100G Network Design & Test

A Visual Guide to Networking Standards and Test Methodology from the Industry Leader in Oscilloscopes

Tektronix

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For Further Information
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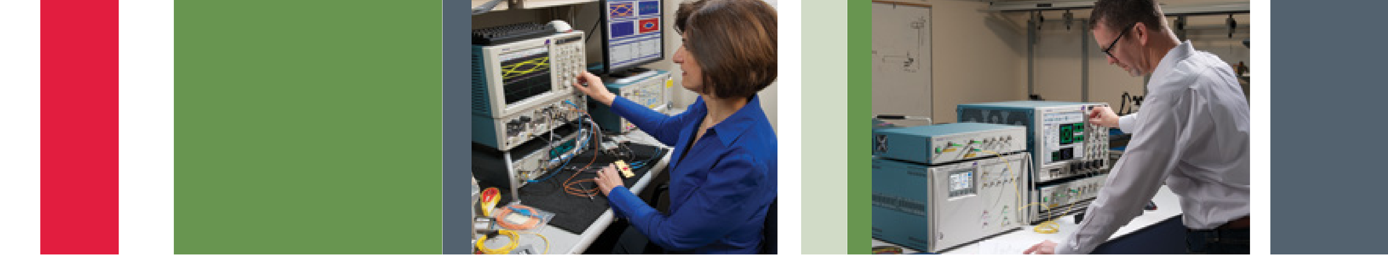
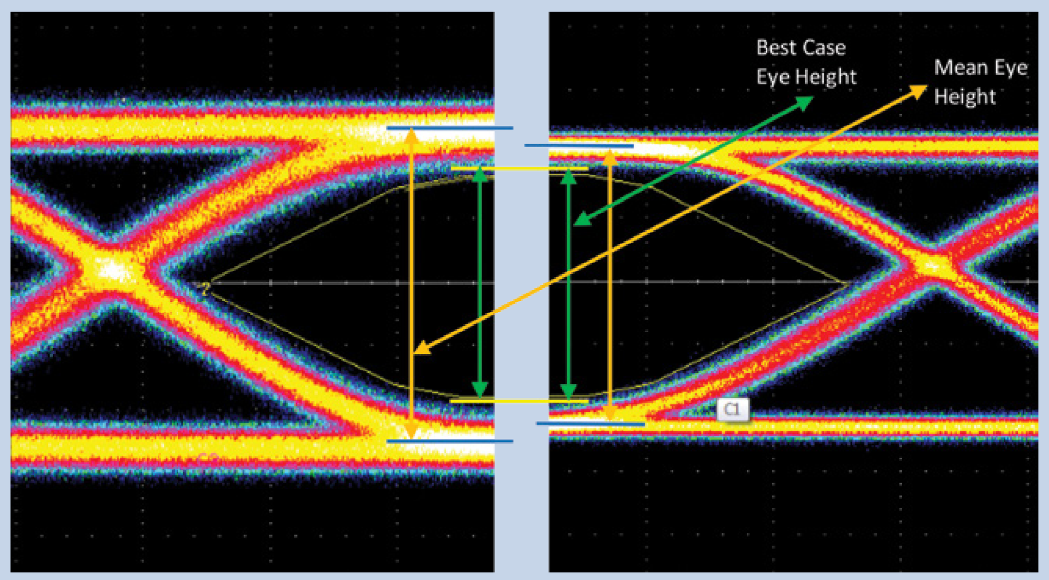


COM Analysis & Tx Impulse Response Extraction

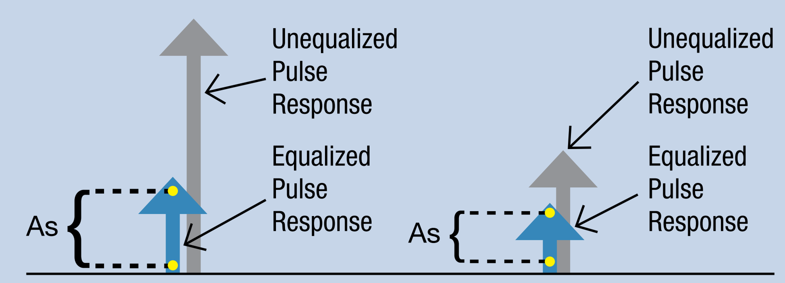
NRZ

DUT1 - Low COM **DUT2 - High COM**



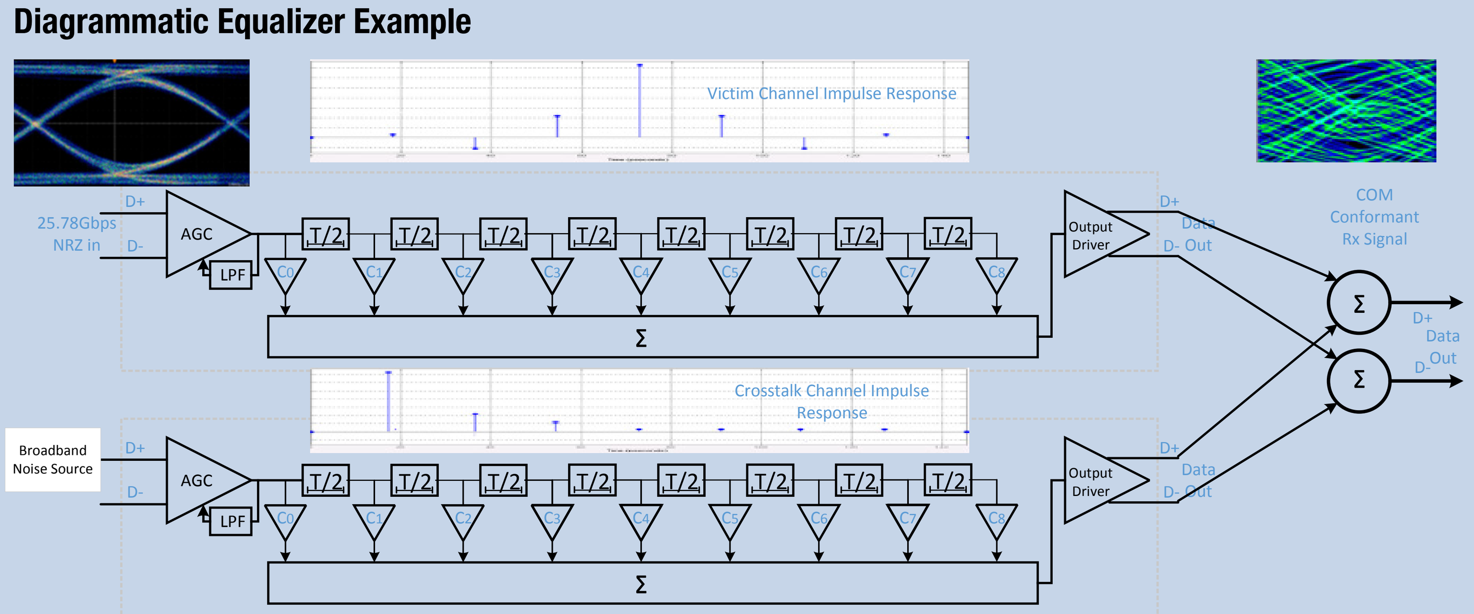
COM measurements on two DUT's show that DUT1's signal (as measured by Mean Eye Height) is really worse in spite of the actual eye opening (green arrows) being consistent.

COM Analysis test methodologies open up flexibility for silicon designers who seek compliant transmit performance.

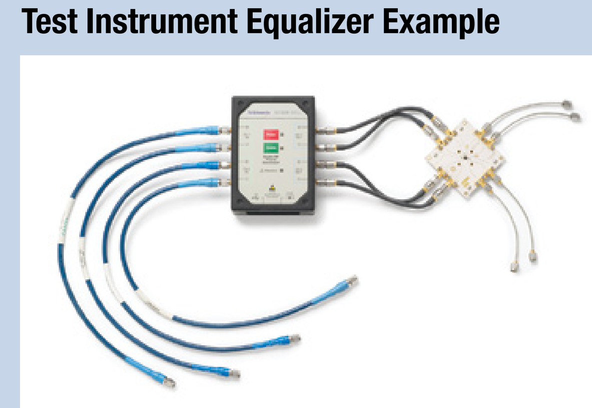


Better Signal to Noise ratio translates to a better COM result. The noise outside of the receiver will scale with SNR or COM.

Diagrammatic Equalizer Example



Test Instrument Equalizer Example



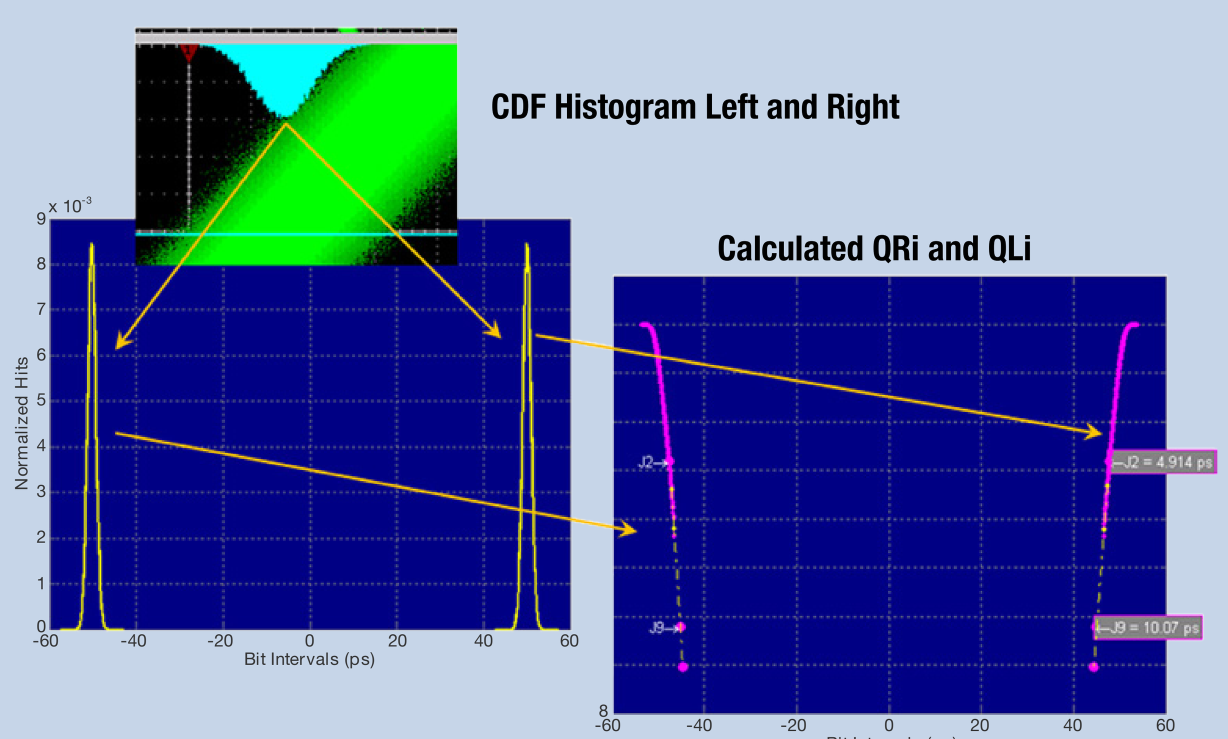
IEEE 802.3bj (100G-KR4/CR4) requires COM conformant receiver impairments. A BERT system with a linear equalizer provides the electronic channel model and random noise PSD control necessary for evaluating a receiver's performance.

25-28Gb/sec Test Methodologies – Effective Bounded Uncorrelated Jitter & Random Jitter

NRZ

CDF Histogram Left and Right

Calculated QRi and QLi



Jitter separation methodologies are evolving to merge comprehensible and non-comprehensible jitter components to help designers better understand 100G network timing performance.

Effective Bounded Uncorrelated Jitter $= EBUJ = b_{left}/m_{left} - b_{right}/m_{right}$

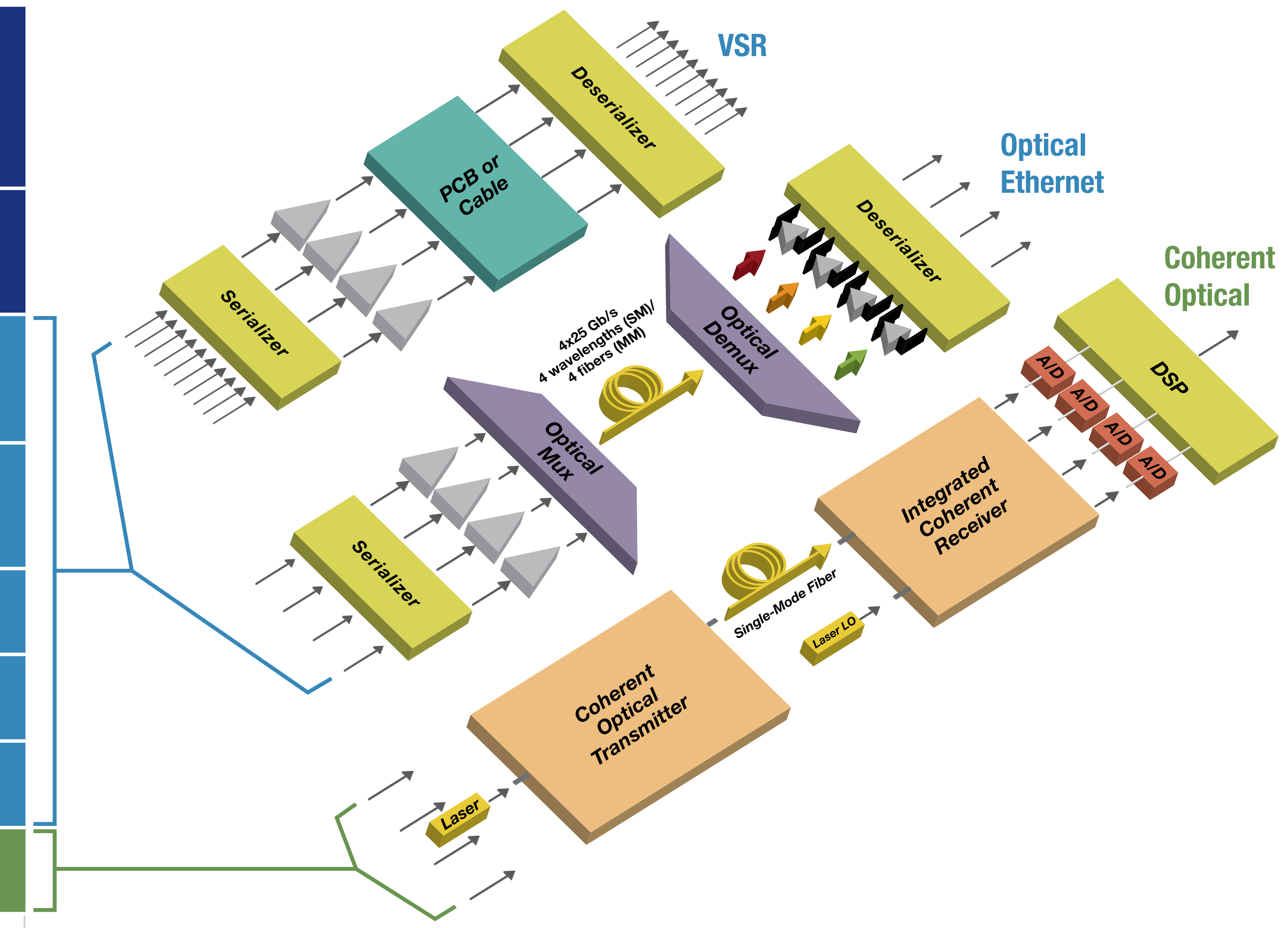
Effective Random Jitter $= ERJ = \frac{m_{left} - m_{right}}{2 \cdot m_{right} \cdot m_{left}}$

Effective Total Uncorrelated Jitter $= ETUJ = 7.9 \cdot ERJ + EBUJ$

Standards

Distance	Standard	Physical Layout Reference	Modulation/Signaling
Interconnect module to chip, chip to chip	IEEE 802.3bm OIF-CEI-3	VSR, CAUI-4	NRZ/PAM2
Backplane <1 m	IEEE 802.3bj OIF-CEI	100GBASE-KR4, KP4, CEI-LR	NRZ/PAM2 and PAM4
10 m	IEEE 802.3bj	100GBASE-CR4	NRZ/PAM2 over cable
100 m to 2 km	IEEE 802.3bm	100GBASE-SR4	NRZ/PAM2, MM and SM
10 to 40 km	IEEE 802.3ba	100GBASE-LR4	NRZ/PAM2 Single-Mode
Long Haul (>40 km)	OIF, OTN, ITU	DP-QPSK	Complex Optical

*This field of standards includes: Infiniband EDR, Fibre Channel 32FC.



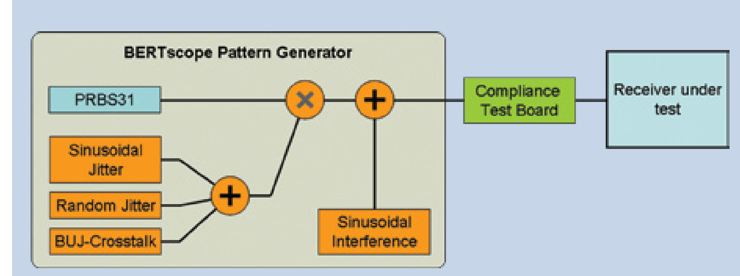
Rx Testing Practices

NRZ

Test patterns	
0x00ff square wave	8 bits low, 8 bits high
PRBS9	511 bits
PRBS15	32,767 bits
PRBS31	2.1 Gbits
Scrambled idle	
OIF CID jitter tolerance pattern	(72 CID bits + ≥ 10328 from PRBS31 + seed) + complement

BUJ-crosstalk for $N-1$ aggressors

$$\approx \frac{5\sqrt{2}}{3}\frac{t_{rf}}{V_{Swing}}\sqrt{X_{rms}(1)^2 + X_{rms}(2)^2 + \cdots + X_{rms}(N-1)^2}$$



OIF-CEI specifies that receiver performance be evaluated with stressed patterns. Today's BER testers can be programmed to transmit stressed, calibrated PRBS patterns, including crosstalk, for 100G receiver tests.

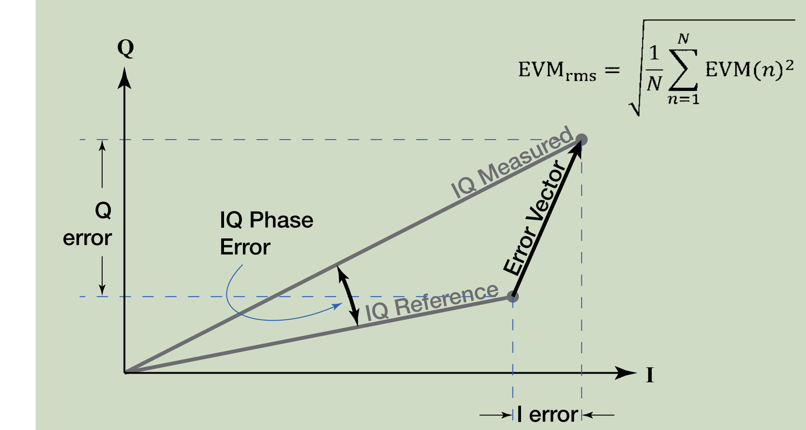
Effective Baud Rates

			28 GBaud	32 GBaud	40 GBaud	46 GBaud	56 GBaud	64 GBaud
NRZ/PAM2	1 bit per symbol	Single Polarization	28 Gb/s	32 Gb/s	40 Gb/s	46 Gb/s	56 Gb/s	64 Gb/s
BPSK	1 bit per symbol per polarization	Single Polarization	28 Gb/s	32 Gb/s	40 Gb/s	46 Gb/s	56 Gb/s	64 Gb/s
		Dual Polarization	56 Gb/s	64 Gb/s	80 Gb/s	92 Gb/s	112 Gb/s	128 Gb/s
PAM4	2 bits per symbol	Single Polarization	56 Gb/s	64 Gb/s	80 Gb/s	92 Gb/s	112 Gb/s	128 Gb/s
QPSK	2 bits per symbol per polarization	Single Polarization	56 Gb/s	64 Gb/s	80 Gb/s	92 Gb/s	112 Gb/s	128 Gb/s
		Dual Polarization	112 Gb/s	128 Gb/s	160 Gb/s	184 Gb/s	224 Gb/s	256 Gb/s
16QAM	4 bits per symbol per polarization	Single Polarization	112 Gb/s	128 Gb/s	160 Gb/s	184 Gb/s	224 Gb/s	256 Gb/s
		Dual Polarization	224 Gb/s	256 Gb/s	320 Gb/s	368 Gb/s	448 Gb/s	512 Gb/s

EVM Measurement

COHERENT

$$EVM_{rms} = \sqrt{\frac{1}{N}\sum_{n=1}^{N} EVM(n)^2}$$



Coherent modulation requires different testing metrics than direct detection. Error Vector Magnitude (EVM) provides a metric for quantifying the quality of a complex modulated signal.

Optical Modulation Analysis

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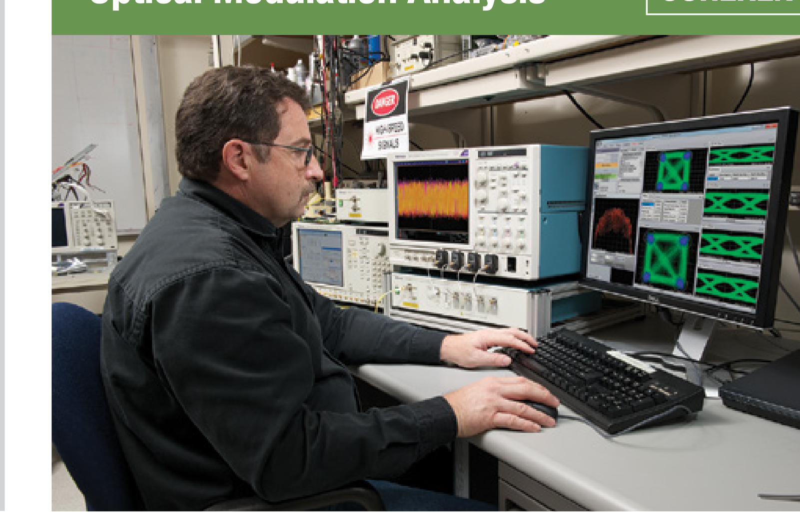
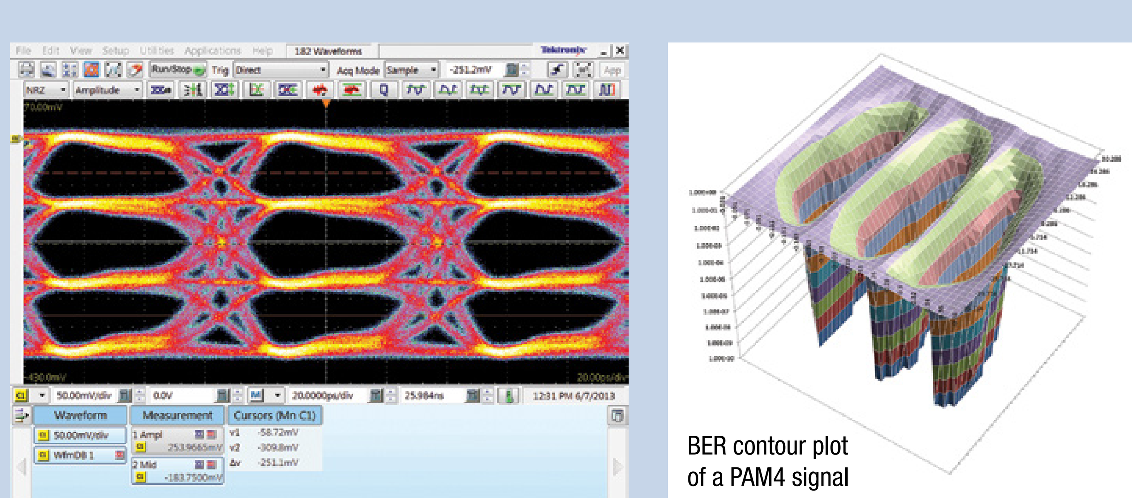


PAM4 Eye Diagram & 3-D Contour Plot

PAM

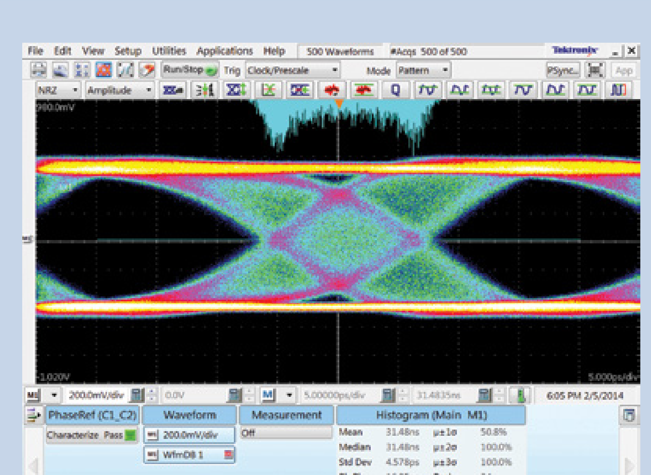


BER contour plot of a PAM4 signal

PAM4 transmission enables the 100GBASE-KP4 standard to run on legacy backplane designs. Multi-level Eye Diagrams and Contour Plots enable designers to evaluate PAM4's multiple data thresholds for accurate performance.

25G Impaired Optical Eye Diagram

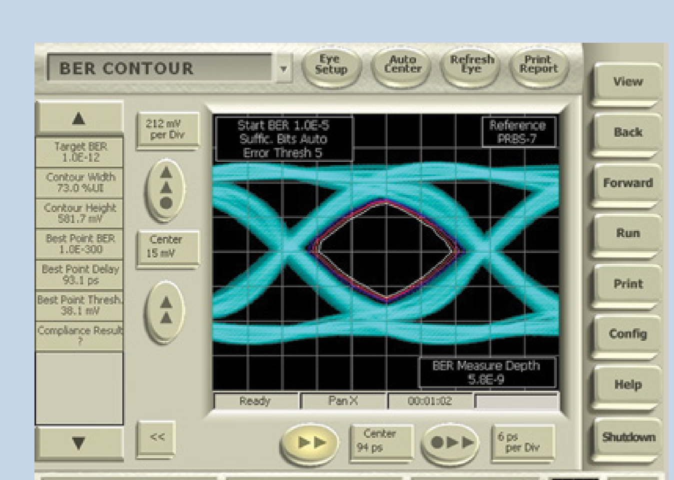
NRZ



IEEE 802.3ba specifications state J2 & J9 jitter measurement points on an eye diagram are critical qualifiers for reliable 100G communications system timing.

BER Contour Measurements

NRZ



OIF-CEI specifies that 100G receiver performance is measured with bit error ratio (BER). A BER contour measurement provides a comprehensive performance indicator to assist in troubleshooting BER performance.

Coherent Optical Transmission & Detection Technology

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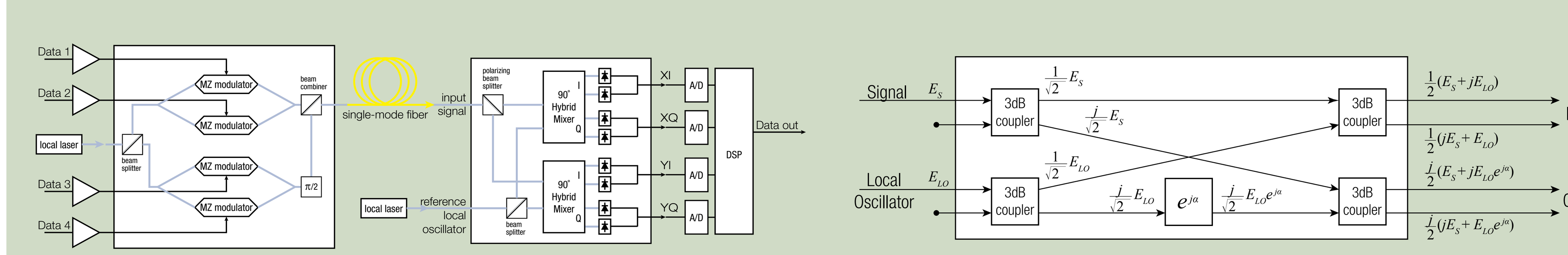

Typical Coherent Transmitter Block Diagram

Typical Integrated Coherent Receiver Block Diagram

90° Hybrid Block Diagram

Coherent optical modulation, utilizing phase and polarization diverse signals, provides greater spectral efficiency and improved noise tolerance over direct detection architectures.

Visit **www.tektronix.com/100G** to see how Tektronix can help in testing 100G designs.

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