Innovative R&D by NTT

Issues for fair comparison of PAM4 and DMT

Yoshiaki Sone　NTT

IEEE802.3bs 400 Gb/s Ethernet Task Force,　San-Diego, July 2014.

Purpose and background

Innovative R&D by NTT

Purpose of this presentation

Discuss issues relevant to comparing PAM4 and DMT and to selecting the appropriate solution for SMF PMD objectives (2km and 10km) by presenting our experimental evaluation results.

Background

- Several proposals for 2km and 10km SMF PMD objectives.

  ⇒Difficult to select one approach since there are various perspectives on the technology.

- Transmission experiment is conducted in our test environment to understand the difference of PAM4 and DMT.

  1) 56Gbps PAM4 transmission (for 8 λ configurations)

  2) 116Gbps DMT transmission (for 4 λ configurations)

NTT

Evaluation results overview and comparison issues

Innovative R&D by NTT

Our evaluation results and findings

Both showed technical feasibility for 10km over SMF **with our experimental configuration (one example).**

1) 56Gbps PAM4 transmission (for 8 λ configurations) -> shown in slide #4
2) 116Gbps DMT transmission (for 4 λ configurations) -> shown in slide #5

➡ It is understood there are many variations of experimental configurations for both PAM4 and DMT.

Issues relevant to comparing the solutions

We need a reasonable policy and assumptions for fair comparison of PAM4 and DMT given the variety of system configurations.

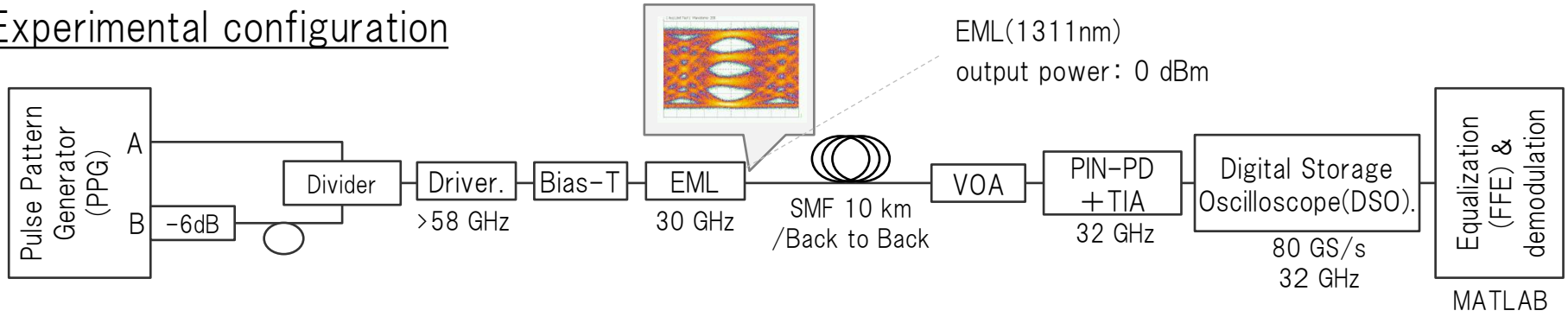
- The estimates of feasible timeline, power consumption, and cost may strongly depend on the system configurations used.

These issues must be addressed to make an appropriate decision given the time constraints of 802.3bs.

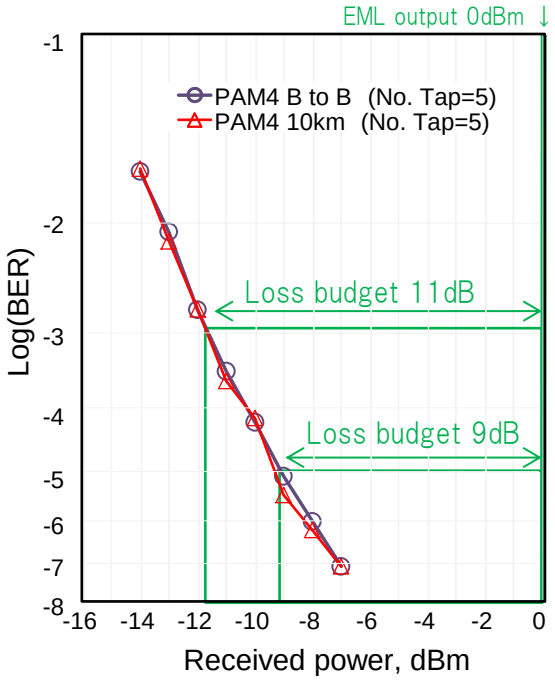
NTT

Evaluation result (1) 56Gbps/λ PAM4

Experimental configuration



BER measurement result



Loss budget estimation

- Target BER #1: $>10^{-5}$ with FEC (OH 3%)
- Target BER #2: $>10^{-3}$ with FEC (OH 7%)

Estimation results(B2B)

	Equalizer TAP No. =5
OH 3% FEC	9 dB
OH 7% FEC	11 dB

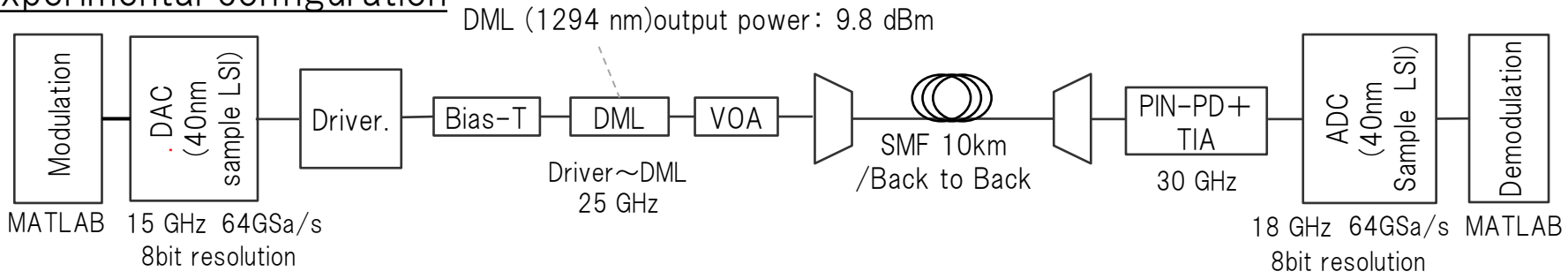
10km SMF and connectors channel insertion loss: 6.3dB

Note

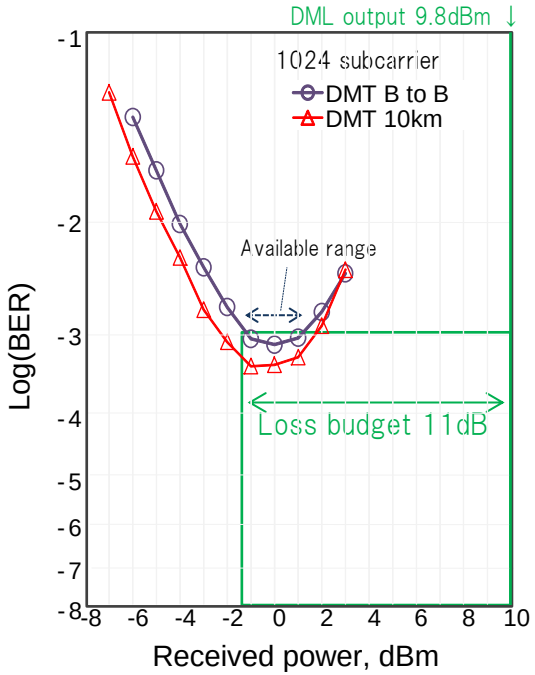
- PPG and DSO are test equipment.
- Equalization algorithm(FFE) is an example.

Evaluation result (2) 116Gbps/λ DMT

Experimental configuration



BER measurement result



Loss budget estimation

- Target BER #1: $>10^{-5}$ with FEC (OH 3%)
- Target BER #2: $>10^{-3}$ with FEC (OH 7%) *1

*1 BCH(9193,8192) and 12.5 % over clocking are proposed in "lewis_3bs_01_0514"

Estimation results(B2B)

	No Equalization
OH 3% FEC	No Loss budget
OH 7% FEC	11dB

10km SMF and connectors channel insertion loss: 6.3dB

Note

- DAC/ ADC is evaluation board .(pre-production level)
- Overload performance is limited by fixed-gain TIA. AGC is desirable.

TIA: Trans impedance amp
AGC: Auto Gain Control

Performance and economical feasibility level of components

Each component has a different performance and economical feasibility level.
The grade of our configurations are as follows.

DAC/ADC

PAM4 : 32GHz analog bandwidth may be the best spec of commercially available equipment.
DMT : DAC/ADC is evaluation board with 40nm LSI (not the latest generation).

Optics

TX side: The bandwidth of EML for PAM4 was larger than the bandwidth of DML for DMT.
RX side: Wide-band PIN-PD applicable to 40Gbps evaluations. AGC is desirable.

Configuration variations and our configuration

PAM4 setup in our experiment | DMT setup in our experiment | *:using test equipment

Tx Side	
DAC	Laser + Mod.
DAC BW = 15 GHz	Common DML for 100GE
Wide Bandwidth DAC	Wide Bandwidth DML
⋮	Common EML for 100GE
	Wide Bandwidth EML
Analog based Signal Generations *	Wide Bandwidth MZ

Low end ↓ High end/ lab equipment

Rx Side			
Detector	TIA	ADC	EQL
PD	Narrow band Fixed Gain	ADC BW = 18 GHz	No EQL
	Narrow band AGC	⋮	5 taps
APD	Wide band Fixed gain		⋮
	Wide band AGC	DSO* BW = 32 GHz	

These variations and differences make comparison very difficult.

Fair comparison requirements

Innovative R&D by NTT

We need a reasonable policy and assumptions for fair comparison given the variety of system configurations The following items must be considered.

1)Variations of system configuration and trade-off

	Pros.	Cons.	note
Number of equalization TAPs	Relaxation of analog bandwidth requirement	Increase in power consumption	Various algorithms are available
Improvement of Optics (etc. APD, high-grade DML/EML)	Relaxation of loss budget requirement	Component cost	Related to FEC overhead

2)Economical feasibility considerations for each system component

Commercial production roadmaps of each component are necessary.

Items		Impact
LSI generation	28nm is currently available. Next generation available by 2017	Power consumption, footprint estimates
DAC/ADC specification	Sampling rate, ENOB, bandwidth	Performance and cost estimates.
Performance of optical component	Analog bandwidth	Significantly impacts transceiver cost

3)Performance degradation with commercial production

Commercial transceiver can not assume ideal environment like measurement in lab.

NTT

Summary

Innovative R&D by NTT

Evaluation result

From the result of 56Gbps PAM4 and 116 Gbps DMT transmission evaluation, both 8λ PAM4 and 4λ DMT are technically feasible to meet 10km SMF objective from the viewpoint of the optical power loss budget.

The following items should be considered in any solution comparison.

1) Variations of system configuration and their trade-offs
2) Economical feasibility regarding each component
3) Possible degradation from moving from experimental configuration to commercial system

Future plans

An evaluation of loss budget/FEC-OH improvement in the case that higher performance optics (e.g. APD, high-performance EML/DML, etc.) are used.

NTT

Thank you