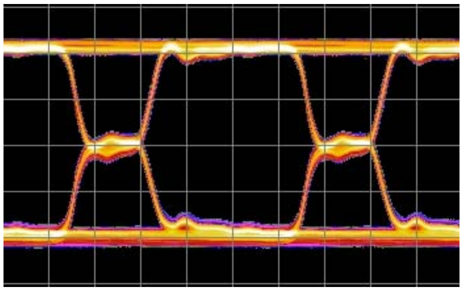

Measurement Brief: Introduction to Measurement of Skew, Including Methods for SATA and SAS Transmitter Compliance Testing

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Introduction

In standards there is often a requirement to introduce skew into measurements to see whether the device under test copes. In this context, skew refers to a differential signal where the path length is different between each side of the differential pair. It can often be an unintended consequence of board layout routing, and also improperly matched test cables. Systems are usually designed to be able to tolerate a certain amount. This measurement note will look at several methods of measuring skew: a generic method, and then the methods for Serial ATA (SATA)[i] and Serial Attached SCSI (SAS) [ii]. They can be accomplished with a BERTScope and also applied to sampling oscilloscopes.

Seeing the Effect of Skew

We are usually careful to make measurements with cables that are phase matched, or manufactured to be the same length. For this example, a phase-matched pair of cables was used to make eye diagram measurements, with the instrument measuring back-to-back. The configuration is shown in Figure 1. The test signal was a 2.488 Gb/s data rate, PN7 pattern, electrical signal. An APC-3.5 adapter combination was used to deliberately extend one cable to unbalance the path lengths.

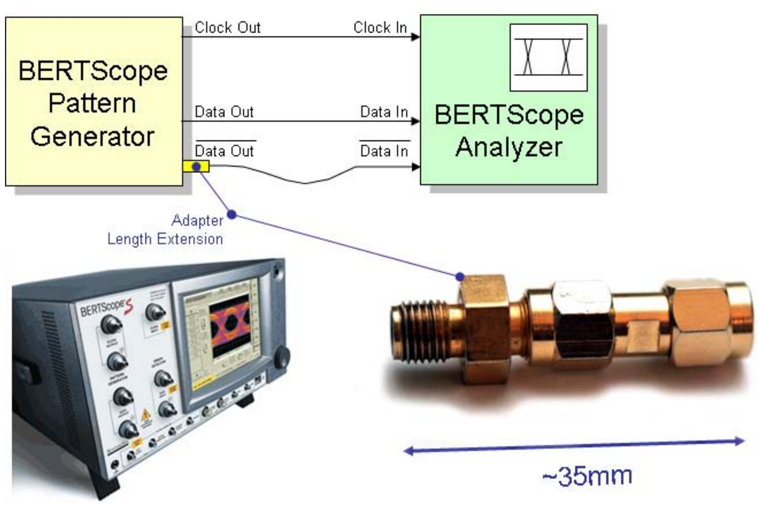

Figure 1: Experimental test setup showing the BERTScope measuring back-to-back, and the length extension (lower right).

The BERTScope has a differential input on the analyzer side. It also has a unique ability to display the incoming waveform as a true voltage-based eye diagram. Figure 2 shows the differential eye diagrams that were acquired for the example in Figure 1, with and without the adapter extension in place.

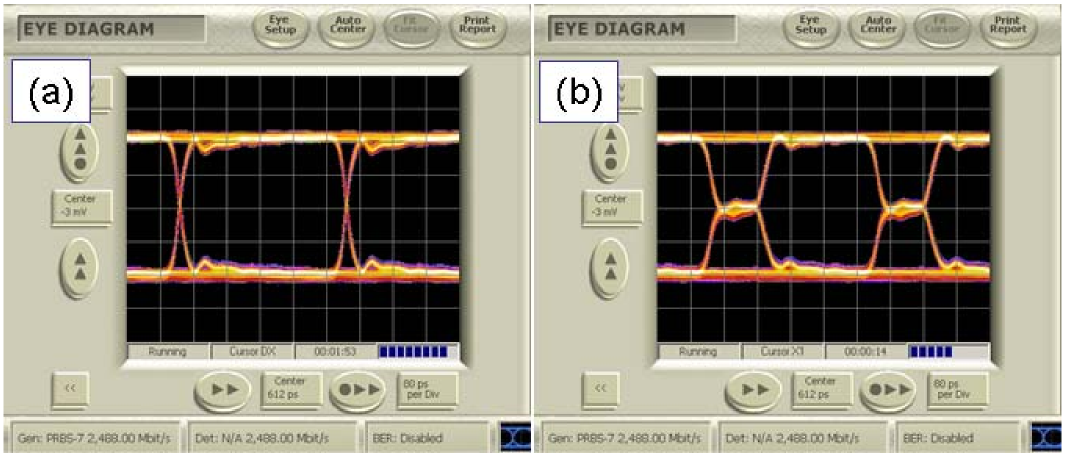

Figure 2: Eye diagrams taken with matched cable lengths (a) and with the adapter length extension in place, (b).

Figure 2 provides a good illustration of why skew can be problematic. With a little over an inch of path length difference in place, Figure 2(b) is a long way from ideal. The reason for this is illustrated in Figure 3. A differential input circuit takes the two signals and inverts one, then sums them together. When the paths are matched, the result is the signal expected, with any interference picked up in transit largely removed (3(a)). When the path lengths are not matched, the picture is more like Figure 3(b) which shows why we got the eye in 2(b).

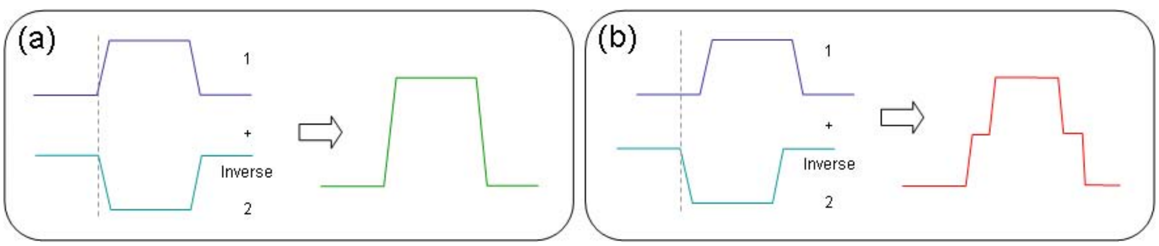

Figure 3: The action of a differential input circuit on input data with identical timing (a), and mismatched timing, (b).

Measuring Skew – A Generic Method

Having seen why skew is important, we are now going to measure the skew between the two sides of the differential pair in our experiment using a common generic method. The procedure is very straight-forward. The idea is to measure one side of the cable pair at a time into either one of the analyzer inputs[1]. This is shown in Figure 4. The positions of the eye transitions in each case give a direct measure of the skew, and can easily be measured using markers (Figure 5). As can be seen, in this example the skew was 129 ps. Given that the adapter has an air dielectric, this is not far off the old rule of thumb that signals travel at around 1 ns/foot (this would predict ~115 ps if the length measurement of 35 mm were exact). The BERTScope measurement is very accurate as the delay accuracy is better than 100 fs.

[1] Choosing to measure with only one of the analyzer inputs removes the possible effect of any slight path length difference present in the instrument, although unlikely.

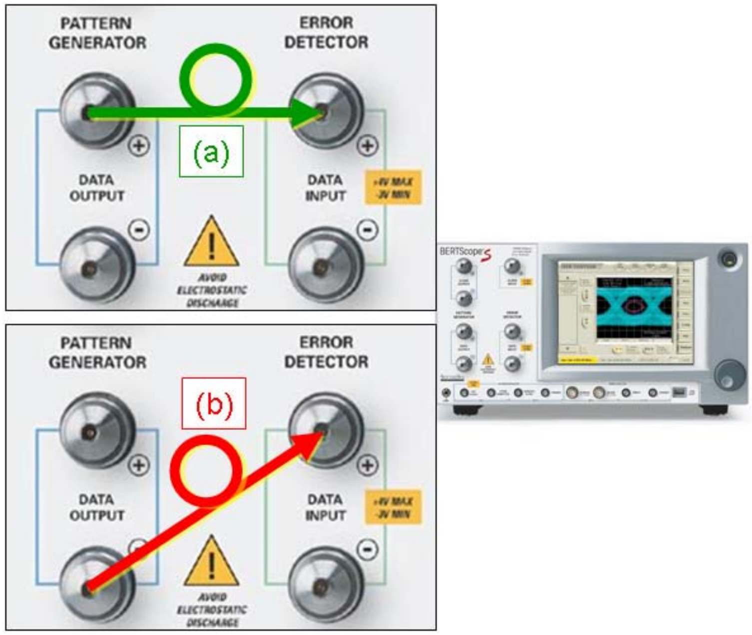

Figure 4: *Procedure for measuring each side of the differential pair.*

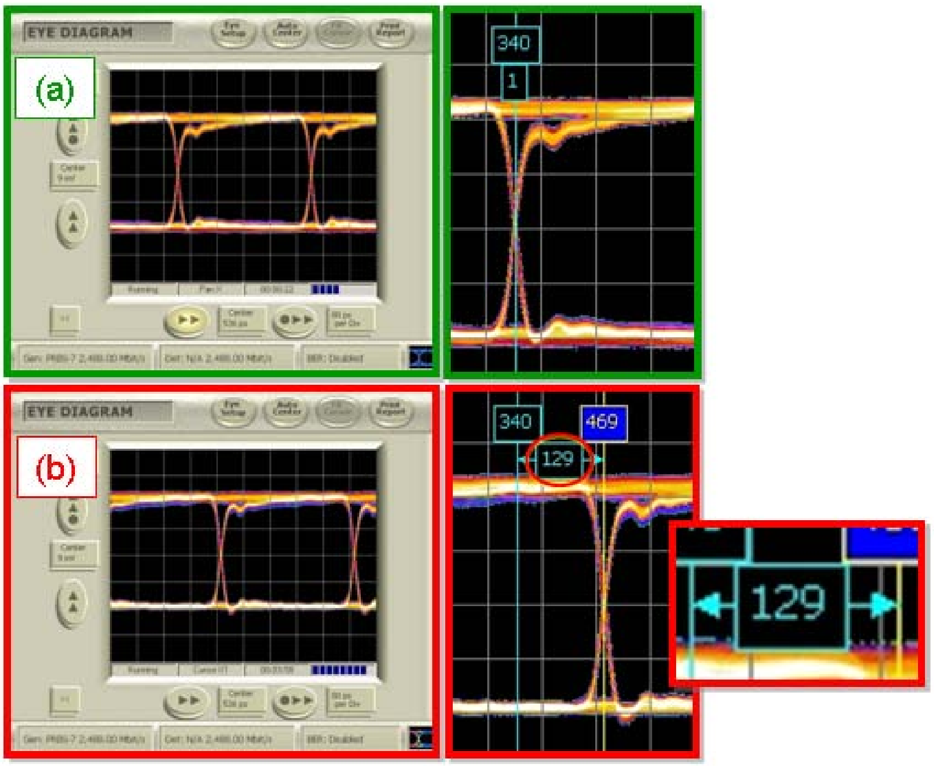

Figure 5: *Eye diagram results for the measurements of each side of the differential pair as shown in Figure 4.*

Measuring Differential Skew for SATA and SAS

Both SATA and SAS use methods that are more complex. The measurement setup described here is given in the SATA MOI[iii] and will be used to illustrate both approaches (Figure 6). It uses compliant clock recovery to trigger the measuring equipment, and each side of the differential output of the clock recovery through-path is separately measured on an eye diagram where the crossing region is magnified. This idea is to locate the crossing point and to zoom in on that region. Having done so, the aim in both SAS and SATA is to place one cursor on the rising edge present on screen, and another on the falling edge. The aim is to center a cursor on each edge at exactly the point where the edge crosses 0 mV, as shown in Figure 7. This might not be the point where the rising and falling edge cross each other. Having separately placed cursors for these two edges and noted the time positions, the clock recovery data output is swapped so the analyzer examines the other side of the DUT differential pair. The same cursor positioning is carried out on this side and the time values noted. The calculations performed on the gathered values are different between SATA and SAS, as we will see.

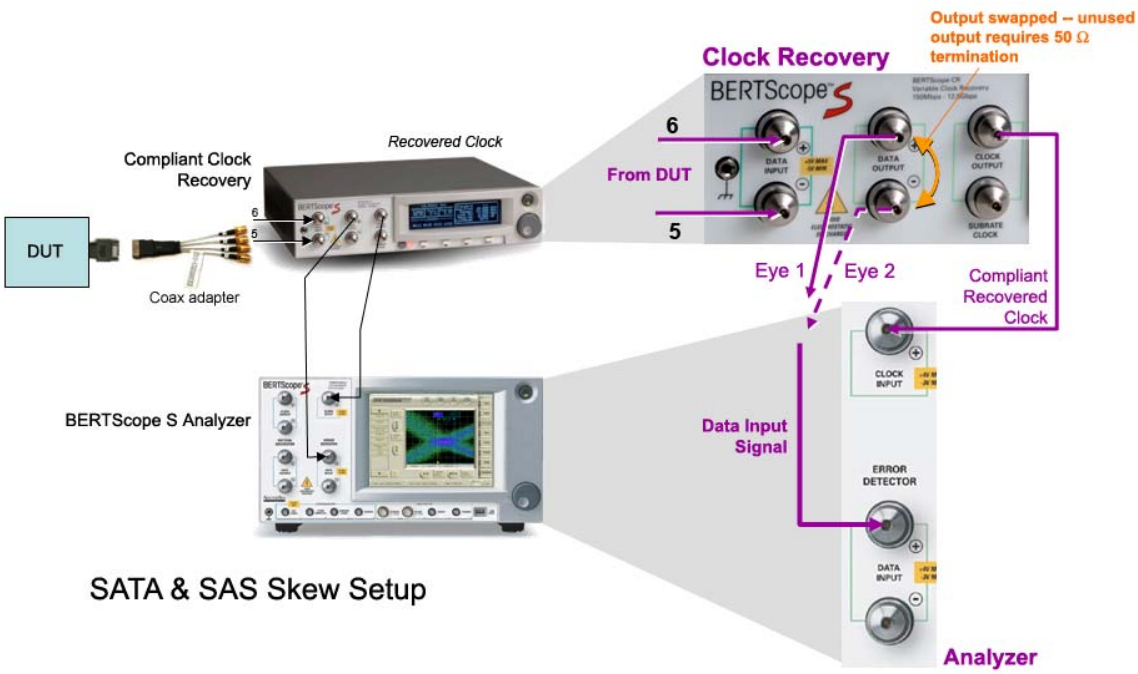

Figure 6: Example Serial-ATA Gen 2 and SAS Transmitter Differential Skew Measurement Setup

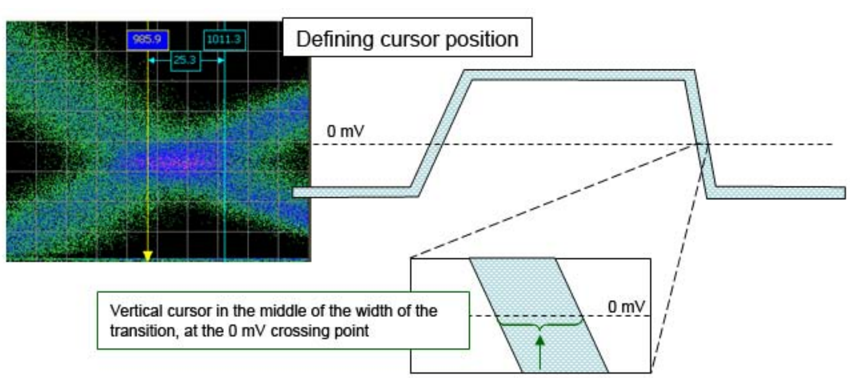

Figure 7: Defining the position of the measurement cursor.

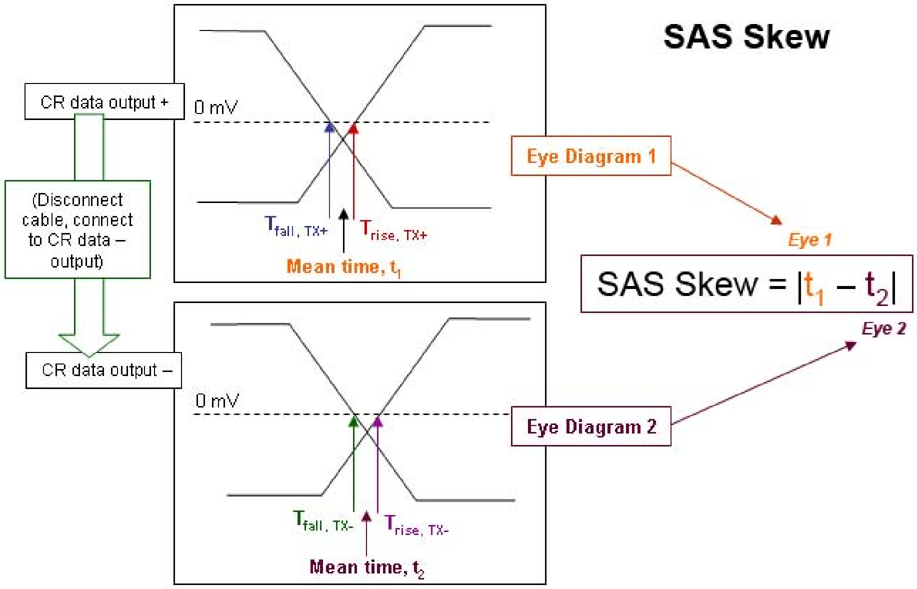

Figure 8: *Calculating differential skew for SAS.*

The conceptually simpler method is SAS, as shown in Figure 8. Here, the pair of cursor values used in each eye diagram is averaged, and then the mean of each eye diagram value subtracted from the other.

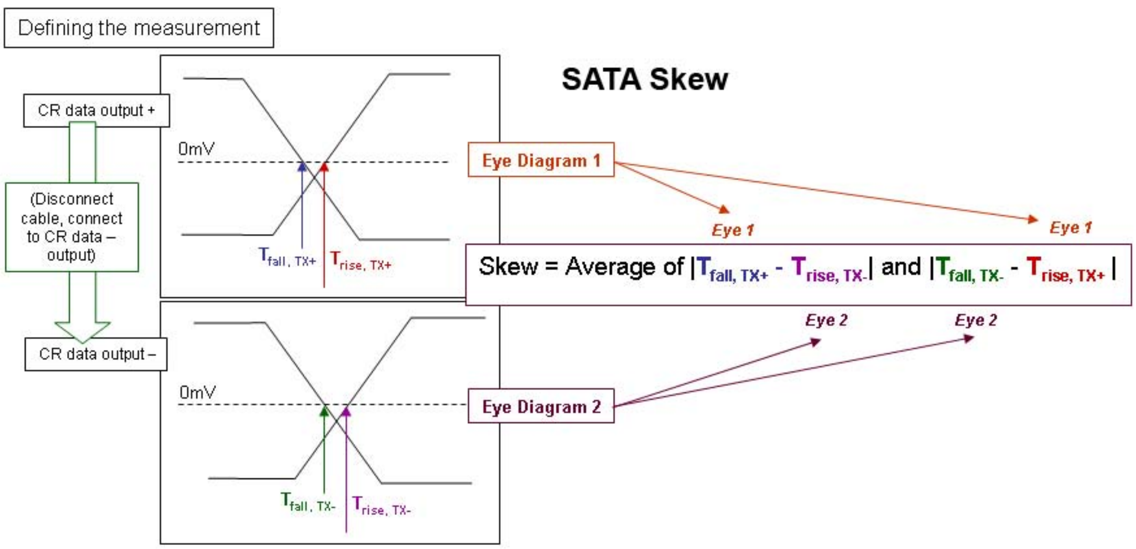

Figure 9: *Calculating differential skew in SATA Gen 2*

SATA has a more complex calculation as shown in Figure 9. Individual values are subtracted from values on the other eye diagram in different combinations, and then values averaged.

From reference [i], 2.6 section 7.4.12: “As the measurement values are typically just a few picoseconds, care should be taken to minimize measurement error.” This clearly makes the BERTScope, with its 100-fs time resolution, well suited for the task; it is recommended that sampling oscilloscopes be used in this application with equivalent high accuracy time bases to achieve similar precision.

Summary

We've seen that skew is an important effect that can catch the unwary. Care should be taken in measurements to ensure that matched path lengths are employed when skew is not an intended part of the measurement. We've also seen that standards such as Serial ATA and Serial Attached SCSI require that it be introduced in some tests, and looked at several methods for measuring the skew in a system using eye diagrams and markers.

References

[i] 'Serial ATA Revision 2.6 Version 0.60', 22 August 2006, www.sata-io.org

[ii] 'Working Draft American National Standard, Serial Attached SCSI-2 (SAS-2)', Revision 5a, 21 July 2006. Document can be download for free from www.t10.org

[iii] 'Serial ATA Interoperability Program, Method of Implementation (MOI) for PHY and TSG Device Certification Tests using the BERTScope by SyntheSys Research, Inc.' June 2006, available from www.bertscope.com