Test patterns

Piers Dawe
Avago Technologies

Supporters

Jonathan King	Finisar
Ryan Latchman	Gennum

Introduction

- Table on next page describes the use of the various test patterns for 40GBASE-SR4 and 100GBASE-SR10 (SRn)
- Shows viable alternative patterns
- Shows which tests need the other lanes in the same direction or other direction operational, and which tests need a different pattern on the lane under test to the pattern on other lanes
- Shows which tests involve error counting
- Most of this would apply to the other optical PMDs. Some of it would apply to nAUI

The full story

Test patterns in 10GbE, SFP+ and for 40/100GbE			Pattern															
Parameter			1	2	3	4	5	A	B @	C %	D	E	F			Related subclause	
Function under test		What 10G serial (optical), SFP+ (electrical) use	Typical	Demanding	PRBS31	PRBS9	Scrambled idles	Scrambled RF	Scrambled "test"	Portion of n0GBASE-Rn signal	10GBASE-R signal	Square 8+8	Un-modulated	Other direction?	One lane special?	Error counting?	Test procedure
Wavelength	Tx	1 or 3 or D a	Y	Y	Y	Y?	Y	Y *	Y	Y	Y	N	N	X	N	N	86.7.5.1
Average optical power	Tx	1, 3, D b	Y	Y	Y	Y?	Y	Y *	Y	Y	Y	?	N	X	N	N	
Spectral width(SMSR in 87,88)	Tx	1, 3, D a	Y	Y	Y	N?	Y	Y	Y	Y	Y	N	N	Y?	N	N	86.7.5.1
Extinction ratio	Tx	1, 3, D c	Y	Y	Y	N?	Y	Y *	Y	Y	Y	N	N	X	N	N	86.7.5.5
Transmitted waveform (eye ma	Tx	1, 3, D d	Y	Y?	Y	N	Y	Y	Y	Y	Y	N	N	Y	N	N	86.7.5.7
AC common mode voltage	Both	1, 3 e	Y	Y?	Y	N?	Y	Y	Y	Y	Y	N	N	Y?	N	N	86.7.4.1
J2	Both	3, D	Y	Y	Y	?	Y ^	Y *	Y	Y	Y	N	N	X?	N	N	86.7.4.4.1
J9	Both	3, D	N?	?	?	N	Y ^	Y *	Y	Y	Y	N	N	Y	N	Maybe	86.7.4.4.2
TDP	Tx	2, 3	N	?	Y	N	Y	Y	Y	Y	Y	N	N	Y	N	Y	86.7.5.4
DDPWS	Tx	PRBS9	N?	N?	N	Y	N	N	N	N	N	N	N	X?	N	N	86.7.4.4.1
Transition time	Both	Square, PRBS9	?	?	?	Y	?	?	?	?	?	Y	N	X?	N	N	86.7.4.3
Transmitter OMA	Tx	Square	N?	N?	N?	Y	N?	N?	N?	N?	N?	Y	N	X	N	N	86.7.5.3
RIN12OMA signal	Tx	Square	May	Mayl	May	May	Maybe	Maybe	Maybe	Maybe	Maybe	Y	N	X	N	N	86.7.5.6
RIN12OMA noise	Tx	Not modulated	N	N	N	N	N	N	N	N	N	(Y)	Y	Y	Y	N	
Rx 3 dBe upper cutoff frequen	Rx	1, 3 f	Y	?	Y	N?	Y ^	Y	Y	Y	Y	N	N	Y?	N	Y	87.8.13
Stressed receiver sensitivity	Rx	2, 3	N	Y	Y	N	Y ^	Y	Y	Y	Y	N	N	Y	N	Y	86.7.5.9
VECP and J calibration	Rx	2, 3	N	Y?	Y	N?	Y ^	Y	Y	Y	Y	N	N	n/a	N	N	52.9.9
Calibration of OMA for Rx tests	Rx	Square	N?	N?	N?	Y	N?	N?	N?	N?	N?	Y	N	n/a	N	N	52.9.9
Total Jitter		n/a				Not needed for D1.2											86.7.4.4
Deterministic Jitter		n/a	Not needed for D1.2														86.7.4.4

a an appropriate PRBS or a valid 10GBASE-R or 10GBASE-W signal, OC-192 signal, STM-64 signal, or another representative test pattern.

b or a valid 10GBASE-R or 10GBASE-W signal, OC-192 signal, STM-64 signal, or another representative test pattern.

c during system operation. However, measurements with an appropriate PRBS (2^23 –1 or 2^31–1) or a valid 10GBASE-R or 10GBASE-W or OC192c or STM-64 signal will give equivalent results.

d during system operation. However, measurements with pattern 3 or 1 defined in 52.9.1, or other patterns such as a 2^23– 1 PRBS or a valid 10GBASE-R, or 10GBASE-W, or OC192c, or STM-64 signal are likely to give very similar results.

e It is expected that any 64B/66B coded signal should give a similar result.

f An appropriate PRBS or a valid 10GBASE-R or 10GBASE-W signal, OC-192 signal, STM-64 signal, or another representative test pattern may be used

X = don't care, Y = yes, N = no

* A DTE will naturally emit RF unless receiving a good signal (could be RF), or test mode enabled

^ Should not send "idle" into a DTE unless you intend to make a network with it; it may try to send you someone's data

@ If we need a pattern that cannot be interpreted by a network

% 5, A and B also qualify as C

Most tests use a mixed-frequency signal, a few use PRBS9 or square wave

Mixed-frequency patterns

- 40G lanes, 100G lanes and 10G lanes are effectively the same: as good as 64/66 parts random
  - Mixed-frequency "patterns" emulate (or are) mission-mode bit sequences
  - PRBS31 is a tolerable approximation to random
  - 10G patterns 1, 2 are special-purpose imitations of the statistics of a 10G signal, 33,792 bits long.
- DTE will naturally emit scrambled idle or scrambled RF depending on input
- DTE will naturally respond to scrambled idle input
  - May not be a good idea
- 10GE allowed several alternatives for practical reasons
  - Usually, analog or optical test equipment can't understand Ethernet coding
  - We should allow alternatives also
  - Implementers may wish to re-use 10 GbE test equipment
  - We have the new issue of multiple lanes – test cost gets multiplied up if we aren't careful
- Used for sensitivity measurements so error counting needed

Lane issues

- A PCS signal (including Pattern 5) will be random enough when bit-muxed up
- A PRBS31 or PRBS9 will bit-mux up or down to a PRBS31 or PRBS9 for a certain skew
- For other, unfortunate, skews (e.g. patterns aligned on all lanes), spectrum of muxed signal is very abnormal (slow)
- Plenty of skews in between where muxed signal is random enough
  - 10:4 mux then demux may not return the original pattern
- Building the PRBS generator across the lanes so that for zero skew it muxes to PRBS should nail the issue: keeps the lanes well un-aligned

- RIN test procedure requires one very "special" (unmodulated) lane
- Lane diagnostics could use one "special" lane e.g. a different PRBS

Short test pattern

- Short mixed-frequency test pattern
  - Choose PRBS9
  - For DDPWS
  - Can be used for risetime
  - Can be used for OMA
    - Good for measurement of signals with only "linear" impairments
      - Good reference signal in TDP comparison
      - Stressed sensitivity conformance signal
    - OMA definition isn't sacred: for example, it varies with line code
  - Not used for sensitivity – no need to count errors

Square wave

- 8 ones and 8 zeros
- More precisely defined than 10G (Clause 52)'s square wave, same as LRM's
- For OMA measurement
  - And sometimes VMA: see slide 9
  - Used for transmitter OMA and RIN specs
- Can be used for risetime
- Not the only option for OMA and risetime
  - nAUI doesn't need it
- Very unnatural spectrum, some clock recovery units may not lock to it
- Useful in the factory: can use slower test jigs, cabling and equipment, don't always need clock recovery unit
- Not used directly for sensitivity – no need to count errors
- Never applied to product receive side
- A nuisance – we should write the standard so it can be avoided

Null pattern (unmodulated)

- RIN_XOMA test description expects
  1. OMA measurement
  2. Noise measurement with laser half on and not modulated
- The second in particular is not practical in a complete equipment – not natural for even a complete module
- Feasible as a factory spec only and should not appear in a black-box interoperability spec such as 802.3
- With a TDP spec in place, the RIN_XOMA spec is not necessary
- Remove the normative RIN_XOMA specs from all three optical clauses. Give a recommendation if wished. Do not go out of our way to provide test-pattern support for RIN_XOMA

KR- and CR-specific requirements

- 10GBASE-KR KR uses a square wave
  - 72.7.1.7 Transition time
    - The rising and falling edge transition times shall be between 24 ps and 47 ps as measured at the 20% and 80% levels referenced to v2 and v5 as defined in 72.7.1.11. Measurement is done using the square wave test pattern defined in 52.9.1.2, with no equalization and a run of at least eight consecutive ones. Transmit equalization may be disabled by asserting the preset control defined in Table 45–55 and 45.2.1.78.3.
  - 72.7.1.11 Transmitter output waveform requirements
    - The test pattern for the transmitter output waveform is the square wave test pattern defined in 52.9.1.2, with a run of at least eight consecutive ones.
  - 49.2.8 Test-pattern generators
    - There are two types of required transmit test patterns: square wave and pseudo-random. The square wave pattern is intended to aid in conducting certain transmitter tests. It is not intended for receiver tests and the receiver is not expected to receive this test pattern.
    - When square wave pattern is selected, the PCS will send a repeating pattern of n ones followed by n zeros where n may be any number between 4 and 11 inclusive. The value of n is an implementation choice.
- D1.1 40GBASE-KR follows 10GBASE-KR
- 40GBASE-KR not expected to bit-mux lanes
  - Square wave generator could be in PCS or in PMA
  - But if 10GBASE-CR10 picks up all the KR baggage?
  - KR could use PRBS9 for transition time
  - Use of PRBS9 for transmitter output waveform might introduce a discrepancy vs. use of square wave
- Expect Backplane Ethernet chips will handle this
  - Make square wave generator conditional for KR4, CR4, CR10, absent for optical PHY types
- KR not an issue for the rest of the presentation

OMA – TDP*

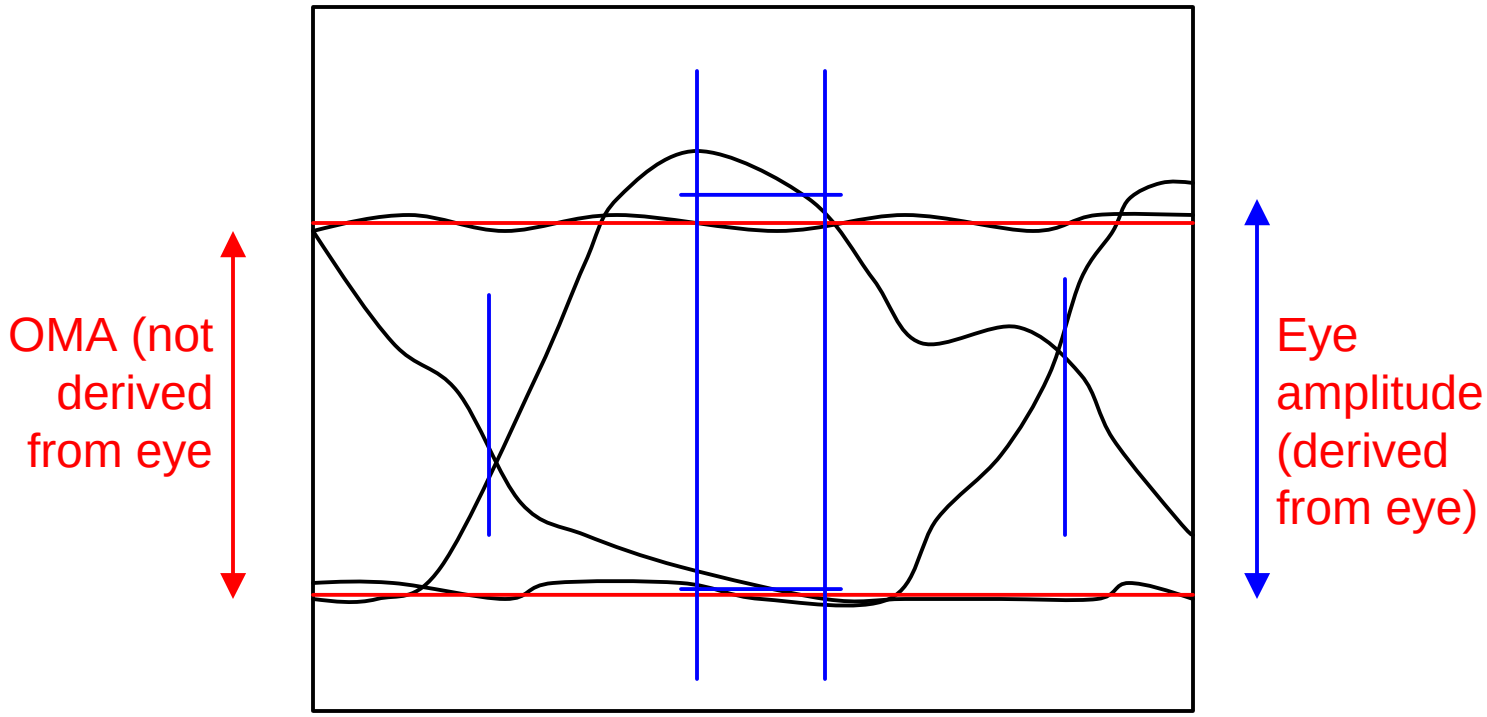
- With a reference receiver, measure sensitivity to a good signal
  - Set good reference transmitter to mixed-frequency signal e.g. Pattern 3 or 5
  - Use an optical attenuator to set the signal strength to BER=10^-12
  - Change transmitted pattern to square wave
  - Measure S = OMA
- With same reference receiver, measure sensitivity to transmitter under test
  - Set transmitter under test to mixed-frequency signal e.g. Pattern 3 or Pattern 5
  - Use an optical attenuator to set the signal strength to BER=10^-12
  - Optionally, change transmitted pattern to square wave
  - Measure P_DUT = OMA or P_DUT_ave = OMA + x
  - TDP = P_DUT – S
- Measure launch OMA or mean power
  - Remove optical attenuator, measure T = OMA or T_ave = T + x
- OMA – TDP = T – P_DUT + S = = T_ave – P_DUT_ave + S (x cancels)
- We don't need to be able to measure OMA of transmitter under test to find OMA – TDP !
- We do have separate transmitter OMA specs – not so critical
- We do have to measure OMA of the good reference transmitter – can use PRBS9
- We also have standalone TDP specs which require OMA measurement

* From 52.9.10.4. Reference fiber and filters omitted for simplicity

Transmitter OMA and TDP specs

- Transmitter has min and max OMA limits and max TDP limit
- Some "AC amplitude" specs are needed to
  - Protect the receiver from overload and underload
  - Give a spec for modulation-detecting signal detect
  - Define a compliant signal for network maintenance purposes
  - Not critical to 1/10 dB
- But "Eye amplitude" would work instead of OMA
- Or, OMA derived from PRBS9 would be fine
- Maximum TDP spec is necessary
  - Its accuracy a little more important than the above
  - What do we require and what do we get with PRBS9?

Illustration of Eye Amplitude vs. OMA



- Eye Amplitude measurement is already built into oscilloscopes

Proposal for D1.2

Test patterns and related subclau		D1.1	Pattern															
Parameter			1	2	3	4	5	A	B	@	C	%	D	E	F			Related subclause
Function under test		What 10G spec (optical), SFP+ (electrical) use	Typical	Demanding	PRBS 31	PRBS 9	Scrambled idles	Scrambled RF	Scrambled "test"	Portion of n0GBASE-Rn signal			10GBASE-R signal	Square 8+8	Unmodulated	Other direction?	One lane special?	Error counting?	Test procedure
Wavelength	Tx	1 or 3 or D a	Y	Y	A	Y?	Y	Y *	Y	Y			Y	N	N	X	N	N	86.7.5.1
Average optical power	Tx	1, 3, D b	Y	Y	A	Y?	Y	Y *	Y	Y			Y	?	N	X	N	N	
Spectral width(SMSR in 87,88)	Tx	1, 3, D a	Y	Y	A	N?	Y	Y	Y	Y			Y	N	N	Y?	N	N	86.7.5.1
Extinction ratio	Tx	1, 3, D c	Y	Y	A	N?	Y	Y *	Y	Y			Y	N	N	X	N	N	86.7.5.5
Transmitted waveform (eye m	Tx	1, 3, D d	Y	Y?	A	N	Y	Y	Y	Y			Y	N	N	Y	N	N	86.7.5.7
AC common mode voltage	Both	1, 3 e	Y	Y?	A	N?	Y	Y	Y	Y			Y	N	N	Y?	N	N	86.7.4.1
J2	Both	3, D	Y	Y	A	?	Y ^	Y *	Y	Y			Y	N	N	X?	N	N	86.7.4.4.1
J9	Both	3, D	N?	?	?	N	Y ^	Y *	Y	Y			Y	N	N	Y	N	Maybe	86.7.4.4.2
TDP	Tx	2, 3	N	?	A	N	Y	Y	Y	Y			Y	N	N	Y	N	Y	86.7.5.4
DDPWS	Tx	PRBS9	N?	N?	N	Y	N	N	N	N			N	N	N	X?	N	N	86.7.4.4.1
Transition time	Both	Square, PRBS9	?	?	?	Y	?	?	?	?			?	A	N	X?	N	N	86.7.4.3
Transmitter OMA	Tx	Square	N?	N?	N?	Y	N?	N?	N?	N?			N?	A	N	X	N	N	86.7.5.3
RIN12OMA signal	Tx	Square	May	May	May	Mayb	Maybe	Maybe	Maybe	Maybe			Maybe	Y	N	X	N	N	86.7.5.6
RIN12OMA noise	Tx	Not modulated	N	N	N	N	N	N	N	N			N	(Y)	Y	Y	Y	N	
Rx 3 dBe upper cutoff frequen	Rx	1, 3 f	Y	?	A	N?	Y ^	Y	Y	Y			Y	N	N	Y?	N	Y	87.8.13
Stressed receiver sensitivity	Rx	2, 3	N	Y	A	N	Y ^	Y	Y	Y			Y	N	N	Y	N	Y	86.7.5.9
VECP and J calibration	Rx	2, 3	N	Y?	A	N?	Y ^	Y	Y	Y			Y	N	N	n/a	N	N	52.9.9
Calibration of OMA for Rx tests	Rx	Square	N?	N?	N?	Y	N?	N?	N?	N?			N?	A	N	n/a	N	N	52.9.9
Total Jitter		n/a									Not needed for D1.2								86.7.4.4
Deterministic Jitter		n/a																	

Bold blue: normative patterns (Scrambled idles out of DTE, scrambled RF into it)

Bold amber A: normative alternative patterns

Show non-bold Y as NOTE- Pattern xxx is expected to give similar results

Greyed out: don't specify in D1.2, but add informative RIN section

Make RIN informative. No special lane here. Make PRBS9 normative and square wave, alternative and conditional. See next page for simpler table

a an appropriate PRBS or a valid 10GBASE-R or 10GBASE-W signal, OC-192 signal, STM-64 signal, or another representative test pattern.

b or a valid 10GBASE-R or 10GBASE-W signal, OC-192 signal, STM-64 signal, or another representative test pattern.

c during system operation. However, measurements with an appropriate PRBS (2^23 –1 or 2^31–1) or a valid 10GBASE-R or 10GBASE-W or OC192c or STM-64 signal will give equivalent results.

d during system operation. However, measurements with pattern 3 or 1 defined in 52.9.1, or other patterns such as a 2^23– 1 PRBS or a valid 10GBASE-R, or 10GBASE-W, or OC192c, or STM-64 signal are likely to give very similar results.

e It is expected that any 64B/66B coded signal should give a similar result.

f An appropriate PRBS or a valid 10GBASE-R or 10GBASE-W signal, OC-192 signal, STM-64 signal, or another representative test pattern may be used

X = don't care, Y = yes, N = no

* A DTE will naturally emit RF unless receiving a good signal (could be RF), or test mode enabled

^ Should not send "idle" into a DTE unless you intend to make a network with it; it may try to send you someone's data

@ If we need a pattern that cannot be interpreted by a network

% 5, A and B also qualify as C

Proposal for D1.2 (easier reading)

For Table 86-16 D1.2	Pattern									Related subclause
Parameter	1	2	3	4	5	A	C %	D	E	
Function under test	Typical	Demanding	PRBS 31	PRBS 9	Scrambled idles	Scrambled RF	Portion of n0GBASE-Rn signal	10GBASE-R signal	Square 8+8	Test procedure
Wavelength	Y	Y	**A**	Y?	**Y**	**Y ***	Y	Y	N	86.7.5.1
Average optical power	Y	Y	**A**	Y?	**Y**	**Y ***	Y	Y	?	
Spectral width(SMSR in 87,88)	Y	Y	**A**	N?	**Y**	**Y**	Y	Y	N	86.7.5.1
Extinction ratio	Y	Y	**A**	N?	**Y**	**Y ***	Y	Y	N	86.7.5.5
Transmitted waveform (eye ma	Y	Y?	**A**	N	**Y**	**Y**	Y	Y	N	86.7.5.7
AC common mode voltage	Y	Y?	**A**	N?	**Y**	**Y**	Y	Y	N	86.7.4.1
J2	Y	Y	**A**	?	**Y ^**	**Y ***	Y	Y	N	86.7.4.4.1
J9	N?	?	**?**	N	**Y ^**	**Y ***	Y	Y	N	86.7.4.4.2
TDP	N	?	**A**	N	**Y**	**Y**	Y	Y	N	86.7.5.4
DDPWS	N?	N?	N	**Y**	N	N	N	N	N	86.7.4.4.1
Transition time	?	?	?	**Y**	?	?	?	?	**A**	86.7.4.3
Transmitter OMA	N?	N?	N?	**Y**	N?	N?	N?	N?	**A**	86.7.5.3
Rx 3 dBe upper cutoff frequen	Y	?	**A**	N?	**Y ^**	**Y**	Y	Y	N	87.8.13
Stressed receiver sensitivity	N	Y	**A**	N	**Y ^**	**Y**	Y	Y	N	86.7.5.9
VECP and J calibration	N	Y?	**A**	N?	**Y ^**	**Y**	Y	Y	N	52.9.9
Calibration of OMA for Rx tests	N?	N?	N?	**Y**	N?	N?	N?	N?	**A**	52.9.9
Bold blue: normative patterns (Scrambled idles out of DTE, scrambled RF into it)										
Bold amber A: normative alternative patterns										
Show non-bold Y as NOTE- Pattern xxx is expected to give similar results										

What to put in the draft 1/2

- Reference columns are useful
  - Definition of pattern (just ones and zeros) is not the same as definition of pattern generator within an Ethernet sublayer
    - It's OK and normal to generate or check patterns with non-802.3-aware test equipment
  - Need two reference columns, one for pattern and one for 802.3-product pattern generator

What to put in the draft 2/2

- In practice, some alternatives are necessary
  - To cover mix of
    - generic test equipment, Ethernet-oriented test equipment,
    - serial and multilane signals,
    - component factory, "system" factory, network operator
  - Could allow alternative pattern
    - As done in 10GE and EFM
    - Standard (or industry generally) absorbs any difference between results with the different patterns
  - Could choose one normative pattern, mention alternatives
    - Implementer has to account for any difference between results with the different patterns
    - Too inflexible
  - Could choose e.g. two normative patterns, mention alternatives
    - e.g. one or two that are best with product (e.g. PCS test pattern(s)), one that's best with generic test equipment (e.g. PRBS31). Informative alternatives
    - Recommend this option

Summary

1. Allow scrambled RF and scrambled idle as PCS test patterns
2. Choose scrambled RF scrambled idle and PRBS31 as normative "long" patterns
3. Choose PRBS9 for the short "TDB" test pattern
4. Remove the normative RINxOMA specs from all three optical clauses
   - Give an informative recommendation if wished. Do not go out of our way to provide test-pattern support for RINxOMA
5. Make square wave generator conditional for KR4, CR4, CR10

   5a And absent for optical PHY types
6. Informatively list alternative patterns (as listed in table in this presentation) which are expected to give similar results in the measurement section

7a. Either: provide "special lane" switches for PRBS9 (for lane debug) or square (if KR4, CRn need it)

7b. Or, don't provide any "special lane" switches

8. Recommend that the PRBS generators are arranged so that when bit-muxed to a serial stream with only a few bits of skew, they form the PRBS again

   8a If not, require offset between individual lanes' PRBSs