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FIBER OPTICS SPECIFICATION DEFINITIONS

GENERAL SPECIFICATIONS

- Operating Frequency Range
- Gain
- Gain Flatness
- Noise Figure
- Input and Output Power at 1 dB Compression
- Input and Output VSWR
- DC Supply Voltage and Current Consumption

The following notes give detailed definitions to these and additional specifications which may relate to your system requirements.

OPERATING FREQUENCY RANGE

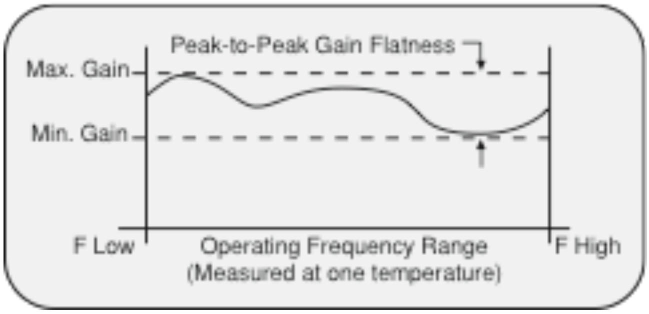
The operating frequency range is the range of frequencies over which the fiber link will meet or exceed the specification parameters. The fiber link may perform beyond this frequency range.

GAIN

Gain is defined as the ratio of the power measured at the output of a fiber link to the power provided to the input port. It is usually expressed in decibels and is typically measured in a swept fashion across the operating frequency range. The gain of all fiber links is verified by a swept measurement before shipment from MITEQ.

GAIN FLATNESS

Gain flatness describes the variation in a fiber links gain over the operating frequency range at any fixed temperature within the operating temperature range. As such, it does not include the variation of gain as a function of temperature (see Gain Variation vs. Temperature).



The gain flatness of a fiber link is measured by viewing the swept gain and determining the difference between the minimum gain and the maximum gain recorded over the operating frequency range. Unless the fiber link is specified to operate over a defined temperature range, this measurement is per-formed at room ambient temperature (+23°C). If a range of temperatures is specified, the measurement must also be verified at the temperature extremes.

NOISE FIGURE

Noise figure is classically defined as:

$$\text{Noise Figure} = \frac{S_i/N_i}{S_o/N_o} = \frac{\text{Signal-to-noise ratio at the fiber link input}}{\text{Signal-to-noise ratio at the fiber link output}}$$

Since all fiber links add thermal noise, the signal-to-noise ratio at the output will be degraded; therefore, noise figure will be a ratio greater than one (NFdB = 10 log10(NFRatio). The additive noise of a fiber link can also be expressed in a parameter referred to as noise temperature. In this approach, the noise temperature of the fiber link is equal to the temperature (in degrees Kelvin) of a 50 Ω termination at the input of an ideal noiseless fiber link with the same gain and generating the same output noise power.

The relationship between noise figure and noise temperature is:

$$\text{Noise Figure} = 10 \text{ Log}_{10} \left\{ \frac{\text{Noise Temperature (Kelvin)}}{290 \text{ Kelvin}} + 1 \right\}$$

Noise figure data is measured at discrete frequencies throughout the band at +23°C unless specified otherwise.

INPUT AND OUTPUT POWER AT 1 dB COMPRESSION

The input 1 dB compression point of a fiber link is simply defined as the input power level at which the gain deviates from the small signal gain by 1 dB. Similarly, the output 1dB compression point of a fiber link is defined as the output power level at which the gain deviates from the small signal gain by 1 dB.

All active components have a linear dynamic range. This is the range over which the output power varies linearly with respect to the input power. As the output power increases to near its maximum capability, the device will begin to saturate. The point at which the saturation effects are 1 dB from linear is defined as the 1 dB compression point. Because of the nonlinear relation between the input and output power at this point, the following relationship holds:

$$P_{out} \text{ 1 dB} = P_{in} \text{ 1 dB} + \text{Linear Gain} - 1 \text{ dB}$$

Explanation Of Why 1 dB of Optical Loss = 2 dB of RF Loss in Fiber Optics

It is important to keep in mind that in fiber optic communications, every optical loss translates into twice as much in RF loss. The reason being, that at the photodiode level, a linear change in optical "power" generates a linear change in photo-"current" (not photo-"power"). In order to extract the "power" from the photo-current, we have to then again square the photo-"current" term using the load impedance into which the photo-current is being delivered. In log terms, this is equivalent to doubling the factor.

This will become clear with the following example:

1) DC Example:

Suppose we have 1mW of optical power (Po) without any modulation and it is shining on a reverse-biased photodiode having responsivity of 0.8A/W. The photodiode is in turn terminated into a 50 ohm load resistor (R). Then the DC power generated at the load R would be calculated as follows:

Case 1: Unmodulated Po = 1 mW = 0 dBm

Photo-current generated (by Po = 1 mW) = 0.8 A/W

* 1 mW ⇨ 0.0008 A

DC Power delivered to the load by this photo-current

= I2R = (0.0008)2 *50 = 0.000032 Watts

or

in dBm, the power delivered to the load would be:

dBm (with Po = 1 mW)

= 10*log10(0.000032*1000) = -14.9485 dBm

Now suppose the optical power was attenuated to Po = 0.5 mW (i.e., half its original value). Now the calculation of DC power generated by the photodiode would go as follows:

Case 2: Unmodulated Po = 0.5 mW = -3.0103 dBm

Photo-current generated (by Po = 0.5 mW) = 0.8 A/W

* 0.5 mW ⇨ 0.0004 A

DC Power delivered to the load by this photo-current = I2R = (0.0004)2 *50 = 0.000008 Watts

or

in dBm, the power delivered to the load would be:

dBm (with Po = 0.5 mW) = 10*log10(0.000008*1000)

= -20.9691 dBm

DC Power Comparison:

Case 1 to Case 2:

"Optical" power loss = 0 dBm – (-3.0103 dBm) = 3.0103 dB

Case 1 to Case 2:

"DC" power loss = -14.9485 – (-20.9691 dBm) = 6.0206 dB

⇨ DC power loss = two times the optical power loss

The same phenomenon occurs with the RF power as well as had been a modulated optical carrier.

2) RF Example:

Suppose we have 1 mW of average optical power (Po) with 100% modulation (i.e., it is swinging sinusoidally from 2 mW to 0 mW and back) and it is shining on a reverse-biased photodiode having responsivity of 0.8 A/W. The photodiode is in turn terminated into a 50 ohm load resistor (R). Then the AC power generated at the load R would be calculated as follows:

Case 3: Modulated Po = 1 mW (average power)

= 0 dBm = (optical power swinging sinusoidally from 2 mW to 0 mW and back)

Maximum photo-current generated by sinusoidal

(Po = 2 mW) = 0.8 A/W * 2 mW = 0.0016 A

Mininum photo-current generated by sinusoidal

(Po = 0 mW) = 0.8 A/W * 0 mW = 0.0000 A

Hence, the peak to peak value of the sinusoidal current generated by such a 100% modulated optical carrier is:

I (peak to peak) = Ip-p = 0.0016 A

I (peak) = Ip = 0.0008 A

To calculate the average power for such an AC current, we fist calculate I (rms):

$$I\ (rms) = \frac{Ip}{\sqrt{2}} = \frac{0.0008}{\sqrt{2}}$$

Now calculating the average AC power delivered to load R from by the above sinusoidal photo-current:

RF Power to load R = $(Irms)^2 R = (0.0008/\sqrt{2})^2$

*50 = 0.000016 Watts

or

in dBm, the power delivered to the load R would be:

dBm (with Po = 1 mW) = 10*log10(0.000016*1000) = -17.9588 dBm

Now suppose the optical power was attenuated to Po = 0.5 mW (i.e., half its original value). Now the calculation of RF power generated by the photodiode would go as follows:

Case 4: Modulated Po = 0.5 mW (average power) = -3.0103 dBm = (optical power swinging sinusoidally from 1 mW to 0 mW and back)

Maximum photo-current generated by sinusoidal

(Po = 1 mW) = 0.8 A/W * 1 mW = 0.0008 A

Minimum photo-current generated by sinusoidal

(Po = 0 mW) = 0.8 A/W * 0 mW = 0.0000 A

Hence, the peak to peak value of the sinusoidal current generated by such a 100% modulated optical carrier is:

I (peak to peak) = Ip-p = 0.0008 A

I (peak) = Ip = 0.0004 A

To calculate the average power for such an AC current, we fist calculate I (rms):

$$I\ (\text{rms}) = \frac{Ip}{\sqrt{2}} = \frac{0.0004}{\sqrt{2}}$$

Now calculating the average AC power delivered to load R from by the above sinusoidal photo-current:

$$\text{RF Power to load R} = (\text{Irms})^2 R = (0.0004/\sqrt{2})^2$$

*50 = 0.000004 Watts

or

in dBm, the power delivered to the load R would be:

dBm (with Po = 1 mW) = 10*log10(0.000004*1000) = -23.9794 dBm

RF Power Comparison:

Case 3 to Case 4:

“Optical” power loss

= 0 dBm – (-3.0103 dBm) = 3.0103 dB

Case 3 to Case 4:

“RF” power loss

= -17.9588 – (-23.9794 dBm) = 6.0206 dB

⇨ RF power loss = two times the optical power loss

INPUT AND OUTPUT VSWR (OR INPUT AND OUTPUT RETURN LOSS)

Most RF and microwave systems are designed around a 50 Ω impedance system. A fiber link's impedance is designed to be as close as possible to 50 Ω; however, this is not always possible, especially when attempting to simultaneously achieve a good noise figure. The VSWR of a fiber link is a measure of a fiber link's actual impedance (Z) with respect to the desired impedance (Zo) in most cases 50 Ω.

The VSWR is derived from the reflection coefficient r, where r is a ratio of the normalized impedance:

$$\rho = \frac{Z - Zo}{Z + Zo}$$

and:

$$VSWR = \frac{1 + |\rho|}{1 - |\rho|}$$

VSWR is "measured" with either a scalar or vector network analyzer by analyzing the incident power and the reflected power at both ports of the device to determine the reflection coefficients which in turn are converted and displayed as VSWR. The ratio of the reflected power to the incident power is also known as the return loss.

SUPPLY VOLTAGE AND CURRENT CONSUMPTION

Transmitter Modules:

All standard models are internally voltage regulated and reverse voltage protected. All un-cooled laser transmitter modules are specified with two voltages: +12 V and -12 V while the cooled versions are specified with three voltages: +12 V, -12 V and +5 V. The +12 V and -12 V are regulated and reverse polarity protected. Hence they can safely be operated from ±11 V to ±20 V without any damage to the link. However, the higher the voltage, the higher the heat dissipation and so a nominal operating voltage of ±12 V is recommended. Depending on the model, the current could vary on the +12 V from 200 mA to 325 mA, and on the -12 V from 100 mA to 250 mA.

In the case of the cooled laser modules, the third voltage of +5 V is unregulated and not reverse polarity protected in order to lower the heat dissipation due to high current consumption by the thermo-electric peltier cooler inside. A voltage range of +3 V to +6 V can be applied on this pin with a recommended voltage of +4 V to +5 V.

All transmitters come with a laser monitor pin which reads -2 V during normal operation and 0 V otherwise. In case of cooled lasers, an additional laser temperature monitor pin is also available which reads near 0 V for normal operation and ±1 V or higher otherwise.

All transmitter modules need to be properly heat sunk.

Receiver Modules:

All non-gain control receiver modules come with a single +12 V supply requirement which is regulated and reverse polarity protected. The range of voltage that can be applied on it can vary from +11 V to +20 V, but +12 V is recommended to reduce the amount of heat dissipation. The amount of current depends on the model and can vary from 100 mA to 275 mA.

All gain control receiver modules come with dual +12 V and -12 V supply requirement which are regulated and reverse polarity protected. The current consumption on these pins are 150 mA on the +12 V supply and 20 mA on the -12 V supply.

ADDITIONAL SPECIFICATIONS

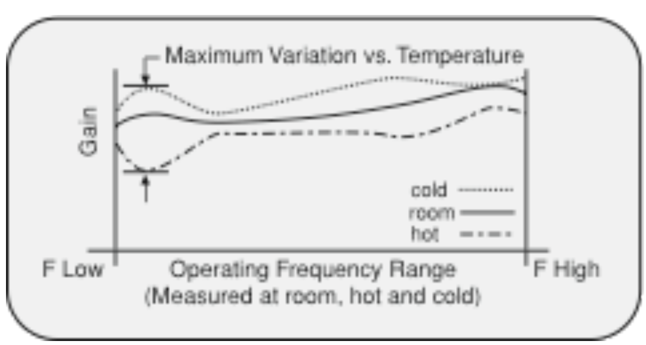
In addition to the electrical specifications included for most of the models within this catalog, there are additional specifications which are useful to the engineer designing around stringent system requirements:

- Gain Variation vs. Temperature
- Overall Gain Window
- Intercept Points
- Dynamic Range
- Harmonic Suppression
- Reverse Isolation
- Phase Linearity
- Peak Wavelength
- Spectral Width
- Side Mode Suppression Ratio
- Relative Intensity Noise
- RF Loss vs. Optical Loss
- Fiber Types
- Optical Connector Types
- Laser MTBF

GAIN VARIATION VS. TEMPERATURE

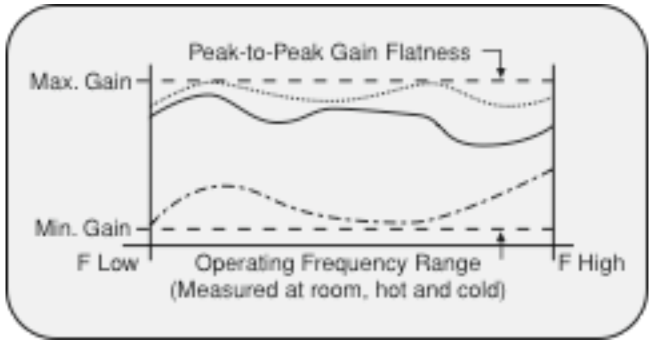
Gain variation versus temperature defines the maximum allowable variation of the linear gain due to temperature at any discrete frequency. As a result, this parameter does not account for drift over frequency.

Gain variation versus temperature is measured by performing swept gain measurements at the specified temperature extremes and comparing the deviations between the two sweeps at each frequency to determine the greatest change. When a ± value is used, then the delta is taken at both temperature extremes with respect to room temperature (+23°C).



OVERALL GAIN WINDOW

An overall gain window specification defines the absolute minimum and maximum gain values over both temperature and frequency.



It is the most complete way to specify a fiber link; however, it also impacts the price due to the additional testing and alignment required from adding this constraining parameter.

SECOND AND THIRD ORDER INTERCEPT POINTS

Fiber optic links use solid state amplifiers to provide gain. Although these amplifiers (FETS and bipolar transistor) are generally used in a linear mode they still exhibit nonlinear phenomenon, such as intermodulation effects and harmonic generation. These effects are evident in spurious products present at the output. In the case of the single-tone condition, the spurious signals are the harmonics of the fundamental input signal. In the case of the two-tone condition, the spurious signals are a mixing product of two input signals at the frequencies f1 and the other at f2. The most commonly discussed being the second order and the third order two-tone spurs.

Second order two-tone spurs are the sum and difference product of the fundamental input frequencies, i.e.;

$$f_{SPUR} = f_1 \pm f_2$$

The spurious signals are only of concern when the band is greater than on octave. If the frequency range is less than one octave, the two-tone second order spurs will be out of band.

These spurious signals are characterized with respect to the input signal by means of a theoretical tool called an intercept point. These points are defined as the point where the linear curve of input vs. output power of the fundamental would intersect with the linear curve of the spurious signal if saturation effects would not limit the output levels of these signals. Since it is known that the second order spurious products have a slope of 2:1 with respect to the fundamental input power, the value of the spurs can be estimated if the input signal power (PIN) and the output second order intercept point (OIP2) are known. The relationship is as follows:

Two-Tone Second Order

Spurious Suppression = OIP2 - (PIN + G)

Two-Tone Second Order

Spurious Level = 2 (PIN + G) - OIP2

Third order spurious products result from combinations of the fundamental signal and the second harmonics.

$$f_{SPUR} = |2f1 \pm f2| \pm |f1 \pm 2f2|$$

The slope of the third order spurious signals is 3:1 with respect to the fundamental input power, and again the value of the spurs can be estimated if the input signal power (PIN) and the output third order intercept point (OIP3) are known. The relationship is as follows:

$$\text{Two-Tone Third Order Spurious Suppression} = 2\{OIP3 - (PIN + G)\}$$

$$\text{Two-Tone Third Order Spurious Level} = 3\,(PIN + G) - 2\,OIP3$$

Third Order Relationship With P1 dB

Third order intercept (TOI) is "sort of " related with 1-dB compression point (P1) in that:

Output TOI (dBm) = Output P1 (dBm) +10 dB (approximately) {Equation A}

Input TOI (dBm) = Input P1 (dBm) +10 dB (approximately) {Equation B}

Also:

Input P1 (dBm) = Output P1 (dBm) – Gain (dB) {Equation C}

Sometimes the added figure can be 8 dB, other times 12 dB above, but generally 10 dB is typical.

Also, dB below carrier (dBc) level of harmonics and Intermodulation Products (IM) is a measurement of linearity of the Device Under Test (DUT). If the DUT is perfectly linear, there will not be any harmonics for a "sine-wave" input. However, if there are non-linearities, then the harmonics and IM products will start to appear for the sine wave indicating that there is some distortion of the carrier sine wave taking place in the DUT. All active devices exhibit some level of distortion. The lower the harmonics are from the carrier (i.e., the higher the dBc), the better the linearity is of the DUT.

Usually the process entails a two-tone measurement. What this means is that two sine carriers equal in amplitude but slightly separated in frequency around the frequency of interest are fed into the DUT (for example; for 1 GHz measurement, the two sine carriers can be set at 1 GHz and 1.05 GHz).The output is monitored on the spectrum analyzer, which typically shows the two carrier sine waves plus third order products and other harmonics. It is the third order IM products that are of greatest concern because of their proximity to the carrier which makes it difficult to filter out plus their triple fold increase relationship (i.e., every 1 dB increase in carrier causes the third order IM products to increase by 3 dB). The relationship used between the TOI and the dBc are:

Output TOI = dBc/2 + (carrier dBm)

{Equation D}

Where:

TOI: third order intercept

dBc = the amount of dB down the IM product is from the carrier sine wave

dBm = the carrier frequency power

So, if the input P1 (dBm) and gain is known, as is the case for the SCMT-18G which is -15 dBm and +18 dB respectively (typical), then equation C and A yield:

Output P1 (dBm) = -15 dBm +18 dB = +3 dBm

Output TOI (dBm) = +3 dBm +10 dB = +13 dBm (approximately)

If the minimum desired dBc is 75, then the maximum dBm of the carrier comes out from Equation D as:

+13 dBm = 75/2 + dBm

⇨Carrier (dBm) = -24.5 dBm (at the output)

What this tells us is that if the carrier power at the output of the SCMR-18G link is less than -24.5 dBm, then the dBc of the IM products would be greater than (or better than) 75 dBc across the band. (OR conversely if the carrier power into the SCMT-18G is less than -42.5 dBm, then the IM products would be at least 75 dB further down across the band).

Similarly for a desired minimum dBc of 100, then the maximum power level of the carrier at the input of the transmitter SCMT-18G would be -55 dBm.

DYNAMIC RANGE

Dynamic range can be defined in several ways. The two classical approaches are to define the linear dynamic range, and the second being the spurious free dynamic range.

The linear dynamic range defines the difference between the minimum detectable signal (MDS), referred to the input of the fiber link or the maximum signal level at which the fiber link remains linear. This is typically defined by the input 1 dB compression point (PIN 1 dB). The minimum detectable signal is defined by system constraints such as noise figure, bandwidth, and predetection signal-to-noise ratio.

SPURIOUS FREE DYNAMIC RANGE (SFDR)

Spurious Free Dynamic Range (SFDR), as the name suggests, is the range of input levels for which the output would be free of any spurs or intermodulation products. In other words, starting at the noise floor at the output (for a given bandwidth), it is the amount of signal in dBs that an input signal can be increased by before you start seeing the intermodulation products creep out of the noise at the output. All active devices exhibit non-linearities which result in harmonics and intermodulation products, and the ones of particular concern are the third order intermodulation products which can fall within the bandwidth of interest and are hard to filter out because of the proximity to the carriers. Also they grow in power three times faster (1-dB increase in carrier level causes the third order products to increase by 3 dB).

The commonly used equation to determine the spur free dynamic range is as follows:

SFDR (dB) = 2/3 [Output Third Order Intercept or

TOI (dBm) - Gain (dB) - { kTB (dBm) + Noise Figure (dB)}]

Where:

1) The terms in { a + b } define the Noise Floor:

a) Theoretical Minimum Noise Floor at 25°C:

kTB (in 1 Hz) = 10 log ((1.38 x 10e-23 x 298(deg Kelvin) x 1 (Hz)) x1000 (for mW) = -174 dBm/Hz

or

kTB (in 1 MHz) = 10 log ((1.38 x 10e-23 x 298(deg Kelvin) x 1 x 10e+6(Hz)) x1000 (for mW) = -114 dBm/MHz

b) Noise figure (dB) of the system or DUT: Measured using the noise diode and a noise figure meter/analyzer. The noise figure meter is calibrated using the known Excess Noise Ratio (ENR) parameters of the noise diode. The DUT is next connected in line and the meter measures the additional noise contributions of the DUT or the system (in dB). This figure, added to the theoretical minimum in (a), defines the noise floor.

2) The term [Output Third Order Intercept (dBm) – Gain (dB)] translates the Output TOI to Input TOI. This is an input level where theoretically output third order product will level off with the carrier. (Remember: 1 dB increase in carrier = 3 dB increase in third order product). (Practically the intercept is never realized).

3) The term in square bracket can thus be simplified to:

Total Dynamic Range = [Input Third Order Intercept (dBm) - Noise Floor]

= [Total Input Dynamic Range from Minimum detection level to Maximum detection level]

4) Finally, to the mystery of the 2/3 factor: The term explained in (3) gives the total dynamic range from minimum to maximum levels. For spurious free dynamic range (i.e., the range of input where there are no third order products present at the output), we back off the input level from its maximum detection level (where the third order was at level with the carrier) by 1/3. The third order products drop down three times faster, and become leveled with the noise floor. Hence, when the input is at two thirds of its maximum range, the third order is at the noise floor. This defines the maximum spurious free dynamic range.

In a typical LBL link:

Noise Figure = 10 dB (typ.)

Input P1 = -9 dBm (typ.)

Input TOI = 0 dBm

(approx. 9 dB higher than the input P1)

Therefore the SFDR calculates out to be:

SFDR = 2/3 [0 dBm - (-174 dBm + 10 dB)] dB/Hz

= 109 dB/Hz*

*Sometimes the unit is also expressed as dB/Hz2/3 due to the fact that the 2/3 multiplication factor ahead of the log (dB) calculations translates into a power factor in the linear calculations.

SPURIOUS FREE DYNAMIC RANGE CALCULATIONS

The calculations for SFDR (Spurious Free Dynamic Range) for our 18 GHz link are as follows:

SFDR = 2/3 [Input TOI (dBm) - NF (dB) - kTB Thermal Noise Floor for the Receiver Bandwidth (dBm)]

where:

TOI = Third Order Intercept of the Link

NF = Noise Figure of the Link

k = Boltzman Constant: 1.38e-23 J/K

T = Temperature in Kelvin

B = Receiver Bandwidth

The kTB noise floor is the theoretical minimum noise floor that can be had for a given bandwidth and temperature. Hence for a 1 Hz bandwidth at room temperature (290 deg Kelvin), the kTB noise floor (in dBm) calculates out to be:

$$\text{kTB (in 1 Hz BW at room temp.)} = 10 \log (1.38e\text{-}23 \times 290 \times 1 \times 1000) = -173.97 \text{ dBm}$$

or

$$\text{kTB (in 1 MHz BW at room temp.)} = 10 \log (1.38e\text{-}23 \times 290 \times 1e{+}6 \times 1000) = -113.9 \text{ dBm}$$

or

$$\text{kTB (in 300 MHz BW at room temp.)} = 10 \log (1.38e\text{-}23 \times 290 \times 300e{+}6 \times 1000) = -89.21 \text{ dBm}$$

So in a 300 MHz receiver bandwidth, the minimum theoretical noise floor comes out to be -89.21dBm. Add to this the noise figure of the link which is say about 17 dB at the frequency of interest, then the Minimum Detectable Signal (MDS) comes out to be:

MDS (in 300 MHz BW) = kTB Noise Floor + Noise Figure of the link

= -89.21 dBm + 17 dB

= -72.21 dBm

This means that if the link has a noise figure of 17 dB, then any signal greater than -72.21 dBm is detectable.

The SFDR calculates out to be:

$$\text{SFDR (in 1 Hz BW)} = 2/3 \text{ (Input TOI - NF + 174) dB/Hz}$$

or

$$\text{SFDR (in 1 MHz BW)} = 2/3 \text{ (Input TOI - NF + 114) dB/MHz}$$

or

$$\text{SFDR (in 300 MHz BW)} = 2/3 \text{ (Input TOI - NF + 89.21) dB/300 MHz}$$

The input TOI is typically 8 to 10 dB higher than the input 1-dB compression point. In our SCMT-18G fiber optic links, the input 1 dB compression typically comes out to be about -13 dBm and the noise figure is about 17 dB at 15 GHz. Taking these numbers, the spur free dynamic range at 15 GHz comes out to be:

$$\text{SFDR (in 1 Hz BW)} = 2/3 \ (-3 - 17 + 174) = 102.67 \text{ dB/Hz}$$

or

$$\text{SFDR (in 1 MHz BW)} = 2/3 \ (-3 - 17 + 114) = 62.67 \text{ dB/MHz or}$$

$$\text{SFDR (in 300 MHz BW)} = 2/3 \ (-3 - 17 + 89.21) = 46.14 \text{ dB/300 MHz}$$

Once knowing the input 1-dB compression and the noise figure of a link, you can calculate the MDS and SFDR along the lines of the above calculation.

MINIMUM DETECTABLE SIGNAL (MDS)/MINIMUM INPUT POWER/SENSITIVITY CALCULATIONS

The Minimum Detectable Signal (MDS) “or” the Minimum Input Power “or” the sensitivity of the fiber optic link is a function of the receiver filter bandwidth and the noise figure of the link. The wider the filter bandwidth at the receiver end, the more thermal noise power will come through it. That in turn would raise the noise floor and make it less sensitive to weak signals.

The MDS or the minimum input power is calculated as:

MDS (at particular frequency for given bandwidth)

= kTB noise floor (given bandwidth) + NF of the Link (at frequency of interest)

where:

k = Boltzman Constant: 1.38e-23 J/K

T = Temperature in Kelvin

B = Receiver Bandwidth

NF = Noise Figure of the Link at that particular frequency of interest

The kTB noise floor is the theoretical minimum thermal noise floor that can be had for a given bandwidth and temperature. Hence for a given bandwidth at room temperature (290 deg Kelvin), the kTB noise floor (in dBm) calculates out to be:

kTB (in 1 Hz BW at room temp.) = 10 log (1.38e-23x290x1x1000) = -173.97 dBm

or

kTB (in 1 MHz BW at room temp.) = 10 log (1.38e-23x290x1e+6x1000) = -113.9 dBm

or

kTB (in 300 MHz BW at room temp.) = 10 log (1.38e-23x290x300e+6x1000) = -89.21 dBm

If the Noise Figure (NF) of the link is say about 17 dB at the frequency of interest (say at 15 GHz), then the MDS at 15 GHz for different filter bandwidths comes out to be:

MDS (in 1 Hz BW) = -173.97 dBm + 17 dB

= -156.97 dBm = Minimum Input Power Level for 1 Hz BW

MDS (in 1 MHz BW) = -113.9 dBm + 17 dB

= -96.9 dBm = Minimum Input Power Level for 1 MHz BW

MDS (in 300 MHz BW) = -89.21 dBm + 17 dB

= -72.21 dBm = Minimum Input Power Level for 300 Hz BW

What the above states is that if the bandwidth is 1 Hz, then any signal higher than -156.97 dBm would be detectable at 15 GHz. Similarly, if the bandwidth is 1 MHz, then any signal higher than -96.9 dBm would be detectable at 15 GHz. Similarly one can calculate the MDS at any frequency once knowing the noise figure at that frequency and the filter bandwidth.

Since the link has typically about +15 dB gain at the output, the output power level for the above minimum input signal levels would be:

Output Power for (MDS = -156.97 dBm in 1Hz BW)

= -156.97 dBm + 15 dB = -141.97 dBm

Output Power for (MDS = -96.9 dBm in 1 MHz BW) = -96.9 dBm +15 dB = -81.9 dBm

Output Power for (MDS = -72.21 dBm in 300 MHz BW) = -72.21 dBm +15 dB = -57.21 dBm

REVERSE ISOLATION

Reverse isolation simply defines the isolation between the input and output. It is tested by injecting a signal to the output port and measuring its level at the input. Since the optical transmitter and receiver pair are unidirectional, there is complete isolation in the reverse direction. There can be no flow of signal from a receiver to a transmitter as there is no light generated by the photodiode to transmit through the fiber toward the transmitter.

PHASE LINEARITY

A phase of a signal versus frequency will be distorted due to the nonlinear phase elements within the fiber link. This distortion is called phase linearity and is measured by means of a vector network analyzer across the operating frequency range.

PHASE NOISE

Phase noise is a measure of the stability of a reference frequency generated by a synthesizer as it passes through a fiber link. MITEQ fiber optic links have measured exceptionally well typically reading below 100 dBc at 1 Hz offset and below 120 dBc at 10 Hz offset from the carrier frequency.

PEAK WAVELENGTH

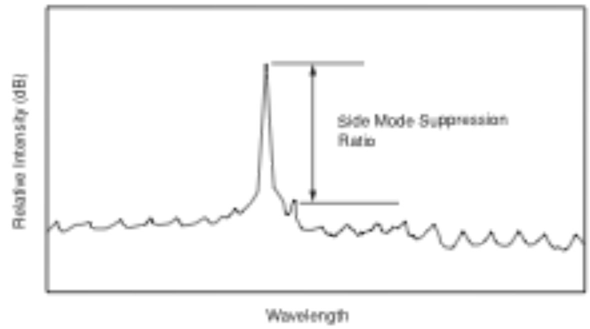
Peak wavelength is the wavelength at which the maximum intensity emission mode occurs at specified optical output power.

SPECTRAL WIDTH (-3 dB) OR FULL WIDTH HALF MAXIMUM (FWHM)

Spectral Width (-3 dB) is defined as the full width of the emission spectrum at half maximum of the peak spectrum intensity and at the specified optical output power. It is also known as FWHM or full width half maximum which translates into the full width of the spectrum at half its maximum power.

SIDE MODE SUPPRESSION RATIO (SMSR)

This parameter is the ratio of the intensity of the highest spectral peak to that of the second highest in the emission spectrum at a defined optical output power and under a defined modulation (or CW) as described in the graph.



RELATIVE INTENSITY NOISE (RIN)

RIN describes the instability in the power level of a laser. It can be generated from cavity vibration or fluctuations in the laser gain medium and is exacerbated with optical reflections into the laser cavity. RIN is plotted as a function of the frequency or as a function of the operating current and is defined by the following equation:

$$RIN = 10^{*}Log_{10} = \frac{[(Pn - Pno) / G^{*} Bn] - 2^{*} q < Iph > Zo}{I < Iph > 2^{*} Zo}$$

RF LOSS VS. OPTICAL LOSS (1 dB OPTICAL LOSS = 2 dB RF LOSS)

In fiber optic communications, every dB of optical loss translates into twice the RF loss. The reason is because a linear change in optical "power" generates a linear change in photo-"current" (not photo-"power"). In order to extract the power from the photodiode, this linear photo-"current" has to be "squared" using the load impedance into which it is delivered. In log terms this translates into doubling of gain or loss factor.

FIBER TYPES

MITEQ links are designed to be used strictly with single mode fiber which gives much stability and better bandwidth vs. distance performance. The variations within single mode fibers are commonly SMF-28 and LEAF fibers. The attenuation in fiber is typically 0.2 dB/km optical which translates into 0.4 dB/km RF loss. For longer distances and wider bandwidths (>10 GHz), LEAF fiber tends to deliver better flatness as chromatic dispersion at 1550 nm wavelength is significantly less (2 ps/nm.km) compared to 15 ps/nm.km for SMF-28. The SMF-28 is designed for zero dispersion at around 1310 nm.

OPTICAL CONNECTOR TYPES

Standard connector type is FC/APC. However, customer can specify any of the following: FC/PC,

E-2000, SC/APC, SC/PC, ST, LC, Green Tweed FC-DRY (weatherproof connector for weatherproof enclosures).

LASER MEAN TIME BETWEEN FAILURE

The lasers used in our SCML models are actively cooled and maintained at room temperature. Based on the accelerated aging data from the manufacturer and the bias operating parameters, the mean lifetime calculates out to about 140 years.