Application Note

Anritsu

# Effective Method for Signal Integrity Test

## — Combining Eye Pattern Analyzer and BER Tester —

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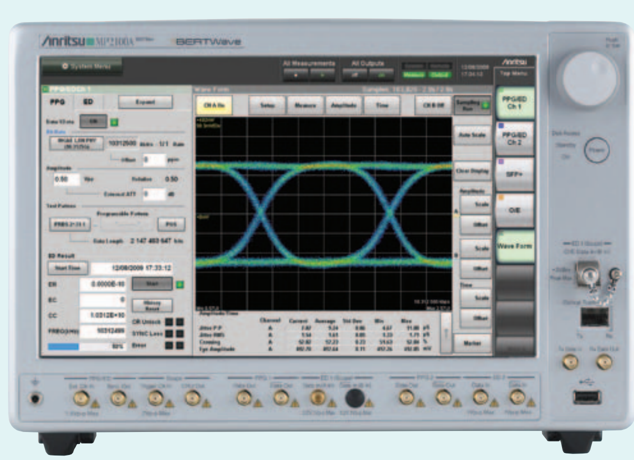
BERTWave

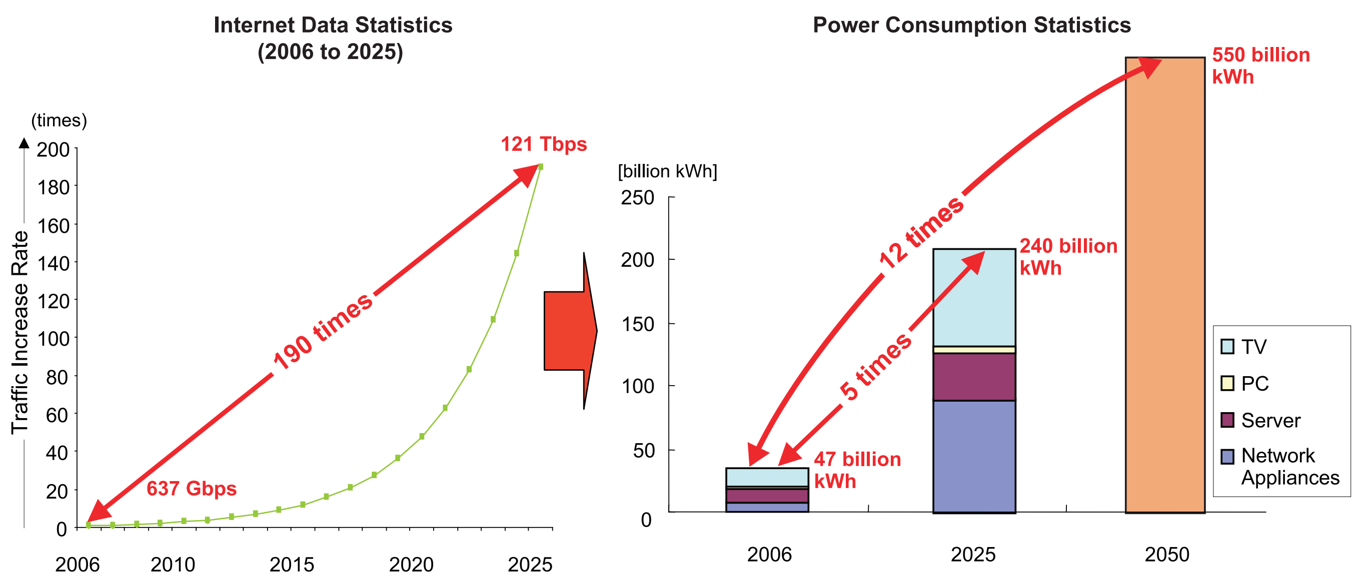


## 1. Trends in Optical Communications

The explosion in internet usage and data transfer volumes is driving increased demand for transmission equipment. As shown in Figure 1, the volume of data on the internet in 2025 is forecast to be 200 times the level of 2006 and this increase is likely to continue growing in the future.
Furthermore, increasing deployment of services such as cloud computing is increasing demand for data centers. To speed up data transfers between servers in data centers, connections are shifting from electrical to optical transmissions, meaning more use of optical interconnection technologies.
Consequently, new problems are occurring due to the increase in the number of servers and pieces of transmission equipment. One such problem is the rapid increase in power consumption. In the USA, power consumption by data centers doubled in the 6 years from 2000 and the increase is equivalent to the base load of five nuclear power stations. Moreover, as shown in Figure 1, the power consumption of IT equipment is forecast to be 5 times that of 2006, becoming a major problem worldwide.
Promising techniques for controlling power consumption include reducing the number of I/O ports being used to speed up transmissions, and reducing the power consumption per port by adopting widespread use of optical interconnects.
As a result, optical communications signal technology is expected to grow in the future along with increased demand for optical modules.

## 2. Trends in Optical Modules

This section examines trends in optical modules, a key device used in optical signal communications technology. Following the 300-pin transponder multi-source agreement (MSA) concluded in 2000, various SFP, XFP, SFP+, and QSFP modules became the standard type. A key theme for vendors manufacturing optical modules like transponders is cost reduction based on economies of scale as the market expands. On the other hand, manufacturers using these modules want to be able to second-source optical modules with the same specifications, while also reducing downtimes when changing out an occasional faulty module.
Unification of optical module specifications resulting from the MSA made the market even more competitive, and optical module manufacturers were faced with achieving conflicting objectives of creating functional priorities (product differentiation), stable supply (assured product quality) and cost advantages (cost reductions). Minimizing the time required for module evaluation is a key point in achieving these conflicting goals.




(Source: Ministry of Economy, Trade and Industry Green IT Initiative)

**Fig. 1 Data Volumes and Power Consumption**

## 3. Evaluating Optical Modules

The optical module is a medium for transferring error-free data using optical signals. Consequently, achievement of the target product quality is evaluated using the following items.

- **Confirming transmission quality**
- **Confirming signal quality**

The best way to confirm transmission quality is to perform a bit error rate (BER) test. The presence of an even a single bit error in the signal transferred by an optical module can be confirmed by the BER test using a combination of a pulse pattern generator (PPG) and an error detector (ED) to validate that the data has been transferred without an error. The best way to confirm signal quality is to use Eye pattern analysis. The waveform (Eye pattern) of the transferred signal is analyzed using an Eye pattern analyzer (Sampling oscilloscope) to confirm the presence of randomness and margins in the product signal with the intention of improving yields and test efficiency.
Consequently evaluation of optical modules requires a BER tester (BERT) with PPG and ED functions and Eye pattern analyzer. The competitive strength of optical modules is linked with the ability to perform efficient evaluations in the shortest possible time.

## 4. BERTWave MP2100A series

This section introduces the BERTWave MP2100A series of measuring instruments targeted at evaluation of optical modules. As explained previously, optical module analysis requires a BERT and an Eye pattern analyzer and this Anritsu BERTWave incorporates both these measuring instruments into one main frame. To meet the customer detailed requirements with flexibility, BERTWave series includes three models: a BERT plus Eye analyzer; a BERT only; and an Eye pattern analyzer only.

- **MP2100A BERTWave:**
  **BERT plus Eye Pattern Analyzer (Sampling Oscilloscope)**
- **MP2101A BERTWave PE: BERT**
- **MP2102A BERTWave SS: Eye Pattern Analyzer**


**MP2100A series**

## 5. Evaluation using BERTWave

This section introduces methods for evaluating optical transceivers and active optical cable (AOC) using the BERTWave.

### 5-1. Evaluating Optical Transceivers

The optical transceiver is an optical module performing two-way optical to electrical conversion. At transmission in the 10 Gbit/s band, the main technologies are XFP and SFP+; the expandability and serviceability are excellent due to the detachable module design.
High efficiency and fast testing are key requirements in reducing costs in this extremely competitive XFP and SFP+ optical transceiver manufacturing market.
This section explains manufacturing evaluation of optical transceivers using the BERTWave. The evaluation setup is shown in Figure 2.

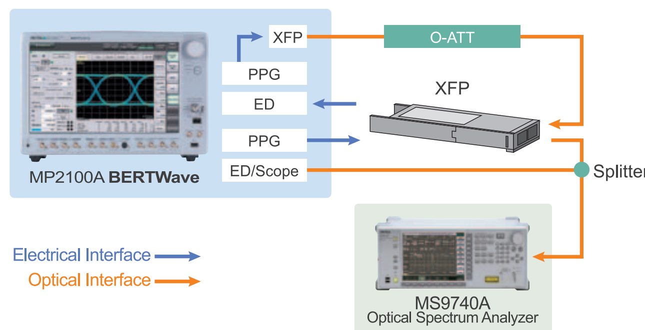



**Fig. 2 Optical Transceiver Manufacturing Evaluation**

The BERTWave is an all-in-one main frame incorporating functions for two BERT and one Eye pattern analyzer with both optical and electrical interfaces for evaluating signal transmission and reception simultaneously. Consequently, it eliminates the need to provide multiple measuring instruments as well as switching between instruments and the device under test.

#### 5-1-1. Measuring Optical Extinction Ratio

The optical extinction ratio is the ratio of ones and zeros in the optical signal as shown in Figure 3. It is calculated using the following equation:

Extinction ratio = $10\log_{10}\{(L_1 - L_D)/(L_0 - L_D)\}$ (dB)

$L_1$: 1 Level (mW), $L_0$: 0 Level (mW), $L_D$: Level with no optical input (mW)

Where, 0 Level and 1 Level are defined as:
0 Level: Average of histogram with lowest level in middle 20% of bit interval
1 Level: Average of histogram with highest level in middle 20% of bit interval

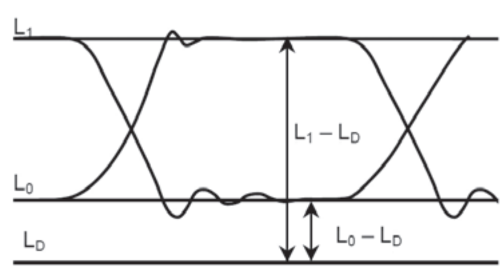



**Fig. 3 Definition of Optical Extinction Ratio**

Figure 4 shows an example of optical extinction ratio measurement using the BERTWave. The extinction ratio results can be displayed in real time simply by selecting “Extinction Ratio” from the “Time/Amplitude Test” menu item.

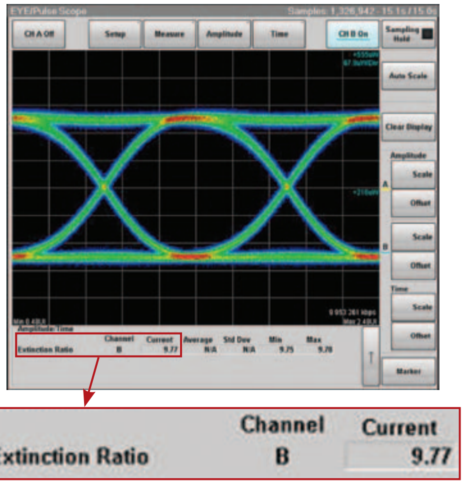



**Fig. 4 MP2100A Optical Extinction Ratio Measurement**

The BERTWave uses the Bessel filters with excellent frequency characteristics approaching the theoretical value to measure the extinction ratio with high accuracy, holding the extinction ratio dispersion between measuring instruments to within ±0.05 dB (typ.).

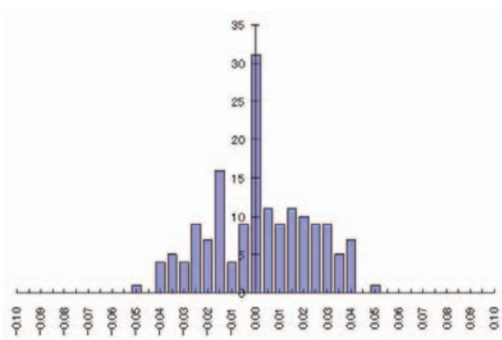
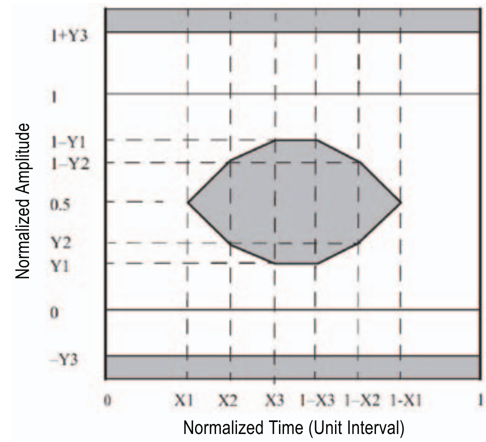


**Fig. 5 MP2100A Extinction Ratio Measurement Dispersion**

Figure 5 uses the Anritsu MU181620A Stressed Eye Transmitter, which is Variable Extinction Ratio Transmitter, as a reference. Measurement is performed at each bit rate to find typical values for instrument error using the average of the set extinction ratio as the reference. The statistics are based on a normalized sample of 162 measurements.

**5-1-2. Mask and Mask Margin Tests**

The mask is defined to regulate the Eye pattern shape at each standard. As an example, Figure 6 shows the 10G BASE-S, L and E templates standardized by IEEE802.3-2005.




| | X1 | X2 | X3 | Y1 | Y2 | Y3 |
|---|---|---|---|---|---|---|
| 10GBASE-S<br>10GBASE-L<br>10GBASE-E | 0.25 | 0.40 | 0.45 | 0.25 | 0.28 | 0.40 |

(Source: IEEE Std 802.3 - 2005)

**Fig. 6 10G BASE-S, L, E Masks**

The mask test is a simple and useful test for evaluating the important optical output characteristics of an optical transceiver. The output optical signal is superimposed on the mask template, and the waveform is in conformance with the mask when no part of the waveform is outside the upper, lower and central parts of the mask.
Additionally, the mask margin test is useful when the product quality must have some margin. As shown in Figure 7, the product can be shown to have a performance margin meeting the standards by setting a severe margin at the standard-defined mask.
The BERTWave has convenient built-in functions for automatically discovering the boundaries of the mask margin for the input signal in almost real time.

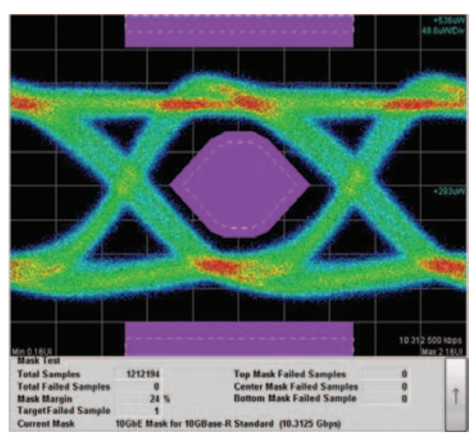


**Fig. 7 Mask Margin Test (24% Margin Added)**

### 5-1-3. Input Sensitivity Test

The extinction ratio measurements and mask test are for checking signal quality, but ultimately it is necessary to confirm the transmission quality by determining whether or not there is even a single bit error in the transferred data. The input sensitivity test is the most effective procedure for this verification and it is executed by attenuating the power of the optical input signal and verifying that the BER measurement is less than $1 \times 10^{-12}$ at the minimum input power (Figure 8).

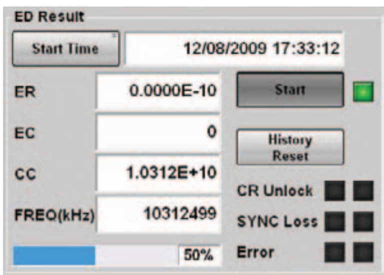



**Fig. 8 BER Measurement Screen**

The input sensitivity test is for finding the minimum input power of the optical signal while monitoring the BER value. This measurement is one of the tests requiring most time so shortening this measurement time is most effective in reducing the time needed for optical transceiver measurements.
As shown in Table 1, a minimum time of about 100 s is required to capture $1 \times 10^{-12}$ BER results at transmission speeds of 10 Gbit/s, but shortening this time is impossible. However, if the extra time required for finding the minimum input power can be shortened, the measurement time for the optical transceiver can also be shortened too.
Previously, when accessing the BERT using remote commands, usually the BER value was queried at a cycle of 100 ms, but using the BERTWave, the BER can be queried every 10 ms. When measuring the BER value for a 10 Gbit/s signal at a cycle of 10 ms, the minimum input power is adequate for an error rate of $10^{-8}$. Consequently, the BERTWave queries the BER value at a period of 10 ms, reducing the extra time required for finding the minimum input power times by 90% and greatly reducing production line input sensitivity testing times.

**Table 1. Bit Error Generation Average Time**

| Rate | Bit Rate (Gbit/s) | | |
|---|---|---|---|
| | 1.25 | 2.50 | 10.00 |
| $1 \times 10^{-4}$ | 8 µs | 4 µs | 1 µs |
| $1 \times 10^{-6}$ | 800 µs | 400 µs | 100 µs |
| $1 \times 10^{-8}$ | 80 ms | 40 ms | 10 ms |
| $1 \times 10^{-10}$ | 8 s | 4 s | 1 s |
| $1 \times 10^{-12}$ | 800 s | 400 s | 100 s |

### 5-2. Evaluating Active Optical Cables (AOC)

As explained above, both the number of data centers and the number of servers in data centers are increasing rapidly. As a result, wiring interconnects are transitioning from copper cables to optical fibers with high expectations for active optical cable (AOC) technology, featuring conversion to full-optical transmissions and offering advantages of faster speeds over longer distances with reduced power consumption as well as easier handling of lighter, smaller cables.
This section explains evaluation of AOCs using the BERTWave. Figure 9 shows the evaluation setup.

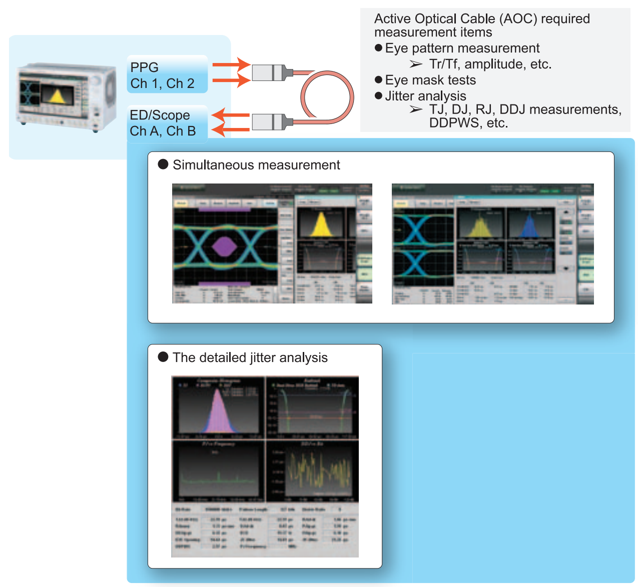



**Fig. 9 AOC Evaluation**

Since the BERTWave incorporates two BERT and one Eye pattern analyzer in a single all-in-one main frame, it easily supports two-way AOC Eye pattern analyses, such as BER and Mask tests. Additionally, the required jitter analyses for AOC evaluation can be executed simultaneously using BERTWave's jitter analysis software. This eliminates unnecessary capital investment in multiple measuring instruments while supporting simultaneous BER tests, Eye pattern measurements and jitter analyses for more cost-effective evaluation.

### 5-2-1. Crosstalk Interference

Internal circuit crosstalk interference cannot be ignored in AOC of multilane, high-density, high-speed and crosstalk suppressing is a key item in assuring signal quality.
With a built-in dual-channel PPG, the BERTWave can generate Aggressor signals (signal lane exerting effect) and Victim signals (lane receiving effect) to evaluate the impact of the Aggressor lane on the Victim lane by measuring the BER and Eye pattern and help assure signal quality (Figure 10).

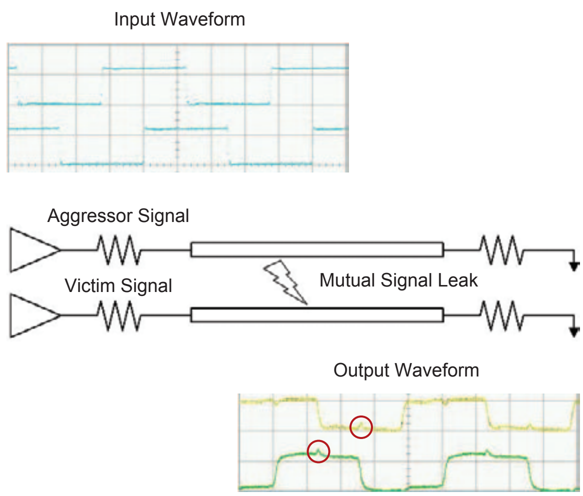



**Fig. 10 Crosstalk Interference**

### 5-2-2 Jitter Analysis

The conflicting needs for increased transmission speeds at lower power consumption and lower costs creates problems with jitter and degraded waveforms. The high-speed serial transmission standards like Fibre Channel, InfiniBand, 10 GbE, USB, PCIe, etc., used in the data communications and computing fields require separate analysis of jitter components, such as DJ, RJ, etc.
Most communications systems assure signal quality by demanding a BER of less than $1 \times 10^{-12}$ and consequently the jitter amount must be less than the standard value for the corresponding bit rate assuring an error rate of less than $1 \times 10^{-12}$. As a result, the working group on Fibre Channel Methodologies for Jitter and Signal Quality Specification (MJSW) examining Fibre Channel jitter measurement methods devised a method for estimating jitter equivalent to a BER of $1 \times 10^{-12}$ using a small number of measurement samples captured over a short time period. This method performs separate analysis of the Deterministic Jitter (DJ) and Random Jitter (RJ) components of jitter.
As shown in Figure 11, at Output Jitter (jitter generation) analysis, there is Level 1 analysis for finding TJ, DJ and RJ, as well as Level 2 analysis for finding the detailed jitter components of the DJ. At Level 1 analysis, the histogram method is the most efficient method because it can be executed at the same time as the Eye mask analysis. Level 2 analysis performs a more detailed analysis of DDJ, DDPWS, etc., by analyzing jitter in synchrony with the Data Pattern.

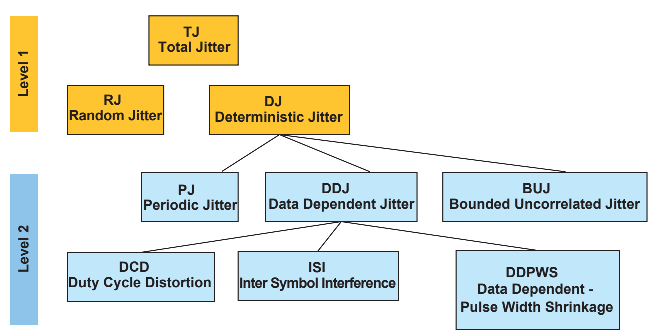



**Fig. 11 Jitter Components and Analysis Level**

## 6. Conclusion

Competition between vendors in the growing optical module market is becoming increasingly severe. Anritsu's BERTWave measurement solution for optical modules is expected to stimulate further growth in this market.

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Specifications are subject to change without notice.


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