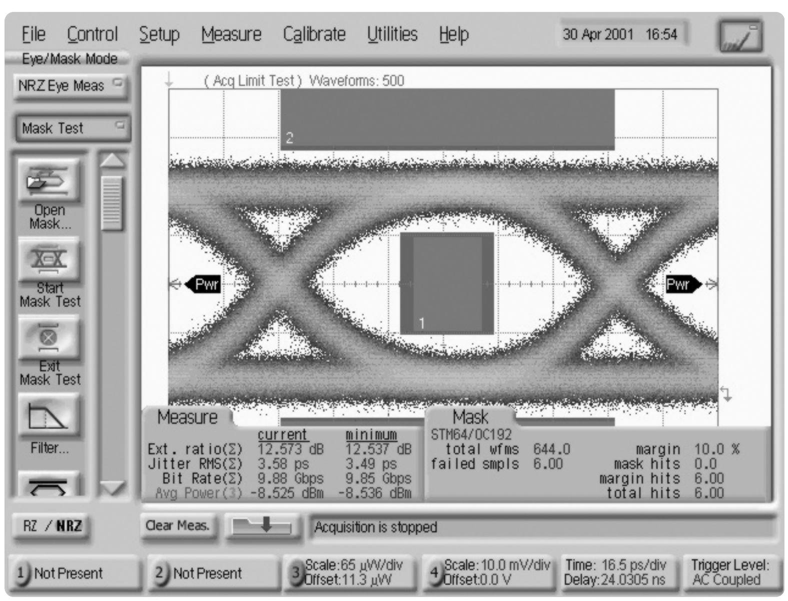
Defining Measurement Sensitivity of the Agilent 86100A Infiniium DCA

Product Note 86100-5



Agilent Technologies

Defining Measurement Sensitivity of the Agilent 86100A Infiniium DCA

The main specification that determines the sensitivity of the Agilent 86100A Infiniium DCA (digital communications analyzer) is the inherent noise level of the specific 86100 plug-in module. For example, the noise specification for the optical channel of the Agilent 86105A plug-in module is 12 µW rms (root mean square), and typical performance is less than 8 µW rms. This can be shown in Figure 2 that was generated directly on the 86100A system.

There are different types of noise sources within a plug-in module. There is noise from the optical detector, from the electronic sampling circuit, and from the electrical amplifier. With all other things being equal, let's consider the optical detector noise. There are three distinct noise sources within the detector; 1/f noise, generation-recombination noise and thermal noise. The Johnson noise voltage is dominant at higher frequencies and is defined as:

$$V_{noise} = \sqrt{4krT\Delta F}$$

where k = Stefan-Boltzmann constant
r = resistance
T = temperature
ΔF = noise equivalent bandwidth (NEQBW)

In other words, the noise of the detector is directly proportional to the square root of the bandwidth. This is one reason why wider bandwidth modules tend to have more noise.

The measurement in Figure 2 shows the instrument display with no signal applied and the compliant fourth order Bessel-Thompson filter turned on. A histogram is constructed to document both the rms and peak-to-peak levels of the internal noise, which are 8.9 µW and 71.5 µW respectively.

A second plug-in module, the Agilent 86103A, also has an optical input, but has an internal amplifier following the photodetector. Hence it has a reduced noise level of 2 µW rms, typically less than 1.5 µW rms. The plot in Figure 3 shows this.

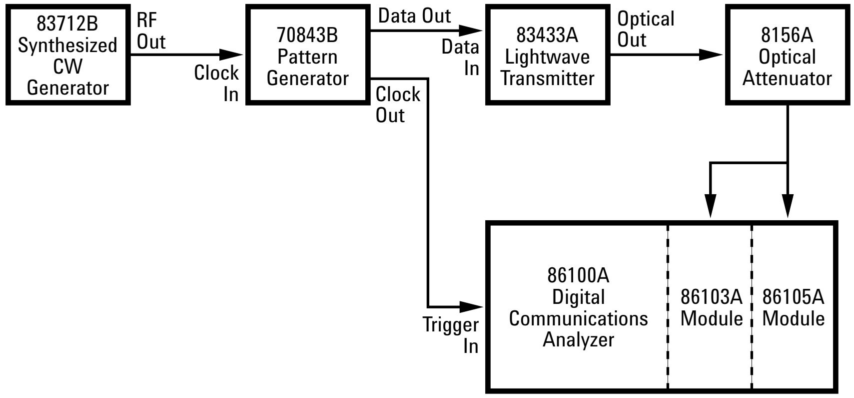


Figure 1. Functional block diagram of DCA sensitivity test set

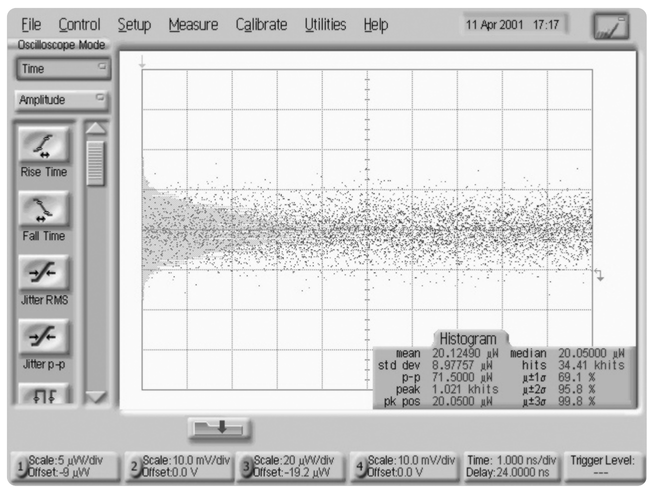


Figure 2. Noise histogram of the 86105A optical channel

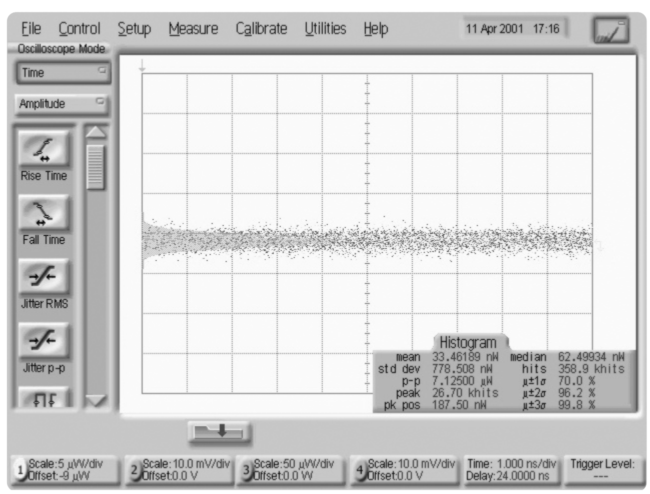


Figure 3. Noise histogram of the 86103A optical channel

The plug-in module noise performance alone does not directly indicate the smallest signal that can be measured by the 86100A. In essence, the issue is one of signal-to-noise ratio (SNR) and its effect on measurement accuracy. Certain measurements require high SNR's, while others do not.

The most common measurement performed with the 86100A is of eye diagrams. This can be further broken down into parametric characterization of the eye and mask testing. Eye parameters include measurements such as extinction ratio, jitter, and eye width. Mask testing is a test methodology that is used to quantify the optical transmitter performance parameters.

Figure 4 shows an example of automatic parametric characterization of a laser transmitter operating at a 2.488 Gb/s data rate measured using the 86105A plug-in module.

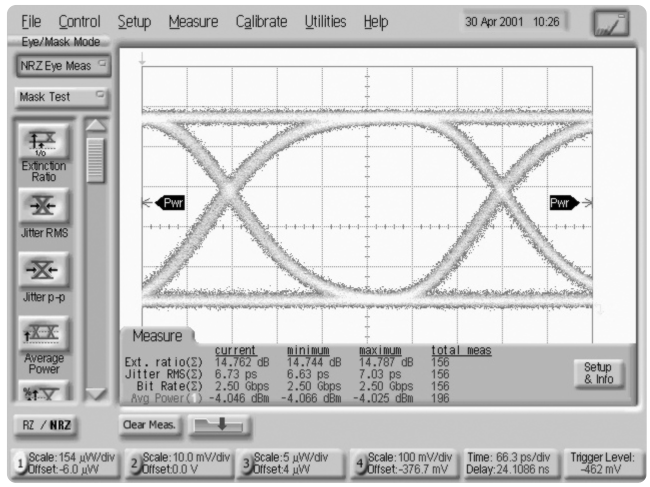


Figure 4. Parametric characterization of a laser transmitter modulated at 2.488 Gb/s

The average power is shown to be –4 dBm with a 14 dB extinction ratio. Jitter and eye width are also shown.

A mask test in Figure 5 is also performed on the same transmitter.

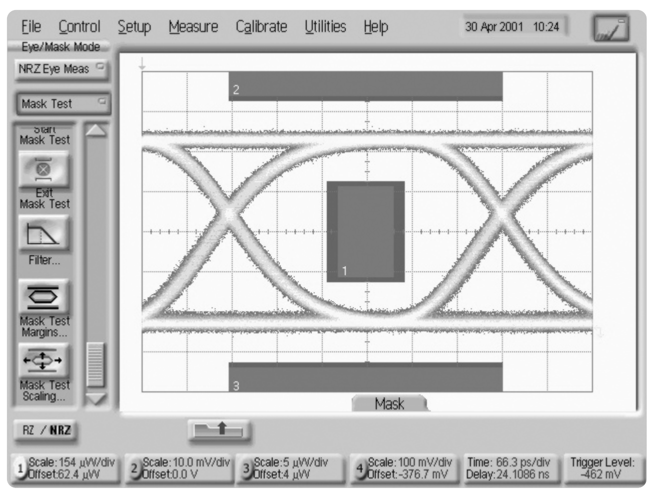


Figure 5. Mask compliance test of laser transmitter

The mask test is a standards-based test that defines the shape of the eye by defining regions where the waveform may not exist. This mask is comprised of three distinct polygons, inside, above, and below the eye. In this example, there are no mask violations or "hits" inside any of the mask polygons.

A novel feature called mask margin testing has been employed in this measurement. Mask margin testing adds an additional margin or "cushion" to the standard mask. This is sometimes helpful when trying to determine how close a transmitter is to an actual mask failure.

Margin testing provides information that is important in evaluating the level of performance of a transmitter in a high-volume manufacturing environment. Statistical failure analysis can be done for specific transmitter designs to reduce test time. By looking at margin hit frequency over long periods of time, actual mask hit failures can be predicted within a shorter period of time. This reverse time extrapolation can significantly reduce transmitter test costs.

Parametric Measurements of the Eye

Parametric eye measurements such as extinction ratio are based on histogram measurements of the waveform data, similar to the previously displayed histogram analysis of noise levels. For example, extinction ratio is the ratio of the mean ‘1’ level to the mean ‘0’ level of the eye diagram. Jitter is derived from a histogram constructed at the eye crossing point from which both rms and peak-to-peak values may be derived.

Measurements based upon mean values of histograms tend to be more tolerant of low SNR’s. This is true of extinction ratio measurements. The histogram effectively extracts the signal from the noise. Jitter on the other hand is a measure of the spread of the histogram constructed at the crossing point. As the SNR drops, noise will make a larger contribution to the histogram and cause the apparent jitter to increase.

The measurements in Figures 6 through 8 are made on the previously mentioned laser transmitter. The eye measurements are made using the Agilent 86105A optical plug-in module while sequentially decreasing the laser power with an external attenuator from the original value of –4 dBm to –15 dBm.

In the measurement using the 86105A in Figure 4, with the average power at –4 dBm, the rms jitter is measured at 6 ps. The extinction ratio is 14 dB. These will be used as the baseline values for comparison as the power level is reduced.

With the power reduced to –10 dBm, the extinction ratio is measured at 12.1 dB. This is results in a 16% difference (in linear terms) from the –4 dBm measurement. The jitter is measured at 11.4 ps, for a 90% difference relative to the –4 dBm power measurement.

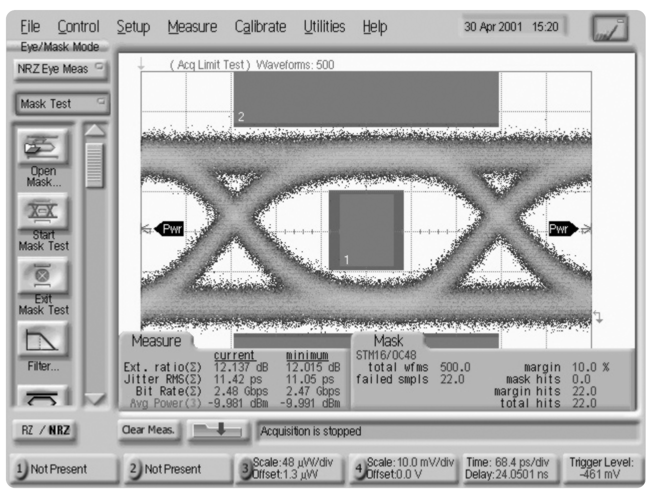


Figure 6. Mask compliance test for transmitter power at –10 dBm using the 86105A

The measurements are repeated for average power levels of –13 dBm and –15 dBm:

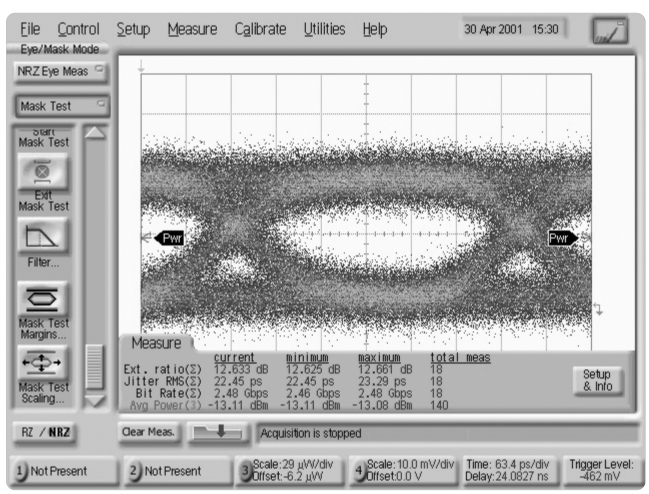


Figure 7. Eye diagram for transmitter power at –13 dBm using the 86105A

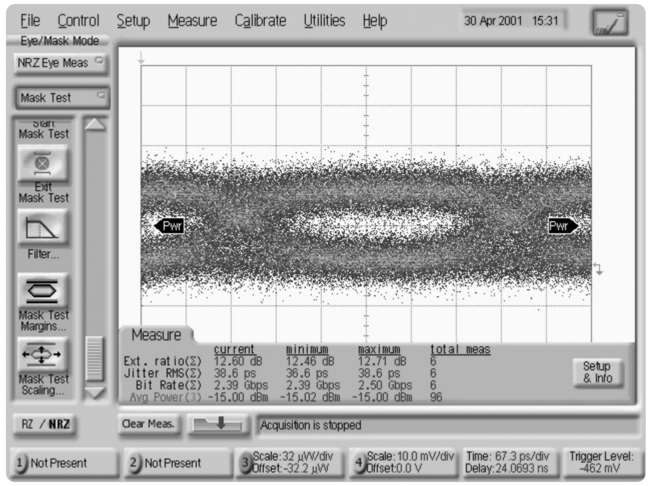


Figure 8. Eye diagram for transmitter power at –15 dBm using the 86105A

The measurement results for the 86105A are summarized in Table 1.

Table 1. Power versus extinction ratio using the 86105A

Power (dBm)	E.R. measured (dB)	Delta %
–4	14	—
–10	12.1	16
–13	12.6	11
–15	12.6	11

Power (dBm)	Jitter rms (ps)	Delta %
–4	6	—
–10	11.4	90
–13	22.45	374
–15	38.6	643

As expected, the extinction ratio measurement is very robust in the presence of noise, whereas the jitter measurement is degraded for signal levels below –10 dBm.

The measurement set is repeated using the 86103A module in Figures 9 through 14. The analysis begins at a –10 dBm power level, as the noise level of this plug-in is much lower than the 86105A. This laser transmitter is modulated at 1.063 Gb/s.

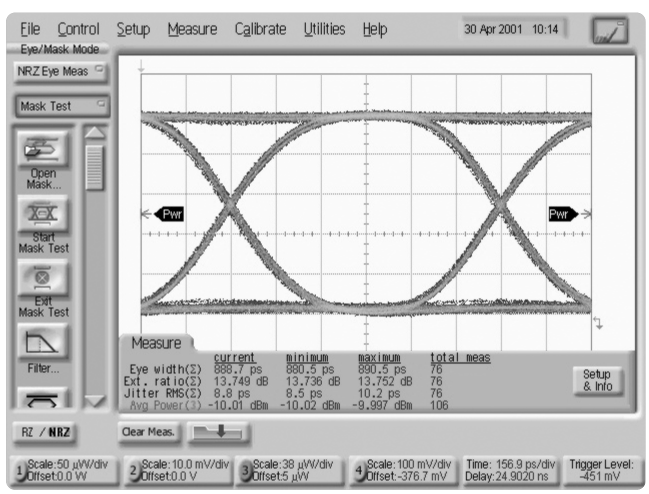


Figure 9. Eye diagram for transmitter power at –10 dBm using the 86103A

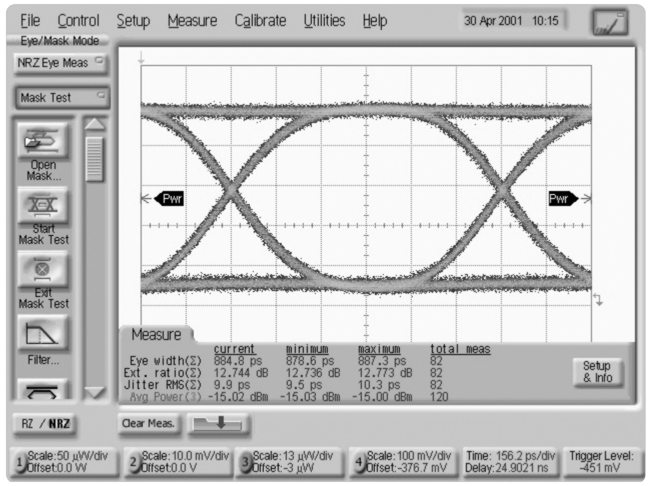


Figure 10. Eye diagram for transmitter power at –15 dBm using the 86103A

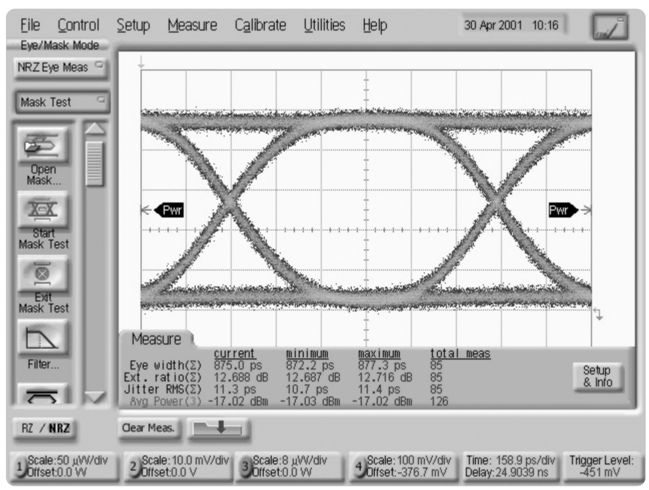


Figure 11. Eye diagram for transmitter power at –17 dBm using the 86103A

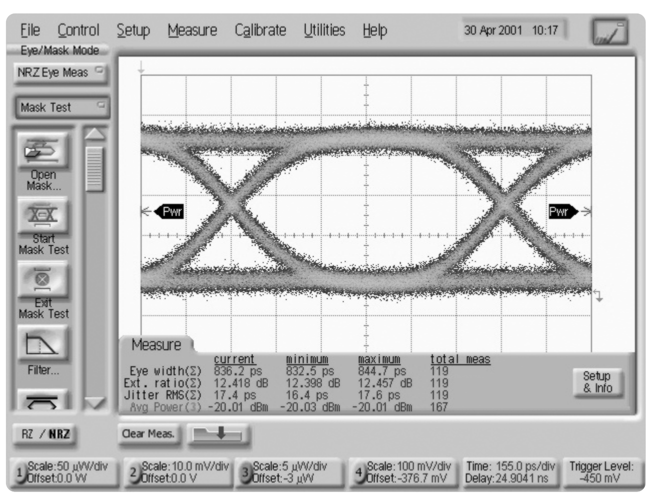


Figure 12. Eye diagram for transmitter power at –20 dBm using the 86103A

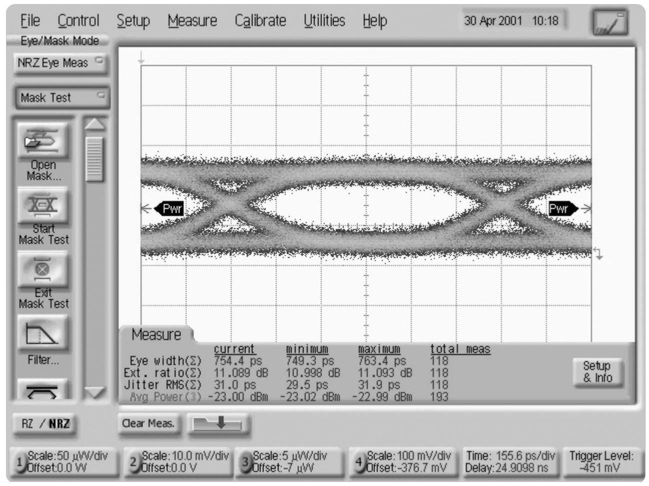


Figure 13. Eye diagram for transmitter power at –23 dBm using the 86103A

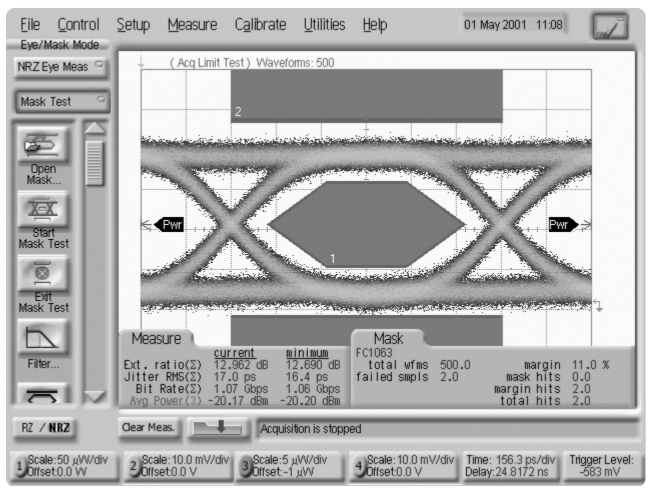


Figure 14. Eye diagram for transmitter power at –20.3 dBm using the 86103A

The measurement results for the 86103A are summarized in Table 2.

Table 2. Power versus extinction ratio using the 86103A

Power (dBm)	Extinction ratio (dB)	Delta %
–10	13.7	—
–15	12.7	8
–17	12.9	6
–20	12.4	10
–23	11.1	23

Power (dBm)	Jitter rms (ps)	Delta%
–10	8.8	—
–15	9.9	13
–17	11.3	28
–20	17.4	98
–23	31	352

While the extinction ratio measurement is stable to levels as small as –23 dBm, the jitter measurement degrades significantly for power levels below –17 dBm.

Mask Measurements

Mask measurements are straightforward to analyze in terms of what signal level can be measured accurately. In a mask measurement the eye mask is positioned relative to the mean high and low levels and the crossing points of the eye. If the transmitter signal strength is reduced, the magnitude of the mask polygons are scaled down and positioned accordingly. However, it should be apparent that as the power of the transmitter signal is reduced, eventually the noise level of the measuring instrument will be large enough to cause mask violations. At what transmitter power does this occur? This is shown in the following measurement set with the Agilent 86105A.

The first measurement in Figure 15, using the Agilent 86105A, is with a –9 dBm average transmitter power. The extinction ratio is 13.9 dB. For 500 waveforms, no mask violations are detected.

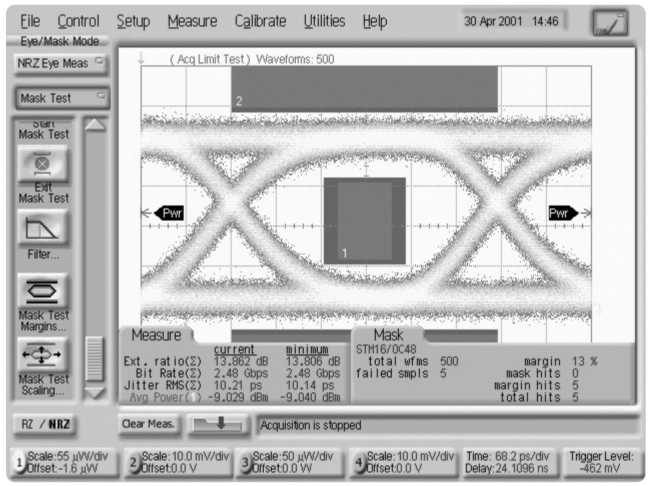


Figure 15. Eye diagram mask test for transmitter power at –9 dBm using the 86105A

When the transmitter power is reduced to –10 dBm, the threshold of mask violations is crossed as 7 sampled points fall within the OC-48 compliant mask:

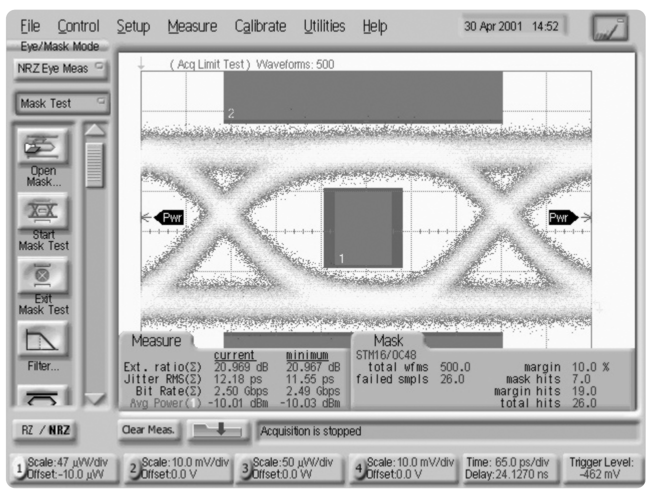


Figure 16. Eye diagram mask test for transmitter power at –10 dBm using the 86105A

For the Agilent 86106B, the analysis begins at a power level of –4 dBm:

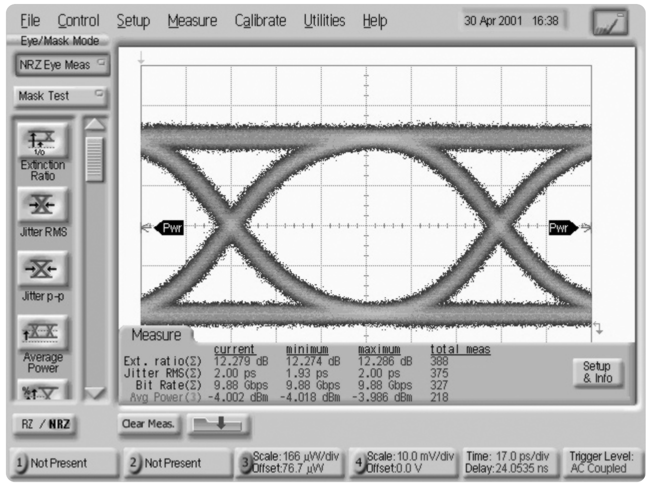


Figure 17. Eye diagram for transmitter power at –4 dBm using the 86106B

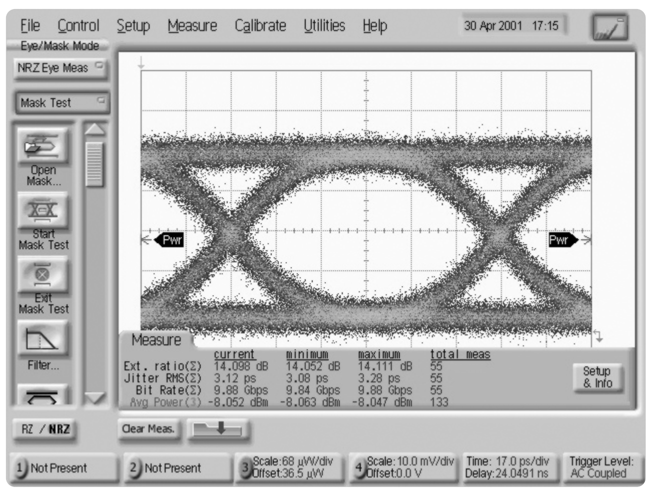


Figure 18. Eye diagram for transmitter power at –8 dBm using the 86106B

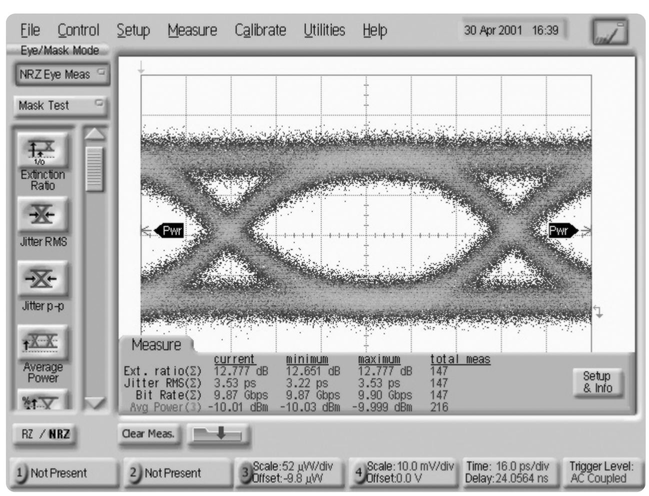


Figure 19. Eye diagram for transmitter power at –10 dBm using the 86106B

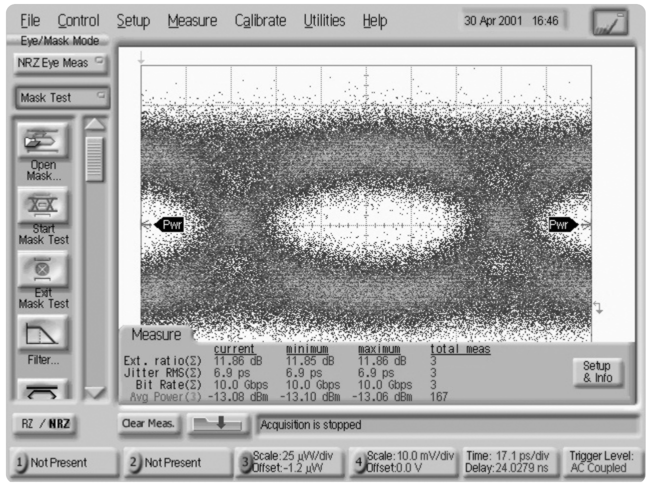


Figure 20. Eye diagram for transmitter power at –13 dBm using the 86106B

The threshold of no mask violations occurs at a –8.5 dBm average power, as seen in Figure 21.

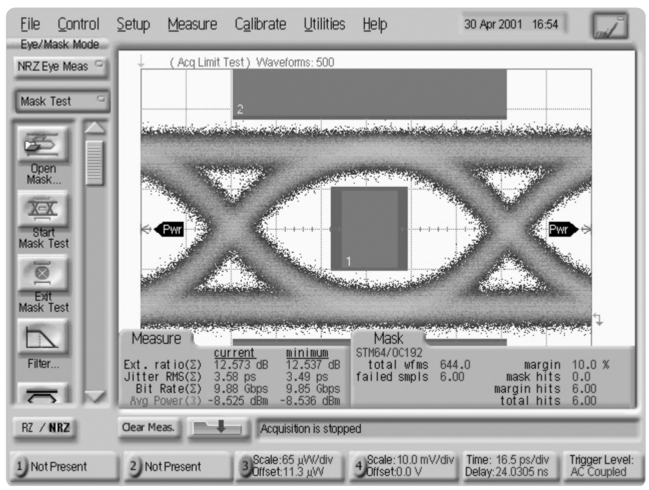


Figure 21. Eye diagram mask test for transmitter power at –8.5 dBm using the 86106B

Summary

Optical modulation characteristics of a laser source can readily be obtained by a digital communications analyzers equipped with the appropriate plug-in modules. As an optical transmitter's average power is reduced, there becomes a point where a plug-in module will yield compliant mask failures. This average power threshold is sometimes referred to as the plug-in module's sensitivity. Table 3 summarizes the data gathered for the plug-in module sensitivity tested in this experiment:

Table 3. Sensitivity summary

Plug-in Module	Sensitivity
86103A	–20 dBm
86105A	–9.0 dBm
86106B	–8.5 dBm

In conclusion, the "smallest measurable signal" depends upon what is to be measured. For extinction ratio measurements, the Agilent 86103A is useable to –23 dBm, the Agilent 86105A to –15 dBm, and the 86106B to –13 dBm For many other measurements, in particular mask testing, the Agilent 86103A is usable to –20 dBm, the Agilent 86105A to –9 dBm and the Agilent 86109B to –8.5 dBm.

As extinction ratios are reduced, the effective signal to noise is degraded. If the modulation power (and hence the extinction ratio) is low, then higher average powers will be required for good measurement accuracy.

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