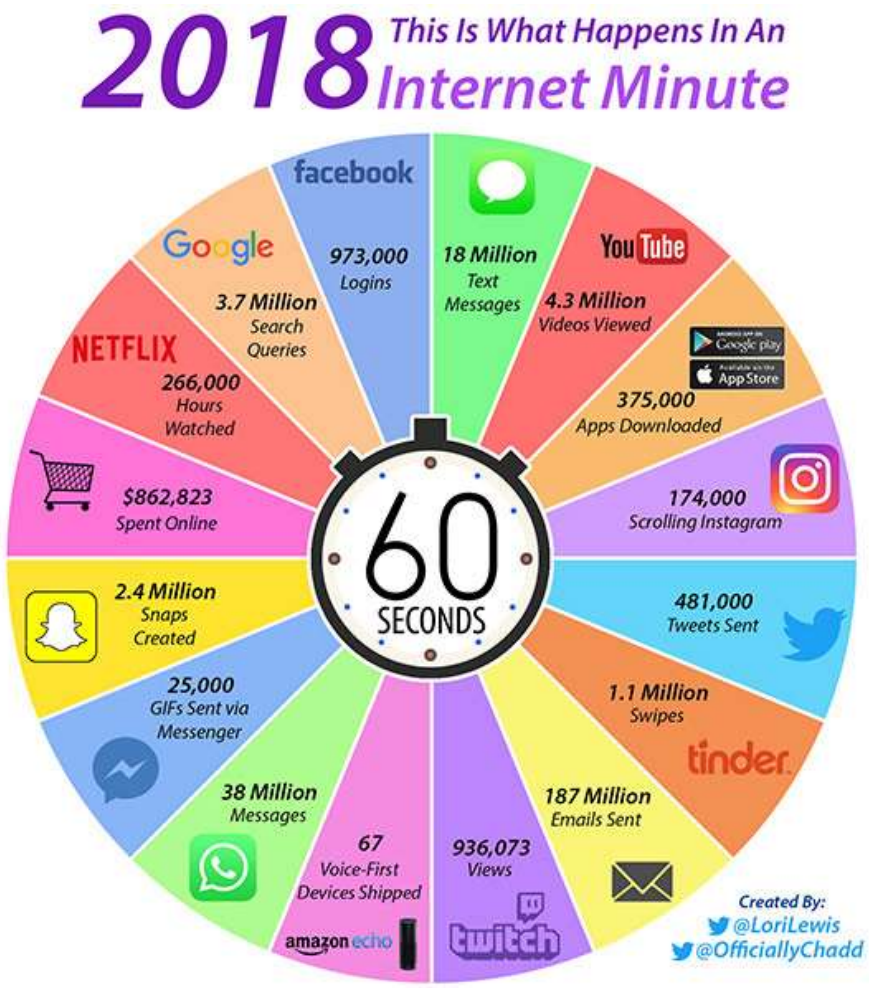

加速创新者创新
2018泰克创新论坛
Tektronix®
2018 TEKTRONIX INNOVATION FORUM

Tektronix

泰克创新助力光通信发展

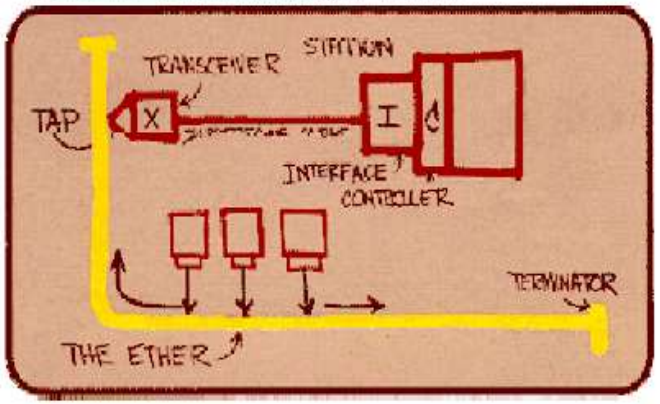
23 JULY 2018

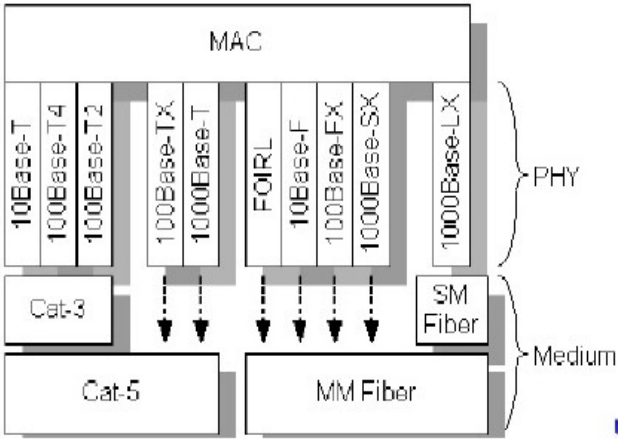

2018 This Is What Happens In An Internet Minute
facebook
973,000 Logins
18 Million Text Messages
YouTube
4.3 Million Videos Viewed
375,000 Apps Downloaded
174,000 Scrolling Instagram
481,000 Tweets Sent
1.1 Million Swipes
tinder
187 Million Emails Sent
936,073 Views
twitch
67 Voice-First Devices Shipped
amazon echo
38 Million Messages
25,000 GIFs Sent via Messenger
2.4 Million Snaps Created
$862,823 Spent Online
NETFLIX
266,000 Hours Watched
Google
3.7 Million Search Queries
60 SECONDS
Created By:
@LoriLewis
@OfficiallyChadd

以太网(Ethernet [i:θərnɛt])的起源与发展

- 1972年Metcalf与他在Xerox PARC的同事们，在研究如何将Xerox Altos工作站与其他Xerox Altos工作站、服务器以及激光打印机相互联网。他们成功的用一个网络实现了2.94Mb/s的数据传输率的互联，并将此网络命名为Alto Aloha网络。1973年Metcalf 将此延伸至支持其他的计算机类型，并改名为Ethernet。因为Ether（以太），曾被科学家认为是电磁波在真空中的传输介质。而Ethernet就是以太网的意思，就是数据传输的网络。如此，以太网便诞生了。1976年，Metcalf拿到了专利，并邀请了Intel 与Digital 成立了DIX group，并在1989 年，演变成了IEEE802标准。基本上IEEE 802.3 是OSI第二层的协议，负责链路的接入管理与流量控制。IEEE 802.3物理层可以通过不同的介质来实现，包括3类、4类、5类线（STP屏蔽与UTP非屏蔽双绞线），同轴铜线，多模与单模光纤等等。其传输速率也从最初的10M发展到100M、1000M乃至当今的100G、400G

Robert Metcalf's的以太网构想:





IEEE 802.3以太网的物理层种类:

IEEE 802.3标准的发展

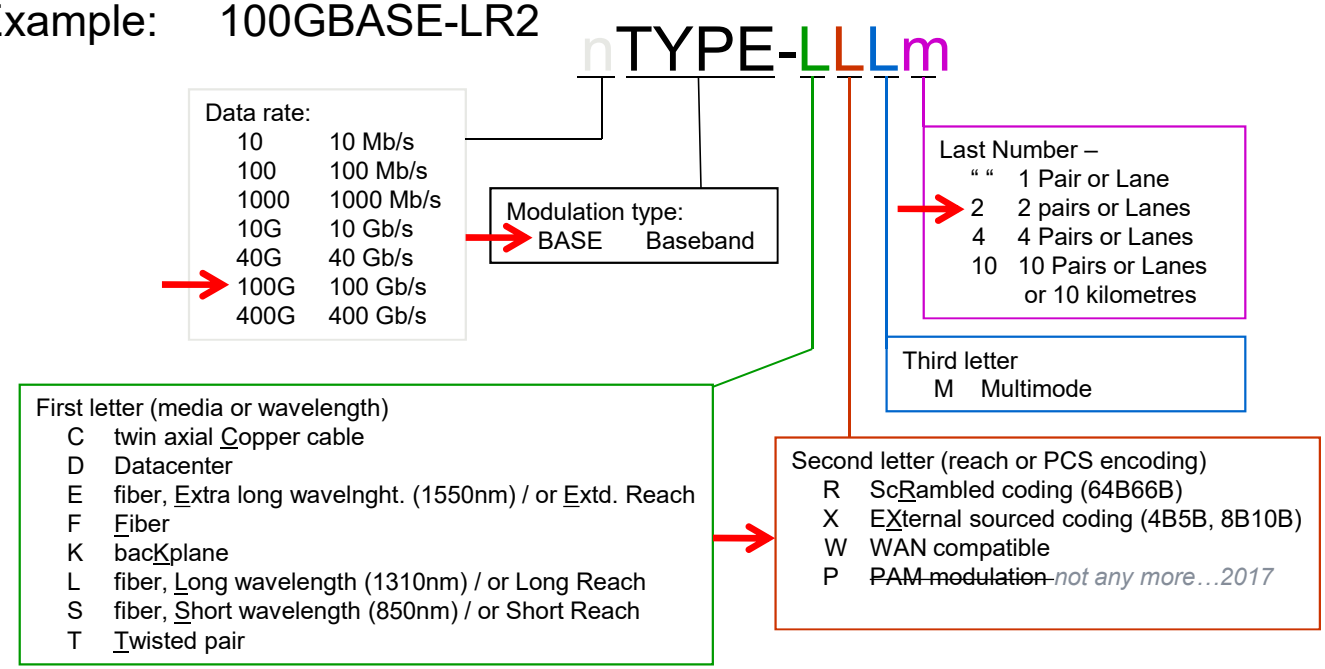
- IEEE 802.3定于1985年
  - 10M速率，采用同轴电缆作为传输载体
- IEEE 802.3i定于1990年
  - 10M速率，采用双绞线(屏蔽/非屏蔽)作为传输载体，曼切斯特编码
- IEEE 802.3u定于1995年
  - 100M速率，采用双绞线(屏蔽/非屏蔽)作为传输载体，MLT-3编码
  - 100M速率，采用光纤（单模/多模）作为传输载体
- IEEE 802.3z定于1998年
  - 1000M速率，采用光纤（单模/多模）作为传输载体
- IEEE 802.3ab定于1999年
  - 1000M速率，采用双绞线（双绞线）作为传输载体，PAM5编码
- IEEE 802.3ae定于2001年
  - 10G速率，采用光纤（单模/多模）作为传输载体

IEEE 802.3标准的发展

- IEEE 802.3ak标准在2002年开始制定，2004年定稿
  - 10G速率，采用Twinax铜线（既InfiniBand 4X电缆）为传输载体。传输距离15米。
- IEEE 802.3an的标准制定中，2006年定稿
  - 10G速率，采用双绞线传输。传输距离100米(CAT-7)，至少55米(CAT-6e超6类)，PAM-16编码
- IEEE 802.3ba定于2010年，40G/100G
  - 40G以及100G标准，单波10G以及单波25G
- IEEE 802.3bj定于2014年，100G背板标准
  - 单路25G，FR4背板
- IEEE 802.3bz定于2016年
  - 2.5G以及5G标准，使用CAT-5或CAT-6
- IEEE 802.3bs定于2017年11月
  - 200G以及400G标准，使用PAM-4编码

Alphabet soup, i.e. Ethernet Nomenclature

- Common interpretation* is as follows:
- Example: 100GBASE-LR2



• The IEEE does not specify the meanings of the letters, rather it simply identifies PHYs by combinations of letters. There is no guarantee that in the future these interpretations will retain whatever meaning they presently have.
Slide based on an Ethernet Alliance slide by Scott Kipp, with Tektronix extensions.

The top-to-bottom of PAM4 x n (50, 100, 200, *400G*) standards

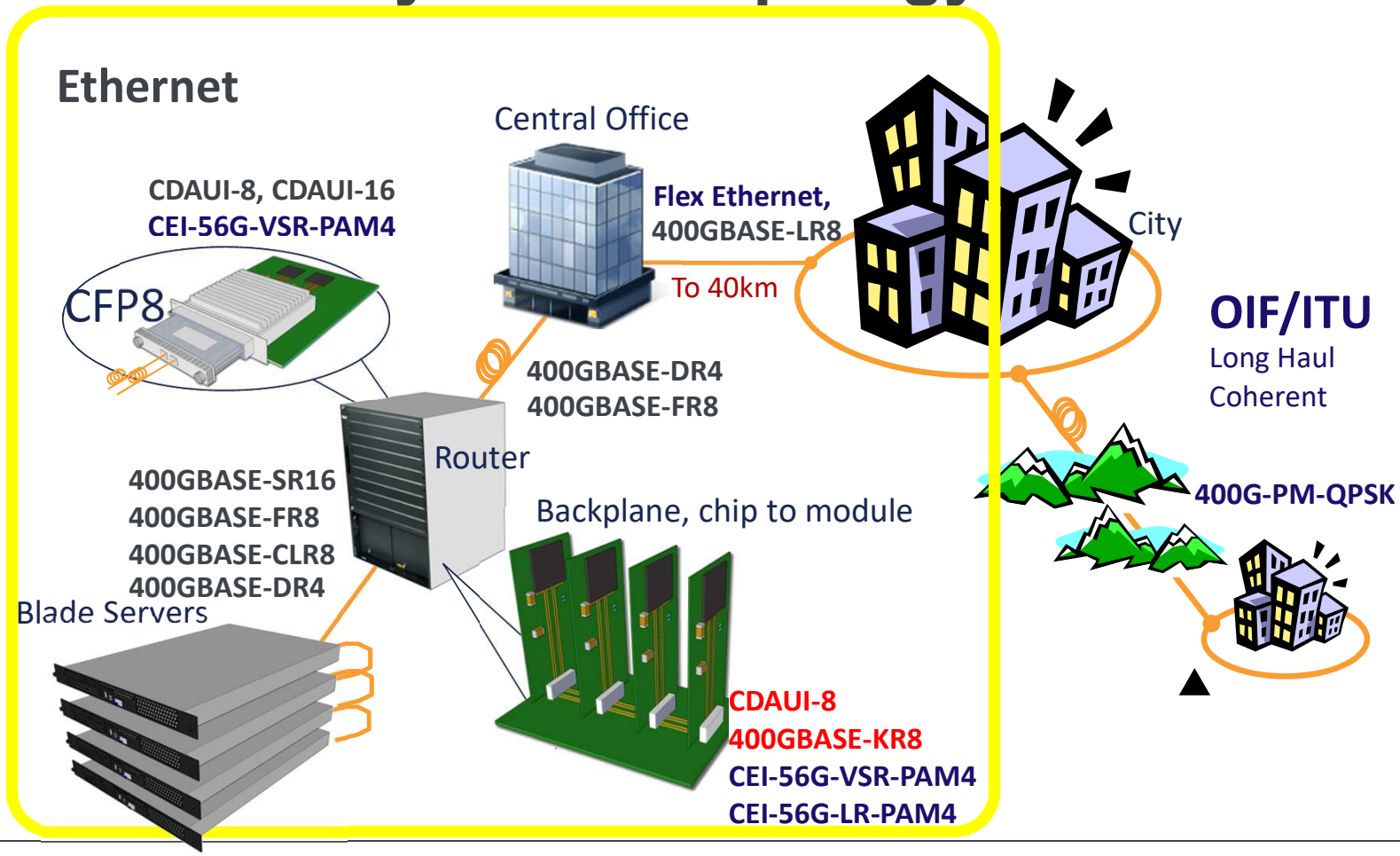
Distance	Standard	Modulation/signaling	e.g.
X,000 km / SM	OIF, OTN, ITU	Complex optical	DP-QPSK
10 km / SM	Ethernet	PAM4 at 25+ GBd	400GBASE-LR8 (802.3bs)similar: 200GBASE-LR4, 50GBASE-LR
2 km / SM	Ethernet	PAM4 at 25+ GBd	200GBASE-DR4 (802.3bs)
2 km / SM	Ethernet	PAM4 at **53+** GBd	400GBASE-DR4;similar: 100GBASE-DR
< 100 m / MM	Ethernet	PAM4 at 25+ GBd	200GBASE-SR4 (802.3cd); similar:100GBASE-SR2, 50GBASE-SR
Backplane < 1m	CEI, E'net	PAM4 at 25+ GBd	CEI LR,
Interconnect module to chip, chip to chip	Ethernet OIF CEI	25+ GBd PAM4, NRZ	50GAUI, 100GAUI-2, 200GAUI-4, 400GAUI-8 (fka CDAUI-8 etc.) CEI VSR

PAM4 across the stack

New standards on the Phy above: 50 Gb/s, 100 Gb/s, 200 Gb/s

DSA8300 :Supports Optical + Electrical. 70kSX (ATI): Supports Electrical only

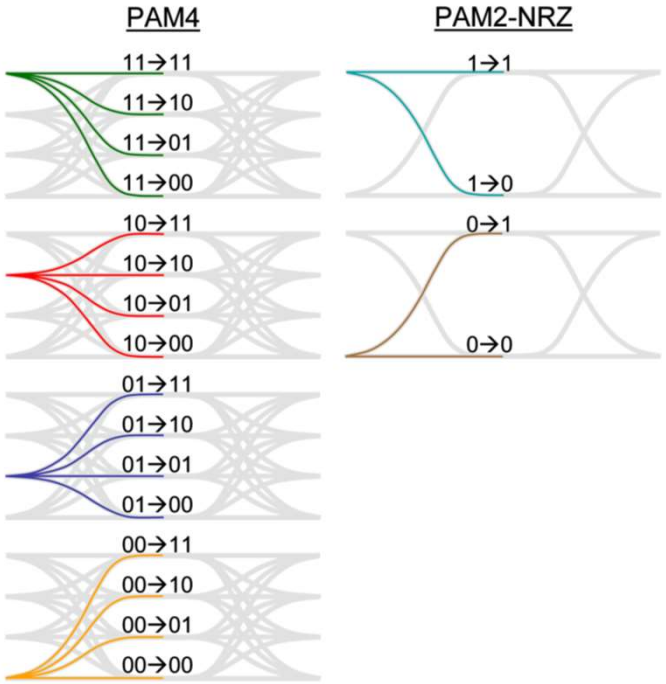
50G~400G Ecosystem & topology



If we can not increase the speed, lets increase the coding density. PAM4 has 2 bits per UI. What is PAM4 ?

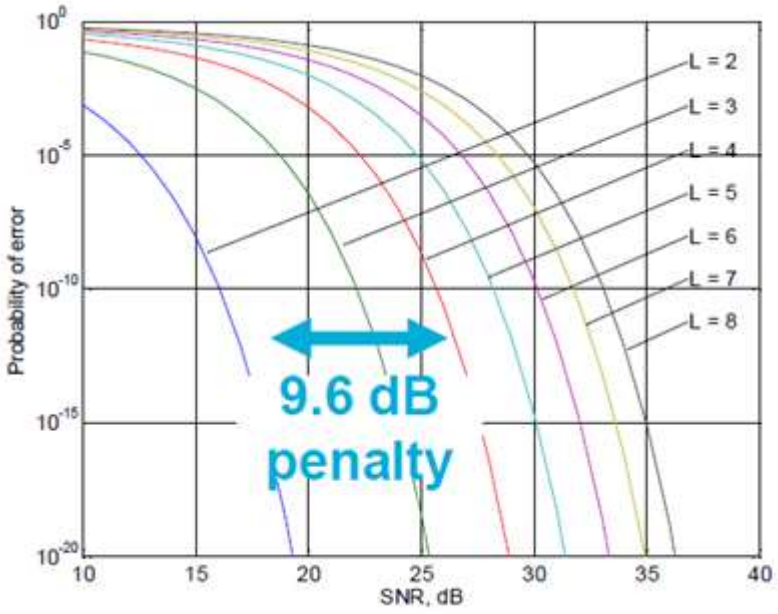
- 4-level signaling
- Transmit 2 bits per UI
- Half the bandwidth compared to NRZ (of same data rate)

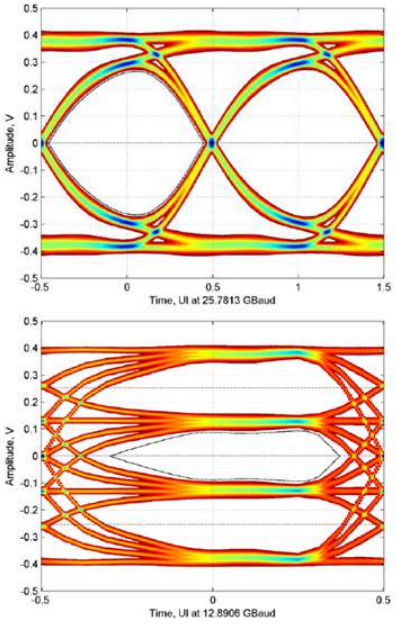
	PAM-4	NRZ
Bits per UI	2	1
Levels	4	2
Rising/Falling Edges	6/6	1/1
Transitions	12	2
Eye Diagrams per UI	3	1



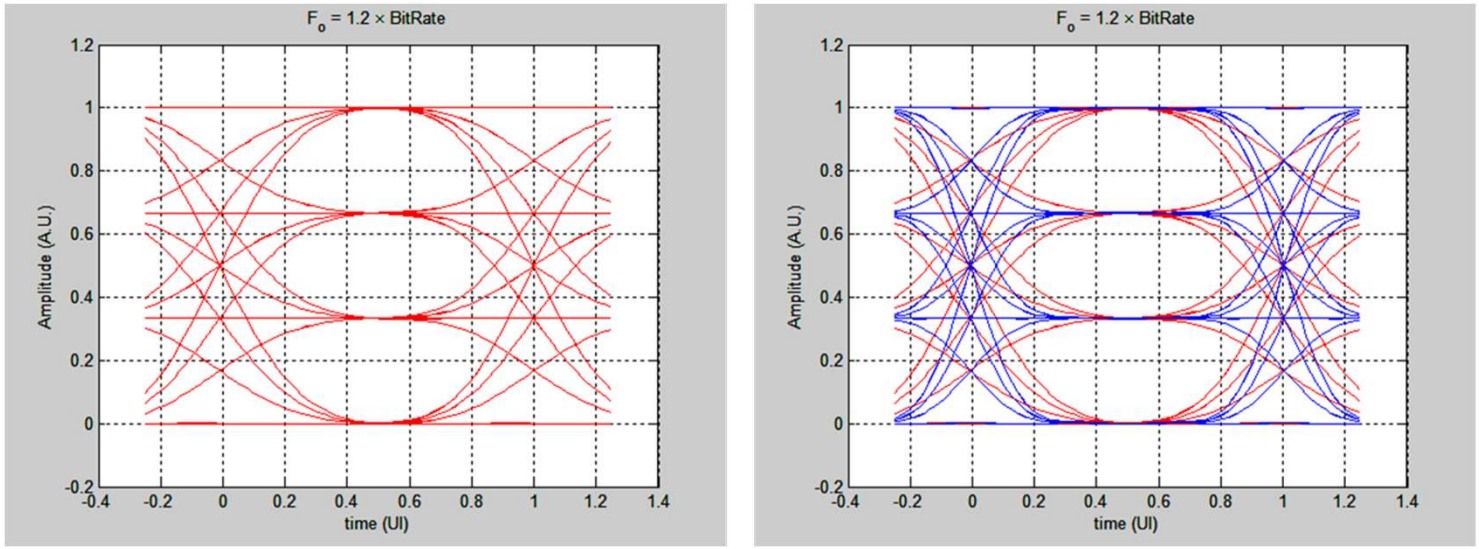
Design and Test Challenges in the 100G-400G transition

- Channels are Modulation methods are ”out of Bandwidth” at 56Gbps.
  - Higher order modulation (PAMn) is one means of combating incredibly high channel losses.
  - Multiple bits/symbols results in a reduced overall symbol rate and fundamental transmission frequency. 14GHz rather than 28GHz.





Design and Test Challenges in the 100G-400G transition



What is the right BW we need?
Higher than the 4th BT filter that NRZ required?
Same with the 4th BT filter that NRZ required?
Or other BW???

PAM4 test: things are different

- Outer OMA and ER test do not base on eye-diagram anymore
  - P3: average of center 2UI from seven “3” of PRBS13Q pattern
  - P0: average of center 2UI of six “0” of PRBS13Q pattern

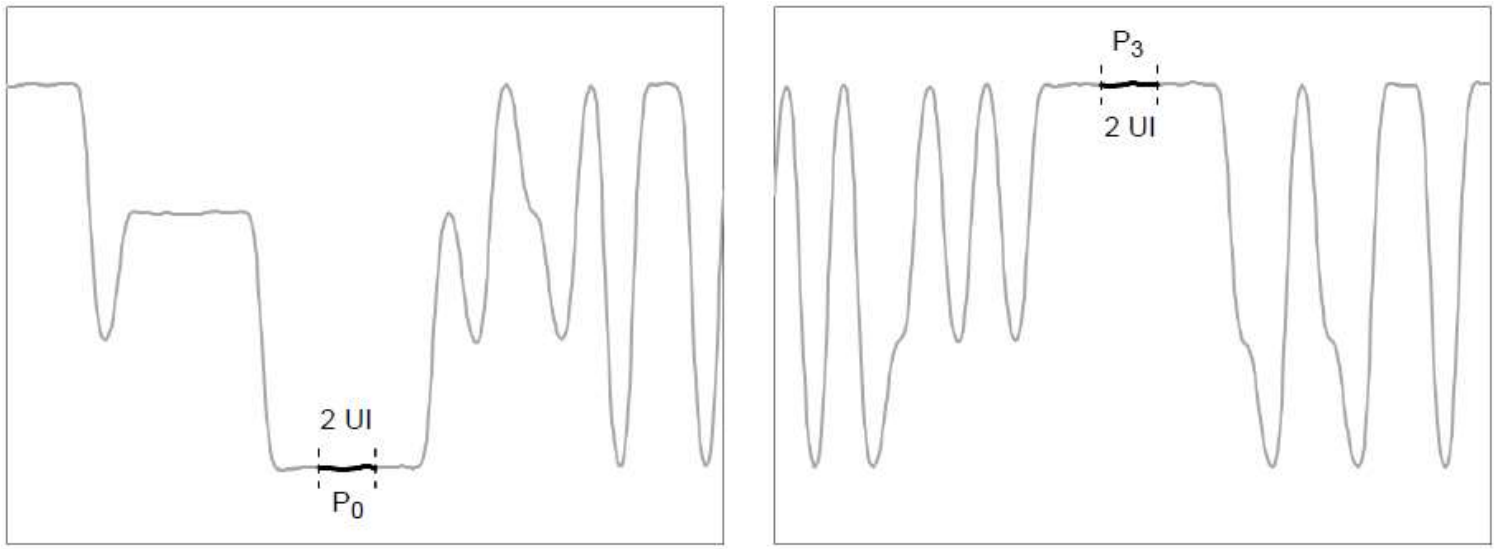
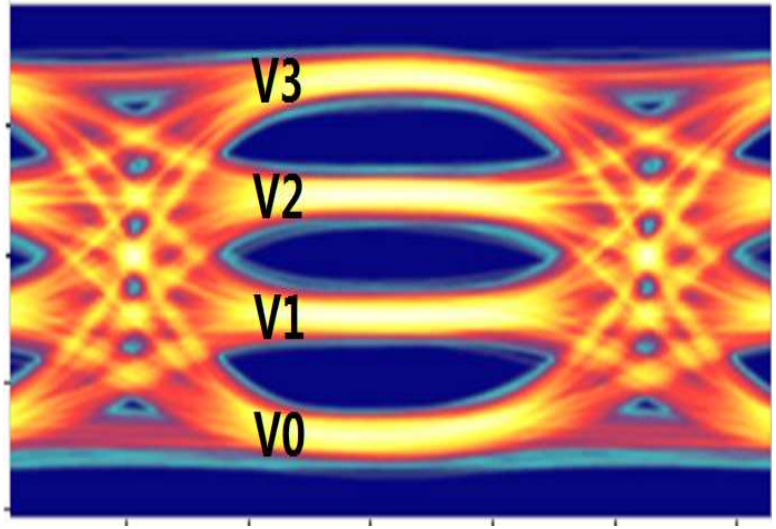


Figure 121–3—Example power levels P_0 and P_3 from PRBS13Q test pattern

PAM4 test: things are different

- More than one eye in one UI
  - Need to considerate the transmitter linearity
  - The level separation mismatch ration: R_{LM} Need to be test
  - The R_{LM} defined as(120D) : min[(3*ES1),(3*ES2),(2-3*ES1),(2-3*ES2)]
  - The idea R_{LM} is 1



V0~V3 is the mean value of the levels
Measure base on PRBS13Q pattern

$$V_{\text{mid}} = \frac{V_0 + V_3}{2}$$

$$ES1 = \frac{V_1 - V_{\text{mid}}}{V_0 - V_{\text{mid}}}$$

$$ES2 = \frac{V_2 - V_{\text{mid}}}{V_3 - V_{\text{mid}}}$$

RIm: Algorithm comparison “Clause 94”/”120D”

$$S_{min} = \frac{min(V_D - V_C, V_C - V_B, V_B - V_A)}{2} \quad \text{(a)}$$

$$V_{avg} = \frac{V_A + V_B + V_C + V_D}{4} \quad \text{(b)}$$

$$ES_1 = \frac{V_B - V_{avg}}{V_A - V_{avg}} \quad \text{(c)}$$

$$ES_2 = \frac{V_C - V_{avg}}{V_D - V_{avg}} \quad \text{(d)}$$

$$R_{LM} = \frac{6 \cdot S_{min}}{V_D - V_A} \quad \text{(e)}$$

$$V_{\text{mid}} = \frac{V_0 + V_3}{2} \quad \text{(120D–3)}$$

$$ES1 = \frac{V_1 - V_{\text{mid}}}{V_0 - V_{\text{mid}}} \quad \text{(120D–4)}$$

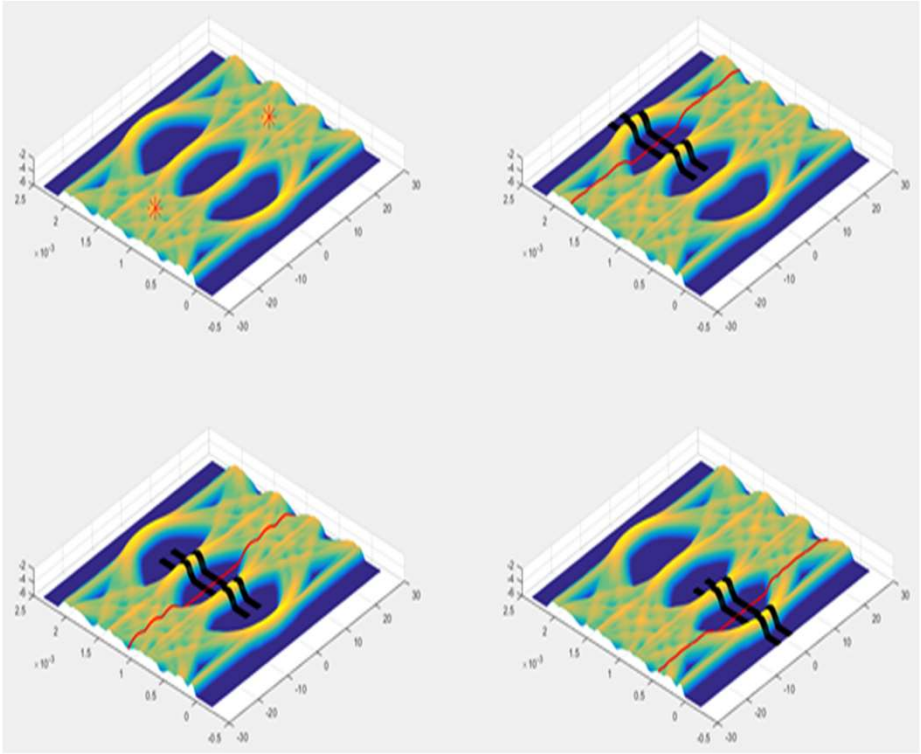
$$ES2 = \frac{V_2 - V_{\text{mid}}}{V_3 - V_{\text{mid}}} \quad \text{(120D–5)}$$

The level separation mismatch ratio R_{LM} is defined by Equation (120D–6).

$$R_{\text{LM}} = \min((3 \times ES1), (3 \times ES2), (2 - 3 \times ES1), (2 - 3 \times ES2)) \quad \text{(120D–6)}$$

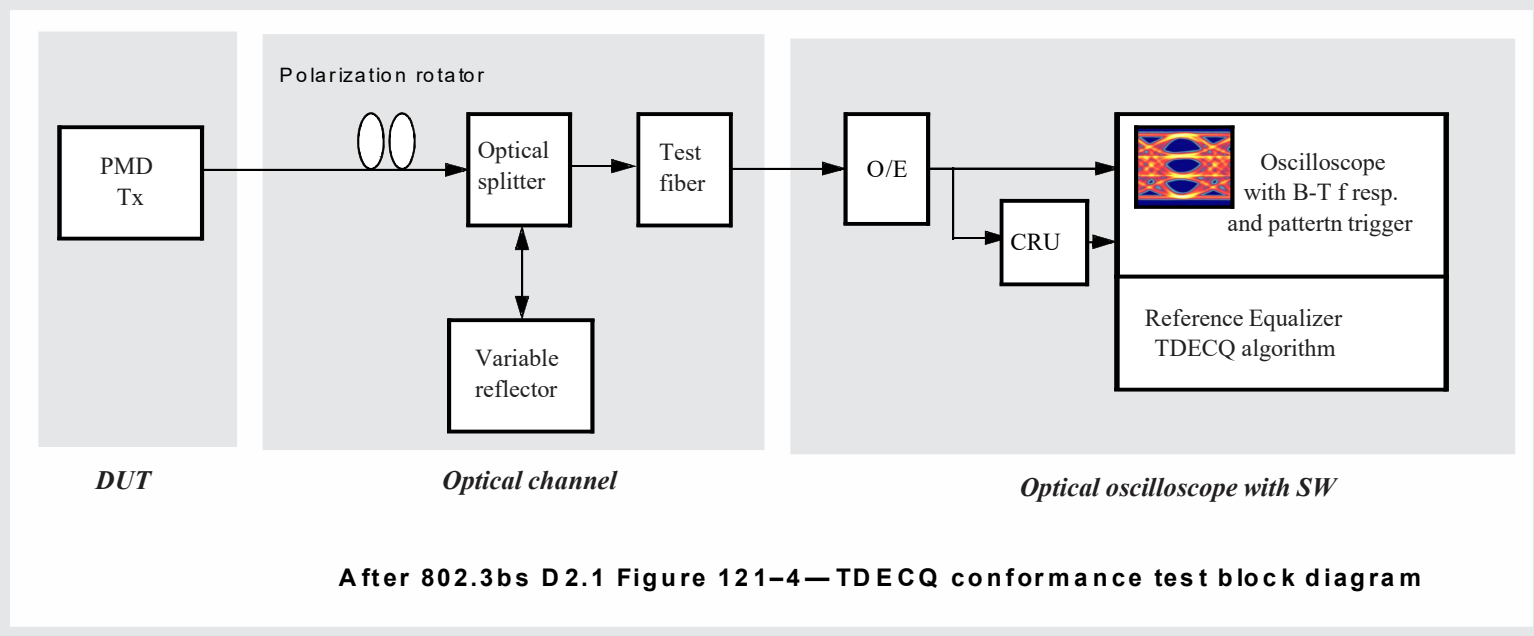
PAM4 test: no eye mask test anymore
Mask → TDECQ (quaternary)

- Optical measurement on *equalized* optical links with PAM4
- Transmitter waveform-shape penalty
- Dispersion penalty: insert fiber (see next page) with max and with min dispersion



TDECQ measurement setup

- (TDEC: Transmitter and Dispersion Eye Closure penalty Quaternary)



After 802.3bs D2.1 Figure 121–4—TDECQ conformance test block diagram

- Difficult part of TDECQ: Equalization!

TDECQ: the remaining piece

TDECQ is a measure of the optical transmitter's vertical eye closure (via closure with noise) when transmitted through a worst case optical channel, as measured through an optical to electrical converter (O/E) with a bandwidth equivalent to a reference receiver, and equalized with the reference equalizer.

It is a penalty vs. ideal (simulated) TX. So TDECQ = 0 dB ➔perfect TX; around 2.5 dB the TX fails the standard.

$$TDECQ = 10\log_{10}\left(\frac{OMA_{outer}}{6} \times \frac{1}{Q_t R}\right)$$

- OMA,outer = amplitude of PAM4 signal
- R = standard deviation of acceptable receiver noise @ SER of 4.8 E-4
- - compensated for scope and E to O noise
- Q,t = 3.414
- Smaller TDECQ is better (penalty). More acceptable receiver noise is better.

Optimizing the TDECQ equalizer - what to optimize?

- Optimizing TDECQ itself was rejected (non-physical in RX)
- Optimizing MSEE matches well what RX does, but it's only partially convergent - note that several near-optimal MMSE solutions yield rather disparate TDECQ results
- Again this is a penalty, so smaller is better

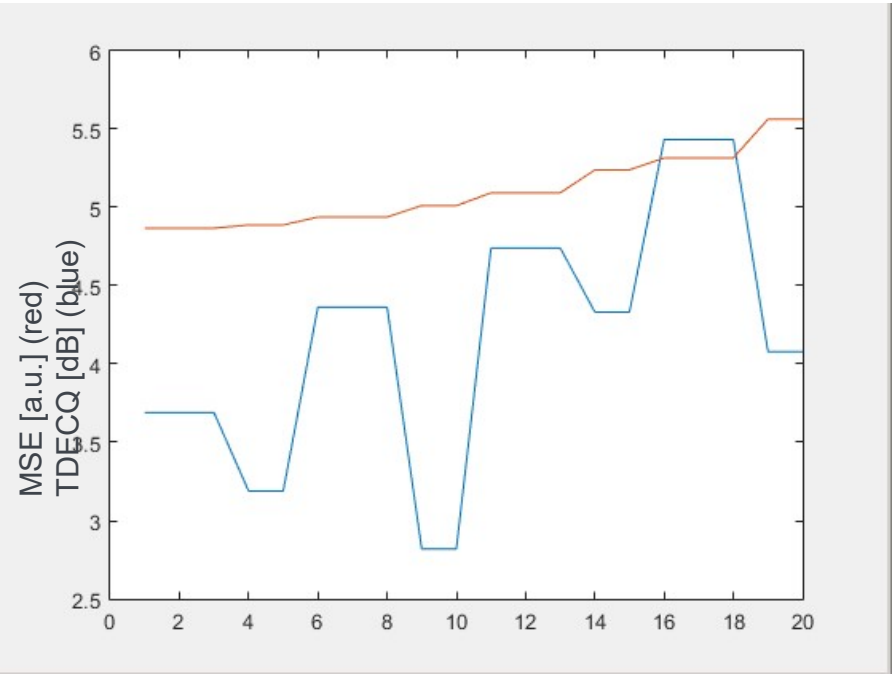
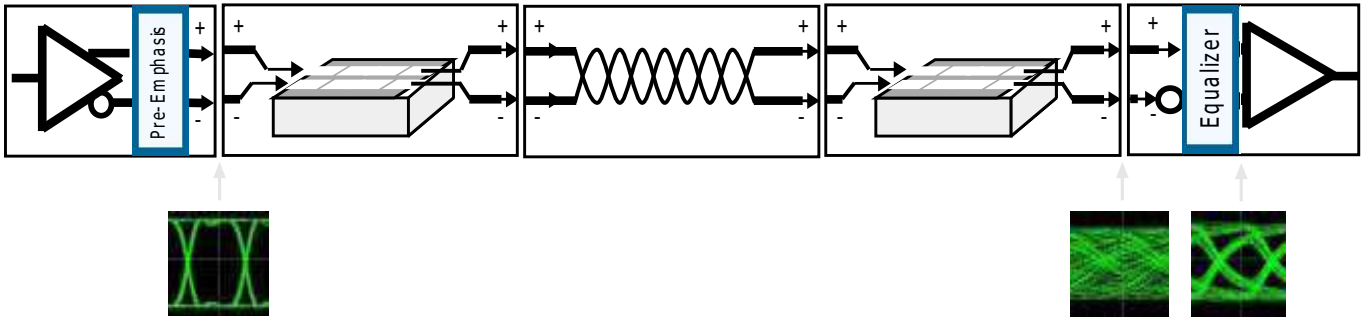


Figure 1: MSE, TDECQ with different phase and cursor positions

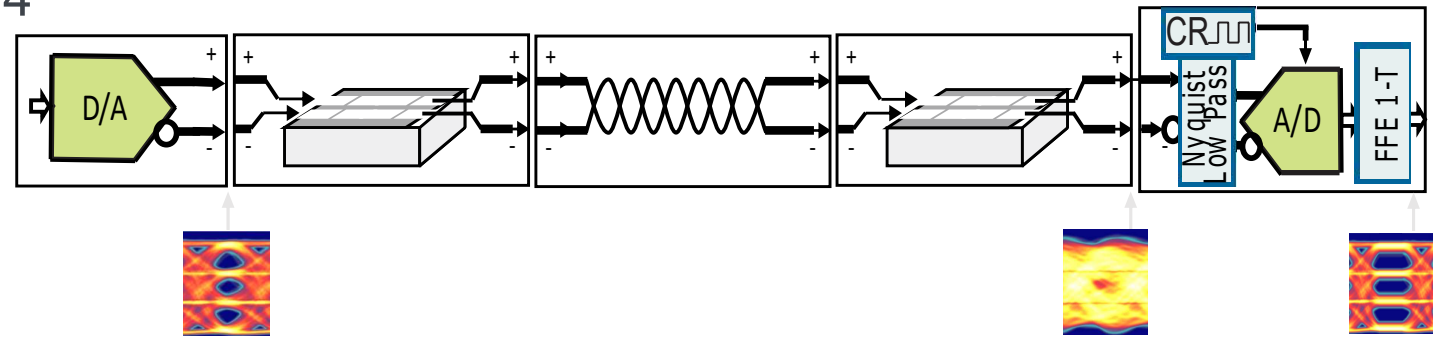
The bandwidth question

- What has changed?

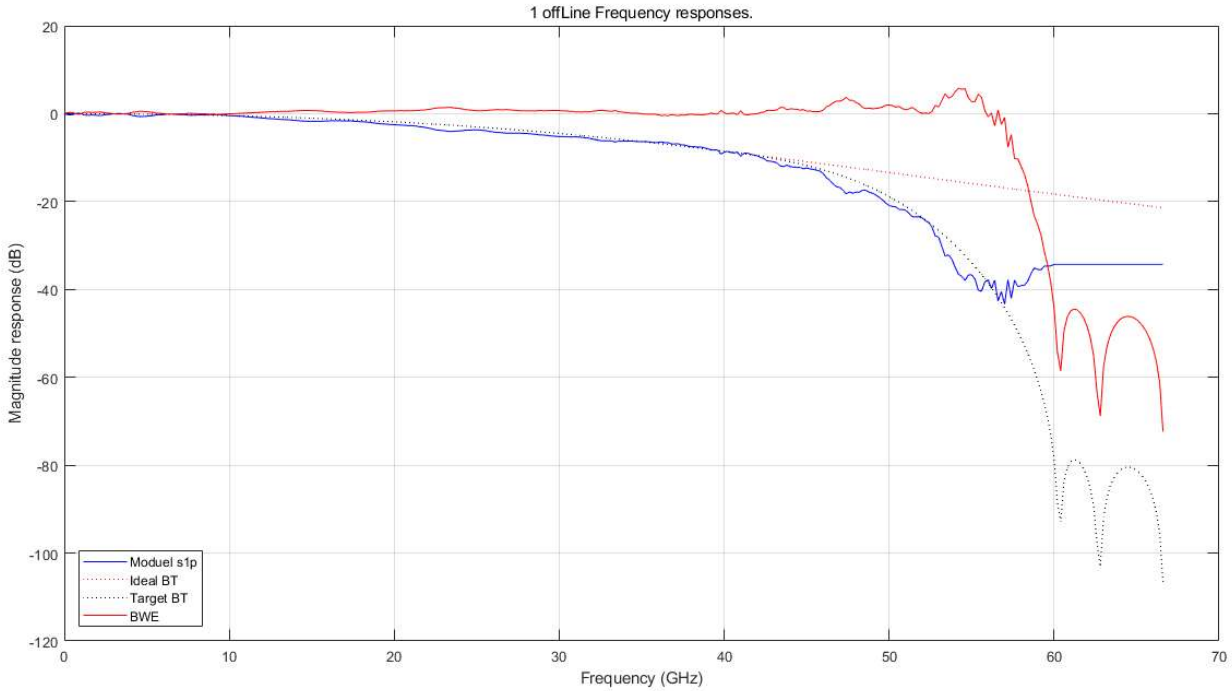
NRZ



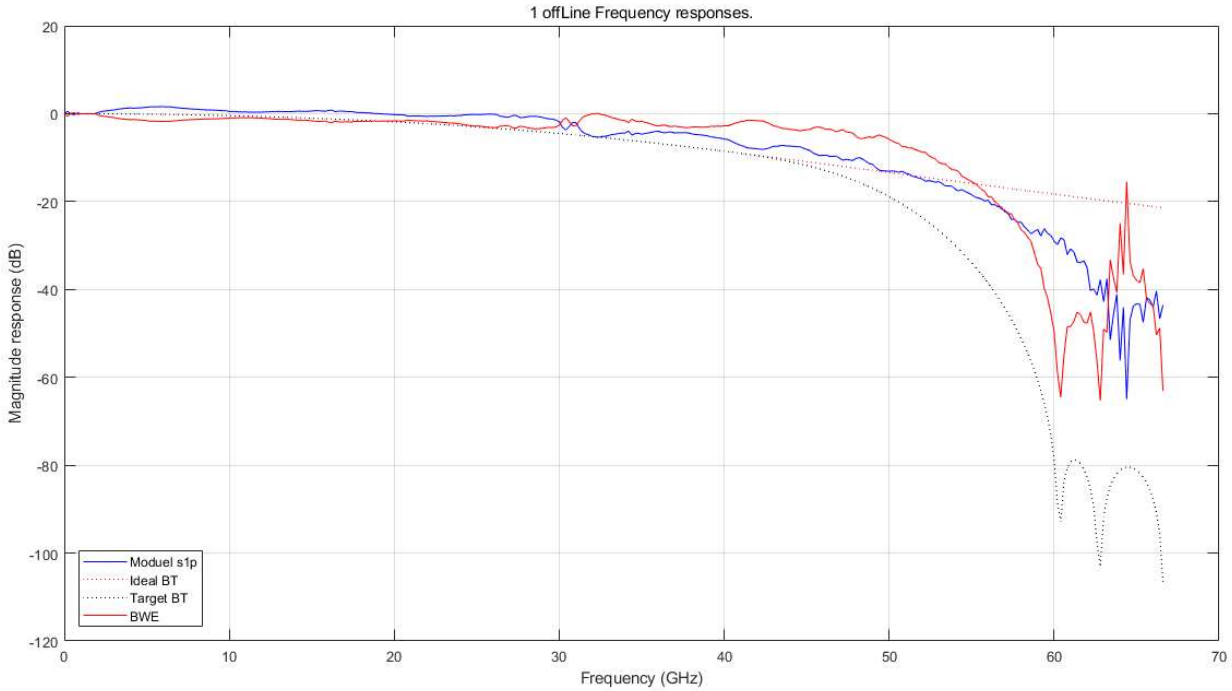
PAM4



Filter: example of 80C17/18

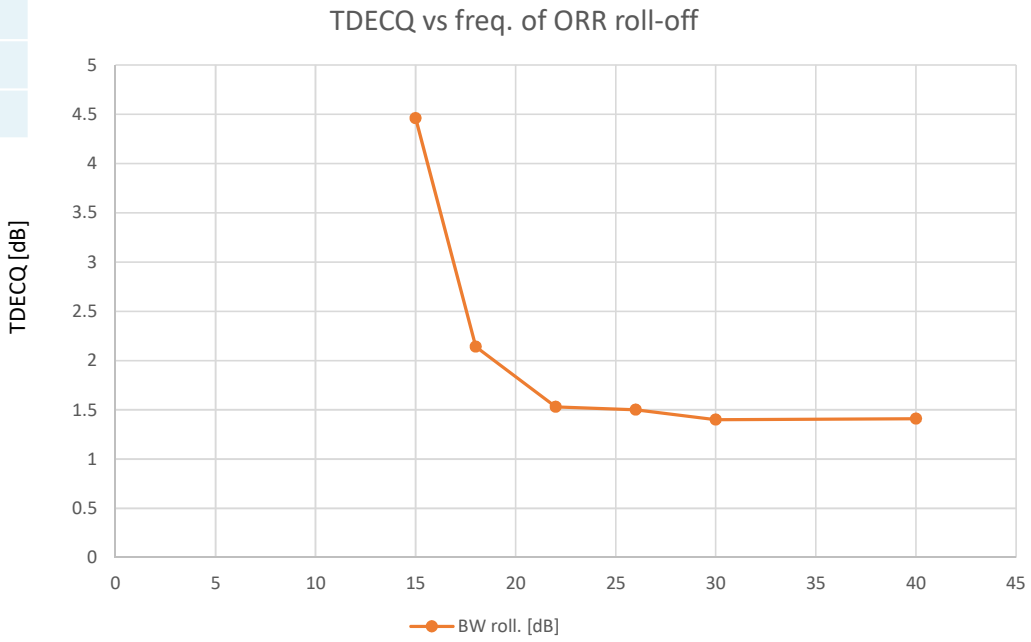


Filter: example of 80C20/21



TDECQ vs. roll off freq (by a DUT with 26.6GBd)

f [GHz]	BW roll. [dB] [dB]
40	1.41
30	1.4
26	1.5
22	1.53
18	2.14
15	4.46



400G-M4

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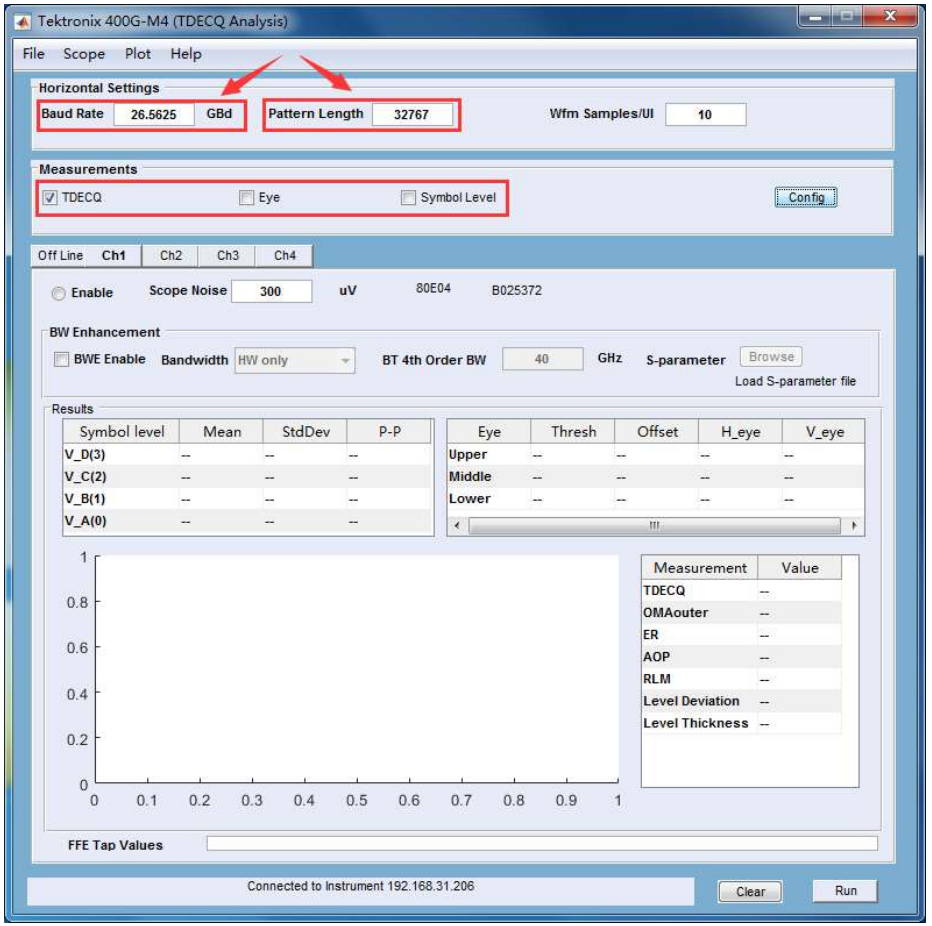
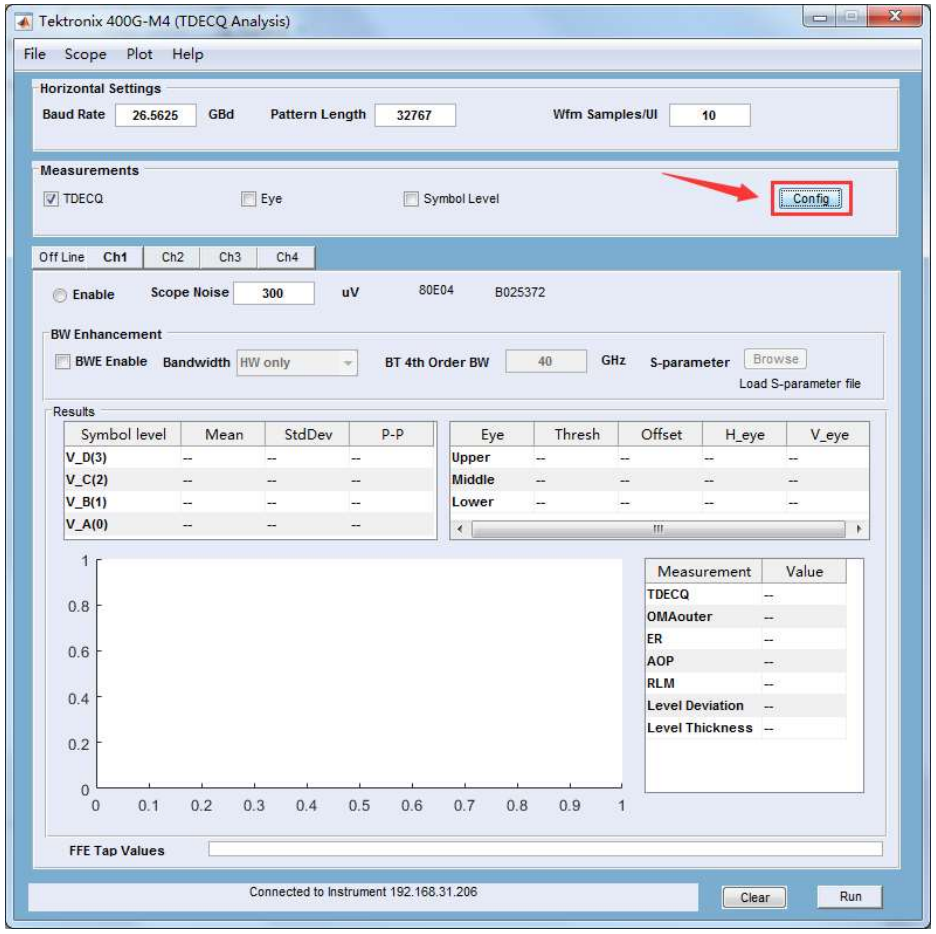
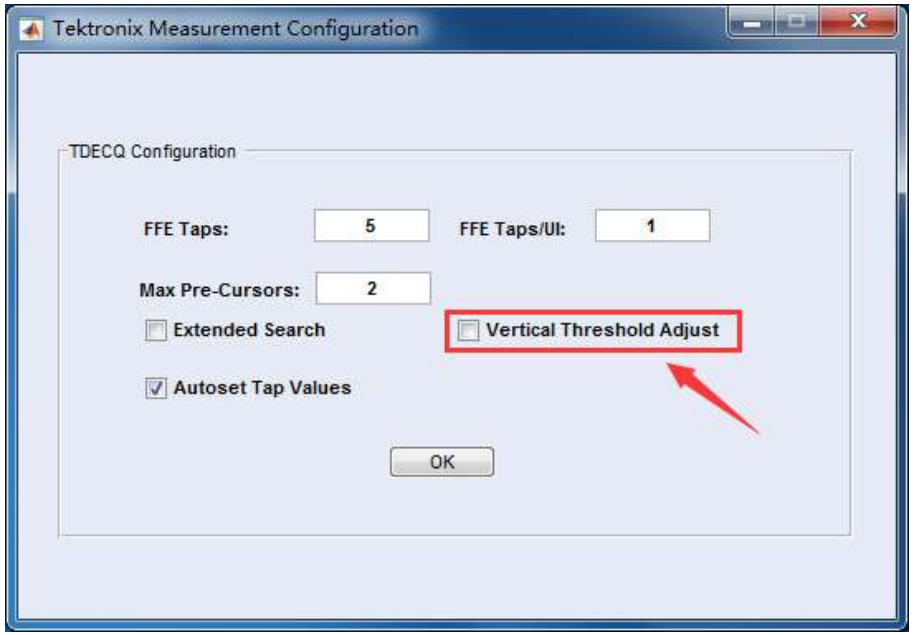
400G-M4 setting

- Baud Rate / Pattern Length and test items
  - Baud Rate: Key in the baud rate of your DUT, default is 26.5625GBd
  - Pattern Length: Key in the pattern length of your DUT, default is 32767 UI
  - TDECQ: if check this item you will get the results: TDECQ/OMAouter/ER/AOP
  - Eye: if you check this item you will get the results:Threshold/Offset/Eye-horizontal/Eye-vertical
  - Symbol Level: if you check this item you will get the results:RLM/Level Deviation/Level Thickness and 4 levels value



400G-M4 setting: EQ and Vertical Threshold

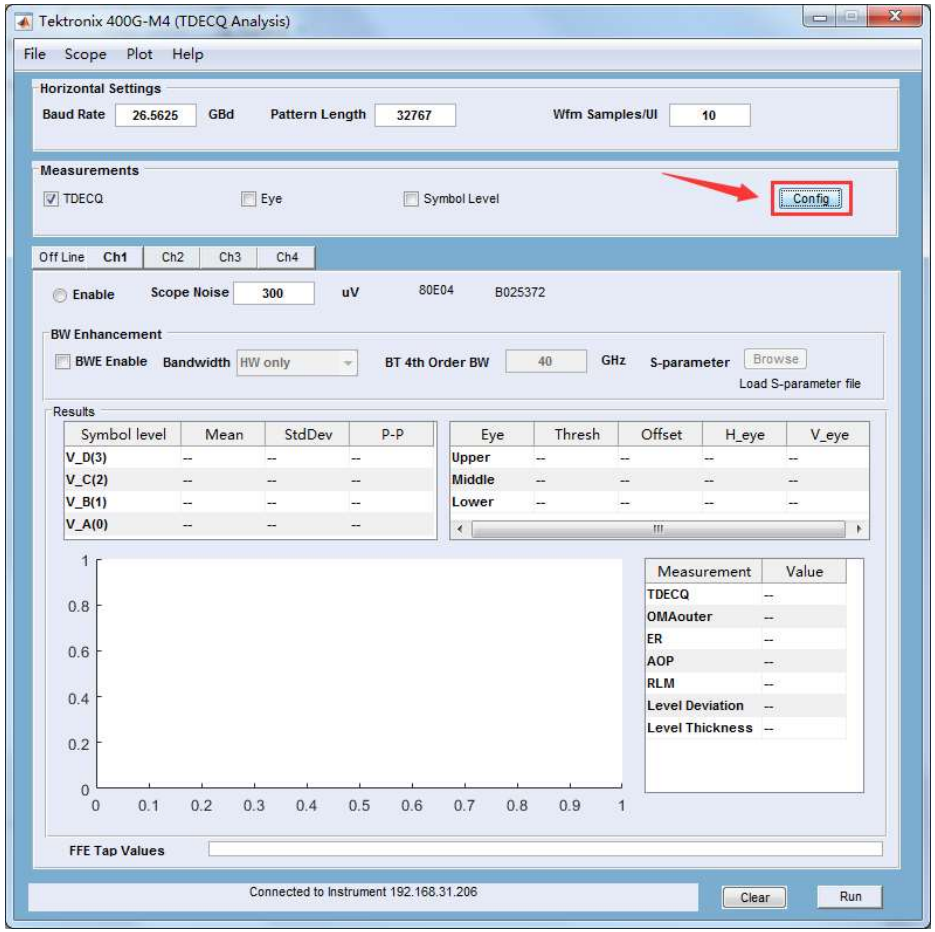


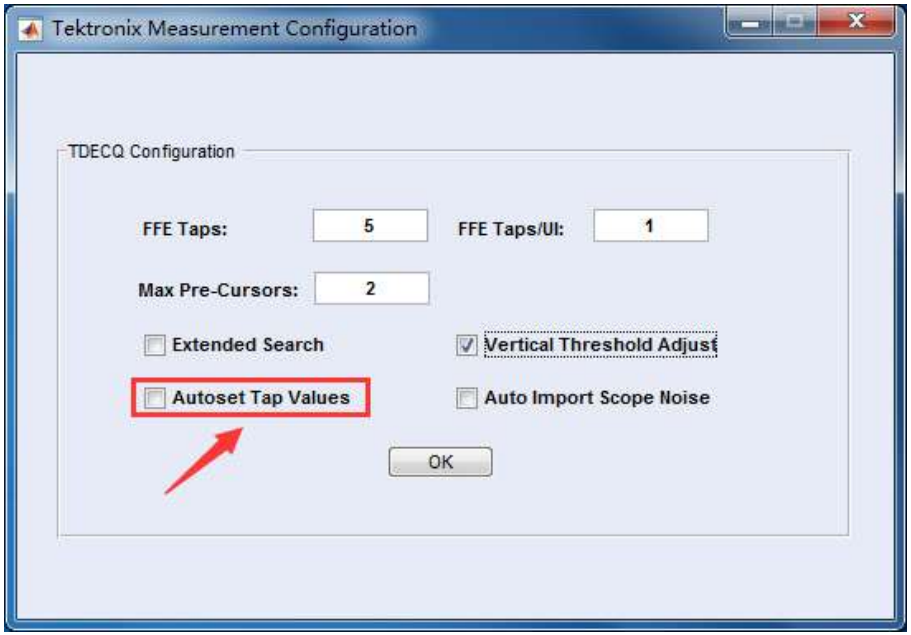


400G-M4 setting: EQ and Vertical Threshold

- EQ setting: Please just keep the default setting, that's fully following the latest IEEE standard, except you want to try with your own EQ parameter
- Vertical Threshold Adjust: after March 2018 IEEE allow the tester to select the PAM4 threshold adjust within 1% to optimize the TDECQ test value. This item default is un-check.

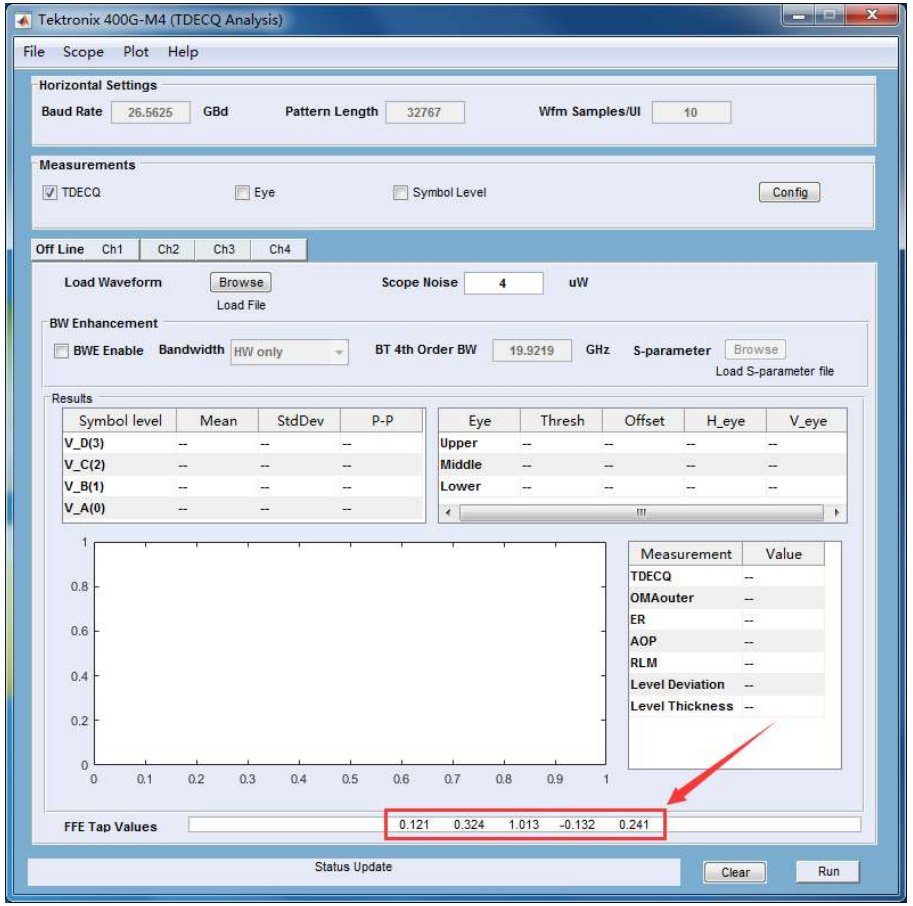
400G-M4 setting: EQ (if you want custom taps)





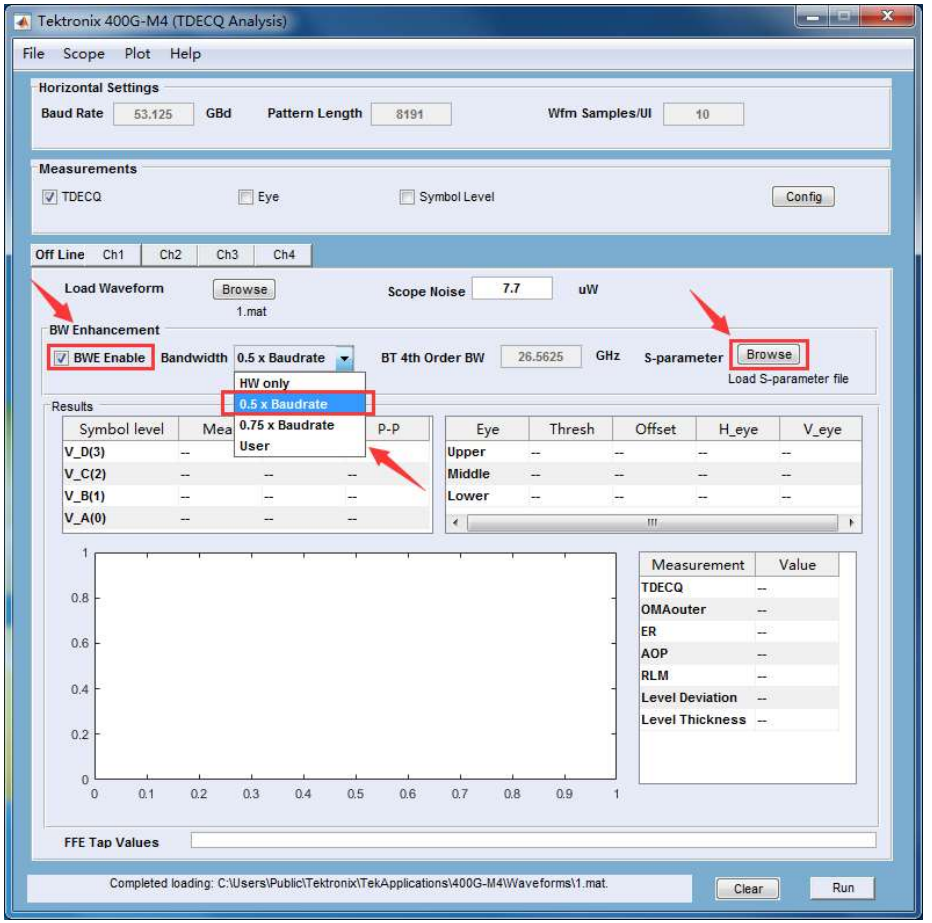
400G-M4 setting: EQ (if you want custom taps)

- Un-check the “Autoset Tap Values” in the config box
- Input your custom FFE Tap Values in the main UI. Values separate by space
- If you want to see the non-EQ results then you can key in the values like “0 0 1 0 0”



400G-M4 setting: BWE filter

- Band Width Enhance filter: default is un-check if you want to use you need:
  - The S-Parameter file of the channel you using. Different scope channels will not have the exactly same frequency response, so every scope channel has dedicated S-Parameter file
  - The BW of the 4th B-T filter that IEEE required is 0.5x baud of the DUT
  - Click the “Browse” to load the s1p file of the channel you are using



The solution we demonstrating today

- DUT: Optical PAM4 with PRBS15 length
- Configuration: DSA8300 + 80C18*2 + external i7 laptop
- Finished 4 lanes PAM4 test in about 35 seconds
  - DSA8300 acquisition and transmit took 9 seconds (Laptop was idle)
  - Laptop computing took 26 seconds (DSA8300 was idle)
  - The utilization ratio of DSA8300 was only 25.7% !!!

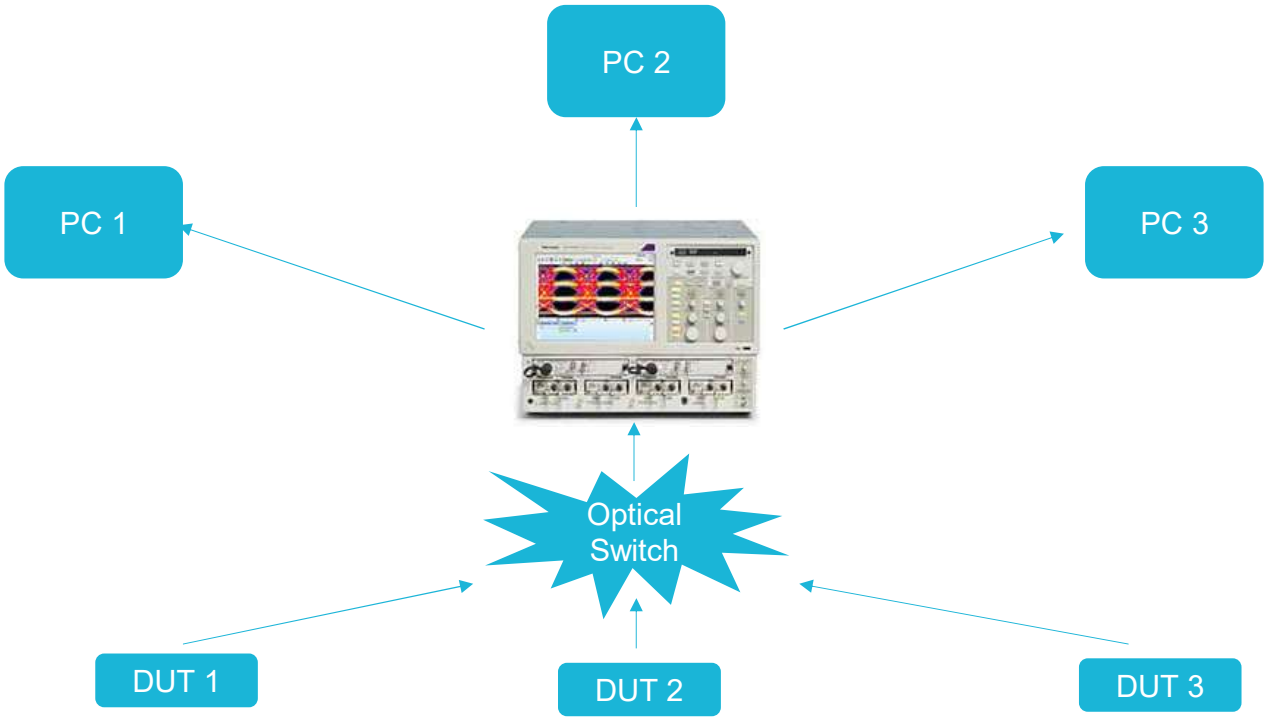
What is Huawei / Hisilicon really need?

Acquisition → Analysis software in external PC

When acquiring can not analysis
When analyzing can not acquire

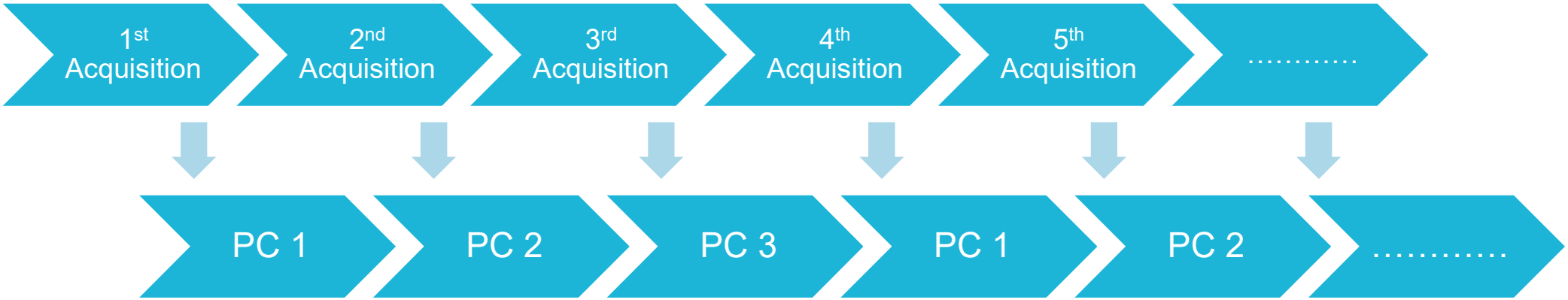
What is customer really need?

- To maximize the utilization ratio of DSA8300
  - One DSA8300 to serve multi PCs.



How to improve the productivity?

Instrument only keep acquiring
PC only keep analyzing
No idle of instruments neither PC



If DSA8300 keep working and no idle

THE COMPARISON OF THROUGHPUT

- Let's compare the single PC and multi PCs
- Let's assume the acquisition and transmit time = 1
  - If the PC computing time is 3x to the ACQ time, the throughput of multi PCs solution will be 400% to single PC solution!!!

Time of ACQ and Trans	Time of Analysis	Time of single PC test	Time of multi PCs test	Throughput % to single PC
1	1	2	1	200
1	2	3	1	300
1	3	4	1	400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