WDM System Test with the Agilent 86120 Multi-Wavelength Meter

Product Note 86120-1

λ₁ ⊥
λ₂ ⊥
Transmitters
λ_{N−1} ⊥
λ_N ⊥

MUX

DEMUX

λ₁
λ₂
Receivers
λ_{N−1}
λ_N

Agilent Technologies
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Abstract
As the need for capacity increases, telecommunications operators
employ new technologies to address this requirement. One such
technique is that of wavelength division multiplexing (WDM). This
product note addresses the WDM system, the design and maintenance
issues warranting measurement, and how the Agilent 86120 Multi-
Wavelength Meter can be used to easily and effectively help engineers
and technicians working with WDM systems.

The WDM System

Advantages of Wavelength Division Multiplexing

A wavelength division multiplexed (WDM) system is one where, typically in order to increase system capacity, multiple optical carriers, operating at different wavelengths, share a common optical fiber. A WDM system can be simple, operating at two very different wavelengths such as 1310 nm and 1550 nm, or more complex whereby four, eight, or even more optical transmitters operate with very small wavelength separations. In either system, the amount of data being transmitted can be significantly increased without increasing the number of fibers or repeaters.

Total amount of data from 1 carrier vs. 4 carriers

WDM System Architecture

The number of laser transmitters in a WDM system is equal to the number of wavelengths being multiplexed. Each laser has a unique wavelength and thus represents a different transmission channel. The individual carriers are amplitude modulated with the transmission data and then coupled into the fiber. In a long transmission system, several links can be used, each with additional amplification to retain good signal-to-noise ratio and thus low bit error response and quality system performance. In a dense WDM system where multiple carriers are separated by only a few nanometers, optical amplifiers (which tend to have optimum gain performance in relatively narrow ranges around 1550 nm) are typically used. The optical amplifiers increase the carrier output powers and can improve the system's signal-to-noise ratios.

Dense WDM system with amplifiers

Measurements in a WDM System

The overall goal of an optical transmission system is to provide the highest quality (most error-free data) with minimum cost. WDM systems address this by leveraging the wide bandwidth of fiber and the operating range of optical amplifiers. To maximize the system performance, transmitter wavelengths are selected such that they operate at the optimum wavelengths for the transmission fiber and amplifiers being used. However to keep these lasers from interfering with each other, they must be spaced sufficiently and be ensured not to drift into the channel of a neighboring transmitter. Carrier power levels can be kept constant or, to account for amplifier efficiencies at different wavelengths, pre-emphasized to keep constant signal-to-noise ratios for each channel. Optimizing signal-to-noise ratios throughout the system directly effects system performance and can remove the need for unnecessary amplifiers. Therefore, WDM systems are designed, installed, verified, and monitored using the following measurements:

- Carrier Wavelengths and Powers
- Channel Spacings
- Flatness
- Drift
- Signal-to-Noise Ratio

Measurement	Benefit
Carrier Wavelengths	Optimize for system components
Carrier Powers	Optimize for transmitter reliability and system performance
Channel Spacings	Optimize for system components and performance
Flatness	Optimize for system components and performance
Drift	Verify system performance
Signal-to-Noise Ratios	Optimize for system performance

Making Measurements with the Agilent 86120 Multi-Wavelength Meter

The Agilent 86120 Multi-Wavelength Meter is a high-performance, yet rugged, wavelength meter that, unlike traditional wavelength meters, not only provides the user with accurate wavelength measurements of a single wavelength, but of multiple wavelengths and powers simultaneously. It is this unique capability that allows the Agilent Multi-Wavelength Meter to address the demanding measurement requirements of WDM systems. Not only at the transmit and receive ends but throughout the entire system these measurements are important. A disruption in service or performance in one link of the system can result in corrupt data at the receive end. The ability to detect and isolate the problem is of paramount importance.

The Agilent 86120C Multi-Wavelength Meter

Carrier Wavelengths and Powers

In any optical transmission system the wavelength and power of the laser transmitter is important. However this is particularly true for WDM systems where accurate wavelengths are necessary to avoid interference with adjacent channels and accurate amplitude levels are required to account for loss and amplifier efficiency at different wavelengths.

To measure the wavelengths and powers of a signal on the Agilent 86120 follow these steps:

Multi-wavelength meter measurement setup

Connect the input fiber with signal to be measured to the Multi-Wavelength Meter and press the green [Preset] button. This establishes a known working state for the Agilent 86120.

Wavelength at the largest amplitude signal

Amplitude of the largest signal

Number of signals being measured

Preset

```
PEAK                                           *
1541.746nm      -4.96dBm    8  LINES
                                             VAC
■■■■■■■■■■■■■■■■■■■■..................         0 M
[PREV WL] [NEXT WL] [ PEAK ] [      ] [NEXT PK]
```

The Agilent 86120 display after pressing [Preset]

The display is currently showing the wavelength and amplitude of the peak signal (the largest amplitude signal in the spectrum). In addition, we can verify the number of carriers which we are measuring.

Press the display button labeled [List by WL] to see, in order of increasing wavelength, the channels being measured. If there are more than five channels at the input to the Agilent 86120 these can be displayed by moving the cursor up or down through the list of signals.

Signals listed by wavelength

List by WL

```
1539.150nm      -9.38dBm ■■■■.....        *
1540.446        -7.44    ■■■■.....    BY WL
1541.746    ↔   -4.94    ■■■■....   6 OF 8
1543.049        -6.83    ■■■■ ....       VAC
1544.352        -12.00   ■■■■......      0 M
[    ↑    ] [    ↓    ] [ PEAK ] [      ] [SELECT]
```

The Agilent 86120 display after pressing [List by WL]

Press the button labeled [List by Power] to see, in decreasing order of amplitude, the channels being measured.

Signals listed by power

List by Power

```
1541.747nm  ↔  -4.95dBm ■■■■....        *
1543.050        -6.81    ■■■■.....    BY PWR
1540.447        -7.47    ■■■■.....   1 OF 8
1539.150        -9.37    ■■■■ .....       VAC
1537.857        -10.40   ■■■■ .....       0 M
[      ] [    ↓    ] [ PEAK ] [      ] [SELECT]
```

The Agilent 86120 display after pressing [List by Power]

Press the button labled [Avg WL] to display the power weighted average wavelength of all the channels being measured and the total power from all channels.

Power weighted average wavelength

Total optical power

```
AVERAGE                                    *

1540.729nm        0.38 dBm    8  LINES
                                        VAC
                                        0  M
┌──────┐ ┌──────┐ ┌──────┐ ┌──────┐ ┌──────┐
│      │ │      │ │      │ │      │ │      │
└──────┘ └──────┘ └──────┘ └──────┘ └──────┘
```

The Agilent 86120 display after pressing [Avg WL]

Avg
WL

Units shown are nm and dBm. Refer to the section on The Agilent Multi-Wavelength Meter Setup Options for other display unit options.

Press the [Peak WL] button to return to the preset condition.

Channel Spacing
In a WDM system it is critical that the desired channel spacings be adhered to. Within the system, filters are used to ensure that optical transmitters operate only within their designated channel. The difference between any two channels is called the channel spacing and is a fundamental specification of the system. Because the Agilent 86120 can determine the individual wavelengths in a system, we can display the wavelengths (and amplitudes) of any channel relative to another. Therefore, to determine the channel spacing between any two channels we need only select one carrier as our reference and measure the adjacent channels relative to it. The wavelength difference is the channel spacing.

λ_1 λ_2

Channel Spacing Between Channels One and Two = $\lambda_2-\lambda_1$

Channel spacing

Preset

List by WL

To measure the channel spacings follow these steps:

Connect the fiber with carriers to be measured to the input of the Multi-Wavelengh Meter and press the green [Preset] button and the display, [List by WL] button to put the Agilent 86120 in a known state.

Turn on relative measurements by selecting the delta mode button [On]. This activates the delta menu.

On

```
 1539.150nm      -9.33dBm ━━━.....        *
 1540.447        -7.46      ━━━.....    BY WL
 1541.747    ↔  -4.95      ━━━.... 6 OF  8
 1543.049        -6.82      ━━━ ....      VAC
 1544.353       -11.98      ━━━......    0 M
   ┃ Δ WL ┃  ┃ Δ PWR ┃ ┃ΔWL/PWR┃         ┃RETURN┃
```

The Agilent 86120 display after activating the Delta mode

From the delta menu we can select to measure relative wavelength [Δ WL], relative amplitude [Δ PWR], or relative wavelength and amplitude [Δ WL/PWR]. For the channel spacing measurement, select by wavelength, press [Δ WL].

Δ WL

```
 1539.150nm      -9.37dBm ━━━.....       Δ WL
 1540.447        -7.45      ━━━....     BY WL
 1541.746    ↔  -4.95      ━━━.... 6 OF  8
 1543.049        -6.81      ━━━ ....      VAC
 1544.353       -12.00      ━━━......    0 M
   ┃  ⇧  ┃   ┃  ⇩  ┃  ┃SELECT┃ ┃RESET┃ ┃EXIT┃
```

The Agilent 86120 display after [Δ wl] is selected

⇧

Using the up and down arrow keys we can scroll through the table of displayed carriers. Scroll to the top of the display so that 1 of 8 is displayed. (Depending on the number of channels in your setup your display may show more or less laser lines).

Press the [SELECT] key at the bottom of the display. This designates the signal at the cursor to be the reference line and all other lines are to have their wavelengths displayed relative to this wavelength. (If in the first step we had selected to display the relative amplitude, [Δ PWR], or both wavelengths and amplitudes, [Δ WL/PWR], then signal amplitudes would be shown relative to the reference signal rather than in absolute amplitude. This is demonstrated in the Flatness measurement).

The Agilent 86120 is now displaying the difference between our refer-ence wavelength and all other wavelengths present at the input. The second line on our display is the channel spacing between the first and second channels.

SELECT

Reference wavelength   Channel spacing between first and second channels

```
1535.273nm  ↔-12.89dBm  ▬▬......        ☆
    1.289      -12.10    ▬▬▬.....     △  WL
    2.583      -10.35    ▬▬▬▬....   BY  WL
    3.876       -9.37    ▬▬▬▬▬...  1 OF  8
    5.173       -7.46    ▬▬▬▬▬...      VAC
                                        0 M
  [        ] [   ◇   ] [ SELECT ] [ RESET ] [ EXIT ]
```

Display with reference wavelength selected and relative wavelengths shown

Press the down arrow on the key pad below the display to move the cursor to the second channel carrier. Again, press [SELECT] to designate this as the reference channel. Now note that channels one and three (the wavelengths preceding and following the reference) are being displayed relative to channel two. These are the channel spacings between channels 1 and 2, and channels 2 and 3.

↓

SELECT

Channel Spacing units shown here are nm. Frequency units are also available, refer to the section on The Agilent Multi-Wavelength Meter Setup Options for other display unit options.

Channel 2 to 1 spacing   Channel 2 to 3 spacing

```
   -1.290nm      -12.88dBm  ▬▬......        ☆
 1536.563      ↔-12.09      ▬▬▬.....     △  WL
    1.293        -10.36     ▬▬▬▬....   BY  WL
    2.587         -9.35     ▬▬▬▬▬...  2 OF  8
    3.884         -7.47     ▬▬▬▬▬...      VAC
                                           0 M
  [   ◇   ] [   ◇   ] [ SELECT ] [ RESET ] [ EXIT ]
```

The display with channel 2 as the reference wavelength

Off

Appendix C includes a programming example whereby this channel spacing measurement can be automated.

These steps can be repeated for all remaining channels.

The delta mode and channel spacing measurement can be discon-tinued at any time by pressing the [EXIT] key and then [RETURN] at the bottom of the display or the [Off] button on the front panel. This returns the Agilent 86120 to the mode of operation utilized prior to entering the delta mode.

Flatness (pre-emphasis)
The relative power levels between channels throughout the WDM system is referred to as flatness. In some systems, to account for the gain variations of the optical amplifiers at different wavelengths, carrier levels are purposely offset from each other. This is referred to as pre-emphasis. By measuring the relative differences between carrier levels in the system, the flatness or pre-emphasis can be determined.

We can easily use the Agilent 86120 Multi-Wavelength Meter to measure flatness within a WDM system. Because the Agilent 86120 can determine the individual channel power levels, we can display the amplitudes of any channel relative to another. Therefore, to determine the flatness between channels we need only select one carrier as our reference and measure the remaining signals in the system relative to the reference carrier's amplitude level. The differences in amplitude between channels represent the system flatness.

System Flatness = $P_{max} - P_{min}$

To measure the flatness follow these steps:
Connect the fiber with signal to be measured to the input of the Agilent Multi-Wavelength Meter and press the green [Preset] button and the display, [List by Power] button to put the Agilent 86120 in a known state.

Preset

List by Power

Signals listed by power


```
1541.747nm  ↔  -4.95dBm  ▬▬▬....         *
1543.050       -6.81      ▬▬▬....     BY PWR
1540.447       -7.47      ▬▬▬.....   1 OF  8
1539.150       -9.37      ▬▬▬.....
1537.857      -10.40      ▬▬▬.....     VAC
                                       0 M
[        ] [  ◇  ] [ PEAK ] [        ] [SELECT]
```

Listing by power puts the largest signal at the top of the display.

Turn on relative measurements by selecting the delta mode button [On]. This activates the delta menu.

```
1541.747nm  ↔  -4.91dBm ▬▬▬....
1543.049        -6.81      ▬▬▬....    BY PWR
1540.447        -7.49      ▬▬▬.....   1 OF  8
1539.150        -9.43      ▬▬▬.....
1537.857       -10.41      ▬▬▬.....   VAC
                                       0 M
┌─────────┐┌─────────┐┌─────────┐┌─────────┐┌─────────┐
│  Δ WL   ││  Δ PWR  ││ ΔWL/PWR ││         ││ RETURN  │
└─────────┘└─────────┘└─────────┘└─────────┘└─────────┘
```

On

The delta menu

From the delta menu we can select to measure relative wavelength [Δ WL], relative amplitude [Δ PWR], or relative wavelength and amplitude [Δ WL/PWR]. For the flatness measurement select relative power by pressing [Δ PWR].

```
1541.747nm  ↔  -4.91dBm ▬▬▬....    Δ PWR
1543.049        -6.81      ▬▬▬....   BY PWR
1540.447        -7.49      ▬▬▬.....  1 OF  8
1539.150       ·-9.43      ▬▬▬....
1537.857       -10.41      ▬▬▬.....  VAC
                                      0 M
┌─────────┐┌─────────┐┌─────────┐┌─────────┐┌─────────┐
│         ││    ◊    ││ SELECT  ││  RESET  ││  EXIT   │
└─────────┘└─────────┘└─────────┘└─────────┘└─────────┘
```

Δ PWR

The Agilent 86120 display after [Δ Pwr] is selected

Using the up and down arrow keys we can scroll through the table of displayed carriers. Scroll to the top of the display so that 1 of 8 is displayed. (depending on the number of channels in your setup your display may show more or less laser lines).

⇧

Because we chose to list by power this is the largest carrier in the system.

Press the [SELECT] key at the bottom of the display. This designates the signal at the cursor to be the reference line and all other lines are to have their amplitudes displayed relative to this power level.

The Agilent 86120 is now displaying the difference between our reference channel level and all other signal levels present at the input. The differences in channel power levels represent the system flatness.

Relative powers, flatness, in our system   Reference power

```
1541.747nm  ↔  -4.93dBm ▬▬▬....       *
1543.050        -1.90dB    ▬▬▬....   Δ PWR
1540.447        -2.54dB    ▬▬▬.....  BY PWR
1539.150        -4.42dB    ▬▬▬....   1 OF  8
1537.857        -5.47dB    ▬▬▬.....  VAC
                                      0 M
┌─────────┐┌─────────┐┌─────────┐┌─────────┐┌─────────┐
│         ││    ◊    ││ SELECT  ││  RESET  ││  EXIT   │
└─────────┘└─────────┘└─────────┘└─────────┘└─────────┘
```

SELECT

The display with the largest signal as the reference and other channel's relative amplitude levels

By pressing the down arrow on the key pad below the display we can move the cursor to any of the signals and select it to be our reference. Doing so will show some signals higher and some lower than the chosen reference. This can be used to demonstrate how some channels are pre-emphasized to account for amplifier efficiencies.

The display with channel three as the reference

You can discontinue the delta mode and flatness measurement at any time by pressing the [EXIT] key and then the [RETURN] key at the bottom of the display or the [Off] button on the front panel. This returns the Agilent 86120 to the mode of operation utilized prior to entering the delta mode.

Drift
Drift measurements are similar to channel spacing in that a relative wavelength measurement is being made. However, unlike the delta mode, the drift mode measures changes in each carrier relative to itself over time. By retaining the maximum and minimum wavelengths (amplitudes are also monitored and retained) and displaying their differences, we can measure the total drift of each optical transmitter simultaneously.

Drift is the change in wavelength or amplitude over time.

Cross Talk measurements can also be made in this manner. To do so will require that the Peak Threshold and Peak Excursion settings be modified. See Optimizing Peak Excursion and Peak Threshold, in the section The Agilent Multi-Wavelength Meter Setup Options.

This allows the Agilent 86120 Multi-Wavelength Meter to be used during laser transmitter evaluation, burn-in, or development. In addition, we can monitor laser and system performance over time, temperature, or other dynamic conditions.

To measure drift on the Agilent 86120 follow these steps: Connect the fiber with signal to be measured to the input of the Agilent Multi-Wavelength Meter and press the green [Preset] button and the display [List by WL] button to put the Agilent Multi-Wavelength Meter in a known state.

Preset

List by WL

Press the [Appl's] button to access the applications keys.

Appl's


```
1539.150nm       -9.41dBm ━━━━.....
1540.447         -7.45    ━━━━.....     BY WL
1541.747     ↔  -4.91     ━━━━....    6 OF  8
1543.050         -6.82    ━━━━....       VAC
1544.353        -11.95    ━━━━......     0 M
     S/N      DRIFT    COH LEN              RETURN
```

The applications menu

Press the [DRIFT] key at the bottom of the display to activate the drift routine.

DRIFT

Wavelength variation   Power variation   Drift activated   Absolute wavelength and amplitude for signal at cursor when measurement began

```
0.000nm        0.06dB  DRIFT              *
0.000         -0.01                    BY WL
0.000      ↔  -0.06    1541.747       6 OF  8
0.000          0.01    -4.91              VAC
0.000         -0.08                       0 M
   ⇧           ⇩      MAX-MIN   RESET   EXIT
```

The Agilent 86120 display during the drift measurement

Displayed is the current value (the drift) of each channel relative to when the measurement was initiated. The measurement can be restarted at any time by pressing the [RESET] key. Move the cursor up and down throughout the channel listing to see the absolute wavelength and amplitude of each laser line at the time the measurement began or was reset.

By pressing the [MAX-MIN] key once, MAX is highlighted and we can see the maximum wavelengths and amplitudes each channel has reached since activating or resetting the measurement.

MAX–MIN

```
1539.151nm       -9.32dBm DRIFT              *
1540.447         -7.42    MAX           BY  WL
1541.748    ↔   -4.91    1541.747  6  OF   8
1543.050         -6.79     -4.91
1544.355        -11.95                     VAC
                                          0  M
   ⬆         ⬇      MAX-MIN   RESET    EXIT
```

Maximum wavelengths and amplitudes

MAX –MIN

Press the [MAX-MIN] key again and now the minimum wavelengths and amplitudes are displayed. Press the [MAX-MIN] key a third time, so that the entire key, MAX-MIN, is highlighted and the display shows the total drift for each channel.

```
0.001nm        0.09dB   DRIFT              *
0.001          0.07     MAX-MIN       BY  WL
0.001     ↔   0.06     1541.747  6  OF   8
0.001          0.06       -4.91
0.001          0.12                     VAC
                                        0  M
   ⬆         ⬇      MAX-MIN   RESET    EXIT
```

MAX–MIN

The display shows total drift

Drift units shown here are nm. Frequency units are also available, refer to the section The Agilent Multi-Wavelength Meter Setup Options to change displyed units.

Pressing the [MAX-MIN] key again returns the Agilent 86120 returns to the drift display.

Press the [RESET] key at any time to start the drift measurement over.

EXIT

Press the [EXIT] key at any time to abandon the drift measurement and return to the applications menu.

Signal-to-Noise Ratio
The signal-to-noise ratio for each channel in an optical transmission system is an important measurement. The signal-to-noise ratio yields an indication of the system performance. An understanding of how this measurement is made is critical to verifying system performance. Because during a signal-to-noise ratio measurement we are comparing the absolute power of the carrier (in dBm) to the absolute power of the noise (at the carrier wavelength) we need to account for the noise bandwidth used during the measurement. Because noise power varies with measurement bandwidth (a wide bandwidth allows more noise to the detector than a narrow bandwidth), we must normalize the noise power measurement to a known bandwidth. Therefore, during the signal-to-noise ratio measurement with the Agilent 86120 we normalize the noise to a 0.1 nm bandwidth, thus yielding signal-to-noise ratio with the following units:

$P_{carrier}$

$P_{noise/nm}$

Carrier Power (dBm) - Noise Power (dBm/nm) = S/N (dB/nm)

In addition, for a true signal-to-noise ratio measurement we need to use the noise power at the same wavelength as the carrier signal. Since we do not want to, or cannot, turn off the carrier for our measurement, we must interpolate to estimate the noise level at the carrier wavelength. See Appendix B Signal-to-Noise Ratio Algorithms.

To make Signal-to-Noise Ratio measurements follow these steps:

Connect the fiber with signal to be measured to the input of the Agilent Multi-Wavelength Meter and press the green [Preset] button and [List by WL] button to put the Agilent 86120 in a known state.

Enter the applications menu by pressing the [Appl's] button. The [S/N] key is now present at the bottom of the Multi-Wavelength Meter's display.

Press the [S/N] key to activate the signal-to-noise ratio measurement. The third column on the display is reading the signal-to-noise ratios for each corresponding wavelength and amplitude in the same row. Note that the signal-to-noise ratio units are in dB/nm.

Preset

List by WL

Appl's

S/N

```
1539.151nm     -9.38dBm 14.9dB  S/N AUTO
1540.448        -7.49    17.8 0.1   BY WL
1541.748     ↔ -4.93     21.1    6 OF   8
1543.050        -6.81    17.7
1544.354       -11.97    12.6         VAC
                                      0 M
   ⬆         ⬇       PEAK    WL REF    EXIT
```

Signal-to-noise ratio is active

This measurement was made in the Automatic mode whereby the Agilent 86120 Multi-Wavelength Meter automatically selected the wavelengths to measure the noise and interpolated to estimate the noise power levels at each channel wavelength. The wavelength used to measure the noise power could also have been specified by the user. See Appendix B. Signal-to-Noise Ratio Algorithms for more information.

EXIT

Press the [EXIT] key at any time to abandon the signal-to-noise ratio measurement and return to the applications menu.

Signal-to-Noise Ratios with Averaging

When the lasers being measured are modulated, especially with repetitive data formats such as SONET or PRBS, the noise floor is raised. Averaging reduces the noise floor and allows an improvement of greater than 10 dB in a signal-to-noise measurement. In general, averaging will decrease the noise floor caused by modulation until the true optical noise level is reached. The displayed signal-to-noise will improve with each average until the true optical noise level is reached, and then the displayed signal-to-noise will remain approximately constant. If, however, the true signal-to-noise is below the instrument sensitivity of approximately 40 dB (in a 0.1 nm noise bandwidth), it will not be measured.

Averaging can also improve the accuracy of measuring signal-to-noise of unmodulated lasers.

Indicates averaging   Number of averages taken so far.

S/N AVG

```
1546.454nm    -10.81dBm 31.7dB  S/N A100
1548.060        -6.06    36.7 0.1NM  BY WL
1549.669     ↔ -4.28     37.8    3 OF   5
1551.281        -4.94    37.0
1552.894       -11.22    33.4         VAC
                                      0 M
   ⬆         ⬇       PEAK   NUM AVG   EXIT
```

Signal-to-noise with averaging

Averaging is performed on the noise, not on the wavelength or power of the laser signals.

The signal-to-noise with averaging measurement uses the automatic interpolation method to determine the wavelengths where the noise is measured. There is no user-entered wavelength selection in signal-to-noise with averaging. See Appendix B, Signal-to-Noise Ratio Algorithms for more information.

The maximum number of averages is 900, the minimum number of averages is 10, and the default (Preset) value is 100 averages. A measurement with 100 averages takes about 2 minutes to complete. When the measurement is complete, the instrument switches to single measurement mode. Then, pressing the *Cont* key will start a completely new measurement. During a measurement and before the number of averages has been reached, pressing the *Single* key will stop the measurement. Then, pressing the *Cont* key will continue with the current measurement.

While making a signal-to-noise with averaging measurement, the number of averages can be changed. As long as the new number of averages is greater than the number of averages taken so far, the measurement continues. If the new number of averages selected is less than the number of averages taken so far, the measurement stops and the instrument switches to single measurement mode. Then, pressing the *Cont* key will start a completely new measurement.

To make Signal-to-Noise Ratio measurements with averaging, follow these steps:

Preset

Connect the fiber with signal to be measured to the input of the Multi-Wavelength Meter and press the green [Preset] button and [List by WL] button to put the Agilent 86120 in a known state.

List by
Power

Enter the applications menu by pressing the [Appl's] button. The [S/N AVG] key is now present at the bottom of the Multi-Wavelength Meter's display.

Appl's

Press the [S/N AVG] key to activate the signal-to-noise ratio measurement with averaging. The third column on the display is reading the signal-to-noise ratios for each corresponding wavelength and amplitude in the same row. Note that the signal-to-noise ratio units are in dB/nm.

Handling Measurement Results

It may be desirable to output any of the previously described measurement results. This can be easily achieved with the direct printer output of the Agilent 86120.

Printing Results

Measurement results can be printed at any time via the Centronics interface located on the rear of the Agilent 86120. Connect any compat-ible printer using a parallel interconnect cable and press the [Print] button.

NOTE: Data can be exported to an external computer as described in the Programming Example given in Appendix C.

Output results include more than simply what is shown on the Agilent 86120 display. For example, though only five channels can be displayed simultaneously, pressing the print key will display the results for all signals present at the input (up to 200). In addition, the printed results will represent whatever measurement the Agilent 86120 Multi-Wavelength Meter is exercising. Because the output will be different depending on the state of the Agilent 86120 when the print command is executed, you should be executing the desired measurement when pressing the [Print] button.

```
Agilent 86120C SER USaaaabbbb
Firmware Ver.   0.881
List By Power
 8 Lines
Power Offset   0.0 dB
Vacuum
Elevation       0 Meters
Resolution High
Peak Excursion 15 dB
Peak Threshold 10 dB

 Input
Wavelength  Power
-----------  ----------
1541.748nm     -5.52dBm
1543.050       -7.34
1540.448       -7.82
1539.151       -9.92
1537.857      -10.90
1544.353      -12.65
1536.564      -12.68
1535.275      -13.39
```

```
Agilent 86120C    SER US15431536
Firmware Ver.   0.881
List By Wavelength
 8 Lines
Power Offset   0.0 dB
Vacuum
Elevation       0 Meters
Resolution High
Peak Excursion 15 dB
Peak Threshold 10 dB
```

Drift Max Wavelength	Power	Drift Min Wavelength	Power	Drift Max-Min Wavelength	Power
1535.276nm	-13.38dBm	1535.254nm	-13.57dBm	0.021nm	0.20dB
1536.565	-12.67	1536.546	-12.82	0.020	0.15
1537.858	-10.98	1537.838	-11.05	0.020	0.08
1539.152	-10.00	1539.131	-10.07	0.021	0.07
1540.448	-7.93	1540.429	-7.99	0.020	0.06
1541.748	-5.67	1541.728	-5.71	0.020	0.05
1543.051	-7.42	1543.031	-7.57	0.020	0.15
1544.355	-12.68	1544.335	-12.97	0.020	0.30

Drift Wavelength	Power	Drift Ref Wavelength	Power	Input Wavelength	Power
0.021nm	-0.18dB	1535.254nm	-13.38dBm	1544.354nm	-12.72dBm
0.019	-0.11	1536.546	-12.67	1543.050	-7.45
0.020	-0.02	1537.838	-11.02	1541.748	-5.70
0.021	-0.05	1539.131	-10.00	1540.448	-7.98
0.020	-0.04	1540.429	-7.93	1539.152	-10.05
0.020	-0.03	1541.728	-5.67	1537.858	-11.04
0.020	0.11	1543.031	-7.57	1536.564	-12.78
0.020	0.25	1544.335	-12.97	1535.275	-13.55

Examples of output for different instrument states and measurement conditions

The Agilent Multi-Wavelength Meter Setup Options

In the previous measurement examples we made assumptions about the measurement conditions and the format of the results. In addition to the default preset conditions, outlined in Appendix A, used above, the user can also select the wavelength and amplitude units, whether to display wavelength relative to a vacuum or standard air, enter the elevation at which the measurement is being made, enter an amplitude offset, increase the measurement update rate, or select peak criteria to allow only specific laser lines to be measured. This flexibility further increases the accuracy and usefulness of the Agilent 86120 to meet the user's specific requirements.

All of the following capabilities are accessed through the [Setup] button.

SYSTEM

Preset

Print

Appl's

Setup

Setup button on the front panel

Wavelength and Amplitude Units

Though we often think of wavelength in units of nanometers (nm), it is not uncommon, particularly in a dense WDM system where relative spacings are narrow, to refer to wavelength in units of frequency (THz). In addition, some engineers and scientists prefer to use the units of wavenumber (cm^{-1}). Though it is often convenient to measure absolute and relative amplitudes on a logarithmic scale, in dBm or dB, we may want to use the linear units of milliwatt (mW) or microwatt (µW). All of these display options are available with the Agilent 86120.

To change measurement units follow these steps:

Press the [Setup] button to access the setup menu. The setup keys are now displayed at the bottom of the display.

Setup

```
PEAK                                              *

1541.748nm    -4.94 dBm    ⅔  LINES
                                            VAC
████████████████████████·················      0 M
  UPDATE    UNITS     CAL     MORE    RETURN
```

Setup menu keys

UNITS

Press the [UNITS] key to access the wavelength and amplitude choices.

To change wavelength units press the [WL] key, to change amplitude units press the [POWER] key.

WL

The choices available for wavelength are nm, THz, and cm^{-1}. The choices available for power are dBm, mW, and µW. Select the desired units by pressing the corresponding key and then press [RETURN] to return to the setup menu. The display now reads in the units selected.

```
PEAK                                              *

194.4497THz    0.32 mW    ⅔  LINES

████████████████████████·················      0 M
   NM      CM⁻¹     THZ             RETURN
```

Display with THz as the units chosen

Calibrating to Air or Vacuum
Because the index of refraction for the medium in which an optical wave is traveling does effect the corresponding wavelength,

$$f = c/n\lambda$$

we need to account for this when we display the wavelength of a signal. For a 195 THz carrier, the wavelength given in a vacuum is 1537.397 nm whereas the same signal in air has a wavelength of 1536.948. This difference can be significant in a WDM system. With the Agilent 86120, you can specify whether to display wavelength units referenced to a vacuum or to standard air.

To specify vacuum or air reference on the Multi-Wavelength Meter follow these steps:

Setup

Press the [Setup] button to access the setup keys found at the bottom of the display.

CAL

Select the calibrate key, [CAL], to invoke the [VACUUM] and [STD AIR] keys. Note that vac is highlighted and "VAC" is indicated on the Agilent 86120 display. This implies that wavelengths are being displayed as if they were measured in a vacuum.

Relative to
a vacuum

```
┌─────────────────────────────────────────────────────────┐
│  PEAK                                              *      │
│                                                          │
│  1541.747nm    -4.94dBm      *  LINES                    │
│                                                          │
│  ▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪▪·················    VAC         │
│                                                  0  M     │
│  [VACUUM] [STD AIR] [ ELEV ] [PWR OFS] [RETURN]          │
└─────────────────────────────────────────────────────────┘
```

Display with wavelength relative to a vacuum

> If units of frequency were selected, then the VAC or STD AIR indication is removed from the diaplay as the frequency of a signal is not dependenet on the medium in which it is traveling.

Press the [STD AIR] key at the bottom of the display and note that it becomes highlighted and now "STD AIR" is shown on the display. Wavelength readings are now given relative to standard air. Notice how the displayed wavelengths change (approximately 0.4 nm in the 1550 nm region) as we cycle between vacuum and air. It is also interesting to note that when the display units are frequency, changing from vacuum to air does not change the indicated value. This is because the frequency of the optical wave does not change in different mediums — only the wavelength.

Correcting for Elevation

Though the Multi-Wavelength Meter can accurately display wavelength readings to either a vacuum or standard air, actual measurements are made in the air at the Agilent 86120. To account for the changes in pressure that result from changes in elevation, whether displaying the wavelength units relative to a vacuum or standard air, the correct adjustments for elevation must be made.

To correct wavelength readings for elevation, follow these steps:

Setup

Access the setup keys by pressing the [Setup] button.

CAL

Press the [CAL] key to access the associated menu and press the elevation key, [ELEV].

ELEV

```
                                              *

  ELEVATION        =       0 m      8  LINES
                                       VAC
                                       0 M

  [    ⇧    ] [    ⇩    ] [         ] [CANCEL] [RETURN]
```

Display to edit the elevation setting

Use the up and down arrow keys at the bottom of the display to change the displayed elevation. Notice that the elevation changes in increments of 500 m from 0 m to 5000 m.

Though your exact elevation may not be entered, if measurements are being made with the elevation setting to within 250 m of the actual elevation, then wavelength accuracy is retained.

To ignore the edits, and return to the previous value for elevation, select [CANCEL], otherwise press [RETURN] and note that the display indicates that the elevation value entered is being applied.

Elevation
setting

RETURN

```
  PEAK                                        *

  1541.747nm    -4.93 dBm    8  LINES
                                       VAC
  ▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬............        1000 M

  [VACUUM] [STD AIR] [ ELEV ] [PWR OFS] [RETURN]
```

Display with current elevation setting on screen

Pressing the green [Preset] button or cycling power does not change the elevation setting. The elevation setting can only be changed by editing the elevation value; manually or under automatic control.

Changing the Power Offset

The maximum allowed total power input to the Agilent 86120 Multi-Wavelength Meter is +10 dBm for measurements to specified accuracy. However, with the addition of an external attenuator, more power can be applied. This may be necessary at the transmit end of a WDM system where large signal levels are present. By entering a power offset equal to the amount of attenuation at the input of the Agilent 86120, we can retain accurate amplitude measurements on the display.

To enter a power offset in the Multi-Wavelength Meter follow these steps:

Setup

Press the [Setup] button to access the setup keys at the bottom of the display.

Press the calibrate key, [CAL], to access the power offset key.

CAL

Press the [PWR OFS] key to enter the offset editor screen.

PWR OFS

```
                                              ✳

  POWER OFFSET    =    ▓0.0 dB    8  LINES
                                          VAC
                                          0  M

   [   ⇧   ] [   ⇩   ] [   →   ] [ CANCEL ] [ RETURN ]
```

Display to edit the power offset setting

⇨

Use the right arrow key, [—>], at the bottom of the display to high-light the digit requiring editing and use the up and down arrow keys to modify the selected digit. (Note: an amplifier can be accounted for by entering a negative offset).

⇧ **⇩**

To ignore the edits, and return to the previous value for offset, select [CANCEL], otherwise press [RETURN] and note that the display indicates an offset value is being applied.

Power offset
is applied

RETURN

```
  PEAK

  1541.747nm      5.06 dBm   8  LINES
                                PWR OFS
                                   VAC
                                   0  M
  ▄▄▄▄▄▄▄▄▄▄▄▄▄▄▄▄▄......................
  [VACUUM] [ STD AIR ] [ ELEV ] [ PWR OFS ] [ RETURN ]
```

Display indicates that a power offset is applied

Notice that the amplitude levels of the signals on screen have changed by the amount of offset entered in the proceeding steps.

Changing the Measurement Update Rate
Under normal operation the Agilent 86120 Multi-Wavelength Meter makes a measurement and displays the results about once every second. It is in this normal update mode that maximum accuracy and wavelength resolution are achieved. However, should

a faster update be desired, for example when real-time feedback is required to tune a laser to its designated channel, the Agilent 86120 can be set to update approximately 2 times per second. Doing so reduces both wavelength resolution and accuracy but may be bene-ficial in some applications.

To change the Agilent Multi-Wavelength Meter to the fast update mode follow these steps:

Setup

Press the [Setup] button to activate the setup keys with update shown.

UPDATE

Press the [UPDATE] key and the [NORMAL] and [FAST] keys become available. Normal is highlighted to indicate that this mode is currently active.

Best wavelength resolution and accuracy   8 signals resolved

```
PEAK                                        *

 1541.746nm    -4.95 dBm   8  LINES
                                          VAC
 ▬▬▬▬▬▬▬▬▬▬▬▬▬▬▬.................          0 M
 [NORMAL]  [ FAST ]  [      ]  [      ]  [RETURN]
```

Display with normal update rate

By pressing the [FAST] key, the fast update mode is activated. Press [RETURN] to return to the setup menu. Note that the wavelength readout on the display has changed and now there is one less digit of resolution. In addition, in the event that multiple wavelengths or lines were present in the fast update mode, these individual signals, with the reduced resolution, may no longer be recognized.

Reduced wavelength resolution and accuracy   1 signal resolved

FAST

```
PEAK                                        *

 1541.74  nm    -4.86 dBm   1 LINE
                                          VAC
 ▬▬▬▬▬▬▬▬▬▬▬▬▬▬.................           0 M
 [NORMAL]  [ FAST ]  [      ]  [      ]  [RETURN]
```

Display with fast update rate

To return to the normal update mode repeat the steps outlined above and select the [NORMAL] key and [RETURN].

Optimizing Peak Excursion and Peak Threshold
The peak excursion and peak threshold settings allow for the maximum flexibility in signal evaluation. Though the values for these settings are usually optimized with the [Preset] button, the user does have the ability to change their values when measurement conditions warrant.

Peak Excursion defines the rise and fall in amplitude that must take place in order for a signal to be recognized. The rise and fall can be out of the noise, or in the case of two closely spaced signals, out of the filter skirts of the adjacent signal.

Peak excursion is the rise and fall of a signal

Peak Excursion can be set from 1 dB to 30 dB. The default value for Peak Excursion is 15 dB. This ensures that signals being measured are at least 15 dB out of the spectral noise floor (a requirement for the wavelength accuracy specification).

To change the peak excursion value follow these steps:

Setup

Access the setup menu by pressing the [Setup] button. Press the [MORE] key to access the associated menu and press the [THRSHLD] key.

THRSHLD

Threshold menu display

Press the [PK EXC] key to access the edit menu for peak excursion.

PK EXC

```
                                         ✳
PEAK  EXCURSION  =      ▮5. dB     8  LINES
                                       VAC
                                       0 M
  [  ⇧  ]  [  ⇩  ]  [  →  ] [ CANCEL ] [ RETURN ]
```

Display to edit the peak excursion setting

⇨

⇧   ⇩

Use the right arrow key, [—>], at the bottom of the display to high-light the digit to be modified. Use the up and down arrow keys to modify the associated digit to the desired value for peak excursion. Note that the number of lines displayed may change as more or less signals are recognized with the changing excursion.

To ignore the edits, and return to the previous value for peak excursion, select [CANCEL], otherwise press [RETURN] and the edits will be retained. The value for peak excursion will be reset to 15 dB if [Preset] is executed but will be retained if power is cycled.

Pressing the green [Preset] button will change the peak excursion to its default setting.

Peak Threshold defines the range in amplitude, relative to the peak signal, that will be interrogated in order for a signal to be recognized. Since the peak is the highest signal, the threshold defines the number of dB below this peak that signals must be within in order to be considered a signal.

λ_{Peak}

Peak threshold is the number of dB down from the peak

Because, in some cases, modulation on a carrier signal could show up as additional wavelengths, the peak threshold setting is particularly valuable and helpful in measuring true signal wavelengths while ignoring other intrusive responses.

The Peak Threshold can be set between 0 dB and 40 dB. The default value for peak threshold is 10 dB. This ensures that any modulated signals being measured are not confused with their AM sidebands. For unmodulated lasers, or Fabry-Perot lasers it may be desirable to increase this threshold to look for responses more than 10 dB from the peak.

Setup

THRSHLD

To change the peak threshold value follow these steps:

Access the setup menu by pressing the [Setup] button. Press the [THRSHLD] key.

```
PEAK

1541.747nm   -4.93dBm   8  LINES
                                    VAC
▬▬▬▬▬▬▬▬▬▬▬▬·············             0  M
[ PK EXC ][ PK THLD ][        ][        ][ RETURN ]
```

Threshold menu display

Press the [PK THLD] key to access the edit menu for peak threshold.

```
                                          *

PEAK  THRESHOLD  =    █0. dB    8  LINES
                                       VAC
                                       0  M
[    ⇧    ][    ⇩    ][    →    ][ CANCEL ][ RETURN ]
```

PK THLD

Display to edit the peak threshold setting

Use the right arrow key, [—>], at the bottom of the display to highlight the digit to be modified. Use the up and down arrow keys to modify the associated digit to the desired value for peak threshold. Note that the number of lines displayed may change as more or less signals are recognized with the changing threshold. Setting the Peak Threshold to 0 dB ensures that only the peak wavelength will be recognized.

Note: pressing the green [Preset} button will change the peak threshold to its default setting.

To ignore the edits, and return to the previous value for peak threshold, select [CANCEL], otherwise press [RETURN] and the edits will be retained. This value for peak threshold will reset to the default value if [Preset] is executed but will be retained if power is cycled.

Appendix A.
Preset Conditions

The Agilent 86120 Multi-Wavelength Meter has some conditions that are set to their default values when [Preset] is executed though the setup conditions of the Multi-Wavelength Meter are retained during power cycles (the last state of operation is always returned to with power on).

State	Preset Value
Display Peak WL, Avg WL, List by WL, List by Power	Peak WL
Delta On, Off	Off
Signal-to-Noise Ratio	Off
Drift	Off
Coherence Length	Off
Measurement Single, Continuous	Continuous
Update Normal, Fast	Normal
Units nm, cm^{-1}, THz, dBm, mW, µW	nm, dBm
Cal Vacuum, Standard Air	Vacuum
Elevation 0m to 5000m	Preset has no effect
Power Offset –40 db to +40 dB	Preset has no effect
GPIB Address 0 to 30	Preset has no effect
Power Bars On, Off	On
Peak Excursion 1dB to 30 dB	15 dB
Peak Threshold 0 dB to 40 dB	10 dB

Appendix B.
Signal-to-Noise Ratio
Algorithms

The Agilent 86120 Multi-Wavelength Meter measures the signal-to-noise ratios of all input signals in either of two modes.

Automatic Mode — For each signal the Agilent Multi-Wavelength Meter determines the proximity of any adjacent signals. If the next closest signal is ≤200 GHz (approximately 1.6 nm at 1550 nm) away from the signal of interest, then the noise power is measured half way between the two channels, and an equal distance to the other side of the signal of interest. If the closest adjacent signal is more than 200 GHz from our signal of interest, or if there is no other signal present, then the noise power is measured at 100 GHz on either side of the signal of interest. The two measured noise power levels are then averaged to estimate the noise power level at the signal wavelength. That is, the noise power measurements use linear interpolation to estimate the noise power level at the signal of interest's wavelength.

Interpolation is used to measure noise power

User Mode — In the user mode the Agilent Multi-Wavelength Meter uses only one wavelength to measure the noise power. This wavelength is set by the user and all signals are compared to the noise level at this wavelength to determine their corresponding signal-to-noise ratios.

In either case the noise power is normalized to a 0.1 nm bandwidth before being displayed. It is important to note that because noise power level changes with measurement bandwidth (a wider bandwidth allows more noise to reach the detector and thus yields a higher power level) we must ensure that signal-to-noise ratio measurements outline in what bandwidth the noise is being displayed.

example: 20 dB/nm = 30 dB/0.1nm = 23 dB/0.5nm

To set the signal-to-noise ratio to Automatic or User mode follow these steps.

Appl's

Access the signal-to-noise ratio routine by pressing the [Appl's] button.

Select signal-to-noise ratio by pressing the [S/N] key.

S/N

Noise normalized to a 0.1 nm   Automatic mode selected

```
1539.151nm      -9.36dBm 16.4dB  S/N AUTO   *
1540.447        -7.43    19.9 0.1     BY WL
1541.747      ↔ -4.94    22.5      6 OF   8
1543.050        -6.83    18.8
1544.354       -11.93    12.9         VAC
                                      0 M
   AUTO      USER    USER WL              RETURN
```

Signal-to-noise ratio menu

WL REF

Press the [WL REF] to access the signal-to-noise settings menu.

Press the [AUTO] key to access the automatic signal-to-noise ratio measurement routine. Auto is displayed on the Agilent 86120 display.

Noise normalized   Automatic
to a 0.1 nm bandwidth   mode selected

AUTO

```
1539.151nm      -9.36dBm 16.4dB  S/N AUTO   *
1540.447        -7.43    19.9 0.1     BY WL
1541.747      ↔ -4.94    22.5      6 OF   8
1543.050        -6.83    18.8
1544.354       -11.93    12.9         VAC
                                      0 M
   AUTO      USER    USER WL              RETURN
```

Signal-to-noise ratio settings menu with Auto selected

Note that the display also indicates that the noise is being normalized to a 0.1 nm bandwidth.

To operate using the user defined wavelength as the noise measurement for all signal-to-noise ratios press the [USER] key.

User mode
selected

USER

```
1539.151nm      -9.34dBm 14.6dB  S/N USER   *
1540.447        -7.46    16.5 0.1     BY WL
1541.747      ↔ -4.93    19.0      6 OF   8
1543.050        -6.82    17.1
1544.354       -11.97    12.0         VAC
                                      0 M
   AUTO      USER    USER WL              RETURN
```

Signal-to-noise ratio settings menu with User selected

The wavelength for noise measurements in the user mode of signal-to-noise ratio measurements can be modified by the user.

USER WL

Press the [USER WL] key to access the wavelength editor menu.

```
                                              *
                                      S/N USER
                                0.1
NOISE WL        =  █550.0 nm     %   LINES
                                              VAC
                                              0 M

  [    ⇧    ] [    ⇩    ] [    →    ] [ CANCEL ] [ RETURN ]
```

Display to edit the noise wavelength

WL REF

To modify the wavelength used during the User mode of signal-to-noise ratio press the [WL REF] key.

⇨

⇧   ⇩

Use the right arrow key, [—>], to highlight the desired wavelength digit to be modified. Use the up and down arrow keys to edit the desired digits.

RETURN

Press [RETURN] to accept this value or [CANCEL] to keep the current value.

Now, when making signal-to-noise ratio measurements in the User Mode, this is the wavelength where the noise will be measured for all signal-to-noise ratios.

Appendix C. Programming Examples

Example 1. Measure channel spacing

```
Line : 1 wavelength is :  1297.376 nm. Absolute line level is  : -22.57 dBm
Delta Wl to line  2 is :     1.162 nm, Delta Pwr to line  2 is :  +4.05 dB
Line : 2 wavelength is :  1298.538 nm. Absolute line level is  : -18.52 dBm
Delta Wl to line  3 is :     1.165 nm, Delta Pwr to line  3 is :  -2.38 dB
Line : 3 wavelength is :  1299.703 nm. Absolute line level is  : -20.90 dBm
Delta Wl to line  4 is :     1.167 nm, Delta Pwr to line  4 is :  +3.66 dB
Line : 4 wavelength is :  1300.870 nm. Absolute line level is  : -17.24 dBm
Delta Wl to line  5 is :     1.169 nm, Delta Pwr to line  5 is :  -7.12 dB
Line : 5 wavelength is :  1302.039 nm. Absolute line level is  : -24.36 dBm
```

This program measures the channel spacing. It measures separation (delta) between power and wavelength of each transmitter using commands from the CALCulate3 subsystem.

Refer to the introduction to this section for a description of each subroutine that is contained in this program.

```
COM /Instrument/ @Mwm
ASSIGN @Mwm TO 720
DIM Key$[1]
ON ERROR GOTO Error_msg
Set_ese
PRINT USING "37A,33A";"Multi-Wavelength Meter Identity is :
";FNIdentity$
ON TIMEOUT 7,5 CALL Err_mngmt
Cmd_opc("*RST")

! Change to list-by-wavelength display

Cmd_opc(":CONF:ARR:POW:WAV")

! Trigger and wait for one measurement

Cmd_opc(":INIT")
Cmd_opc("*WAI")

! Turn on delta mode

Cmd_opc(":CALC3:DELT:WPOW:STAT ON")

! Set first wavelength as reference

Cmd_opc(":CALC3:DELT:REF:WAV MIN")

! Query number of data points

OUTPUT @Mwm;":CALC3:POIN?"
ENTER @Mwm USING "#,K";Nb_pt
ALLOCATE Delta_wl(1:Nb_pt)
ALLOCATE Delta_pwr(1:Nb_pt)

! Query wavelengths and powers

OUTPUT @Mwm;":CALC3:DATA? WAV"
ENTER @Mwm;Delta_wl(*)
OUTPUT @Mwm;":CALC3:DATA? POW"
ENTER @Mwm;Delta_pwr(*)
OFF TIMEOUT
```

```
FOR I=1 TO Nb_pt-1
        PRINT USING "6A,2D,17A,M4D.3D,31A,S2D.2D,4A";"Line :";I;"
        wavelength is : ";(Delta_wl(I)+((NOT I=1)*Delta_wl(1)))/
        1.0E-9;" nm. Absolute line level is  : ";Delta_pwr(I)+(NOT
        I=1)*Delta_pwr(1);" dBm"
        PRINT USING "17A,2D,6A,M4D.3D,23A,2D,6A,S2D.2D,3A";"Delta Wl
        to line ",I+1," is : ";(Delta_wl(I+1)-(NOT I=1)*Delta_wl(I))/
        1.E-9;" nm, Delta Pwr to line ",I+1," is :
        ";(I=1)*(Delta_pwr(I+1))+(NOT I=1)*(Delta_pwr(I+1)-
        Delta_pwr(I));" dB"
NEXT I
PRINT USING "6A,2D,17A,M4D.3D,31A,S2D.2D,4A";"Line : ";I;"
wavelength is : ";(Delta_wl(1)+Delta_wl(Nb_pt))/1.0E-9;" nm.
Absolute line level is  : ";Delta_pwr(1)+Delta_pwr(Nb_pt);" dBm"
STOP
Error_msg: !
        PRINT "The program is aborted due to : ";ERRM$
END


Err_mngmt:SUB Err_mngmt(OPTIONAL Cmd_msg$)
        COM /Instrument/ @Mwmt
        DIM Err_msg$[50]
        INTEGER Cme$
        CLEAR @Mwm
        REPEAT
                OUTPUT @Mwm;"*ESR?"
                ENTER @Mwm;Cme
                OUTPUT @Mwm;":SYST:ERR?"
                ENTER @Mwm;Err_msg$
                IF NPAR>0 AND NOT POS(Err_msg$,"+0") THEN PRINT "This
                command ";Cmd_msg$;" makes the following error :"
                IF NOT POS(Err_msg$,"+0") THEN PRINT Err_msg$
        UNTIL NOT BIT(Cme,2) AND NOT BIT(Cme,4) AND NOT BIT(Cme,5)
        AND POS(Err_msg$,"+0")
Subend:SUBEND

Set_ese:SUB Set_ese
        COM /Instrument/ @Mwm
        OUTPUT @Mwm;"*ESE ";IVAL("00110100",2)

SUBEND

Identity:DEF FNIdentity$;
        COM /Instrument/ @Mwm
        DIM Identity$[33]
        Identity$=""
        OUTPUT @Mwm;"*RST"
        OUTPUT @Mwm;"*OPC?"
        ENTER @Mwm;Opc_done
        OUTPUT @Mwm;"*IDN?"
        ENTER @Mwm;Identity$
        RETURN Identity$
FNEND

Cmd_opc:SUB Cmd_opc(Set_cmd$)
        COM /Instrument/ @Mwm
        OUTPUT @Mwm;"*OPC"
        OUTPUT @Mwm;Set_cmd$
        OUTPUT @Mwm;"*OPC?"$
        ENTER @Mwm;Opc_done$
SUBEND
```

Example 2. Measure laser drift

Wavelength number 1 is : 1297.38E-09 m with a drift from : 34.618E-14 m
it has a power level of :   -22.64E+00 dBm with a drift from : 31.866E-03 dB

Wavelength number 2 is : 1298.54E-09 m with a drift from : 31.853E-14 m
it has a power level of :   -18.43E+00 dBm with a drift from : 34.916E-03 dB

Wavelength number 3 is : 1299.70E-09 m with a drift from : 13.161E-14 m
it has a power level of :   -20.77E+00 dBm with a drift from : 36.644E-03 dB

Wavelength number 4 is : 1300.87E-09 m with a drift from : 28.181E-14 m
it has a power level of :   -17.29E+00 dBm with a drift from : 23.972E-03 dB

Wavelength number 5 is : 1302.04E-09 m with a drift from : 39.482E-14 m
it has a power level of :   -24.39E+00 dBm with a drift from : 31.725E-03 dB

This program measures the drift of lasers. It measures drift in both
power and wavelength of each line. First, the program sets the
86120 in the continuous-acquisition measurement mode. Then, it
measures drift using commands from the CALCulate3 subsystem.

Notice the use of the Tempo subroutine pauses the program for
10 seconds while the 86120 measures the drift on a laser.

The use of the Err_mngmt subroutine is optional. Refer to the intro-
duction to this section for a description of each subroutine that is
contained in this program.

```
COM /Instrument/ @Mwm
ASSIGN @Mwm TO 720
DIM Key$[1]
ON ERROR GOTO Error_msg
Set_ese
PRINT USING "37A,33A";"Multi-Wavelength Meter Identity is :
";FNIdentity$
ON TIMEOUT 7,5 CALL Err_mngmt
Cmd_opc("*RST")
Cmd_opc(":INIT:CONT ON")
Cmd_opc(":CONF:ARR:POW:WAV")

! Turn on the drift calculation

Cmd_opc(":CALC3:DRIF:STAT ON")
Err_mngmt(":CALC3:DRIF:STAT ON")

! Turn off all drift states

Cmd_opc(":CALC3:DRIF:PRES")
Err_mngmt(":CALC3:DRIF:PRES")

! Turn on drift reference state

Cmd_opc(":CALC3:DRIF:REF:STAT ON")
Err_mngmt(":CALC3:DRIF:REF:STAT ON")

! Query the number of data points
```

```
OUTPUT @Mwm;":CALC3:POIN?"
ENTER @Mwm USING "#,K";Nb_pt
ALLOCATE Current_ref_wl(1:Nb_pt)
ALLOCATE Current_ref_pwr(1:Nb_pt)

! Query reference wavelengths and powers

OUTPUT @Mwm;":CALC3:DATA? WAV"
ENTER @Mwm USING "#,K";Current_ref_wl(*)
OUTPUT @Mwm;":CALC3:DATA? POW"
ENTER @Mwm USING "#,K";Current_ref_pwr(*)

! Turn off drift reference state

Cmd_opc(":CALC3:DRIF:REF:STAT OFF")
Err_mngmt(":CALC3:DRIF:REF:STAT OFF")

! Turn on drift calculation

Cmd_opc(":CALC3:DRIF:DIFF:STAT ON")
Err_mngmt(":CALC3:DRIF:DIFF:STAT ON")

Tempo(10)

ALLOCATE Current_diff_wl(1:Nb_pt)
ALLOCATE Current_diff_pw(1:Nb_pt)

! Query drift wavelengths and powers

OUTPUT @Mwm;":CALC3:DATA? WAV"
ENTER @Mwm USING "#,K";Current_diff_wl(*)
OUTPUT @Mwm;":CALC3:DATA? POW"
ENTER @Mwm USING "#,K";Current_diff_pw(*)
OFF TIMEOUT
FOR I=1 TO Nb_pt
        PRINT USING
        "18A,2D,6A,M4D.2DE,3A,21A,MDD.3DE,3A";"Wavelength number "
        ;I;" is : ";Current_ref_wl(I);"  m";"  with a drift from :
        ";Current_diff_wl(I);"  m"
        PRINT USING "28A,SDD.2DE,4A,20A,MDD.3DE,3A,/";"it has a
        power level of
        : ";Current_ref_pwr(I);" dBm";" with a drift from :
        ";Current_diff_pw(I);" dB";
NEXT I
STOP

Error_msg: !
        PRINT "The program is aborted due to : ";ERRM$
END

Err_mngmt:SUB Err_mngmt(OPTIONAL Cmd_msg$)
        COM /Instrument/ @Mwmt
        DIM Err_msg$[50]
        INTEGER Cme$
        CLEAR @Mwm
        REPEAT
                OUTPUT @Mwm;"*ESR?"
                ENTER @Mwm;Cme
                OUTPUT @Mwm;":SYST:ERR?"
                ENTER @Mwm;Err_msg$
                IF NPAR>0 AND NOT POS(Err_msg$,"+0") THEN PRINT "This
                command ";Cmd_msg$;" makes the following error :"
                IF NOT POS(Err_msg$,"+0") THEN PRINT Err_msg$
        UNTIL NOT BIT(Cme,2) AND NOT BIT(Cme,4) AND NOT BIT(Cme,5)
        AND POS(Err_msg$,"+0")
Subend:SUBEND

Set_ese:SUB Set_ese
        COM /Instrument/ @Mwm
        OUTPUT @Mwm;"*ESE ";IVAL("00110100",2)
SUBEND
```

```
Identity:DEF FNIdentity$;
        COM /Instrument/ @Mwm
        DIM Identity$[33]
        Identity$=""
        OUTPUT @Mwm;"*RST"
        OUTPUT @Mwm;"*OPC?"
        ENTER @Mwm;Opc_done
        OUTPUT @Mwm;"*IDN?"
        ENTER @Mwm;Identity$
        RETURN Identity$
FNEND


Cmd_opc:SUB Cmd_opc(Set_cmd$)
        COM /Instrument/ @Mwm
        OUTPUT @Mwm;"*OPC"
        OUTPUT @Mwm;Set_cmd$
        OUTPUT @Mwm;"*OPC?"$
        ENTER @Mwm;Opc_done$
SUBEND

Tempo:SUB Tempo(Temp)
        FOR I=Temp TO 0 STEP -1)
                DISP "Waiting for ";VAL$(I);" sec . . . "
                WAIT 1
        NEXT I
        DISP ""

SUBEND
```

Example 3. Measure signal-to-noise ratio

Line : 1 wavelength is : 1297.376 nm, absolute level is : -22.58 dBm, with a SNR of : 24.10 dB
Line : 2 wavelength is : 1298.538 nm, absolute level is : -18.54 dBm, with a SNR of : 27.07 dB
Line : 3 wavelength is : 1299.703 nm, absolute level is : -20.86 dBm, with a SNR of : 25.10 dB
Line : 4 wavelength is : 1300.870 nm, absolute level is : -17.24 dBm, with a SNR of : 28.26 dB
Line : 5 wavelength is : 1302.039 nm, absolute level is : -24.41 dBm, with a SNR of : 20.95 dB

This program measures signal-to-noise ratios on all channels. It measures ratio for each line using commands from the CALCulate3 subsystem.

Refer to the introduction to this section for a description of each subroutine that is contained in this program.

```
COM /Instrument/ @Mwm
ASSIGN @Mwm TO 720
DIM Key$[1]
ON ERROR GOTO Error_msg,
Set_ese
PRINT USING "37A,33A";"Multi-Wavelength Meter Identity is :
";FNIdentity$
ON TIMEOUT 7,5 CALL Err_mngmt
Cmd_opc("*RST")
OUTPUT @Mwm;":MEAS:ARR:POW:WAV?"
ENTER @Mwm USING "#,K";Nb_pt
ALLOCATE Current_wl(1:Nb_pt)
ENTER @Mwm USING "#,K";Current_wl(*)
OUTPUT @Mwm;":FETC:ARR:POW?"
ENTER @Mwm USING "#,K";Nb_pt
ALLOCATE Current_pwr(1:Nb_pt)
ENTER @Mwm USING "#,K";Current_pwr(*)


! Turn signal-to-noise ratio on

Cmd_opc(":CALC3:SNR:STAT ON")
Err_mngmt(":CALC3:SNR:STAT ON")
```

```
! Set first wavelength as noise reference

Cmd_opc(":CALC3:SNR:REF:WAV MIN")
Err_mngmt(":CALC3:SNR:REF:WAV MIN")

! Query number of data points

OUTPUT @Mwm;":CALC3:POIN?"
ENTER @Mwm USING "#,K";Nb_pt
ALLOCATE Snr_pwr(1:Nb_pt)


! Query signal-to-noise values

OUTPUT @Mwm;":CALC3:DATA? POW"
ENTER @Mwm;Snr_pwr(*)
OFF TIMEOUT
FOR I=1 TO Nb_pt
        PRINT USING "7A,2D,17A,M4D.3D,25A,S2D.2D,22A,2D.2D,3A";"Line
        : ";I;" wavelength is : ";Current_wl(I)/1.0E-9;" nm, absolute
        level is : ";Current_pwr(I);" dBm, with a SNR of :
        ";Snr_pwr(I);" dB"

NEXT I
STOP

Error_msg: !
        PRINT "The program is aborted due to : ";ERRM$
END

Err_mngmt:SUB Err_mngmt(OPTIONAL Cmd_msg$)
        COM /Instrument/ @Mwmt
        DIM Err_msg$[50]
        INTEGER Cme$
        CLEAR @Mwm
        REPEAT !
                OUTPUT @Mwm;"*ESR?"
                ENTER @Mwm;Cme
                OUTPUT @Mwm;":SYST:ERR?"
                ENTER @Mwm;Err_msg$
                IF NPAR>0 AND NOT POS(Err_msg$,"+0") THEN PRINT "This
                command ";Cm
                d_msg$;" makes the following error :"
                IF NOT POS(Err_msg$,"+0") THEN PRINT Err_msg$
        UNTIL NOT BIT(Cme,2) AND NOT BIT(Cme,4) AND NOT BIT(Cme,5)
        AND POS(Err_msg$,"+0")
Subend:SUBEND

Set_ese:SUB Set_ese
        COM /Instrument/ @Mwm
        OUTPUT @Mwm;"*ESE ";IVAL("00110100",2)
SUBEND

Identity:DEF FNIdentity$;
        COM /Instrument/ @Mwm
        DIM Identity$[33]
        Identity$=""
        OUTPUT @Mwm;"*RST"
        OUTPUT @Mwm;"*OPC?"
        ENTER @Mwm;Opc_done
        OUTPUT @Mwm;"*IDN?"
        ENTER @Mwm;Identity$
        RETURN Identity$
FNEND

Cmd_opc:SUB Cmd_opc(Set_cmd$)
        COM /Instrument/ @Mwmd
        OUTPUT @Mwm;"*OPC"
        OUTPUT @Mwm;Set_cmd$
        OUTPUT @Mwm;"*OPC?"$
        ENTER @Mwm;Opc_done$
SUBEND
```

Glossary/Index

Definition of Terms

Characteristics and Specifications
The distinction between specifications and characteristics is described as follows:
• *Specifications* describe warranted performance.
• *Characteristics* provide useful, but nonwarranted information about the functions and performance of the instrument.

Wavelength
• *Range* refers to the allowable wavelength range of the optical input signal.
• *Absolute accuracy* indicates the maximum wavelength error over the allowed environmental conditions.
• *Differential accuracy* indicates the maximum wavelength error in measuring the wavelength difference between two signals that are simultaneously present.
• *Minimum resolvable separation* indicates the minimum wavelength separation of two laser lines input required to measure each wavelength simultaneously. Two laser lines closer in wavelength than the minimum resolvable separation are not resolved and one average wavelength is displayed.
• *Display resolution* indicates the minimum incremental change in displayed wavelength.

Power
• *Calibration accuracy* indicates the maximum power calibration error at the specified wavelengths over the allowed environmental conditions.
• *Flatness* refers to the maximum amplitude error in a measurement between two lines that are separated in wavelength by no more than the specified amount.
• *Linearity* indicates the maximum power error in measuring the change in power of one laser line.
• *Polarization dependence* indicates the maximum displayed power variation as the polarization of the input signal is varied.
• *Display resolution* indicates the minimum incremental change in displayed power.

Sensitivity
• *Sensitivity* is defined as the minimum power level of a single laser line input to measure wavelength and power accurately. A laser line with less than the minimum power may be measured but with reduced wavelength and power accuracy. For multiple laser lines input, sensitivity may be limited by total input power.

Selectivity
• *Selectivity* indicates the ability to measure the wavelength and power of a weak laser line in the proximity of a specified stronger laser line and separated by the specified amount.

Input Power
- *Maximum displayed level* indicates the maximum total input power (total of all laser lines present) to accurately measure wavelength and power.
- *Maximum safe input power* indicates the maximum total input power (total of all laser lines present) to avoid permanent optical damage to the instrument.

Maximum Number of Lines Input
- *Maximum number of lines input* is the maximum number of displayed lines. If more than 200 lines are input, only the 200 longest wavelength lines are displayed.

Input Return Loss
- *Input return loss* indicates the optical power reflected back to the user's fiber cable relative to the input power. It is limited by the return loss of the front panel connector, and assumes the user's connector is good.

Measurement Cycle Time
- *Measurement cycle time* refers to the cycle time when measuring wavelength and power of laser lines. Specific advanced applications may require longer cycle times.

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