40G/100G Transmitter Compliance Testing

40G TESTING RECOMMENDATIONS

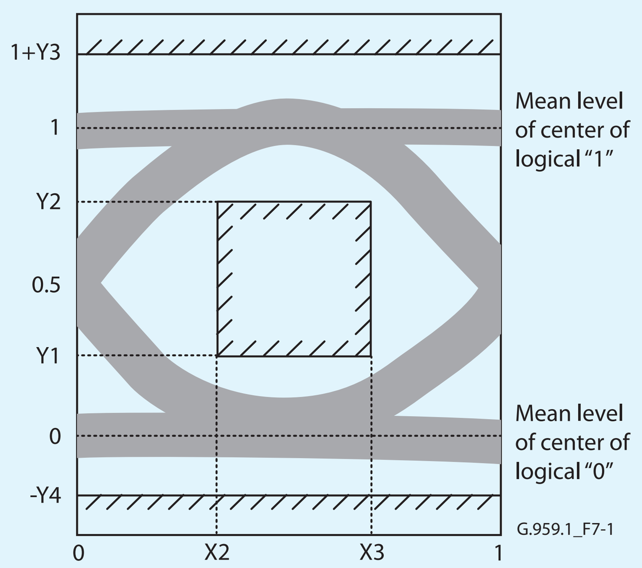
The ITU-T G.959.1 (line side) and IEEE 802.3ba-2010 (client side) standards define the requirements for transmitter pulse shape characteristics such as rise time, fall time, pulse overshoot, pulse undershoot and ringing. These parameters are specified by a mask in the transmitter eye diagram. A good transmitter eye diagram does not cross any of the hatched or grey areas. The recommended masks for non-return-to-zero (NRZ) 40G, return-to-zero (RZ) 40G/100G and the mask parameters are shown below.

These masks allow control of several potential transmitter impairments:

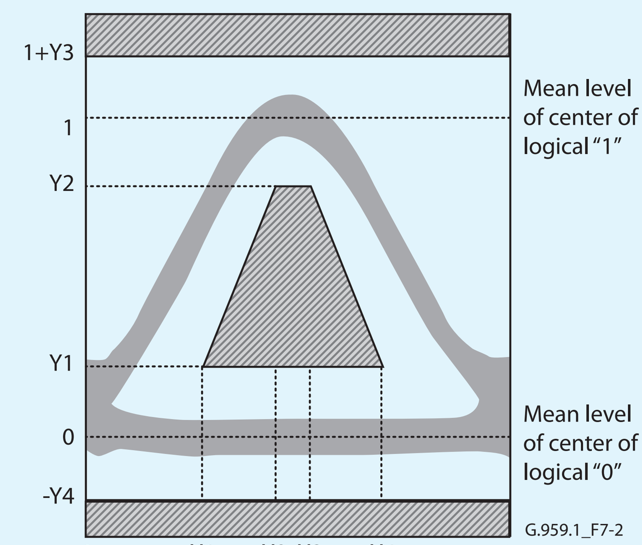
- Timing jitter
- ISI interference
- RF levels
- Modulator bias

For DP-QPSK and other phase-modulated signals, it is recommended to use a constellation diagram (see flip side of poster) in conjunction with the eye diagrams to fully characterize a transmitter.

40G NRZ MASK FOR LINE SIDE AS RECOMMENDED BY ITU-T



40G NRZ MASK FOR LINE SIDE AS RECOMMENDED BY ITU-T

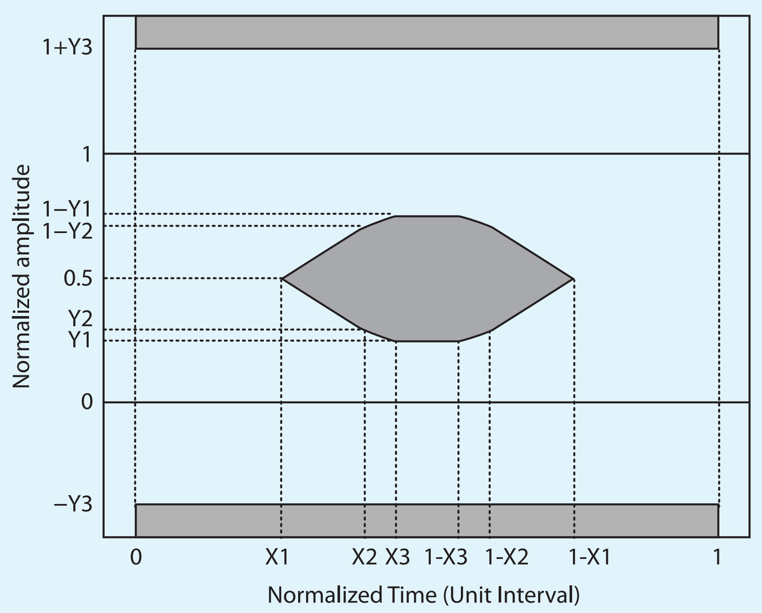


	NRZ 40G	RZ 40G
X4-X1	N/A	ffs
X1-X2	N/A	ffs
X3-X2	0.2	N/A
Y1	0.25	ffs
Y2	0.75	ffs
Y3	0.25	ffs
Y4	0.25	ffs

ffs = for further study

Source: Recommendation ITU-T G.959.1 (11/2009), Optical Transport Network Physical Layer Interfaces.

40G AND 100G MASK FOR LINE SIDE AS RECOMMENDED BY IEEE

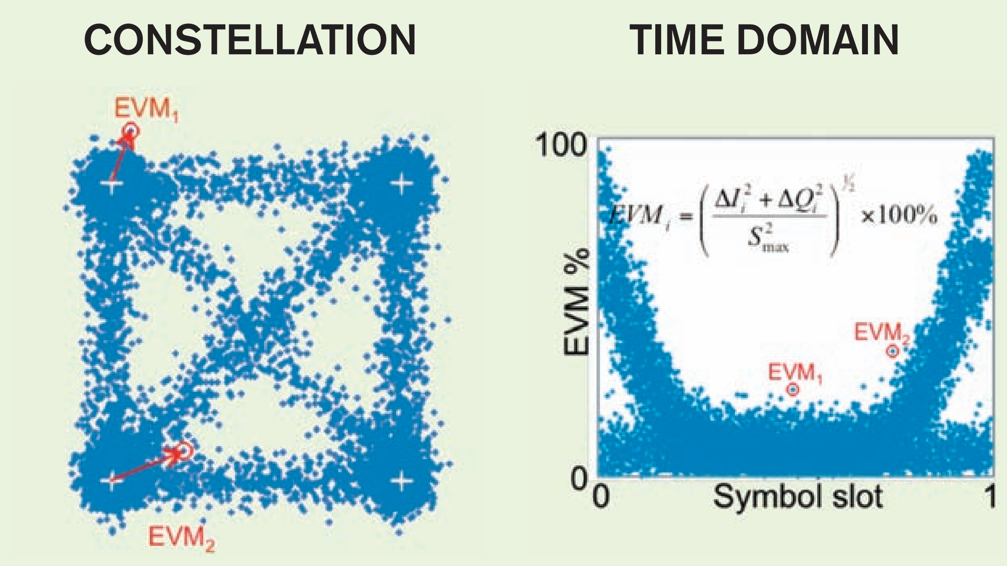


	40GBASE-SR4 100GBASE-SR10	40GBASE-LR4 100GBASE-LR4/ER4
X1	0.23	0.25
X2	0.34	0.4
X3	0.43	0.45
Y1	0.27	0.25
Y2	0.35	0.28
Y3	0.4	0.4

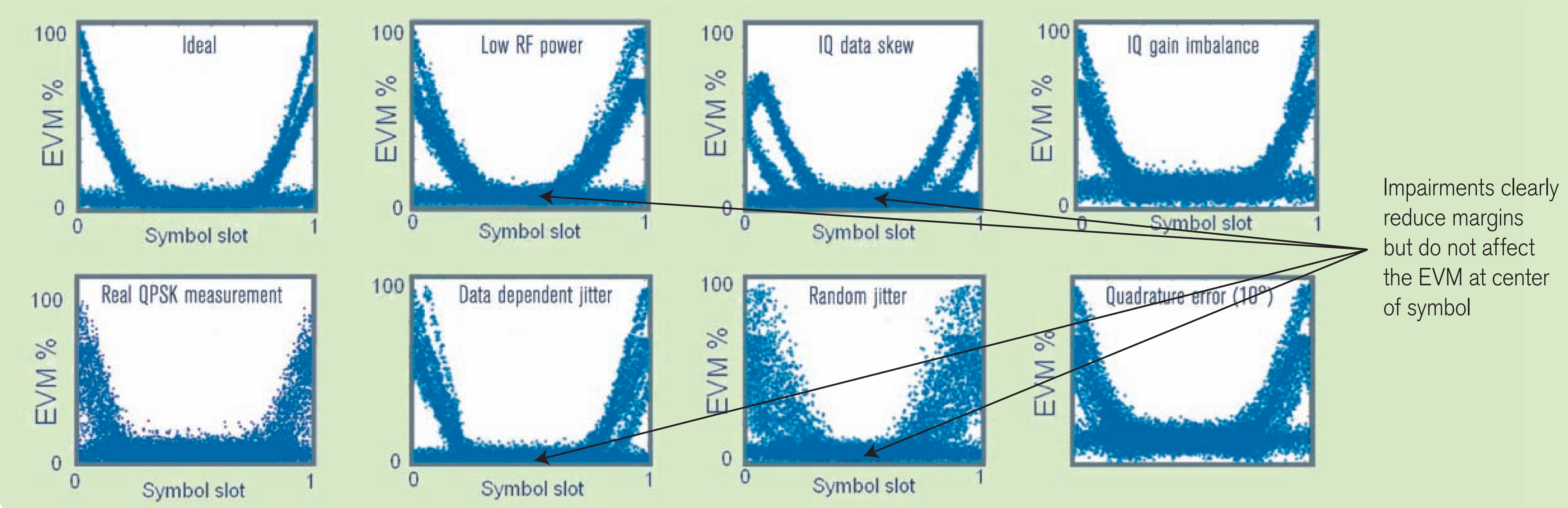
TIME-RESOLVED ERROR VECTOR MAGNITUDE

Time-resolved EVM is a unique approach developed by EXFO to ease and fasten transmitter compliance testing, enabling mask testing by EVM. This approach is closely related to the familiar concept of eye-diagram mask testing. It consists of displaying the EVM value as a function of time, more specifically as a function of the position in the symbol slot. It uses the same principle as the eye diagram, which consists of combining several periods into a single diagram.

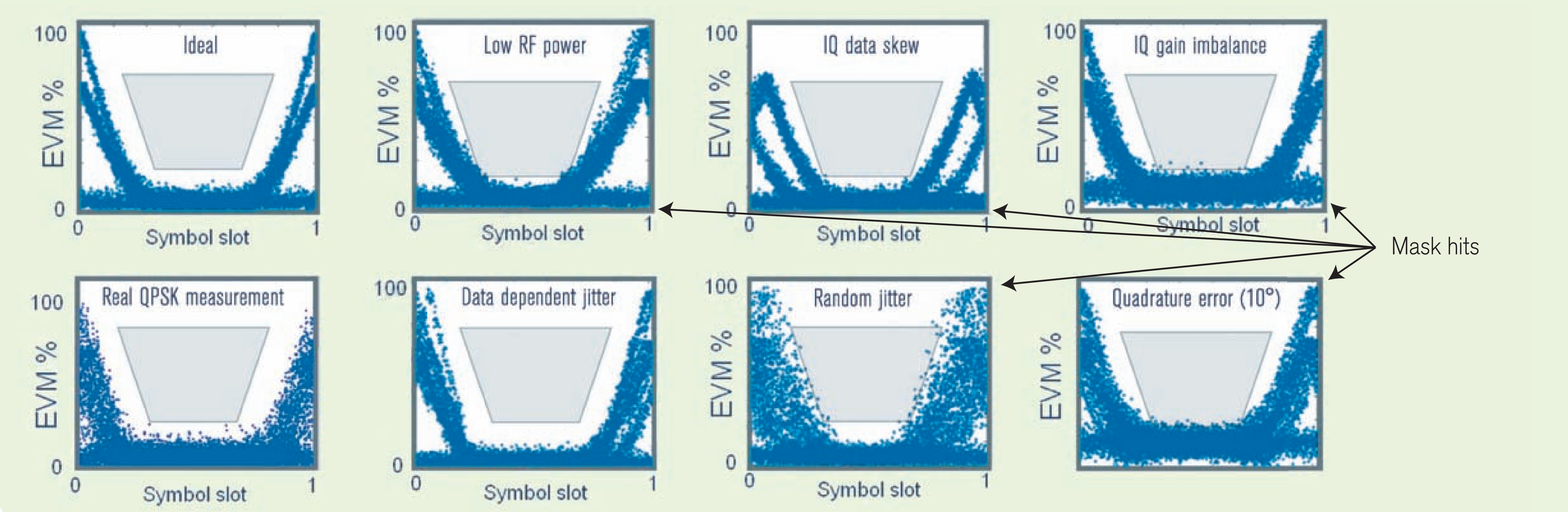
Time-resolved EVM combines the strengths of both EVM and eye-diagram analysis and provides complete transmitters' characterization for multilevel signaling in a single measurement.



IMPAIRMENT IDENTIFICATION WITH TIME-RESOLVED EVM

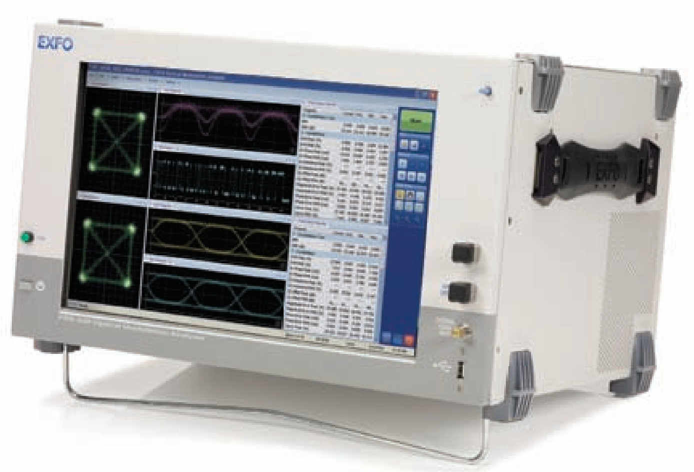


USE OF MASKS IN TRANSMITTER TESTING



40G/100G Transmitter Analysis Reference Poster

EXFO Assessing Next-Gen Networks



EXFO'S PSO-200 MODULATION ANALYZER

- Supports data rates of 40 Gbit/s, 100 Gbit/s, 400 Gbit/s, 1 Tbit/s and beyond
- For NRZ, RZ, DPSK, DQPSK, QPSK, 16-QAM
- Single- or dual-polarization transmission
- Distortion-free signal recovery

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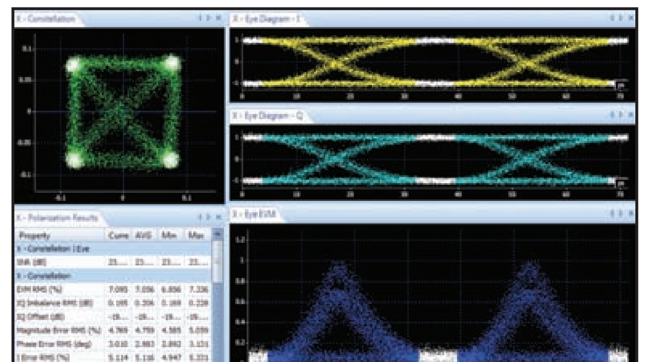
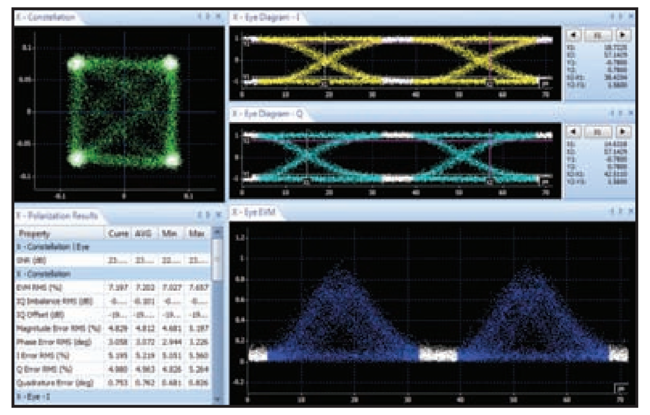
EXAMPLE OF AVERAGED QPSK TIME-RESOLVED EVM

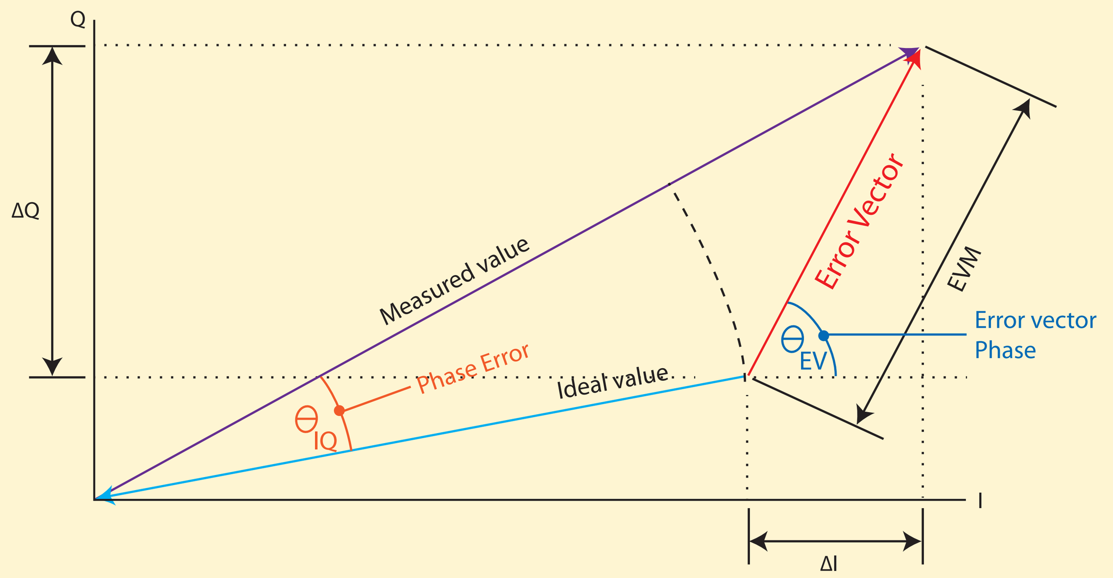


EXAMPLE OF AVERAGED QPSK TIME-RESOLVED EVM WITH 4 PS SKEW



ERROR VECTOR MAGNITUDE (EVM), BIT ERROR RATE (BER) AND SIGNAL-TO-NOISE RATIO (SNR)

DEFINITION OF ERROR VECTOR MAGNITUDE

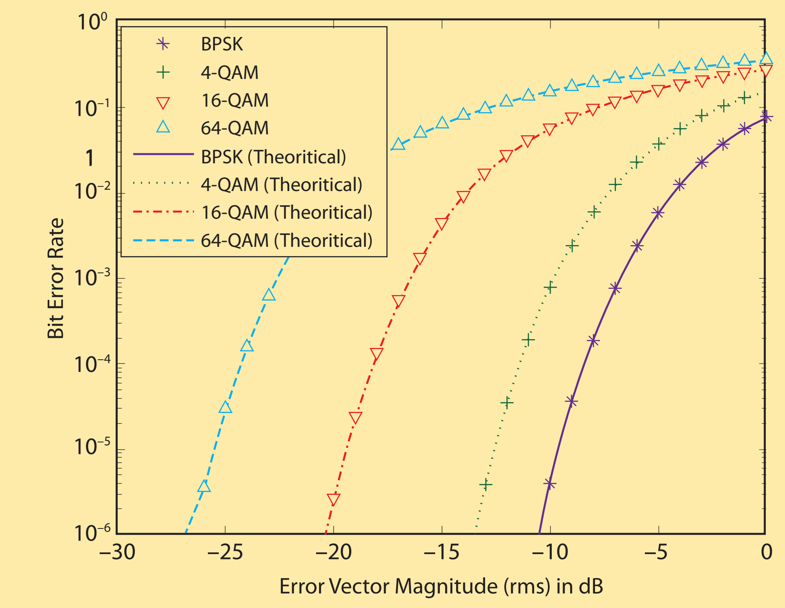


- The error vector magnitude (EVM) is the comparison of the received signal with the ideal signal taking into consideration both the phase and the magnitude errors.
- Its value is calculated using the formula:

$$EVM_i = \sqrt{\frac{\Delta I_i^2+\Delta Q_i^2}{\sqrt{\Delta I^2+\Delta Q^2}}}$$

where EVMi is the error vector magnitude for point I, ΔI and ΔQ are defined in the figure above; I and Q, and the x and y coordinates of the measured value.

BER vs. EVM



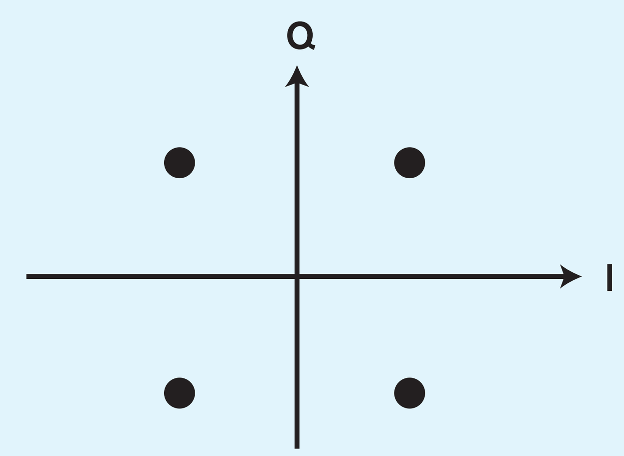
- This figure assumes that the noise distribution is Gaussian and that the number of symbols in the measured constellation is much greater than the number of unique modulation symbols.

Source: Shafik, Rishad Ahmed, Md Shahriar Rahman, AHM Razibul Islam, "On the Extended Relationships Among EVM, BER and SNR as Performance Metrics", ICECE 2006, 19-21 December 2006, Dhaka, Bangladesh.

Advanced Modulation Schemes and Impairments in 40 Gbit/s and 100 Gbit/s Networks

CONSTELLATION DIAGRAM

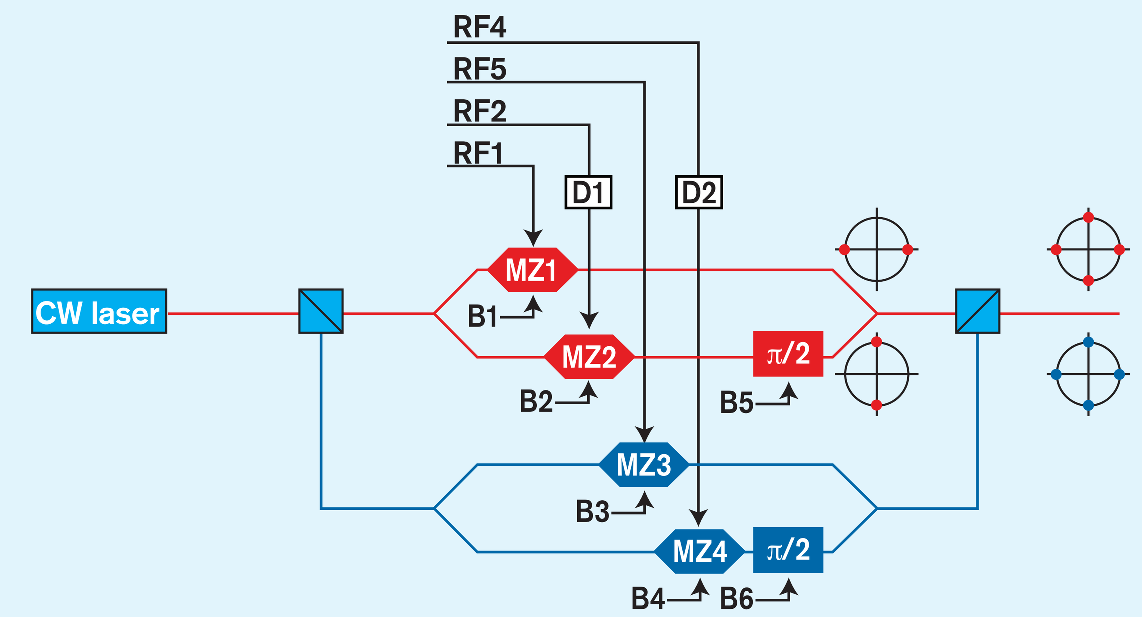
A constellation diagram is a representation of a signal modulated by a digital modulation scheme (phase and/or amplitude). In other words, it shows the possible symbols that can be selected by a given modulation format as points in the complex plane.



Example of a quadrature phase-shift keying (QPSK) constellation diagram

I = In-phase axis or real part of the signal
Q = Quadrature axis or imaginary part of the signal

DP-QPSK TRANSMITTER BLOCK DIAGRAM

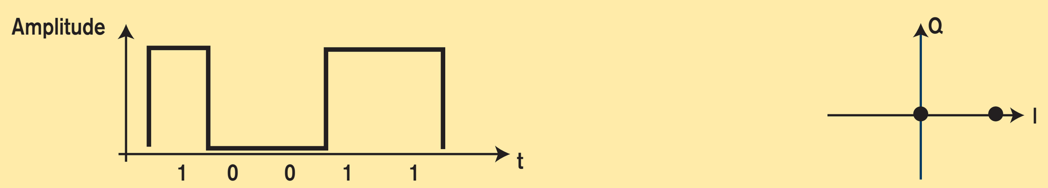


Typical implementation recommended by the Optical Internetworking Forum (OIF).

MODULATION SCHEMES

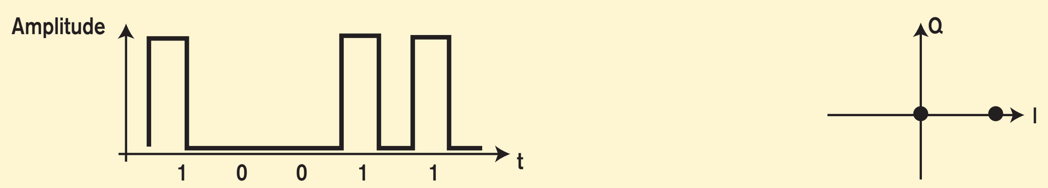
ON/OFF KEYING (OOK) NON-RETURN-TO-ZERO (NRZ)

Amplitude modulation
Presence of signal = '1'
Absence of signal = '0'
One bit encoding



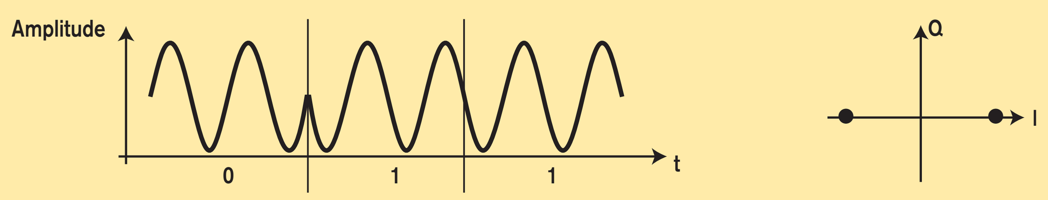
ON/OFF KEYING (OOK) RETURN-TO-ZERO (RZ)

Amplitude modulation
Presence of signal = '1'
Absence of signal = '0'
One bit encoding



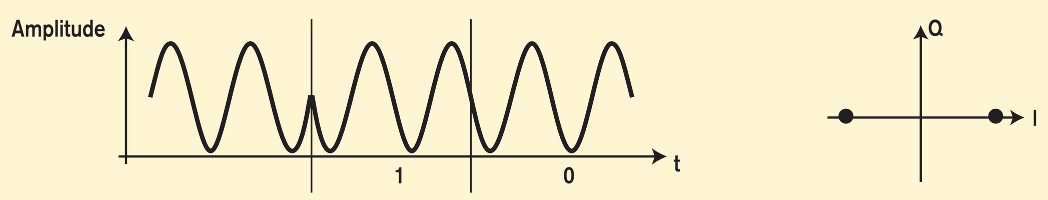
BINARY PHASE-SHIFT KEYING (BPSK)

Phase modulation
Two possible values
E.g.: - Phase of 0˚ = '1'
- Phase of 180˚ = '0'
One bit encoding



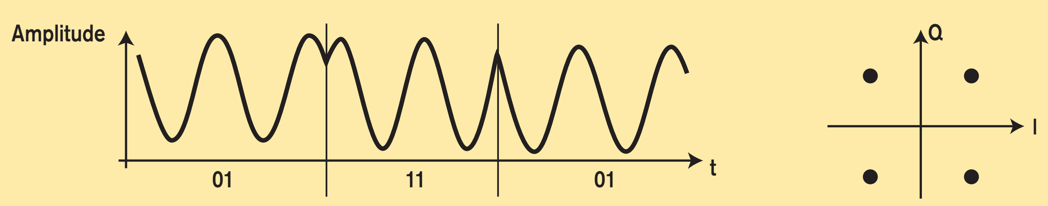
DIFFERENTIAL PHASE-SHIFT KEYING (DPSK)

Same as BPSK, but data is encoded in the phase difference between adjacent symbols
E.g.: - Phase of 0˚ = '0'
- Phase of 180˚ = '1'



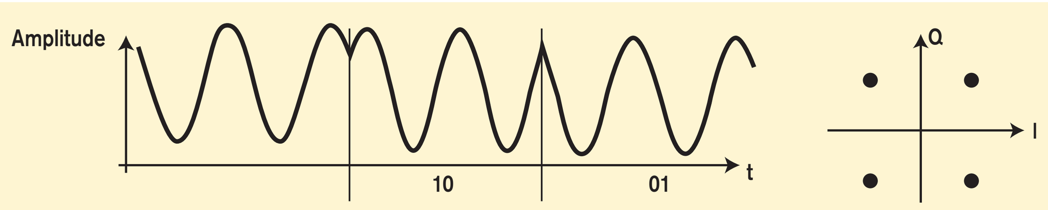
QUADRATURE PHASE-SHIFT KEYING (QPSK)

Phase modulation
Quadrature phase shifts are separated by 90˚ (e.g., 45˚, 135˚, 225˚, 315˚)
Two bits encoding



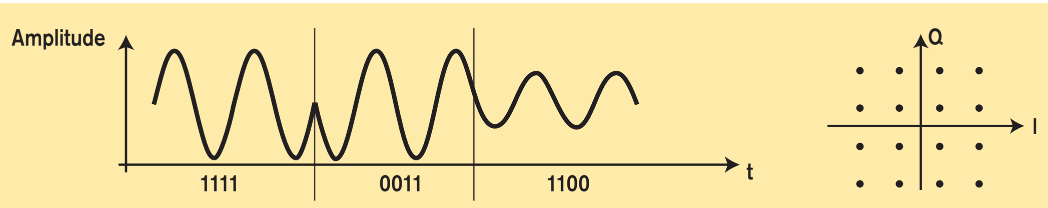
DIFFERENTIAL QUADRATURE PHASE-SHIFT KEYING (DQPSK)

Same as QPSK, but data is encoded in the phase difference between adjacent symbols
Phase shift = 0˚, 90˚, 180˚ or 270˚
(each phase shift depends on encoding scheme)
Two bits encoding



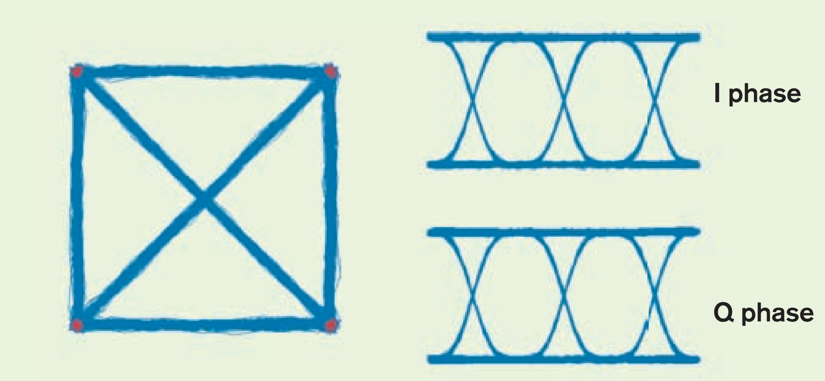
16 QUADRATURE AMPLITUDE MODULATION (16-QAM)

Both waves (I and Q) show a phase difference of 90˚ and their amplitude has four discrete levels
Four bits encoding



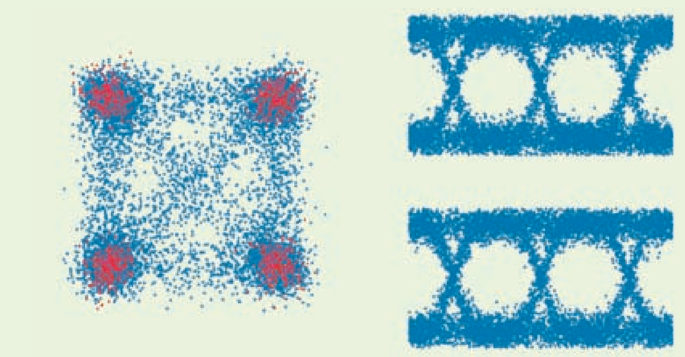
COMMON QPSK IMPAIRMENTS

IDEAL QPSK CONSTELLATION



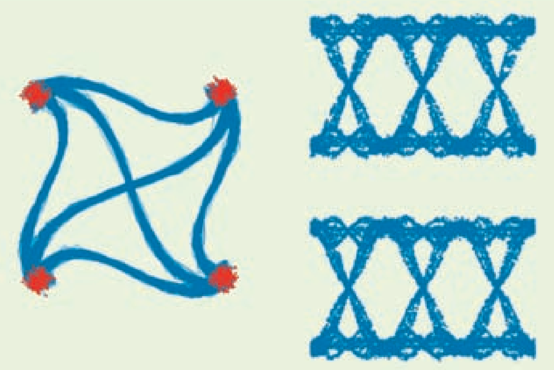
Constellation diagram — Eye diagram

POOR SIGNAL-TO-NOISE RATIO TRANSMITTER



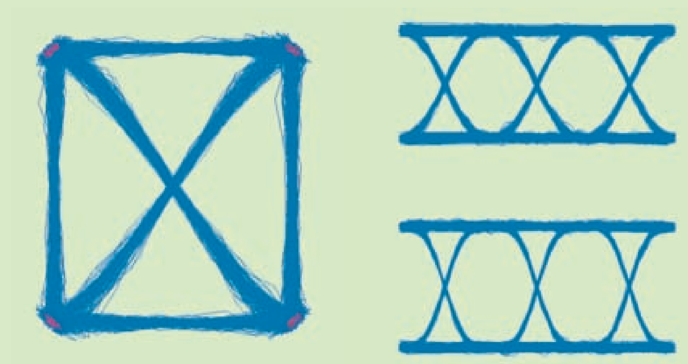
Clouded constellation and eye diagrams are typically of poor SNR due to an instrument limitation.

CHIRP



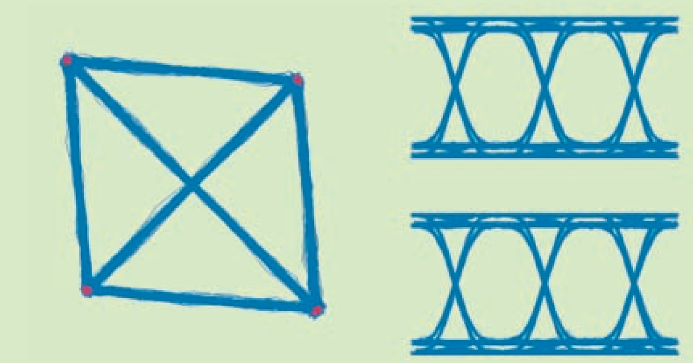
The S-shape transitions of the chirp impairment can stem from data modulation or from residual fiber dispersion.

I/Q GAIN IMBALANCE



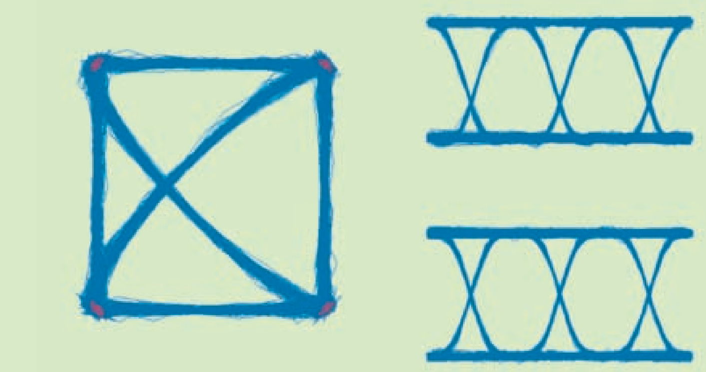
This impairment, shown as a rectangular constellation, is due to a gain that is different in the I port with respect to the Q port, i.e. the power of RF drive signals (RF3 and RF4) is not optimized.

I/Q QUADRATURE ERROR



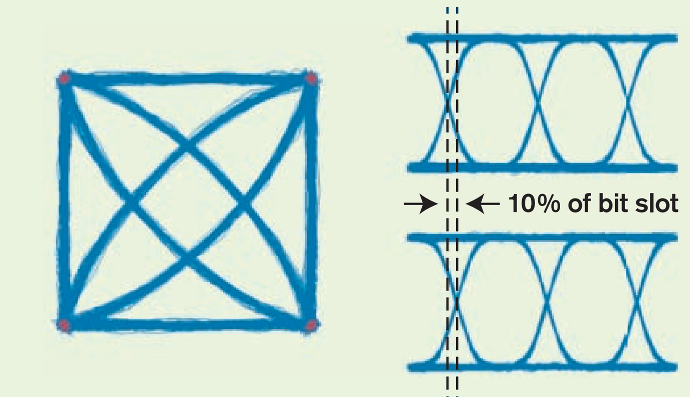
A rhombic constellation appears when the I and Q phases do not show a perfect 90˚ phase shift, which occurs when bias B5 is not optimized.

I/Q MODULATOR BIAS ERROR



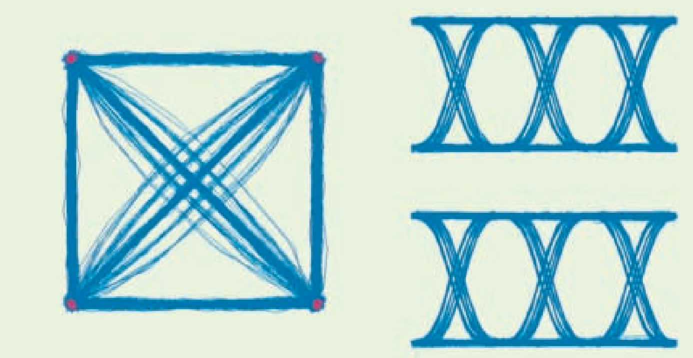
This impairment, caused by an incorrect bias in the I-branch of the I/Q modulator (bias B1), results in an overshoot in the I direction and an undershoot in the Q direction.

I/Q DATA SKEW



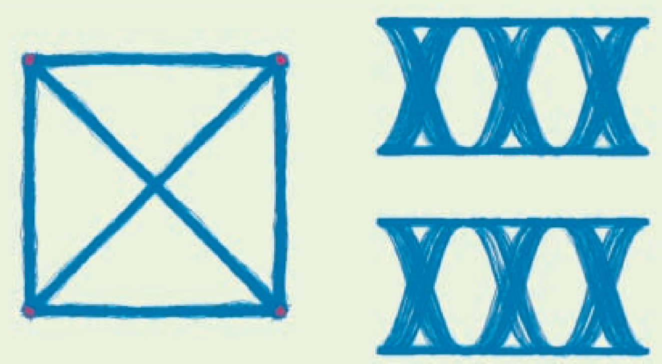
The opening in the center of the constellation is caused by a constant time delay between the I and Q RF drive signals (RF3 and RF4).

DETERMINISTIC DATA DEPENDENT JITTER



The I and Q RF drive signals (RF3 and RF4) may contain deterministic jitter originating from driver circuits or SERDES that leads to a delay in the transitions.

RANDOM DATA CLOCK JITTER



An equal delay in the I and Q phases due to clock jitter (RF3 and RF4 drive signals) leads to an impairment that is only visible in the eye diagram.

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- > Distortion-free signal recovery

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