Data-Dependent Effects on Jitter Measurement

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Abstract

Data-dependent jitter of transmitter for Non-Framed PRBS and SDH-Framed signal weresimulated. The results showed that Jitter evaluation for transmitters should be identical to the Framed pattern used at the final equipment testing.

Introduction

When performing Jitter generation tests on optical transmitters for SDH/SONET/OTN, most device vendors use a data pattern with randomly generated transitions like a Non-Framed Pseudo-Random Bit Sequence (PRBS) as a test pattern. In contrast, when these devices are installed in transmission equipment, the final Jitter evaluation is performed with an actual data pattern used by SDH/SONET/OTN which is Framed. As a consequence, there is often a problem of inconsistent Jitter values between device vendors and equipment vendors. There are two main reasons for this difference. First, the theoretical difference of Jitter values of the device under test (DUT) for the Non-Framed and Framed signals, and parameters of DUT causing the difference, have never been verified quantitatively. Second, the measurement error of the measurement method used by many Jitter testers (convert Data signal to Clock and measure Clock Jitter) for the Non-Framed and Framed signals has never been quantified and verified. This paper examines how the test data pattern affects the Jitter results by simulating measuring equipment modeling the DUT and Jitter measurement method.

Simulation Model

In this simulation, we evaluate that data dependent Jitter (DDJ) can be caused by the frequency bandwidth of the DUT and Jitter measurement instrument. We quantified how the Jitter in the DUT output signal changes with the Non-Framed and Framed signals.

Fig. 1 shows a simulation model in which a pseudo-random Jitter-free NRZ 9.95 Gbps data signal with the discrete series *x(n)* (*n* = 0, 1, 2,....) is input as the evaluation signal. Here the *x(n)* value is either 1 (High level) or 0 (Low level),The sampling interval is set to 1/1000 th of the assumed 1 unit interval (UI) to obtain a simulation resolution of 1 mUI.Three Non-Framed PRBS 2^7-1, 2^{15}-1, and 2^{31}-1 signals and a STM-64 SDH Framed signal were used as the *x(n)* data pattern. The SDH Framed payload was a PRBS 2^{31}-1 pattern scrambled by a PRBS 2^7-1 pattern. Each PRBS was generated using a polynomial complying with ITU-T Rec. O.150, and O.151.H (i.e. PRBS 2^7-1: $1 + X^6 + X^7$, PRBS 2^{15}-1: $1 + X^{14} + X^{15}$, PRBS 2^{31}-1: $1 + X^{28} + X^{31}$).

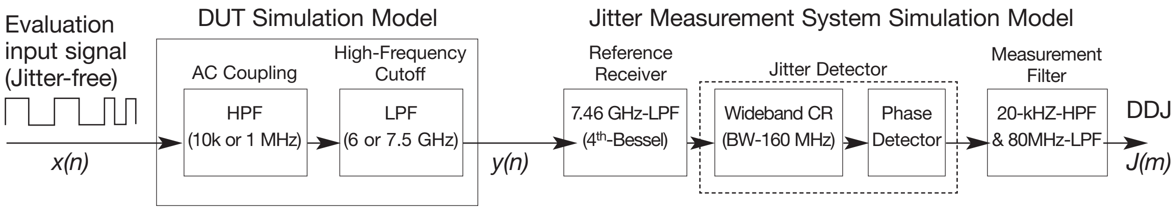

Fig. 1 Simulation Model for Data-Dependent Jitter of DUT and Jitter Measurement System.
Input signal bit rate: 9.95 Gbps, Evaluation pattern: Non-Framed PRBS 27-1, 215-1, 231-1, or SDH-Framed Signal with Payload PRBS 231-1 + Scramble PRBS 27-1.

Generally, it is thought that the primary factor generating DDJ is the frequency bandwidth of DUT [1?3]. The HPF and LPF are used to model the frequency bandwidth of DUT due to AC coupling and high-frequency cutoff components. The AC coupling was modeled using a 1st-order HPF with a cutoff frequency of 10 kHz or 1 MHz. In contrast, a 4th-order Butterworth LPF with a cutoff frequency of 6 GHz or 7.5 GHz was used to model the optical transmitter high-frequency cutoff. A Butterworth filter is used as LPF, because some frequency characteristics of actual optical transmitters resemble a Butterworth filter. The impact on DDJ caused by changing the cutoff frequency of the HPF and LPF is examined.
The transfer function of the reference receiver configuring the Jitter measurement system uses a 4th-order Bessel filter with a cutoff frequency of 0.75 times the data rate (i.e. 7.46 GHz) in compliance with ITU-T Rec. ANNEX B/G.957. The Jitter detector simulation model, the second element, refers to the phase detection method under discussion in ITU-T Q5/Study Group 4 [4]. In this phase detection method, after the input data signal is converted to a clock signal with a center frequency of 9.95 GHz by wideband clock recovery (W-CR), the Jitter at each rising edge of the clock signal is found using phase detection. In this simulation, the W-CR passband was set to 160 MHz which was twice the upper Jitter measurement band (80 MHz). The Jitter measurement filter, the third element, is a filter for suppressing high and low Jitter as described in ITU-T Rec. G.783 and G.825. It is defined as a 20-kHz 1st-order HPF and a 80-MHz 3rd-order LPF. A DDJ series of *J(m)* (*m* = 0, 1, 2, …) with a sampling interval equivalent to 1 UI is output from the Jitter measurement system.

Simulation Results

Table 1 lists the peak-to-peak DDJ values, DDJpp, for the J(m) time series (m = 0, 1, 2, …, M -1) obtained from the simulation model shown in Fig. 1. The simulation No. 1 intends the measurement error of the Jitter measurement system, because the HPF and LPF of DUT were passed through. In simulations No. 2 to No. 9, the DUT was modeled with a combination of HPF and LPF with different cutoff frequencies (fL and fH). The results are explained in sequence on the next page.

Table 1 DDJpp of DUT using simulation model in Fig.1 (Units: mUIpp)

Sim No.	DUT Bandwidth Limit (-: No-Filter)		Data Pattern			
			Non-Framed Signal			SDH Framed Signal
	f_L of HPF	f_H of HPF	PRBS 2^7-1 (M=127)	PRBS 2^{15}-1 (M=32767)	PRBS 2^{31}-1 (M=20x10^6)	Payload : PRBS 2^{31}-1 +Scramble PRBS 2^7-1 (M=20x10^6)
1	–	–	1	4	5	4
2	10 kHz	–	1	4	5	4
3	1 MHz	–	1	4	5	4
4	–	7.5 GHz	1	5	8	7
5	–	6 GHz	1	7	37	60
6	10 kHz	7.5 GHz	1	5	8	7
7	1 MHz	7.5 GHz	1	7	16	8
8	10 kHz	6 GHz	1	7	38	61
9	1 MHz	6 GHz	1	8	45	61

In Simulation No. 1, DDJ is generated in the measurement system even though the input signal is Jitter-free, because when the data signal is converted to a clock signal by W-CR of the phase detector, timing errors occur in the recovered clock signal corresponding to the variance of time intervals of High and Low levels in the data. The results show that the data-dependent measurement error for the Jitter measurement method used by most Jitter testers is 5 mUIpp max. This is much smaller than the 100 mUIpp maximum permissible Jitter for measurement equipment specified by ITU-T Rec. G.783.

Simulations No. 2 and No. 3 modeled the DUT using only a HPF. The DDJpp values for each data pattern are extremely small and are the same as the Jitter measurement error of simulation No. 1. In other words, the DDJpp resulting from the HPF is sufficiently small to be ignored as measurement error.

Simulations No. 4 and No. 5 modeled the DUT using only a LPF. With a Non-Framed PRBS 215-1, 231-1 and SDH Framed signal, the DDJpp increased. Especially in simulation No. 5, the DDJpp values with a Non-Framed signal of PRBS 231-1 and an SDH Framed signal are extremely large at 37 mUIpp and 60 mUIpp, respectively. This corresponds with the large waveform distortion for y(n) due to the low value of fH.

Simulations No. 6 to No. 9 modeled a DUT using both a HPF and LPF. Due to the effect of both the HPF and LPF, with a Non-Framed PRBS 231-1 signal, the DDJpp is larger than with only a LPF. For example, the DDJpp for No. 5 is 37 mUIpp but 45 mUIpp for No. 9. In contrast, with an SDH Framed signal the effect of adding a HPF is small.

Fig. 2 shows typical examples of the DDJ time series J(m) when using an SDH Framed signal in simulations No. 2 and No. 8. In each graph, J(m) for m = 1000 to 6000 are the DDJ samples at the header section of the SDH frame. (Note that the header section is not scrambled by PRBS 27-1.) In Fig. 2(a), which modeled the DUT as a HPF only, DDJpp is determined by Jitter generated at the payload section. Alternatively, in Fig. 2(b), which all took a LPF into account, DDJpp is determined by Jitter generated at the header section.

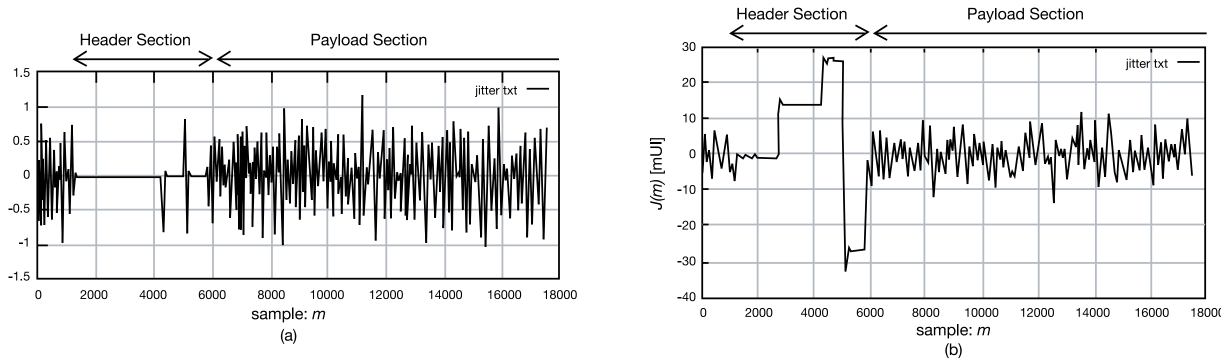

Fig. 2 DDJ Time Series for SDH Framed Signals: (a) for Simulation No. 2, (b) for Simulation No.8 in Table 1.

Discussions

In the simulations No.2–No.9 in Table 1, the difference in the DDJpp generated with Non-Framed PRBS 2^7-1 and PRBS 2^{31}-1 has a wide range from 5 to 45 times. The increase in the DDJpp with the long maximum pattern length of the PRBS is thought to be due to the occurrence of long High and long Low levels contained in the data pattern.

Since the SDH Framed signal payload is a PRBS 2^{31}-1 pattern scrambled by a PRBS 2^7-1 pattern, the longest High level is 38 UI, This length is longer than for the Non-Framed PRBS 2^{31}-1. Irrespective of this, the DDJpp for the SDH Framed signal in simulations No. 2–No. 4, No. 6, and No. 7 is smaller than for the Non-Framed PRBS 2^{31}-1 pattern. This occurs because a 3-tap polynomial generates the PRBS 2^{31}-1 pattern in which the long High (or long Low) level strings occur closely, making it relatively easy to generate large DDJpp by filtering. On the other hand, with an SDH Framed scrambled PRBS 2^{31}-1 pattern, it is hard to generate a large DDJpp because the above-described bias is dispersed.

As is clearly indicated in Fig. 2, with an SDH Framed signal, there is a tendency to generate larger DDJ in the header section due to the LPF effect. As a result, there is significant inconsistency in the Jitter values between an SDH Framed signal and a Non-Framed signal even when the SDH Framed payload is a PRBS2^{31}-1 pattern. Consequently, the best test pattern to use for evaluating DUT Jitter should be the SDH Framed pattern used at the final equipment testing.

Conclusion

The dependency of DDJpp on the transmission data pattern was verified by a computer simulation model. The DDJ measurement error of the Jitter measurement method used by most Jitter testers is 5 mUIpp max. (@9.95 Gbps). Moreover, combining a HPF and LPF as the DUT model shows that DDJpp is increased more by the LPF than HPF. Additionally, the difference between DDJpp for Non-Framed PRBS 2^7-1 and PRBS 2^{31}-1 pattern signals varies significantly from 5 to 45 times depending on the HPF and LPF combination. With an SDH Framed signal, larger DDJ is generated at the unscrambled header section than the payload section due to the LPF effect. As a result, it is clear that there is significant inconsistency in the Jitter values between an SDH Framed signal and a Non-Framed signal even when the SDH Framed payload is a PRBS2^{31}-1 pattern. In other words, we have confirmed that the test pattern used for device Jitter evaluation must be identical to the Framed pattern used at the final equipment testing. of a separate PC or be operated manually. The MT8815B is a full-featured tester designed for Level 1, 2 and 3 testing at a high rate of speed. It supports WCDMA, GSM/GPRS/EGPRS, cdma2000 1xRTT, cdma2000 1xEV-DO, AMPS voice channel and PHS. The MT8820B essentially combines the functionality of two MT8815B units into one mainframe. When used in combination with the Parallel Phone measurement option, the MT8820B can test two phones at the same time, enabling substantial increases in throughput at a minimal increase in cost.

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Specifications are subject to change without notice.

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