Difference in Jitter definition of ITU and IEEE 10G initiative

Presentation for March 12 - 16 2001 IEEE 802.3 Meeting

Juergen Rahn

Difference in Jitter definition of ITU and IEEE 10G initiative

- **ITU in main discusses timing jitter (related to network timing concepts)**
  - **Jitter of the Clock of the specific entity (Receiver, Transmitter, NE) against a reference clock with reference quality**
- **IEEE 10GE initiative discusses bit pattern jitter**
  - **All effects that contribute to horizontal eye closure of the receiver signal relative to the reference receiver PLL clock are considered as components of jitter**

Difference in Jitter definition of ITU and IEEE 10G initiative

- **ITU defines timing jitter (related to network timing concepts)**
  - **Split into low frequency (Wander) and high frequency (jitter components)**
  - **For network timing the components are important falling into PLL filter bandwidth (as further transmitted) those components are irrelevant for 10GE interface definitions (only components are accumulated that fall into PLL bandwidth)**
  - **For jitter tolerance of an interface the important components are :**
    - Frequencies at or above the PLL filter bandwidth
    - Separation into
      - Jitter generated at transmitter
      - Jitter tolerance against a reference transmitter signal
      - components generated by frequency or phase modulation of the optical signal together with the group delay behavior of the optical fibre

Difference in Jitter definition of ITU and IEEE 10G initiative

- **Common ground rules for both IEEE as well as ITU for jitter tolerance at receive side of interface are the same**
  - **Physical base: The eye has to be open at decision point in relation to available clock (recovered clock)**

Difference in Jitter definition of ITU and IEEE 10G initiative

- **Total generated transmitter horizontal eye closure at interface point is the total phase deviation of the input signal which depends on:**
  - **Transmitter side Clock noise**
  - **Signal dependent phase deviation in the bit stream which depends on transmitter implementation**
  - **Phase deviation (Horizontal bit slope deviation in relation to decision threshold) related to Base line wander with respect to signal statistics (should be neglectable at transmitter as normally dc coupled implementation present)**
  - **Laser non-linearity (difference in rise , fall time and other effects...)**

Difference in Jitter definition of ITU and IEEE 10G initiative

- **Total generated receiver input horizontal eye closure at interface point is the total phase deviation of the input signal which depends on (eye closure after the fibre, in front of receiver):**
  - **Transmitter side eye closure**
  - **Fibre dispersion induced phase modulation at the bit slopes that is induced by:**
    - **Dispersion related ISI at the slope related to modulation speed (Interaction of signal bandwidth together with dispersion gives the so called transform limit).**
    - **Frequency and phase modulation of the optical carrier related to modulator or laser effects at the slopes (chirp).**
    - **Phase modulation of the optical pulses related to different group velocity of polarization states of the fibre and presence of the polarization states at the transmitter signal (PMD).**
    - **Phase modulation of the optical pulses due to fibre non linearity (kerr effect) (fibre induced chirp).**

Difference in Jitter definition of ITU and IEEE 10G initiative

- **Total generated receiver input horizontal eye closure at decision circuit relative to phase of the regenerated clock is relevant for BER degradation.**
  - **Difference jitter at this point is total of the phase deviation of the input signal related to the eye closure after the fibre and eye closure related to the receiver front end which consists of :**
    - Signal dependent phase deviation in the bit stream related to receiver implementation (receiver bandwidth related non linear phase distortions)
    - Phase deviation (Horizontal bit slope deviation in relation to decision threshold) related to Base line wander with respect to signal statistics and receiver transfer function
    - Signal depended phase deviation in the bit stream related to clock extraction circuit implementation
    - Receiver side clock noise
    - Receiver side filtered transmitter clock variation relative to recovered clock signal (Frequency components present in transmitter side clock, filtered at receiver side PLL filter.
  - + **Transmitter side eye closure**
  - + **Fibre dispersion induced phase modulation at the slopes**

Difference in Jitter definition of ITU and IEEE 10G initiative

- **Consideration of different jitter (Horizontal Eye closure) components**
  - Transmitter side eye closure
    - Transmitter side Clock noise :
      - Portion of generated transmitter jitter as specified by ITU. Not visible if measured against transmit side clock (portion between 4 MHz and 80 MHz specified to be less than 0.1 UI (ITU Option1)). Components above this frequency range to be part of the transmitter side eye closure in case of measurement with reference clock and have to be in line to the eye diagram.
    - Signal dependent phase deviation in the bit stream related to transmitter implementation
      - Portion of generated transmitter jitter as specified by ITU (portion between 4 MH and 80 MHz specified to be less than 0.1 UI (ITU Option1)). Normally present in frequency range above several hundreds of MHz, and as such part of the transmitter side Eye mask closure. Portion below 80MHz part of the mentioned budget.
    - Phase deviation (Horizontal bit slope deviation in relation to decision threshold) related to Base line wander with respect to signal statistics (should be neglectable at transmitter)
      - Portion of generated transmitter jitter as specified by ITU. (portion between 4 MH and 80 MHz specified to be less than 0.1 UI). If present likely in frequency range above several hundreds of MHz, and as such part of the transmitter side Eye mask closure. Portion below 80MHz part of the mentioned budget.
    - Laser non-linearity (difference in rise , fall time and other effects...)
      - In principle also Portion of generated transmitter jitter as specified by ITU. (portion between 4 MH and 80 MHz specified to be less than 0.1 UI). If present very likely only in frequency range above several hundreds of MHz, and as such part of the transmitter side Eye mask closure

Difference in Jitter definition of ITU and IEEE 10G initiative

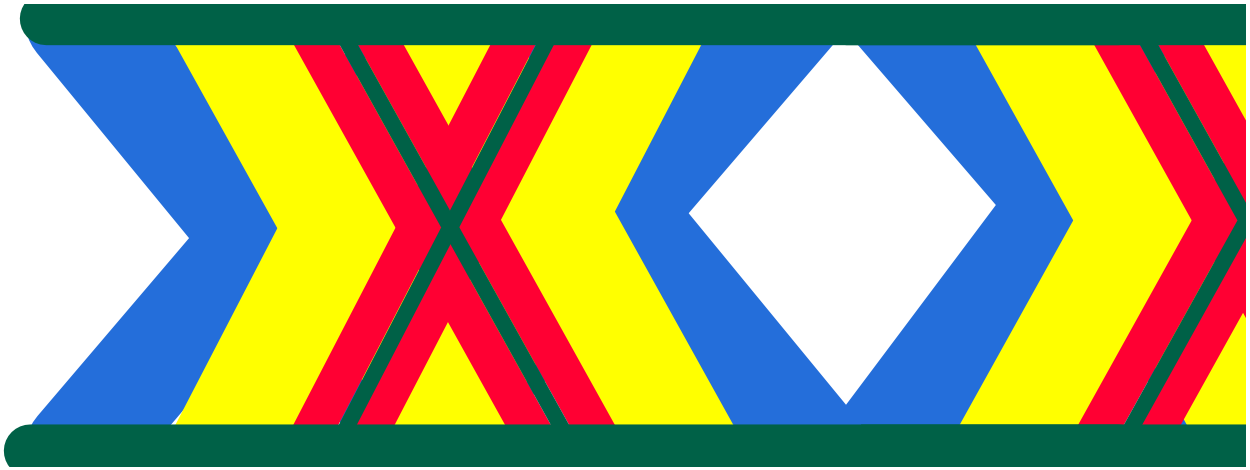
- **Consideration of different jitter (Horizontal Eye closure) components (continuation))**
  - Fibre induced eye closure (phase modulation at the slopes)
    - Frequency modulation of the optical carrier at the slope related to modulation speed (Defines transform limit related to dispersion).
      - Related performance degradation in ITU terms specified as path penalty. Contains spectral components of ultra high frequencies. As such will always lead to performance degradations on a per bit level independent of the clock recovery circuit and as such part of the receiver eye closure described by path penalty.
    - Frequency and phase modulation of the optical carrier related to modulator or laser effects at the slopes (chirp).
      - Effect of additional phase modulation at the pulse slopes. Represents additional red or blue-shift to the modulation components under the firs bullet item. Of same nature as effects of the first bullet item as well as related performance degradation (or improvement in case of negative chirp on G.652 fibres) in ITU terms specified as path penalty. Contains spectral components of ultra high frequencies. As such will always lead to performance degradations (or improvement) on a per bit level independent of the clock recovery circuit and as such part of the receiver eye closure described by the path penalty.
    - Phase modulation of the optical pulses related to different group velocity of polarization states of the fibre and presence of the polarization states at the transmitter signal (PMD).
      - Effect of statistical nature generating horizontal as well as vertical eye closure. Viewed as a per bit effect containing as such ultra high frequencies not part of the SONET jitter budget. Part of the path penalty. Should be small on short distances .
    - Phase modulation of the optical signals related to fibre non linearity (kerr effect) (fibre induced chirp).
      - Effect induced by non linearity proportional to dP/dt. As such bound to high power values and consists of ultra high frequency components. Of same nature as effects of the first bullet item. Part of the path penalty. Is small at power levels as defined for 10GE.

Lucent Technologies
Bell Labs Innovations

Difference in Jitter definition of ITU and IEEE 10G initiative

- **Consideration of different jitter (Horizontal Eye closure) components (continuation))**
  - Receiver:
    - Signal dependent phase deviation in the bit stream related to receiver implementation (receiver bandwidth related non linear phase distortions)
      - Effect of frequency components near to upper receiver border frequency. Of high frequency nature far beyond PLL bandwidth an as such covered by receiver sensitivity
    - Phase deviation (Horizontal bit slope deviation in relation to decision threshold) related to Base line wander with respect to signal statistics and receiver transfer function.
      - In line to probability distributions of signals containing frequencies above the PLL bandwidth. As such not visible in the behavior of the clock recovery circuit and covered by receiver sensitivity
    - Signal dependent phase deviation in the bit stream related to clock extraction circuit implementation
      - Effect that would add signal correlated Clock noise relative to incoming bit clock signal to the recovered receiver clock . Filtered by the PLL filter.
    - Receiver side clock noise
      - Additional portion of relative jitter at the decision point related to VCO phase noise. Not visible outside the receiver, covered by receiver sensitivity. Is an effect that is independent of to incoming signal and will also determine the sensitivity.
    - Receiver side filtered transmitter clock variation relative to recovered clock signal (Frequency components present in transmitter side clock, filtered at receiver side PLL filter.
      - Effect of decrease of receiver sensitivity by phase/frequency modulation/noise of the transmitter side bit timing. This degradation is described by the jitter penalty as used by ITU

Difference in Jitter definition of ITU and IEEE 10G initiative



Nominal Bit

Fibre effect
Dispersion, PMD..
Very high frequency

Transmitter impairment
(Laser, Driver,...)
High frequency

Clock noise
Moderate frequency

Lucent Technologies
Bell Labs Innovations

Conclusion for Jitter definition in IEEE 10G initiative

In order to determine the jitter budget and transmission impairments the following must de done

- **Determine input jitter to link**
  - In Order to determine the Input jitter to the link the Transmitter side clock needs to be specified in order to allow a proper receiver PLL spec.
    - This should for serving common understanding be done in the frequency domain similar to ITU specifications
  - transmitter jitter to be defined out of:
    - Transmitter side Clock noise
    - Signal dependent phase deviation in the bit stream related to transmitter implementation / Phase deviation related to Base line wander / Laser non-linearity (Includes duty cycle distortions)
    - The mentioned is equal to Jitter generation as defined by ITU Could be slightly increased as no regeneration foreseen in 10GE.
    - Proposal use modified ITU jitter spec between 4 MHz and 80 MHz as basis . Maximum UI values tbd. Can be slightly increased against values of ITU as no regeneration present. But does not represent the complete budget.
    - Components above upper limit of this measurement have to be covered by the eye mask distortions.

Conclusion for Jitter definition in IEEE 10G initiative

In order to determine the jitter budget and transmission impairments the following must de done

- **The link and receiver influence can be obtained as follows:**
  - Optical path
    - Additional horizontal eye closure due to effects as :
      - Signal and chirp related ISI
      - PMD and Nonlinear impairments
    - High frequency effects covered by path penalty. Independent degradation of receiver PLL.. If a signal emulating the path impairments for receiver verification is defined this should be done separate from Transmitter jitter as effect with totally different nature. This penalty has to be subtracted from the Back to back sensitivity. Not available for link budget.
    - Proposal: define 1 dB Penalty at 1310 nm interface, 2 dB penalty at 1550 due to higher chromatic dispersion.
  - Receiver:
    - Internal Receiver bandwidth effects, Base line wander effects, Receiver PLL noise:
      - Internal receiver implementation related effects that are independent on other system parts. To be covered by the worst case receiver sensitivity
    - Receiver side filtered transmitter clock variation relative to recovered clock signal
      - This effect gives the effect of the PLL performance on the receive side in relation to transmitter signal.
      - To be verified with test signal giving a defined transmitter input jitter in a known bandwidth. Possibility of definition would be to define the penalty (sensitivity reduction of the receiver) at maximum transmitter output jitter as described in the previous slide.
      - Proposal : 1 dB penalty at maximum transmitter jitter