



## Ethernet Bit Error Ratio (BER) and Frame Error Ratio (FER) Testing with Aukua MGA2510

### BER Explained

A key metric describing the integrity of data in a network communications system is called the Bit Error Ratio (BER) measurement. A BER measurement is created by directly comparing a known sequence of transmitted bits to the corresponding bits received at a downstream measurement point. The number of errors or bits that arrive with an incorrect value are counted, and a BER measurement is then calculated as the number of *errored* bits received divided by the *total* number of bits received. Since bit errors are fundamentally random, not uniformly distributed, the resulting BER measurement is essentially the probability of any particular bit being received in error for that tested network communications system.

$$\text{BER} = \frac{\text{Number of Errored Bits}}{\text{Total Number of Bits}}$$

BER measurement results are often expressed as a ten to a negative power number (e.g.,  $3 \times 10^{-9}$  or  $3.0e-9$ ). Thus, a BER of  $3e-9$  means that three (3) bits out of every 1,000,000,000 bits on average were in error. And BER pass/fail criteria for communications devices depends upon the type of interface, device and even application involved. A BER requirement for a 1000BASE-X interface of  $1e-12$  for example means that the probability of any single bit being errored shall be no more than 1 in 1,000,000,000,000 bits or on average no more than 1 bit in error for every 1 trillion bits transmitted.

BER measurements are typically performed at the physical or data-link layers of a communications system. It is worth mentioning, for perspective, that bit errors received by an Ethernet communications system at the physical layer, can result in Layer 2 MAC frame FCS (Frame Check Sequence) errors which cause the entire MAC frame to be discarded. These lost frames can result in higher layer protocols such as TCP to request retransmission of data, which increases bandwidth congestion, reducing overall performance in a network communications system.

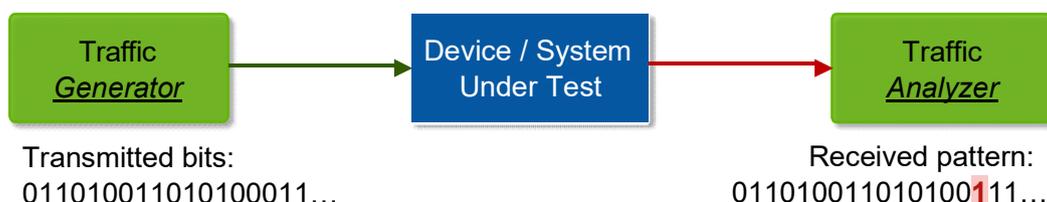


Figure 1: Simple BER Testing example illustrating one bit error received at the Traffic Analyzer

### BER Testing over an Ethernet Link

The purpose of a Bit Error Ratio Test is to verify the data integrity of a Device or System Under Test (DUT / SUT). But, how do you perform Bit Error Ratio Testing over a frame-based transmission link, such as Ethernet, where the payload bit pattern to be measured is interleaved with periods of “Inter-Frame Gap” data as shown in Figure 2?

It is possible to conduct a BER measurement at the data-link or MAC layer. However, it is important to note that not every ‘bit’ in the serial communication link will be analyzed with respect to a known pattern sequence as done with traditional physical layer BER testing. Using the Aukua MGA2510, we can transmit Ethernet frames of various sizes, at different frame rates, and with a variety of protocol overhead fields, including no protocol header. In all cases, only the ‘payload’ bits of these frames are actually measured bit-wise for bit errors.

As a method to most closely relate to a traditional physical layer BER Test, it is generally ideal to maximize the ratio of payload bits to total transmitted bit over the entire serial communications link. To achieve this, you need to test with the maximum size Ethernet frames possible, and at the highest frame rate possible for the device or system under test. It is also desired to conduct the test at the lowest protocol layer possible, which will depend on the type of device being tested. For example, in testing a simple Layer 2 device, it may be possible to configure the system to not require a MAC header. In such a case, the entire Ethernet frame can consist of the ‘payload’ test pattern for a true Layer 2 BER Test. But, in the case of a router interface, this may not be possible because the system may require a full MAC and L3 IP header to properly function. In which case, the payload pattern would be after the MAC and IP header, and this would be more analogous to a Layer 4 BER Test.

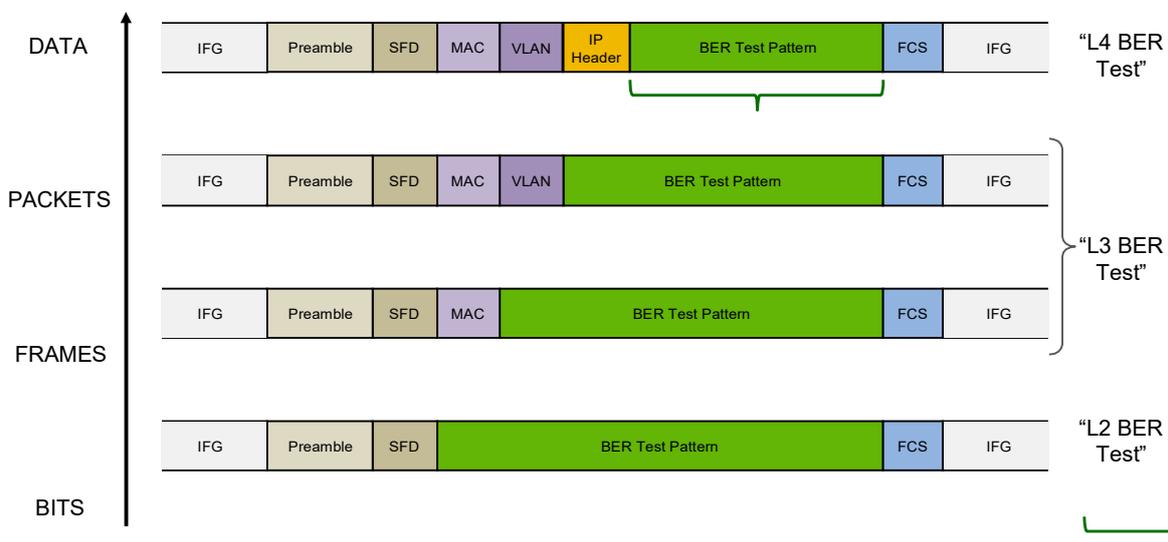


Figure 2: The Aukua MGA2510 can conduct BER measurements with any configuration of protocol headers in the Ethernet MAC Frame. In the above examples, the green ‘payload’ area indicates the portion of the serial Ethernet data stream that is measured for BER.

### How Long to Test?

Since bit errors caused by noise occur randomly, such that all bits have an equal chance of being errored, and the errors can occur in bursts or individually at unpredictable times, it would require an infinite test duration to perfectly state the true BER performance of a communication system. This is of course not practical! A classic question then asked is, “*How long should I test for BER performance?*” It is only necessary to test long enough to get an *estimation* of the system’s BER performance with a *reasonable* “confidence level”. In summary, this confidence level, expressed as a percentage, indicates the probability that a system’s actual BER performance will be better than the required BER criteria. The formula looks like this<sup>[1]</sup>:

$$\text{Required Test Time (sec)} = \frac{[-\ln(1 - \text{Confidence Level})]}{(\text{Bit Error Ratio} * \text{Bit Rate})}$$

So for example, testing to a 90% confidence level would indicate that if you measured the BER of a system many times over, then 90% of the time, the measured BER will be better than the required value.

95% CL	1GbE	2.5GbE	5GbE	10GbE
1E-15	2,995,732	1,198,293	599,146	299,573
1E-12	2,995.73	1,198.29	599.15	299.57
1E-10	29.96	11.98	5.99	3.00
1E-09	3.00	1.20	0.60	0.30
1E-06	0.00	0.00	0.00	0.00

Minimum Time to Test (seconds)

Figure 3: Chart showing how long to test BER in seconds with a 95% confidence level for various Ethernet interface speeds.

With the above formula, an easy to remember rule-of-thumb is discovered. For a confidence level of 95% one can quickly determine how long to test in seconds with this formula: 3 / Target BER / Bit Ratio. Or, for the case of 1000BASE-X passing a 1E-10 requirement, this comes to 3 / 1E-10 / 1,000,000,000 which equals 30 seconds.

### Frame Error Ratio (FER) Testing

Another important metric for testing data integrity, especially over Ethernet, is called Frame Error Ratio (FER). The FER measurement is a similar concept as BER, except that the unit of measurement is changed from a ‘bit’ to an Ethernet MAC ‘frame’. Specifically, the FER measurement is calculated as the number of *errored* Ethernet frames received divided by the *total* number of frames received. A frame is considered errored if it has a bad Frame Check Sequence (FCS) value which is a 32 bit CRC value calculated over the entire Ethernet frame. It is important to note that if a bit error occurs anywhere within a MAC frame, this will result in the frame having a bad FCS value, which in turn causes an Ethernet network device to drop the *entire* frame. Therefore, a single bit error can result in 12,144 data bits to be lost in the case of a 1518 Byte sized Ethernet frame; something which is not considered in a BER measurement alone.

[1] Yongquan Fan, McGill University, Montreal “Accelerating Jitter and BER Qualifications of High Speed Serial Communication Interfaces” February 2010

### Testing BER and FER with the Aukua MGA2510

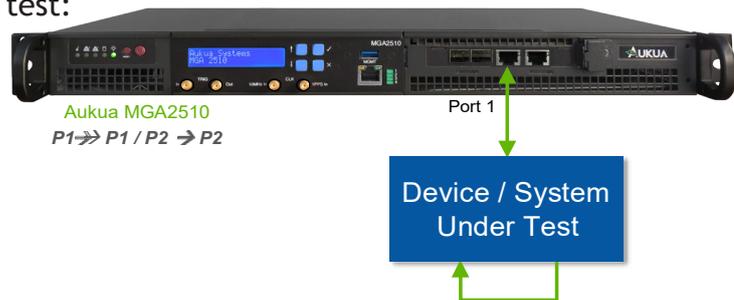
The Aukua MGA2510 is capable of testing BER and FER simultaneously and bidirectionally for all Ethernet data rates from 10MbE to 10GbE. In addition, LDPC errors are also counted in the case of 2.5GBASE-T, 5GBASE-T, and 10GBASE-T Ethernet interfaces.

Key items to consider when conducting BER/FER testing over Ethernet:

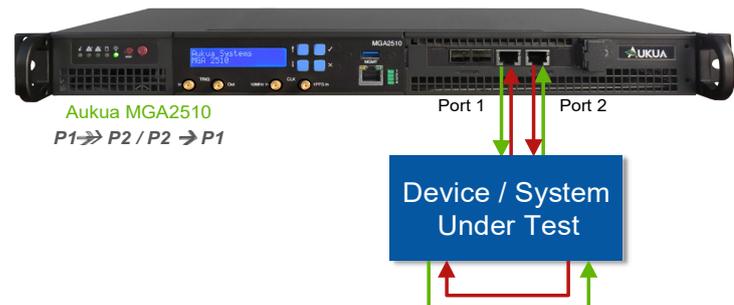
- Use the largest L2 frame size supported by the system under test
- Set the highest frame rate supported by the system under test (as close to line rate as possible)
- Choose a payload pattern with the appropriate level of stress (e.g., PRBS31)
- Perform the test at the lowest protocol layer possible with the system under test (e.g., L2 vs L3)
- Test for a long enough time duration to achieve the desired and acceptable confidence level

Below are three common example BER/FER test bed configurations supported with the Aukua MGA2510:

1) One port (internal or external) loopback test:



2) Two port loopback bidirectional test:



3) Two port bidirectional inline test:

