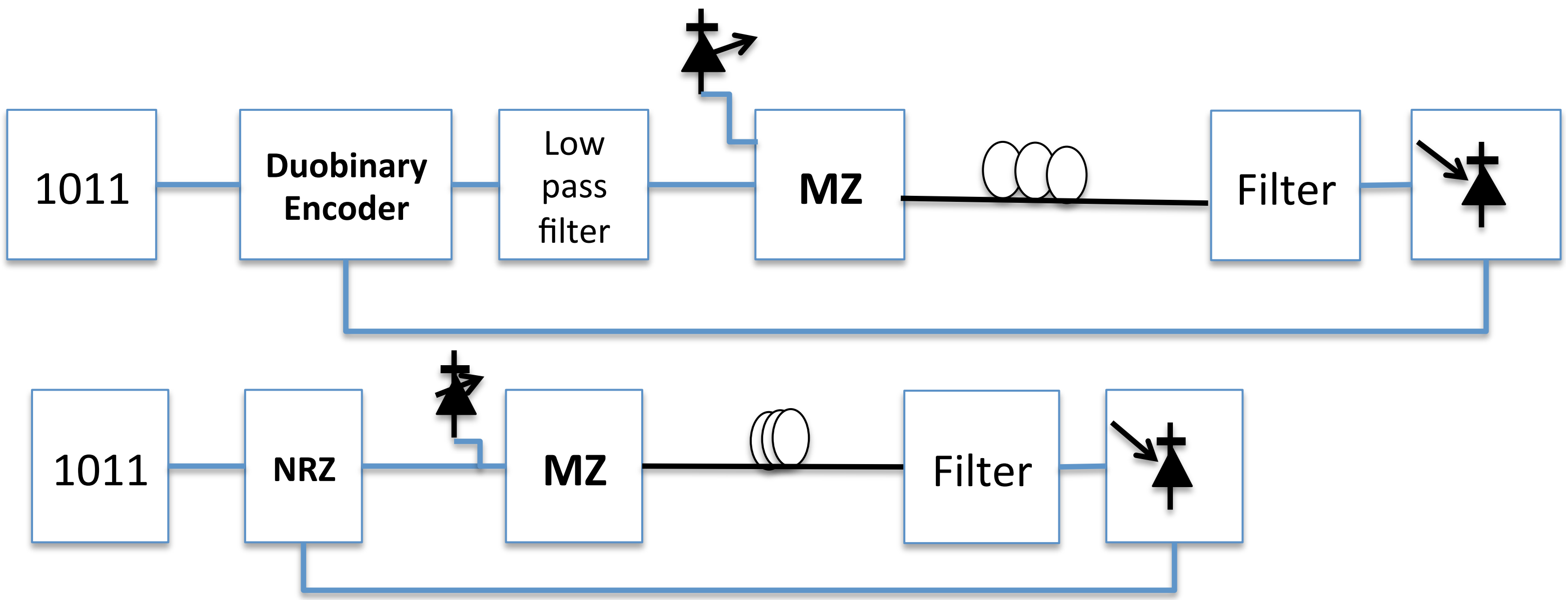
- The modulation efficiency of PAM4 is 2bit/Hz, so the spectrum efficiency of PAM4 is the same as duobinary
- But PAM4 has 4 levels instead of 3, the eye opening of PAM4 is narrower than duobinary, as the result PAM4 is less tolerant to dispersion than that of duobinary

Benefits of Duobiary Modulation

- Since duobinary modulation uses B/2 Hz bandwidth to transmit B bit/s, it can be used in DWDM systems to pack more channels
- At given data transmit rate, the spectrum of duobinary is half of NRZ, as the result, duobinary signal is more tolerant to fiber chromatic dispersion

We should explore the benefits of duobinary modulation in mitigating dispersion for 25Gbps/ch 100G EPON

Duobinary and NRZ optical simulation setup



Simulation parameters

- Wavelength: C, O bands
- Fiber length = 5 km to 50 km
- C band dispersion ~ 16 ps/nm/km
- O band dispersion ~ 2 ps/nm/km
- PMD = 1.58 10^{-11} s/m
- Bit rate = 25Gb/s and 40Gb/s
- Laser short noise, thermo noise…

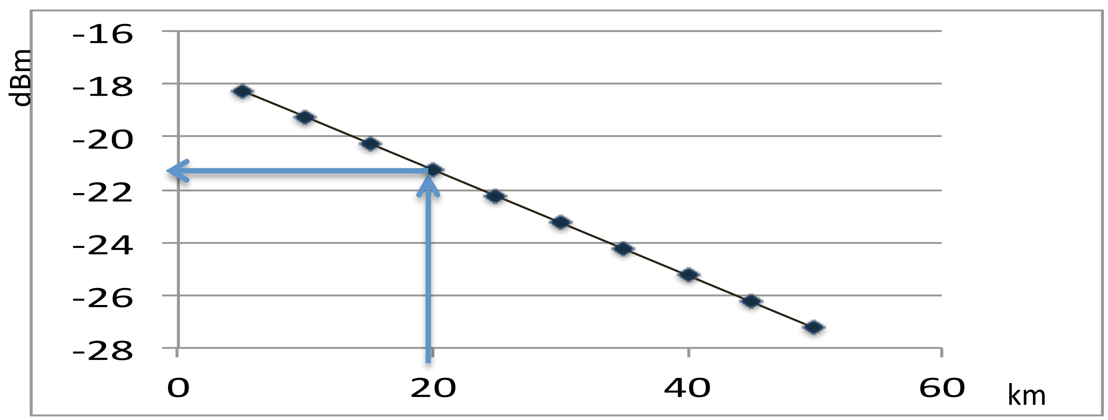
Simulation Methods: Study the relation of BER with ODN distances

- Fixed transmitter output power, varying fiber lengths (normal PON)
- Vary fiber lengths with fixed receiving power (long reach)

Simulation scenario A – Fixed transmitting power

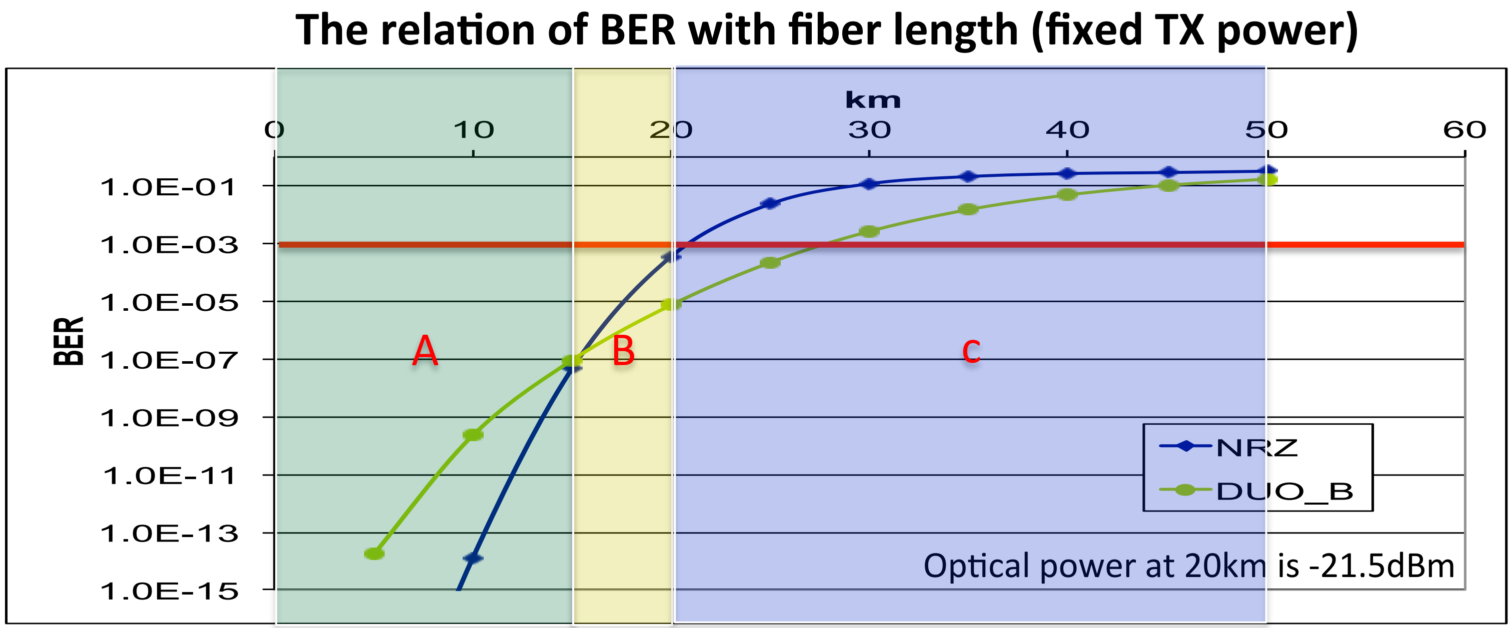
- Fixed transmitter output power, varying fiber lengths
- This will be the normal PON operation condition up to 20 km fiber lengths
- We simulated fiber length up to 50km in order to compare the performance NRZ and duobinary modulations in various signal strengths

Optical receiving power at different fiber length



Optical power at 20km is -21.5dBm

Duobinary & NRZ at 25Gb/s in C band

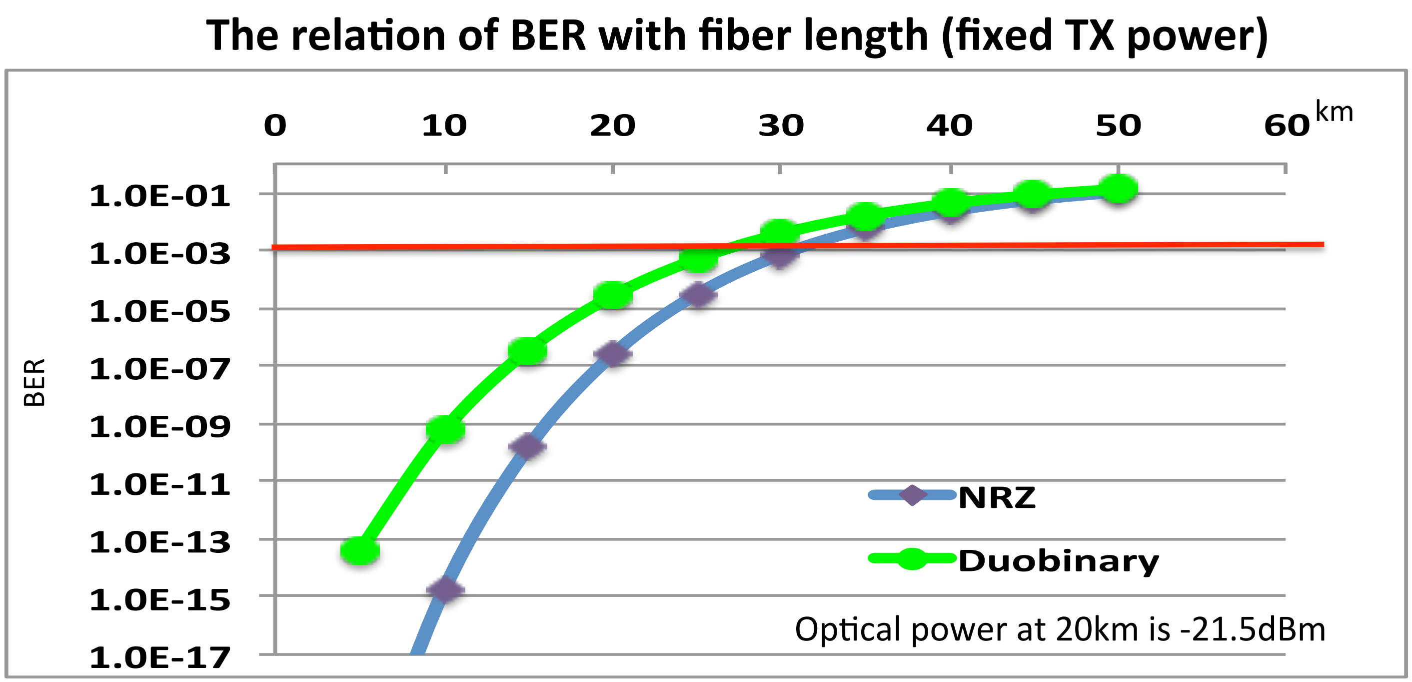


- The main contribution to BER in region A (0-15km) is noise
  - NRZ has better performance than duobinary in region A
- Dispersion starts to be a dominant factor to BER in region B (15-20km)
  - Duobinary has better performance in this region
- In region C, dispersion impact is still strong but noise is becoming dominant due to diminishing receiving power
  - Duobinary still has better performance in region C

Duobinary & NRZ at 25Gb/s in C band discussions

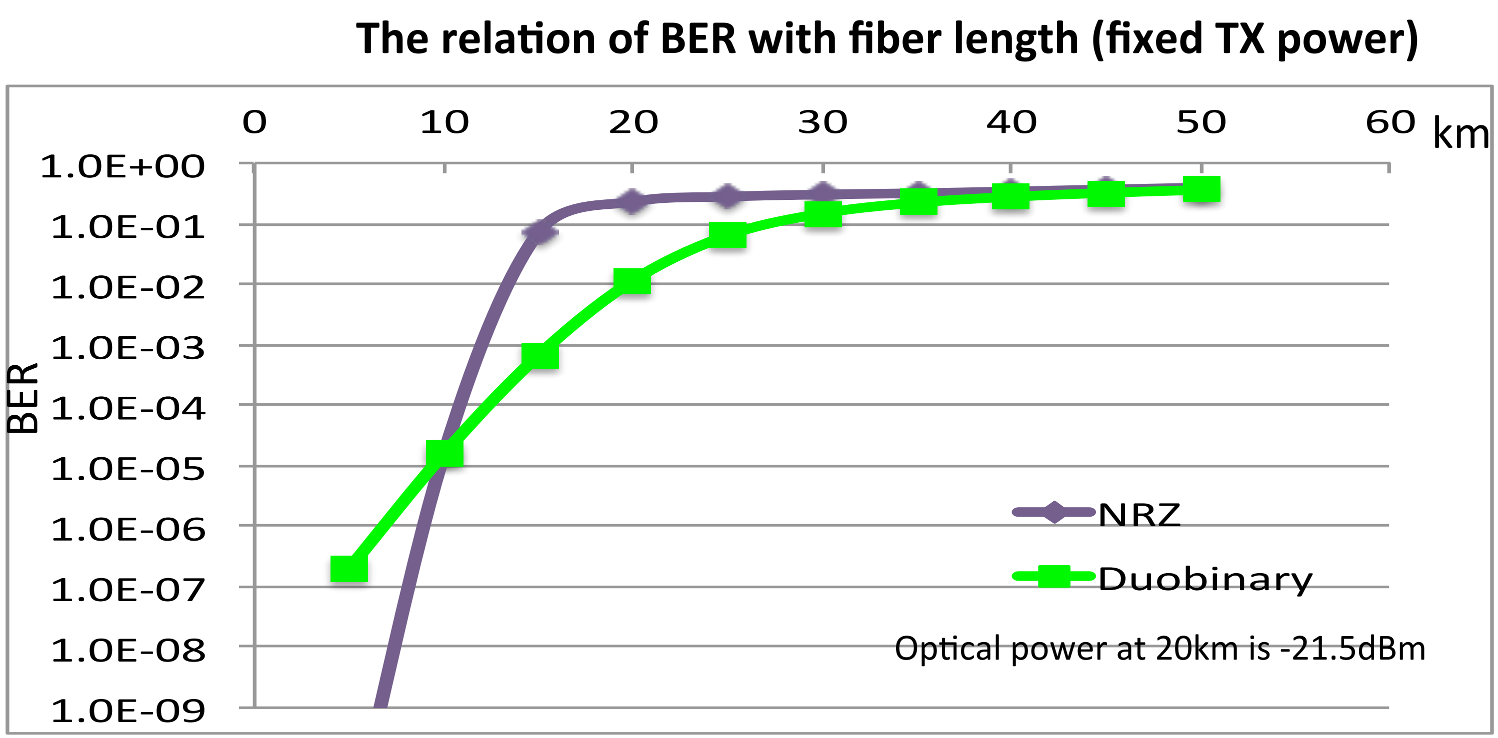
- In the simulation conditions (fixed TX power, -21dBm receiving power at 20km), for 25Gb/s C band channel:
  - Duobinary has better performance than NRZ when fiber length > 15km
  - When fiber length < 15km, NRZ performs better
- At 20 km, BER is <= 10^(-5) for duobinary modulation
  - Dispersion compensation could be avoided in C band with FEC
- At 20 km, BER is ~10^(-3) with NRZ modulation
  - At the top limit for FEC, dispersion compensation may be needed

Duobinary & NRZ at 25Gb/s in O Band



- **NRZ has better performance than duobinary**
- **Without dispersion the dominant contribution to BER is noise, so it is not surprise that NRZ won**
- **At 20km fiber length, BER is <=10^(-6) for NRZ**
- **With FEC, NRZ modulation at 25Gb/s O band channel could reach 20 km without dispersion compensation**

Duobinary & NRZ at 40Gb/s in C band

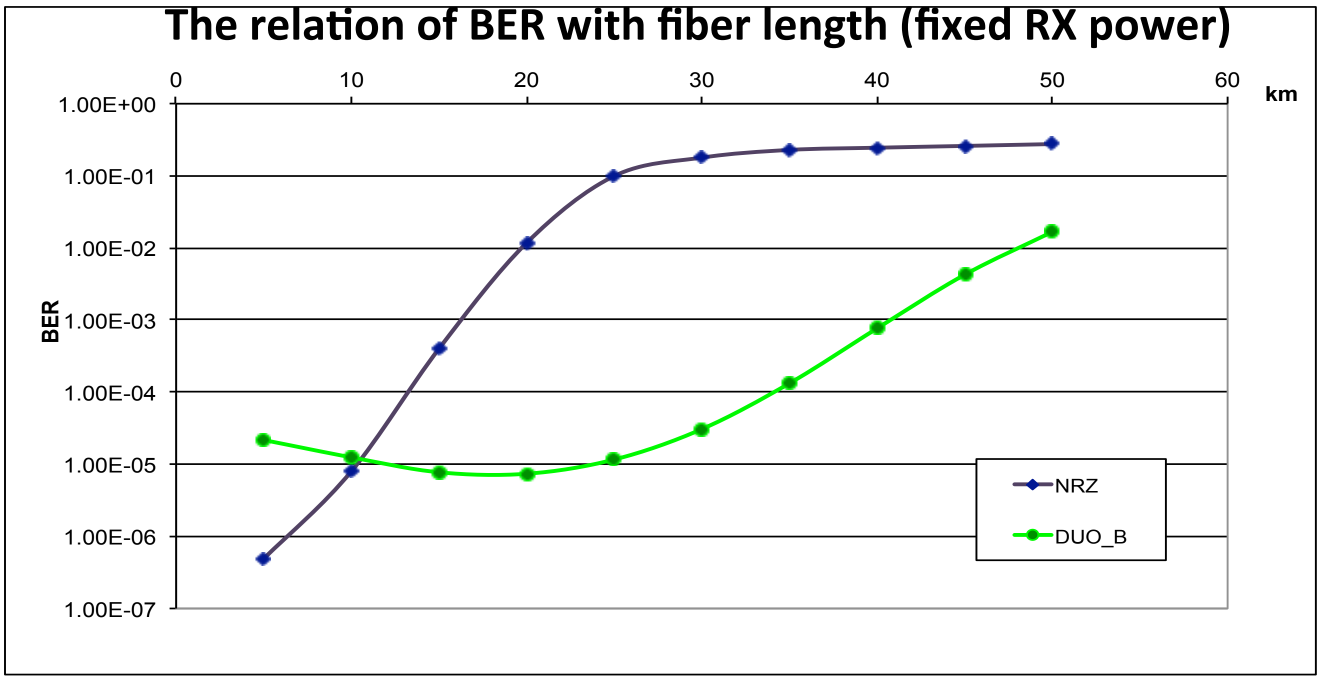


- **At 10 km fiber length duobinary starts to show benefits**
- **With transmitting rates goes higher, the benefits of duobinary in dispersion tolerance become more apparent**

Simulation Scenario B – Fixed receiving power

- Varies fiber lengths with fixed receiving power
- This will simulate long reach (>20km) PON with optical amplifier
- This will also simulate standard reach PON (<=20km) with optical amplifier for high splitting ratios
- The receiving powers at fiber lengths from 5 km to 50 km are set to be -21.5 dBm
- The setup enables exploring impacts of dispersion on line codes

Duobinary & NRZ at 25Gb/s in C band



- **The NRZ wining region reduced to <10km due to the reduced RX power compare with fixed TX power case**
- **The duobinary wining region expends from 10km to >= 50 km**
- **The fixed RX power in fiber length > 20km is achieved by using OA**
- **The BER at 40 km is < 10^(-3) with duobinary which is correctable with FEC**

Duobinary & NRZ at 25Gb/s in C band discussions

- The simulation results with fixed RX power in C band at 25Gb/s show that duobinary modulation has advantage over NRZ in extended reach PON with optical amplifier
- Duobinary may enable 40km reach in C band without dispersion compensation at 25Gb/s
- At standard 20 km reach, duobinary may enable higher splitting ratio with optical amplification
- All previously PON standards have reach extension defined
- Duobinary may make it possible to add reach extension to 100G EPON at later time without adding dispersion compensation

Conclusions

- **NRZ modulation at 25Gb/s in O band channel could reach 20 km without dispersion compensation with FEC**
- **NRZ modulation is preferred for 25Gb/s O band channel**
- **Duobinary modulation may enable 20k to 40 km reach in C band without dispersion compensation at 25Gb/s**
- **Duobinary modulation is preferred for 25Gb/s C band channels**

Thanks

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