UHD-SDI Standards Overview – Towards a Hierarchy of SDI data Rates

John Hudson
Semtech Corporation – Gennum Products Group
UHD – IT’S HERE – IT’S GREAT…..but what is it?

**UHD = HR+HFR+HDR**

**HR (High Resolution) - Big Images**
- 1080-line -> 2160-line UHDTV1 -> 4320-line UHDTV2 “8k”
- 2k D-Cinema -> 4k D-Cinema

**HFR (Higher Frame Rate)**
- Higher spatial resolution needs higher frame rates to control motion blur
  - 25/30 fps -> 50/60 fps -> 100/120 fps
  - 24 fps -> 48 fps -> 96fps -> 100/120 fps

**HDR (High Dynamic Range) & wider color Gamut**
- At least 10 or 12 bits for color depth
- 22.2 channel surround sound audio
- Might be Stereoscopic 3D……..
UHD – IT’S HERE – IT’S GREAT…..but where is it [defined]?

SMPTE ST 2036-xx
- ST 2036-1 Ultra High Definition – Image Parameter Values for Program production

IRU-R BT.2020
- Parameter values for ultra-high definition television systems for production and international programme exchange

ST 2048-1 D-Cinema production image formats
- 2048 1080 and 4096 2160 Digital Cinematography Production Image Formats FS/709

SMPTE TC 24TB UHDTV Ecosystem Study group report
UHD – IT’S HERE – IT’S GREAT…..but when is it?

UHD TVs Are Available

• Direct view TVs are coming down in size and price
• Is a race to the bottom good or bad?

<table>
<thead>
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<th>Manufacturer</th>
<th>Model</th>
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Source: Cnet.com
IHS UHD Forecast

Suppliers are very aggressive for UHD products, but market growth will be limited by insufficient content, inefficient production, high price and insufficient capacity

• Penetration into the TV panel market is 1% in 2013, but rising to over 8% in 2017
UHD – IT’S HERE – IT’S GREAT…..but when is it?

HDMI 2.0 – Increases data rate from 10.2Gb/s to 17.9Gb/s
Will allow UHD, 10-bit, 60fps, 4:4:4 content over a single cable
  – HDMI 1.4b which is available on all first generation UHD TVs limited to 4kp30

Only Panasonic UHD has HDMI 2.0 built in now
  – Uses new silicon

Sony and Toshiba have announced firmware upgrades by end of year
  – Uses HDMI1.4b to support UHD, 8-bit, 60 fps at 4:2:0

Samsung uses outboard box and a proprietary connection for 60p content
Expect all major TV makers to add HDMI 2.0 to all 2014 models.
UHD – IT’S HERE – IT’S GREAT…..but *when* is it?

4k Home Theatres and Monitors

- **Home Theater**
  - Slim 3
  - Display Development
  - JVC
  - Sony
  - Others

- **Monitors**
  - Asus
  - Sharp
  - Dell
  - Acer
  - Others

PCs

- Graphics cards from nvidia, others

Laptops

- 15.6” UHD panel production from Sharp

Tablets

- Panasonic 20” for professionals

Game Consoles

- PS4 playback of 4k video but not games
- Xbox One – not clear but probably similar

Media Servers

- RED RAY; Sony, Nanotech, others?

Upscaling TVs

Set top boxes

- Only prototypes
UHD – IT’S HERE – IT’S GREAT…..but when is it?

Smartphones with 4k recording
  – Sony Xperia i1(C690X)
  – Acer Liquid S2

Digital Still Cameras

Camcorders
  – JVC <$5,000
  – Sony <$4,500

Android 4.3 supports UHD

Qualcomm Snapdragon 800 chip
  – Can record and play back 4k video
UHD – IT’S HERE – IT’S GREAT…..but when is it?

Download to media server
- Sony will offer ~70 titles by year end

Over the top
- Netflix & others planning to start next year
- TV brands may offer too

Satellite
- Trial and one-offs
- Regular service in 2014?

Over the Air
- Not for a while

Cable
- In Discussion

Very little native content available today
UHD – IT’S HERE – IT’S GREAT…..but *when* is it?

- NHK will showcase SUPER Hi-VISION at big events such as the Olympic Games.
- NHK will study applications of SUPER Hi-VISION to fields other than broadcasting, such as cinema and medicine.

- London Olympic Games in 2012
  - Public viewing in the UK, Japan, and the USA
- Brazil FIFA world Cup 2014
  - Public viewing in Japan, the USA, and possibly Europe
- Rio de Janeiro Olympic Games in 2016
  - Public viewing in Japan, the USA, and possibly Europe
  - Full-spec SUPER Hi-VISION format
- Olympic Games in 2020 (Tokyo)
  - Experimental broadcasting using full-spec SUPER Hi-VISION equipment
UHD – IT’S HERE – IT’S GREAT…..but when is it?

<table>
<thead>
<tr>
<th>UHDTV Phase</th>
<th>“UHD-0”</th>
<th>“UHD-1”</th>
<th>“UHD-2”</th>
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<td>Video resolution</td>
<td>3840 x 2160</td>
<td>1920 x 1080</td>
<td>3840 x 2160</td>
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<tr>
<td>Frame rate</td>
<td>p50 / p60</td>
<td>p100 / p120</td>
<td>p100 / p120</td>
</tr>
<tr>
<td>Bit depth</td>
<td>10</td>
<td>10</td>
<td>10, 12, 14 ?</td>
</tr>
<tr>
<td>Color Gamut</td>
<td>BT.709</td>
<td>BT.2020 profile</td>
<td>Full(er) BT.2020 ?</td>
</tr>
<tr>
<td>High Dynamic range</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>
UHDTV Timelines / on air broadcast

Tokyo Olympics

Rio de Janeiro Olympic Games

Brazil World Cup
NHK UHDTV Timelines on air / trial broadcasts
Meanwhile in International Standards land…..

240Gb/s Interface based on 24 lanes of multi-mode fiber at 10.692Gb/s per lane
Meanwhile in International Standards land.....

15Gb/s Interface based on 16 wavelength DWDM over a single single-mode fiber at 10.692Gb/s per wavelength
Meanwhile in International Standards land…..
A new Working Group in SMPTE is tasked with continuing the evolution of SDI:

TC-32NF-70 WG UHD-SDI Interfaces

Proponents are broadcasters, equipment manufacturers and semiconductor manufacturers
Arguments could be made for any rate between 6Gb/s and 192Gb/s.

### Next Generation SDI – Is There an Obvious Sweet Spot ?

<table>
<thead>
<tr>
<th>Data Rate Gb/s</th>
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<tbody>
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<td></td>
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</tr>
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<td>6</td>
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</tr>
<tr>
<td>≤ 30 fps</td>
<td>4:4:4 / 12-bit</td>
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<td>4:2:2 / 10-bit</td>
</tr>
<tr>
<td></td>
<td>4:2:2 / 10-bit</td>
<td>1.5</td>
<td>4:2:2 / 10-bit</td>
</tr>
</tbody>
</table>

- **High Frame Rate:** 60 – 120 fps
- **Mid Frame Rate:** 30 – 60 fps
- **Low Frame Rate:** ≤ 30 fps

- **Data Rates:**
  - 6Gb/s
  - 12Gb/s
  - 24Gb/s
  - 48Gb/s
  - 96Gb/s
  - 192Gb/s

- **Frame Rates:**
  - High Frame Rate: 60 – 120 fps
  - Mid Frame Rate: 30 – 60 fps
  - Low Frame Rate: ≤ 30 fps

- **Frame Rates:**
  - Mid Frame Rate: 30 – 60 fps
  - Low Frame Rate: ≤ 30 fps
### A Hierarchy of Data Rates

#### What if we could allow for simple cost effective migration of infrastructure over time

#### Chose the right data rate for the desired format and the infrastructure?

#### And navigate easily to other rates when needed

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<td>4:4:4 / 12-bit</td>
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</tr>
</tbody>
</table>
The Telco and Datacom industries have needed to address the issue of increasing data rate requirements for many years.

They have developed a hierarchy of data rates, using single and multiple lanes as necessary, with protocols which allow simple conversion between rates.
The equipment which converts between a single signal at a higher rate and multiple signals at a lower rate within the hierarchy is called a **Gearbox**.
Now that the SMPTE is standardising Dual-Link and Quad-Link 3Gb/s SDI for transport of 6Gb/s and 12Gb/s payloads, the first application of gearbox technology could be in combining these into 6G SDI or 12G SDI single links.

The same approach could then be used to combine the 6Gb/s and 12Gb/s links into 24, 48, 96 and 192Gb/s links, once the technology for these links becomes appropriately affordable.
### 3G SDI – where we are now(ish)

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<td>Single</td>
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<tr>
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<td>4:4:4 / 12-bit</td>
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<td>48</td>
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<tr>
<td></td>
<td>4:2:2 / 10-bit</td>
<td>6</td>
<td>24</td>
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<tr>
<td><strong>Mid Frame Rate</strong> 30 – 60 fps</td>
<td>4:4:4 / 12-bit</td>
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<td>4 x 3</td>
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<tr>
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<td>4:2:2 / 10-bit</td>
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</tbody>
</table>

**NOTE:** today there are no standardized SDI interfaces for frame rates beyond 60p
<table>
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<th>Data Rate Gb/s</th>
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### High Frame Rate
60 – 120 fps

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### Mid Frame Rate
30 – 60 fps

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### Low Frame Rate
≤ 30 fps

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**24G SDI**
## 24G SDI

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<td>2 x 24</td>
</tr>
</tbody>
</table>

There are no standardized 200G interface technologies to leverage.
UHD-SDI – Continuing the evolution of SDI

A „hierarchy“ of interface profiles, operating at 6Gb/s, 12Gb/s and 24Gb/s nominal line rates for UHDTV and D-Cinema applications

HDTV@120Hz to UHDTV2@120Hz (Including Stereoscopic 3D) for television
2k@24Hz to 4K@120Hz (Including Stereoscopic 3D) for D-Cinema

75 ohm Coax and Single Mode Fiber-Optic physical layer interface for all rates
- Re-use of existing infrastructure
- Re-use of existing single-mode fibre infrastructure

Backwards compatible with existing single link and multi-link 3Gb/s SMPTE SDI interfaces
- Directly compatible with Single link, Dual-link and Quad-link 3G standards
- Maximum re-use of existing 3G and multi-link 3G implementations
- Confidence monitoring of UHD images on each link
  - Each link carries a complete representation of the original image (at reduced resolution)
The current proposal is for a separate standard number for each of 6G, 12G and 24G SDI

ST 2081 for 6G; ST 2082 for 12G; ST 2083 for 24G

Each standard number will consist of several parts:

- **Parts 0** is a descriptive list of the other parts in the document suite.
- **Parts 1-9** are allocated for serialisation and physical interface standards.
- **Parts 10-19** are allocated for single image mappings on to single link or multi-link interfaces.
- **Parts 20-29** are allocated for stereoscopic image mappings on to single link or multi-link interfaces.
- **Part 30** is allocated for Multi-stream mapping.
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Please join the working group if you wish to contribute to this process.
SMPTE Standardization Activity 3G Multi-link

ST 274, 296, 428-9, 428-19 & 2048-2
1920x1080, 1280x720 & 2048x1080

ST 274, 428-9, 428-19, 2048-1, 2048-2 & 2036-1
1920x1080, 2048x1080, 4096x2160 & 3840x2160

ST 2048-1 & 2036-1
4096x2160 & 3840x2160

ST 425-1
Source Image Format & Ancillary Data Mapping for the 3Gbps SDI Interface

ST 425-3
Image Format and Ancillary Data Mapping for the Dual Link 3 Gbps Serial Interface

ST 425-5
Image Format and Ancillary Data Mapping for the Quad Link 3 Gbps Serial Interface

ST 425-2
Source Image Format and Ancillary Data Mapping for Stereoscopic Image Formats on a Single-Link 3 Gbps Serial Interface

ST 425-4
Dual 3 Gbps Serial Digital Interface for Stereoscopic Image Transport

ST 425-6
Quad 3 Gbps Serial Digital Interface for Stereoscopic Image Transport

ST 424 3Gbps Signal / Data Serial Interface
ST 297 Optical Interface
SMPTE Standardization Activity ST 2081-xx 6G SDI

ST 274, 296, 428-9, 428-19 & 2048-2
1920x1080, 1280x720 & 2048x1080

ST 274, 428-9, 428-19, 2048-1, 2048-2 & 2036-1
1920x1080, 2048x1080, 4096x2160 & 3840x2160

ST 2048-1 & 2036-1
4096x2160 & 3840x2160

ST 425-1
Source Image Format & Ancillary Data Mapping for the 3Gbps SDI Interface

ST 425-3
Image Format and Ancillary Data Mapping for the Dual Link 3 Gbps Serial Interface

ST 425-5
Image Format and Ancillary Data Mapping for the Quad Link 3 Gbps Serial Interface

ST 425-4
Dual 3 Gbps Serial Digital Interface for Stereoscopic Image Transport

ST 425-6
Quad 3 Gbps Serial Digital Interface for Stereoscopic Image Transport

ST 2081-10
1080-line P 96, 100 & 120
2160-line and 1080-line Image Formats on a single link 6Gbps interface

ST 2081-11
2160-line and 1080-line Image Formats on a dual link 6Gbps interface

ST 2081-12
4320-line and 2304-line Image Formats on a Quad link 6Gbps interface

ST 2081-20
1080-line and 720-line Stereoscopic Image Transport on a single link 56Gbps interface

ST 2081-21
2160-line and 1080-line Stereoscopic Image Transport on a dual link 56Gbps interface

ST 2081-22
2160-line and 1080-line Stereoscopic Image Transport on a quad link 56Gbps interface

ST 2081-1 6Gbps Signal / Data Serial Interface - Electrical
ST 2081-2 6Gbps Signal / Data Serial Interface - Optical
SMPTE Standardization Activity – ST 2082-xx 12G SDI

ST 274, 428-9, 428-19, 2048-1, 2048-2 & 2036-1
1920x1080, 2048x1080, 4096x2160 & 3840x2160

ST 2048-1 & 2036-1
7680x4320, 4096x2160 & 3840x2160

ST 425-3
Image Format and Ancillary Data Mapping for the Dual-Link 3 Gb/s Serial Interface

ST 425-5
Image Format and Ancillary Data Mapping for the Quad-Link 3 Gb/s Serial Interface

ST 425-6
Quad 3 Gb/s Serial Digital Interface for Stereoscopic Image Transport

ST 2081-10
2160-line and 1080-line image formats on a single link 6Gb/s interface

ST 2081-11
2160-line and 1080-line image formats on a dual link 6Gb/s interface

ST 2081-12
2160-line and 1080-line Stereoscopic Image Transport on a single link 6Gb/s interface

ST 2081-21
2160-line Stereoscopic Image Transport on a dual link 6Gb/s interface

ST 2081-22
4320-line and 2160-line Stereoscopic Image Transport on a quad link 12Gb/s interface

ST 2082-10
2160-line P 96, 100 & 120

ST 2082-20
2160-line image formats on a single link 12Gb/s interface

ST 2082-50
2160-line image formats on a single link 12Gb/s interface

ST 2082-11
3840-line and 2160-line image formats on a dual link 12Gb/s interface

ST 2082-21
2160-line Stereoscopic Image Transport on a dual link 12Gb/s interface

ST 2082-22
4320-line and 2160-line Stereoscopic Image Transport on a quad link 12Gb/s interface

ST 2082-23
10308b/s Signal / Data Serial Interface - Electrical
ST 2082-2110308b/s Signal / Data Serial Interface - Optical
### SMPTE Standardization Activity – ST 2083-xx 24G SDI

<table>
<thead>
<tr>
<th>SMPTE Standard</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>2048-1 &amp; 2036-1</td>
<td>4096x2160 &amp; 3840x2160</td>
</tr>
<tr>
<td>ST 2048-1 &amp; 2036-1</td>
<td>7680x4320, 4960x2160 &amp; 3840x2160</td>
</tr>
</tbody>
</table>

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**Don’t forget to pick up your Free UHD-SDI Standards poster Today !!**

Free shipping and handling: carry it home yourself
Some restrictions apply: only one per household – strictly limited while stocks last
SMPTE 32NF70 UHD-SDI Standards Timeline

- **HDTV**
  - 2k60 422 10-bit @ 3Gb/s
  - 4k30 422 10-bit @ 6Gb/s
  - 4k120 422 10-bit @ 12Gb/s
  - 1080p100/120 @ 6Gb/s

- **UHDTV-1**
  - 4k60 422 10-bit @ 12Gb/s
  - 4k120 422 10-bit @ 24Gb/s
  - 6G UHD-SDI

- **UHDTV-2**
  - 8k60 422 10-bit @ 48Gb/s
  - 8k120 422 10-bit @ 96Gb/s

- **8k**
  - 8k120 444 12-bit @ 200Gb/s

- **1080p100/120**
  - 1080p100/120 @ 6Gb/s

- ** Formats**
  - Multi-link 3G SDI
  - Dual-link 12G UHD-SDI
  - Quad-link 12G UHD-SDI
  - Octa-link 24G UHD-SDI

Confidential & Proprietary
Larger formats divided to multiple 1080-line sub-images using 2-sample division

2160-line images (4k) divided to 4 x 1080-line sub images

Even sample pairs (e.g. samples 0,1) from even lines (e.g. line 0) make up sub-image 1
Odd sample pairs (e.g. samples 2,3) from even lines make up sub-image 2
Even sample pairs from odd lines (e.g. line 1) make up sub-image 3
Odd sample pairs from odd lines make up sub-image 4

Samples are paired to accommodate 4:2:2 sampling structures

NOTE: no “square” (quadrant split), sub-division
Larger formats divided to multiple 1080-line sub-images using 2-sample division

4320-line images (8k) divided to 4 x 2160-line sub images

2160-line images (4k) divided to 4 x 1080-line sub images
## UHD-SDI Mapping Rules & Structures

1080-line sub-images each mapped onto 10-bit Data Streams – compatible with 3G SDI

2 per 3G link; 4 per 6G link; 8 per 12G link; and 16 per 24G link

### Example 3G virtual interface

<table>
<thead>
<tr>
<th>Stream 1</th>
<th>Stream 2</th>
<th>Stream 3</th>
<th>Stream 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>DATA Stream 1 of Virtual Interface SDI Stream Frequency: 144.5 MHz</td>
<td>DATA Stream 2 of Virtual Interface SDI Stream Frequency: 144.5 MHz</td>
<td>DATA Stream 3 of Virtual Interface SDI Stream Frequency: 144.5 MHz</td>
<td>DATA Stream 4 of Virtual Interface SDI Stream Frequency: 144.5 MHz</td>
</tr>
<tr>
<td>Optional Auxiliary Data</td>
<td>Optional Auxiliary Data</td>
<td>Optional Auxiliary Data</td>
<td>Optional Auxiliary Data</td>
</tr>
</tbody>
</table>

### Example 6G UHD-SDI virtual interface

<table>
<thead>
<tr>
<th>Stream 1</th>
<th>Stream 2</th>
<th>Stream 3</th>
<th>Stream 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>DATA Stream 1 of Virtual Interface SDI Stream Frequency: 144.5 MHz</td>
<td>DATA Stream 2 of Virtual Interface SDI Stream Frequency: 144.5 MHz</td>
<td>DATA Stream 3 of Virtual Interface SDI Stream Frequency: 144.5 MHz</td>
<td>DATA Stream 4 of Virtual Interface SDI Stream Frequency: 144.5 MHz</td>
</tr>
<tr>
<td>Optional Auxiliary Data</td>
<td>Optional Auxiliary Data</td>
<td>Optional Auxiliary Data</td>
<td>Optional Auxiliary Data</td>
</tr>
</tbody>
</table>

### Example 12G UHD-SDI virtual interface

<table>
<thead>
<tr>
<th>Stream 1</th>
<th>Stream 2</th>
<th>Stream 3</th>
<th>Stream 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>DATA Stream 1 of Virtual Interface SDI Stream Frequency: 144.5 MHz</td>
<td>DATA Stream 2 of Virtual Interface SDI Stream Frequency: 144.5 MHz</td>
<td>DATA Stream 3 of Virtual Interface SDI Stream Frequency: 144.5 MHz</td>
<td>DATA Stream 4 of Virtual Interface SDI Stream Frequency: 144.5 MHz</td>
</tr>
<tr>
<td>Optional Auxiliary Data</td>
<td>Optional Auxiliary Data</td>
<td>Optional Auxiliary Data</td>
<td>Optional Auxiliary Data</td>
</tr>
</tbody>
</table>
Ancillary Data – Including Audio

Ancillary data are carried preferentially by data stream one.
Audio data are carried preferentially by data stream pair one/two
Mapping to SDI Links

A 2160-line Image mapped to quad-link 3G SDI (ST 425-5)
UHD-SDI Mapping Rules & Structures

Mapping to SDI Links

A 2160-line Image mapped to dual-link 6G SDI (Proposed ST 2081-11)
Only the Payload Identifiers change to signify carriage over 6G SDI
UHD-SDI Mapping Rules & Structures

Mapping to SDI Links

The same 2160-line Image mapped to single-link 12G SDI (Proposed ST 2083-10)
Only the Payload Identifiers change to signify carriage over 12G SDI
High Frame Rate Images – This bit is new

Everything so far is a direct extension of the ST 425 multi-link 3G standards

However, there is no precedent in the ST 425 multi-3G standards for High Frame Rate images

HFR images are defined in SMPTE and ITU-R standards for UHDTV and D-Cinema

   BUT Their transport is not defined anywhere……. and there are no HFR standards for HDTV

In order to be able to divide these source images to 1080-line sub-images for transport, two additions are needed:

   (1) A standard for a 1920 x 1080 image container at 100 and 120 fps and a 2048 x 1080 image container at 96, 100 and 120 fps is required

   (2) A method for mapping the 1080-line HFR sub-images into SDI is also required
2-sample division, creates 1080-line frames at the native frame rate, but with the lines at half-length.
Once the half-length container is mapped into a physical interface it appears like any other SDI interface.
Each data stream of the Virtual Interface carries the SMPTE ST 352 Video Payload Identification Codes to identify:

The image format, mapping structure and interface;
Frame rate, sampling structure and color space;
Bit-depth and channel number for multilink interfaces

<table>
<thead>
<tr>
<th>Bits</th>
<th>Byte 1</th>
<th>Byte 2</th>
<th>Byte 3</th>
<th>Byte 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bit 7</td>
<td>Interlaced or progressive transport</td>
<td>Interlaced or progressive transport</td>
<td>Aspect Ratio</td>
<td>Channel assignment</td>
</tr>
<tr>
<td>Bit 6</td>
<td>Payload, interface and Mapping identification Assigned by SMPTE HQ</td>
<td>Payload, interface and Mapping identification Assigned by SMPTE HQ</td>
<td>Aspect Ratio</td>
<td>Interface Assignment</td>
</tr>
<tr>
<td>Bit 5</td>
<td>Progressive picture</td>
<td>Progressive picture</td>
<td>Horizontal sampling</td>
<td>Audio Channel Assignment</td>
</tr>
<tr>
<td>Bit 4</td>
<td>Reserved (0)</td>
<td>Reserved (0)</td>
<td>Color Gamut</td>
<td>Channel Valid</td>
</tr>
<tr>
<td>Bit 3</td>
<td>Reserved (0)</td>
<td>Reserved (0)</td>
<td>Color Gamut</td>
<td>Bit depth</td>
</tr>
<tr>
<td>Bit 2</td>
<td>Picture rate</td>
<td>Picture rate</td>
<td>Sampling structure</td>
<td></td>
</tr>
<tr>
<td>Bit 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bit 0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## UHD-SDI Physical Layer - Electrical

<table>
<thead>
<tr>
<th></th>
<th>270Mb/s</th>
<th>1.5Gb/s</th>
<th>3Gb/s</th>
<th>6Gb/s</th>
<th>12Gb/s</th>
<th>24Gb/s</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Standard:</strong></td>
<td>ST 250M</td>
<td>ST 292-1</td>
<td>ST 424</td>
<td>Proposed ST 2081-1</td>
<td>Proposed ST 2082-1</td>
<td>Proposed ST 2083-1</td>
</tr>
<tr>
<td><strong>Coding:</strong></td>
<td>Scrambled NRZI</td>
<td>Scrambled NRZI</td>
<td>Scrambled NRZI</td>
<td>Scrambled NRZI</td>
<td>Scrambled NRZI</td>
<td>Scrambled NRZI</td>
</tr>
<tr>
<td><strong>Amplitude:</strong></td>
<td>800mV ±10%</td>
<td>800mV ±10%</td>
<td>800mV ±10%</td>
<td>800mV ±10%</td>
<td>800mV ±10%</td>
<td>800mV ±10%</td>
</tr>
<tr>
<td><strong>DC Offset:</strong></td>
<td>0.0V ±0.5V</td>
<td>0.0V ±0.5V</td>
<td>0.0V ±0.5V</td>
<td>0.0V ±0.5V</td>
<td>0.0V ±0.5V</td>
<td>0.0V ±0.5V</td>
</tr>
<tr>
<td><strong>Rise-/fall time:</strong></td>
<td>≤ 400ps ... 1.5ns</td>
<td>≤ 270ps</td>
<td>≤ 135ps</td>
<td>≤ 80ps</td>
<td>≤ 45ps</td>
<td>≤ 28ps</td>
</tr>
<tr>
<td><strong>A Rise-/fall time:</strong></td>
<td>≤ 500ps</td>
<td>≤ 100ps</td>
<td>≤ 50ps</td>
<td>≤ 35ps</td>
<td>≤ 18ps</td>
<td>≤ 8ps</td>
</tr>
<tr>
<td><strong>Over-/under-shoot:</strong></td>
<td>10% of the amplitude</td>
<td>10% of the amplitude</td>
<td>10% of the amplitude</td>
<td>10% of the amplitude</td>
<td>10% of the amplitude</td>
<td>10% of the amplitude</td>
</tr>
<tr>
<td><strong>Timing Jitter:</strong></td>
<td>&lt; 0.2 UI up to 10 Hz</td>
<td>&lt; 1 UI up to 10 Hz</td>
<td>&lt; 2 UI up to 10 Hz</td>
<td>&lt; 2 UI up to 10 Hz</td>
<td>&lt; 2 UI up to 10 Hz</td>
<td>&lt; 2 UI up to 10 Hz</td>
</tr>
<tr>
<td><strong>Alignment Jitter:</strong></td>
<td>&lt; 0.2 UI</td>
<td>&lt; 0.2 UI</td>
<td>&lt; 0.3 UI</td>
<td>&lt; 0.3 UI</td>
<td>&lt; 0.3 UI</td>
<td>&lt; 0.3 UI</td>
</tr>
<tr>
<td><strong>Lower edge Mhz:</strong></td>
<td>100 KHz</td>
<td>100 KHz</td>
<td>100 KHz</td>
<td>100 KHz</td>
<td>100 KHz</td>
<td>100 KHz</td>
</tr>
<tr>
<td><strong>Return Loss:</strong></td>
<td>&lt; 15 dB - 5 MHz to 270 MHz</td>
<td>&lt; 15 dB - 5 MHz to 1.5 GHz</td>
<td>&lt; 15 dB - 5 MHz to 1.5 GHz</td>
<td>&lt; 15 dB - 5 MHz to 1.5 GHz</td>
<td>&lt; 15 dB - 5 MHz to 1.5 GHz</td>
<td>&lt; 15 dB - 5 MHz to 1.5 GHz</td>
</tr>
<tr>
<td><strong>75 Ω Coaxial Cable length (Point-to-point):</strong></td>
<td>400 m+</td>
<td>300 m</td>
<td>200 m</td>
<td>100 m+</td>
<td>60 m+</td>
<td>≤ 40 m</td>
</tr>
</tbody>
</table>

**NOTE:** Cable lengths for 6G, 12G and 24G UHD-SDI are based on “first generation” silicon capabilities with “Industry standard” ST 424 (3G) compliant cables and connectors.
# UHD-SDI Physical Layer – Optical Transmitter

<table>
<thead>
<tr>
<th>Transmit Unit Optical Output</th>
<th>270Mb/s</th>
<th>1.5Gb/s</th>
<th>3Gb/s</th>
<th>6Gb/s</th>
<th>12Gb/s</th>
<th>24Gb/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High-Power</td>
<td>ST 297</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium-Power</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low-Power</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transmission circuit fiber</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SM (9.0/125 um)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SM (9.0/125 um)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light Source</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laser</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Laser</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Optical wavelength</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1310 nm +/- 40nm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1550 nm +/- 40nm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum spectral line width</td>
<td>&lt;=1 nm</td>
<td>&lt;=4 nm</td>
<td>&lt;=10 nm</td>
<td>&lt;=4 nm</td>
<td>&lt;=1 nm</td>
<td></td>
</tr>
<tr>
<td>Maximum Optical Power</td>
<td>+10 dBm</td>
<td>+0 dBm</td>
<td>-3 dBm</td>
<td>+0.5 dBm</td>
<td>3.0 dBm</td>
<td></td>
</tr>
<tr>
<td>Minimum Optical Power</td>
<td>0 dBm</td>
<td>-3 dBm</td>
<td>-12 dBm</td>
<td>-5.5 dBm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum Extinction ratio</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rise fall times (optical)</td>
<td>400ps ... 1.5ns</td>
<td>&lt;= 270ps</td>
<td>&lt;= 135ps</td>
<td>&lt;= 80ps</td>
<td>&lt;= 45ps</td>
<td>&lt;= 28ps</td>
</tr>
<tr>
<td>Maximum intrinsic jitter (Optical)</td>
<td>&lt;0.2 UI</td>
<td>&lt;0.2 UI</td>
<td>&lt; 0.3 UI</td>
<td>&lt; 0.3 UI</td>
<td>&lt; 0.3 UI</td>
<td>&lt; 0.3 UI</td>
</tr>
<tr>
<td>Maximum reflected power</td>
<td>1KHz to 27Mhz</td>
<td>100KHz to 150Mhz</td>
<td>100KHz to 300Mhz</td>
<td>100KHz to 600Mhz</td>
<td>100KHz to 1200Mhz</td>
<td>100KHz to 2400MHz</td>
</tr>
<tr>
<td>Electrical / Optical Transfer function</td>
<td>Logic “1” = Higher optical power</td>
<td>Logic “0” = Lower optical power</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preferred Connector</td>
<td>LC PC</td>
<td>MPO / MTP® Fiber Connector 8-degree angled end-face</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Module form factor</td>
<td>SFP / SFP+</td>
<td>QSFP / QSFP+</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# UHD-SDI Physical Layer – Optical Receiver

<table>
<thead>
<tr>
<th>Standard:</th>
<th>270Mb/s</th>
<th>1.5Gb/s</th>
<th>3Gb/s</th>
<th>6Gb/s</th>
<th>12Gb/s</th>
<th>24Gb/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>ST 297</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Transmission circuit fiber</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>SM (9.0/125 um)</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Nominal Wavelength</td>
<td>1310 nm +/- 40nm</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Minimum input overload power</td>
<td>-7.5 dBm, 0 dBm preferred</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum Input power</td>
<td>-20 dBm</td>
<td>-17 dBm</td>
<td>-14 dBm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Detector damage threshold</td>
<td>+1 dBm (minimum)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electrical / Optical Transfer Function</td>
<td>Higher optical power = Logic “1” / Lower optical power = Logic “0”</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preferred Connector</td>
<td>LC PC</td>
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<td>MPO / MTP® Fiber Connector 8-degree angled end-face</td>
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<td>Module form factor</td>
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<td></td>
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</tr>
</tbody>
</table>
A single “robust” optical connector solution is proposed for standardization.

One form factor (multi-fiber), to support data rates from 270Mb/s to 200Gb/s on a single (multi-fiber optical), cable.

- Rugged, robust and dirt-protected (shuttered apperture)
- Simple integration – LC connection or MTP ®
- Versatile – multichannel 4 and 8 fibers connection system
- Common QSFP optical module form factor
- Up to 2km link distance at all data rates
The basic technology required to implement 6G, 12G, and 24G UHD-SDI was demonstrated at IBC 2013.
At InterBEE last week – 96Gb/s

- Demonstrates all of the “Gearbox” principals and multiplexing techniques required for 7680x4320p120 YCbCr 4:2:2 10-bit images

- **Note:** Due to lack of availability of 8kp120 source or display, this demo was restricted to “4kp60 YCbCr 4:2:2 10-bit 8-times”
Technology Demonstrations

InterBEE Technology demonstration – 2 x 48Gb/s or 96Gb/s total payload

2 x UHDTV1@120p RGB 4:4:4 12-bit (48Gb/s payload)
1 x UHDTV2@120p YCbCr 4:2:2 10-bit (96Gb/s payload)
What are we showing today?

Dual 6G to Quad 12G (x2)

Quad-link 12G (x2)

Quad 12G (x2) to Dual 6G

(one of 8 selector)

Quad 12G (x2) to Dual 6G

(one of 8 selector)

Single-mode Fibre

Dual 6G to Quad 12G (x2)

Quad-link 12G (x2)

Quad 12G (x2) to Dual 6G

(one of 8 selector)

Single-mode Fibre

Dual 6G to Quad 12G (x2)

Quad-link 12G (x2)

Quad 12G (x2) to Dual 6G

(one of 8 selector)

Single-mode Fibre

Dual 6G to Quad 12G (x2)

Quad-link 12G (x2)

Quad 12G (x2) to Dual 6G

(one of 8 selector)

Single-mode Fibre

Dual 6G to Quad 12G (x2)

Quad-link 12G (x2)

Quad 12G (x2) to Dual 6G

(one of 8 selector)

Single-mode Fibre

Dual 6G to Quad 12G (x2)

Quad-link 12G (x2)

Quad 12G (x2) to Dual 6G

(one of 8 selector)

Single-mode Fibre

Dual 6G to Quad 12G (x2)

Quad-link 12G (x2)

Quad 12G (x2) to Dual 6G

(one of 8 selector)

Single-mode Fibre

Dual 6G to Quad 12G (x2)

Quad-link 12G (x2)

Quad 12G (x2) to Dual 6G

(one of 8 selector)

Single-mode Fibre

Dual 6G to Quad 12G (x2)

Quad-link 12G (x2)

Quad 12G (x2) to Dual 6G

(one of 8 selector)

Single-mode Fibre

Dual 6G to Quad 12G (x2)

Quad-link 12G (x2)

Quad 12G (x2) to Dual 6G

(one of 8 selector)

Single-mode Fibre

Dual 6G to Quad 12G (x2)

Quad-link 12G (x2)

Quad 12G (x2) to Dual 6G

(one of 8 selector)

Single-mode Fibre

Dual 6G to Quad 12G (x2)

Quad-link 12G (x2)

Quad 12G (x2) to Dual 6G

(one of 8 selector)

Single-mode Fibre

Dual 6G to Quad 12G (x2)

Quad-link 12G (x2)

Quad 12G (x2) to Dual 6G

(one of 8 selector)

Single-mode Fibre

Dual 6G to Quad 12G (x2)

Quad-link 12G (x2)

Quad 12G (x2) to Dual 6G

(one of 8 selector)

Single-mode Fibre

Dual 6G to Quad 12G (x2)

Quad-link 12G (x2)

Quad 12G (x2) to Dual 6G

(one of 8 selector)

Single-mode Fibre

Dual 6G to Quad 12G (x2)

Quad-link 12G (x2)

Quad 12G (x2) to Dual 6G

(one of 8 selector)

Single-mode Fibre
SMPTE Continues the evolution of SDI

A "hierarchy" of interface profiles for both Television and D-Cinema applications

Provides an interface solution for HDTV, UHDTV and D-Cinema production image formats from 6Gb/s (HDTV@120Hz) to 192Gb/s (UHDTV2@120Hz).

6Gb/s, 12Gb/s and 24Gb/s nominal line rates for coaxial cable and single mode fiber optic

Gearbox concept maximizes compatibility and affordability

Continues re-use of existing coaxial cable infrastructure for all legacy and future SDI requirements from 270Mb/s up to 200Gb/s

Allows for simple migration of infrastructure over time

Simple evolution from existing single-link and multi-link 3Gb/s SMPTE SDI interfaces

A robust optical fiber connector and cable

QSFP Optical module, & robust cable and connectors provides a single optical interface for all legacy and future SDI requirements from 270Mb/s up to 200Gb/s.
Thank you & on to the demos

John Hudson