Excess power and its effects on WaveAnalyzer 1500S measurements

The WaveAnalyzer 1500S is capable of measuring spectral power densities as high as 0 dBm/150 MHz and is also sensitive enough to detect signals as low as -85 dBm/150 MHz. This is achieved through two input ports: the Normal port, for use with most signals; and the High Sensitivity Port, a more sensitive port better suited for use with lower signal strengths. To make full use of this capability, the maximum spectral power density and total optical power specifications should be considered when choosing the most appropriate port for your measurement.

This article explores the detrimental effects that arise when excess power enters into the WaveAnalyzer 1500S.

Units

The numerical values associated with the trace data from an OSA measurement (i.e. y-axis units) are typically measured in dBm within a certain bandwidth. For example, a WaveAnalyzer 1500S measurement will be returned in units of dBm within the native bandwidth of 150 MHz, and is written dBm/150MHz. This is a measurement of spectral power density and can thought of as the amount of optical power lying within a 150 MHz bandwidth. It's worth noting that the frequency bandwidth component of the unit is almost always omitted on OSA displays, and in academic literature. But it is included in this article to provide clarification.

Under-reported power through excess spectral power density

Avoiding excess spectral power density is crucial for taking accurate optical measurements with the WaveAnalyzer 1500S. When exceeded, saturation effects in the detection system produce power non-linearities causing power values to be reported as lower than their true value. This effect is shown in the following figures:

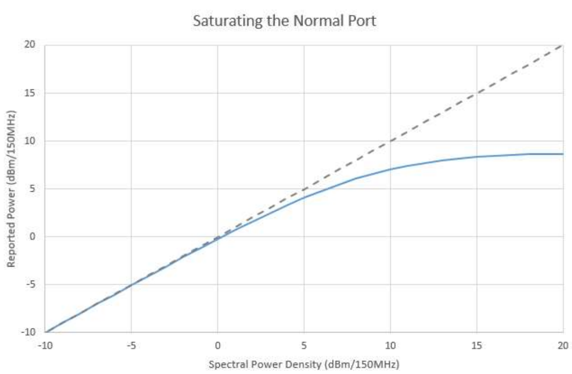


Figure 1: Saturation of the normal port from excess spectral power density

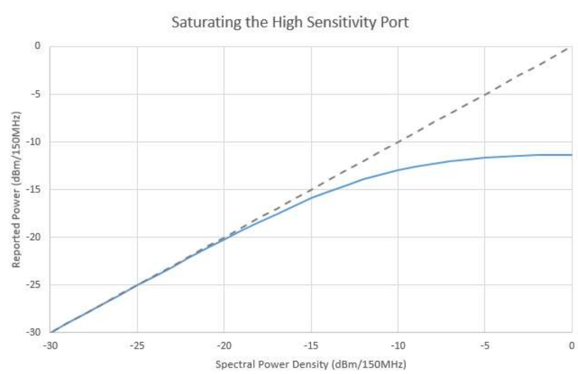


Figure 2: Saturation of the high sensitivity port from excess spectral power density

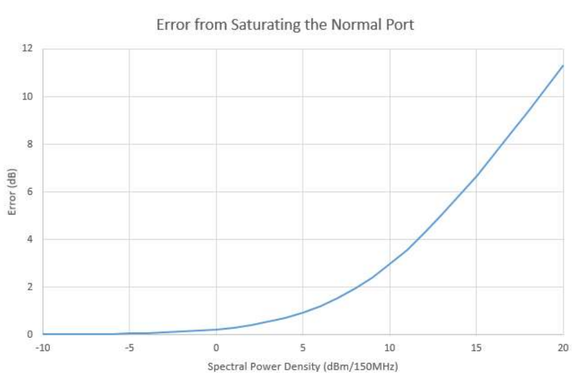


Figure 3: Error due to saturation of the normal port from excess spectral power density

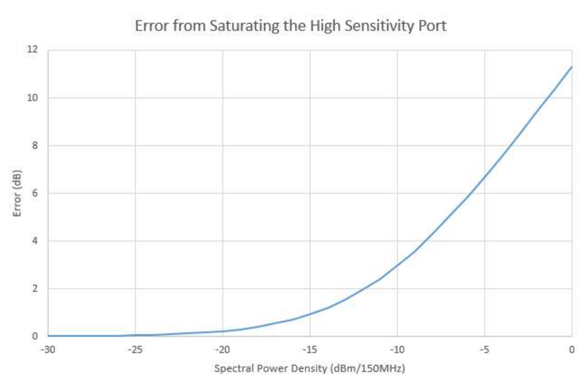


Figure 4: Error due to saturation of the high sensitivity port from excess spectral power density

Figures 1 and 2 show how with increased spectral power density, the reported power rolls off progressively until reaching full saturation after around 20 dB of excess power. This is translated in to power error shown in the figures 3 and 4. Please note that these curves in Figures 1 to 4 are meant as a guide and actual curves may vary from unit to unit.

The following table below summarizes the recommended maximum spectral power densities for each port:

Input Port	Maximum Spectral Power Density (dBm/150MHz)
Normal	0
High Sensitivity	-20

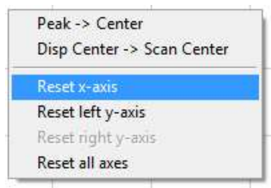
Table 1: Maximum spectral power densities for the Normal and High Sensitivity ports.

Figures 1-4 and Table 1 above show that it is important to make sure your measurement remains below the saturation threshold of 0 dBm/150MHz for the Normal port and -20 dBm/150MHz for the High Sensitivity port.

Avoiding Excess Power Spectral Density

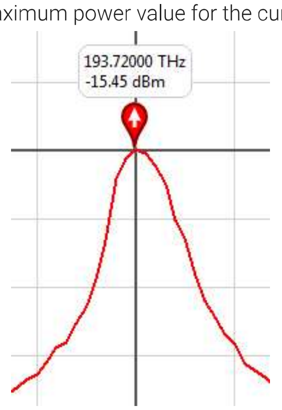
A good way of determining if your signal is exceeding this requirement is to simply take note of the maximum power value for a given trace via the Peak Marker feature:

1. Set your WaveAnalyzer with a resolution of 150 MHz (or 1.2 pm in wavelength units) via the Resolution Bandwidth drop-down menu under the display section.
2. Right-click the graph area and select Reset x-axis:



3. Click the Show Peak Button in the Button Bar on the right side. This will display a peak marker on the currently selected trace:

4. A peak marker will appear showing you the maximum power value for the current trace:

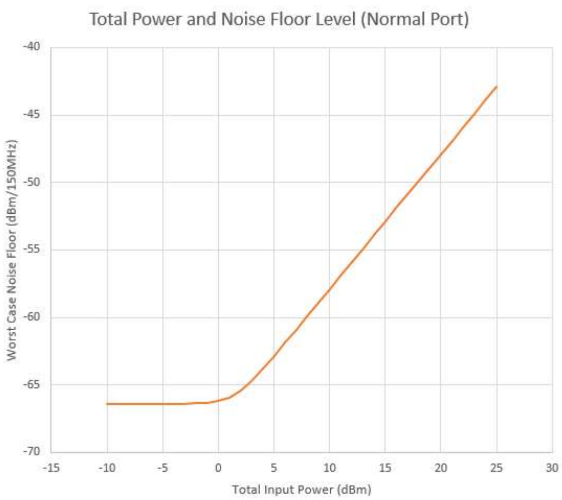


Since the resolution bandwidth is configured to 150 MHz, this indicates in the above case the highest spectral power density for this signal is -15.45 dBm/150 MHz. This result suggests that using Normal port would be the most appropriate port to take this measurem

Increased noise floor from excess total power

An excessive amount of total signal power entering in the WaveAnalyzer causes the noise floor to rise up. This increase is due to the appearance of a spurious broadband signal across the entire spectrum, whose strength depends linearly on the total input power.

This effect should be considered when taking measurements, particularly those that depend on accurate lower power measurements, since it has a detrimental impact on power linearity. The figures below summarizes this effect for the Normal and High Sensitivity ports:



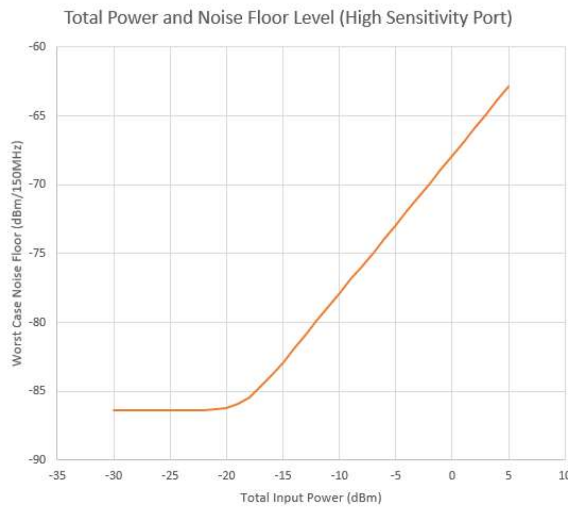


Figure 5: Saturation of the normal port from excess spectral power density

Figure 6: Saturation of the high sensitivity port from excess spectral power density

They show that for noise floor for the High Sensitivity port rises after the total input power begins to exceed -20 dBm/150 MHz. this is likewise true for the Normal ports for total powers exceeding 0 dBm/150MHz. Please note that these curves in Figures 5 and 6 are meant as a guide and actual curves may vary from unit to unit. The following table summarises the above:

Input Port	Recommended Total Power (dBm)	Maximum Power (dBm)
Normal	0 dBm	23 dBm
High Sensitivity	-20 dBm	3 dBm

Table 2: Recommended and maximum total powers for the Normal and High Sensitivity ports

The recommended total power differs from the instrument's maximum power specification, which denotes the maximum power that is safe to put into the WaveAnalyzer without risk of damage. It is safe to exceed the recommended total power although its effect on the noise floor should be considered. Some use-cases involve using the Normal port to measure fully-loaded channel plans with total powers exceeding 20 dBm, in cases like this the total power **must not exceed 23 dBm to avoid permanent damage to the unit.**

Impact on Measurements

Excess input power into the WaveAnalyzer 1500S reduces its performance for almost all major specifications including: absolute and relative power accuracy, power linearity, polarization dependent responsivity, Close-in dynamic Range etc. The following is an analysis on how excess power can detrimentally impact OSNR measurements.

OSNR Measurements of Saturated Signals

With excess power, OSNR measurements will typically be reported as lower than the true OSNR value. Consider the measurement of a modulated signal using the High Sensitivity port of the WaveAnalyzer 1500S as depicted in the figure below:

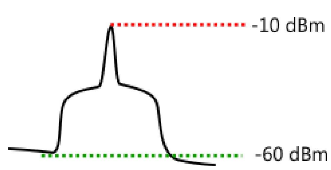


Figure 7: Example OSNR measurement. The red line denotes the maximum spectral power density of the signal. The green line denotes the spectral power density of the noise.

The total power of the signal is -9 dBm, with the majority of the power lying within the carrier with a peak spectral power density of -10 dBm/150MHz. Noise due to stimulated emission sits around -60 dBm/150 MHz or equivalently around -41 dBm normalized to a 0.1 nm integration window. The OSNR for this signal is then approximately 32 dB.

The Table 2 indicates that both the spectral power density and the total power of this signal are too high for measurement using the High Sensitivity port. Let's consider what happens numerically when we take an OSNR measurement of this signal using the High Sensitivity Port.

Spectral Power Density

From the above figure, we can see that the excess power causes a saturation effect causing the *signal power to be measured lower by about 3 dB.*

Excess Total Power

The above figure shows that a total signal power of -10 dBm will raise the instrument noise floor up to about -77 dBm/150 MHz or -58 dBm normalized to a 0.1 nm integration window. This contributes as an error to the noise measurement but since this error is 18 dB lower than the signal noise we can expect to see the *noise power to be measured higher by about 0.07 dB.*

This will then result in an OSNR value of around 29 dB instead of the true OSNR value of 32 dB, with most of the error due to the effect of excessive spectral power density.

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