Optical & Electrical jitter reduction techniques for characterisation of 10G transceivers using sampling oscilloscope

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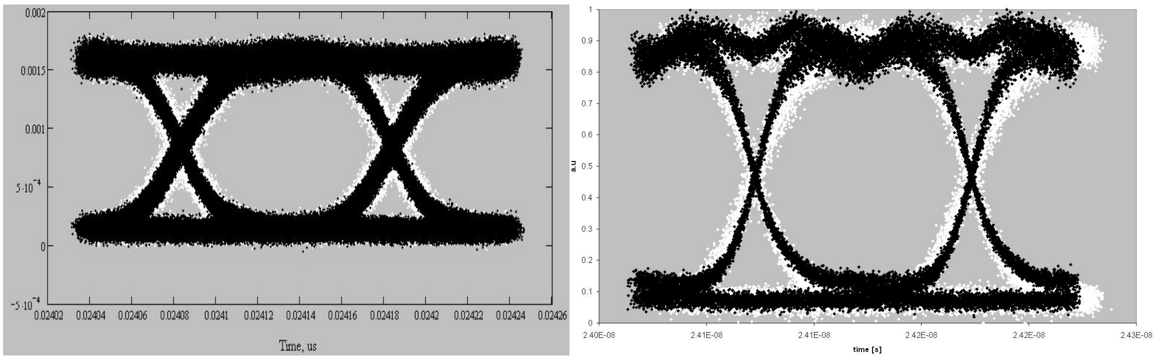
Abstract
We present the utilisation of two jitter reduction techniques to measure the intrinsic jitter of a 10 Gbits/s transceiver. We use In-phase and Quadrature referencing technique to reduce the jitter due to sampling oscilloscope used for the measurement and the pulse-carving technique to provide low jitter optical data stream to the receiver of the transceiver.

1. Introduction
Jitter generation is an important parameter when evaluating the performance of high speed optical transceivers, as the jitter can be directly linked to the Bit Error Ratio (BER) [1]. But careful consideration must be taken to minimise the intrinsic jitter of the measurement system as it is added to the result. In this paper we present the jitter measurement of a Bookham 10 Gbits/s XFP IGF 32511-B1 transceiver using two techniques to remove the jitter of the measurement system. An In-phase and Quadrature (IQ) referencing technique [2] has been used to reduce the jitter contribution of the sampling oscilloscope used for the measurement. A pulse-carving technique [3], [4], [5] has been used to obtain a low jitter optical signal in order to measure the jitter generated by the receiver of the transceiver.

2. In phase and Quadrature referencing technique
High precision timebase modules can be added to the sampling oscilloscope giving a very accurate timebase and minimising the intrinsic jitter of the trigger and the sampler of the channels. A simple alternative technique, known as the In-phase and Quadrature (or simply IQ) referencing technique, has the advantages of being cheap and only requiring commercial microwave components. The principle is briefly described here. Two sinewave signals derived from the fundamental clock of the system are positioned in quadrature using a power splitter and a delay line. These two signals plus the signal(s) of interest are acquired by the sampling oscilloscope using the same trigger signal. Due to the imperfections of the system, the parametric plot of the IQ signals is an ellipse and may not centred on the origin. A series of mappings transform the ellipse to the unit circle. From the argument of the data, the jitter due to the trigger is determined and removed from the other signals as all the signals share the same trigger. This technique removes only the trigger jitter, which is common to all channels of the oscilloscope, but the jitter of each channel remains. An example of an eye-diagram with and without IQ correction is shown in Figure 1a.



(a) *(b)*

Figure 1, (a) IQ improvement: Eye diagram with raw data (white) and IQ corrected data (black). The black data has 50% less jitter than the white data; (b) Pulse-Carving improvement: Eye diagram with normal optical signal (white) and retimed optical signal (black), the black data has 68% less jitter the white data.

3. Pulse-carving technique

Generation of low jitter or jitter free optical signal is more complicated than in the electrical domain, where high speed flip-flop can be used. In the optical domain, the pulse-carving technique is one solution. The method is as follows: An NRZ optical data stream is modulated at clock frequency using a Mach-Zehnder modulator, producing a RZ signal. The clock and the data signal must be in phase in order to sample the data in the middle of the eye. The jitter of the new optical RZ signal is the jitter of the clock signal and therefore can be made quite low. The original data stream is then recovered by launching the RZ signal at 45º of the axis of a high birefringence fibre. The length of the fibre must be carefully calculated to have the differential group delay equals to half of the clock period. The "pulse carving" or retimed signal can then be used to test optical receivers. An example of an eye diagram of optical data before (white dots) and after (black dots) the pulse carving is shown in Figure 1b.

4. Experimental set-up

A pattern generator (HP73040A) provides the electrical data stream (PRBS31 at 10.31 Gbits/s) to the XFP transceiver, which is plugged to the reference Intel board REF. The RF clock of the pattern generator is used to obtain the IQ signals, which are connected to the two channels of a 50 GHz HP54752 oscilloscope module fitted in an Agilent 86100B mainframe. The optical and electrical channels of the Agilent 8611B module are used for the acquisition of the data (either electrical or optical). The measurement were made without a Bessel-Thompson 4th filter with a cut-off frequency at 0.75 of the bit rate, which is usually the case for jitter measurements [6], as this filter is not integrated into the Agilent module. The jitter measured is therefore higher than it would be with this kind of filter included in a measurement system. The clock output of the pattern generator is used by the pulse-carving set-up to modulate the MZ modulator (Figure 2).

The jitter was measured at different points within the system as shown in Figure 2: Data output of the pattern generator (point 1), optical output of the XFP (point 2), electrical output (RD-) of the Intel board in a back-to-back configuration (without the pulse carving) (point 3), optical signal after the pulse carving system (point 4), electrical output (RD-) of the Intel board when it is supplied by a clean jitter signal (point 5).

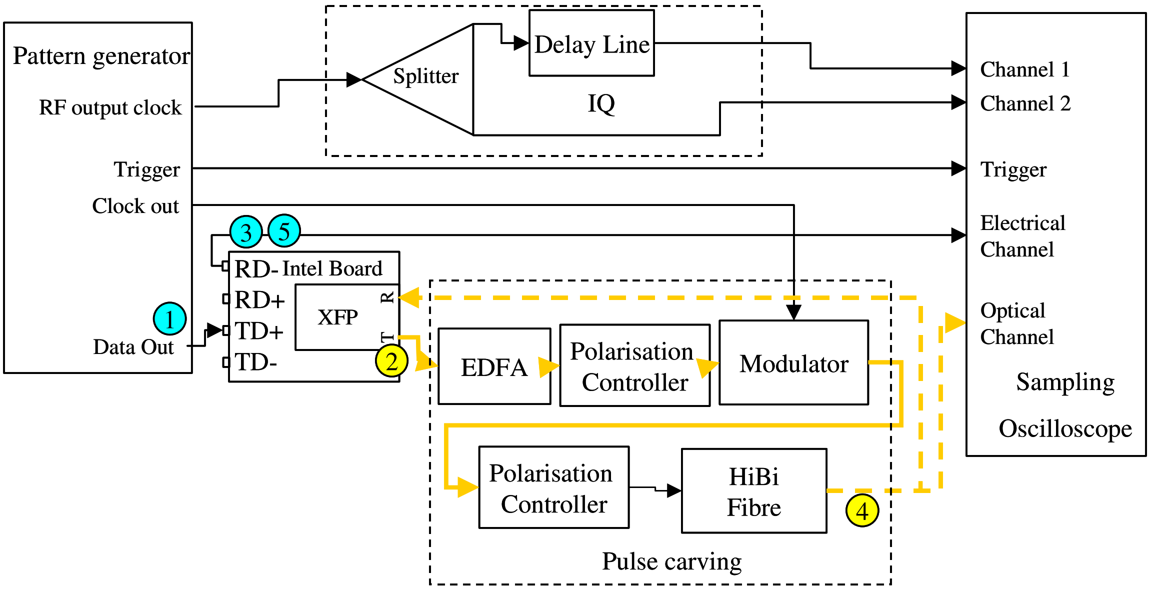


Figure 2, Experimental set-up. Jitter have been measured at different points in the system (1-5).

5. Results

Each set of data consists of 100 acquisitions of 4050 points from three channels. Measurement results are outlined in Table 1 and Figure 3. The peak-to-peak jitter is measured after 300 s and is defined as the maximum deviation of the data set at the crossing-point of the eye. The rms jitter is defined as the standard deviation of a Gaussian curve fitted to the data at the crossing point. The rms random jitter (RJ) is defined as the standard deviation of the two fitted Gaussian curves using the Dual-Dirac approximation [7]. The deterministic jitter (DJ(δδ)) is defined as the distance in time between the two centers of the fitted Gaussian curves using the Dual-Dirac approximation. The rms RJ and DJ(δδ) have been calculated only where the eye clearly shows a data dependent feature, at the RD- output of the Intel board.

Position	Jitter PP mUI		Jitter RMS mUI		RMS RJ mUI	DJ(δδ) mUI
	Raw data	IQ Corrected	Raw data	IQ corrected	IQ corrected	IQ corrected
Pattern generator	141	71	26	16	N/A	N/A
TX	185	116	31	19	N/A	N/A
RD- back to back	187	136	35	32	14.4	42
Retimed optical signal	126	43	22	8	N/A	N/A
RD- with retimed optical signal	175	128	34	31	13.5	41

Table 1, Jitter measurements at different points in the set-up using IQ correction and retimed optical signal

The IQ technique was able to reduce the jitter present in the data by up to 65%, with a reduction of 41% on average for the Peak-to-Peak jitter and 34% on average for the rms jitter. The pulse carving system has created an optical signal with 45 mUI Peak to Peak and less than 10 mUI rms jitter. This corresponds to a reduction of around 60% from the original signal. However the impact of this clean jitter signal on the receiver of the XFP is small: a ~4-5% reduction of the jitter. This means that the intrinsic jitter of the receiver is 140 mUI

Peak to Peak, and ~30 mUI rms. This can also be seen on the RJ and D(δδ) jitter, which is just slightly lower with the retimed signal than without.

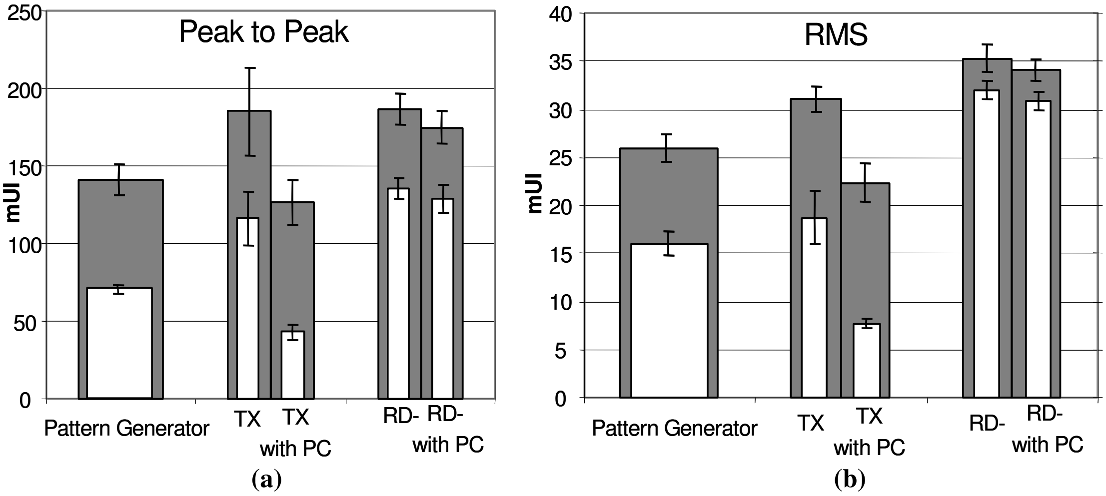


Figure 3, (a) Peak to Peak and (b) RMS jitter. Grey histograms are jitter without IQ correction, white histograms are jitter with IQ correction.

6. Conclusion

We have measured the jitter of an XFP tranceiver, using two jitter reduction techniques. The IQ referencing method has reduced the jitter by 41% peak to peak (34% rms) on average compensating for the trigger of the oscilloscope. The pulse carving technique has produced an optical signal with 45 mUI peak to peak (10 mUI rms) jitter. The intrinsic jitter of the receiver part of the transceiver is 128 mUI peak to peak (34 mUI rms). The two combined techniques presented here are therefore appropriate to reduce the jitter of the measurement system and produce low jitter optical data stream. They can be used as an alternative to other more expensive equipments.

Acknowledgments

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Reference

[1] “Jitter in Digital Communication systems, part 1 & 2”, MAXIM application note HFAN-4.03 & HFAN-4.04 (2001 & 2002)

[2] David A Humphreys & Fabrice Bernard, ‘Compensation of sampling oscilloscope trigger jitter by an In-phase and quadrature referencing technique’, ARMMS Meeting 18 & 19 April 2005, Abingdon, Oxfordshire, UK.

[3] Rory Van Tuyl, Donald Ingram, David Humphreys, David Taylor, ‘Optical Retiming for Jitter Measurement Calibration’, ECOC 2005, Glasgow, UK. 25-29 Sept. 2005 Volume: 4, On page(s): 973- 974 vol.4

[4] U.S. Patent 10/650,255, “Method and System for Generating Low Jitter NRZ Optical Data Utilizing an Optical Pulse Stretcher.”

[5] ITU recommendation O.172, Appendix VII (April 2005)

[6] ITU recommendation G.957, Annex B (March 2006)

[7]“Jitter Analysis: The dual-Dirac Model, RJ/DJ, and Q-Scale”, white paper, Agilent technologies (2004), http://cp.literature.agilent.com/litweb/pdf/5989-3206EN.pdf