Status and Area of Applicability of Timing Requirements for Uncompressed Serial Digital Interface Video

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Outline

- Overview and summary
- Uncompressed serial digital interface (SDI) video signals of interest for transport in an Audio/Video Bridging (AVB) network
- Summary of timing requirements for SDI video
- Background on timing requirements for SDI video
- Question on applicability of timing requirements for SDI video
  - i.e., to which applications do the timing requirements apply?
- Proposal to send liaisons to relevant SMPTE-EBU and ITU-R committees
- Appendix – Derivation of MTIE masks from jitter, frequency offset, and frequency drift requirements

Overview and Summary - 1

- Several of the requirements for uncompressed Serial Digital Interface (SDI) video are extremely stringent, and are very difficult to meet
  - These requirements result in peak-to-peak phase variation of less than 1 ns over observation intervals of approximately 0.25 s for standard definition and 0.03 s for high definition signals
- Note: In referring to *SDI video* here, the interest is in the uncompressed video signals described in the references at the end of this presentation. When transported over an AVB network, the signals will be carried in Ethernet frames. This presentation is not referring to the physical Serial Digital Interface.
- Meeting these requirements for transport of SDI video over an AVB network using 802.1AS will require very narrow-bandwidth endpoint filters, with very stable oscillators, resulting in higher cost for the end systems
  - Averaging of propagation time in the intermediate time-aware systems may help

Overview and Summary – 2

- While the cost of the expensive filtering will be borne by the end systems and not the network devices (and therefore not result in higher cost for all applications), it still desirable to avoid the high cost unless absolutely necessary
- It is not clear why the stringent requirements must be met for digital video signals in modern equipment
  - One of the requirements arose from the need to constrain the frequency stability of the chroma subcarrier in an analog composite video signal
  - The other requirement is a wide-band jitter requirement, with a tight peak-to-peak jitter constraint (less than 1 ns) and a 10 Hz measurement filter bandwidth
    - It is not clear what constraint or requirement the wide-band jitter requirement is trying to meet

Overview and Summary – 3

- To clarify these requirements, it is proposed that a liaison be sent to the appropriate SMPTE-EBU Synchronization Task Force and appropriate ITU-R committee, asking for more information on this topic
- If it were to turn out that any of these requirements could be relaxed, it would result in lower cost for the end systems

Uncompressed SDI Video Signals – 1

- Standard definition (SD) SDI signals
  - Sampled NTSC (approximately 143 Mbit/s)
  - Sampled PAL (approximately 177 Mbit/s)
  - Sampled component video (270 Mbit/s)
  - Sampled component video (360 Mbit/s)
- High definition (HD) SDI signal
  - 1.485 Gbit/s
  - 1.485/1.001 Gbit/s
  - 2.97 Gbit/s
  - 2.97/1.001 Gbit/s
- Jitter requirements for the SD SDI signals are given in [1] and [2]
- Frequency offset and frequency drift rate requirements for SD SDI signals are given in [5]

Uncompressed SDI Video Signals – 2

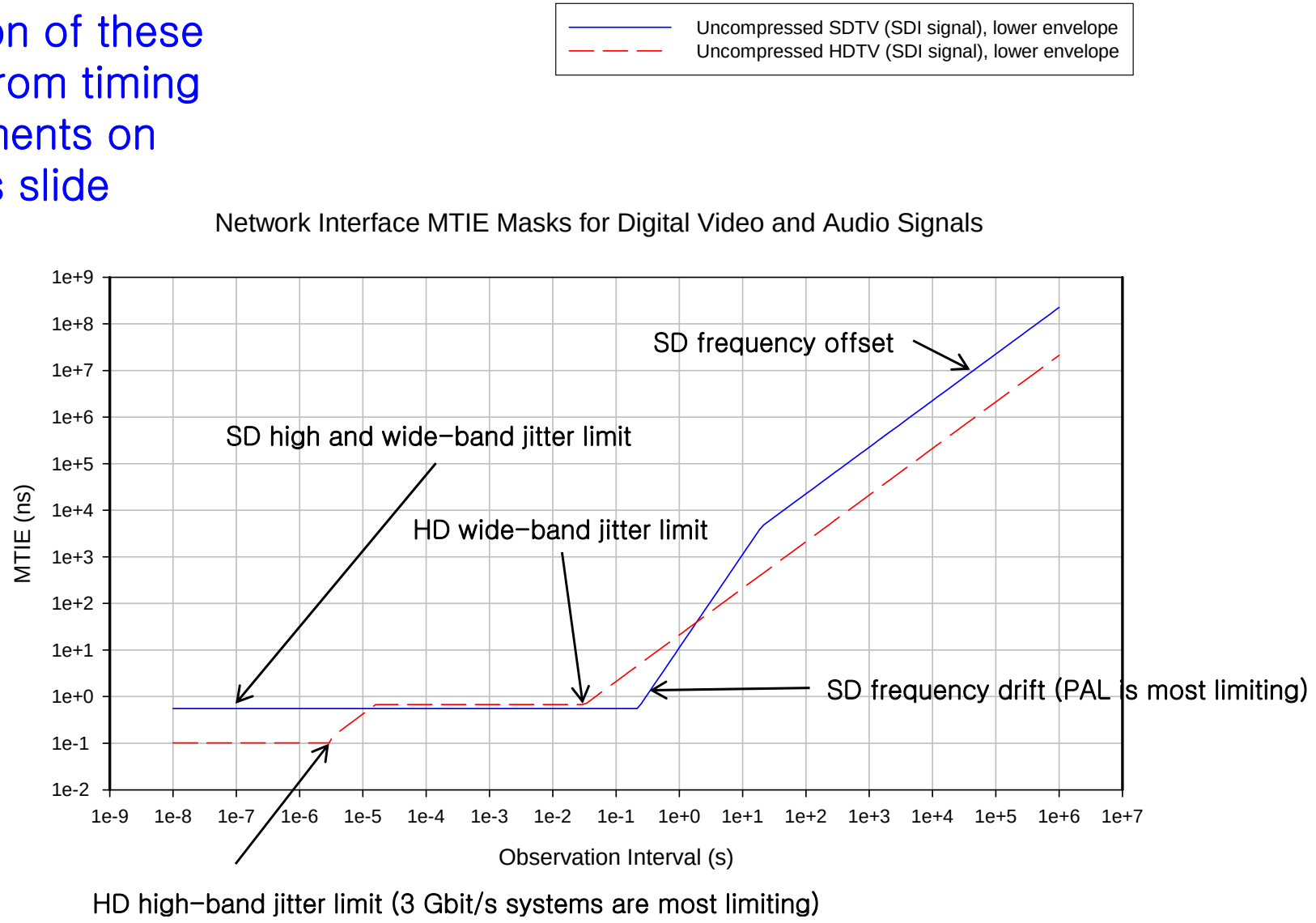
- Jitter and frequency offset requirements for the HD SDI signals are given in [3], [4], and [9]
- Additional information on the formats for the SDI signals is given in [6], [7], and [8]
- Background information on analog and digital video signals is summarized in the presentation of [10]
- Background information on jitter/wander requirements and the derivation of MTIE masks from jitter, frequency offset, and frequency drift requirements is given in [11]
- Note: As indicated on slide 3, the interest here is in the uncompressed video signals described in the references at the end of this presentation. When transported over an AVB network, the signals will be carried in Ethernet frames. This presentation is not referring to the physical Serial Digital Interface.

Summary of Timing Requirements for SDI Video

Requirement	Uncompressed SDTV	Uncompressed HDTV (1.485 or 1.485/1.001 Gbit/s)	Uncompressed HDTV (2.97 or 2.97/1.001 Gbit/s)
wide-band jitter (UIpp)	0.2	1.0	2.0
wide-band jitter measurement filter (Hz)	10	10	10
high-band jitter (UIpp)	0.2	0.2	0.3
high-band jitter measurement filter (kHz)	1	100	100
Frequency offset (ppm)	±2.79365 (NTSC) ±0.225549 (PAL)	±10	±10
Frequency drift rate (ppm/s)	±0.027937 (NTSC) ±0.0225549 (PAL)	No requirement	No requirement

SDI Video Timing Requirements - Equivalent MTIE Masks

See Appendix for derivation of these masks from timing requirements on previous slide



Background on Timing Requirements – 1

- Frequency offset requirements are related to frequency tolerances for the respective signals
  - 10 ppm requirement means that the phase-locked loop is required to have pull-in range of ±10 ppm
- Frequency drift requirement is related to frequency stability requirement for chroma subcarrier in NTSC and PAL signals
  - The relatively tight requirement is easier for the transmitter to meet than the receiver
  - Historically, this was done on purpose, so that a receiver would be cheaper than a transmitter (because the number of receivers, i.e., TV sets, was large compared to the number of transmitters)
  - PAL is more stringent than NTSC
- High-band jitter requirement is related to ability to detect the signal with required bit error ratio

Background on Timing Requirements – 2

- Not clear what wide-band jitter requirement is related to
  - In telecommunications, wide-band jitter is typically constrained so that jitter accumulation will be acceptable in a chain of regenerators
  - The jitter requirement is set so that the buffer of the regenerator phase-locked loop will not overflow or underflow (1.5 UIpp is a typical requirement)
  - Telecommunications regenerators are typically wide-bandwidth, e.g., their transfer 3 dB bandwidths are on the order of kHz to MHz
    - i.e., they are not clocks
    - Typically, other mechanisms are used at clock locations to address buffer overflow/underflow
      - Slip buffers in PDH systems
      - Pointer processors in SDH systems
- Need to determine what the objective is of constraining the wide-band jitter

Question on Applicability of Timing Requirements – 1

- The most stringent of the timing requirements are the wide-band jitter requirement for HD SDI video, and the frequency drift requirement at shorter observation intervals for SD SDI video
- HD SDI video wide-band jitter requirement
  - Approximately 0.67 ns peak-to-peak phase error over 0.03 s
- SD SDI video frequency drift requirement
  - Approximately 0.56 ns peak-to-peak phase error over 0.25 s
- These are the most difficult of the video requirements to meet
  - In transport over an IEEE 802.1AS network, require very narrow bandwidth endpoint filter
    - Averaging of propagation time measurements at intermediate time-aware systems may help
  - However, these requirements are also difficult to meet when carrying SDI video over other transport technologies, e.g., Optical Transport Network (OTN) and Synchronous Digital Hierarchy (SDH)

Question on Applicability of Timing Requirements – 2

- Given that
  - The frequency drift requirement for SD is related to the stability of the chroma subcarrier in an analog composite video signal
  - It is not clear what the objective is of the wide-band jitter requirement for HD and, particularly, why the jitter measurement filter corner frequency is 10 Hz
- It would be useful to obtain more information on
  - why these requirements exist for digital video transport
  - The extent to which these requirements are actually met by digital video (SDI) transport
    - i.e., which applications need these requirements to be met

Proposal

- Send a liaison to the appropriate SMPTE-EBU Synchronization Task Force (which is currently considering synchronization requirements for digital video) and the appropriate ITU-R committee responsible for digital video Recommendations
- The liaison would provide the known background on the video requirements (given in the preceding slides) and then ask
  - What constraint or requirement is the wide-band jitter requirement for HD SDI video attempting to meet?
  - Why is the wide-band jitter filter corner frequency 10 Hz?
  - Why must the frequency drift requirement for SD SDI video be met for digital signals, given that it arose from trying to constrain the stability of the chroma subcarrier in analog composite video signals?
  - To what extent, and for what applications, are these requirements actually met for digital video (i.e., SDI) signals and for modern digital video equipment?

Appendix
Derivation of MTIE masks from jitter, frequency offset, and frequency drift requirements

The material in this appendix is taken from [11], with minor modifications

Derivation of MTIE Masks – 1

❑Uncompressed digital video – SDTV

- Jitter requirement – A_0 = 0.2 UIpp
- Both wide-band (10 Hz) and high-band (1 kHz)
  - –Most stringent breakpoint on MTIE mask corresponds to the 10 Hz filter; breakpoint is 1/[π(10 Hz)] = 0.0318 s
- Most stringent requirement is obtained for highest rate – 360 Mbit/s

  A_0 = 0.2 UI = 0.5556 ns

- Most stringent frequency offset requirement
  - y = 0.225549 ppm = 2.25549×10^{-7} = 225.549 ns/s
- Most stringent frequency drift requirement
  - D = 0.0225549 ppm/s = 2.25549×10^{-8} s^{-1} = 22.5549 ns/s^2
- Intersection between frequency offset and frequency drift MTIE curves
  - $yS = 0.5DS^2$, which implies
  - $S_{break} = 2y/D$ = 20 s
- Intersection between frequency drift and jitter flat level curves
  - $A_0 = 0.5DS^2$, which implies

$$S_{break} = \sqrt{2A_0 / D} = \sqrt{\frac{2(5.556\times10^{-10}\ \mathrm{s})}{2.25549\times10^{-8}\ \mathrm{s}^{-1}}} = 0.22196\ \mathrm{s}$$

Derivation of MTIE Masks – 2

❑Uncompressed digital video – SDTV (Cont.)

- The jitter flat level intersects with the frequency drift curve at a larger observation interval than that corresponding to the jitter measurement filter breakpoint; therefore, this is more stringent
- Then the MTIE mask is

$$\mathrm{MTIE}(S) = \begin{cases} 0.5556\ \mathrm{ns} & S < 0.22196\ \mathrm{s} \\ 11.27745 S^2\ \mathrm{ns} & 0.22196\ \mathrm{s} \le S < 20\ \mathrm{s} \\ 225.549 S\ \mathrm{ns} & S \ge 20\ \mathrm{s} \end{cases}$$

Derivation of MTIE Masks – 3

❑Uncompressed digital video – HDTV

- Wide-band jitter requirement – A_0 = 1.0 UIpp
- 10 Hz high-pass measurement filter
  - Breakpoint is $1/[\pi(10\ \text{Hz})] = 0.0318$ s
  - Most stringent requirement is obtained for highest rate – 1.485 Gbit/s

    A_0 = 1.0 UI = 0.6734 ns
- High-band jitter requirement – A_1 = 0.3 UIpp at 2.97/1.001 Gbit/s rate
- 100 kHz high-pass measurement filter
  - Breakpoint is $1/[\pi(10^5\ \text{Hz})] = 3.183 \times 10^{-6}$ s
  - Most stringent requirement is obtained for highest rate – 1.485 Gbit/s

    A_1 = 0.3 UI at 2.97/1.001 Gbit/s = 0.1011 ns
- Frequency offset requirement
  - y = 10 ppm = 10^{-5} = 10^4 ns/s
- No frequency drift requirement
- Intersection between frequency offset and wide-band jitter flat level curves
  - $A_0 = yS$, which implies
  - $S_{break} = A_0/y = 6.734 \times 10^{-5}$ s
  - The wide-band jitter measurement filter breakpoint of 0.0318 s is more stringent; therefore, we use that

Derivation of MTIE Masks – 4

❑Uncompressed digital video – HDTV (Cont.)

- Intersection between high-band jitter 20 dB/decade and wide-band jitter flat level curves

$$\frac{A_1 S}{3.183\times10^{-6}\ \text{s}} = A_0$$

$$S = 5(3.183\times10^{-6}\ \text{s}) = 1.592\times10^{-5}\ \text{s}$$

- Then the resulting MTIE mask is

$$\text{MTIE}(S) = \begin{cases} 0.1011\ \text{ns} & S < 3.183\times10^{-6}\ \text{s} \\ 4.231\times10^{4} S\ \text{ns} & 3.183\times10^{-6}\ \text{s} \le S < 1.592\times10^{-5}\ \text{s} \\ 0.6734\ \text{ns} & 1.592\times10^{-5}\ \text{s} \le S < 0.03183\ \text{s} \\ 21.16 S\ \text{ns} & S \ge 0.03183\ \text{s} \end{cases}$$

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