Joint ITU/IEEE Workshop on Ethernet - Emerging Applications and Technologies

Standardization of advanced modulation formats

Pete Anslow, Ciena

Associate Rapporteur ITU-T SG15 Q6

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Outline

- NRZ specification methodology

- Recent updates
  - Eye mask
  - Spectral excursion

- Advanced modulation formats

- Reference receiver approach

- Error vector magnitude

- Further work

NRZ specification methodology

The first version of CCITT (now ITU-T) G.957 in December 1990 established the basic methodology for specification of multi-vendor optical interfaces:
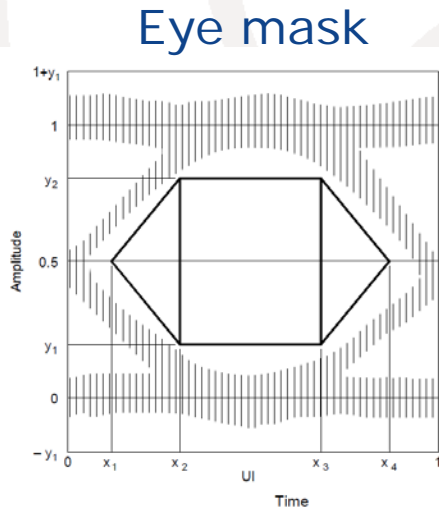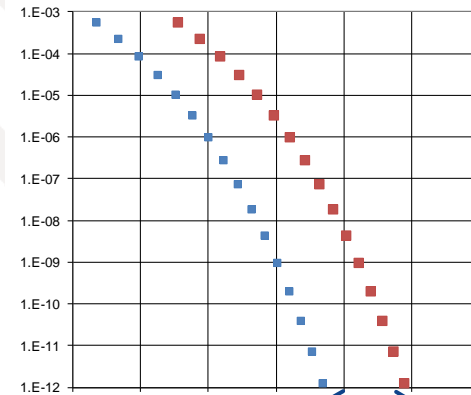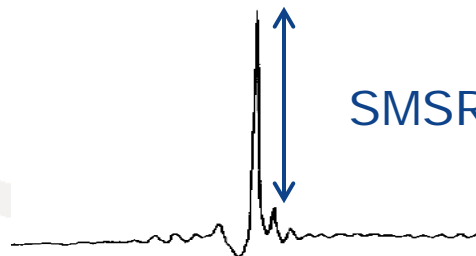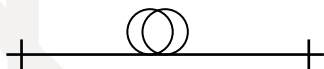
Eye mask

Extinction ratio

Path penalty

Launched power

Receiver sensitivity

SMSR

Link loss

Link dispersion

Eye mask update

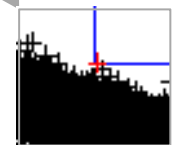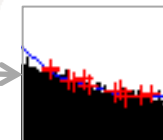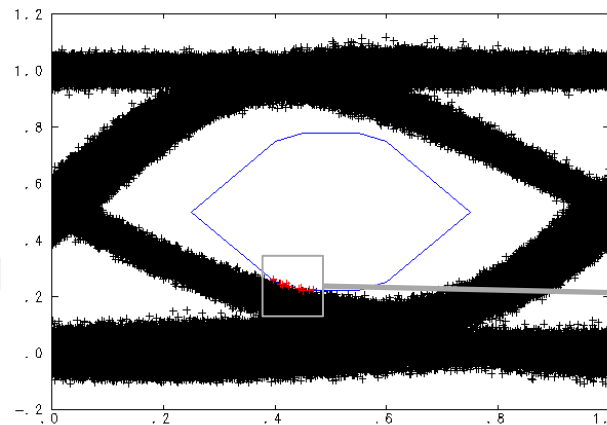In recent years (starting with IEEE 802.3ba-2010) the eye mask test has been updated to allow a proportion of "hits"
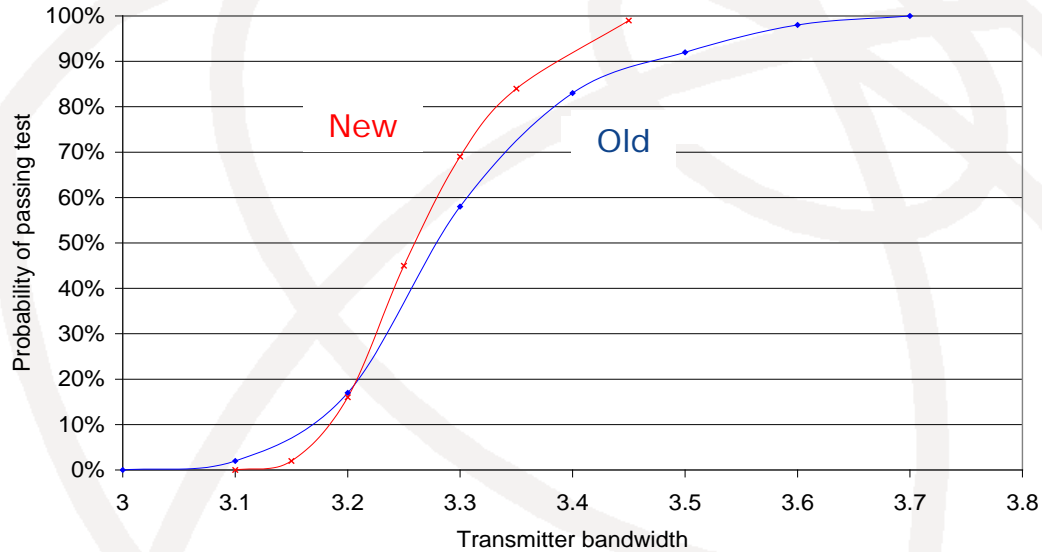
"Old" mask could fail on a single sample
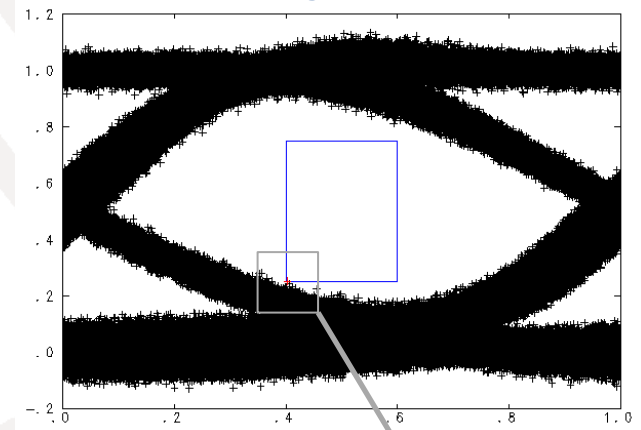
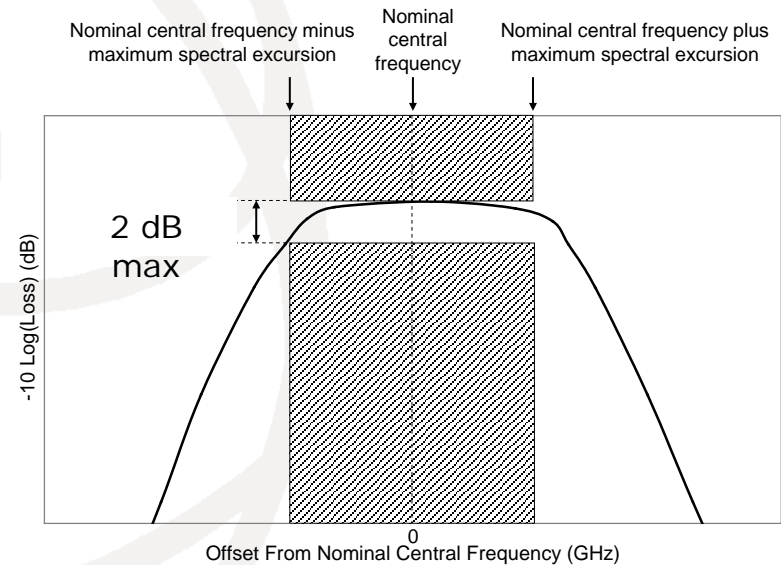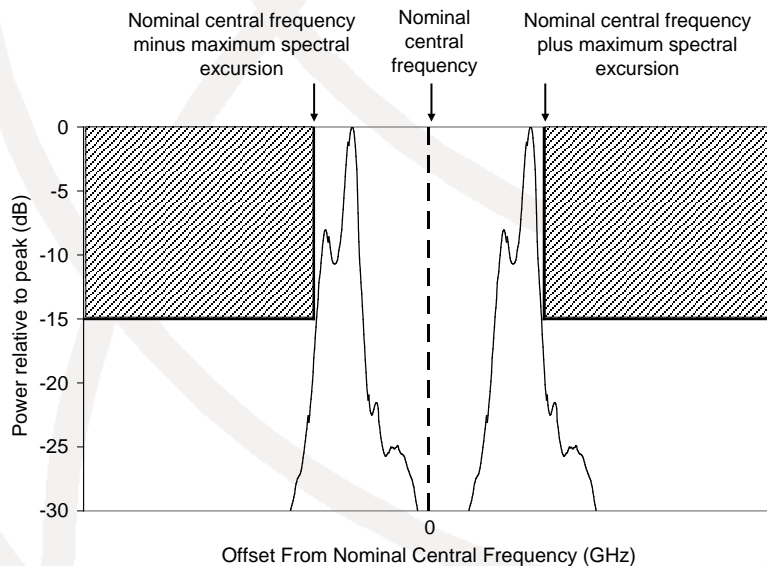"New" ratio mask allows a proportion of hits and changes from all fail to all pass more abruptly

Spectral excursion

When ITU-T G.698.1 introduced a Mux/Demux into the link "spectral excursion" was added to the methodology to ensure that the signal would pass through the filters.

-15 dB points of Tx spectrum must remain within -2 dB points of link filter function

Advanced modulation formats

Moving from 10 Gbit/s to 40 Gbit/s and 100Gbit/s , NRZ is no longer the dominant line-side modulation format.

Formats currently being considered by ITU-T SG15 Q6 at 40G are:

- (P) DPSK   (Partial) Differential Phase Shift Key
- RZ-DQPSK   Return-to-Zero Differential Quadrature Phase Shift Key
- DP-QPSK   Dual-Polarization Quadrature Phase Shift Key
- ODB   Optical Duobinary

The format currently being considered by ITU-T SG15 Q6 at 100G is:

- DP-QPSK   Dual-Polarization Quadrature Phase Shift Key

With the exception of ODB, these are all formats that encode the data using the phase of the optical signal rather than its amplitude.

New methodology needed

Eye mask and extinction ratio are of no use in determining the quality of the transmitted signal for any of the phase modulated formats.

DPSK	RZ-DQPSK	DP-QPSK	ODB
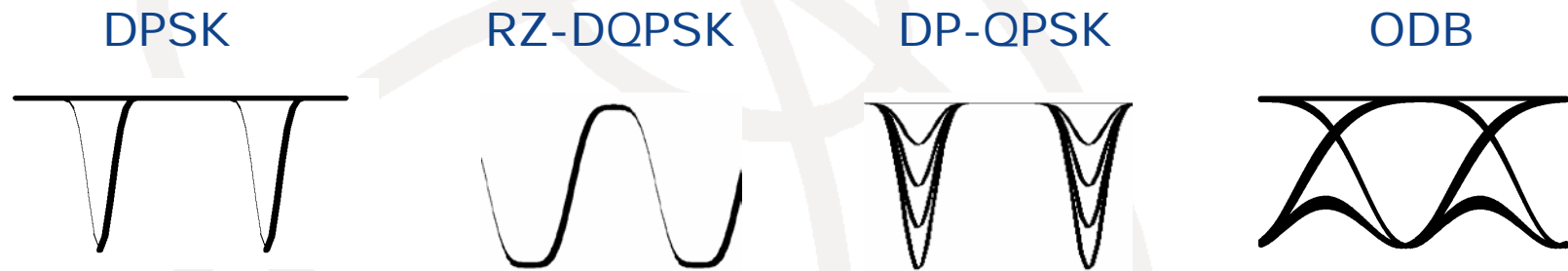
Spectral excursion limit adjusted to -5 dB points of Tx spectrum within -2 dB points of link filter function (red) still too conservative
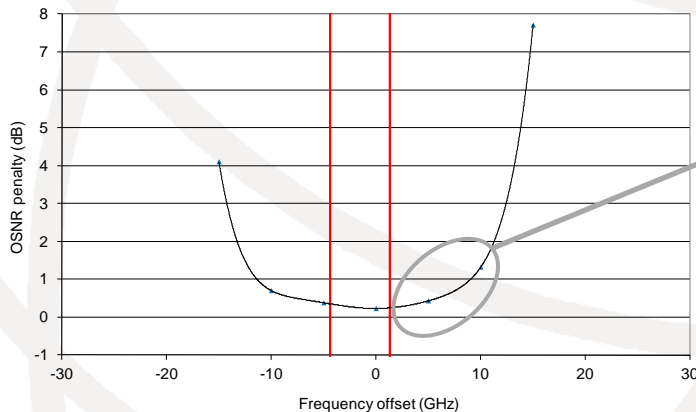

| Good combination fails test	Good combination passes test
Bad combination fails test	Bad combination passes test

Reference receiver approach

One approach being pursued for (P) DPSK is to define a reference phase-to-intensity demodulator which is used to turn the (P) DPSK transmitted signal into an amplitude modulated signal which then has to meet a "demodulated eye mask" and a "demodulated extinction ratio"
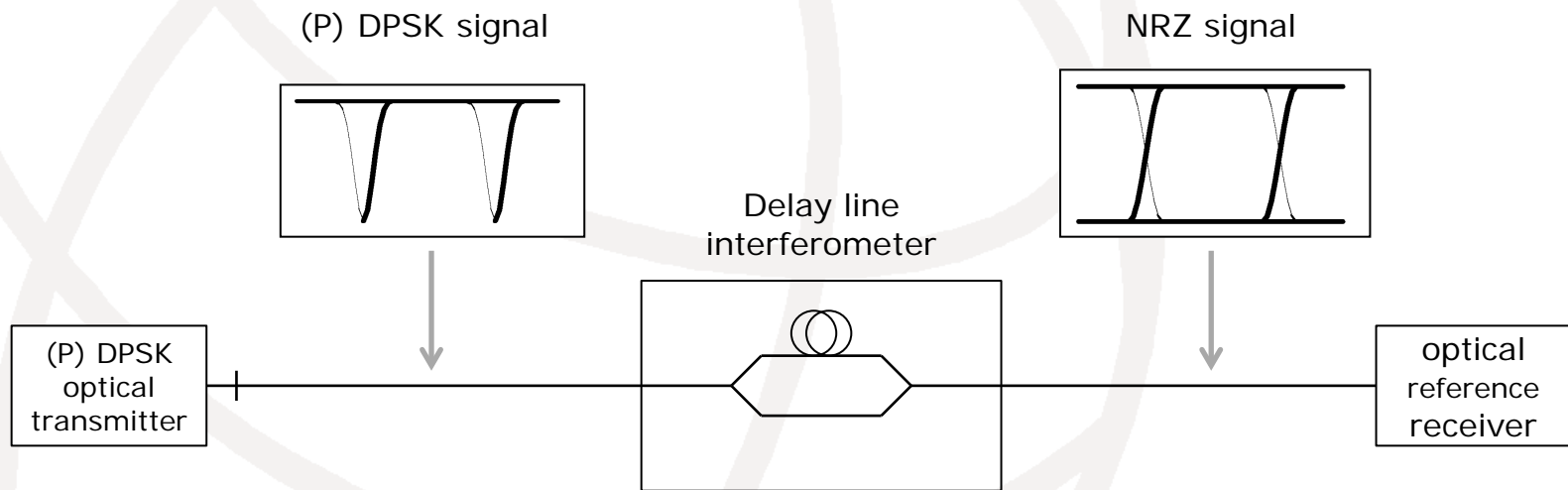
I/Q plane representation

To define a reference demodulator for a more complex modulation format such as DP-QPSK (or DP-16QAM in the future) does not seem like the best way forward.

The alternative that is being developed is to represent the magnitude and phase of the optical signal in the centre of each symbol on an I/Q (in-phase/quadrature) plane – commonly called a constellation.
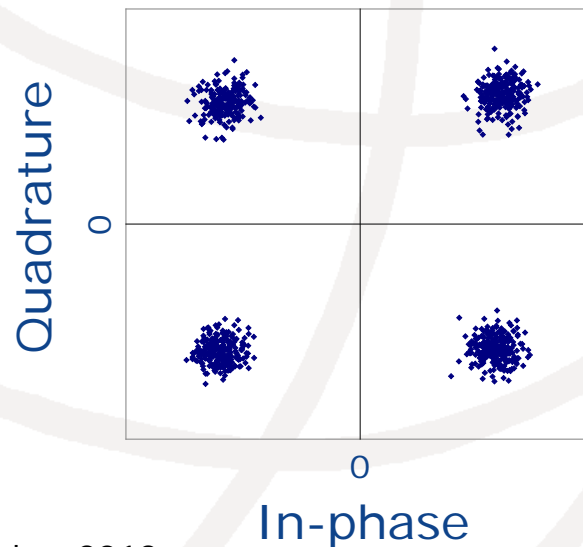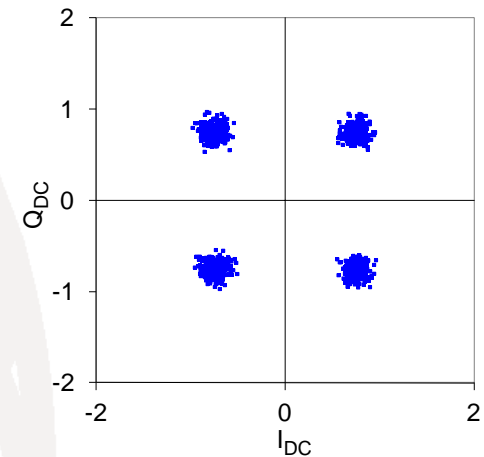
Error vector magnitude

The pass/fail metric being developed is based on the error vector magnitude (EVM) definition in IEEE Std 802.11 (WiFi) with an allowed hit ratio
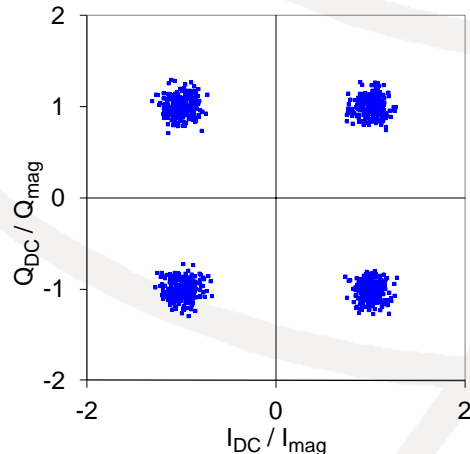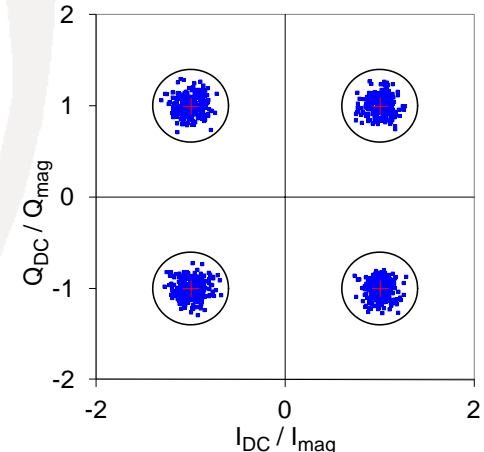
Capture points
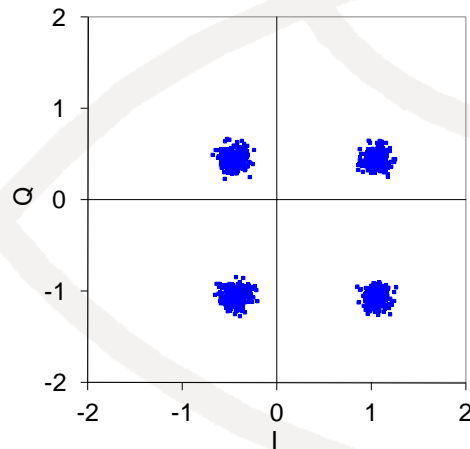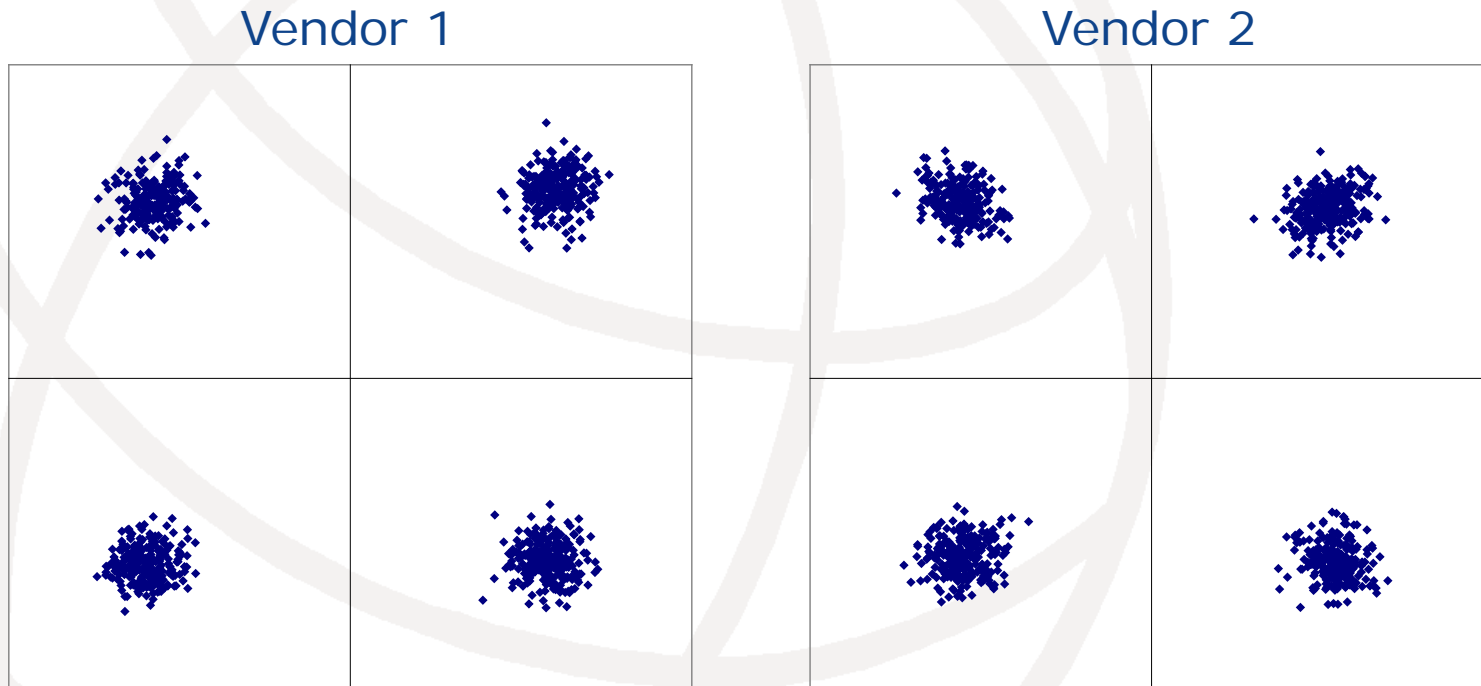
Remove offsets

Normalise amplitude

Apply limits

Commercial EVM measurements

Measurements using two commercially available test sets and the unmodified EVM algorithm from IEEE 802.11

- Vendor 1 Mean EVM Max 0.439 std dev 0.0377
- Vendor 2 Mean EVM Max 0.417 std dev 0.0364

Vendor 1

Vendor 2

Further work

EVM definition

Work is ongoing to identify the key elements in the capture process that need to be defined (e.g. the phase tracking algorithm) and the complimentary parameters that need to be specified (e.g. I/Q imbalance)

Spectral excursion

More measurements of the OSNR penalty vs offset between the signal and the end-to-end filter function of the link are needed in order that a less conservative spectral excursion criterion can be developed.

Once the methods of defining the quality of a transmitter and ensuring a signal can traverse a link with acceptable penalty have been defined, the work to define multi-vendor interoperable phase modulated applications can move forward.

Thank you