31 March 2017: Rev 5

Bit Error Ratio Tests

Purpose:

To get an empirical measurement of the "light power budget" and characterize the steepness of that empirical limit.

Summary:

This document contains descriptions of three experiments related to the bit error ratios and "light power budget". These three experiments involve measuring the insertion loss and bit error ratio when the MiniPod has just lost synchronization, comparing the insertion loss levels when the MiniPod has just lost and just regained synchronization, and measuring the bit error ratio over a broader range of insertion loss levels. For some channels the insertion loss level for when the MiniPod just lost synchronization was very similar to the insertion loss level when the MiniPod just regained synchronization, while other channels showed a difference of up to about 2.5 dB from when the MiniPod just lost synchronization to when the MiniPod just regained synchronization. For most channels the bit error ratio increased as a function of insertion loss. For channels 9 and 11, as measured by MiniPods 1 and 5, and for channels 1,3,5,7,10 and 11 as measured by MiniPods 2 and 3 there is additional data indicating that the bit error ratio increases linearly as a function of insertion loss for these channels.

Procedure for all Experiments:

Before each experiment, all connections were cleaned via the standard cleaning procedure.

The IBERT console was turned on. On the IBERT console, "MyDevice2" was used.

Before each experiment, five reference measurements were taken. The reference measurements are light input measurements form the receiving MiniPod with no variable attenuators in the light path. For each experiment, the average of these five light input measurements was taken to be the zero reference.

For these reference measurements, the MTP end of octopus cable 1 was connected to the front side panel connector for the transmitting MiniPod. The LC ends of octopus cable 1 were directly connected to the LC ends of octopus cable 2. The MTP end of octopus cable 2 was connected to the front panel side connector for the receiving MiniPod.

Setup for placing variable attenuators in the light path of channels:

One end of the variable attenuator was connected to an adapter. One end of octopus cable 1 was also connected to this adapter. The other end of the variable attenuator was connected to an adapter which was connected to octopus cable 2. The figure below shows this setup:

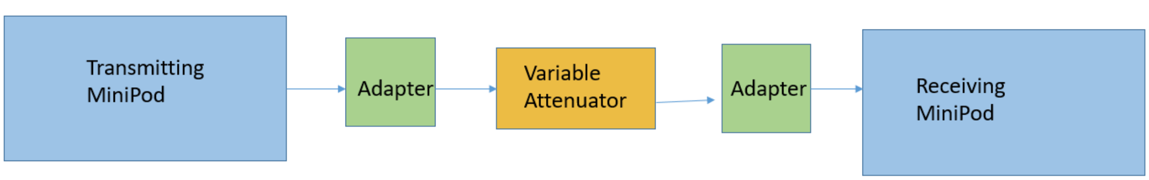


Figure 1: Setup for variable attenuator in light path.

Measuring the attenuation level with the Fluke and CMX when the MiniPod just lost synchronization:

Procedure:

For this experiment the transmitting MiniPod was MiniPod 1 and the receiving MiniPod was MiniPod 5. Variable attenuator 1 was plugged into channel 0 of the CMX. The dial on variable attenuator 1 was turned until the MiniPod had just lost synchronization. This was repeated with variable attenuators 2 and 3, on the CMX channels 1 and 2, respectively. Five measurements were taken from MiniPod 5 in order to measure the attenuation levels of the variable attenuators when the MiniPod had just lost synchronization. One at a time, each variable attenuator was carefully moved to the Fluke meter without touching the setting on the dial, and the attenuation was measured with the Fluke meter. This was repeated with variable attenuators 4, 5, and 6, using channels 0, 1, and 2, respectively. This procedure was repeated for two trials.

Data Collection/Analysis:

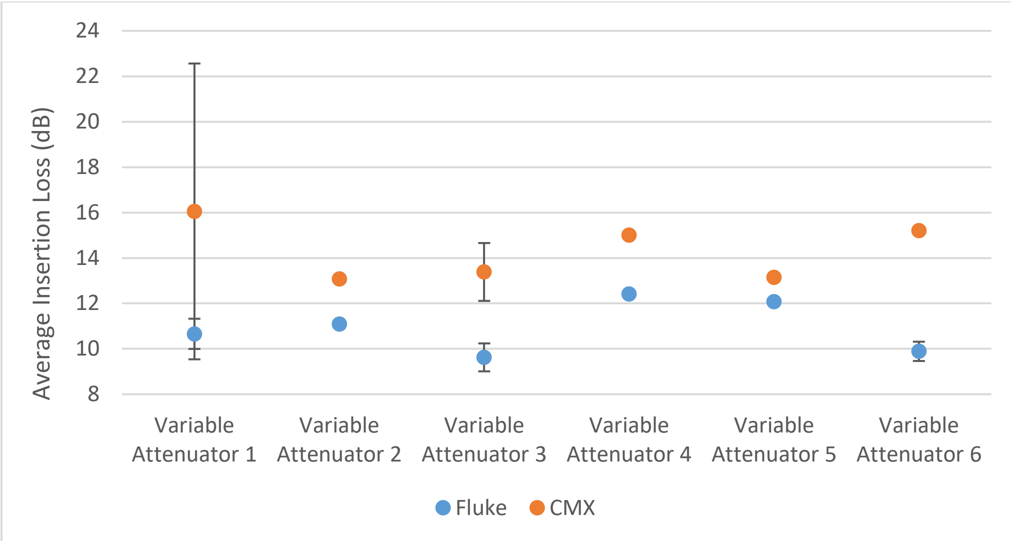
To calculate the average insertion loss levels measured by the CMX, the average of the five light input measurements taken from MiniPod 5 were averaged. This average of the five light input measurements was subtracted from the zero reference (see “Procedures for all Experiments” above for explanation of zero reference).

For some of the measurements the CMX was unable to measure any light input and reported “-inf”. These measurements were not used in the data analysis.

To measure the insertion loss level with the Fluke meter, the Fluke meter reference was set with two cables and one adapter in between the Fluke light source and meter. The variable attenuator and an additional adapter were placed in the light path of the Fluke light source and meter. The number displayed on the Fluke meter with this setup was taken to be the loss measured by the Fluke meter.

Results:

Plot 1 shows the insertion loss levels of the variable attenuators as measured by the Fluke meter and the CMX when the MiniPod reported just losing synchronization. The error bars indicate the difference in measured insertion loss levels between the two trials.



Plot 1: Insertion loss at just lost synchronization

Plot 1 shows that the CMX consistently measure higher insertion loss levels than the Fluke meter. The largest difference in insertion loss levels between the Fluke and CMX when synchronization is just lost was found to be about 5.5 dB.

For most of the measurements, the two trials yielded similar results, with the exception of the measurements done with variable attenuator 1 with the CMX. This is due to a fluctuation in the light input measurements from trial 1. The raw light input measurements, in order, for variable attenuator 1 on channel 0 from the first trial are as follows: -27.696, -15.638, -27.696, -15.918, and -inf dB. This shows that the attenuation level of variable attenuator 1 measured by the CMX changed by about 12 dB from one measurement to the next with no change in the light path. This occurred twice before the CMX was unable to measure any light input from channel 0.

Just Lost vs Just Regained Synchronization Experiment:

Procedure:

For this experiment MiniPod 1 was the transmitting MiniPod and MiniPod 5 was the receiving MiniPod. Variable attenuator 1 was set to its minimum attenuation and placed in the light path of one of the channels of the CMX. The attenuation level of variable attenuator 1 was slowly increased until the point at which the MiniPod lost synchronization with the channel which had variable attenuator 1 in its light path. Three light input measurements were taken with the CMX with variable attenuator 1 at this attenuation.

The attenuation level of variable attenuator 1 was slowly decreased until the point at which the MiniPod regained synchronization with the channel which had variable attenuator 1 in its light path. Two light input measurements were taken with the CMX with variable attenuator 1 at this attenuation.

This was repeated for all channels using all variable attenuators. The variable attenuators were measured with the CMX and then the Fluke meter one at a time. This was repeated for three trials.

In a similar experiment with only one trial:

Variable attenuator 1 was set to its minimum attenuation and placed in the light path of one of the channels of the CMX. The attenuation level of variable attenuator 1 was slowly increased until the point at which the MiniPod lost synchronization with the channel which had variable attenuator 1 in its light path. Two light input measurements were taken with the CMX with variable attenuator 1 at this attenuation. Without changing the attenuation level of variable attenuator 1, the cables of variable attenuator 1 were connected to the Fluke meter and the attenuation was recorded.

Without changing the attenuation level, the cables for variable attenuator 1 were reconnected to the CMX. The attenuation level of variable attenuator 1 was slowly decreased until the point at which the MiniPod regained synchronization with the channel which had variable attenuator 1 in its light path. Two light input measurements were taken with the CMX with variable attenuator 1 at this attenuation. Without changing the attenuation level of variable attenuator 1, the cables of variable attenuator 1 were connected to the Fluke meter and the attenuation was recorded.

This was repeated for all channels using all variable attenuators. The variable attenuators were measured with the CMX and then the Fluke meter one at a time.

The table below shows which variable attenuators were used to test each channel.

Channel	Variable Attenuator Used
0	1
1	2
2	3
3	4
4	5
5	6
6	1
7	2
8	3
9	4
10	5
11	6

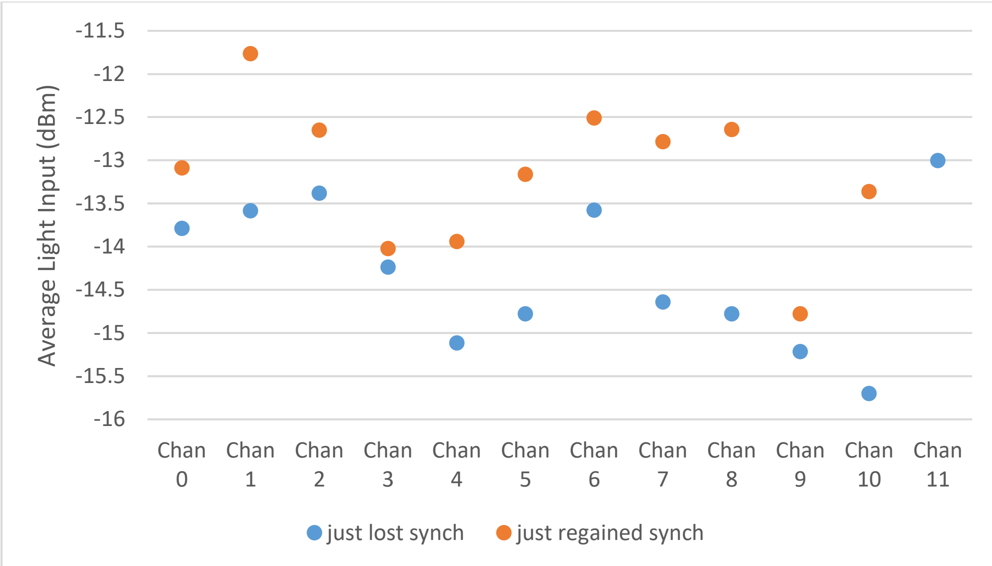
Data Collection/Analysis:

To calculate the average insertion loss measured by the CMX, the average of the five light input measurements taken from MiniPod 5 were averaged. This average of the five light input measurements was subtracted from the zero reference (see “Procedures for all Experiments” above for explanation of zero reference).

To measure the insertion loss levels with the Fluke meter, the Fluke meter reference was set with two cables and one adapter in between the Fluke light source and meter. The variable attenuator and an additional adapter were placed in the light path of the Fluke light source and meter. The number displayed on the Fluke meter with this setup was taken to be the insertion loss measured by the Fluke meter.

Results:

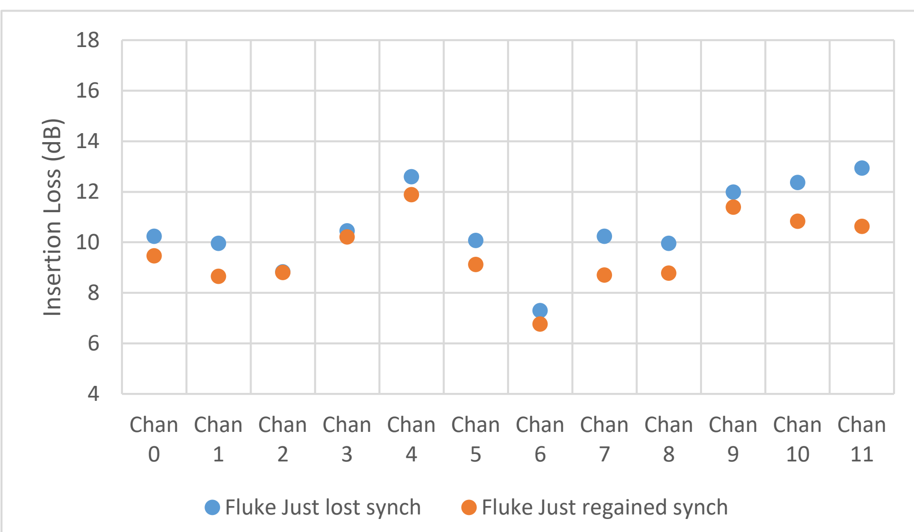
Plot 2 shows the raw values of the light input measured by MiniPod 5 (the receiving MiniPod) at the points at which the MiniPod just lost synchronization and just regained synchronization.



Plot 2: Light input from CMX when MiniPod just lost and just regained synch.

Plot 2 shows that the light input measured when the MiniPod just regained synchronization is consistently higher than the light input measured when the MiniPod just lost synchronization, which is to be expected. Plot 2 shows that the light input at which the MiniPod just regained synchronization ranges from about -11.5 dBm to -15.0 dBm while the light input at which the MiniPod just lost synchronization ranges from about -13 dBm to -16 dBm.

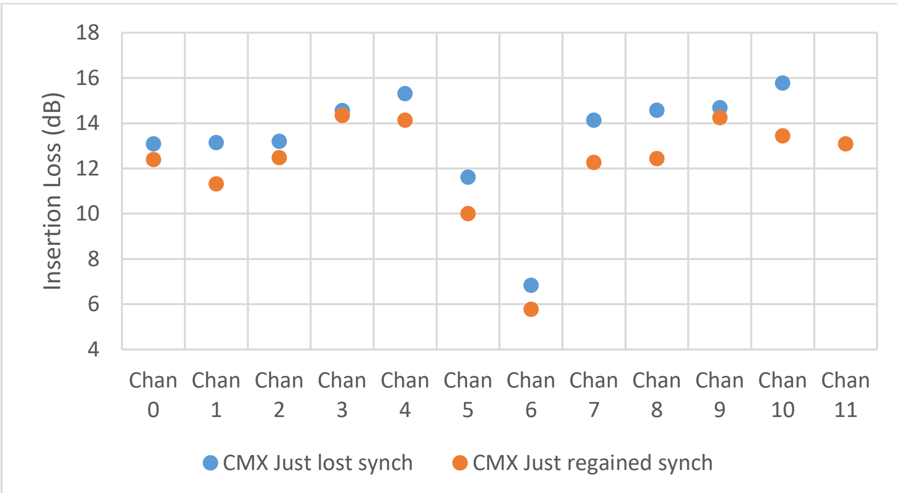
Plot 3 shows the insertion loss levels measured by the Fluke meter when the MiniPod just lost and just regained synchronization.



Plot 3: Fluke measurement when MiniPod just lost and just regained synchronization

Plot 3 shows that the insertion loss level at which the MiniPod just lost synchronization is consistently higher than the insertion level at which the MiniPod just regained synchronization, which is to be expected.

Plot 4 shows the insertion loss levels measured by the CMX at which the MiniPod just lost and just regained synchronization.



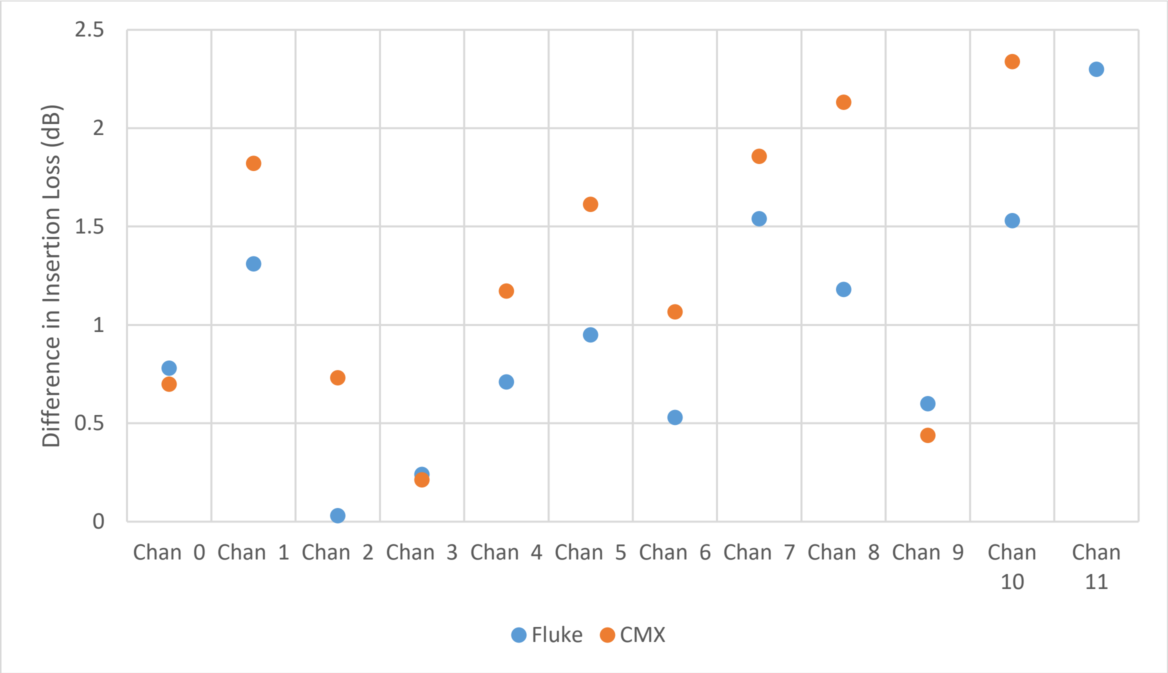
Plot 4: CMX measurement when MiniPod just lost and just regained synchronization

Plot 4 shows that the insertion loss level at which the MiniPod just lost synchronization is consistently higher than the insertion loss level at which the MiniPod just regained synchronization, which is to be expected.

On Plot 4, channels 5 and 6 have significantly lower attenuation levels than the rest of the channels at the points at which they lose and regain synchronization. This is to be expected because it is known from previous measurements that channels 5 and 6 on MiniPod 5 measure significantly less light input than the rest of the channels.

For channel 11, the CMX was unable to measure any light input at the attenuation level at which the MiniPod just lost synchronization.

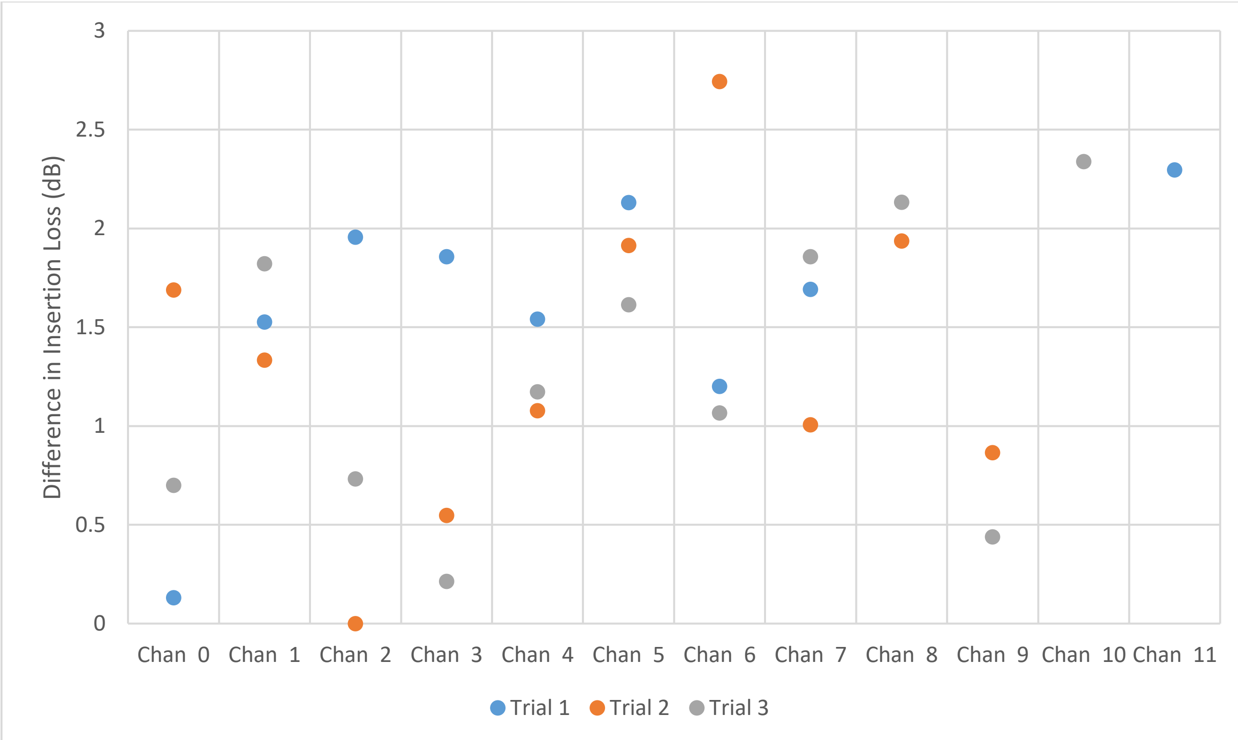
Plot 5 shows the difference between the measured insertion loss levels when the CMX and Fluke meter had just lost and just regained synchronization.



Plot 5: Difference in insertion loss for just lost and just regained synchronization.

Plot 5 shows that the larges variation in insertion loss level between just losing and just regaining synchronization is about 2.5 dB.

Plot 6 shows the difference in insertion loss measurements when the MiniPod had just lost and just regained synchronization for three trials. If a channel has less than three data points it is because the CMX was unable to measure any light input at the attenuation level at which the MiniPod had just lost synchronization for that trial.



Plot 6: Difference in just lost and just regained synch as measured by the CMX

Plot 6 shows that the maximum measured difference in insertion loss between the MiniPod just losing and just regaining synchronization is about 2.5 dB. Plot 6 also shows that this difference in insertion loss can vary by up to about 1.5 dB from one trial to another.

Steepness Tests:

Procedure:

Variable attenuator 1 was placed in the light path of channel 0. The dial on variable attenuator 1 was turned until the MiniPod just lost synchronization with channel 0. The dial on variable attenuator 1 was turned slowly in the opposite direction until the MiniPod just regained synchronization. The error count on the MiniPod for channel 0 was reset and after about 10 minutes, the bit error ratio for channel 0 was recorded. The dial on the variable attenuator connected to channel 0 was turned until channel 0 reached a different attenuation level. Three light input measurements were taken for channel 0. The error count on the MiniPod for channel 0 was reset. After about 10 minutes the bit error ratio for channel 0 was recorded. This was repeated for 6 different attenuation levels of the variable attenuator connected to channel 0. (For the first trial, 28 minutes instead of 10 minutes passed before the bit error ratio was recorded.)

This was repeated for variable attenuators 1-6 on channels 0-5.

This entire procedure was repeated again for variable attenuators 1-6 on channels 6-11

The table below shows which variable attenuators were used to test each channel.

Channel	Variable Attenuator Used
0	1
1	2
2	3
3	4
4	5
5	6
6	1
7	2
8	3
9	4
10	5
11	6

After the insertion loss and bit error ratio data was collected for all channels, the procedures above were repeated for only channels 9 and 11 for a broader range of insertion loss and bit error ratio. This was done in order to show more information over a wider range of values and better resolution over the regions with high insertion loss. For all measurements of the bit error ratio that were below E-13, the CMX and MiniPod was left running overnight in order to allow time for the MiniPod to accumulate errors at the lower levels of insertion loss.

For the measurements with only channels 9 and 11, variable attenuators 2 and 5 were used on channels 9 and 11, respectfully.

The steepness test experiment was repeated using MiniPod 2 as the transmitting MiniPod, and MiniPod 3 as the receiving MiniPod. While these MiniPods were in use, channels 1, 3, 5,7,10 and 11 were measured for a broader range of insertion loss and bit error ratio.

Data Collection/Analysis:

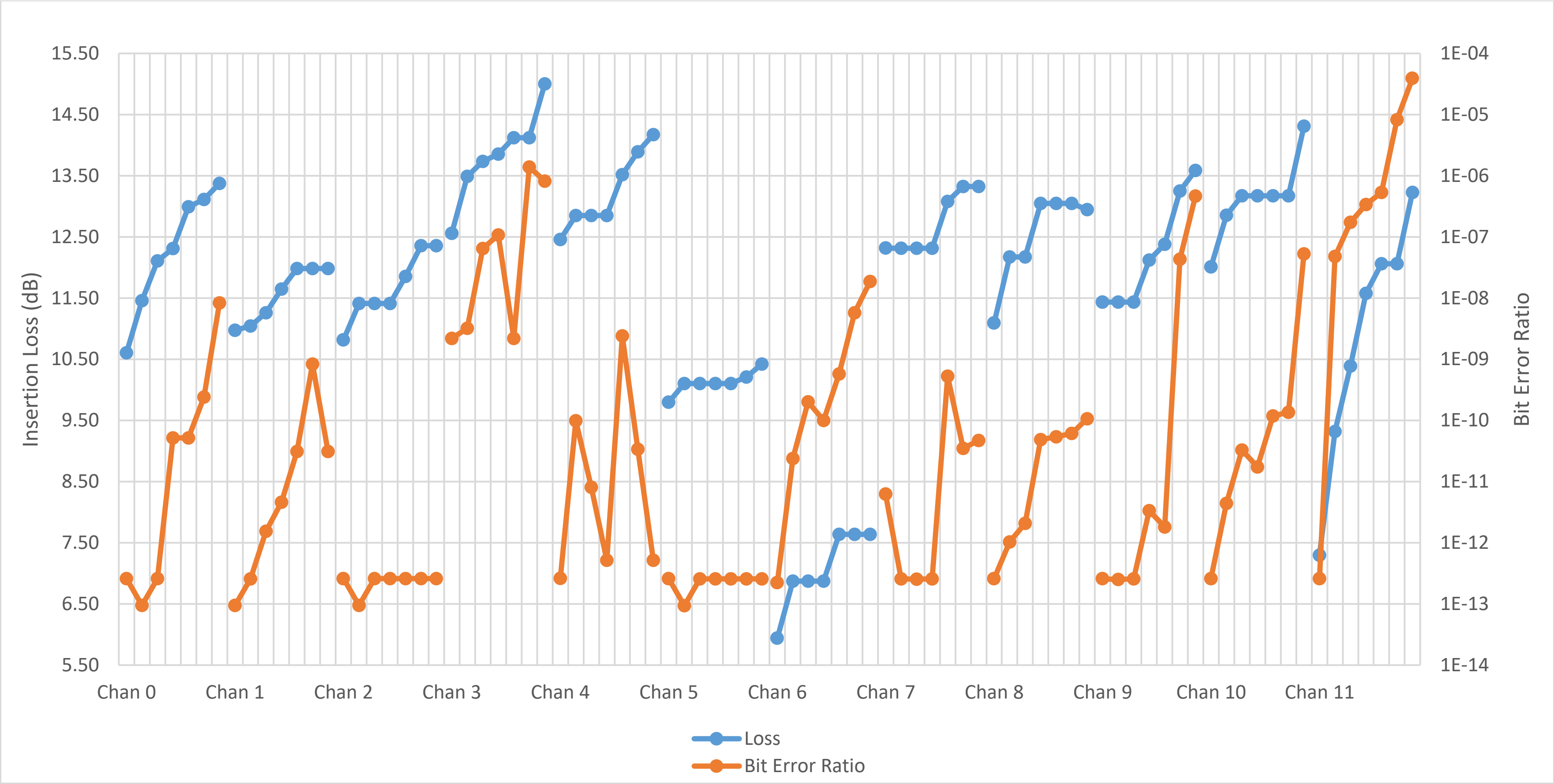
As before, several light input measurements were taken for each attenuation level that was measured. To find the insertion loss, the average of these measurements was subtracted from the zero reference (see "Procedures for all Experiments" above for explanation of zero reference).

It may also be worth noting that in exploring the range of attenuation levels above the point at which the MiniPod just regained synch, the CMX tended to measure similar values when the dial was turned to different points. For example: as the dial was turned up and down and different measurements were taken, a value for the light input in the middle of the range that showed up several times on the CMX was -13.686 dB. The Fluke meter did not exhibit this behavior, instead the values went up and down relatively smoothly with the turning of the dial on the variable attenuator. (Almost as if the CMX "liked" certain light input values).

Another notable aspect of the behavior of the CMX while doing these tests is that sometimes the light input measurements would vary by up to about 2 dB from measurement to measurement with no change in the light path.

Results:

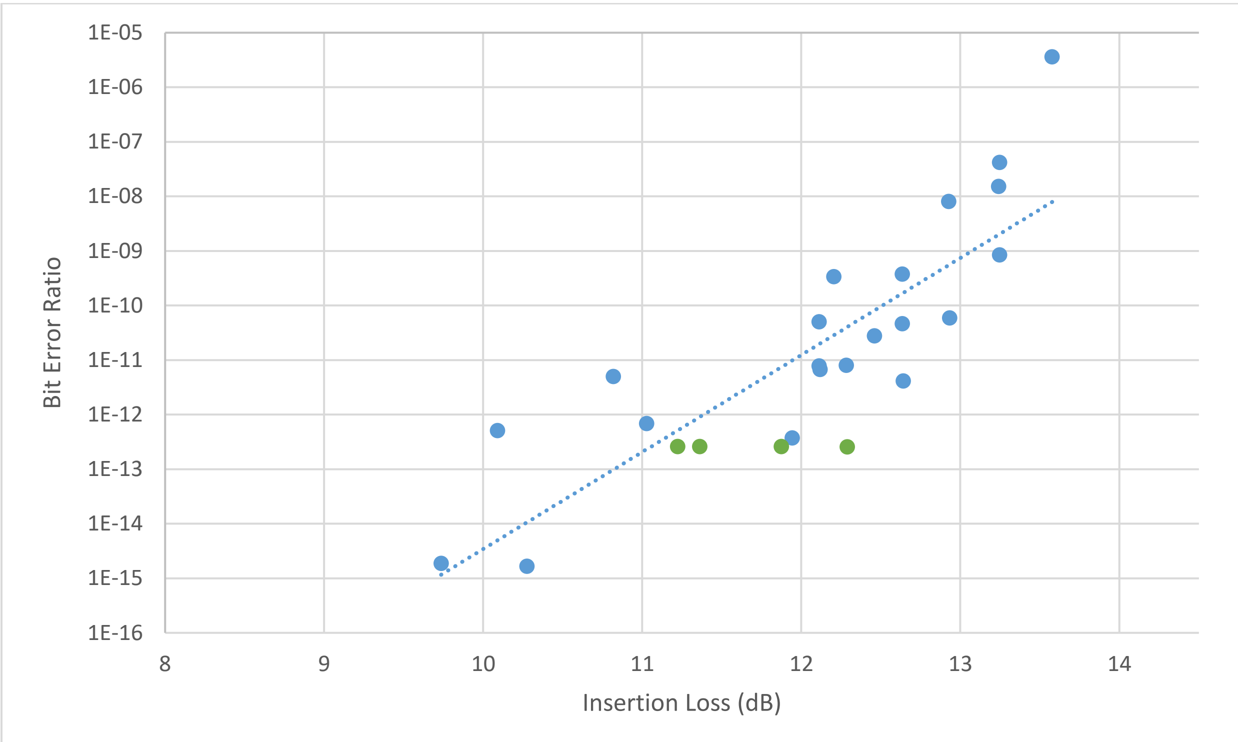
Plot 7 shows the measured insertion loss and the bit error ratio for each channel. The insertion loss and bit error ratio are displayed on two different y axes, and the axis for the bit error ratio is logarithmic.



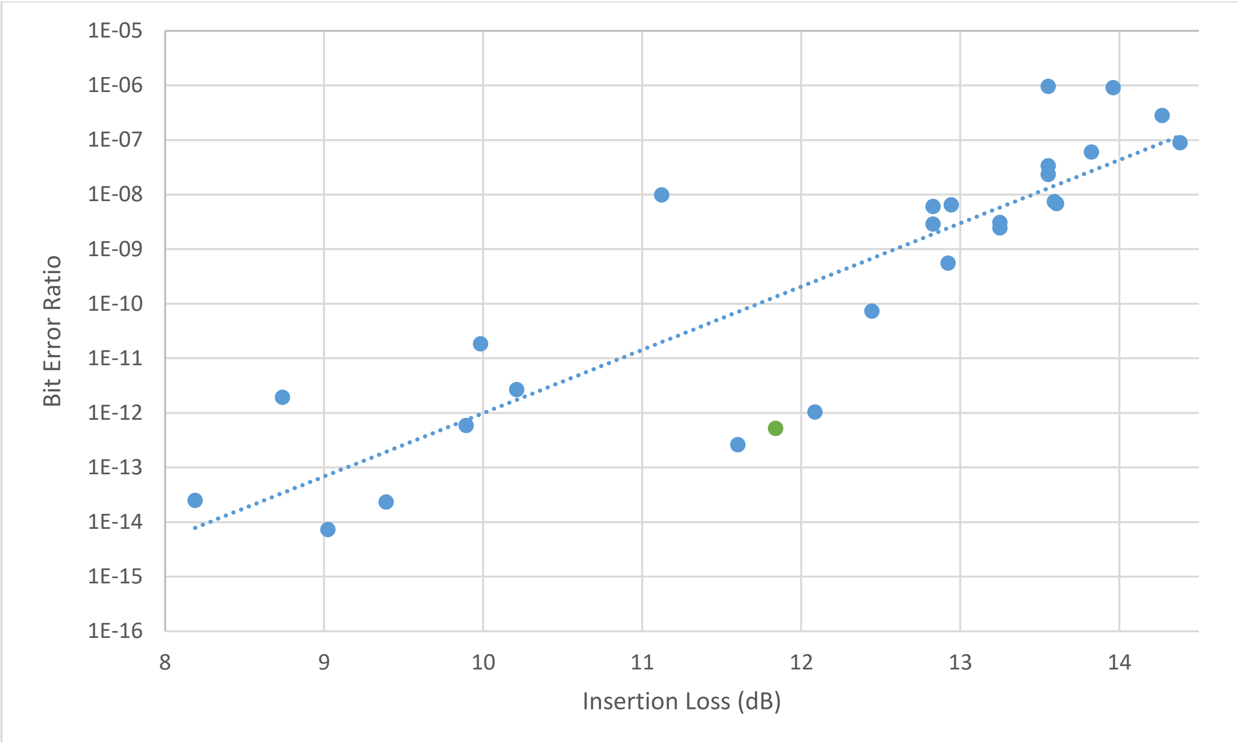
Plot 7: Insertion loss and bit error ratio measured using MiniPods 1 and 5

Plot 7 shows the relationship between the insertion loss and the bit error ratio for each channel measured using MiniPods 1 and 5. For some channels, the bit error ratio increases as the insertion loss increases, however a few channels do not show this relationship.

Plots 8 and 9 show the bit error ratio as a function of insertion loss for channels 9 and 11, respectfully, as measured using MiniPods 1 and 5. The bit error ratio axes were made to be logarithmic.



Plot 8: Insertion loss and bit error ration for channel 9 measured using MiniPods 1 and 5



Plot 9: Insertion loss and bit error ratio for channel 11 measured using MiniPods 1 and 5

On plots 8 and 9 the green data points represent values of the bit error ratio for which no errors occurred.

Plot 10 shows the measured insertion loss and the bit error ratio for each channel measured using MiniPods 2 and 3. The insertion loss and bit error ratio are displayed on two different y axes, and the axis for the bit error ratio is logarithmic.

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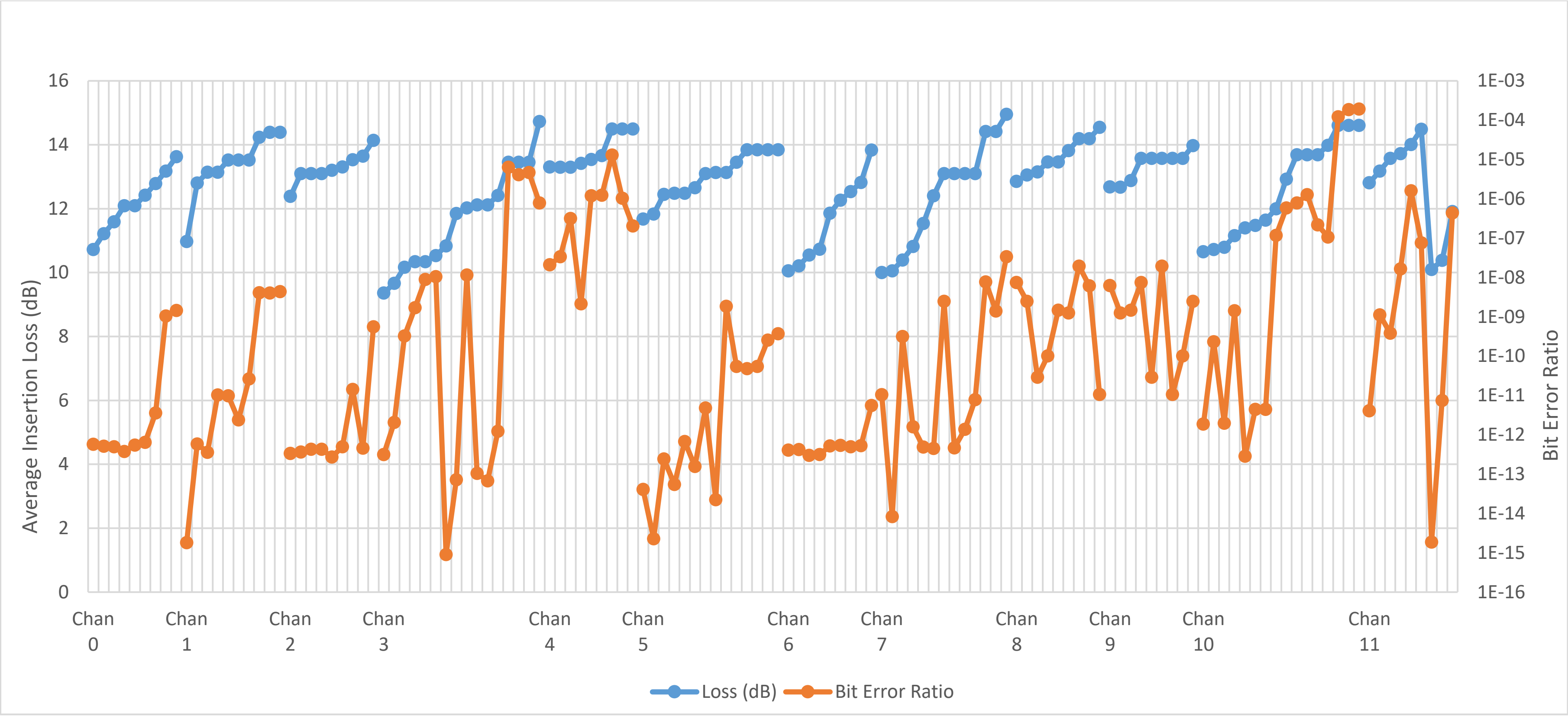
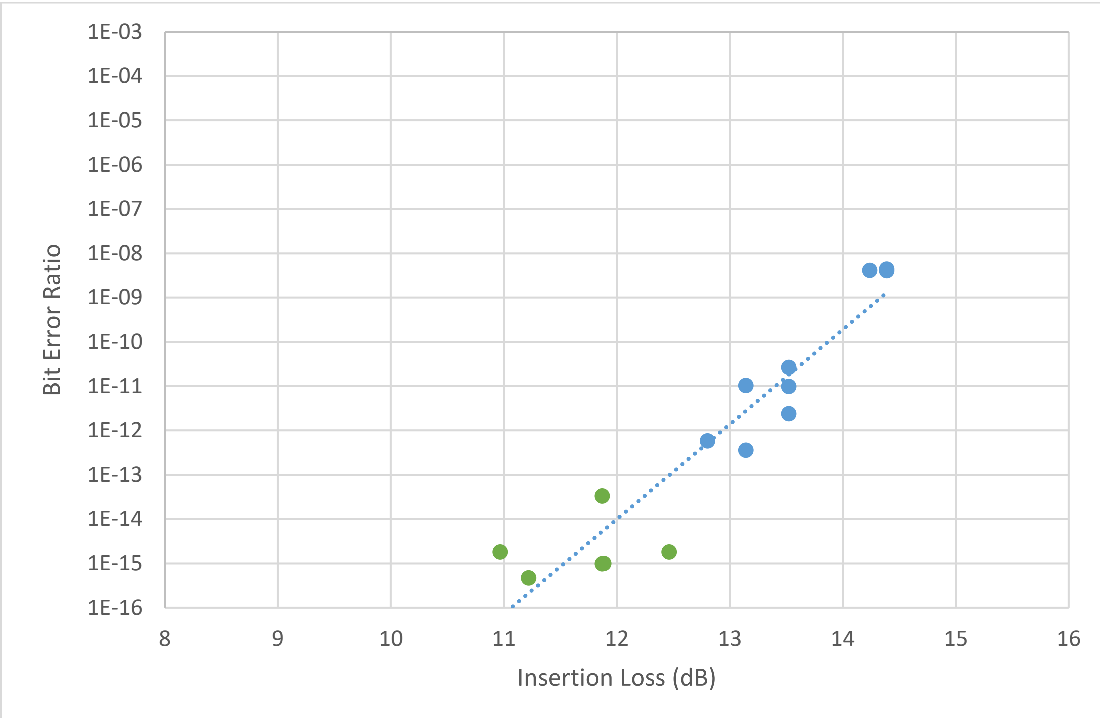
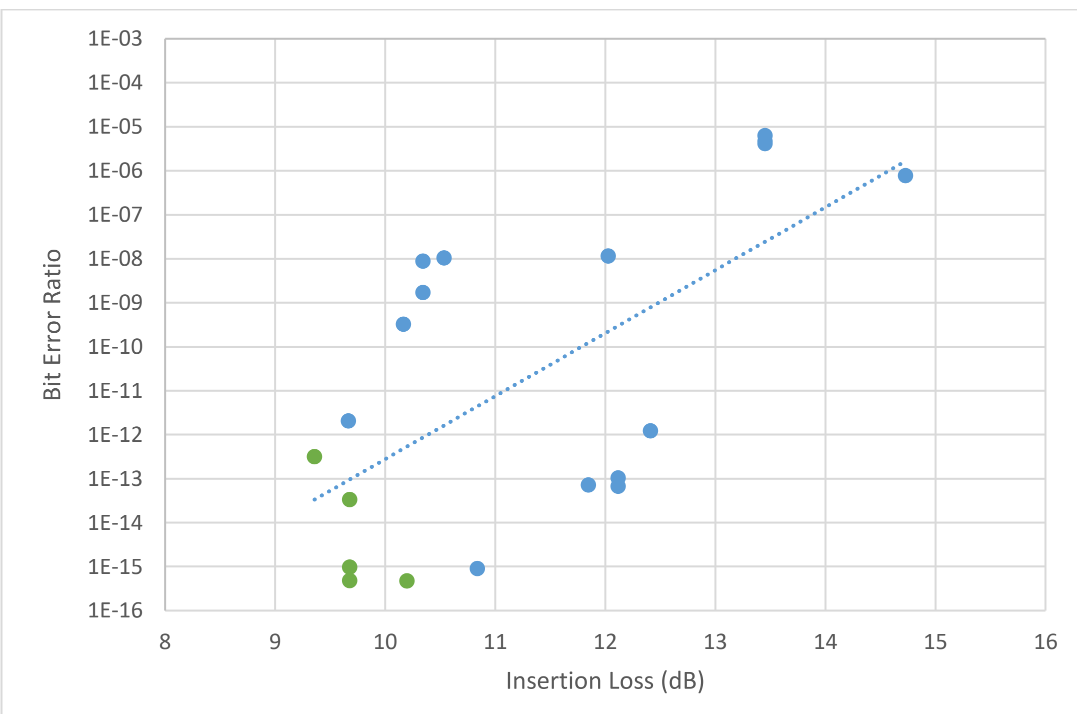


Plot 10: Insertion loss and bit error ratio measured using MiniPods 2 and 3

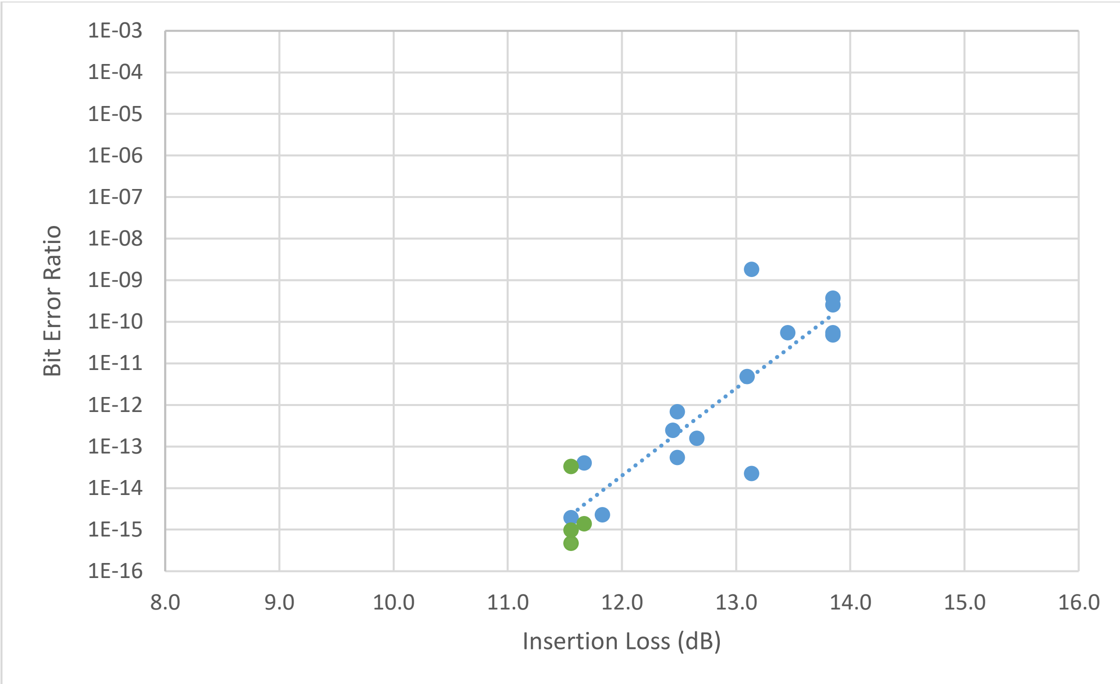
Plots 11 through 16 show the bit error ratio as a function of insertion loss for channels 1, 3, 5,7,10 and 11, respectfully, as measured using MiniPods 2 and 3. The bit error ratio axes were made to be logarithmic.



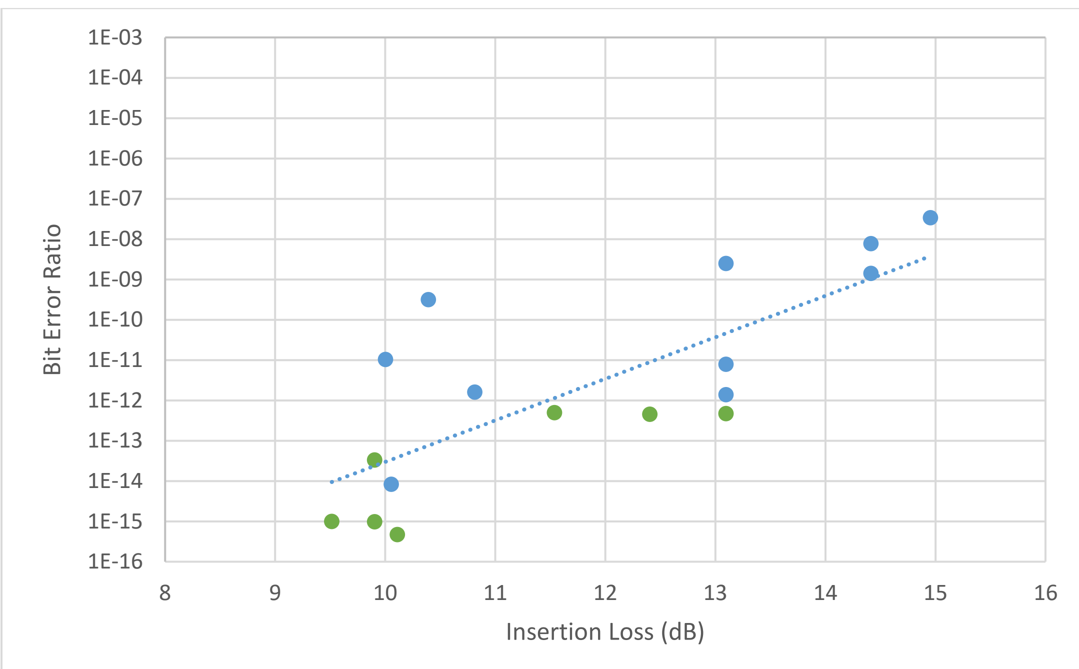
Plot 11: Insertion loss and bit error ratio for channel 1 measured using MiniPods 2 and 3



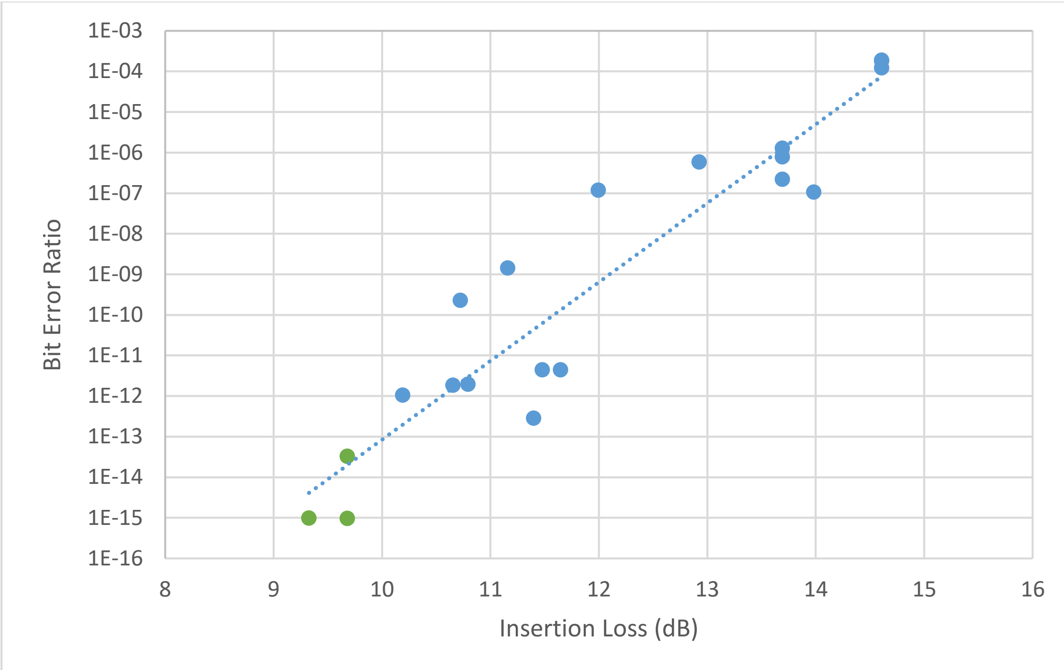
Plot 12: Insertion loss and bit error ratio for channel 3 measured using MiniPods 2 and 3



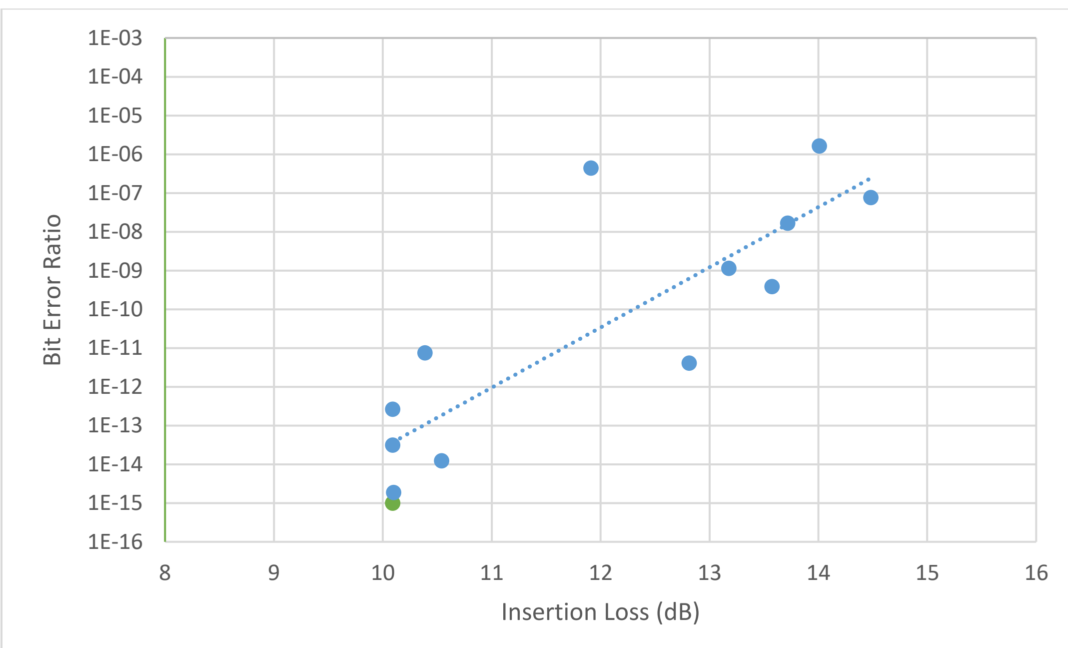
Plot 13: Insertion loss and bit error ratio for channel 5 measured using MiniPods 2 and 3



Plot 14: Insertion loss and bit error ratio for channel 7 measured using MiniPods 2 and 3



Plot 15: Insertion loss and bit error ratio for channel 10 measured using MiniPods 2 and 3



Plot 16: Insertion loss and bit error ratio for channel 11 measured using MiniPods 2 and 3

On plots 11 through 16 the green data points represent values of the bit error ratio for which no errors occurred.