Measurement Note: Using the XFI 'EQ Filter' to Equalize a Channel to Enable Eye Measurements

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Abstract

The XFI 10 Gb/s electrical interface document describes eye measurement methods using a channel equalizing filter. This note gives a brief introduction to the topic, and shows measurements made on a suitable equalizing filter.

Introduction

An increasingly common type of optical transceiver is the XFP. This 10 Gb/s optical transceiver is notable for the fact that as well as operating with a 10 Gb/s serial optical signal, it also uses a 10 Gb/s serial signal on its electrical side. This sets it apart from most 10 Gb/s transceivers, which usually use multiple lower rate electrical inputs and then multiplex them up to the transmission rate. XFP uses a unique serial electrical interface, known as XFI. This interface is described in the XFI document[i].

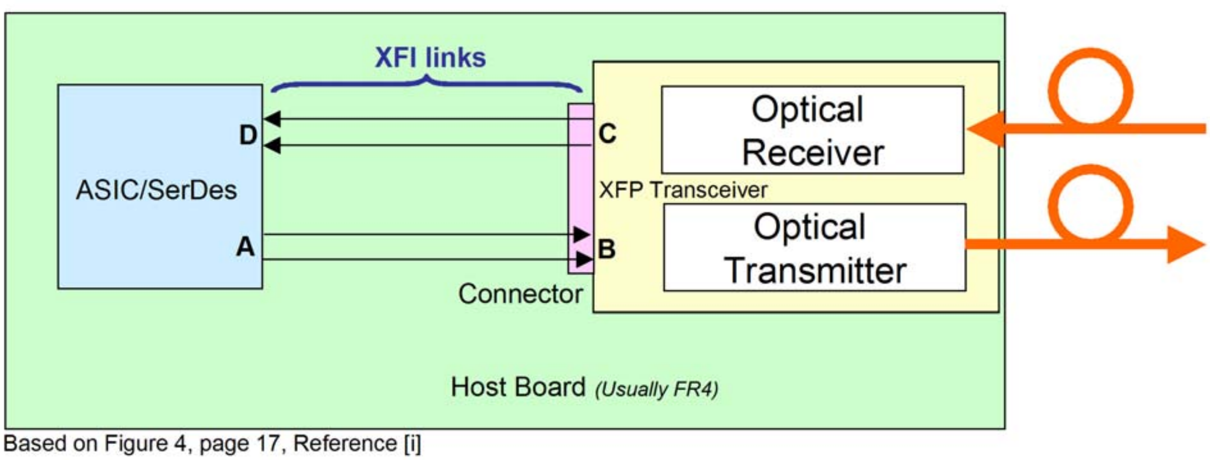

Figure 1: An illustration of the XFI reference notation.

The XFI interface (illustrated in Figure 1) is designed to overcome the obvious difficulty of successfully passing 10 Gb/s signals across low cost circuit board. It wasn't many years ago that 10 GHz signals were confined to brass waveguides. By keeping distances short, and using other modern methods such as equalization, the document describes how transmission may be achieved successfully. An allowable channel is described in the document, and the loss profile is reproduced in Figure 2. A compliant channel must have an SDD21 (forward loss) that keeps out of the red area.

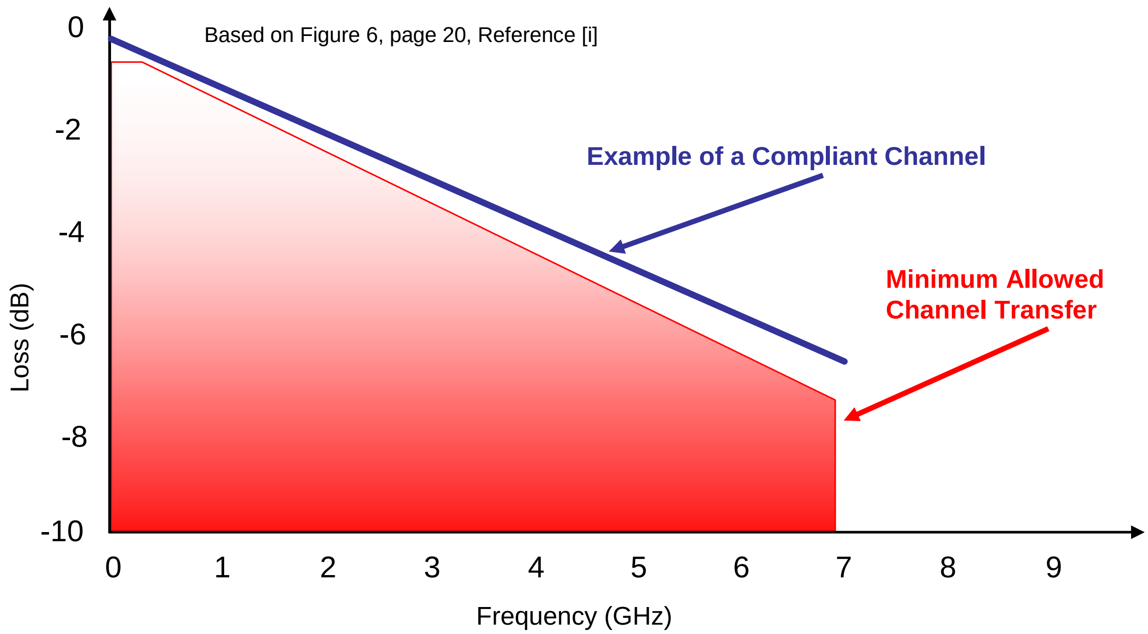

Figure 2: *An acceptable loss profile for an XFI channel.*

Appendix E.2 of the document describes making eye mask measurements of an XFI link, either at point 'B' or point 'D' of Figure 1 – in other words, measuring the eye after it has passed across a compliant channel. This description is intended to measure 'bounded non-DDJ jitter'. The intention is to remove the effects of inter-symbol interference (ISI) that arise as a consequence of the board loss profile, and measure the remaining degradation. The recommended setup is shown in Figure 3.

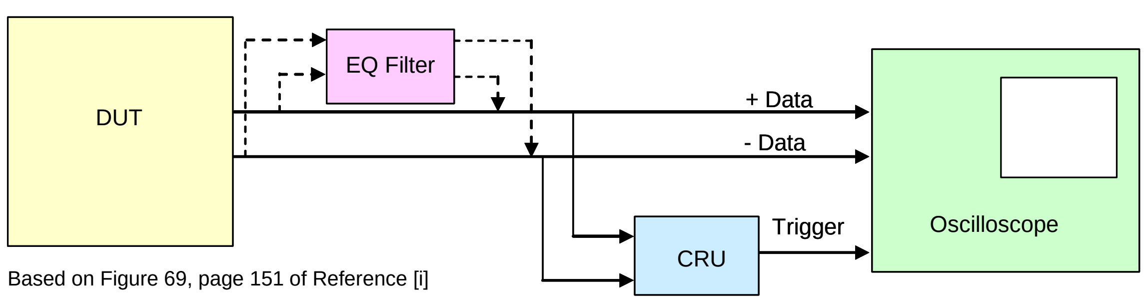

Figure 3: *The test setup recommended for 'bounded non-DDJ jitter'.*

In order to remove as much of the effect of the channel frequency response as possible, the use of an equalizing filter (the 'EQ Filter') is recommended.

The EQ Filter

The EQ Filter is intended to have the opposite response to the red area in Figure 2. An equation for the worst case channel transfer is given below:

Worst case channel transfer

$$\text{Loss}\ (dB) = (-0.1 - (0.78 \times \sqrt{f}\,) - (0.74 \times f\,))$$

(f = frequency in GHz)
Taken from page 19, reference [i]

To counter this, an equation for a filter with approximately the inverse response is given below:

Approximate EQ filter transfer

$$H(f) = \frac{(2.5 + f)}{(5.0 + f)}$$

(f = frequency in GHz)
Taken from page 151, reference [i]

Also specified is that the real filter should follow this to within +/–1 dB, and have a return loss greater than 20 dB. A plot of these two functions is shown in Figure 4, along with the net effect of the channel and filter combined.

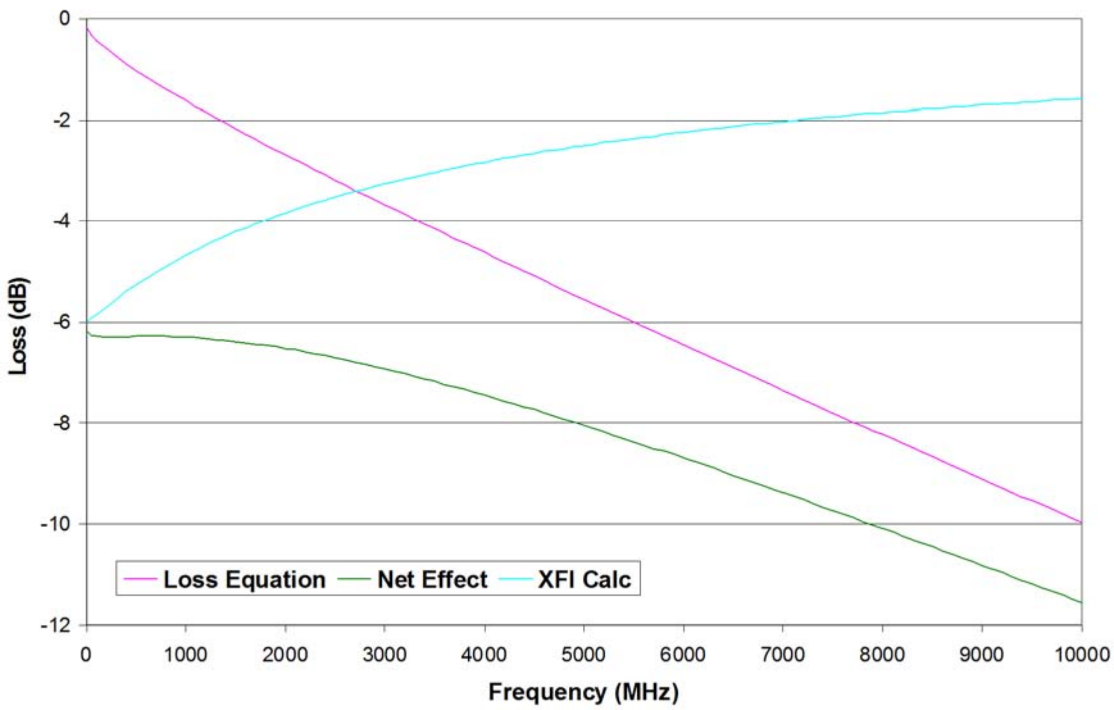

Figure 4: Combining modeled frequency responses of the XFI channel (pink line) with the EQ Filter (blue line) to give the net effect shown by the green line.

As can be seen from Figure 4, the change in loss of the channel is around 7 dB from low frequency to 7 GHz. Through use of the filter the variation has been reduced to less than 3 dB. The effect should be to open up an eye closed down by ISI, at the expense of signal magnitude.

A Practical EQ Filter

We used a commercial filter pair[ii] to examine the effectiveness of the recommended response. The filters used are shown in Figure 5. As shown in Figures 1 and 3, the XFI link is differential, and so a pair of filters is required.

Figure 5: Commercial filters employed in the measurements.

The measured filter frequency response is shown in Figure 6 compared to the mathematically predicted response. As can be seen, the filter was slightly outside the tolerable range in one small area. Similarly, the return loss was greater than 20 dB for most of the range, but did rise to 16 dB in one region.

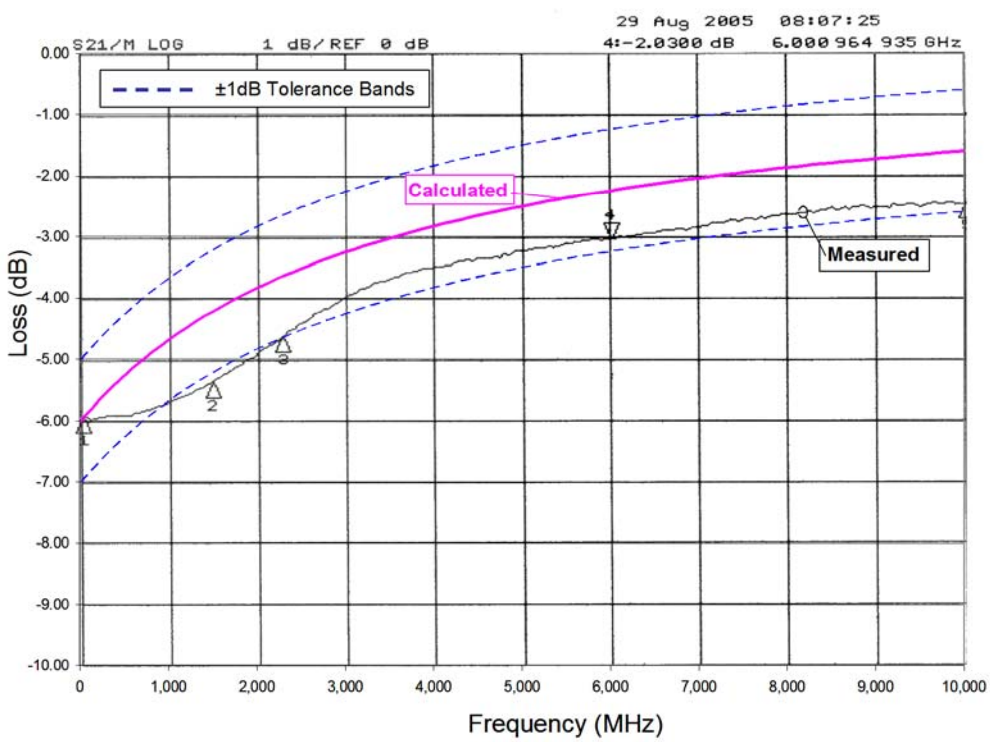

*Figure 6: Comparing the measured filter frequency response **(black** line) with the calculated response and associated tolerance window (**pink** and **dotted blue** lines, respectively).*

Measuring the Eye

Experiments were carried out using 10 inches of Getek board, as shown in Figure 7. This was used because it was convenient for investigating the effect of the filter, rather than being directly representative of an XFI compliant link. The setup is photographed single ended for clarity. Measurements were carried out differentially.

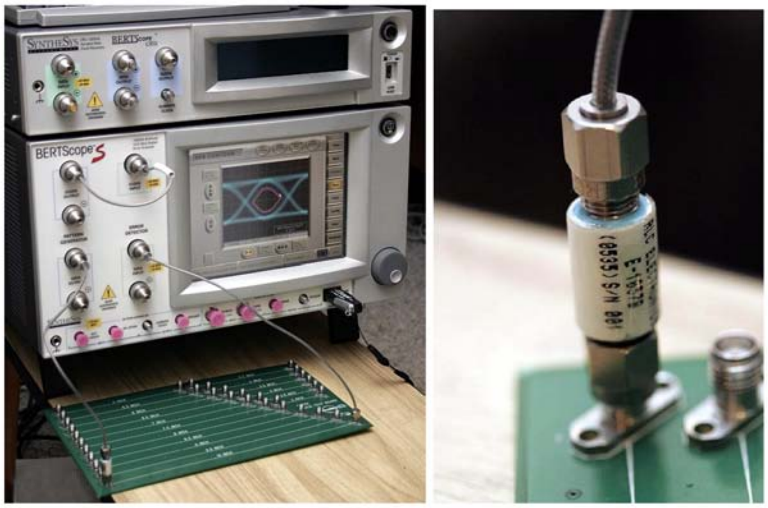

Figure 7: The measurement setup showing 10" Getek board connected between the pattern generator and error detector. The filter is also in the path, as shown on the right.

As can be seen in the figure, a pattern generator was used as a stimulus, transmitting a 10 Gb/s PRBS-31 pattern. This was connected with high quality coax cables to the combination of devices being tested, in the photo the filter and test board are combined. The receive end of the link was the analyzer error detector.

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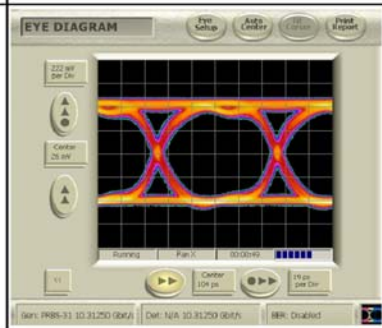
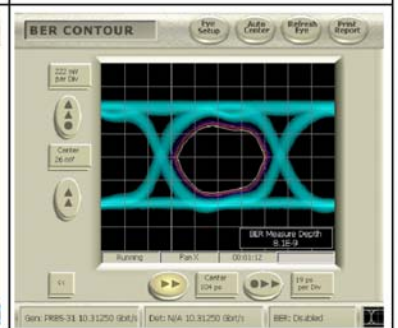
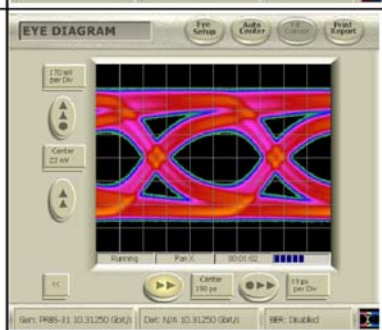
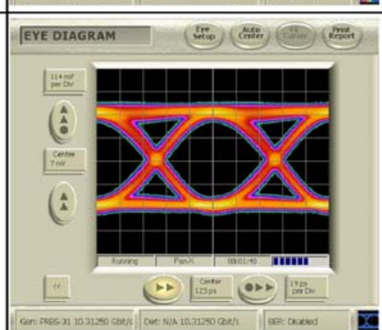
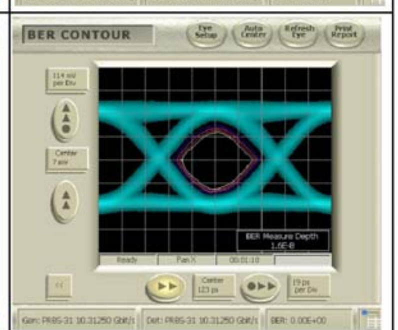
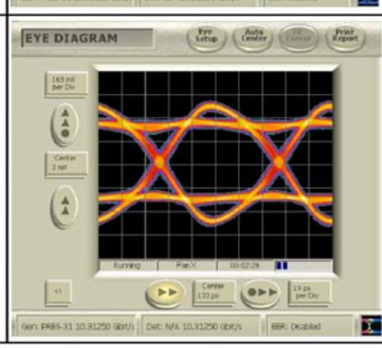
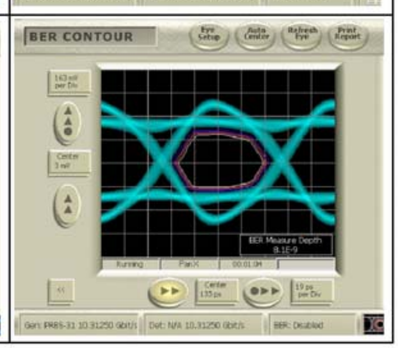
10.3125Gb/s PRBS-31	Eye Diagram	BER Contour
(A) Cables Back to Back		
(B) Adding Getek Board		
(C) Adding EQ Filter		
(D) Filter Alone		

Figure 8: Results with different combinations of board and filter.

Results are shown for different measurement combinations in Figure 8. (A) is simply to show the overall measurement system, including coax cables. Of more interest is (B) where we see the dispersive effect of the circuit board, particularly when viewed through the BER contour which shows significant closure. Adding the EQ Filter in (C) shows significant improvement in the eye opening in the eye diagram and BER contour. The reason can be seen in (D) where the effect of the filter alone can be seen, with a dramatic effect on edge behavior.

Summary

We've briefly reviewed the role of the 'EQ Filter' in the XFI specification. We have examined the equations given recommending how such a filter should behave. We've seen the beneficial effect a practical realization of the filter can have on an eye closed from passage through a length of circuit board.

Acknowledgment

Thanks to engineers at RLC Electronics for measured data used in this brief. Thanks are also due to Molex for the Getek test board.

References

[i] High Speed Electrical Specification XFI, Revision 4.1, 21st June 2005. http://www.xfpmsa.org

[ii] Model E-1057, RLC Electronics, 83 Radio Circle, Mount Kisco, New York 10549, http://www.rlcelectronics.com