Proposed Draft

Serial ATA International Organization

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Title : SSC Profile df/dt Excursion Limitation

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Document History

Version	Date	Comments
1.1	3/11/2007	Initial release.
1.2	3/21/2007	Chuck Hill Comments incorporated
1.3	5/22/2007	SB. Added some examples with detailed calculations
1.4	2/28/2007	SB. More examples & text clarifications on ppm definitions
1.5	2/30/2007	SB. Increase minimum period for df/dt measmt. from 1.0usec to 1.5 usec
1.6	9/26/2007	SB. Updated to rename to TN-003 (Technical Improvement)

1 Introduction

Problem Statement: Df/dt Excursions in the SSC profile reduce jitter margins and impact the link error rate. Jitter measuring devices (JMD) sample jitter and miss low occurance excursions, rendering the use of JMDs ineffective at ensuring error rate.

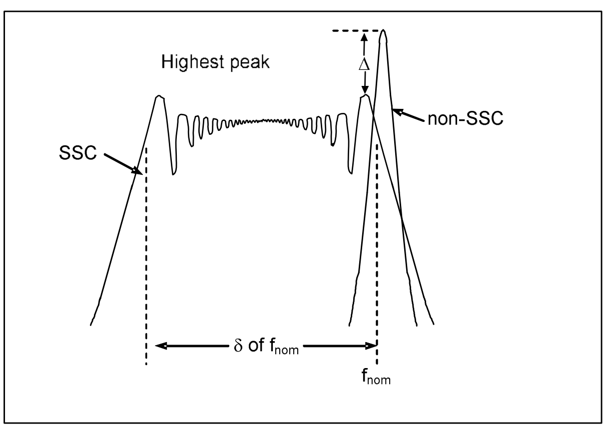
Remedy: Constrain excursions in the SSC profile.

Currently the SATA interface is specified to support plesiochronous operations, where transmitters and receivers are “nearly synchronized”. In other words, the interface is designed such that the transmitter signals have the same nominal digital rate as the receiver, with an allowance for constrained and limited variations in instantaneous digital rates.

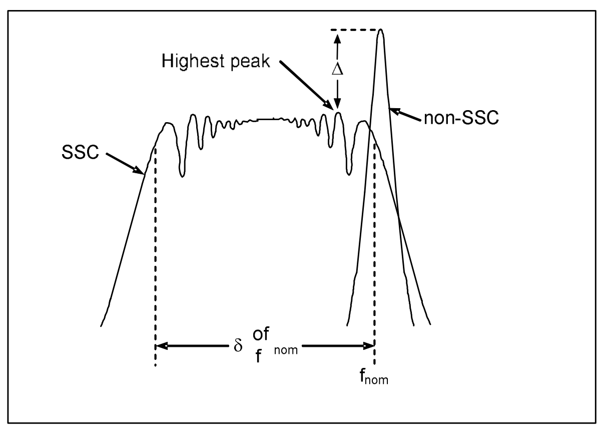
The SATA specification allows for limited variations in the digital transmit/receive rates consistent with the Spread Spectrum clocking (+0/-5000 ppm) used to mitigate EMI for SATA products.

The SATA specification uses jitter measuring devices (JMD) to predict the error rate performance of the link. This prediction by JMDs is practical and necessary because it dramatically reduces test time.

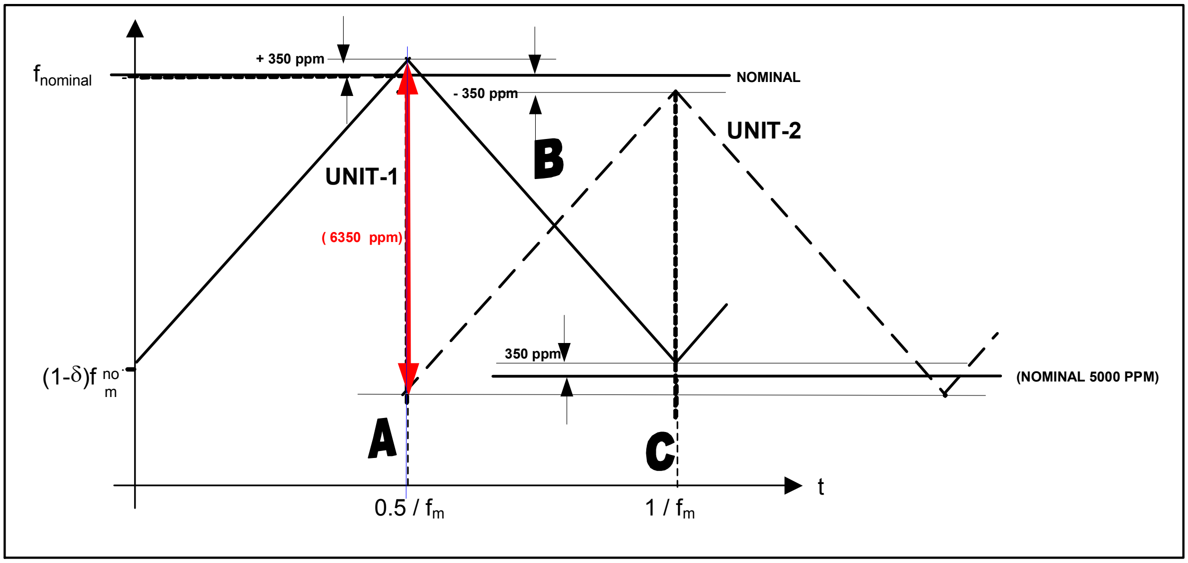
Different types of spread-spectrum clocking profiles have different effectiveness with regard to EMI emissions, however, producing these spread-spectrum profiles has required careful engineering design. Some under-designed products have been prone to low occurance excursions outside the SATA allotted ppm-range, and have been proven to result in inter-operabilty issues, that is, the predicted error rate by JMDs underestimates the true error rate since the excursions occur seldom enough to be missed by the JMD but often enough to limit error rate. Examples are shown below.



Triangular Spread Profile



Lexmark Spread Profile

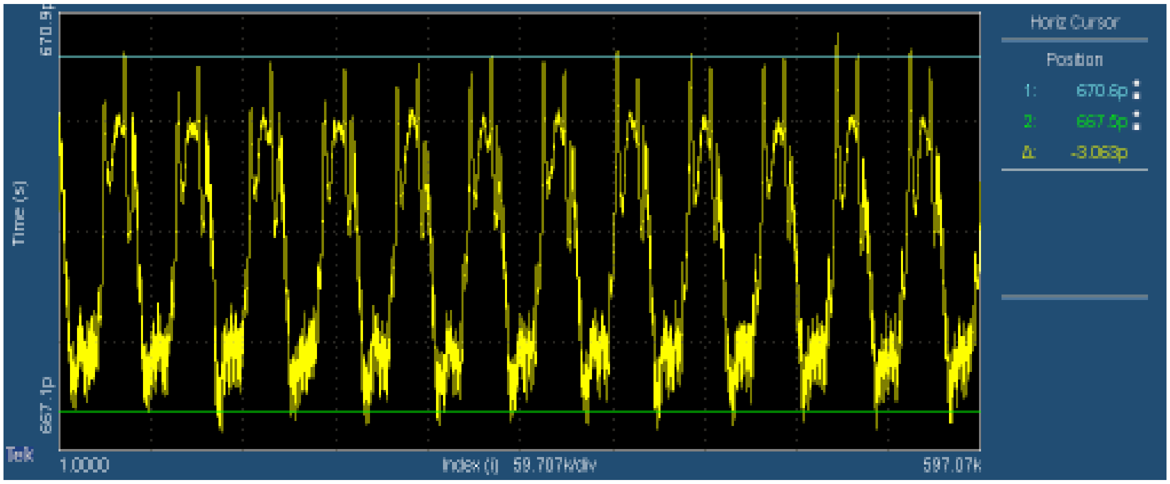


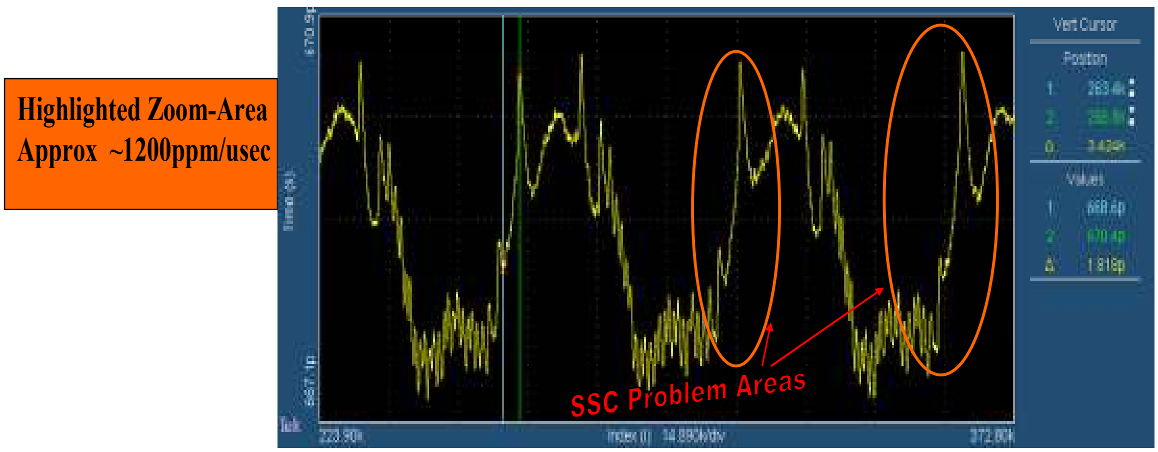
$$f = \begin{cases} (1-\delta) f_{nom} + 2 f_m \cdot \delta \cdot f_{nom} \cdot t & when \quad 0 < t < \frac{1}{2 f_m}; \\ (1+\delta) f_{nom} - 2 f_m \cdot \delta \cdot f_{nom} \cdot t & when \quad \frac{1}{2 f_m} < t < \frac{1}{f_m}, \end{cases}$$

where f_{nom} is the nominal frequency in the non-SSC mode, f_m is the modulation frequency, δ is the modulation amount, and t is time.

The SSC profiles that are still within the allotted spread-spectrum ppm-range, but that do exhibit sudden instantaneous extreme ppm-variations are also problematic, and may result in inter-operability issues, as well as degraded SATA interface performance.

An example is shown below:





The spec change proposal is to limit the instantaneous ppm-variation to a maximum of 1250 ppm/usec.

This measurement is to be performed , with the specific measurement contraints, which include specific 2nd-order low-pass filtering (3dB @ 1.8MHz), minimum delta time (1.5usec), as well as being measured over a time-period with “same-sign” frequency change (1-direction).

Although examples included illustrate the method for a single instantaneous SSC df/dt measurement, using cursors & marked points in the SSC profile, it is understood that techniques for scanning the entire data-set captured, or real-time continuous acquisitions can be developed for more thorough coverage of this measurement.

Note: “ppm” is defined as “absolute ppm deviation” from the Gen1 [666.6666ps], or Gen2 [333.3333ps] nominal data rates.

Example 1 (Cycle-Trend Plot, on Hi-Transition-Density Pattern without ALIGNS, see Figure 3) :

Cursor Position #1: 668.6 ps = > -2901 ppm from Nominal 666.6666ps
Cursor Position #2: 670.4 ps = > - 5600ppm from Nominal 666.6666ps

Calculated df/dt ppm / usec

2699 ppm / [3424 cycles] , where Cursor1[263.4K] – Cursor2[266.8K]; Δ –> 3.424K cycles)

Thus this works out to: ~1182 ppm/usec , given that each cycle is 666.6666 ps

- Note that 3424 cycles exceeds minimum evaluation period of 1.5 usec (3424 * 666.6666ps = 2.2827 usec)
- It is also important to note, for this example case, that the instantaneous df/dt was causing the interoperability issue, although the ppm-range was slightly violated (5350ppm was exceeded).

Figure 3 - Violating df/dt (ppm/usec) SSC Profile

Example 2 (Cycle-Trend Plot, on Hi-Transition-Density Pattern without ALIGNS, see Figure 4) :

Cursor Position #1: 334.4 ps = > -3200ppm from Nominal 333.3333ps
Cursor Position #2: 334.1 ps = > - 2300ppm from Nominal 333.3333ps

Calculated df/dt ppm / usec

900 ppm / [4159 cycles] , where Cursor1[255.5K] – Cursor2[259.7K]; Δ –> 4.159K cycles)

Thus this works out to:

- Note that 4159 cycles needs to exceed minimum evaluation period of 1.5 usec (4159 * 333.333ps = 1.3863 usec)

Given that each cycle is 333.333 ps
~649 ppm/usec (measurement time period slightly too short)

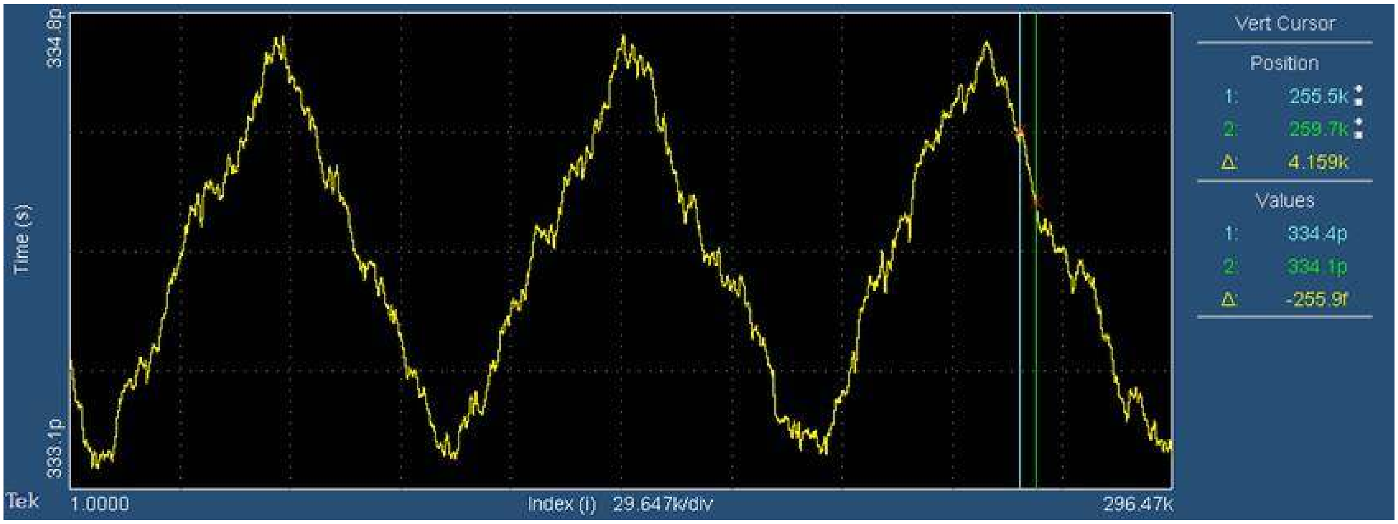


Figure 4 - Typical Triangular df/dt (ppm/usec) SSC Profile

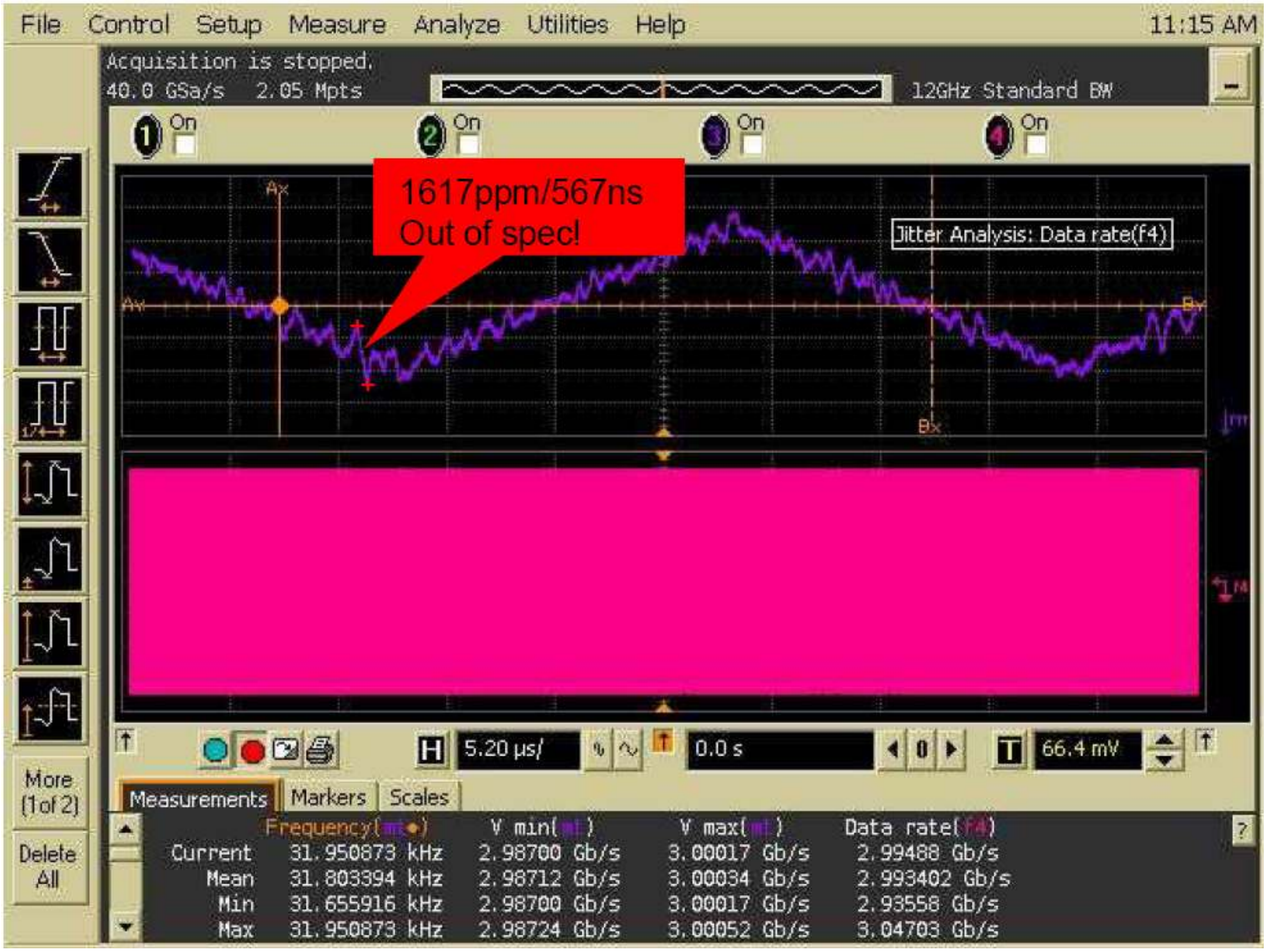


Figure 5 - Example of Erroneous Measurement

Example 3 (Figure 5):

If the minimum period over which the measurement is taken is too small (less than 1.5usec) the declared ppm/usec will be too high, and not representative of the df/dt parameter we are verifying.

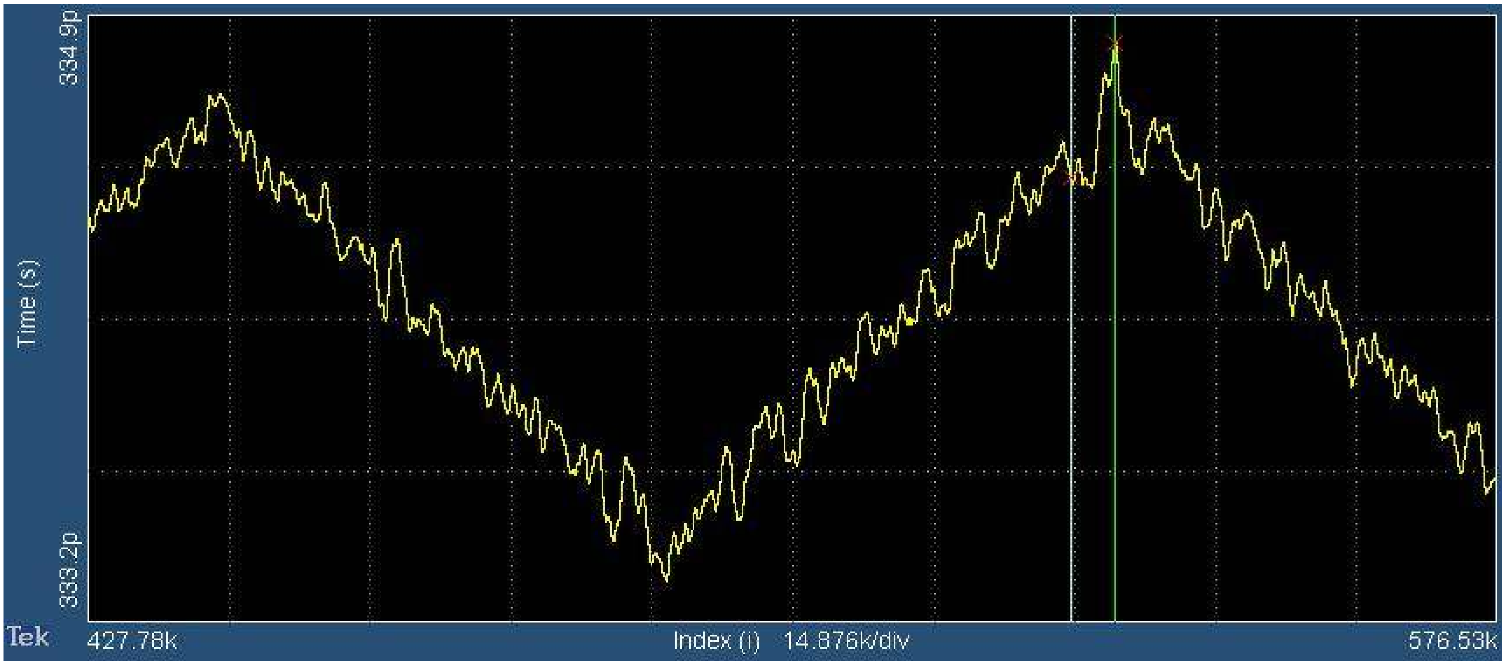


Figure 6- Same Device as Figure 6

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Example 4 (Figure 6) (Cycle-Trend Plot, on Hi-Transition-Density Pattern without ALIGNS, see Figure 7) :

Cursor Position #1: 334.5 ps = > -3500 ppm from Nominal 333.3333ps
Cursor Position #2: 334.9 ps = > - 4700ppm from Nominal 333.3333ps

Calculated df/dt ppm / usec
1200 ppm / [4780 cycles] , where Cursor1[531.5K] – Cursor2[536.3K]; Δ –> 4.780K cycles)

Thus this works out to: ~753 ppm/usec , given that each cycle is 333.3333ps

- Note that 4780 cycles exceeds minimum evaluation period of 1.5 usec (4780* 333.3333ps = 1.5933 usec)

2 Technical Specification Changes

2.1 Section 7.2.1 Physical Layer Requirements Tables

Physical Layer Requirements Tables

Table 27 – General Specifications

Parameters	Units	Limit	Electrical Specification						Detail Cross-Ref Section	Meas. Cross-Ref Section
			Gen1i	Gen1m	Gen1x	Gen2i	Gen2m	Gen2x		
Channel Speed	Gbps	Nom	1.5			3.0			7.2.2.1.1	-
Fbaud	GHz	Nom	1.5			3.0			-	-
FER, Frame Error Rate		Max	8.2e-8 at 95% confidence level			8.2e-8 at 95% confidence level			7.2.2.1.2	7.4.1
T_{UI}, Unit Interval	ps	Min	666.4333			333.2167			7.2.2.1.3	7.4.11
		Nom	666.6667			333.3333				
		Max	670.2333			335.1167				
f_{tol}, TX Frequency Long Term Stability	ppm	Min	-350			-350			7.2.2.1.4	7.4.6
		Max	+350			+350				
f_{SSC}, Spread-Spectrum Modulation Frequency	kHz	Min	30			30			7.2.2.1.5 7.3.3	7.4.11
		Max	33			33				
SSC_{tol}, Spread-Spectrum Modulation Deviation	ppm	Min	-5000			-5000			7.2.2.1.6 7.3.3	7.4.11
		Max	+0			+0				
SSC_{tol}, Spread-Spectrum Modulation Rate	ppm/ usec	Max	1250			1250			7.2.2.1.6 7.3.3	7.4.11
$V_{cm,dc}$, DC Coupled Common Mode Voltage	mV	Min	200		-	-			7.2.2.1.7	7.4.4
		Nom	250		-	-				
		Max	450		-	-				

Parameters	Units	Limit	Electrical Specification						Detail Cross-Ref Section	Meas. Cross-Ref Section
			Gen1i	Gen1m	Gen1x	Gen2i	Gen2m	Gen2x		
$V_{cm,ac\ coupled}$, AC Coupled Common Mode Voltage	mV	Min	0		-	-			7.2.2.1.8	7.4.25
		Max	2000		-	-				
Z_{diff}, Nominal Differential Impedance	Ohm	Nom	100		-	-			7.2.2.1.9	7.4.22
$C_{ac\ coupling}$ AC Coupling Capacitance	nF	Max	12			12			7.2.2.1.10	7.4.14

7.2.2.1.6 Spread Spectrum Modulation Deviation

This is the allowed frequency variation from nominal due to the SSC AC modulation expressed in terms of the unit interval deviation from the unit interval value of the long term frequency value. See further details of Spread Spectrum in section 7.3.3.

7.3.3 Spread Spectrum Clocking

Serial ATA allows the use of spread spectrum clocking, or intentional low frequency modulation of the transmitter clock. The purpose of this modulation is to spread the spectral energy to mitigate the unintentional interference to radio services. The modulation frequency of SSC shall be in the range defined for f_{SSC} in Table 27.

The modulation frequency deviation shall be in the prescribed range for SSC_{tol} in Table 27. The instantaneous frequency (each period) of the Reference Clock shall fall within the prescribed T_{UI} range. If the rate of change of the instantaneous frequency is excessive jitter is increased.

The SSC modulation only moves the frequency below the nominal frequency. This technique is often called “down-spreading”. An example triangular frequency modulation profile is shown in Figure 123. The modulation profile in a modulation period is expressed as:

$$f = \begin{cases} (1-\delta) f_{nom} + 2 f_m \cdot \delta \cdot f_{nom} \cdot t & \text{when } 0 < t < \dfrac{1}{2 f_m}; \\ (1+\delta) f_{nom} - 2 f_m \cdot \delta \cdot f_{nom} \cdot t & \text{when } \dfrac{1}{2 f_m} < t < \dfrac{1}{f_m}, \end{cases}$$

where f_{nom} is the nominal frequency in the non-SSC mode, f_m is the modulation frequency, δ is the modulation amount, and t is time.

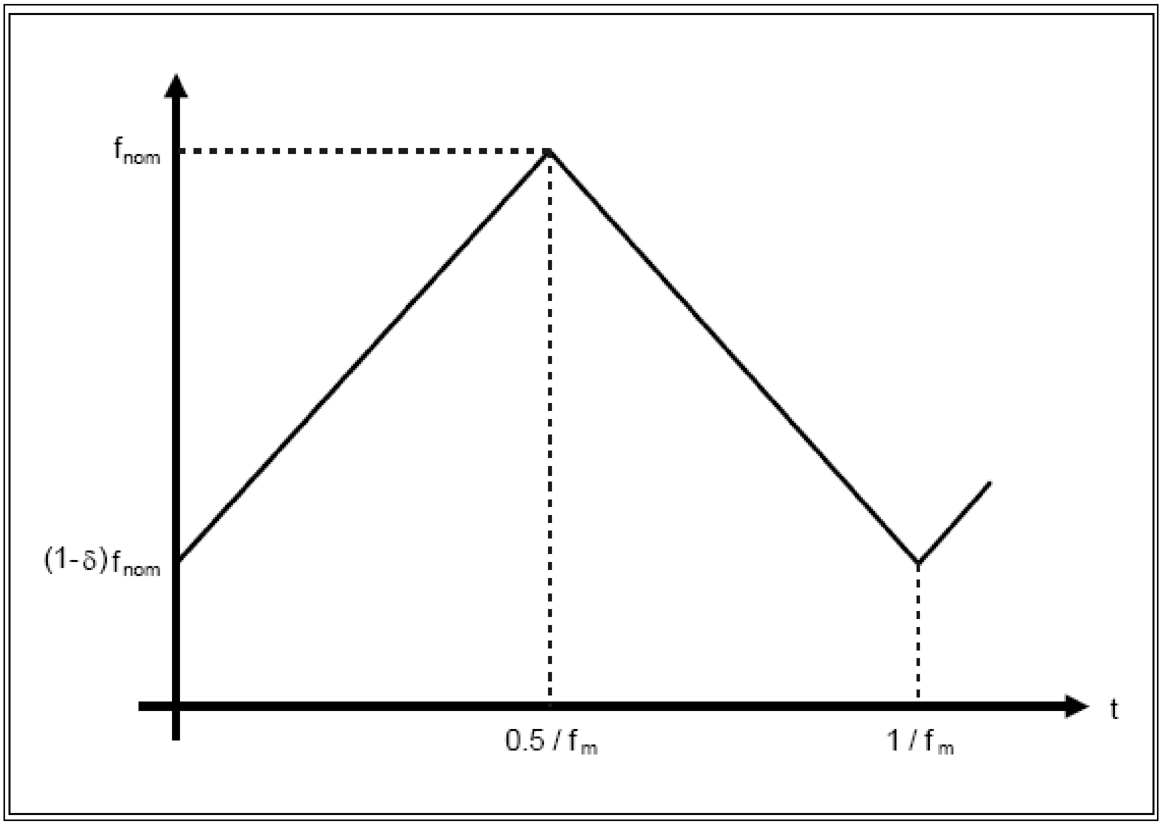

Figure 123 – SSC Profile Example: Triangular

Editors note: the figure above is changed

As an example, for triangular modulation, the absolute spread amount at the fundamental frequency is shown in Figure 124, as the width of its spectral distribution.

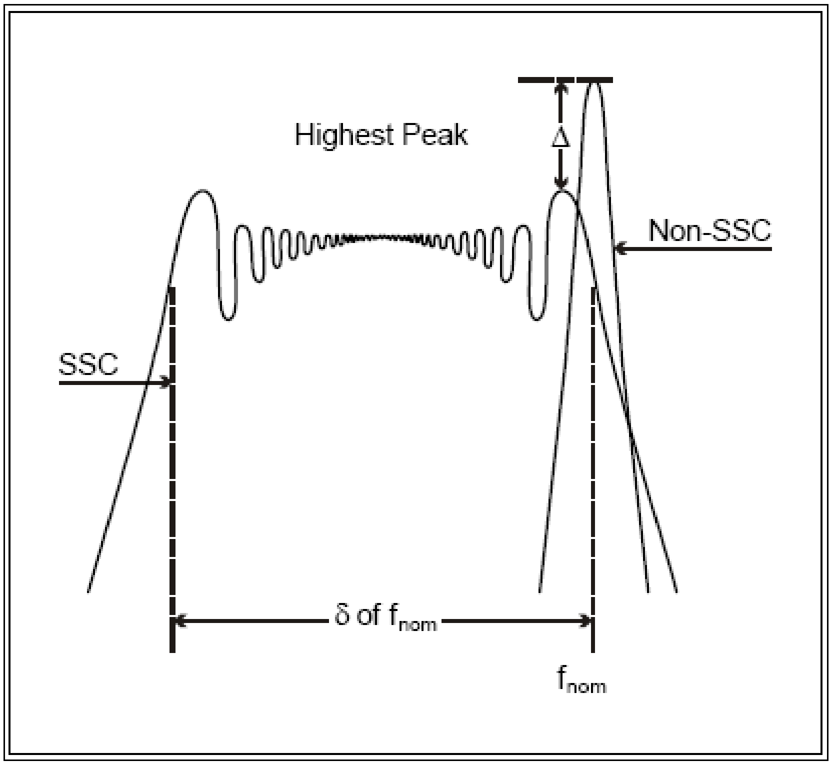

Figure 124 – Spectral Fundamental Frequency Comparison

Editors note: the figure above has been updated

7.4.11 SSC Profile

Spread Spectrum Clocking is intentional low frequency modulation of the bit clock. The SSC profile is the modulation on the bit clock. To measure the SSC profile, a frequency demodulator and low pass filter are necessary. There are many possible realizations of this, in hardware and software. The low pass filter is necessary to reject undesired post-demodulation frequency components from bit patterns and jitter. To minimize these undesired signals the HFTP bit pattern shall be used. This may be produced using the BIST Activate FIS to invoke the Transmit-Only option. The SSC Profile measurement is also used to determine the Unit Interval values.

The Reference Clock as defined in section 7.3.2 should be used with an additional low pass filter in the phase detector output to measure the SSC profile. The output is DC coupled and should be calibrated with a signal source with sufficient long term frequency accuracy.

A single shot capture oscilloscope should be used to measure the times of zero crossings (through interpolation) and perform the FM demodulator and low pass filter function. The memory record of the oscilloscope shall be long enough to achieve the low pass filter cutoff frequency. The long term frequency accuracy of the oscilloscope time base should be significantly better than the 350 ppm limit in this specification; oscilloscopes that do not have this frequency accuracy may be calibrated using a separate signal source of sufficient accuracy into a separate channel.

Modulation analysis tools with sufficient bandwidth provide alternative methods of measuring the SSC profile. These exist in some spectrum analyzers, modulation analyzers, or could be implemented as a separate frequency modulation receiver. Calibration is easier when the FM receiver has a DC coupled modulation path.

The low pass filter 3 dB cutoff frequency shall be 60 times the modulation rate. The filter stopband rejection shall be greater or equal to a second order low-pass of 20 dB per decade.

Evaluation of the maximum df/dt can be achieved by inspection of the low-pass filtered waveform at its various high magnitude df/dt ppm-changes, making sure that the maximum df/dt ppm/usec is never exceeded.

With the Host/Device under test continuously transmitting D10.2 patterns, this measurement can be achieved by plotting the periods of the differential waveform versus time, and then using the cursor-data to calculate the instantaneous ppm-variations over the time segment of interest. The minimum time segment that should be used for this evaluation shall be 1.5 usec +-3%.