Understanding HDMI “Eye Pattern”, “BER” and “Cliff Effect”

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You probably have heard these terms. You are bound to hear them more and more in the near future. They are all related to the digital transmission performance and test methods. Although digital is not new to home theater (digital audio connections have been around for a long time), HDMI is the first digital home theater technology which pushes the limit of high speed digital transmission, considerably raising the standard needed for stringent design and quality control monitoring.

To better understand digital transmission, let’s first take a look at analog video transmission.

Analog video signals related to cable length:

When the analog video cable length increases, the video signal quality gradually declines. See fig 1 below.

Fig. 1 - Picture quality of an analog signal gradually declines over longer length of cable.
The main types of analog video signal loss are:
1) Amplitude loss: the result is a dimmer image.
2) High frequency signal loss: the result is a softer image.
3) Low frequency signal loss: the result is horizontal smearing on the image.

There are marked differences in image quality between a good and bad cable. So it’s an easy up-sell to better cable products.

No matter how bad the signal loss is, the display will still generally show a picture. Many viewers would not know how much image quality was lost without comparing pictures to a perfectly functioning display. In addition, there is no two-way communication between the source and display in an analog video based system. These are the two key reasons for the relatively low service call rate for analog video based systems.

**Digital video signals over long cables: the “Cliff Effect”**

Digital video signals behave quite differently from analog video. When the cable length increases, the image quality is perceived to be perfect by human eyes until a certain length. After that length, the image is either totally not viewable or disappears all together. The fig 2 below illustrates what it’s called “Cliff Effect”.

**Fig. 2 - Picture quality of a digital signal (e.g. HDMI) drops suddenly after certain length of cable.**
Why should consumers pay for better cables if they are below the “Cliff Effect”?  

This is a hot topic among consumers and manufacturers. One side insists that you do not need to pay more for higher performance cables, because as long as the signal has not exceed the cliff, even cheap HDMI cables will provide a quality image. The other side argues that there are always differences between higher and lower quality products and this is a difference worth paying for.  

Let’s use an analogy to further elaborate this point: schools usually use 60 out of 100 points as the pass/fail threshold for students. Student A gets 95 points. Student B gets 65 points on their final exam. They both “pass” this final test. However, is their performance the same? Which one would you hire to work for you? The answer is quite obvious.  

Similarly, good and bad HDMI cables pass the test right up to the point where they fall off the “cliff”. But there are indeed differences between the two beyond the capability of the human eye to detect.  

Seeing is deceiving  

Even when the cable length is within the “cliff” and human eyes are unable to detect any defect of image, there are data errors already occurring in transmission. See fig 3.  

Fig. 3 - Long before reaching the “cliff”, the signal error rate starts to increase with length of cable.  

Why wouldn’t we see these defects when we are near or on the cliff”? The answer is the built-in error correction technology used in digital transmission. The display
can tolerate a certain amount of error bits per second; the picture would still be perfect as long as the error rate is below that threshold. Once the error rate exceeds the capability of the display, signal recovery may fail altogether.

HDMI cables are not created equal. But if we can’t see the difference on the display, how would we know that there are meaningful differences? There are two industry standard tests for HDMI cable: the BER test and the “Eye Pattern” test.

**BER test:**

BER stands for Bit Error Rate. In a BER test, the signal generator would output billions of data bits (per the HDMI standard) send them to the cable (or the input of other devices) and receive them from the other end of the cable (or the output of other devices). Then, a comparison is made bit by bit with the sent data. The BER display then shows the results as the total numbers of error bits in a given period of time (usually less than a second).

The BER test accurately shows the real number of bad data bits a display could receive under a given condition. The higher the number, the worse the signal. The BER test is the most accurate real world test for HDMI cable performance and quality control.

**Fig. 4 - BER (Bit Error Rate) test counts the number of error data at the far end of the cable. The “cliff” effect is visible.**

![BER Test Diagram](image)
**Eye pattern test:**

“Eye pattern” is what the digital signal looks like on an oscilloscope. The traces of many 1s and 0s overlap together on the oscilloscope to form a pattern that resembles an eye shape. See Fig 5.

**Fig. 5 HDMI “Eye” patterns**

![Poor Signal](image1)

![Good Signal](image2)

The Eye pattern test shows many aspects of the digital signal, more specifically the following two:

1) **Signal amplitude**: the height of the “eye” represents the signal amplitude. It must not fall into or become smaller than the marked diamond shaped area in the middle. Otherwise the signal will be too small for the display to recover. The “eye” will appear to be closed in the vertical direction.

2) **Timing jitter**: the rising and falling edges of digital bits do not always arrive at the precise time they should. This is called “timing jitter”. On an oscilloscope, it appears that the eye gets fuzzy in the horizontal direction as a result of some bits shifting left, some shifting right and overlapping together. The internal width of the eye can’t fall into or become narrower than the marked diamond area in the middle; otherwise the display won’t recover the data.

In short, if the “eye” collapses in either horizontal or vertical direction, the signal is lost.

**BER vs. eye pattern test**

Both tests are essential in the HDMI industry. They are similar in that they both show elements of digital signal integrity. Fig 6 and 7 show these two different tests revealing the same cliff effects.
However the two tests are different in some ways:

The BER test shows the scale (how many) of data errors, but does not tell the cause of the problem. The equipment costs tens of thousands of dollars. The test time is about a second for all 4 TMDS pairs and all other lines within an HDMI cable. These
make the **BER test the best for QC (quality control) and real world field support applications.**

The eye pattern test on the other hand shows the cause (what went wrong) of the problem, but not the scale (how many) of the data errors. This equipment costs hundreds of thousands of dollars. This test takes about 15 to 20 minutes because the technician needs to test one pair at a time, and needs to analyze the pattern subjectively one by one. This makes the **eye pattern test the best for engineering design and fault analysis.**

AudioQuest proudly utilizes both types of test gear and use them extensively throughout the design and 100% QC process to ensure the highest quality for each cable.
In the analog world, we use bandwidth to describe the amount of information of the signal. The higher the picture resolution, the higher the signal bandwidth.

In the digital world, we use data rate to describe the amount of data bits per second of the signal. The higher the picture resolution, the higher the refresh rate. The deeper the color, the higher the data rate. 720p and 1080i have about the same data rate of 2 Gbps (regular 24 bit encoding). 1080p has about twice the data rate at 4 Gbps (regular 24 bit encoding). 48-bit deep color has about twice the data rate of the 24 bit encoding, or about 8 Gbps for 1080p deep color.

The higher the data rate, the shorter the maximum length for a given HDMI cable design. See the chart below:

<table>
<thead>
<tr>
<th>Cable Length</th>
<th>Max data rate</th>
<th>Equivalent HDTV format</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 m (6')</td>
<td>25 Gbps</td>
<td>Future</td>
</tr>
<tr>
<td>4.5 m (15')</td>
<td>18 Gbps</td>
<td>Future</td>
</tr>
<tr>
<td>9 m (30')</td>
<td>9 Gbps</td>
<td>1080p 48bit</td>
</tr>
<tr>
<td>12 m (39')</td>
<td>7 Gbps</td>
<td>1080p 36bit</td>
</tr>
<tr>
<td>15 m (49')</td>
<td>5 Gbps</td>
<td>1080p 24bit</td>
</tr>
<tr>
<td>20 m (65')</td>
<td>4 Gbps</td>
<td>720p/1080i</td>
</tr>
<tr>
<td>40 m (130')</td>
<td>2 Gbps</td>
<td></td>
</tr>
</tbody>
</table>

Higher data rate signals post a bigger challenge to the long cables.

**Future proof your system**

Taking a look at the cable length and data rate from the cliff effect chart, it is clear that **the higher the data rate, the closer the cliff.**

**Fig. 8 - The edge of the “cliff” of a given cable varies by signal rate. The max distance of 1080p is only 1/2 of 1080i.**
In other words, we can expect the cliff to “move in” with the advance of technology that enables higher data rate over time.

From the discussion above, we see that there are absolute differences among cables. **The worse the cable, the closer the cliff.**

A low quality cable that may work fine for the 1080i signal you are using today may not work for the 1080p signal you may use tomorrow. A good quality HDMI cable does not cost much more than a mediocre one, especially compared to the cost of the HDTV in your system.

**Summary**

In this article, we have discussed the cliff effect. Even in a given system combination where no picture defects are visible, there are plenty of data errors occurring. This is where the difference between a good and a bad cable becomes important. The tests to reveal the data error are the BER and Eye pattern tests.

We have also found that the higher the data rate, the closer the cliff. Likewise, the worse the cable, the closer the cliff.

Technology is constantly moving forward. We are offered higher and higher data rates for improved performance in our home entertainment systems. The use of high quality HDMI cable is a reliable and cost effective way to future proof your system.

Should you have any questions or comments, please do not hesitate to contact your local AudioQuest RSM or call our technical support team here in Irvine at 800-747-2770.

Please visit [www.audioquest.com](http://www.audioquest.com) for more information.