Application Note

Anritsu

Jitter Analysis
Basic Classification of Jitter Components using Sampling Scope

MP2100A
BERTWave Series

Contents

1. Introduction

To cope with the rapid increases in data volumes, data centers are introducing high-speed interconnects between servers with transmission speeds faster than 10 Gbit/s. However, in conflict with these speed increases, there is increasing demand for lower power consumption as well as cost reductions. Furthermore, higher jitter levels and degraded waveforms are becoming a problem. Various measuring instruments, such as sampling scopes (Eye Pattern analyzer) and BERTs are being used to classify and analyze jitter components, such as DJ, RJ, etc., that affect communications quality over Fibre Channel, Infiniband, 10GbE, USB, PCI, etc., high-speed serial transmission standards used in data communications and computing.

Sections 2 to 4 of this application note explain the historical background to Jitter analysis and define the measurement items; section 5 outlines actual measurement methods using the Anritsu MP2100A Sampling Scope functions.

2. What is Jitter?

Jitter is fluctuation in the time-axis direction of a digital signal. When this fluctuation is in a long-term cycle, or more specifically less than 10 Hz, it is called "wander", and when the fluctuation is in a cycle above 10 Hz, it is called "jitter". Figure 2-1 shows an ideal signal and a signal containing jitter with a sine-wave component (see section 4.2 Sinusoidal Jitter for more details). As shown, the jitter component reduces the phase margin of digital signals, causing errors. Avoidance of signal errors requires accurate measurement of jitter caused by devices.

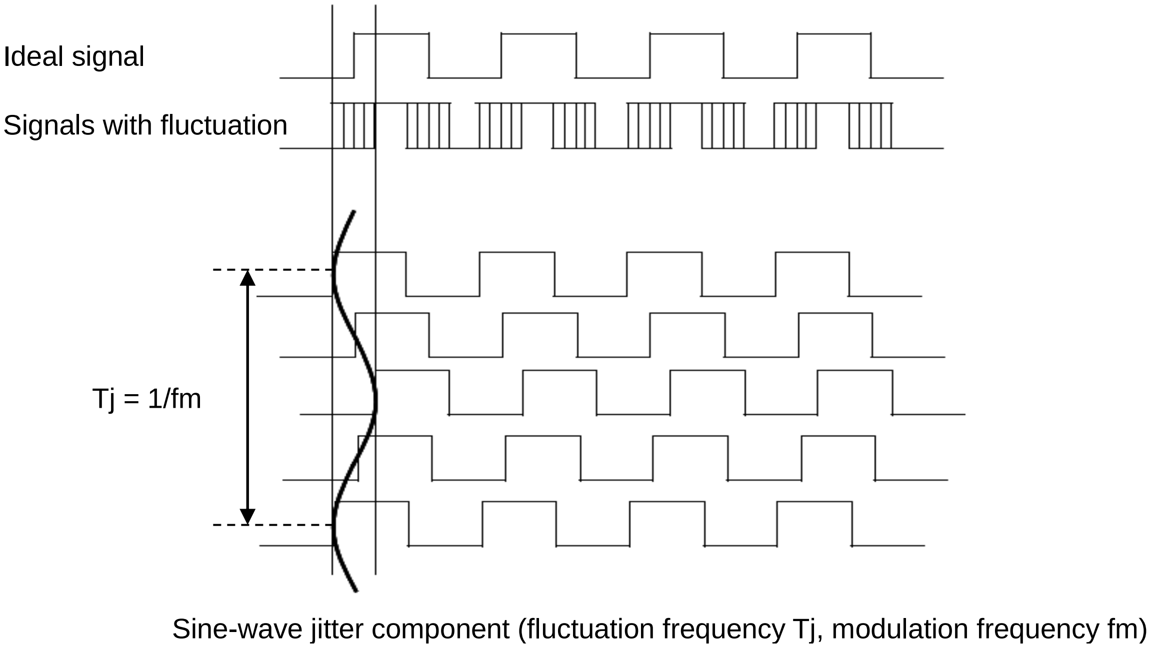

Figure 2-1. Jitter Modulation Frequency

As well as expressing the amount of jitter in time units, such as ps and ns, jitter can also be expressed as the Unit Interval (UI). The UI is the proportion of jitter per bit and is calculated using Eq. 2-1 where the jitter amount is represented as T_j [ps], and the interval per bit is represented as T_{bit} [ps]:

$$Jitter = \frac{T_j}{T_{bit}} \quad [UI] \qquad \text{Eq. 2-1}$$

For example, using a 10 Gbit/s signal, the interval per bit is 100 ps. If there is jitter of 10 ps in this signal, the amount of jitter is calculated as 0.1 UI.

3. Purpose of Jitter Measurement

Why is it necessary to measure jitter in the first place? To understand this, it is necessary to understand the relationship between Output Jitter (Jitter Generation), Jitter Tolerance, and Jitter Transfer. Figure 3-1 outlines a simplified TRx system, showing the Clock Data Recovery block in the receiver.

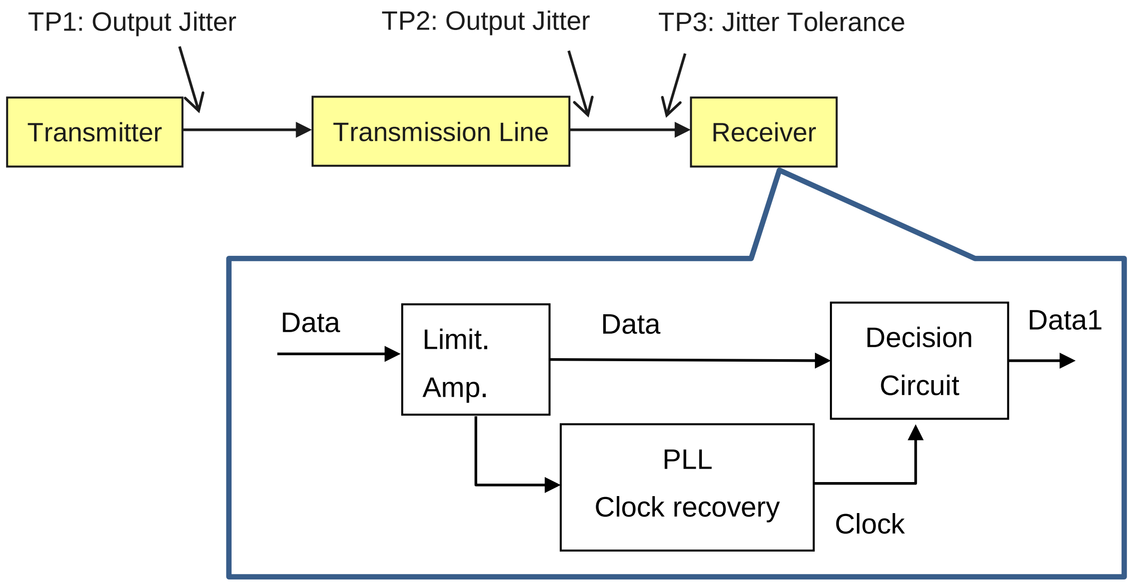

Figure 3-1. Simplified TRx System and CDR

- Output Jitter (Jitter Generation)

The amount of jitter generated by the Device Under Test (DUT) is called the Output Jitter (Jitter Generation). The ITU-T, which regulates standards such as SONET/SDH in the telecommunications field, defines the Jitter Generation as the amount of jitter produced by devices and equipment. In traditional measurement method, a dedicated jitter measuring instrument is used to recover the Clock signal from the Data signal output by the DUT and the jitter components are extracted from the Clock signal by demodulation using the fm detection method as well as by adding specified band limits. For example, using the 9.95328 Gbit/s OC-192/STM-64 standard, the measurement target is the 50 kHz to 80 MHz (B1 band) and the 4 MHz to 80 MHz (B2 band); the total in-band jitter is measured as the rms and peak-to-peak value, without analyzing the each jitter component.

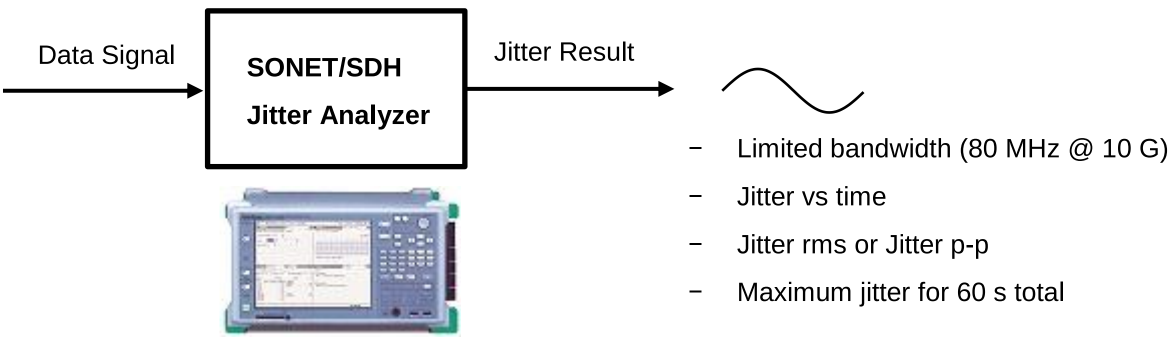

Figure 3-2. SONET/SDH Jitter Measurement Instrument (MP1590B)

However, in the fields of data communications and computing, such as Fibre Channel, 10GbE, SATA/SAS, USB, PCIe, etc., jitter is not measured by recovering the Clock, but instead, the amount of jitter in the Data signal is measured directly. Typical measuring instruments for this procedure are the sampling oscilloscope (Eye Pattern analyzer), real-time oscilloscope, Bit Error Rate Tester (BERT), time interval analyzer, etc. Each measurement is different, depending on the instrument, but a common feature to all methods is the division of jitter into its component parts, such as Deterministic Jitter (DJ), Random Jitter (RJ), etc. This application note explains this jitter separation and analysis.

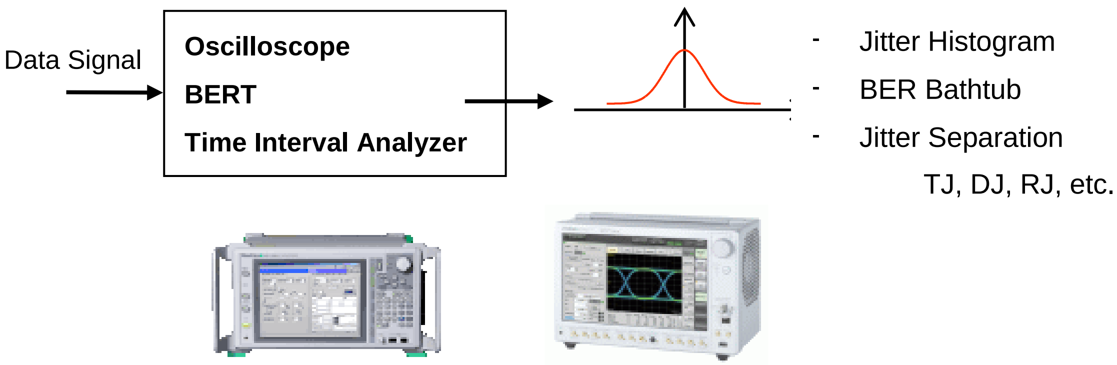

Figure 3-3. Jitter Measurement Instruments for Datacoms/Computing Fields

(Anritsu MP1800A (left), Anritsu MP2100A (right))

- Jitter Tolerance

  The ability and degree to which a receiver can withstand jitter in the received Data signal and the maximum permissible value is defined as the Jitter Tolerance. An error occurs when the input jitter value exceeds the Jitter Tolerance of the receiver. Since jitter can also be generated by the transmission path as well as by the transmitter (TP1 in Figure 3-1), the aggregate jitter (TP2 in Figure 3-1) should be less than the Jitter Tolerance of the receiver (TP3 in Figure 3-1). The various communications standards for FC, Infiniband, PCIe, etc., regulate the upper limit of the transmitter Output Jitter so as not to exceed the receiver Jitter Tolerance.

- Jitter Transfer

  The Clock Data Recovery (CDR) circuit is a key block in the receiver. It recovers the Clock from the received Data signal using the PLL circuit and regenerates the Data retimed with the recovered Clock. Clock recovery suppresses jitter and the suppression ratio is defined as Jitter Transfer. Jitter Transfer is a function of the jitter modulation frequency and is usually expressed in dB units. Jitter exceeding a jitter modulation frequency, depending on the PLL band, can be suppressed and—in principle—the suppression ratio increases as the jitter modulation frequency increases.

$$Jitter\ Transfer(f) = 20 \times log\left(\frac{Jout(f)}{Jin(f)}\right) \quad [\mathrm{dB}] \qquad \text{Eq. 3-1}$$

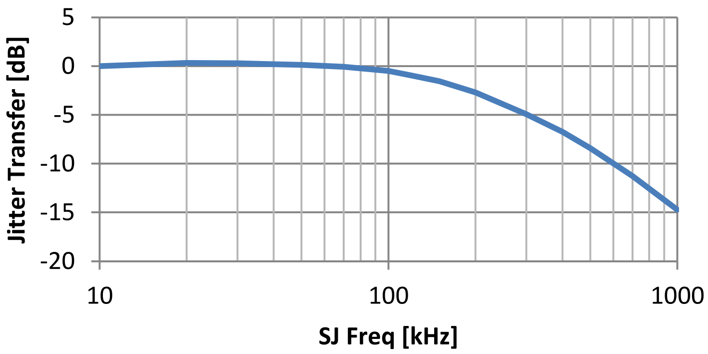

Figure 3-4. Example of Jitter Transfer Measurement Result

The factor influencing the actual Jitter Tolerance of the receiver is this CDR circuit, but speaking more precisely, it is the design of the PLL band and the phase margin of the Decision Circuit. If the jitter modulation frequency of the recovered clock is sufficiently lower than the PLL band, the jitter is broadly the same as the jitter in the original signal and since the variation is synchronized with the Data signal too, the Decision Circuit (Flip-Flop) phase margin is not exceeded. However, if the jitter modulation frequency exceeds the PLL band, this causes a difference in the amount of jitter in the Clock and Data signals, causing a difference in the phase margin. If this phase difference exceeds the phase margin of the Decision Circuit, an error results. To prevent this, jitter must be measured at the design and manufacturing stages to ensure that the total of the transmitter Output Jitter and jitter generated by the transmission circuit does not exceed the phase margin of the receiver Decision Circuit.

4. Need for Separation and Definition of Jitter Components

Most communications systems require an error rate of 1E-12 or less to assure communications quality. As a result, the amount of jitter must also meet the standards for bit counts to assure error rates of 1E-12 or less. For example, when measuring jitter at transmission speeds of 10 Gbit/s, it is necessary to measure for 100 s using a BERT to capture 1E+12 bits and determine the maximum value. Using a sampling scope, which generally has a sampling speed on the order of 30 to 100 ksps, assuming a speed of 100 ksps, measurement will require 10,000,000 s, which is an impractically long time. Consequently, the working group on Fibre Channel MJSQ (Methodologies for Jitter and Signal Quality Specification) examining FC jitter measurement methods proposed a method for estimating jitter equivalent to a BER of 1E-12 using a small measurement sample obtained by short-term measurement. This analysis was split into two jitter components called Deterministic Jitter (DJ) and Random Jitter (RJ). Additionally, the DJ division was further subdivided into a second level analysis called Level 2 Jitter (Figure 4-1).

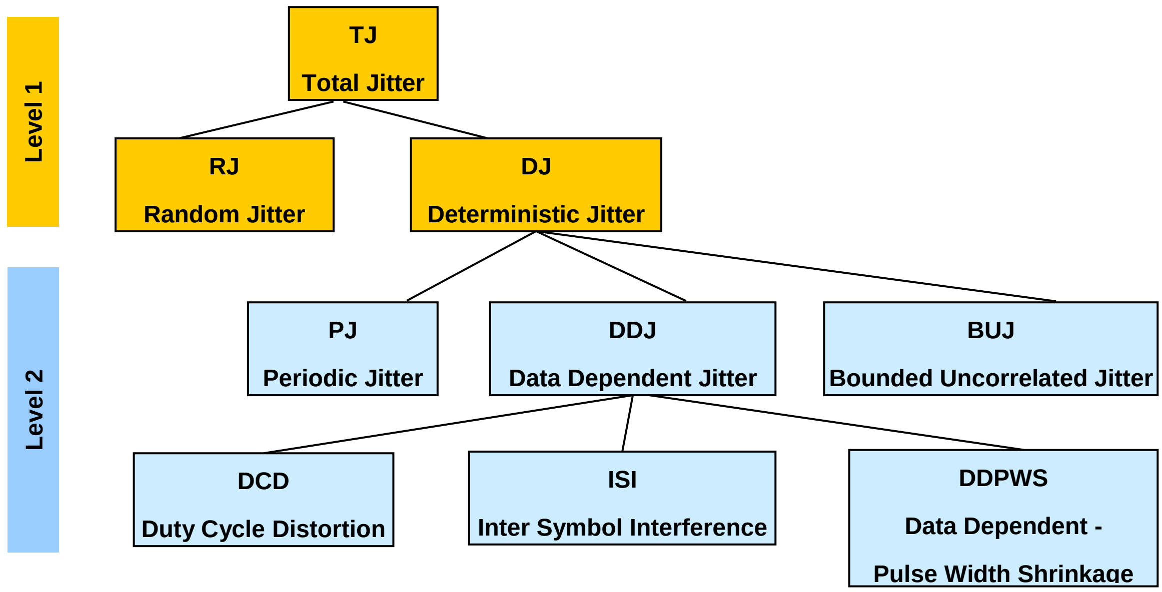

Figure 4-1. Jitter Components and Analysis Level

4.1 Level 1 Jitter

Level 1 Jitter analysis is a method for separating jitter components into DJ and RJ and then recombining them as Total Jitter (TJ). The objective is to compute the TJ, RJ and DJ using a simplified jitter model called the Dual Dirac model. As described above, it is premised on the amount of jitter in a short time period being equivalent to the specified BER (usually 1E-12). This measurement result is also called the Effective Jitter, and although it is important in unifying measurement results for communications standards such as Fibre Channel, it is not the same as the true value of physical jitter.

The details of TJ, RJ and DJ are explained below.

- TJ (Total Jitter)

Total Jitter is composed of a complex mix of various types of jitter and is expressed as the sum of these parts—as indicated by its name. Since it is not possible to completely model all the jitter components, the MJSQ Working Group proposed a method for handling TJ as a synthesis of the simplified Dirac function and the Gauss function.

$$TJ(BER) = N(BER) \times RJ + DJ \qquad \text{Eq. 4-1}$$

Equation 4-1 shows that TJ is composed of an RJ component based on the Gauss function and a DJ component based on the Dirac function. RJ uses the rms value while DJ uses the peak-to-peak value. In addition, the RJ coefficient N is the BER function and varies according to the assumed BER. In most cases, the value of N is 14.069, which is equivalent to a BER of 1E-12. Both J2 and J9 in the Infiniband standard are one type of TJ and mean the jitter amounts equivalent to BER 2.5E-3 and 2.5E-10, respectively.

The estimated TJ is visualized as the BER Bathtub Curve. The BER Bathtub Curve is a method for evaluating the Eye Pattern waveform as a graphical representation with time on the x-axis and error rate (cumulative probability distribution) on the y-axis. The left and right sides of the graph indicate the Eye Pattern crossover points, which increase with the error rate. The central area is the center of the Eye Pattern waveform; this type of graph form is called a Bathtub Curve. Figure 4-2 shows an example of a Bathtub Curve with J2, J9 and EYE Margin (1E-12), etc., determined for the Fibre Channel and InfiniBand standards.

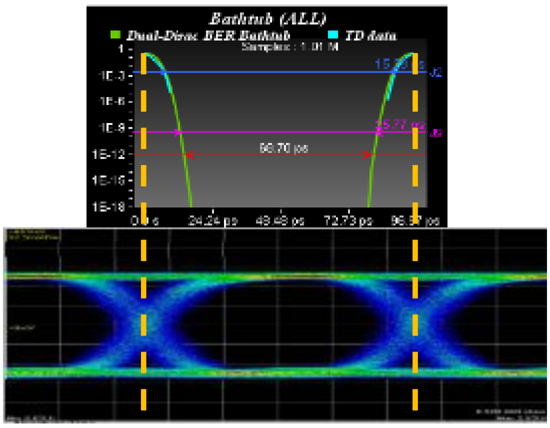

Figure 4-2. Relationship between BER Bathtub Curve and Eye Pattern

- RJ (Random Jitter)

Random jitter is jitter caused by external factors such as thermal noise. The peak-to-peak units indicate it has the property of infinite (unbounded) spread, approximating a normal distribution. As a result, in theory it is a constant value and can be generally expressed as the rms value using the standard deviation (σ).

In Eq. 4-1, RJ is multiplied by the coefficient N, which is the BER function. The N multiplier converts the RJ value in rms to the peak-to-peak value. The RJ peak-to-peak (p-p) value is a function of the BER (bit shift value) expressed as shown in Eq. 4-2 and Eq. 4-3 and uses the property of inverse proportionality to the estimated BER.

$$RJpp(BER) = N(BER) \times RJrms \quad = 2 \times \mathrm{Q(BER)} \times \mathrm{RJrms} \qquad \text{Eq. 4-2}$$

$$Q(BER) = \sqrt{2}\, erf^{-1} \left[1 - \frac{1}{\rho t} BER \right] \qquad \text{Eq. 4-3}$$

It is not necessary to learn the above equations by heart, but it is necessary to understand that RJp-p is a function of BER and that RJp-p has a fixed ratio to RJrms depending on the BER. Table 4-1 shows the ratio of RJp-p and RJrms for BER obtained from Eq. 4-1 and Eq. 4-2. Using these known ratios, we simply multiply the captured RJrms value by 14.069 to estimate the value of RJp-p equivalent to a BER of 1E-12.

Table 4-1. RJrms vs RJpp Multiplier

Estimated BER	Multiple: N = 2 × Q (BER)	Note
2.5E-3	5.614 = 2 x 2.807	Equivalent to J2
1E-7	10.339 = 2 x 5.1695	
1E-9	11.996 = 2 x 5.998	
2.5E-10	12.438 = 2 x 6.219	Equivalent to J9
1E-11	13.412 = 2 x 6.706	
1E-12	14.069 = 2 x 7.0345	
1E-13	14.698 = 2 x 7.349	
1E-15	15.883 = 2 x 7.9415	

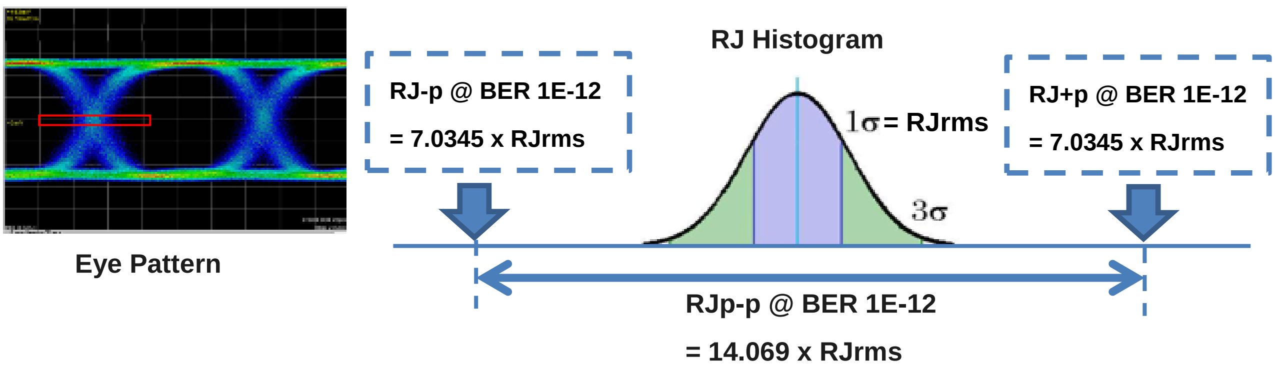

Figure 4-3. Typical Waveform including RJ, and RJ Histogram

- DJ (Deterministic Jitter)

Jitter with a limited spread compared to RJ is called Deterministic Jitter (DJ). DJ is a composite of many parts as described later and its distribution is a complex form. Notwithstanding this, Level 1 Jitter analysis uses the Dual Dirac method which simplifies to a pair of DJ components using the Dirac function. In other words, as previously explained for TJ, the jitter is considered to be composed of normally distributed RJ components and a fixed pair of DJ components. Using the Dual Dirac distribution, the dual normal distributions can be combined using Eq. 4-4 and represented using the graph shown in Figure 4-4.

$$PDF = \frac{1}{\sqrt{2\pi}\sigma}\left[exp\left\{-\frac{(x-\mu_L)^2}{2\sigma^2}\right\} + exp\left\{-\frac{(x-\mu_R)^2}{2\sigma^2}\right\}\right] \qquad \text{Eq. 4-4}$$

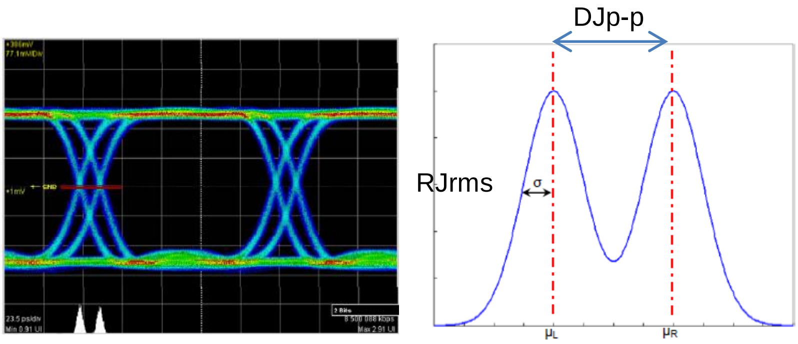

Figure 4-4. Typical DJ Waveform, and Histogram

μ_L and μ_R in the graph are the Dual Dirac lines representing the peak-to-peak value of the DJ component. The standard deviation σ of the RJ component clearly appears to be superimposed on the paired left and right Dirac lines.

As described previously, the DJ value obtained using the Dual Dirac method is called Effective Jitter and is obtained by fitting complex DJ components to a paired DJ model. Care is required because the calculation tends to produce a smaller value than the actual true DJ value.

4.2 Level 2 Jitter

Level 1 Jitter analysis stresses integration of measurements for communications standards and models complex DJ components using a simplified Dual Dirac model. On the other hand, we actually need detailed analysis of what components comprise DJ, what are the causes, and what tests we can use to suppress this jitter. This type of detailed analysis is called Level 2 Jitter analysis (Level 2 DJ analysis). The components of DJ classified by Level 2 analysis are explained below.

- PJ (Periodic Jitter)

As indicated by its name, this type of jitter occurs periodically. A typical example is sinusoidal jitter (SJ) caused by the ripple of a switching power supply, or the oscillation of a PLL circuit. SJ can be produced by a general signal generator and every engineer is well acquainted with SJ. A histogram representing SJ shows the characteristic peaks at each side. SJ is not synchronized with the Data signal and is also classified as jitter with no correlation to data.

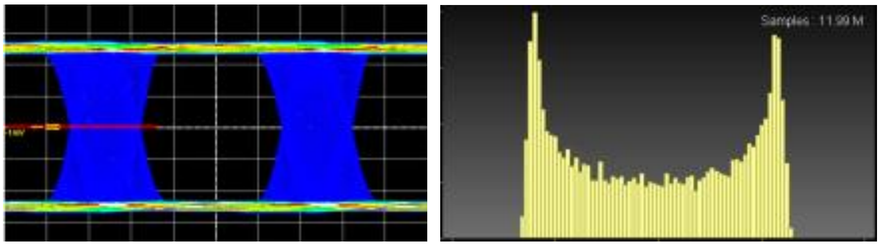

Figure 4-5. Typical Waveform with SJ, and Jitter Histogram

On the other hand, there are PJ components with a correlation to data. Commonly, the output of a MUX (multiplexer) circuit typically contains Half Period Jitter (HPJ) and as shown in Figure 4-6, when the width of adjacent Eye openings changes regularly, jitter occurs at every 2 bits in synchrony with the Data pattern.

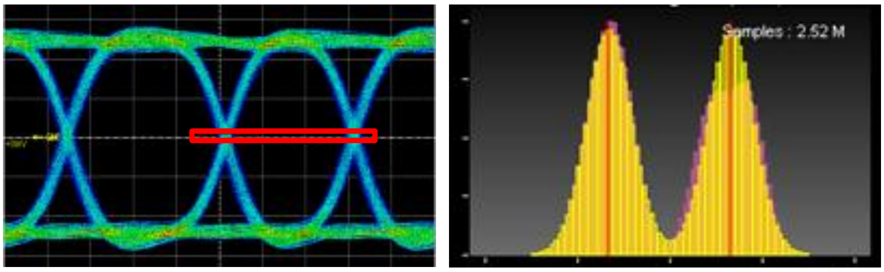

Figure 4-6. Typical Waveform with HPJ, and Jitter Histogram

- BUJ (Bounded Uncorrelated Jitter)

This type of jitter is caused by external factors such as crosstalk from an adjacent signal line, etc. Although it has random properties rather like RJ, since it has limited spread, it is expresses as p-p. To assure the bandwidth of recent high-speed systems like InfiniBand, PCIe, Fibre Channel, etc., with transmissions at 40 GbE (4 x 10G) using QSFP+ modules and at 100 GbE (10 x 10G) using CXP modules, bit rate speeds have both been increased and shared in parallel, increasing the importance of evaluating BUJ caused by crosstalk at the backplane and in Active Optical Cables (AOC).

At jitter measurement, BUJ can be captured reliably as part of DJ to determine the effect of increases in BUJ on DJ measurement results. Care is required at measurement because some models of sampling oscilloscope in the market cannot reflect increases in BUJ in the entire DJ value.

Anritsu MP2100A and MP1800A can reflect increases in BUJ in the entire DJ value.

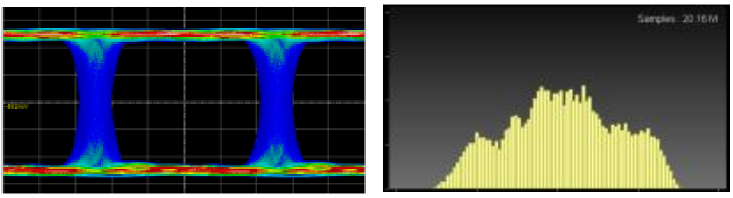

Figure 4-7. Typical Waveform including BUJ, and Jitter Histogram

- DDJ (Data Dependent Jitter)

This type of jitter depends on the data pattern and is due to the effects of inadequate bandwidth and reflections in the transmission path. As shown in Figure 4-8, when components with no correlation to data are removed, if the time difference at each edge referenced to the basic timing is Δt_n, the peak-to-peak value is obtained from Eq. 4-5. Additionally, DDJ can be separated into three types: DCD, ISI, and DDPWS.

$$DDJ = \max(\Delta t1,\ \Delta t2,\ \ldots,\ \Delta tn) - \min(\Delta t1,\ \Delta t2,\ \ldots,\ \Delta tn) \qquad \ldots \text{ Eq. 4-5}$$

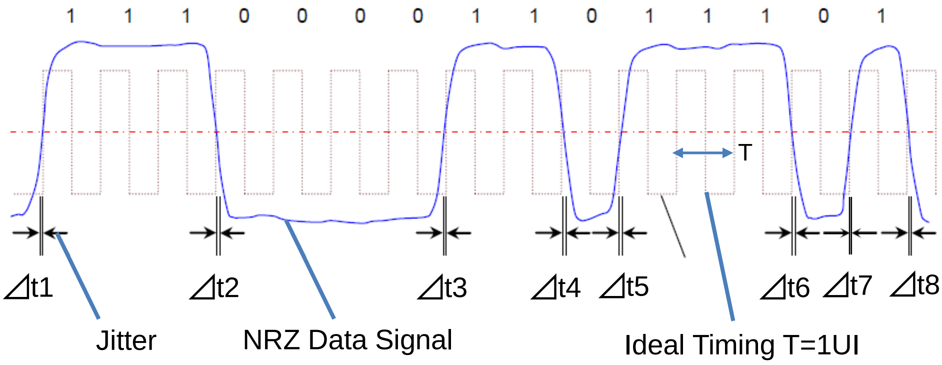

Figure 4-8. Outline of DDJ

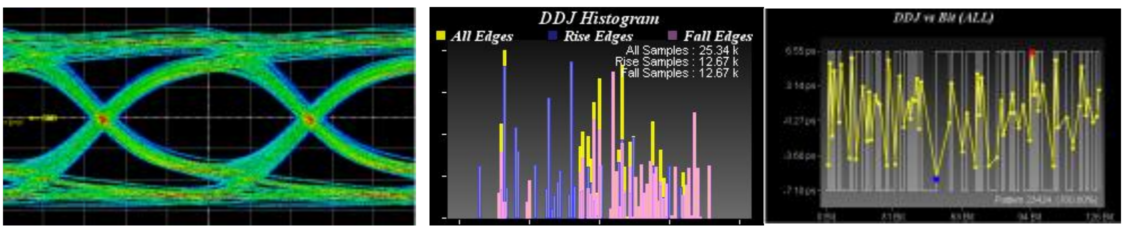

Figure 4-9. Typical Waveform including DDJ, ISI, and DDPW, and Jitter Histogram

- DCD (Duty Cycle Distortion)

This type of jitter is caused by drift, etc., in the voltage threshold of the TRx circuit. It is defined as the difference between the Hi and Lo logic pulse widths. Since it is dependent on the data pattern, it is classified as part of DDJ. Figure 4-10 shows an example of the jitter measurement point (Threshold Level) for the signal GND level (Eye Pattern) indicated by the red rectangle and the corresponding histogram. DCD can be disregarded when the signal cross-point is the Threshold Level.

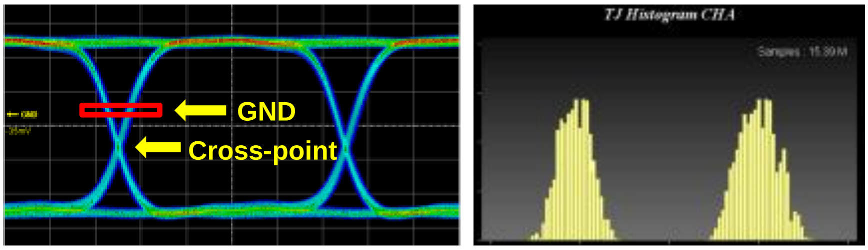

Figure 4-10. Typical Waveform including DCD and Jitter Histogram

- ISI (Inter Symbol Interference)

This phenomenon occurs due to inadequate bandwidth and reflections caused by impedance mismatching, etc., in the transmission path. When components with no correlation to data are removed, it is defined either as the difference between the fastest and slowest rising edges, or as the difference between the fastest and slowest falling edges.

- DDPWS (Data Dependent Pulse Width Shrinkage)

This phenomenon is expressed as a decrease in the pulse with caused by inadequate bandwidth and reflections in the transmission path. As shown in Figure 4-11 and Eq. 4-6, when components with no correlation to data are removed, it is defined as the time difference between the ideal 1-bit width and the smallest pulse width.

$$DDPWS = T - min(t2 - t1, t3 - t2, \ldots\ldots tn + 1 - tn) \qquad \ldots \quad \text{Eq. 4-6}$$

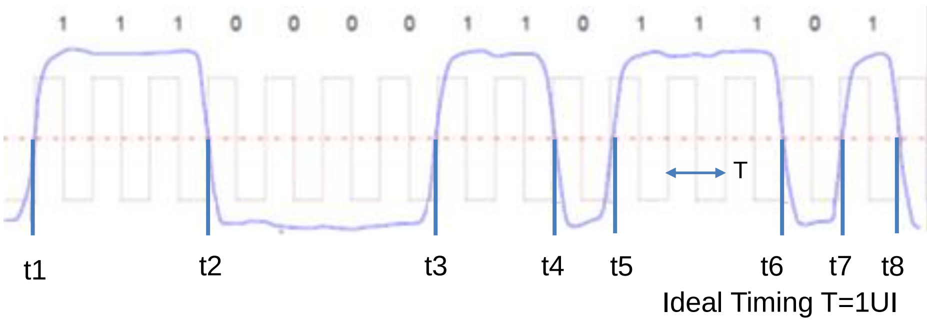

Figure 4-11. Outline of DDPWS

5. Measurement Methods using MP2100A

This section explains some actual measurement procedures for analyzing jitter using the MX210001A Jitter Analysis Software for the MP2100A BERTWave. As described previously, there are two jitter analysis levels: Level 1 and Level 2. The MX210001A has a Histogram Mode supporting Level 1 analysis, as well as a Pattern Search Mode supporting both Level 1 and Level 2 analyses. Measurement examples for each mode are explained below.

In addition, refer to Technical Note No. MP2100A-JE-2100 (Intrinsic Jitter Correction for Jitter Measurements) for how to prevent the effect of measuring instrument residual jitter.

[Measurement Setup]

Figure 5-1 shows an example of a measurement system for a 10.3125G SFP+ Optical Transmitter using the MP2100A.

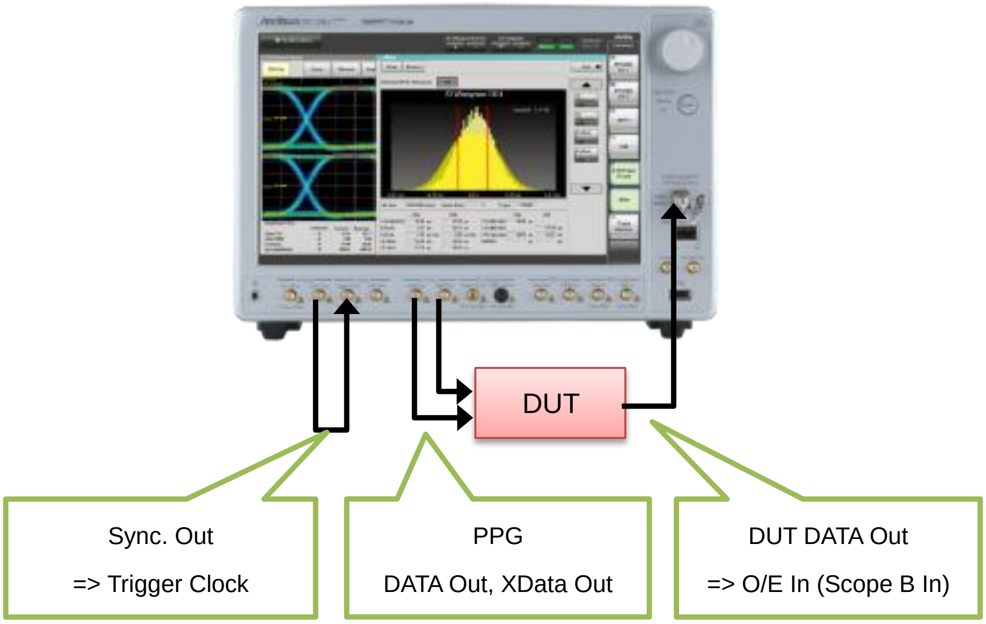

Figure 5-1. Measurement System using MP2100A

(1) Supply the PPG Differential Data output signal to the DUT Tx and connect the Optical Data signal output from the DUT Tx to the O/E input (CH_B Input) of the MP2100A. The recommended range of the input power to the O/E input is –5 to –9 dBm (1310 nm, Average). There is a risk of damage to the O/E converter if this power range is exceeded.

(2) Connect Sync. Out and Trigger Clock In of the MP2100A. In this example, the PPG Sync. Clock Output is used as the Trigger Clock for driving the sampling scope but Recovered Clock can also be used.

5.1 Level 1 Jitter Analysis - Histogram Mode

In the MX210001A Jitter Analysis Software Histogram Mode, as the name implies, the Eye Pattern cross-point are plotted as a histogram to perform Level 1 jitter analysis. Any Data pattern, including PRBS31, can be measured, and moreover, Eye Mask tests as well as Eye Pattern analyses such as Eye Amplitude can be performed simultaneously with jitter measurements.

[Jitter Measurement Items]

Measurement Item	Units (switchable)		Note
TJ (BER = 1E-12)	psp-p	mUIp-p	TJ for BER = 1E-12
TJ (user specified BER)	psp-p	mUIp-p	TJ for user-defined BER
DJ $_{(d\text{-}d)}$	psp-p	mUIp-p	DJ based on Dual Dirac method
RJ $_{(d\text{-}d)}$	psrms	mUIrms	RJ based on Dual Dirac method
J2	psp-p	mUIp-p	TJ for BER = 2.5E-3
J9	psp-p	mUIp-p	TJ for BER = 2.5E-10
Eye Opening	psp-p	mUIp-p	1 Bit jitter-free Eye Opening

[Procedure]

The MP2100A settings are presumed made from the initial setting status after initialization. To initialize, open the System Menu and click [Initialize].

Figure 5-2. MP2100A Initialize Screen

(1) Select PPG/ED CH1 from the Top Menu. Set the PPG to Bitrate: 10.3125 Gbit/s, Test Pattern: PRBS 31, and Data Output Amplitude: 0.25 V. Set PPG Data output to ON. Set the signal level to the appropriate value matching the DUT.

(2) Select Eye/Pulse Scope from the Top Menu. Set Scope CH_A to OFF and Scope CH_ to ON. Run Auto Scale and check that the Eye Pattern is displayed at the screen center.

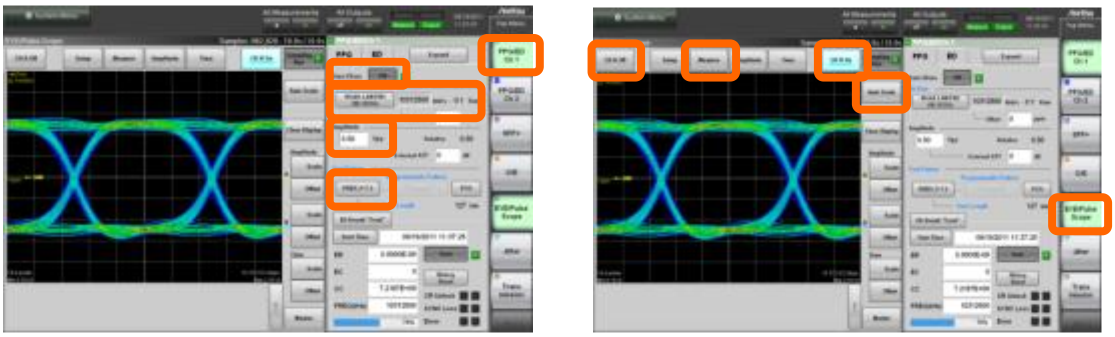

Figure 5-3. PPG and Scope Measurements

(3) Set the Amplitude/Time&Mask mode at the Scope Measure tab to display the Mask and Mask Margin.

(4) Select Jitter from the Top Menu to open the Measure dialog at the Jitter measurement screen and open the Algorithm tab. Check that the measurement mode is the Histogram mode. (The Histogram mode is the initialization default setting.)

(5) Press the [Start/Stop] button to display the Histogram mode jitter measurement results. To analyze jitter from the Eye Pattern histogram, collect jitter measurement results using a large capture sample count. Depending on the DUT status, aim to capture about 1 Msamples to obtain stable results.

Figure 5-4. Histogram Mode Analysis Screen

[Measurement Results]

The jitter measurement results are displayed as numeric values, TJ histogram, and BER Bathtub. The Eye Mask and Eye Pattern results are displayed simultaneously. Figure 5-5 shows the jitter analysis results for two types of DUT.

The TJ Histogram displays the actually measured histogram as well as the estimated histogram after separation of jitter into DJ and RJ using the Dual Dirac method assuming the time with is for the estimated DJ(d-d) peak-to-peak value. The estimated TJ histogram is the sum of the simple RJ component and the simplifed pair of DJ components, so it appears as an ideal normal distribution overlaying the two peaks.

The BER Bathtub graph displays the BER Bathtub Curve based on the estimated TJ Histogram. The Eye opening time width is displayed for points corresponding to BER = 1E-12.

Comparing the two jitter analysis results in Figure 5-5, the RJ and DJ of DUT_B (right side) are larger than DUT_A (left side) as seen from the graphs and numeric values. We can see that the difference in DJ(d-d) between the two is 9.15 psp-p and estimated TJ becomes increasingly larger in the order J2 (BER:2.5E-3), J9 (BER:2.5E-10), and TJ (BER:1E-12). As explained in section 4.1 this occurs because RJ is unbounded and the jitter becomes larger as the estimated BER becomes smaller. Reduction of RJ is very important to obtain lower error rates.

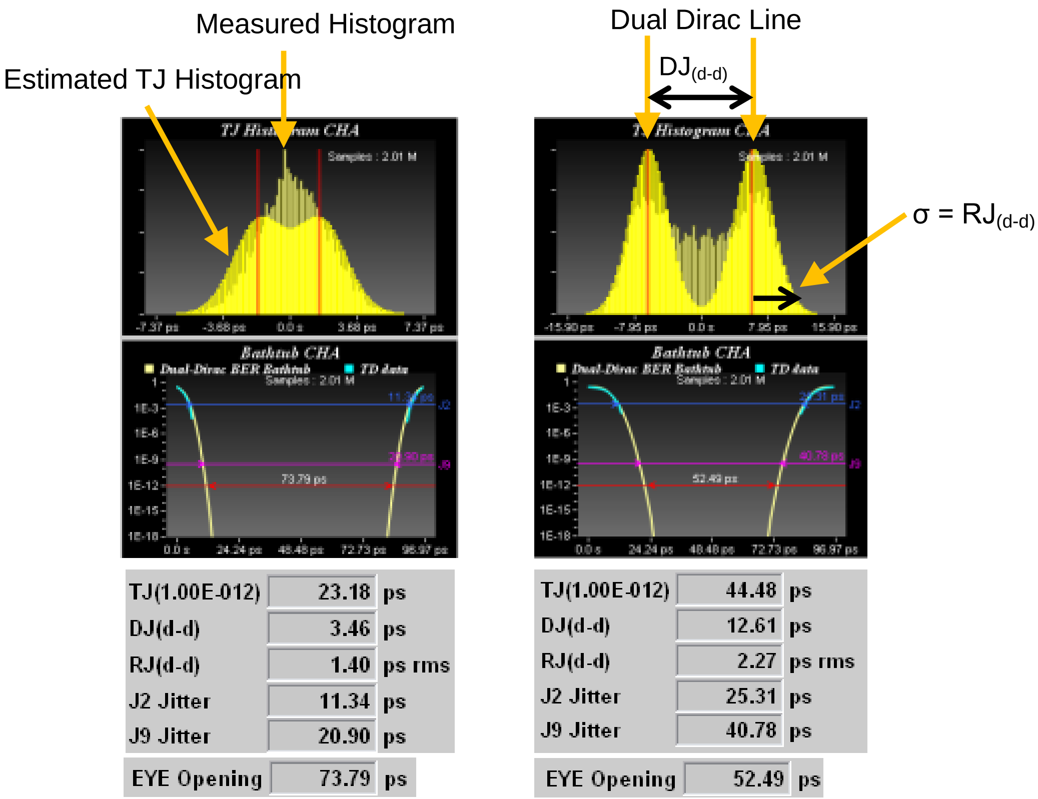

Figure 5-5. Example of Analysis Result using Histogram Method (left: DUT_A, right: DUT_B)

5.2 Level 1 and Level 2 Jitter Analysis - Pattern Search Mode

The MX210001A Jitter Analysis Software Pattern Search Mode performs both Level 1 and Level 2 jitter analysis. It can perform high-speed jitter analysis of detailed jitter components such as DDJ and DDPWS by capturing jitter time series data synchronized to the input Data pattern for a Data length corresponding to PRBS15. Detailed jitter analysis plays a key role in tracing the causes of jitter.

[Jitter Measurement Items]

	Measurement Item	Unit (switchable)		Note
Level 1	TJ (BER= 1E-12)	psp-p	mUIp-p	TJ for BER = 1E-12
	TJ (user specified BER)	psp-p	mUIp-p	TJ for user-defined BER
	DJ $_{(d-d)}$	psp-p	mUIp-p	DJ based on Dual Dirac method
	RJ $_{(d-d)}$	psrms	mUIrms	RJ based on Dual Dirac method
	J2	psp-p	mUIp-p	TJ for BER = 2.5E-3
	J9	psp-p	mUIp-p	TJ for BER = 2.5E-10
	Eye Opening	psp-p	mUIp-p	1 Bit jitter-free Eye Opening
Level 2	DDPWS	ps	mUI	Data Dependent Pulse Width Shrinkage
	RJ (rms)*	psrms	mUIrms	RJ* using Averaged Spectrum
	PJ (p-p)	psp-p	mUIp-p	Periodic Jitter
	DDJ(p-p)	psp-p	mUIp-p	Data Dependent Jitter
	DCD	ps	mUI	Duty Cycle Distortion
	ISI(p-p)	psp-p	mUIp-p	Inter Symbol Interference

*: RJ (rms) is calculated using Anritsu's patented Averaged Spectrum Method; unlike RJ estimated based on the Dual Dirac method, it displays an RJ value that is closer to the true value. The Averaged Spectrum method uses complex averaging of the jitter spectrum obtained by FFT processing of the captured time series jitter data to separate the jitter into PJ and RJ components.

[Procedure]

The procedure assumes that the status is that after performing measurement using the Histogram Mode described in section 5.1.

(1) Select [PPG/ED CH1] from the Top Menu and set PPG to Test Pattern: PRBS 7.

(2) Select Eye/Pulse Scope from the Top Menu and press the [Time] dialog. Set [Pattern Length – Tracking] in the Scale/Offset tab to ON. These settings automatically track the Scope and Jitter Analysis Software Pattern Length settings at the PPG Pattern Length settings. Auto-tracking is not supported when the PPG is set to PRBS31.

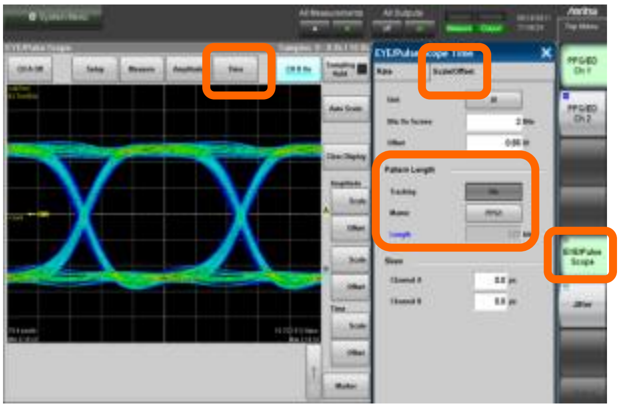

Figure 5-6. Pattern Length Tracking

(3) Select Jitter from the Top Menu to open the [Measure] dialog. Select [Pattern Search] at Algorithm Measurement Algorithm in the Algorithm tab.

(4) Press the [Start/Stop] button to display the Pattern Search Mode jitter measurement results.

Figure 5-7. Pattern Search Mode Analysis Screen

[Measurement Results]

The jitter measurement results are displayed as numeric values, DDJ vs Bit graph, various histogram and BER Bathtub. The Eye Mask and Eye Pattern results are not displayed simultaneously in the Pattern Search Mode. Zooming in on the DDJ vs Bit graph permits observation of the increase in jitter synchronized with the Data pattern. The red symbol on the screen indicates the most delayed edge (edge shifted in delayed time direction with most jitter) corresponding to the ideal timing. The blue symbol indicates the most advanced edge (edge shifted in advanced time direction with most jitter). Comparing the data patterns, the red symbol identifies the section of the Data pattern where 101010.... is repeated over at a short cycle. At a short repetition cycle, the signal frequency components are high and transfer delays occur due to the effect of the DUT frequency characteristics. Conversely, the blue symbol shows where the 000000111111... data pattern is repeating on a long cycle and, since the signal frequency components are low, it indicates that the phase timing is earlier than other data edges. These results can help clarify the correlation between the DUT transmission band and DDJ (ISI, DDPWS).

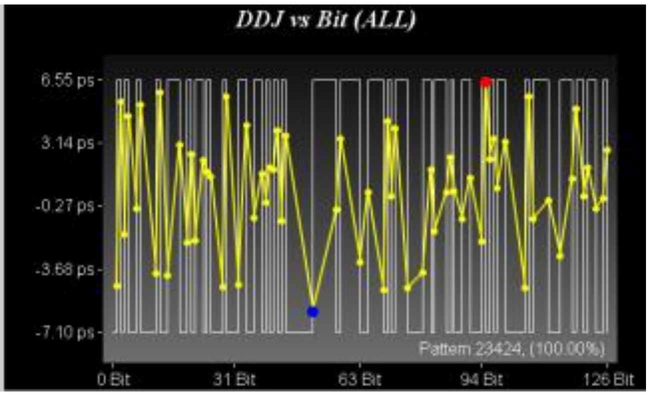

Figure 5-8. DDJ vs Bit Zoom Screen

TJ(1.00E-012)	34.20	ps	TJ(1.00E-012)	34.20	ps	DDJ(p-p)	13.65	ps
DJ(d-d)	11.63	ps	EYE Opening	132.47	ps	DCD	3.10	ps
RJ(d-d)	1.60	ps rms	DDPWS	7.86	ps	ISI(p-p)	13.90	ps
J2 Jitter	20.65	ps	RJ(rms)	1.27	ps rms	PJ Frequency		MHz
J9 Jitter	31.59	ps	PJ(p-p)	2.77	ps			

Figure 5-9. Numerical Results

6. Summary

We have defined jitter analysis and explained analysis procedures targeting high-speed serial communications in the fields of data communications and computing. The number of jitter parameters required for analysis of each communications standard, such as Fibre Channel, Infiniband, PCI-e, etc., is becoming increasingly complex. In addition, device operating margins are becoming stricter and the importance of jitter analysis is growing, while demand is increasing for faster bit rates coupled with lower power consumption.

Analysis of Output Jitter (Jitter Generation) can be split into Level 1 analysis for determining TJ, DJ, and RJ, and Level 2 for separating and analyzing the detailed components of DJ. Level 1 analysis can be executed simultaneously with Eye Mask analysis and a histogram-based measurement method is ideal for this purpose. Level 2 analysis performs even more detailed analysis of DJ components such as DDJ, DDPWS, etc., by measuring jitter in synchrony with the Data pattern.

The MP2100A is an all-in-one tester with built-in sampling scope, BERT and optical interface. Using it in combination with the MX210001A Jitter Analysis Software supports a full range of measurements, including Eye Pattern, Eye Mask, BER, and jitter separation and analysis, as a cost-effective and time-saving Anritsu measurement solution.

References:

- Anritsu Corporation, Technical Note No. MP2100A-J-E-2 'Residual Jitter Correction at Jitter Measurement'
- Anritsu Corporation, Application Note No. MP2100A-J-F-2 'Basics of Eye Pattern Analysis'
- Anritsu Corporation, Technical Note No. MP2100A-J-E-1 'Enabling Precision Eye Pattern Analysis'
- Anritsu Corporation, Application Note No. MP1800A-Signal_Integrity-J-F-1 'Signal Integrity Analysis of 28 Gbit/s High-Speed Digital Signals'
- Wolfgang Maichen, 'Digital Timing Measurements from Scopes and Probes to Timing and Jitter', Springer, ISBN-10 0-387-31418-0

-Note-

Specifications are subject to change without notice.

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No. MP2100A-E-F-3-(1.00) 公知 Printed in Japan 2012-6 MG