Extinction ratio (ER) is among the most common optical measurements, yet it’s often misunderstood or misapplied. Perhaps one reason is that while the formula for the extinction ratio has not changed, the conditions of its use have changed significantly. The formula below applies to both non-return-to-zero (NRZ) and return-to-zero (RZ) signal formats:

$$ER_{\text{dB}} = 10 \log_{10} \left( \frac{\text{high}}{\text{low}} \right)$$

But what are the definitions of “high” and “low” levels? Initially, the statistical mode of the whole signal was used for each term. Later, this was refined to include only the mode value within a restricted aperture of the unit interval (UI). For NRZ signals, this aperture width is 20% of a UI, whereas for RZ signals, the aperture width is only 5% of a UI.

The optical community soon noted that using the mode value alone could cause erratic results when there were multiple modal peaks. To remedy this problem, ER measurements now use the arithmetic mean of the signal to determine the high and low values. The ANSI TIA/EIA-526-4A standard prescribes this methodology. A high-bandwidth sampling oscilloscope fitted with an optical-to-electrical converter and optical reference receiver (ORR) is the accepted tool for ER measurements. The ORR improves repeatability among instruments by controlling the signal harmonics, which has a negligible effect on the accuracy of the ER measurement and is small because most of the values contributing to the mean come from pulses that have settled for one UI or more.

### RZ changes the big picture

In general, 40 Gb/s data rates benefit from RZ formats, which impacts the ER measurements. Fast RZ signals have no settled high-level trajectories, such as those in an NRZ 1111 pattern. The high value is built entirely from transitions (see figure). As a result, the frequency response of the ORR now strongly influences all of the data measurements at high level. Measurements of RZ signals performed with and without an ORR show significant differences. Unfortunately, in contrast to the NRZ realm, no industry standard currently exists for the characteristics of ORRs used in making RZ measurements.

Equally important, the architecture of the evolving 40 Gb/s designs affects the usage of ER measurements. Many 40 Gb/s transmitters achieve the needed data rate by combining several slower data streams—for example, multiplexing four channels at 10 Gb/s. The resultant data stream often exhibits a sub-harmonic periodicity. In an ideal sampling oscilloscope triggered by a 40 Gb/s clock, this periodicity would not be apparent, as the sub-harmonics would randomly overlap; in the real world, however, the trigger signal is usually a sub-clock (e.g., 10 GHz). The trigger circuits of the oscilloscope typically have a bandwidth of about 3 GHz, which is too low to trigger on 10 GHz. To trigger on a 10 GHz sub-clock, you should use a pre-scaler trigger input, which divides the input trigger signal by a scale factor of eight so that the acquisition triggers on the 32nd sub-harmonic of the fundamental (40 GHz) and therefore remains stable with respect to the fourth sub-harmonic component created by the four-way multiplexing.

If this stability is a desired feature of your measurement need, then the result you get is good. If it is undesirable and you need a single all-inclusive result that is a composite of all contribution streams, there are several possible approaches you can take. One approach, practical if your data stream contains a small number of phases, is to measure all existing phases and average the result from all measurements. Another simple method that will yield an unbiased composite result is to re-position the signal through the possible phases. Some instruments can carry out this process automatically.

Standards for RZ signaling at 40 Gb/s are not yet settled, and neither are the measurement methods. Designers must study the distinctive characteristics of their signals, and they must choose tools with the necessary bandwidth, ORR capabilities, and automated measurement features to keep pace with a fast-changing technology.

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