



APPLICATION NOTE

Q Factor Measurement/Eye Diagram Measurement,
SDH/SONET Pattern Editing

MX163205A/MX176400A

Q Factor/Eye Analysis Software

MX163206A/MX176401A

SDH/SONET Pattern Editor

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1. Introduction

With the shift from STM-16/OC-48 to STM-64/OC-192, 10 Gb/s has become the mainstream in WANs such as WDM using 10 Gb/s optical amplifiers. On the other hand, looking at LANs, in addition to an explosive increase in the number of internet nodes over 1 or 2 years, the variety of network applications is likely to cause a major change from megabit transfer rates to gigabit rates.

The MP1632A 3.2Gb/s Digital Data Analyzer and the MP1763B/MP1764A 12.5 Gb/s BERTS¹ are measuring instruments that have been developed for R&D, manufacturing and inspection of devices and modules at speeds ranging up to 3.2 Gb/s or 12.5 Gb/s.

This application note introduces the MX163205A/MX163206A/MX176400A/MX176401A software for measuring the Q factor and Eye Diagram and editing the SDH/SONET pattern using the MP1632A and MP1763B/MP1764A.

■ Functions

1) Q factor Measurement

The Q factor can be measured automatically in accordance with ITU-T G.976/OSFTP-9.

2) SDH/SONET Pattern Editing

A frame signal can be created for testing the functions of SDH/SONET transmission equipment and devices.

3) Eye Diagram Measurement

The DUT eye diagram and margin can be measured automatically. As a result, evaluation of optical transmission functions such as eye aperture (ITU-T G.957) by bit error rate measurement, which is difficult to accurately measure with an oscilloscope, etc., becomes very simple.

Function Instrument	Q factor/Eye Diagram Measurement	SDH/SONET Pattern Editing
MP1632A	MX163205A	MX163206A
MP1763B/MP1764A	MX176400A	MX176401A

¹ MP1763B 12.5 Gb/s Pulse Pattern Generator + MP1764A 12.5 Gb/s Error Detector

2. Q factor Measurement

2.1. What is Q factor?

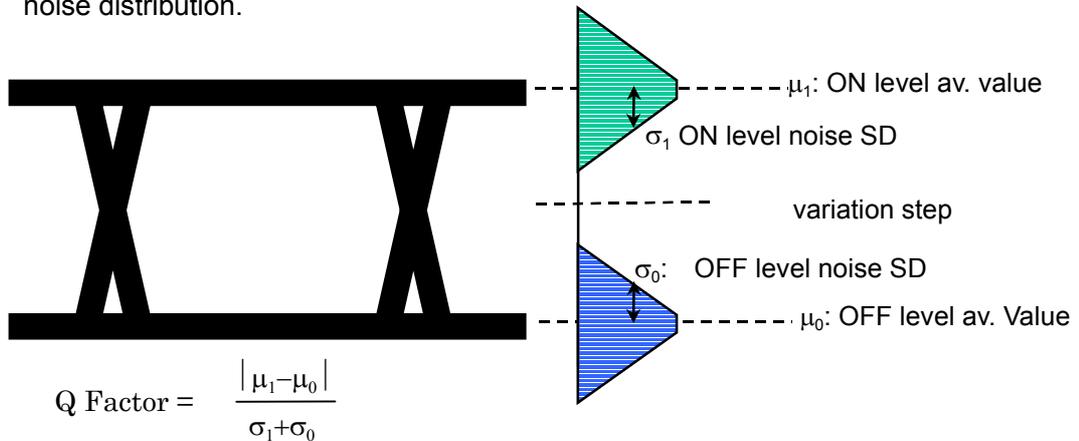
With the introduction of high-quality optical transmission circuits centered mainly on long-distance trunk lines and undersea cables, transmission path quality requirements have become extremely severe. For example, when requiring a bit error rate of $1.0E-15$, a minimum measurement time of 27 hours is required for bit error measurement using previous methods even for a 10 Gb/s signal. In these circumstances, instead of measuring bit error rate, Q factor measurement has become the new quality evaluation parameter.

The Q factor theory was announced in 1993 and was subsequently standardized as ITU-TG.976 (1997) Q factor Measurement Recommendation. In N. America, it was adopted in 1999 as Rec. OFSTP-9 TIA/EIA-526-9.

Currently, quality evaluation using the Q factor is increasingly becoming the method of choice for R&D, manufacturing, installation, acceptance inspection, and maintenance of high-quality optical circuits such as undersea optical circuits and long-distance trunk circuits.

2.2. Definition of Q factor

The Q factor is a measure of the digital signal eye aperture; it adopts the concept of S/N ratio in a digital signal and is an evaluation method that assumes a normal noise distribution.

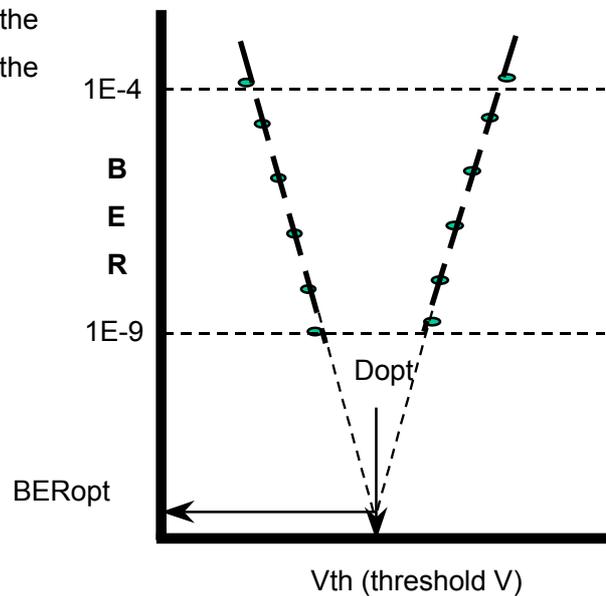


Using the MX163205A/MX176400A software, the noise distribution is measured from the bit error distribution and the Q factor is calculated by the method recommended in OFSTP-9/ITU-T G.976. In comparison to measuring the Q factor with a sampling oscilloscope, non-normally distributed noise is eliminated, so an accurate Q factor can be obtained.

The Q factor is used to predict the minimum bit error rate (BER_{opt}) and the threshold voltage (D_{opt}) at that time.

$$BER = \frac{1}{\sqrt{2\pi}} \frac{\text{Exp}(-Q^2/2)}{Q}$$

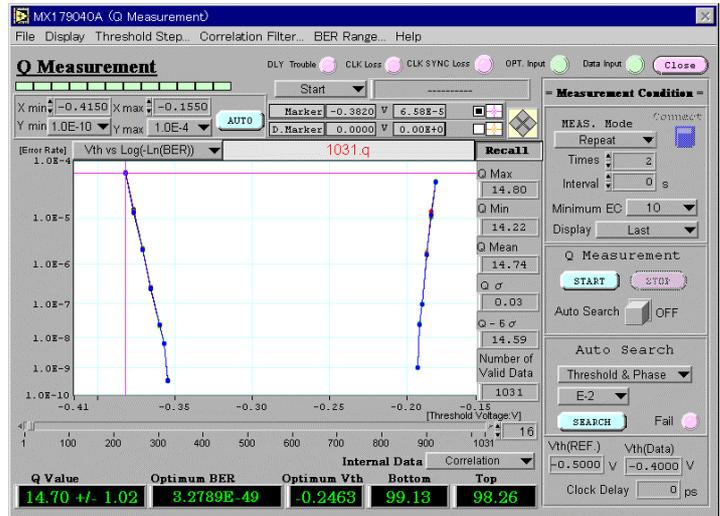
$$D_{opt} = \frac{\sigma_0 \mu_1 + \sigma_1 \mu_0}{\sigma_1 + \sigma_0}$$



2.3. Various Graphs and Analysis Functions for Measurement Results

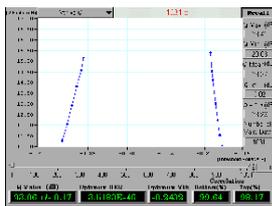
In addition to the Q factor, BER, minimum BER and best threshold, it is also possible to display σ_0 , σ_1 , μ_0 , μ_1 and intermediate data obtained at calculation of the Q factor and correlated with the normal distribution.

When several measurements are performed, statistical data such as max., min., mean and distribution can be displayed.

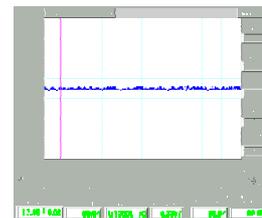


The following graph displays are supported.

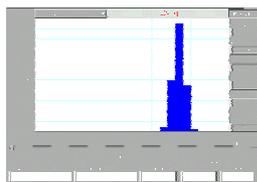
- 1) Threshold voltage vs. $\text{Log}(-\sqrt{\text{Ln}(\text{BER})})$
- 2) Threshold voltage vs. $\text{Log}(\text{BER})$
- 3) Threshold voltage vs. Q factor
- 4) Measurement times vs. Q factor
- 5) Clock phase vs. Q factor
- 6) Histogram



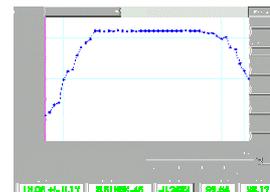
Threshold voltage vs. Q factor



Measurement times vs. Q factor



Histogram



Clock phase vs. Q factor

2.4. Flexible Measurement Parameter Setting

1) Minimum Error Count

When measuring bit error rate, select the required error bit count from 1, 10, 100, and 1000. This parameter indicates the bit error rate measurement accuracy.

2) Bit Error Rate Measurement Range

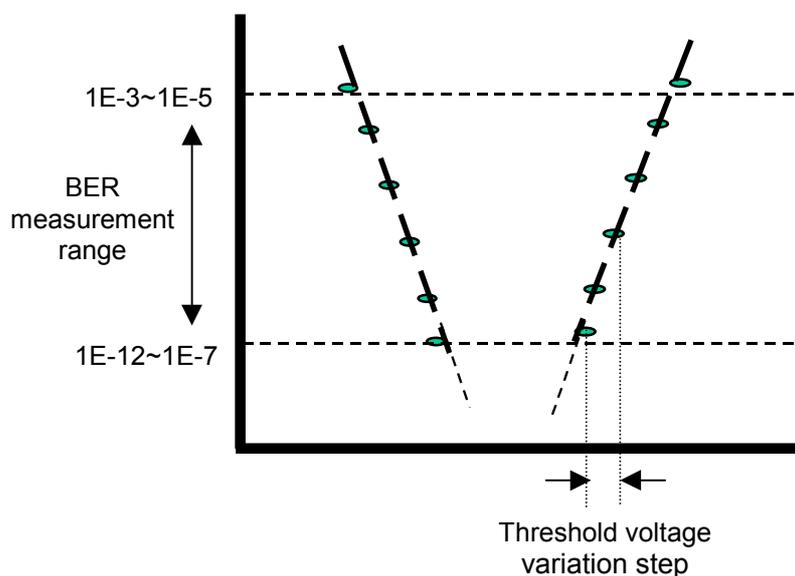
The bit error rate measurement range can be selected (see below). The rate between the upper and lower rate is measured and the Q factor can be recalculated when this range is changed at the end of measurement.

3) Threshold Voltage Variation Step

When measuring the threshold voltage vs. bit error rate characteristics, the threshold voltage variation step can be set (see diagram below). Any value can be fixed, and it is also possible to vary the setting dynamically so the best point can be measured.

4) Minimum Correlation Coefficient

When the threshold voltage vs. bit error rate characteristics are poorly correlated with a normal distribution, the measurement results can be disabled.



2.5. Other functions

1) Saving Measurement Results

The measurement results can be saved as a CSV format file that can be read and manipulated by applications such as MS Excel. In addition, the screen can be saved as a graphics file in any of three formats: BMP, JPEG, and PNG.

2) Printing Measurement Results

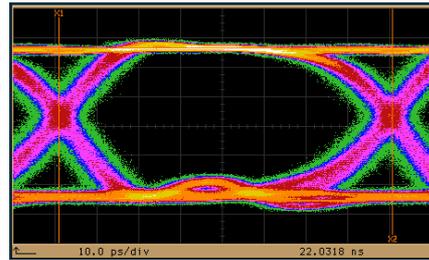
The measurement results can be printed in text format and the screen can also be output to a printer.

3. Eye Diagram Measurement

3.1. Eye Diagram Measurement with Oscilloscope

Eye diagram measurement is one typical method for evaluating the quality of digital signals.

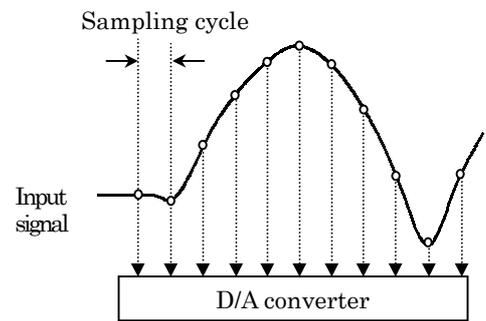
Usually, a digital oscilloscope is used to measure the eye diagram.



Eye-Diagram observed by oscilloscope.

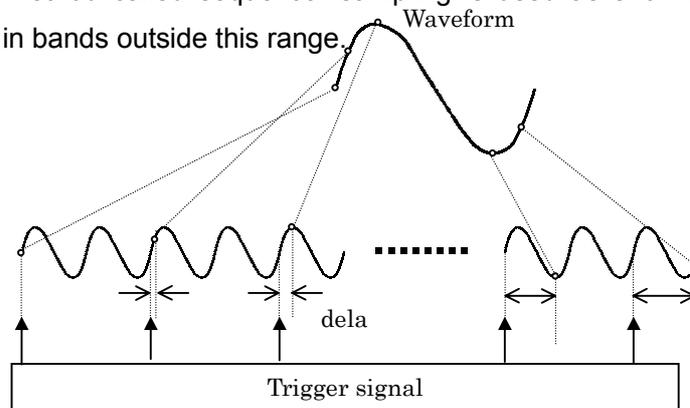
As shown in the diagram on the right, the analog voltage of the input waveform is converted to digital values at the specified sampling cycle and saved to memory.

To reproduce the waveform accurately, sampling must be performed at least as twice as fast as the maximum frequency (Shannon sampling theory). For example, to measure a 10 GHz signal, a sampling frequency of at least 20 GHz is required, but since the input signal includes wideband noise components, the required sampling speed exceeds the speed of even today's fastest A/D converters.



Oscilloscope operating principle

A measurement method called sequential sampling is used as shown below to measure signals in bands outside this range.



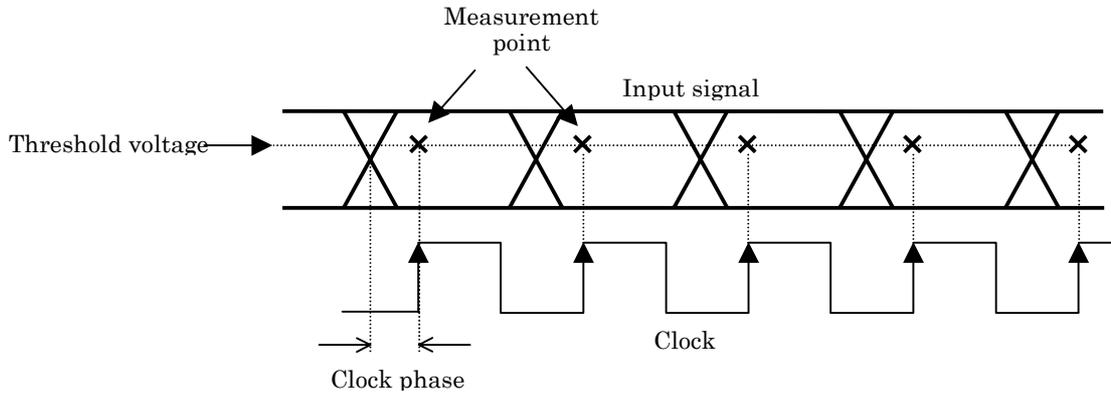
In this method, a signal that is wider than the narrow sampling cycle can be measured but the signal between the trigger signals (hold time) is not reflected in the measurement results.

3.2. Bit Error Rate Measurement based on Eye Diagram Measurement

Results measured with a digital oscilloscope may sometimes detect errors when performing bit error measurement even with a sufficient eye aperture.

In this case, the noise observed in the hold time is not “seen” by the oscilloscope, but with a bit error detector, all bits can be measured by using a clock signal synchronized with the input signal as a trigger.

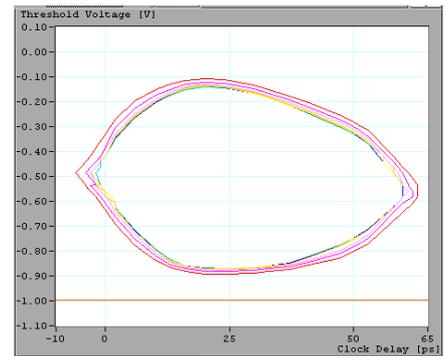
With an error detector, as shown in the diagram below, the bite error rate is measured at the point specified by clock phase and the threshold voltage in the eye pattern.



At eye-diagram-based bit error rate measurement, the clock phase and threshold voltage are varied and the bit error rate at any position in the eye pattern is measured as a bit error rate contour.

Any combination from E2 to E15 can be chosen as the contour.

This measurement principle achieves a much higher accuracy than the previous method using a sampling oscilloscope.



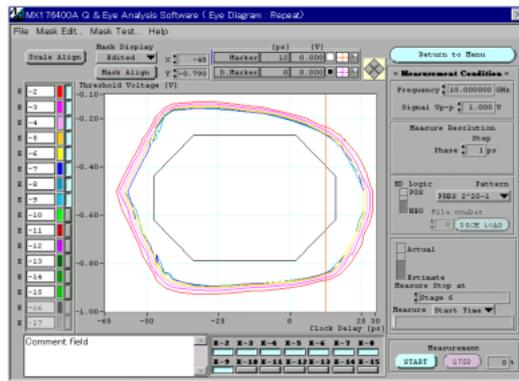
Eye-Diagram based on bit error rate

3.3. Signal Quality Pass/Fail Evaluation based on Eye Diagram Measurement

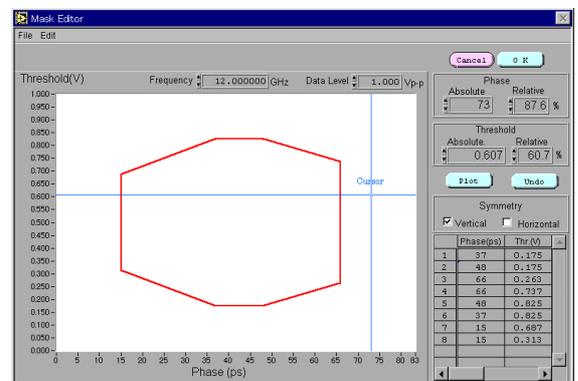
Signal quality pass/fail evaluation can be performed by comparing the eye diagram measurement results with a template. Templates for STM-1/OC-3~STM-16/OC-48 are standardized by ITU-T G.957.

Since the MX163205A/MX176400A software supports the above-described pass/fail evaluation, a template mask can be displayed. The template mask can be selected from an ITU-T standard mask or a user-defined mask.

In addition, the user can easily create a template mask using a dedicated editing screen with Undo function, vertical/horizontal switching, coordinate relative/absolute input, etc. The created mask template can also be saved to/read from a file.



Template display

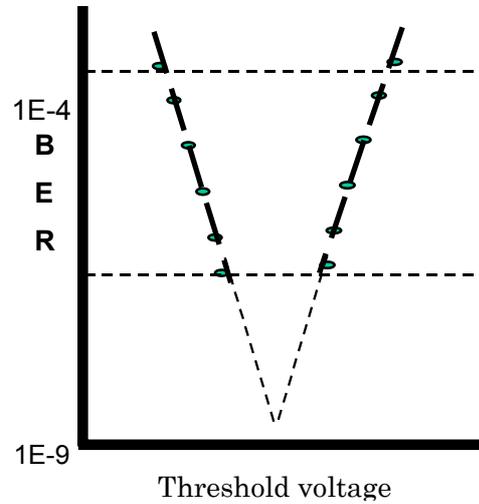


Editor screen of template

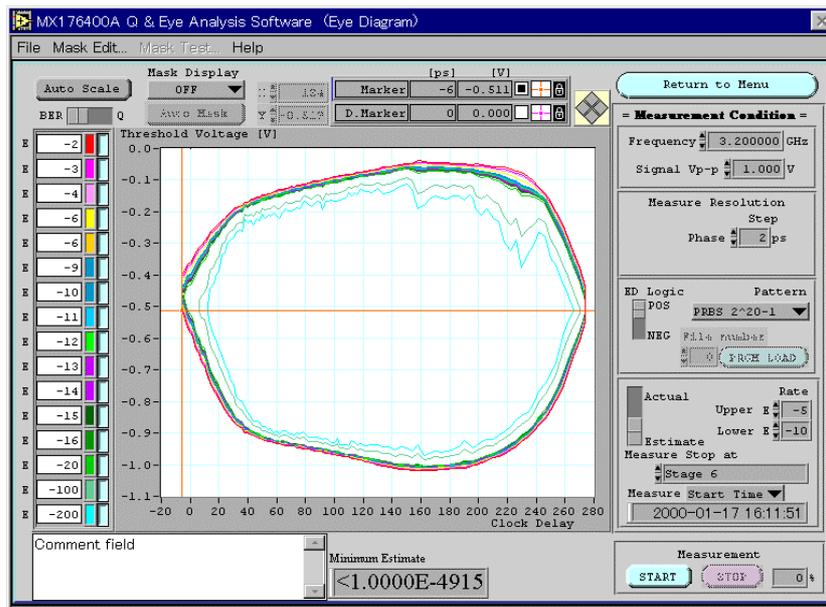
3.4. High-speed Eye Diagram Measurement using Q factor

By measuring the Q factor, the bit error rate of low rates that cannot be presently measured can be predicted.

$$BER(D) = \frac{1}{2} \left\{ \frac{e^{-\frac{(\mu_1 - D)^2}{\sigma_1^2}}}{\left(\frac{\mu_1 - D}{\sigma_1}\right)\sqrt{2\pi}} + \frac{e^{-\frac{(\mu_0 - D)^2}{\sigma_0^2}}}{\left(\frac{\mu_0 - D}{\sigma_0}\right)\sqrt{2\pi}} \right\}$$

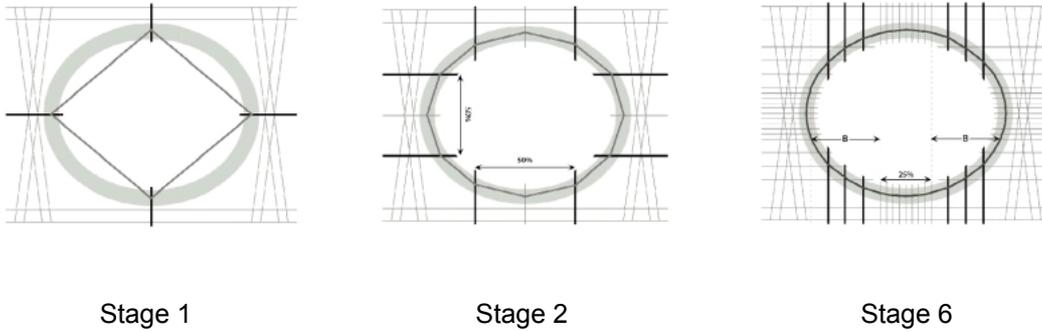


By using the Q factor, any bit error rate diagram up to E-4915 can be displayed.



3.5. Selecting Measurement Accuracy

To shorten the measurement time, the measurement procedure is divided into 6 stages. The measurement accuracy is increased as the number of measurement stages increases. Consequently, measurement can be stopped when the required accuracy is obtained.



The measurement accuracy corresponds to the number of measurement points. The number of points at each measurement stage is shown in the table below.

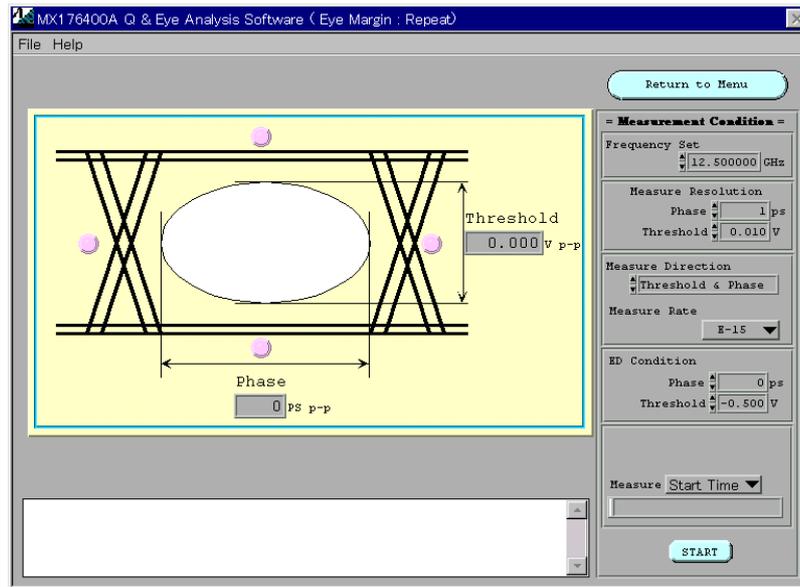
Stage	1	2	3	4	5	6
No. of points	4	12	24	36	48	Depends on phase margin*

* When measuring up to stage 6, the number of points varies with the phase direction at the clock phase setting resolution step (MX176400A: 1 ps, MX163205A: 2 ps).

3.6. Eye Margin Measurement

Eye diagram measurement measures the bit error rate as a 2D contour diagram. On the other hand, eye margin measurement measures threshold voltage/clock phase direction as a one-dimensional margin

The bit error rate that forms the margin boundary can be selected from E-2 to E-15. The margin direction can be selected from either the threshold voltage direction/clock phase direction, or both directions.



3.7. Other Functions

1) Saving Measurement Results

The measurement results can be saved to a CSV format file that can be opened and manipulated by applications such as [MS Excel](#).

In addition, the screen image can be saved as a graphics file in any of three formats: [BMP](#), [JPEG](#), and [PNG](#).

2) Printing Measurement Results

The measurement results can be printed as a text file and the screen can also be printed.

4. SDH/SONET Pattern Editing

4.1. Outline

The Anritsu MP1552A and MP1570A are useful dedicated measuring instruments for R&D, manufacturing, installation and maintenance of SDH/SONET equipment and devices. Since dedicated measuring instruments are expected to be used on transmission systems, the signal level and bit rate are specified for each interface. Conversely, when measuring amplitude and phase margin, etc., at R&D and inspection of devices and modules for SDH/SONET equipment, a general-purpose signal generator and bit error detector are required.

By using the MX163206A/MX176401A, the SDH/SONET frame pattern can be created as a measurement pattern at the MP1632, and MP1761B/MP1762A.

In addition, the MP1632A and MP1762A support burst measurement so SDH/SONET patterns can be used as patterns for inspecting optical circuits in actual use.

SDH/SONET Equipment

R&D, Manufacturing,

BER Test of parts and modules Installation and Maintenance

~ST~M-64/STS-192



MP1761B/62A + MX176401A



MP1570A SONET/SDH/PDH/ATM
Analyzer (10G unit)

~STM-16/STS-48



MP1632A + MX163206A



MP1570A SONET/SDH/PDH/ATM
Analyzer (2.5G unit)

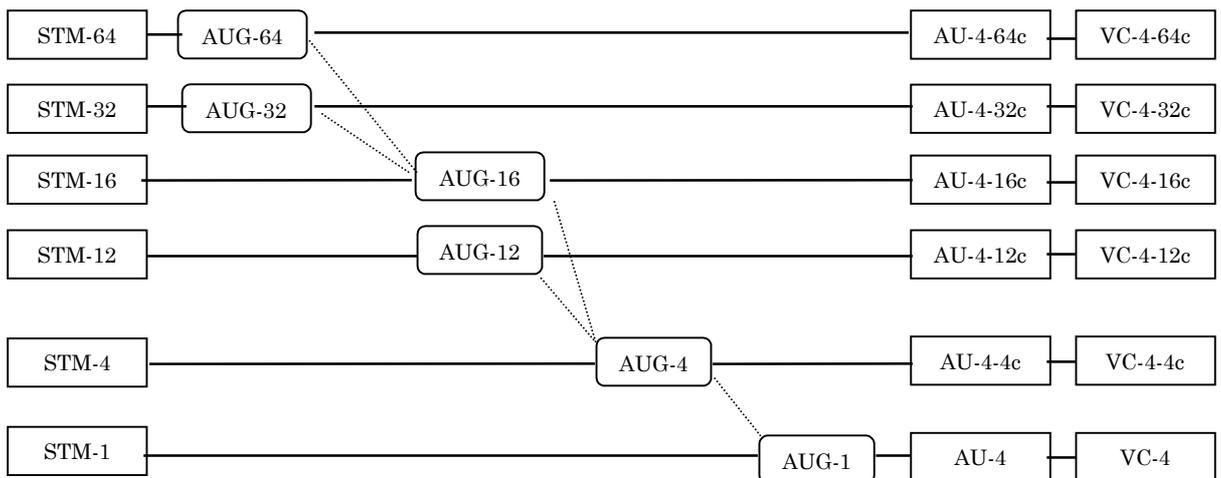
4.2. Supported Mappings

The supported mappings are STM-1, STM-4, STM-12, STM-16, STM-32, and STM-64 for SDH, and STS-1, STS-3, STS-12, STS-48, STS-192 [SPE for SONET](#).

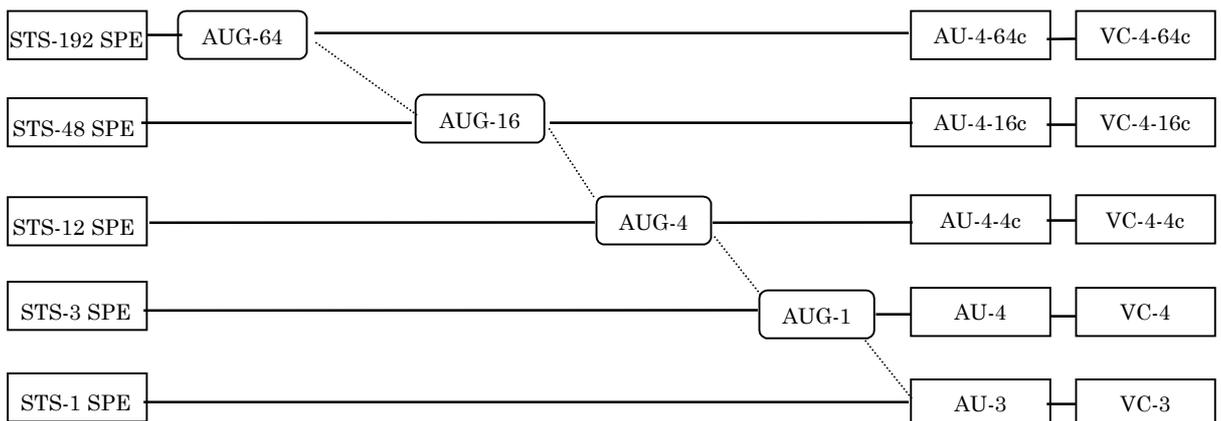
Up to 6 frames can be created for STM-64/STS-192SPE frames.

At the frame layer, only VC and above are supported; the STM-N or STS-N frame SOH and one POH string can be edited.

SDH supported frames are shown below (actual line only).



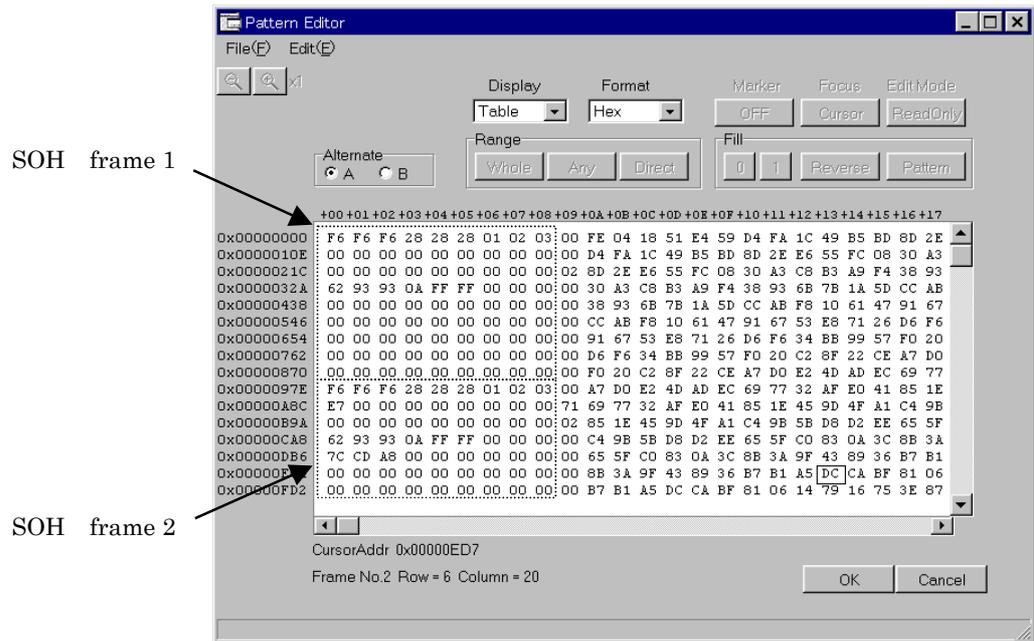
SONET supported frames are shown below (actual line only).



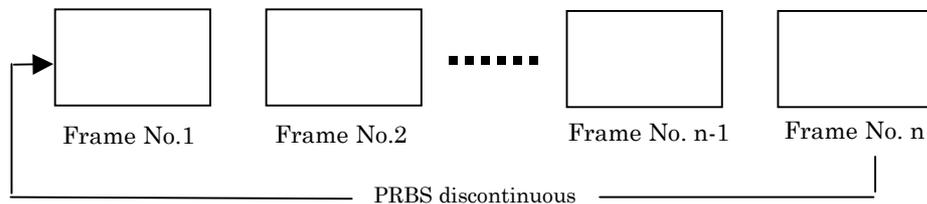
4.3. Editing Screen

Pattern editing can be performed by intuitively grasping the frame image using the table display. An easy-to-edit display method can be selected from binary, hexadecimal and byte count setting per line. In addition, simple programmable pattern editing can be performed by using word-processor-like editing functions such as Undo, Find, Repeat, etc.

This software also supports use as general-purpose pattern editing software.

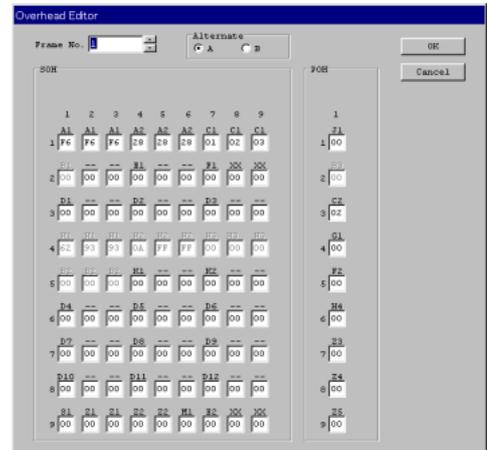


The payload can also be made as PRBS code. However, even in this case, the payload can be expanded in memory as a programmable pattern. The created pattern can be repeated for a countable frame number so there is no continuity between the last frame and header frame.



A dedicated SOH/POH editing screen is provided and overhead can be edited simply.

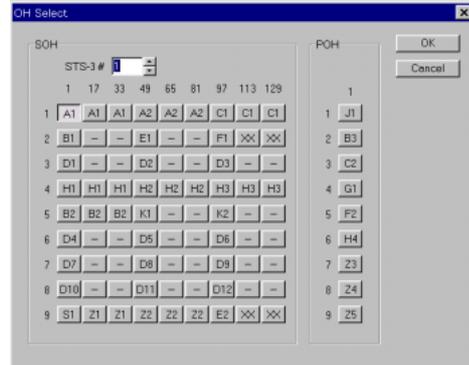
An auto-correction function (described later) is also provided for B1/B2/B3.



4.4. Measurement Target Zone Specification (only MX176401A)

In the case of the MX176401A software, the MP1762A Block Window and Bit Window functions can be used to select the target zone for bit error measurement. The selectable ranges are shown below.

- 1) All zones
- 2) All payload only
- 3) All SOH only
- 4) All POH only
- 5) OH (D1~D3)
- 6) OH (D4~D12)
- 7) Any 1 byte over OH

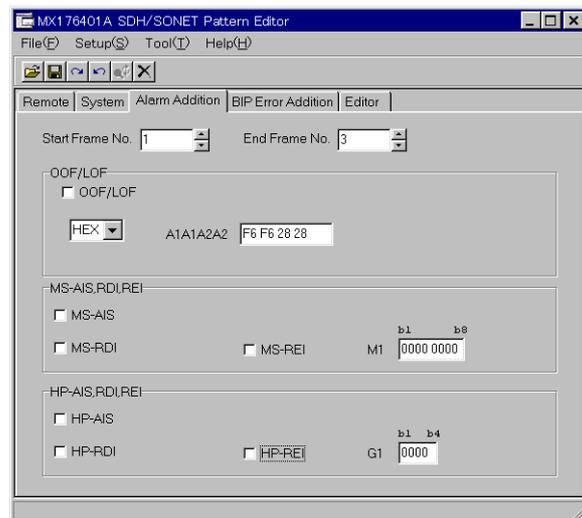


Select only A1 byte in measurement zone

4.5. Alarm/BIP Error Addition

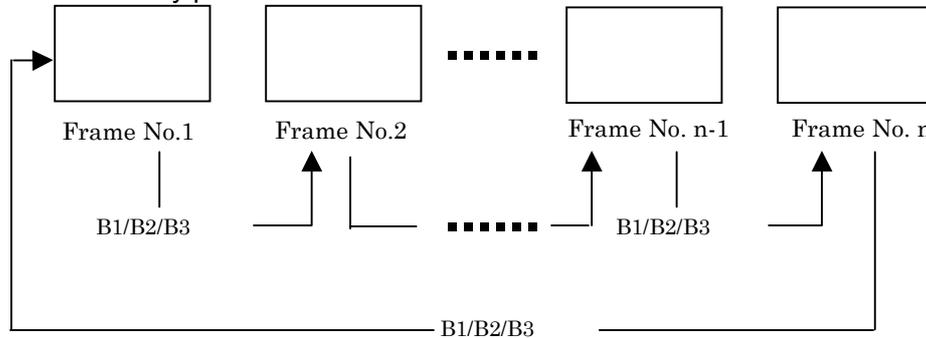
A dedicated editing screen is provided for creating frame patterns with added alarms and BIP errors; evaluation of alarm/BIP error detection modules is supported. The supported alarms/BIP errors are listed below. Items in parenthesis () are SONET names.

- 1) OOF/LOF
- 2) MS-AIS (L-AIS)
- 3) MS-RDI (L-RDI)
- 4) MS-REI (L-REI)
- 5) HP-AIS (P-AIS)
- 6) HP-RDI (P-RDI)
- 7) HP-REI (P-REI)

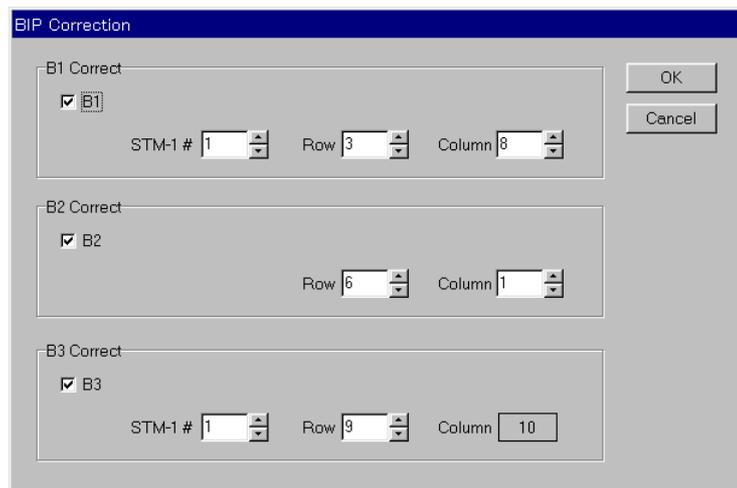
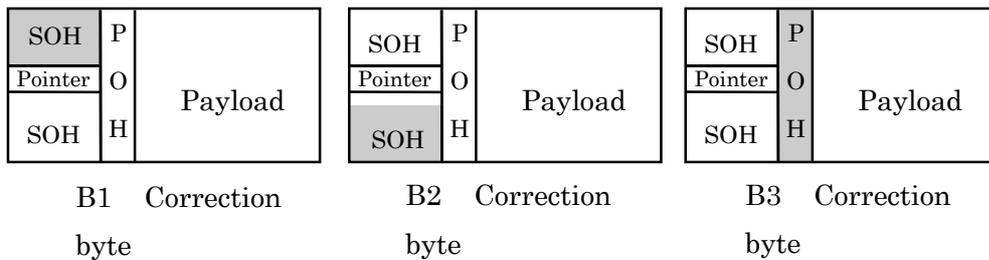


4.6. BIP Error Correction Function

Since the SDH/SONET pattern is created as a programmable pattern, sometimes correction is necessary so that the BIP calculated value does not cause problems in the finite memory pattern.



The BIP correction can be performed automatically. The correction byte range can be selected from the range shown below for each of B1/B2/B3.



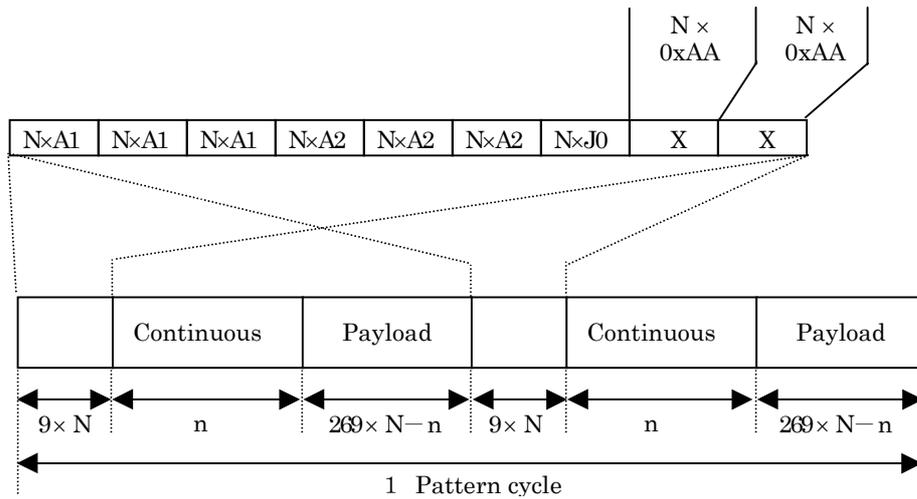
BIP Correction Byte Specification Screen

4.7. Creating Pattern for Optical Interface Continuous 0/1s Endurance Test

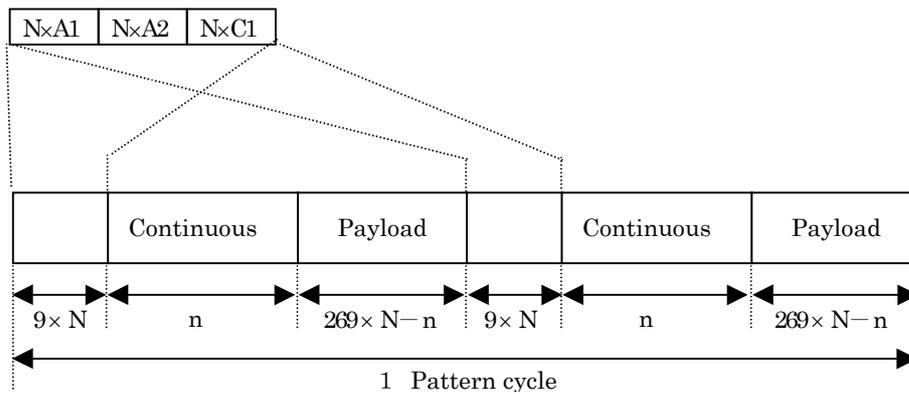
The CID pattern recommend by ITU-T G.958 can be created.

The created CID pattern has the composition shown below. The PRBS code is unaffected by the continuous 0/1s pattern length and resetting is performed by the bit after the last byte of SOH line 1.

(STM-N)



(STS-N)



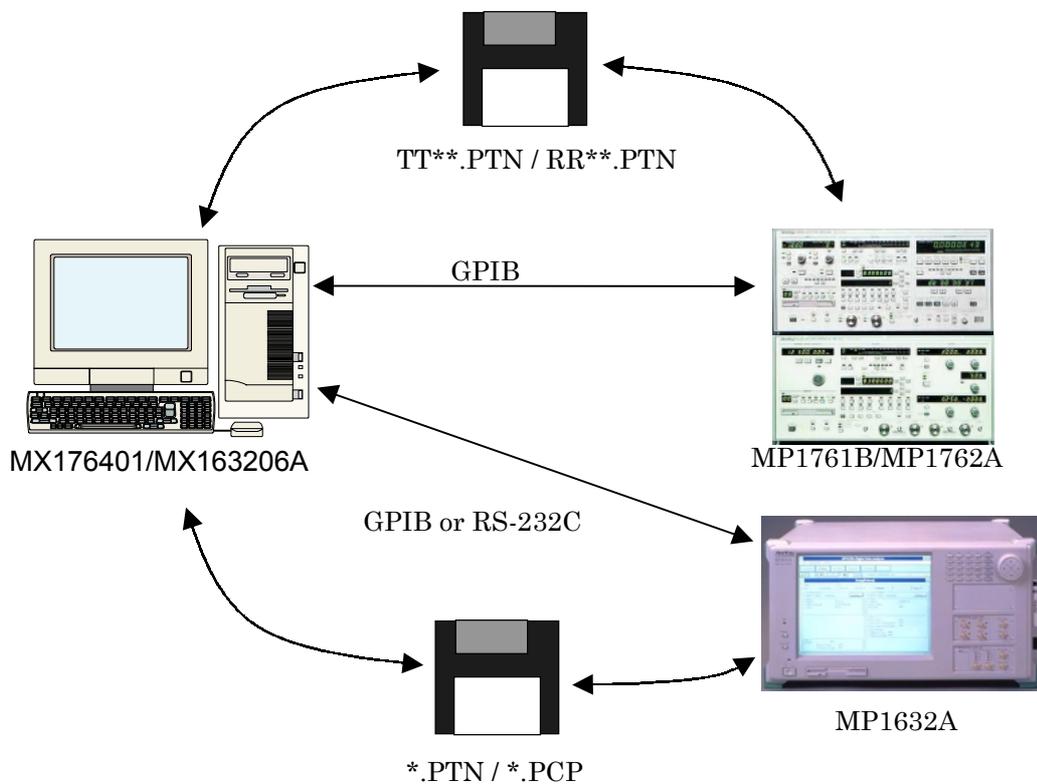
* The PRBS code in Payload can be selected, but in this case, the CID pattern is created as a completely programmable pattern.

4.8. Pattern Transfer

A pattern created on a PC can be transferred remotely via GPIB or RS-232C to the measuring instrument or saved as a file to FD and then opened via the FD at the measuring instrument.

The reverse transfer is also true.

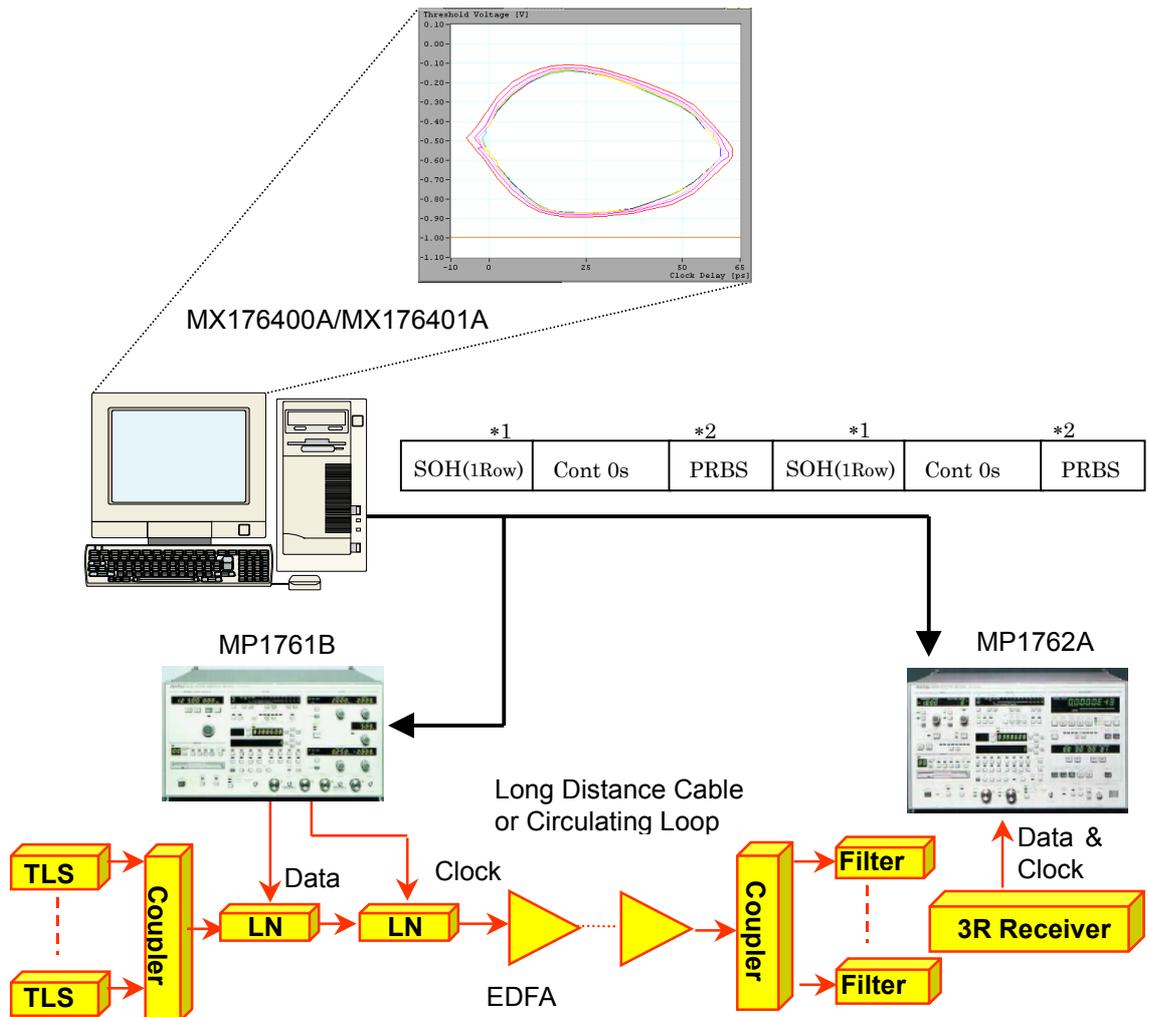
The file formats are the measuring-instrument-specific format and the normal text file format., so processing on a PC is also possible. If this editing software is used, the pattern to be used can be saved to and processed on a PC.



5. Application Examples

5.1. 3R Receiver Continuous 0/1s Endurance (Withstand) Test using CID Pattern

The CID pattern edited by the MX176401A is used as the measurement pattern to perform the continuous 0/1s endurance (withstand) test recommended by ITU-T G.958. The margin can be checked by performing eye diagram measurement simultaneously.

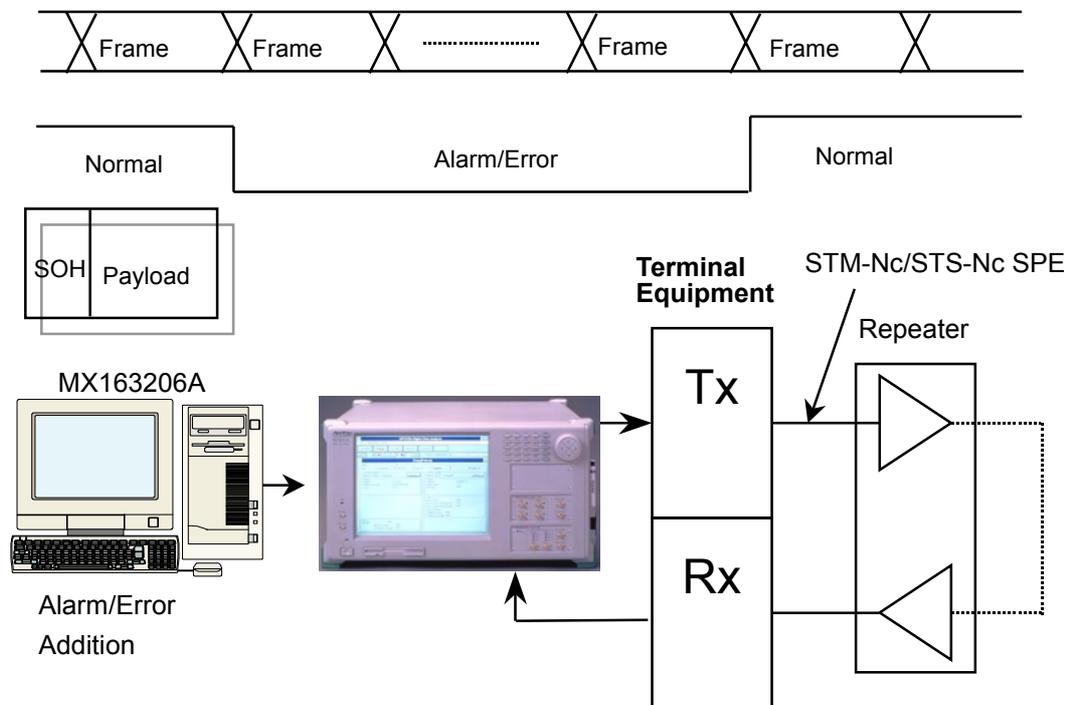


Note 1 The last SOH byte SOH is AAH for SDH, and hexadecimal N of STS-N for SONET.

Note 2 The payload PRBS code is created as a programmable pattern.

5.2. Equipment/module Function Test by Alarm/BIP Error Addition

The alarm/BIP error detection function of network element is tested by sending a pattern to which alarms and BIP errors have been added to any frame.





Specifications are subject to change without notice.

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