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Considerations for Testing Jitter Tolerance Using the “Inverse JTF” Mask

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Overview

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- JT Mask Based on Inverse JTF
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- Discussion of Equipment Capabilities
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Link to Previous material (1)

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- In 08-232r0, Mike Jenkins resuscitated and formalized the idea of using an inverse JTF mask for jitter tolerance to guarantee the SSC tracking capability of receivers:
  - The idea is to replace the 0.1UI BUJ in the stressed receiver test with a swept SJ, which magnitude is:
    - Greater than 0.1 UIpp above 2 MHz
    - Increasing by 40 dB/decade below 2MHz
  - This unifies the stressed receiver test and the jitter tolerance test
  - It can potentially test the SSC tracking capability of a receiver.

Link to Previous material (2)

- This approach has several benefits:
  - Simpler than adding SSC to the input data stream
  - No need to determine which SSC pattern to apply
  - Follows SAS-1.1 methodology
  - Directly compares the receiver under test to the reference receiver, since the latter has to meet the JTF
- The current proposal reviews and extends the proposed approach of using the inverse JTF as a JT mask.

Guiding Principles (1)

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- The mask corner frequency to use for the inverse JTF is derived from the -73.5 dB rejection at 30 kHz and 40 dB/decade slope of the nominal JTF.
  - We set our mask corner frequency at 2.064 MHz, which is the point at which the 40 dB/decade line crosses 0dB

Guiding Principles (2)

- A SAS-2 SSC capable receiver is required to track SSC modulation of up to +/-2300 ppm, in addition to a +/-100 ppm static frequency offset, for a maximum frequency offset of +/-2400 ppm.
- From sinusoidal jitter frequency and amplitude, the frequency offset can be calculated from the derivative of the phase.

Guiding Principles (3)

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- We express the sinusoidal jitter as:

$$SJ = \frac{A_{SJ}}{2} \cdot \sin(2\pi \cdot f_{SJ} t)$$

- Where:
  - A_{SJ} is the SJ amplitude in UIpp
  - f_{SJ} is the SJ frequency in Hz

- And convert this jitter to phase (in rad):

$$\Theta_{SJ} = SJ \cdot \frac{2\pi \cdot rad}{UIpp} = \pi \cdot A_{SJ} \cdot \sin(2\pi \cdot f_{SJ} t)$$

Guiding Principles (4)

- From the derivative of phase, we obtain the angular frequency offset (rad/s):

$$\frac{d\Theta_{SJ}}{dt} = \omega_{OFFSET\_SJ} = \pi \cdot A_{SJ} \cdot 2\pi \cdot f_{SJ} \cdot \cos(2\pi \cdot f_{SJ} t)$$

- And finally the frequency offset resulting from the SJ (Hz):

$$f_{OFFSET\_SJ} = \frac{\omega_{OFFSET\_SJ}}{2\pi \cdot rad} = \pi \cdot A_{SJ} \cdot f_{SJ} \cdot \cos(2\pi \cdot f_{SJ} t)$$

Guiding Principles (5)

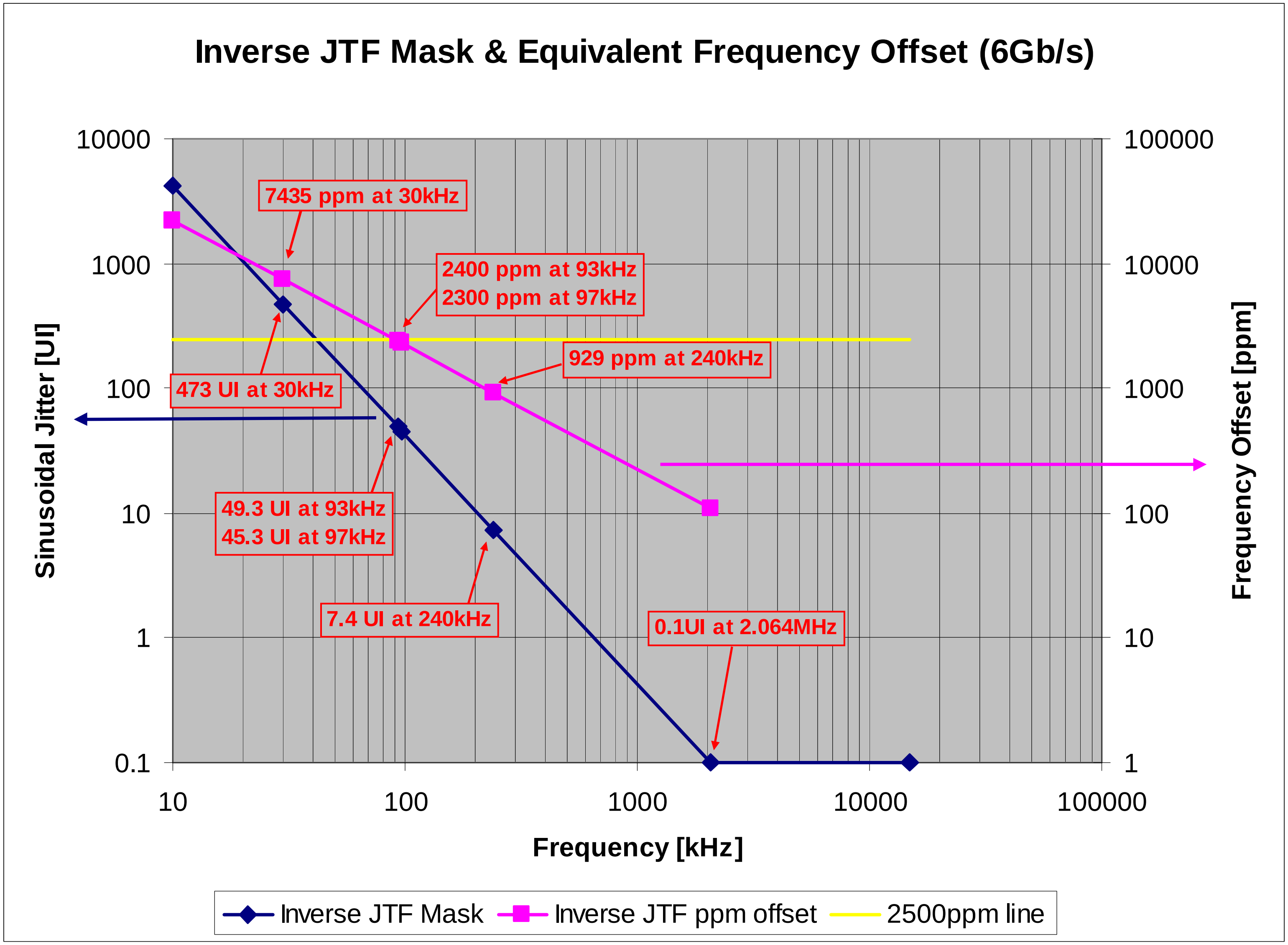
- We normalize the frequency offset vs. the baud rate to obtain a convenient ppm offset:

$$f_{OFFSET\_SJ\_PPM} = \frac{f_{OFFSET\_SJ}}{f_{baud}} \cdot \frac{1e6\,ppm}{1}$$

$$f_{OFFSET\_SJ\_PPM} = \left(\frac{\pi \cdot A_{SJ} \cdot f_{SJ} \cdot 1e6}{f_{baud}} ppm \right) \cdot \cos(2\pi \cdot f_{SJ} t)$$

- $f_{OFFSET\_SJ\_PPM}$ is the frequency offset that results from a sinusoidal jitter modulation. It provides a view of the stress applied to the frequency tracking loop of the CDR.

JT Mask Based on Inverse JTF (1)



JT Mask Based on Inverse JTF (2)

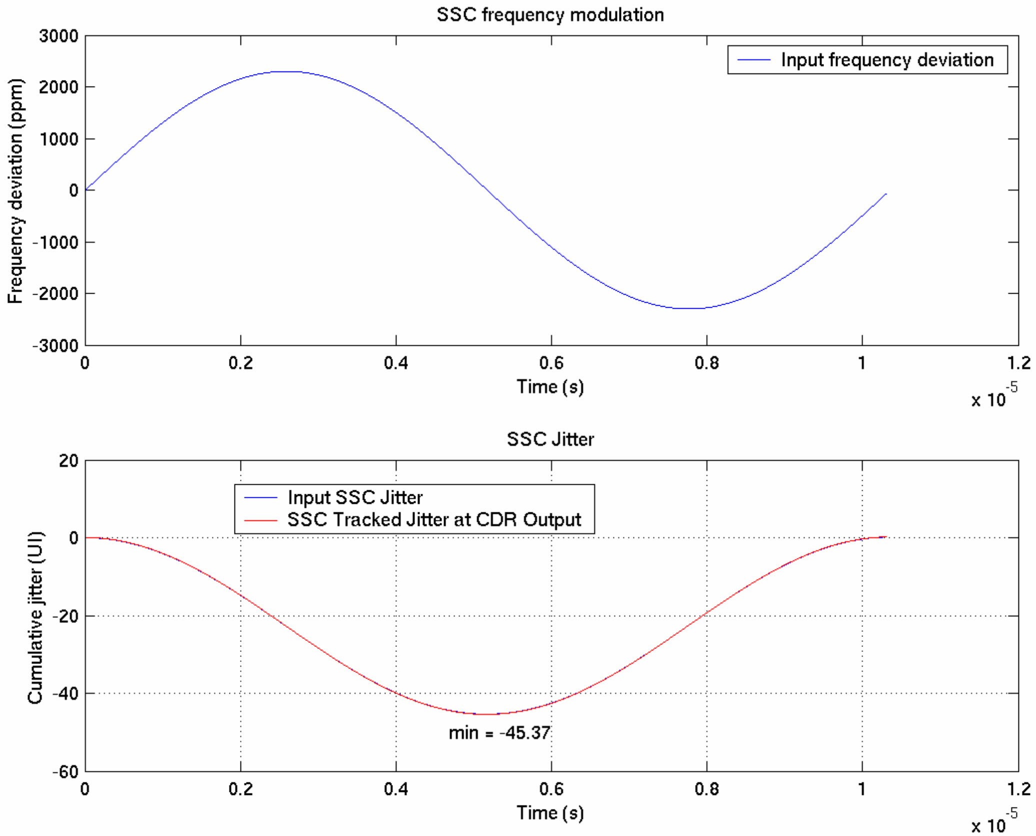
- The plotted Inverse JTF mask is from a nominal JTF.
- A few points of interest on the mask:
  - Mask corner frequency is 2.064MHz, with a 40 dB/decade slope below it.
  - At 240 kHz, which was proposed as a low frequency limit for the JT mask in 08-232r0, we get 7.4 UIpp of SJ, but a frequency offset of only +/-929 ppm.
  - To get a frequency offset of +/-2400 ppm, we need to go down to 93 kHz.
  - At 30 kHz, the SJ amplitude is 473 UIpp and the frequency offset of +/-7435 ppm far exceeds the SAS-2 requirements.

Correlation with Residual Jitter Simulations (1)

- A +/-2300ppm frequency offset is obtained on the mask with an SJ of 45.3 UI at 97 kHz.
- If the inverse JTF mask is an accurate representation of the tracking capabilities of a receiver that implements a nominal JTF, we expect that a sine SSC modulation of +/- 2300 ppm at 97kHz will result in 45.3 UIpp of unfiltered jitter and in 0.1 UIpp of residual jitter after application of the JTF.
- Matlab simulations of this SSC profile through the JTF shows very good correlation with expectations
  - This confirms that the inverse JTF mask is a good criterion to compare a receiver's CDR to the JTF.

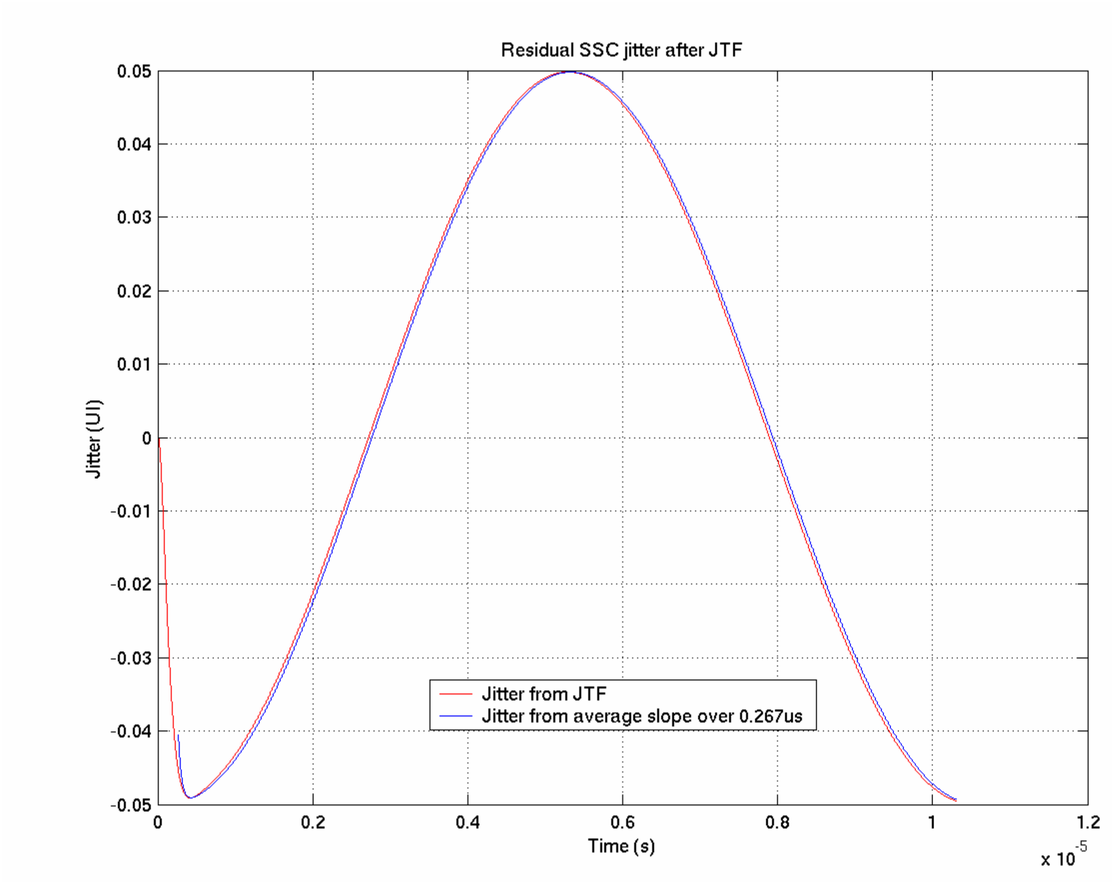
Correlation with Residual Jitter Simulations (2)

- SSC Profile (+/-2300ppm) and Unfiltered SSC Jitter (45.37 UIpp)



Correlation with Residual Jitter Simulations (3)

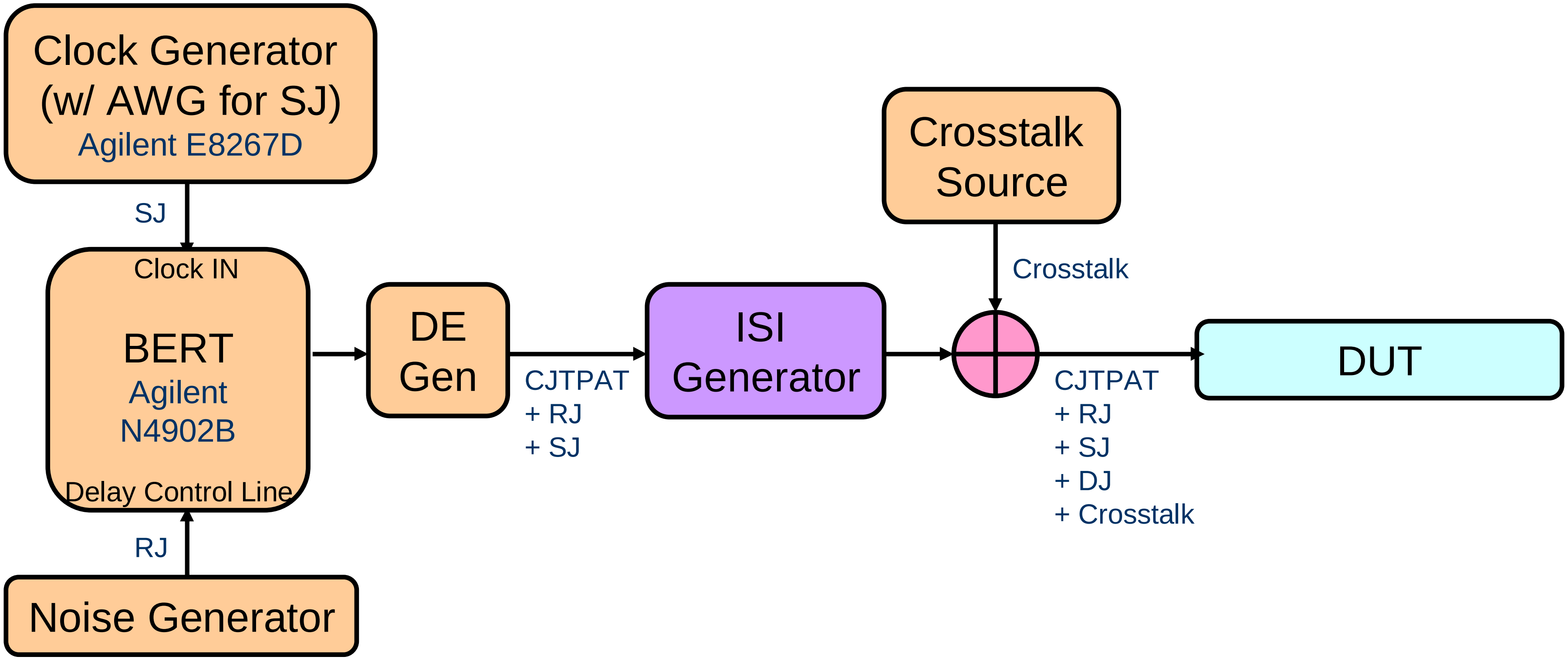
- Residual Jitter after applying a nominal JTF (0.1 UIpp)



Discussion of Equipment Capabilities (1)

- In 08-232r0, it was tentatively stated that the SJ modulation capabilities of common lab equipment may be limited to 8UI.
- The setup presented on the next page was used to produce sweep SJ of several hundred UIpp down to 10 kHz.
  - Is this equipment commonly available?

Discussion of Equipment Capabilities (2)



Extension to 1.5G & 3G (1)

- The SAS-2 JTF scales with transition density (TD):

  A proportional decrease of the JTF -3 dB corner frequency should be observed for a decrease in pattern transition density compared to a 0.5 transition density. If a JMD shifts the JTF -3 dB corner frequency in a manner that does not match this characteristic, or does not shift at all, measurements of jitter with patterns with transition densities different than 0.5 may lead to discrepancies in reported jitter levels. In the case of reported jitter discrepancies between JMDs, the JMD with the shift of the -3 dB corner frequency that is closest to the proportional characteristic of the reference channel shall be considered correct. This characteristic may be measured with the conditions defined above for measuring the -3 dB corner frequency, but substituting other patterns with different transition densities.

- With the JTF being calibrated at 6Gb/s, a scaling with TD also implies a scaling with baud rate
  - A TD of 0.5 at 3Gb/s is equivalent to a TD of 0.25 at 6Gb/s

Extension to 1.5G & 3G (2)

- With respect to transition density, the scaling of the JTF reflects the scaling of the gain in a CDR that implements it
- Based on the scaling of the gain in the JTF CDR, the rejection of low frequency jitter will be cut in half at 3Gb/s and to a quarter at 1.5Gb/s. The nominal JTF jitter rejection is then:
  - 6Gb/s: -73.5 dB at 30kHz with D24.3
  - 3Gb/s: -67.5 dB at 30kHz with D24.3
  - 1.5Gb/s: -61.5 dB at 30kHz with D24.3
- Despite this reduced rejection of low frequency jitter at lower baud rates, the residual jitter from SSC stays constant in UI
  - The increase of the UI width (in ps) compensates for the increase of the residual jitter (in ps)

Extension to 1.5G & 3G (3)

- From the rejection at 30kHz and the 40 dB/decade slope, we can extrapolate the mask corner frequency of the inverse JTF (as per page 5):
  - 6 Gb/s: 2.064 MHz
  - 3 Gb/s: 1.459 MHz
  - 1.5 Gb/s: 1.032 MHz

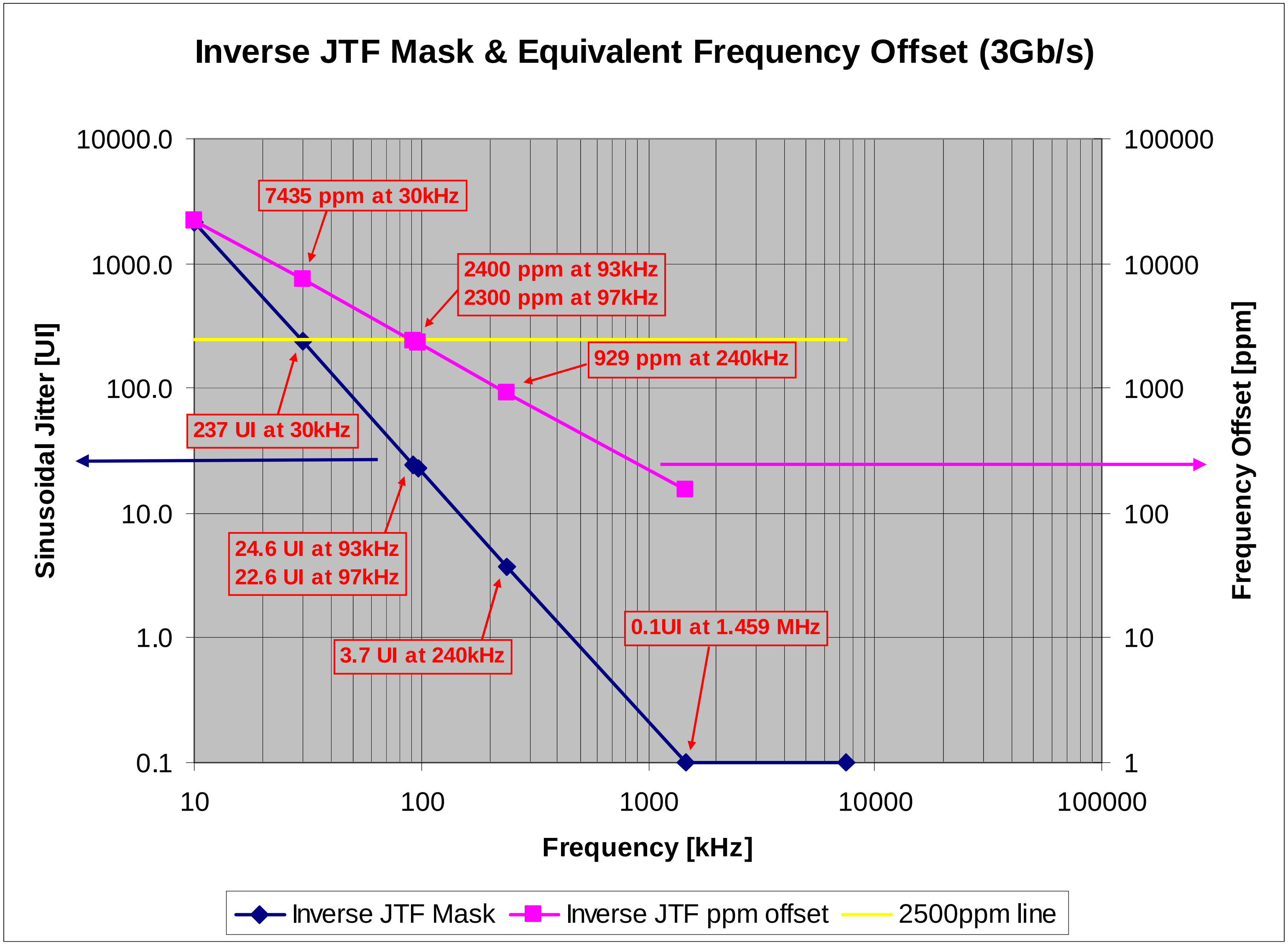
  (Because of the 40dB/decade slope, the corner frequency only varies by the square-root of the rate (or transition density) change.)

- The resulting corner frequencies for 1.5Gb/s and 3Gb/s are close to those of the SAS-1.1 JT mask (900 kHz and 1.8 MHz)
  - Minimizes risk for existing IP

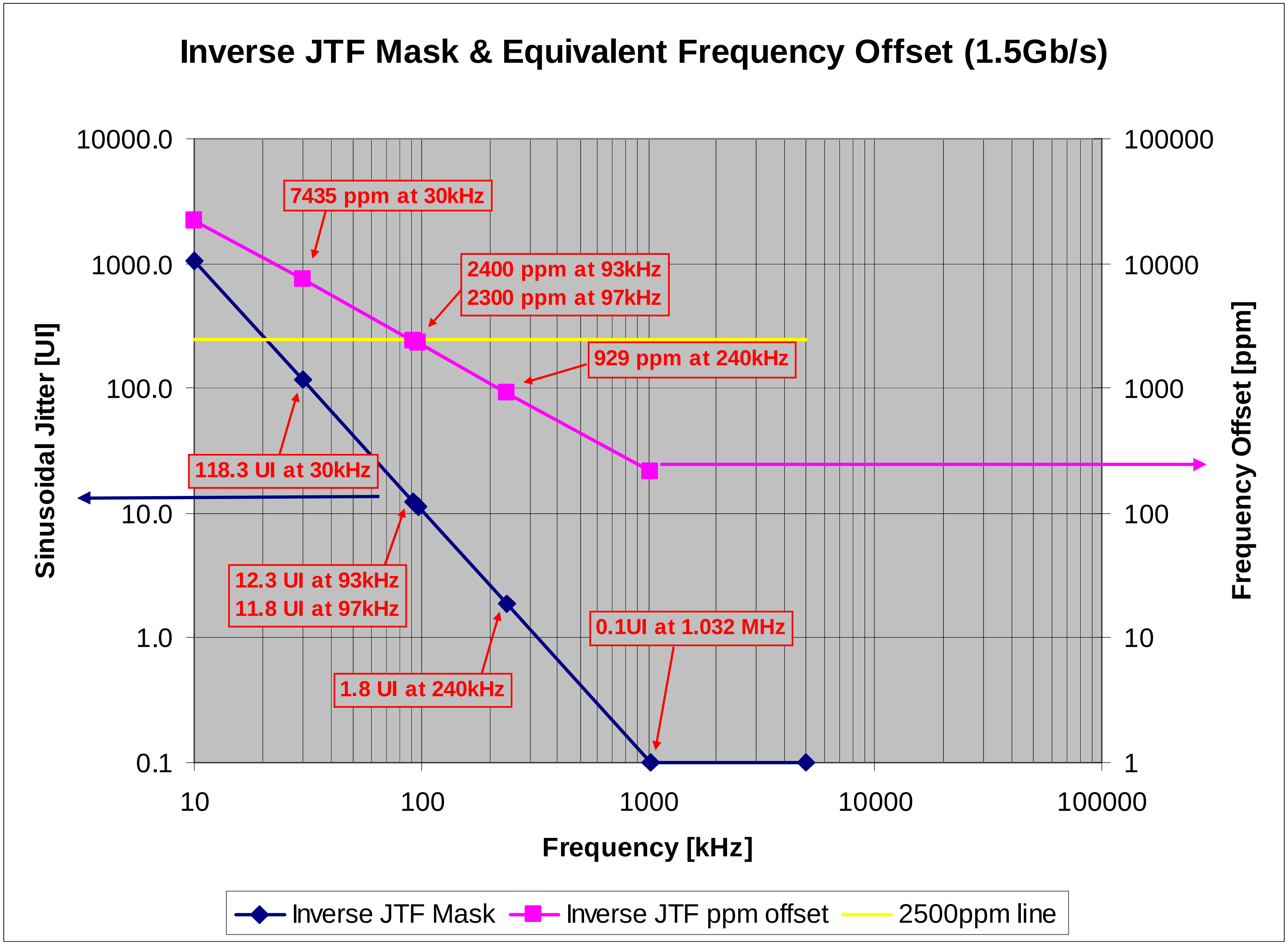
Extension to 1.5G & 3G (4)

- Calculating $f_{OFFSET\_SJ\_PPM}$ (page 9), we find that the JTF masks produces an equivalent frequency offset of 2400ppm at 93 kHz for all 3 rates.

Extension to 1.5G & 3G (5)



Extension to 1.5G & 3G (6)



Summary

- The inverse JTF mask proposed in 08-232r0 can be a good approach to simplify the jitter tolerance setup.
- However, limiting the test to 240 kHz with 7.4 UIpp SJ results in a frequency offset of only +/- 929 ppm
  - This does not demonstrate that the receiver can track +/- 2400 ppm
- It is proposed to extend the mask down to 93 kHz at all rates to cover +/-2400 ppm
  - If commonly available lab equipment supports such SJ modulations
- The mask corner frequency should scale as the square-root of the baud rate variation vs. 6 Gb/s.

Proposed Clarifications For JTF Definition

- Section 5.3.5.2,
  - 3rd paragraph:
    - "The JTF shall have the following characteristics for a repeating 6 Gbps 0011b or 1100b pattern (e.g., D24.3)(see table 236 in 10.2.9.2):"
  - Last paragraph:
    - "A proportional decrease of the JTF -3 dB corner frequency should be observed for a decrease in pattern transition density compared to a 0.5 transition density and for a decrease in baud rate compared with a 6 Gbps baud rate. If a JMD shifts the JTF -3 dB corner frequency in a manner that does not match this characteristic, or does not shift at all, measurements of jitter with patterns with transition densities different than 0.5 or baud rates different than 6 Gbps may lead to discrepancies in