

Appendix 4 Detailed Explanations of WDM Analysis Function

This function provides the analyses of NOISE level and SNR in each mode within the measurement range of WDM waveforms.

Items for analysis

NO:	Channel No. i
WAVELENGTH:	Center wavelength λ_i of the channel
LEVEL:	Level (peak level – noise level) L_i of the channel
OFFSET WL:	Relative wavelength to the wavelength of the reference channel (REF)
OFFSET LVL:	Relative level to the level of the reference channel (REF)
SPACING:	Wavelength spacing to the adjacent channel
LVL DIFF:	Level difference from then adjacent channel
NOISE:	Noise level LN_i of the channel
SNR:	SNR value SN_i of the channel
GRID WL:	Nearest GRID wavelength to the channel
MEAS WL:	Center wavelength λ_i of the channel
REL WL:	Relative wavelength to the nearest GRID wavelength of the channel

Note

Indications of dBm/nm and dBm/THz are forcibly changed to dBm indications before execution.

List of Parameters

Related to Channel Detection

Parameter	Default	Setting Range	Unit	Description
THRESH	20.0	0.1 to 99.9	dB	Threshold value for channel detection.
MODE DIFF	3.0	0.0 to 50.0	dB	Minimum value for peak/bottom difference during channel detection.
DISPLAY MASK	OFF	OFF, -100.0 to 0.0	dBm	Levels equal to or below this level are not detected as WDM channels.

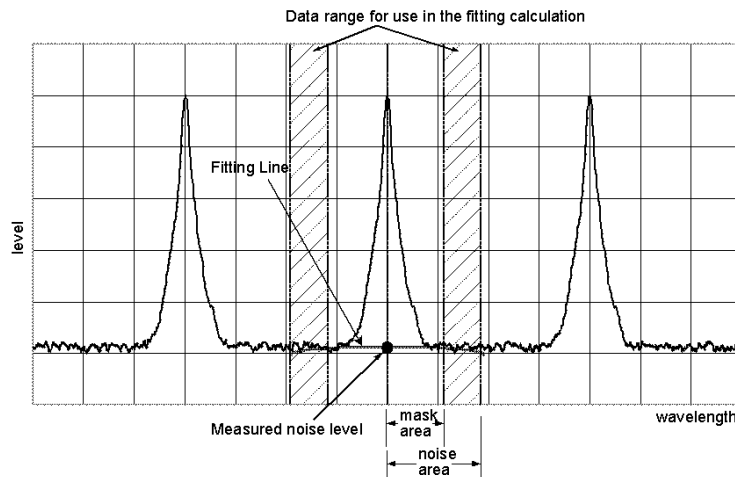
Related to SNR Analysis

Parameter	Default	Setting Range	Unit	Description
NOISE ALGO	AUTO-FIX	AUTO-FIX MANUAL-FIX AUTO-CTR MANUAL-CTR PIT	-	Selection of algorithms for noise level measurement.
NOISE AREA	0.40nm	0.01 to 10.00nm	nm	A range of waveform data for use in noise level analysis is specified as a range centering on channel wavelengths. When N_ALGO is: <ul style="list-style-type: none"> • AUTO-FIX "AUTO" • MANUAL-FIX **_** • AUTO-CTR "Between Ch" • MANUAL-CTR "Between Ch" • PIT "-"
MASK AREA	0.20nm	0.01 to 10.00nm	nm	Specify the signal optical spectrum range to be masked within the waveform data, while using the channel wavelength as its center. When N_ALGO is: <ul style="list-style-type: none"> • AUTO-FIX "-" • MANUAL-FIX When F_ALGO is LINEAR: "-" Other cases: input of parameter values <ul style="list-style-type: none"> • AUTOL-CTR "-" • MANUAL-CTR When F_ALGO is LINEAR: "-" Other cases: input of parameter values Limiter is applied during input to ensure NOISE AREA is MASK AREA or more. <ul style="list-style-type: none"> • PIT "-"
FITTING ALGO	LINEAR	LINEAR GAUSS LORENZ 3RD POLY 4TH POLY 5TH POLY	-	Selection of a fitting algorithm for obtaining noise levels.
NOISE BW	0.10nm	0.01 to 1.00nm	nm	Setting of noise bandwidth.
DUAL TRACE	OFF	ON/OFF	-	OFF: Active trace is handled as the target for analysis. ON: Wavelengths and levels are calculated from TRACE A. Noise levels are calculated from TRACE B.

Appendix 4 Details of WDM Analysis Function

Related to display				
Parameter	Default	Setting Range	Unit	Description
DISPLAY TYPE	ABSOLUTE	ABSOLUTE RELATIVE DRIFT(MEAS) DRIFT(GRID)	-	Setting of the format to display wavelengths, levels, noises, and SNRs, which are the results of analyses. ABSOLUTE: display of absolute values RELATIVE: display of relative values compared to GRID. DRIFT(MEAS): display of drift values by using wavelengths measured previously as references. DRIFT(GRID): display of drift values by using the grid wavelengths as references.
CH RELATION	OFFSET	OFFSET SPACING	-	Setting of the format to display wavelengths between channels and level relative values during DISPLAY: ABSOLUTE. This parameter is valid only when DISPLAY is set to ABSOLUTE. OFFSET: Display of offset values by using one arbitrary channel as the reference. SPACING: Display of offset values compared to an adjacent channel
REF CH	HIGHEST	HIGHEST ****	-	Setting of the reference channel when CH RELATION is set to OFFSET. This parameter is valid only when DISPLAY is set to ABSOLUTE and also when CH RELATION is set to OFFSET. HIGHEST: A channel at the highest level is used as the reference. ****: A ****th channel is used as the reference.
MAX/MIN RESET	-	-	-	If pressed, MAX/MIN is RESET. Button valid only when DISPLAY is set to DRIFT
OUTPUT SLOPE	OFF	ON/OFF	-	ON/OFF of the function to obtain the least square approximation line of the channel peak.
POINT DISPLAY	ON	ON/OFF	-	ON/OFF of the function to display the data range used for fitting into the waveform window.

Algorithm for Analysis



1. Apply channel detection to measured waveform data using the following procedure:
 - Find all maximum points and minimum points to obtain mode peaks where peak/bottom differences between maximum points and minimum points on both sides are equal to or greater than MODE DIFF.
 - Of the obtained mode peaks, choose only the ones whose level difference compared to the highest peak is equal to or greater than THRESH. Note, however, that mode peaks with a level difference equal to or less than DISPLAY MASK shall be excluded. The number of mode peaks chosen in this manner shall be the Number of Channels "N."
2. Obtain the wavelength λ_i of each mode peak.
3. Obtain the level LPi of each mode peak.
4. Obtain the center wavelength λ_i of each mode peak, which is the center of the two points below the mode peak λ_i by A[dB] both on the left and on the right. (A[dB] shall be either 3 dB or the setting value of MODE DIFF, whichever is smaller.)
5. Follow the setting of the parameter NOISE ALGO to determine the noise area and mask area for performing the NOISE fitting.
(If the mask area is set outside the noise area when the channel wavelength λ_i is the center, the mask area and the noise area will become the same value.)
6. Obtain the measurement resolution RBi of each channel from the values stored in the AQ6370.
7. According to the setting of the parameter FITTING ALGO, generate fitting waveforms from the noise area and mask area determined in 5 and obtain the level at the center wavelength λ_i as the noise level LNi.
8. Use the peak level LPi and the noise level LNi obtained in 3 and 7 to obtain the level Li of each channel from the following equation.

$$Li = LPi(\text{linear}) - LNi(\text{linear})$$
9. Obtain the normalized noise level LNNi from the equation below.

$$LNNi = [LNi(\text{LOG}) - 10 \times \text{Log}(RBi[\text{nm}])] + 10 \times \text{Log}(NBW)$$
 NBW = noise bandwidth (configurable parameter)
10. Use the mode peak level Li obtained in 8 and 9 and the normalized noise level LNNi to obtain SNi from the following equation.

$$SNi = Li - LNNi$$
11. Display the results of foregoing analyses according to the settings of the parameter DISPLAY SETTING.

Automatic Parameter Setting Function

This unit provides the noise area/mask area automatic setting function. To activate the automatic setting, set the algorithm to AUTO-FIX or AUTO-CTR.

AUTO-FIX

Noise Algorithm

Obtain the left and right noise areas (NA_Ri, NA_Li) of each channel according to the number of detected WDM channels as follows:

When the number of WDM channels “n” is 1

Internally obtain the measurement resolution of SNI calculation trace and the value of the noise measurement point NOISE AREA in accordance with the resolution, and then obtain the values from the following equations.

$$NA_Ri = \lambda_i + NOISE\ AREA$$

$$NA_Li = \lambda_i - NOISE\ AREA$$

When the number of WDM channels “n” is 2 or more

Obtain the channel spacing of each channel (spacing of λ_i .) With the minimum spacing set to SPACING as well as NOISE AREA = SPACING / 2, obtain the NOISE AREA.

Finally, obtain the values from the following equations.

$$NA_Ri = \lambda_i + NOISE\ AREA \ (i = 1, 2, \dots, n)$$

$$NA_Li = \lambda_i - NOISE\ AREA \ (i = 1, 2, \dots, n)$$

Fitting Algorithm

While the setting is at AUTO-FIX, LINEAR is used for the fitting algorithm, which is calculated as follows.

- Obtain ELi and ERI as the level (LOG) of each position of the noise areas NA_Li and NA_Ri.
- Use the data of the straight line connecting the two points of ELi and ERI to fill the inside of the fitting range.
- Set the level of λ_i of the data generated in the fitting to the noise level LNi.

Note

Due to being set to LINEAR, it is not possible to set the mask areas.

AUTO-CTR

Noise Algorithm

Obtain the left and right noise areas (NA_Ri, NA_Li) of each channel according to the number of detected WDM channels as follows (while treating the center points between channels as NA_Ri and NA_Li).

When the number of WDM channels “n” is 1

Internally obtain the measurement resolution of SNI calculation trace and the value of the noise measurement point NOISE AREA in accordance with the resolution, and then obtain the values from the following equations.

$$NA_Ri = \lambda_i + NOISE\ AREA$$

$$NA_Li = \lambda_i - NOISE\ AREA$$

When the number of WDM channels “n” is 2 or more

$$\lambda_{N1} = (3\lambda_1 - \lambda_2)/2$$

$i = 2, 3, \dots, n$

$$\lambda_{Ni} = (\lambda_i - \lambda_{i-1})/2$$

$$\lambda_{Nn+1} = (3\lambda_n - \lambda_{n-1})/2$$

If the above values are calculated, the following results will be generated.

$i = 1, 2, \dots, n$

$$NA_Li = \lambda_{Ni}$$

$$NA_Ri = \lambda_{Ni+1}$$

Fitting Algorithm

While the setting to AUTO-CTR, LINEAR is used for the fitting algorithm, which is calculated as follow.

- Obtain ELi and ERi as the level (LOG) of each position of the noise areas NA_Li and NA_Ri.
- Use the data of the straight line connecting the two points of ELi and ERi to fill the inside of the fitting range.
- Set the level of λi of the data generated in the fitting to the noise level LNi.

Note

Due to being set to LINEAR, it is not possible to set the mask areas.

PIT

Noise Algorithm

Obtain the noise areas for measured waveform to the minimum level position of a before the next channel in each channel.

When inside noise areas obtain at the left and right noise areas of each channel. outside noise areas is applied.

When the number of WDM channels “n” is 1

Internally obtain the measurement resolution of SNi calculation trace and the value of the noise measurement point NOISE AREA in accordance with the resolution, and then obtain the values from the following equations.

$$NA_Ri = \lambda i + NOISE\ AREA$$

$$NA_Li = \lambda i - NOISE\ AREA$$

When the number of WDM channels “n” is 2 or more

i=1

$$NA_Li = \lambda i - (\lambda Ni - \lambda i)$$

$$NA_Ri = \lambda Ni$$

i=2,3,...,n-1

$$NA_Li = \lambda N(i - 1)$$

$$NA_Ri = \lambda Ni$$

i=n

$$NA_Li = \lambda N(i - 1)$$

$$NA_Ri = \lambda i + (\lambda i - \lambda N(i - 1))$$

Fitting Algorithm

While the setting to PIT, LINEAR is used for the fitting algorithm, which is calculated as follows.

- Obtain ELi and ERi as the level (LOG) of each position of the noise areas NA_Li and NA_Ri.
- Use the data of the straight line connecting the two points of ELi and ERi to fill the inside of the fitting range.
- Set the level of λi of the data generated in the fitting to the noise level LNi.

Note

Due to being set to LINEAR, it is not possible to set the mask areas

Setting of the Parameter “DUAL TRACE”

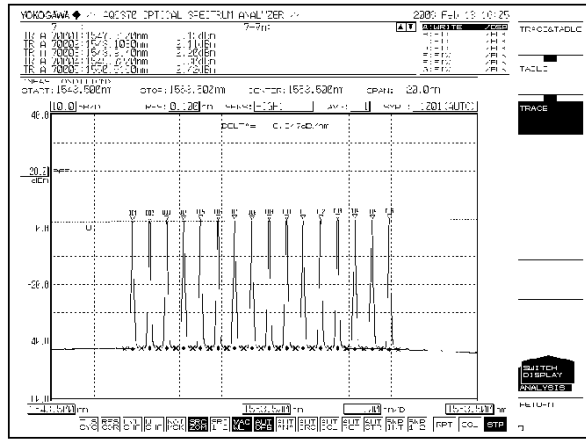
This function enables more precise analyses by measuring waveforms with different measurement resolutions at trace A and trace B and also by performing measurements with resolutions different in noise level from the signal level of each channel.

When “DUAL TRACE” is ON, targets for the analysis of each trace will be:

- TRACE A: trace subject to channel detection
- TRACE A: calculation traces λ_i and L_i
- TRACE B: noise level LNI calculation trace

OUTPUT SLOPE Function

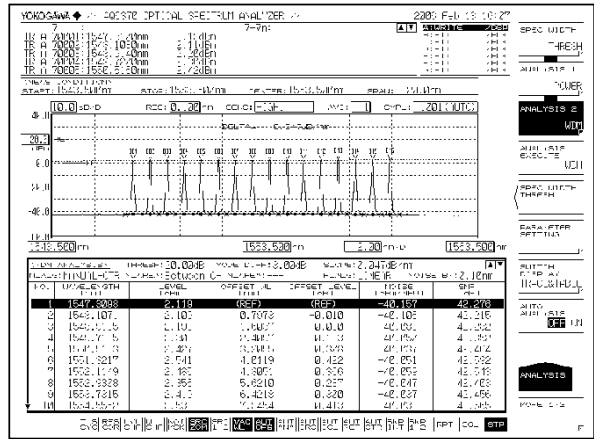
The parameter “OUTPUT SLOPE” provides a function to obtain the least square approximation curve of channel peaks. This function makes it possible to measure gain tilts. If “OUTPUT SLOPE” is set to ON, results will be displayed in the waveform display section and in the analysis table.



Items to be Displayed When DISPLAY is Set

ABSOLUTE

Results of analyses are displayed in absolute values.



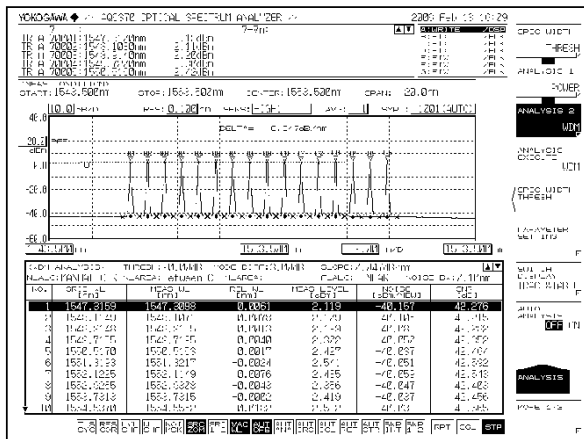
Explanations of display items

- NO: Channel number
- WAVELENGTH: Center wavelength of the channel
- LEVEL: Level of the channel (peak level – noise level)
- OFFSET WL: Relative wavelength to the wavelength of the reference channel (REF)
- OFFSET LVL: Relative level to the wavelength of the reference channel (REF)
- SPACING: Wavelength spacing with the adjacent channel
- LVL DIFF: Level difference from the adjacent channel
- NOISE: Noise level of the channel
- SNR: SNR value of the channel

- OFFSET WL/LVL is displayed when the parameter CH RELATION is "OFFSET."
- SPACING and LVL DIFF are displayed when the parameter CH RELATION is "SPACING."
- When ABSOLUTE and CH RELATION are OFFSET, it is possible either to set the reference channel to the mode peak with the highest level or to set a mode peak that will become the reference arbitrarily.
 - When REF CH is HIGHEST
 - The WDM mode peak with the highest level shall be the reference. The wavelength difference and level difference (LOG) compared to it shall be OFFSET WL and OFFSET LVL of each WDM mode peak.
 - When REF CH is ***
 - REF CHANNEL *** shall be the reference. The wavelength difference and level difference (LOG) against it shall be OFFSET WL and OFFSET LVL of each WDM mode peak. (If the ***th mode peak does not exist, the WDM mode peak on the longest wavelength shall be the reference.)

RELATIVE

Of the analytical results, wavelength values are displayed as relative values to the values in the grid table.

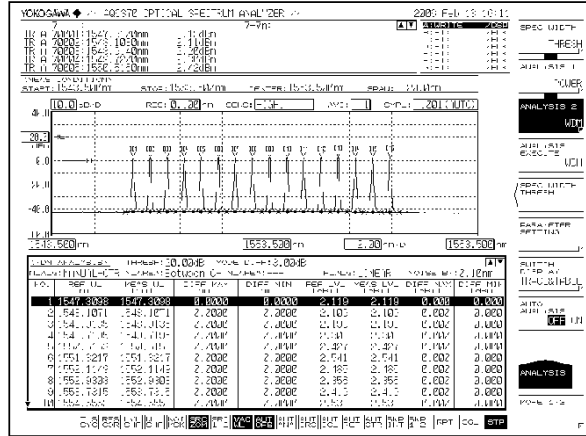


Explanations of display items

- NO: Channel number
- GRID WL: GRID wavelength of the channel
- MEAS WL: Center wavelength of the channel
- REL WL: Relative wavelength to the GRID wavelengths of the channel
- MEAS LVL: Level of the channel (peak level – noise level)
- NOISE: Noise level of the channel
- SNR: SNR value of the channel

DRIFT(MEAS)

Wavelengths measured previously are used as references to display wavelength/level changes (drifts).



Explanations of display items

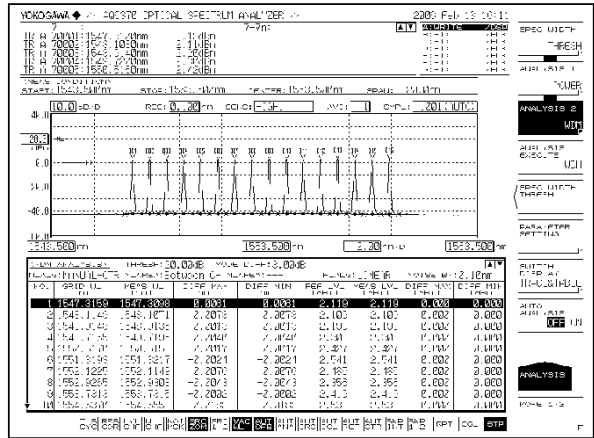
- NO: Channel number
- REF WL: Reference wavelength of the channel (previous wavelength measured)
- MEAS WL: Center wavelength of the channel
- DIFF MAX (wavelength): Maximum value of the relative wavelength to the reference wavelength of the channel
- DIFF MIN (wavelength): Minimum value of the relative wavelength to the reference wavelength of the channel
- REF LVL: Reference level of the channel (previous measurement level)
- MEAS WL: Measurement level of the channel
- DIFF MAX (level): Maximum value of the relative level to the reference level of the channel
- DIFF MIN (level): Minimum value of the relative level to the reference level of the channel

Reference wavelength/level can be changed under the following conditions.

- Active trace waveform data when MAX/MIN RESET is set by the parameter.
- The first waveform data measured when wavelength axes (SPAN WL/START WL/ STOP WL) were changed according to the measurement conditions.

DRIFT(GRID)

Grid wavelengths are used as references to display wavelength/level changes (drifts).
 Note that reference levels are previous measurement levels.



Explanations of display items

- NO: Channel number
- GRID WL: Reference wavelength of the channel (grid wavelength)
- MEAS WL: Center wavelength of the channel
- DIFF MAX (wavelength): Maximum value of the relative wavelength to the reference wavelength of the channel
- DIFF MIN (wavelength): Minimum value of the relative wavelength to the reference wavelength of the channel
- REF LVL: Reference level of the channel (previous measurement level)
- MEAS LVL: Measurement level of the channel
- DIFF MAX (level): Maximum value of the relative level to the reference level of the channel
- DIFF MIN (level): Minimum value of the relative level to the reference level of the channel

- Absolute values and reference values to the GRID table are displayed. The GRID table can be freely configured.
- Reference wavelengths/levels can be changed under the following conditions:
 - When MAX/MIN RESET is set by the parameter, reset is performed by the active trace waveform data.
 - Reset is performed by the first waveform data that was measured when wavelength axes (SPAN WL/START WL/STOP WL) were changed by measurement conditions.