Optical ZONU

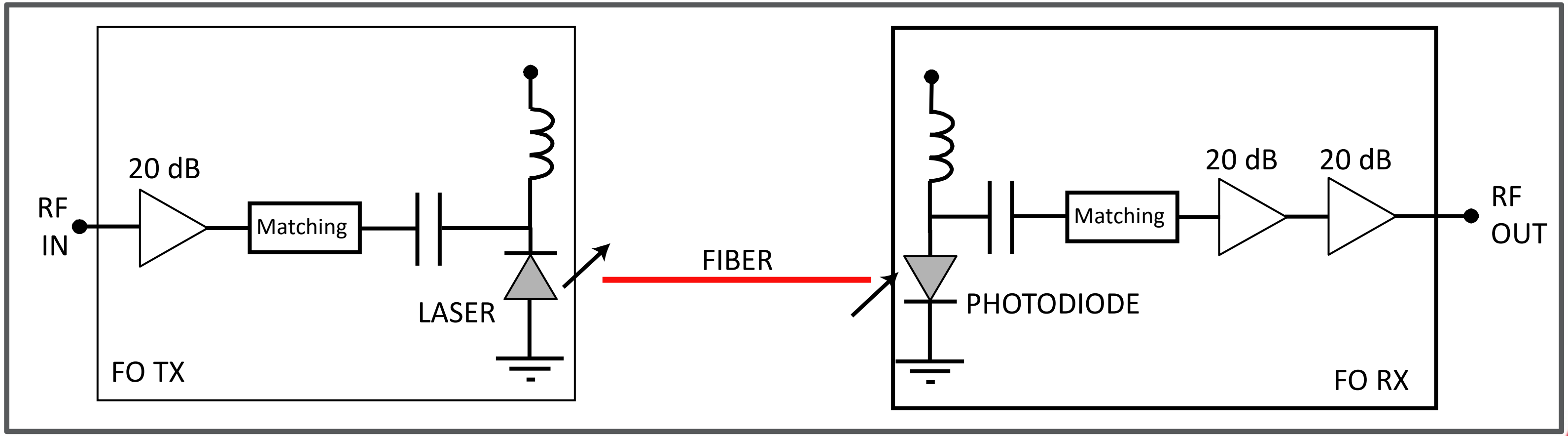
RFoF FUNDAMENTALS

- *RF-Over-Fiber Equivalent Circuit*
- *Gain*
- *Signal to Noise Ratio (SNR)*
- *Input Noise Density*
- *Noise Figure (NF)*
- *Input Intercept Point 3rd order (IIP3)*
- *SFDR Spurious Free Dynamic Range*
- *Signal Delay & Group Delay*
- *Phase Noise*

RF-Over-Fiber Equivalent Circuit

Fiber Transport is Analog RF-Over-Fiber

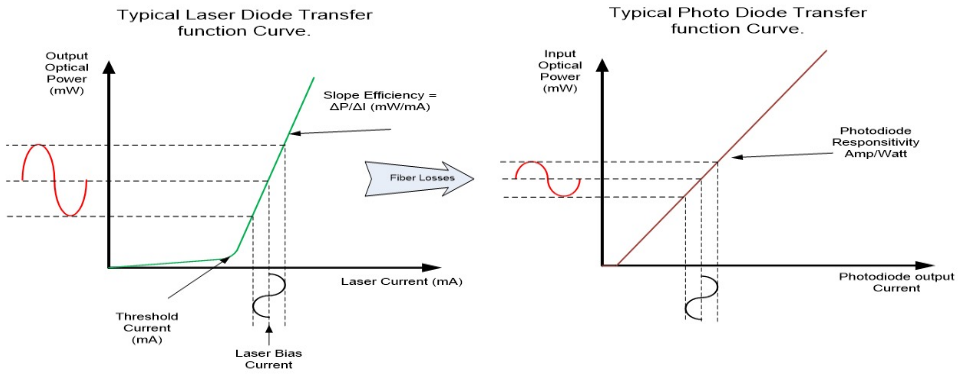
- RF Signal Amplitude Modulates Laser Light Output – Fiber Optic Transmitter (direct or external modulation)
- Photodiode Receiver detects modulated light and outputs RF Signal
- Fiber Optic Link – Laser Transmitter + Fiber + Photodiode Receiver
  - Standard RF specifications: Noise, Gain, Linearity
- Optimize Noise Figure, Gain, Output Power for Specific Applications with pre- and post amplifiers



Typical Example - OZ510

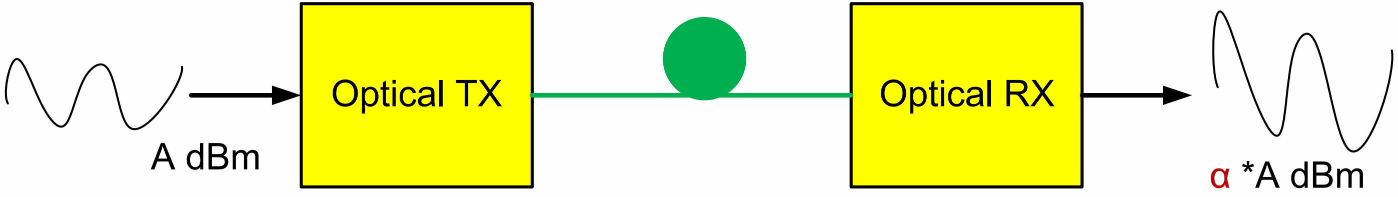
Spur Free Dynamic Range	SFDR		110		(dB/Hz) ⅔
Spur Free Dynamic Range (with LNA)	SFDR		109		(dB/Hz) ⅔
RF Link Gain		-1	+1	+3	dB
RF Link Gain (with LNA)		19	20	22	dB
Input Noise Floor Density @ 1 GHz	EIN		-134	-130	dBm-Hz
Input Noise Density @ 1 GHz (with LNA)	EIN		-154	-150	dBm-Hz
Input Third Order Intercept @ 1 GHz	IIP3	29	31		dBm
Input Third Order Intercept @ 1 GHz (with LNA)	IIP3	8	10		dBm
Group Delay TX/RX Link (electronics only)	GD		0.5	1	nS

Gain



RF Signal Input PK-PK Volts or power level in dBm

RF Signal Output PK-PK Volts or power level in dBm

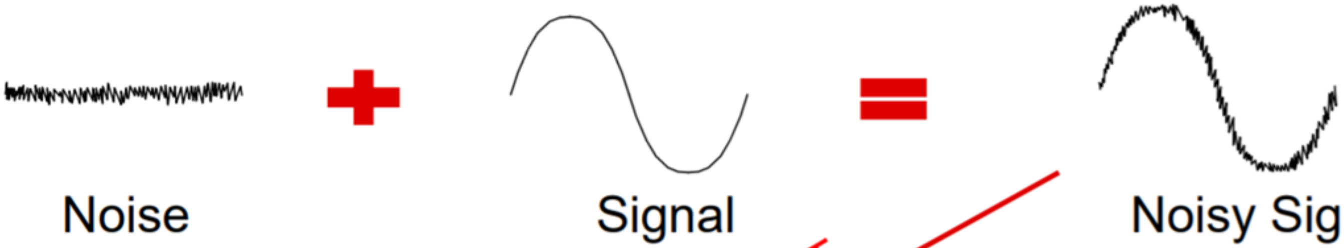


$$\text{Gain (linear)} = \frac{\alpha \text{ *A dBm}}{\text{A dBm}} = \alpha$$

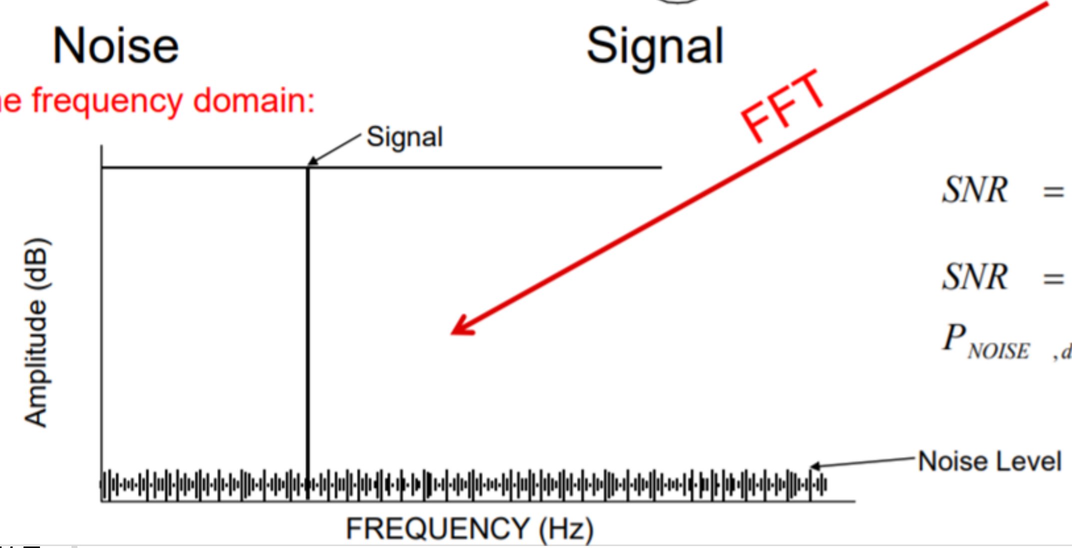
Gain (Log scale) = 10*LOG(α) in dB

Signal to Noise Ratio SNR

SNR is the ratio of the signal power to the noise power that corrupts the signal.



In the frequency domain:



$$SNR = 10 \log \frac{P_{SIGNAL}}{P_{NOISE}}$$

$$SNR = P_{SIGNAL,dBm} - P_{NOISE,dBm}$$

$$P_{NOISE,dBm} = 10 \log P_{NOISE,dBm/Hz} + 10 \log BW_{Hz}$$

Input Noise Density

Equivalent Link Input Noise Density (dBm-Hz), EIN is the amount of Noise at the input of the RFoF link measured in 1Hz bandwidth that produces output Noise Density (EON) measured in 1Hz bandwidth at the receiver end if the total link itself were Noiseless.

Minimum Noise In electronics is thermal Noise (KT) measured at Room Temperature approximately -173.8 dBm-Hz

Input Noise Density Relationship to **Noise Figure (NF).** Next Slide.

Input Noise Density = -173.8-NF dBm-Hz

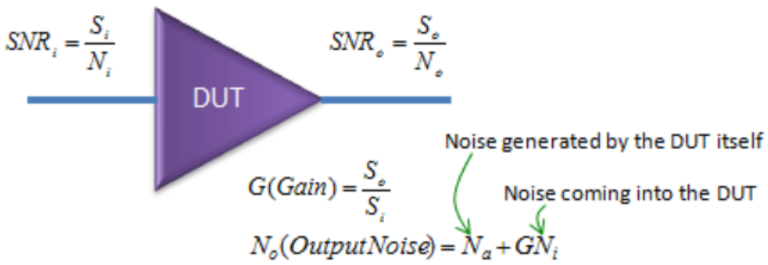
Noise Figure (NF)

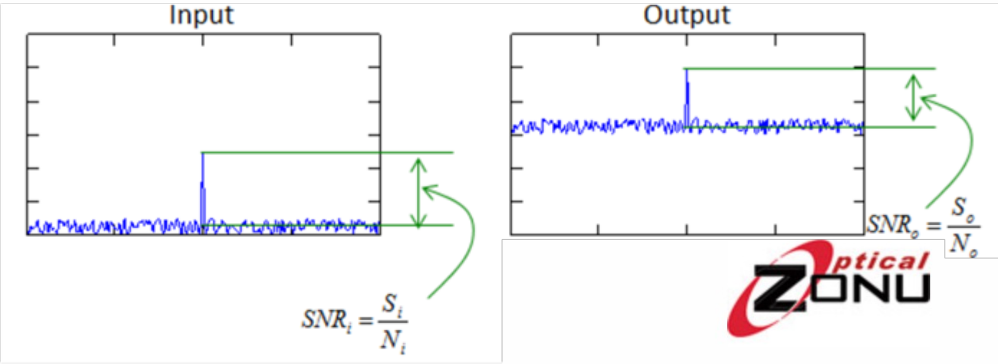
Noise Figure is the measure of degradation of the signal to noise ratio in a device. It is the ratio of the Signal to Noise Ratio at the input to the Signal to Noise Ratio at the output. Since the signal to noise ratio at the output will always be lower than the Signal to Noise ratio at the input, the Noise Factor is always more than 1. The Lower Noise Factors results in better performance of a devices.

$$\text{NF (linear)} = \frac{(\text{SNR input})}{(\text{SNR output})} > 1$$

NF (Log scale) = 10*LOG(NF) in dB

No Device is perfect, Signal to Noise ratio will degrade as signal pass through a Device, by added Noise..

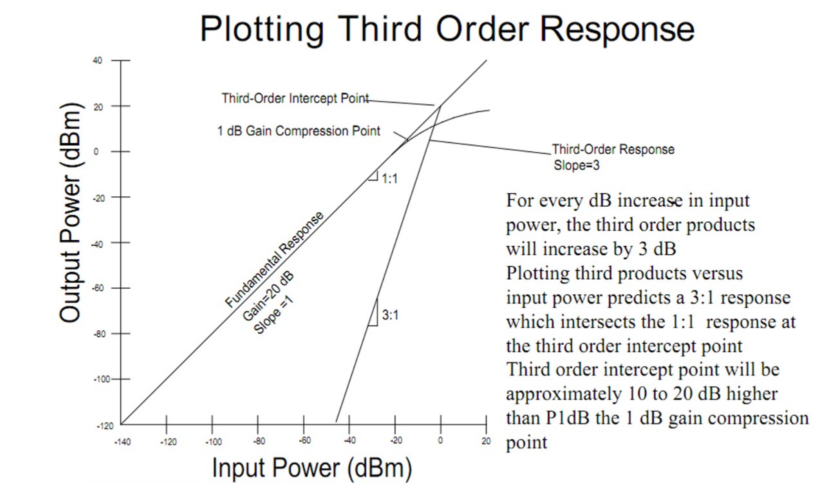


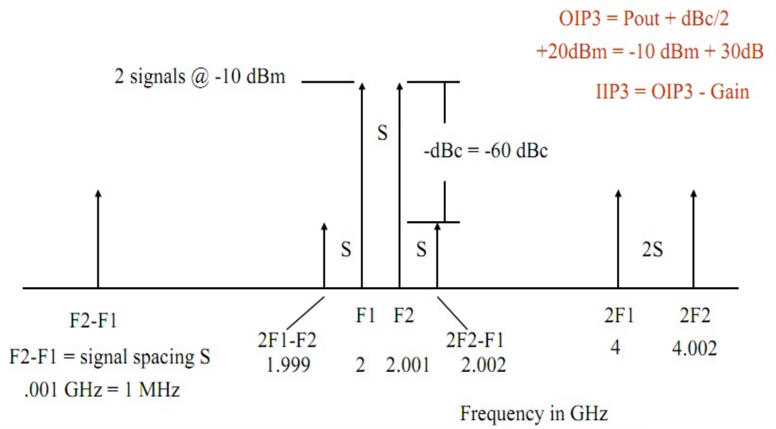


Input Intercept Point 3rd order (IIP3)

A Input third-order intercept point (IIP3) is a measure of nonlinearity of the RFoF link and where the 3rd order distortion power becomes equal to the main fundamental signal power. Although it's a extrapolated but critical parameter to calculate the overall Intermodulation distortion produced by the RFoF link.

IIP3 = OIP3 – Link Gain



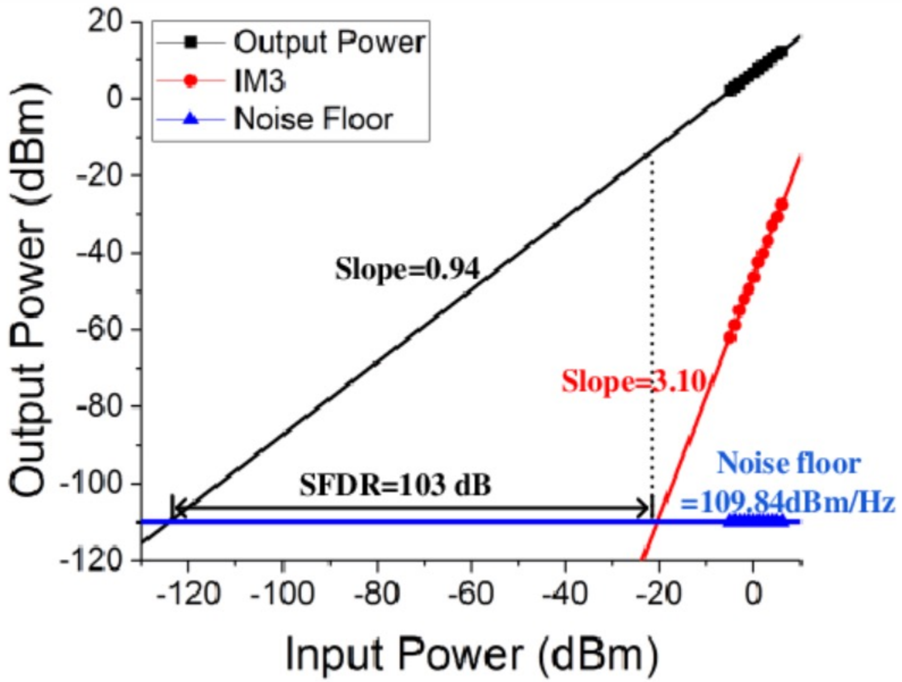


SFDR Spurious Free Dynamic Range

Spurious Free Dynamic Range (SFDR), is defined as the power level range of a pair of two input signals in which the two signals are above the noise floor and the 3rd order Intermodulation distortion products are below the noise floor. system This is the range of RFoF Link Able to detect the smallest signal (***a signal just above the noise level***), and the **largest signal** that can be introduced into a system without **creating detectable distortions** in the bandwidth of concern. The larger SFDR becomes the higher dynamic range, the RFoF link posses

SFDR = 2/3 x (IIP3 – EIN)

The 2/3 rate, is the difference between the slope of the output signal and distortion curves.



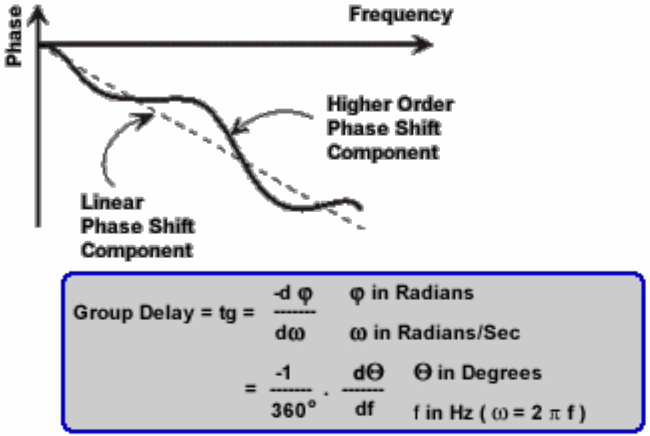
Signal Delay & Group Delay

Signal delay is:

- A measure of time delay of signal propagation.
- The transit time of a signal through a device, free-space, cable, fiber link, etc..

Group delay is:

- A measure of device phase distortion.
- The transit time of a signal through a device versus frequency.
- The derivative of the device's phase characteristic with respect to frequency.



Group Delay

Gain

https://en.wikipedia.org/wiki/Gain_(electronics)

Input Intercept Point 3rd order or IIP3

https://en.wikipedia.org/wiki/Third-order_intercept_point

Input Noise Density

https://en.wikipedia.org/wiki/Input_noise_density

Noise Figure or NF

https://en.wikipedia.org/wiki/Noise_figure

Signal to Noise Ratio

https://en.wikipedia.org/wiki/Signal-to-noise_ratio

Spurious Free Dynamic Range or SFDR

https://en.wikipedia.org/wiki/Spurious-free_dynamic_range

Group Delay

https://helpfiles.keysight.com/csg/pxivna/Tutorials/Group_Delay6_5.htm

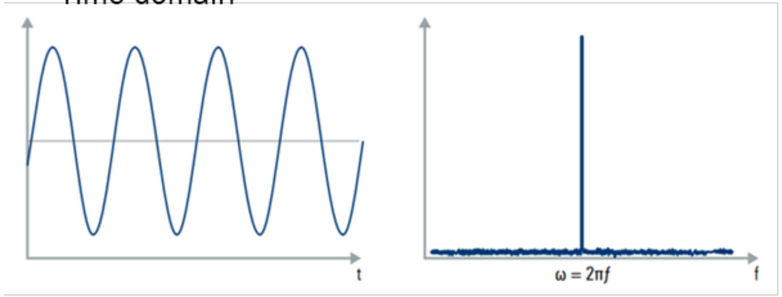
https://en.wikipedia.org/wiki/Group_delay_and_phase_delay

Phase Noise (1 of 2)

Highly stable clock sources at fixed frequencies are used in a wide range of applications, including frequency up-conversion and down-conversion in satellite ground stations. An ideal clock signal is a pure sinusoidal waveform.

Ideal Oscillator in Time domain

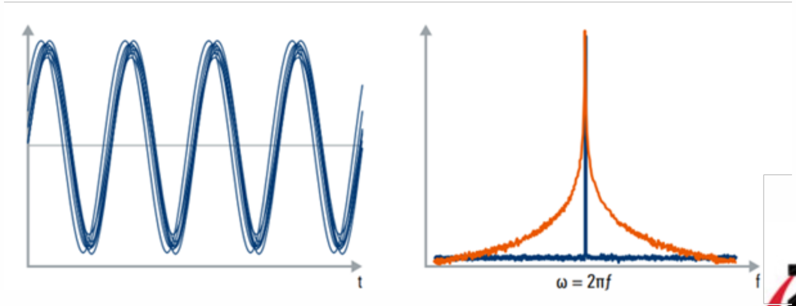
Ideal Oscillator in Frequency domain



A non-ideal clock source exhibits variations in both amplitude and phase over time. In the time domain, this instability is referred to as jitter, while in the frequency domain, it is known as phase noise—measured as frequency deviations relative to the carrier's center frequency.

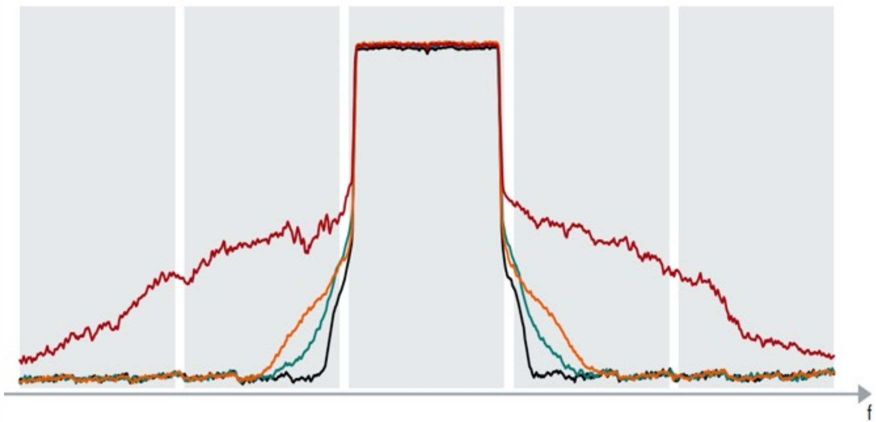
None-Ideal Oscillator in Time domain

None-Ideal Oscillator in Frequency domain

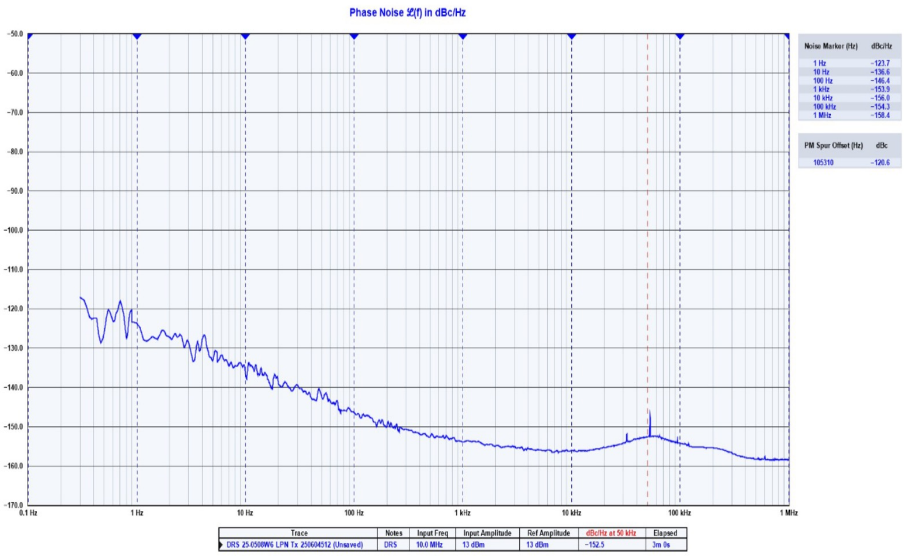


Phase Noise (2 of 2)

The importance of low phase noise becomes especially evident when using a low-jitter clock in ground station systems for the down-conversion and up-conversion of satellite signals. Supplying a clean, low phase noise clock is critical for accurate frequency conversion. Excessive phase noise can lead to several performance issues, including spectral regrowth, reduced sensitivity, lower signal-to-noise ratio (SNR), and increased bit error rates. An example illustrating these effects is shown below.



Example of Phase noise Plot measurement of Optical Zonu RFoF link measured using Microchip 53100A which is a phase noise analyzer designed for measuring the stability of RF sources.



Thank You!