Technical Report 002

Advice on the use of 3 Gbit/s HD-SDI interfaces

EBU TECHNOLOGY AND DEVELOPMENT

Your reference in media technology and innovation

Level A
Level B-DL (Dual Link)
Level B-DS (Dual Stream)

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Keywords: Serial Digital Interface, HDTV, 3DTV, 3 Gbit/s, 3G-SDI, SMPTE ST 425

Please Note

This document is an EBU Technical Report, *not* a Recommendation.

A broadcaster's or facility company's choice of 3 Gbit/s infrastructure using the current, established 3 Gbit/s (3G-SDI) standards mentioned in this document must be based on the business and operational requirements of the company.

1. Scope

The 3G-SDI interface is required primarily to deliver 1080p/50 (or 59.94) over a single link. Recently it has also been used by some organisations to transport twin 1.5G-SDI signals for Stereoscopic 3DTV.

Although the 3G-SDI interface can be used for other standards such as Digital Cinema, this information will *only* concern itself with its use in high definition television production for 1080p/50 and twin 1080i/25 (or 1080p/25) applications.

For further information on other formats that can be mapped into the 3G-SDI see Annex D for a listing of the relevant standards documents.

2. Document objectives

An EBU Strategic Programme focused on the **H**armonisation and the **I**nteroperability of HDTV **P**roduction **S**tandards (SP-HIPS). The project was a joint effort between major HDTV industry players and the EBU community to drive harmonisation and interoperability of standards related to HDTV production.

One of its areas of interest was the evolution of the HD-SDI standards and particularly, 3G-SDI. The aim of the 3G-SDI sub-group was to identify the broadcasting organisations' requirements and to supply guidance and information to new users and the industry.

This information is provided by SP-HIPS with the intention of assisting EBU Members who are investigating the use of 3G-SDI within their own infrastructure or for the exchange of programmes and to highlight the interoperability of 3G-SDI equipment using the current standards.

3. Relevant Standards

The Society of Motion Picture and Television Engineers (SMPTE) is the organisation that produces the standards mentioned in this document. 3G-SDI SMPTE has recently published the 3G-SDI standards described in this document. See **Annex D** for details of the relevant standards documentation.

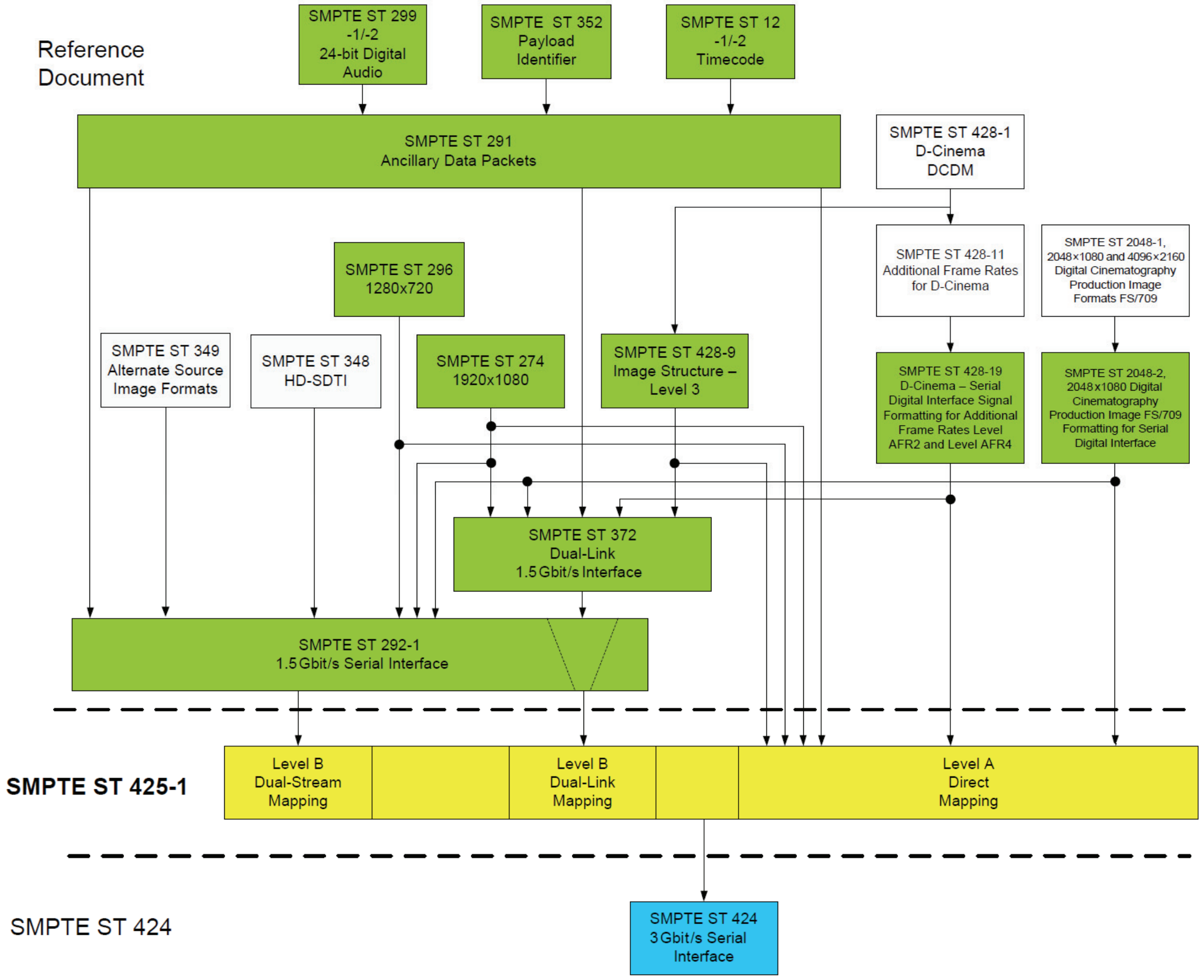

Figure 1: (SMPTE ST 425-1:2011) Standards Document Mapping (see Annex D)

4. Background

4.1 Analogue to digital transition

Analogue links are generally simpler to implement than digital but suffer from the effects of noise, crosstalk, poor frequency response, reflections etc. It is possible to fix or partially repaired such damage but the result is seldom as good as the original.

Digital signals usually originate from an analogue source that is converted to digits. Some of the fine detail present in the analogue signal is lost in this conversion due to the infinite number of possibilities in an analogue signal is converted into a finite set of numbers that can be stored and transmitted.

How well the digital signal represents the image depends upon the precision, accuracy, and quantity of the numbers. This requires decisions to be made concerning sampling rates and the number of bits per sample.

A digital signal can be transmitted by many different methods, but the generally accepted format in professional television is the Serial Digital Interface (SDI).

The SDI is an 800 mV binary serial digital signal but it must be remembered that the actual digital signal is an analogue representation of the digitised image, and is therefore subject to the problems of any analogue system. The challenge is to tell the difference between the two binary values at the destination with sufficient accuracy to recover all of the numbers correctly. As the number of bit per second goes up, the bigger this challenge becomes.

The length of coaxial cable that will operate reliably between two devices depends on several factors. The frequency of the signal, the quality of the coaxial cable, how the cable is installed, the quality of connectors or terminations, the layout of the device circuit boards and the design of the transmitter and receivers are all factors that affect the ability to successfully recover the digital signal and therefore, the length coaxial cable that signal can successfully pass through.

4.2 Overview

The SMPTE has described three different mapping schemes for transporting uncompressed video, ancillary data such as the audio data, the audio control packets, the payload ID, the time code, etc. into a serial digital interface operating at a nominal rate of 3 Gbit/s. These are defined as Level A, Level B Dual Link (B-DL) and Level B Dual Stream (B-DS).

In the context of *this* document;

Level A Is the direct mapping of an uncompressed 1080p/50 video stream into a serial digital interface operating at a nominal rate of 3 Gbit/s.

Level B-DL Is the dual-link mapping of a 1080p/50 video stream into a serial digital interface operating at a nominal rate of 3 Gbit/s.

Level B-DS Is the dual-stream mapping of two independent 1080i/25 (or 1080p/25) video streams into a single serial digital interface operating at a nominal rate of 3 Gbit/s.

More detailed descriptions of each standard and the other formats that can be mapped can be found in Annexes A, B and C.

4.3 General Issues

Level A and Level B-DL support 1080p/50 and the end-user should establish the capabilities of existing standard equipment or of proposed purchases before designing new installations or making additions to established television infrastructures.

The facility designer will probably wish to select one format (Level A or Level B-DL) for each facilities routing/vision mixer (switcher) signal “cloud”.

Level B-DS carries two 1.5G-SDI streams on a single coax cable; however cable length and cable installation practices are the same as those for Level A and Level B-DL.

In the absence of other standards, Level B-DS is being used by some organisations to carry the left and right eye signals of stereoscopic 3DTV.

It is not the primary purpose of this document to give advice on the carriage of 3D signals as work is being considered by relevant standard bodies to produce a standard for the labelling of two 1.5G-SDI links to include left/right eye identifiers. The EBU intends to issue further information on the carriage of twin images for stereoscopic 3DTV via 3G-SDI at a later date.

4.3.1 Conversion

Conversion between Level A and Level B-DL introduces a delay of at least one video line. A conversion from one level to the other and back introduces at least two lines of delay.

These delays can concatenate in installations with a mix of Level A and Level B-DL plant if it is not compensated for. This is very important around vision mixers and routers where signals may pass through many times often via other external devices, during processing such as compositing.

Conversion of signals with embedded audio or other ancillary data may increase the delay and introduce additional complexity to correct the positioning or timing of some ancillary data packets.

Some devices process signals internally using a different standard to their own input/output standard. It always advisable to confirm these devices compensate for any conversion delay internally before installation.

Note: These delays are not incurred for Level B-DS when used for 1080i/25 signals.

4.3.2 Pathological Test Patterns

For out of service testing of 3 Gbit/s links, different pathological test patterns are required for each of the mapping modes to ensure the interface is correctly stressed.

For Level A mapping, the Bit-Serial Digital Check-Field pattern as defined in SMPTE RP198 is applicable. This check-field pattern does not produce a pathological stress signal when applied to Level B-DL or Level B-DS mapping.

The SMPTE is in the process of revising SMPTE RP 198 to include specific 3 Gbit/s pathological test patterns for Level B-DL and Level B-DS.

4.3.3 Switch Regions

For 1080p/50, Level A, B-DL and B-DS serial streams use switching point defined in SMPTE RP 168:2009. In the case of Level B-DS mapping, there is no requirement for frame alignment of each image carried on the link. If the two images are not frame aligned, video switching could be adversely affected. For this reason frame alignment should always be recommended for Level B-DS interfaces.

Note: As new video formats have been standardised, switching points have also evolved and some devices may not support the appropriate switching points defined in SMPTE RP 168:2009 for these formats.

4.3.4 Payload Mapping

The use of the SMPTE ST 352 Payload ID is mandatory due to the large number of different video formats that can be carried in the 3 Gbit/s interface,

Without the payload ID, it is not possible to correctly identify all of the supported formats or mapping modes purely from inspection of the payload data.

4.3.5 Embedded Audio

The mapping of embedded audio is explained in the audio mapping sections of **Annex A**, **B** and **C**. Level A, B-DL and B-DS can carry up to 32 audio channels. Level B-DS carries the 32 channels as two groups of 16, (that is 16 audio channels on each of the two 1.5 Gbit/s streams.

4.3.6 Corruption of Non PCM Audio Blocks

To prevent corruption of non PCM audio blocks a Two-Frame Marker, or Fr/2 reference signal may be used to delineate frame-pairs for all progressive video signals.

A new SMPTE standard (SMPTE ST 2051:2010) defines a two-frame marker relationship between the mapped image format and the embedded Fr/2 services.

However the implementation of SMPTE ST 2051 is not mandatory and equipment in the production chain that does not use the standard may strip the two-frame marker. It may not be possible to upgrade all such existing equipment.

5. Installation and Measurement

3G-SDI signals can be carried over coaxial cable as well as over optical circuits. This section of the document gives advice to users who are upgrading existing or planning new *coaxial* 3G-SDI installations.

5.1 Overview

The quality of the digital serial data signal can be represented in an eye-diagram. The eye-diagram is an analogue view in the physical layer of the HD (or SD) SDI Signal.

The eye-diagram shows the amplitude, the rise and fall-time, the over and under-shoot and the duration of one unit interval.

Where the analyser is DC-coupled, the DC-offset of the signal is also shown. It is also possible to measure the jitter from the eye-diagram, but for weighting the jitter, the parameters of the filters used are needed. If more and detailed information about the jitter is necessary, it is recommended to use a separate Jitter waveform-diagram.

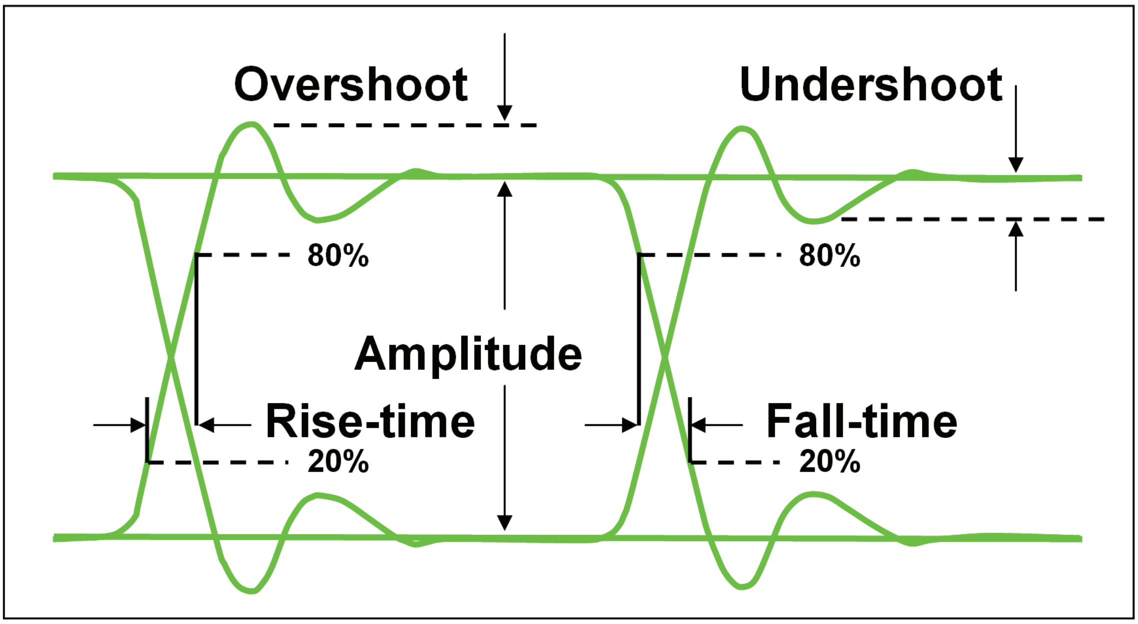

Figure 2: Eye Height Overview

Table 1 lists and compares the measurements parameters for standard definition and high definition at the nominal 1.5 and 3 Gbit/s standards:

Table 1: Signal tolerances in SDI

	Standard:	ITU-R BT.656	SMPTE ST 259
SD	Amplitude:	800 mV ±10%	800 mV ±10%
	DC Offset:	0.0 V ±0.5 V	0.0 V ±0.5 V
	Rise-/fall time:	750 ps … 1.5 ns	400 ps … 1.5 ns
	Δ Rise-/fall time:	≤ 500 ps	≤ 500 ps
	Jitter:	A1 and A2 < 0.2 UI	A1 and A2 < 0.2 UI
	Over- / under-shoot:	No value give	10% of the amplitude

	Standard:	ITU-R BT.1120-7	SMPTE ST 292-1
HD 1.485 Gbit/s	Amplitude:	800 mV ±10%	800 mV ±10%
	DC Offset:	0.0V ±0.5 V	0.0V ±0.5 V
	Rise-/fall time:	≤ 270 ps	≤ 270 ps
	Δ Rise-/fall time:	≤ 100 ps	≤ 100 ps
	Jitter:	A1 < 1 UI; A2< 0.2 UI	A1 < 1 UI; A2< 0.2 UI
	Over- / under-shoot:	10% of the amplitude	10% of the amplitude

	Standard:	ITU-R BT.1120-7	SMPTE ST 424
HD 2.97 Gbit/s	Amplitude:	800 mV ±10%	800 mV ±10%
	DC Offset:	0.0 V ±0.5 V	0.0 V ±0.5 V
	Rise-/fall time:	≤ 270 ps*	≤ 135 ps
	Δ Rise-/fall time:	≤ 100 ps*	≤ 50 ps
	Jitter:	A1 < 1 UI; A2< 0.2 UI	A1 < 2 UI; A2< 0.3 UI
	Over- / under-shoot:	10% of the amplitude	10% of the amplitude

Note: *Rise-/fall time and Δ Rise-/fall time specifications given in ITU-R BT.1120-7 for the 3 Gbit/s signal (published 2007) may now give rise to a compromised transmit eye leading to non optimal performance of 3 Gbit/s systems.*

5.2 Return Loss

Return Loss (RL) is a measure of the impedance of an interface. The higher the measured value of return loss in an interface, the better is the impedance of the interface to the infrastructure.

Although a return loss figure outside the ITU-R BT.1120 specification will not necessarily stop a link from working, it may influence the length of cable that can successfully be compensated by the receiver cable equaliser.

With really inferior return loss figures, shorter cables lengths may prevent the link from working due to the small attenuation of reflections of the short cable. Adding a few tens of metres to the cable length may in fact allow the link to work normally.

5.3 Jitter

There are several types of jitter:

- Timing jitter: fast changes related to an ideal time reference.
- Alignment jitter/relative jitter: changes related to a reference derived from the signal itself.
- Absolute jitter: fast and slow changes related to an ideal time reference.
- Wander/drift: slow changes (<10 Hz) related to an ideal time reference.

ITU-R BT.1363 and SMPTE RP 184 define Timing and Alignment Jitter for SDTV and HDTV signals, but there is no specification for Wander.

SMPTE RP 192 sets out the jitter measurement procedures to be followed in Bit-Serial Digital Interfaces:

1. Oscilloscope measurements to a stable external time reference.
2. Oscilloscope measurement to a time reference that is extracted from the video signal.
3. Spectral display of the jitter extracted from the video signal.
4. Spectral display of the phase difference from the jitter extracted from the video signal and to a high stable reference.

Table 2 lists the pertinent standards that define permissible values for jitter in SDI systems used at different data rates.

Table 2: Jitter specifications

SD	**Standard:**	**ITU-R BT.656**	**SMPTE ST 259**
	Timing Jitter:	< 0.2 UIpp [> 10 Hz]	< 0.2 UIpp [> 10 Hz]
	Alignment Jitter:	< 0.2 UIpp[1 kHz - 27 MHz]	< 02 UIpp[1 kHz – 27 MHz]
HD 1.485 Gbit/s	Standard:	**ITU-R BT.1120-6**	**SMPTE ST 292-1**
	Timing Jitter:	< 1 UIpp [10 Hz - 20 kHz]	< 1 UIpp [10 Hz – 20 kHz]
	Alignment Jitter:	< 0.2 UIpp [0.1 - 148.5 MHz]	< 0.2 UIpp [0.1 – 148.5 MHz]
HD 2.97 Gbit/s	Standard:	**ITU-R BT.1120-6**	**SMPTE ST 424**
	Timing Jitter:	< 1 UIpp [10 Hz - 20 kHz]	< 2 UIpp [10 Hz – 20 kHz]
	Alignment Jitter:	< 0.2 UIpp [0.1 – 297 MHz]	< 0.3 UIpp [0.1 – 297 MHz]

Jitter may cause a link to fail if it is outside the specifications set in ITU-R BT.1120. It has also been observed that HD-SDI equipment/systems can be sensitive to the type of synchronisation source used. For instance, (old) analogue Black-Burst reference signals are inferior to Tri-level sync or to a low jitter HD-SDI source.

5.4 Quality of an SDI input

The quality of a serial digital input is characterised by the following criteria:

- Design and dynamics of the input circuitry (impedance matching, frequency response and phase linearity)
- Cable equaliser design (equalizing circuit matching cable loss characteristics)
- Robust and jitter resilient clock recovery

Doubling the data rate from 1.5 Gbit/s to 3 Gbit/s has increased the difficulty of building workable equipment and systems:

At 3 Gbit/s the bits are about 7.5 cm long in a cable, and are about 5 cm long on a circuit board track, which means that all circuit interconnections must be treated as transmission lines!

At 3 Gbit/s, cable losses increase by 40%, connector discontinuities become twice as significant, the signal bandwidth doubles, the crosstalk potential increases and amplifier gain is harder to achieve at the higher bandwidth.

5.4.1 Dynamics of the input & robustness of clock recovery

The dynamics of the input and its robustness for clock recovery are measured by using a particular stress signal called the SDI check field. The SDI check field is defined in SMPTE RP 198 and consists of two parts.

The upper part of the image creates data words with long runs of zeros in the serial data stream. This results in a DC step in the SDI signal. Using an equaliser with insufficient dynamic could lead to image distortions.

The data words in the lower image of the check field provide only very few reference edges for the clock recovery. Insufficient design of the input PLL will result in image distortions.

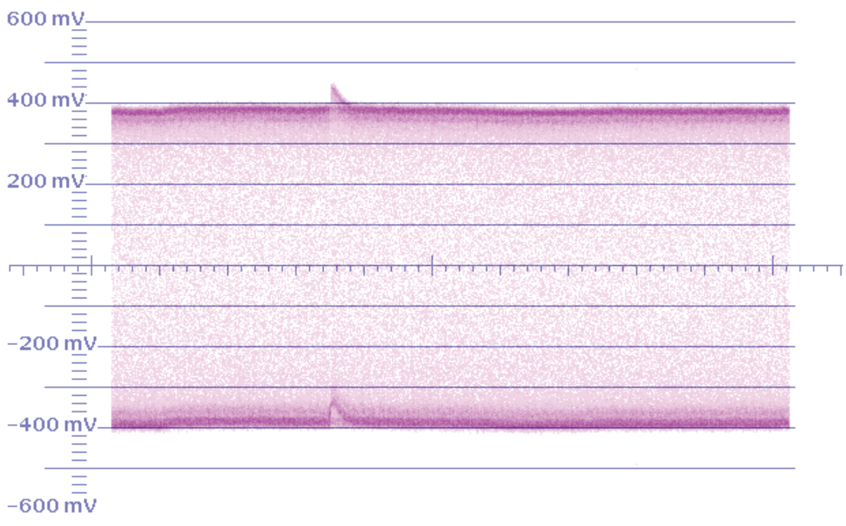

Figure 3: Visualisation of the difference of the dc part using a pathological HD-SDI signal

The above-described image distortions can be used for a fast diagnosis on a simple HD SDI capable monitor. For a more precise analysis CRC error measurement can be applied.

According to ITU-R BT.1120 Part 2 and to SMPTE ST 424:2006, output amplitude excursions due to signals with a significant dc component occurring for a horizontal line (pathological signals) shall not exceed 50 mV above or below the average *peak-peak* signal envelope.

5.4.2 Cable length & Equalisation

ITU-R BT.1120-7 requires the transmission loss to be ≤ 30 dB at ½ clock frequency for 2.97 Gbit/s operation. The current generation cable equalizers are capable of 35 to 40 dB gain at this frequency.

By planning installations with regard to the overall link losses such as cable loss (has a $\sqrt{f}$ characteristic) and losses through connectors, patch panels etc. not to exceed the recommended values of 30 dB at 3 Gbit/s, there should be sufficient safety margin to ensure reliable operation

Coaxial cable has signal losses that increase with frequency, much like a low pass filter. Some of the losses are due to the resistance of the wire and to skin effect, while other losses are caused by dielectric absorption in the insulation. The loss curve is approximated by the following formula where L is the loss in dB per unit of cable length:

$$L = A + C_f + B\sqrt{f}$$

Where “f” is frequency and A, B and C are constants that depend upon the type of cable and unit length.

In many cases, the A and C components are ignored, resulting in the common approximation of cable losses being proportional to the square root of the frequency.

This means, if the frequency is multiplied by four, the attenuation of the cable, expressed in dB, doubles. This can be a good rule of thumb, but the other terms are still a part of the losses and may be important.

To enable proper recovery of the serial data, a system (from the transmitter to detector), must have a frequency response that is nearly flat to at least half the clock rate. It is also important that the roll-off be reasonably gentle out to three times the clock rate.

Belden 1694A cable, for example, is specified to have a frequency dependent insertion loss of 26 dB per 100 m at 1.5 GHz. This amount of loss requires equalisation in order for the cable to work successfully for serial digital video.

Since the length of a cable is not always predictable, adaptive equalisers have become a practical solution. They will automatically adjust the equalisation to match the apparent cable losses, up to a specified equalisation limit.

Circuit boards also have losses that increase as the frequency increases. These losses are usually much greater per metre than coax cable, but the PCB track lengths are usually short. It must nevertheless be remembered that circuit board materials and the geometry of circuit board signal paths will have an effect on the final signal quality.

As tracks become longer on PCBs, the losses increase, and equalisation may become necessary on the internal connections. Some ICs have built-in equalisation capability with fixed settings, but they may not be optimum for a given path. As a general rule, backplane interconnect lengths should be kept to a minimum.

5.5 Cable Distance Considerations

SMPTE ST 292 and SMPTE ST 424 require the input cable length to be specified by the manufacturer of the receiver.

For example, the maximum cable lengths listed by Belden are for a 20dB equaliser in the receiver. In real systems, this distance will increase or decrease depending upon the receiver characteristics. If a better receiver is available, the maximum cable lengths will be greater.

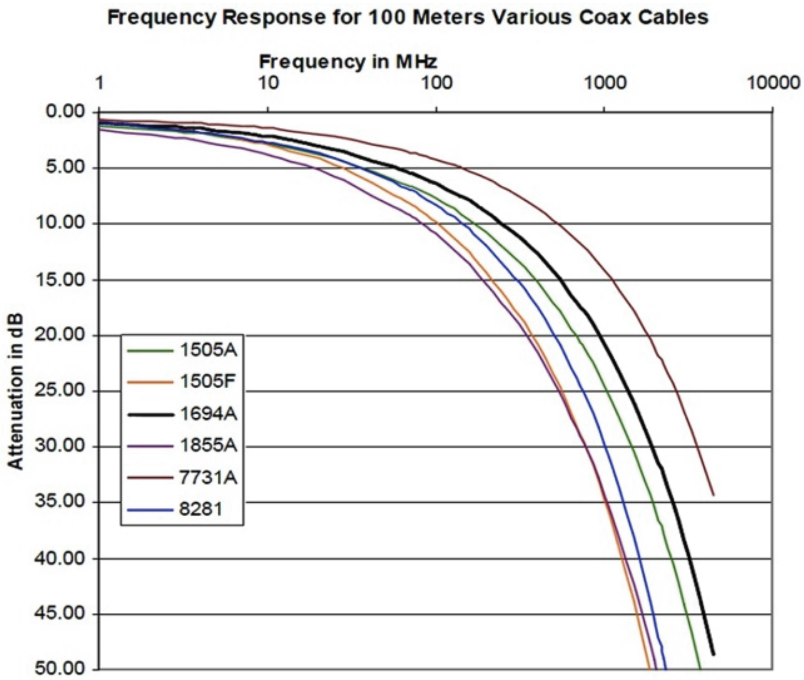

Figure 4: Comparison of frequency response for 100m of various coaxial cables

In general, a physically smaller coax cable will have higher losses, resulting in a shorter maximum distance. Belden 1505F, the more flexible version of 1505A, has about 43% more loss than regular 1505A.

This gives 1505F about the same losses as the physically smaller 1855A up to 1.5 GHz, and greater losses above 1.5 GHz.

5.6 Connectors

According to the interface standards the return loss must be better than -15 dB; this means for the cable/connector loss not to influence this figure the return loss for the cable/connector must ideally be below -15 dB. Not all combinations fulfil this requirement.

5.7 Cable Measurement Examples (measurements by NRK)

Measurements of transmission loss for 100 m lengths cable were made and a parameter called SRL (Structural Return Loss) was determined. SRL is a measure of how "good" the cable is along its entire length (how the RL varies along the cable with frequency). It highlights the evenness in the manufacturing process and shows if the cable has been subject to excessive mechanical stresses.

All measurements were performed with a HP 8714ET RF Network Analyser with an SRL and Fault Analysis option installed.

Before every measurement session the analyser was calibrated with the aid of an HP 85036B Calibration Kit to ensure consistency of the results.

Some connectors are listed several times in Table 3; this is to see if there is a spread between examples and in the way the connector is crimped on the cable. Some figures in brackets () show if there are differences if the cables are connected to the test instrument in the reverse direction. All connector RL figures are measured with a short, typically 2 m, cable.

The Belden 1694 cable is NRK's reference cable. It has mechanical dimensions of 1.0/4.8 (diameter of inner conductor/outer conductor). It is rather stiff and not very suitable for use inside equipment racks but the transmission loss is low and it passes 3G-SDI signals over more than 100 m (a longer continuous length of Belden 1694 must ideally be acquired to find out where transmission of 3G-SDI breaks down). The thinner Belden cables (0.6/2.8) pass 1.5G-SDI signals for more than 100 m and 3G-SDI signals for more than 75 m (but less than 100 m).

5.8 Practical Cable Installation guidelines

Ladder trays reduce "cable sag" and minimise signal reflections that can increase losses.

The use of Velcro® strips instead of tie-wraps minimise distortions in the dielectric (changing the internal dimensions of the coaxial cable) that affect return loss performance.

Maximum cable run lengths depend on many factors so planning using the guidance given above is vital (§ 5.4.2)

Monitoring the consistency and quality of cable cutting and stripping where connectors are attached is vital.

Patch panels are best avoided but where they are required, the connector quality e.g. spring tension, must be considered.

The long-term performance of jackfields must be monitored.

The choice between fibre and copper is a quality and consistency issue and not just a cost and cable length decision.

Table 3: Results of Measurements performed by NRK on various Cables & Connectors

Transm. loss(dB)/100m	Belden 1694	Belden 1505	Belden 1855	Draka 0.6/2.8	Draka 1.0/4.8	Bedea 0.6/2.8	NEK 0.6/2.8	Draka HD Pro; 1.0/4.8
@ 742.5MHz	-17.67	-22.09	-27.9	-30.05	-19.35	-30.73	-28.96	-18.7
@ 1485MHz	-25.11	-31.36	-39.73	-42.94	-27.82	-43.85	-41.17	-26.7
@ 2970MHz	-36.2	-45.32	-57.62	-62.55	-40.35	-63.6	-58.93	-38.4
Structural return Loss (SLR)	-29.12	-29.44	-28.23	-28.08	-28.57	-14.9	-35.05	-29.4
Connector impedance matching (RL in dB)								
/Amphenol 1	-33.38							
/Amphenol 2	-34.53							
/Canare 1	-29.65							
/Canare 2	-30.28							
/D&H (1)	-19.86							(D&H 1-6054) -25.0
/D&H (2)	-20.56	-30.28	-26.21					(D&H 1-6054) -25.9
/D&H 1 (1)		-30.28	-26.21					(D&H 1-6054) -26.1
/D&H 1 (2)		-30.4	-28.64					(D&H 1-6054) -25.7
/D&H 2 (1)		-32.56	-27.28					
/D&H 2 (2)		-32.05	-27.25					
/D&H II (1)	-20.94							
/D&H II (2)	-19.8							
/Neutrik 1	-31.26							
/Neutrik 2	-29.01							
/Suhner 1		-29.4			-33.4			
/Telegartner 1	-29.81							
/Telegartner 2	-30.67							
/Suhner				-34.4				
/D&H 1-6769				30				

Annex A: Level A

A1.1 Overview

Level A specifies the direct mapping of various television, Cinematography and Digital Cinema Distribution Master (DCDM) signals along with the carriage of embedded audio, ancillary data and the payload ID, in a serial digital interface operating at a nominal rate of 3 Gbit/s.

A1.2 Mapping

Level A establishes four different mapping structures for the carriage of full HD signals (4:2:2 or 4:4:4 with 10-bit or 12-bit resolution), at up to 60 progressive frames per second, over the nominal 3 Gbit/s SDI. These include the HD rasters of 1920 x 1080 and 1280 x 720, the 2k Cinematography raster of 2048 x 1080, as shown in the table below.

Table A1a:
(SMPTE ST 425-1:2011) Source Image Formats supported by Level A mapping

Mapping Structure	Reference SMPTE Standard	Image Format	Signal Format Sampling Structure/Pixel Depth	Frame/Field Rates	Transport
1	SMPTE ST 274	1920 × 1080	4:2:2 ($Y'C'_BC'_R$)/10-bit	60, 60/1.001 and 50 Frames Progressive	Progressive
	SMPTE ST 2048-2	2048 x 1080	4:2:2 ($Y'C'_BC'_R$)/10-bit	60, 60/1.001, 50, 48 and 48/1.001 Frames Progressive	Progressive
2	SMPTE ST 296	1280 x 720	4:4:4 (R'G'B'), 4:4:4:4 (R'G'B' +A)/10-bit 4:4:4 ($Y'C'_BC'_R$), 4:4:4:4 ($Y'C'_BC'_R$+A)/10-bit	60, 60/1.001 and 50 Frames Progressive	Progressive
				30, 30/1.001, 25, 24 and 24/1.001 Frames Progressive	Progressive
	SMPTE ST 274	1920 x 1080	4:4:4 (R'G'B'), 4:4:4:4 (R'G'B' +A)/10-bit 4:4:4 ($Y'C'_BC'_R$), 4:4:4:4 ($Y'C'_BC'_R$+A)/10-bit	60, 60/1.001 and 50 Fields Interlaced	Interlaced
				30, 30/1.001, 25, 24 and 24/1.001 Frames Progressive	Progressive
				30, 30/1.001, 25, 24 and 24/1.001 PsF	PsF
	SMPTE ST 2048-2	2048 x 1080*6	4:4:4 (R'G'B'), 4:4:4:4 (R'G'B' +A)/10-bit 4:4:4 ($Y'C'_BC'_R$), 4:4:4:4 ($Y'C'_BC'_R$+A)/10-bit	30, 30/1.001, 25, 24 and 24/1.001 Frames Progressive	Progressive
				30, 30/1.001, 25, 24 and 24/1.001 PsF	PsF
3	SMPTE ST 274	1920 x 1080	4:4:4 (R'G'B')/12-bit 4:4:4 ($Y'C'_BC'_R$)/12-bit	60, 60/1.001 and 50 Fields Interlaced	Interlaced
				30, 30/1.001, 25, 24 and 24/1.001 Frames Progressive	Progressive
	SMPTE ST 2048-2	2048 x 1080	4:4:4 (R'G'B')/12-bit 4:4:4 (Y'C'BC'R)/12-bit	30, 30/1.001, 25, 24 and 24/1.001 Frames Progressive	Progressive
				30, 30/1.001, 25, 24 and 24/1.001 Frames PsF	PsF
	SMPTE ST 428-9	2048 x 1080	4:4:4 (*X'Y'Z'*)/12-bit	24 Frames Progressive	Progressive

Mapping Structure	Reference SMPTE Standard	Image Format	Signal Format Sampling Structure/Pixel Depth	Frame/Field Rates	Transport
				24 Frames PsF	PsF
	SMPTE ST 428-19	2048 x 1080	4:4:4 (*X'Y'Z'*)/12-bit	25 and 30Frames Progressive	Progressive
				25 and 30Frames PsF	PsF
4	SMPTE ST 274	1920 x 1080	4:2:2 ($Y'C'_BC'_R$)/12-bit	60, 60/1.001 and 50 Fields Interlaced	Interlaced
				30, 30/1.001, 25, 24 and 24/1.001 Frames Progressive	Progressive
				30, 30/1.001, 25, 24 and 24/1.001 Frames PsF	PsF
	SMPTE ST 2048-2	2048 x 1080	4:2:2 ($Y'C'_BC'_R$)/12-bit	30, 30/1.001, 25, 24 and 24/1.001 Frames Progressive	Progressive
			4:2:2:4 ($Y'C'_BC'_R$+A)/12-bit	30, 30/1.001, 25, 24 and 24/1.001 Frames PsF	PsF

Table A1b:
(SMPTE ST 425-1:2011): Locations of the First and Last Active Samples for 4:2:2 (Y'C'BC'R)/10-bit Signals at 60, 60/1.001, 50, 48 and 48/1.001 Progressive Frame/s

Reference SMPTE Standard	Frame Rate	First Active sample number	Last Y' active sample number	Last C'B/C'R active sample number	Last Y' sample number '2n+1' (total line)	Last C'B/C'R sample number 'n' (total line)
SMPTE ST 274 system 1 and 2	60 or 60/1.001	0	1919	959	2199	1099
SMPTE ST 274 system 3	50	0	1919	959	2639	1319
SMPTE ST 2048-2 system 1 and 2	60 or 60/1.001	0	2047	1023	2199	1099
SMPTE ST 2048-2 system 3	50	0	2047	1023	2639	1319
SMPTE ST 2048-2 system 4 and 5	48 or 48/1.001	0	2047	1023	2749	1374

A1.3 Virtual Interface

The 3G-SDI standard describes a 20-bit Virtual Interface consisting of two data streams — data stream one and data stream two.

Data stream one is analogous to the 1.5G-SDI Y channel and Data stream two is analogous to the 1.5G-SDI C channel.

Each data stream describes a 10-bit virtual interface operating at a nominal rate of 148.5 MHz or 148.5/1.001 MHz, containing timing reference code words (SAV/EAV); line numbers; line based CRCs; payload ID and optional ANC data such as audio data etc.

ANC data insertion follows the same conventions adopted for the 1.5 Gbit/s interface as defined SMPTE ST 292 and ST 291. For HANC data, data stream two (the C data channel), is the preferred channel for general HANC data with data stream one (the Y data channel), being reserved for specialised ANC data such as audio control packets and timecode etc.

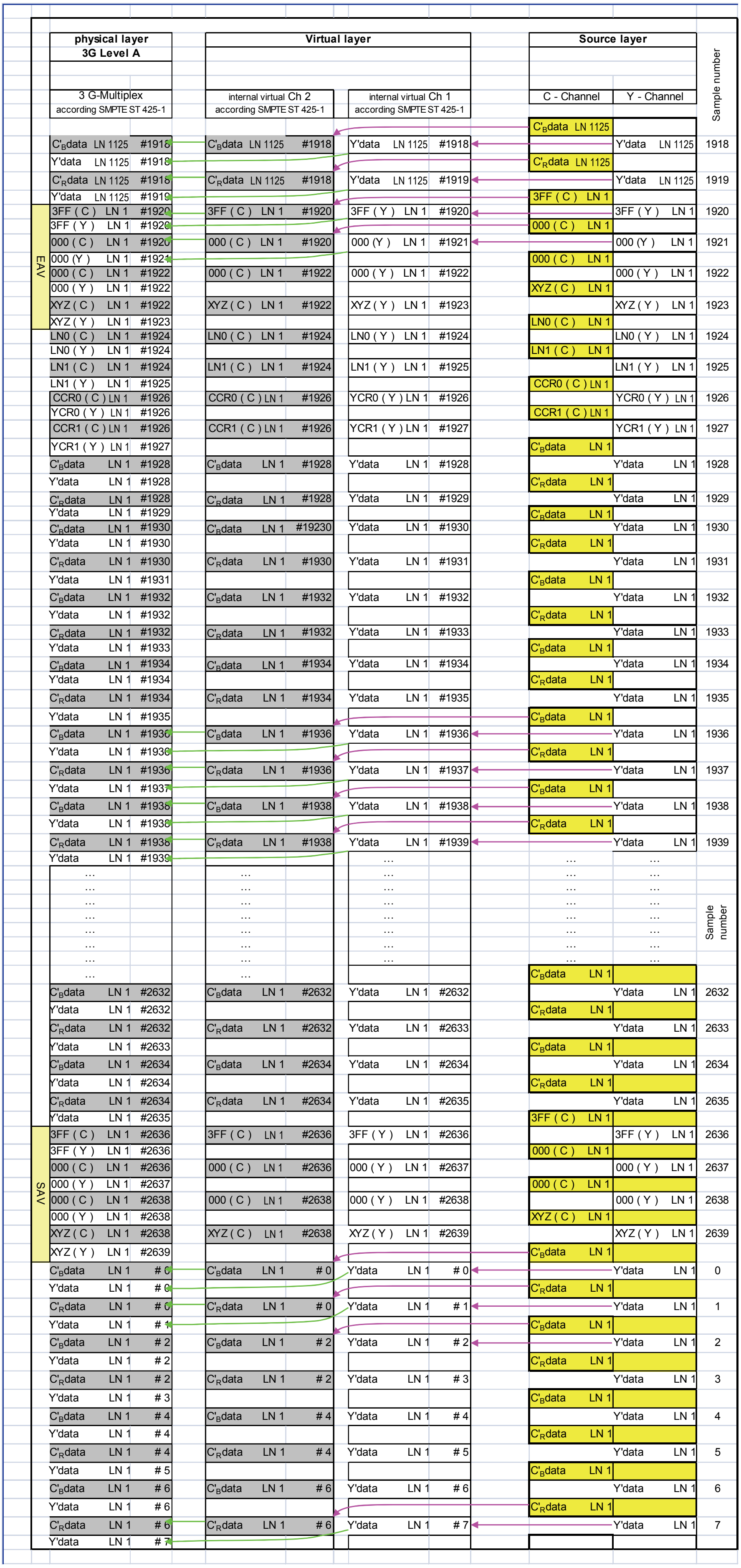

Figure A1: Level A Multiplex Structure

Unless otherwise stated, the ancillary data in VANC or HANC is mapped into data stream one first.

In the Level A mapping, data-stream one and data-stream two are multiplexed as shown in Figure A1, above.

The four different mapping structures identified in Table A1 describe the specific mapping of the video data into the active line of the virtual interface.

For $Y'C'_BC'_R$ 4:2:2 10-bit formats, the Y and C components of the active pixels are distributed into data stream one and data stream two to produce the same mapping of the Y and C components as defined for the 1.5G-SDI interface (see SMPTE ST 292-1).

For $Y'C'_BC'_R$ 4:2:2 12-bit formats, and all 4:4:4 and 4:4:4:4 formats the active pixels are distributed across data stream one and data stream two of the virtual interface in a manner that breaks up pathological code sequences.

Note: The distribution of pixels across the virtual interface for Level A is different to the distribution employed in Level B-DL.

A1.4 Alpha Channel

An auxiliary component signal (Alpha channel) may optionally accompany the R'G'B', R'FSG'FSB'FS (hereafter R'G'B' indicates both R'G'B' and R'FSG'FSB'FS) or Y'C'BC'R video signal. If present it must have the same characteristics as the Y' or G' channel as defined for the source image formatting interface. Interfaces containing the auxiliary component are denoted as R'G'B'+A and Y'C'BC'R +A.

A1.5 Audio

Up to 32 audio channels sampled at 32 kHz, 44.1 kHz or 48 kHz (16-bit samples at 96 kHz sampling) may be mapped into the horizontal ancillary data space of data stream one and data stream two of the virtual interface. SMPTE ST 299-1:2009 defines the mapping of 16 embedded audio channels and SMPTE ST 299-2:2010 describes the mapping of an additional 16 embedded audio channels.

The maximum number of audio channels that can be mapped into the available horizontal ancillary data space varies in accordance with the video format and the video frame rate.

Table A2:
(SMPTE ST 425-1:2011): Maximum number of audio channels in horizontal ancillary data space

Image Format	Frame/Field Rates	Max. number of audio channels:	
		32 kHz, 44.1 kHz or 48 kHz sampling	96 kHz sampling
1920 x 1080	60, 60/1.001 and 50 Frames Progressive	Up to 32 channels	Up to 16 channels
	60, 60/1.001 and 50 Fields Interlaced		
	30, 30/1.001, 25, 24 and 24/1.001 Frames Progressive		
SMPTE ST 2048-2 2048 x 1080	60, 60/1.001, 30 and 30/1.001, Frames Progressive, 30 and 30/1.001 PsF	Up to 16 channels	Up to 8 channels
	50, 48, 48/1.001, 25, 24 and 24/1.001 Frames Progressive, 25, 24 and 24/1.001 PsF	Up to 32 channels	Up to 16 channels
SMPTE ST 428-9 2048 x 1080	24 Frames Progressive and 24 Frames PsF	Up to 32 channels	Up to 16 channels
SMPTE ST 428-19 2048 x 1080	30 Frames Progressive and 30 Frames PsF	Up to 16 channels	Up to 8 channels
	25 Frames Progressive and 25 Frames PsF	Up to 32 channels	Up to 16 channels
1280 x 720	60, 60/1.001 and 50 Frames Progressive	Up to 32 channels	Up to 16 channels
	30, 30/1.001, 25, 24 and 24/1.001 Frames Progressive		

When the number of audio channels at up to 48 kHz sampling rate is less than or equal to 16, audio control packets mapped into data stream one and audio data packets mapped into data stream two shall use the DIDs for audio groups 1 to 4.

A1.6 Payload ID

The payload ID is inserted into both data stream one and two of the virtual interface to identify the video format payload and interface (SMPTE ST 352).

Annex B: Level B-DL (Dual-Link)

B1.1 Overview

Level B-DL specifies the Dual-Link mapping of various television, Cinematography and Digital Cinema Distribution Master (DCDM) signals along with the carriage of embedded audio, ancillary data and the payload ID, in a serial digital interface operating at a nominal rate of 3 Gbit/s.

Table B1:
(SMPTE ST 425-1:2011): Source image formats supported by Level B-DL mapping

Mapping Structure	Ref. SMPTE Standard	Image Format	Signal Format Sampling Structure/Pixel Depth	Frame/Field Rates	Transport
§5.1	SMPTE ST 274	1920 x 1080	4:2:2 (Y'C'BC'R)/10-bit	60, 60/1.001 and 50 Frames Progressive	Interlaced
	SMPTE ST 2048-2	2048 x 1080	4:2:2 (Y'C'BC'R)/10-bit	60, 60/1.001, 50, 48 and 48/1.001 Progressive	Interlaced
§5.2, §5.4	SMPTE ST 274	1920 x 1080	4:4:4 (R'G'B'), 4:4:4:4 (R'G'B' +A)/10-bit 4:4:4 (Y'C'BC'R), 4:4:4:4 (Y'C'BC'R+A)/10-bit	60, 60/1.001 and 50 Fields Interlaced	Interlaced
				30, 30/1.001, 25, 24 and 24/1.001 Frames Progressive	Progressive
				30, 30/1.001, 25, 24 and 24/1.001 PsF	PsF
	SMPTE ST 2048-2	2048 x 1080	4:4:4 (R'G'B'), 4:4:4:4 (R'G'B' +A) /10-bit	30, 30/1.001, 25, 24 and 24/1.001 Progressive	Progressive
			4:4:4 (Y'C'BC'R), 4:4:4:4 (Y'C'BC'R+A) /10-bit	30, 30/1.001, 25, 24 and 24/1.001 PsF	PsF
§5.3, §5.4	SMPTE ST 274	1920 x 1080	4:4:4 (R'G'B')/12-bit 4:4:4 (Y'C'BC'R)/12-bit	60, 60/1.001 and 50 Fields Interlaced	Interlaced
				30, 30/1.001, 25, 24 and 24/1.001 Frames Progressive	Progressive
	SMPTE ST 2048-2	2048 x 1080*6	4:4:4 (R'G'B')/12-bit	30, 30/1.001, 25, 24 and 24/1.001 Progressive	Progressive
			4:4:4 (Y'C'BC'R)/12-bit	30, 30/1.001, 25, 24 and 24/1.001 PsF	PsF
	SMPTE ST 428-9	2048 x 1080	4:4:4 (X'Y'Z')/12-bit	24 Frames Progressive	Progressive
				24 Frames PsF	PsF
	SMPTE ST 428-19	2048 x 1080	4:4:4 (X'Y'Z')/12-bit	25 and 30Frames Progressive	Progressive
				25 and 30Frames PsF	PsF
§5.5	SMPTE ST 274	1920 x 1080	4:2:2 (Y'C'BC'R)/12-bit	60, 60/1.001 and 50 Fields Interlaced	Interlaced
				30, 30/1.001, 25, 24 and 24/1.001 Frames Progressive	Progressive
				30, 30/1.001, 25, 24 and 24/1.001 Frames PsF	PsF
	SMPTE ST 2048-2	2048 x 1080 *6	4:2:2 (Y'C'BC'R)/12-bit, 4:2:2:4 (Y'C'BC'R)/12-bit + A	30, 30/1.001, 25, 24 and 24/1.001 Progressive	Progressive
				30, 30/1.001, 25, 24 and 24/1.001 PsF	PsF

B1.2 Mapping

Level B-DL establishes 4 different mapping structures for the carriage of full HD signals (4:2:2 or 4:4:4 with 10-bit or 12-bits), at up to 60 progressive frames per second, over the nominal 3 Gbit/s SDI. These include the HD raster of 1920 x 1080, the 2k Cinematography raster of 2048 x 1080 and the DCDM raster of 2048 x 1080 as shown in Table B1.

B1.3 Virtual Interface

The 3G-SDI standard describes two 10-bit Virtual Interfaces- data stream one (Link A) and data stream two (Link B).

The Level B-DL interface (Link A and Link B) is based upon the HD-SDI data structure and has the same mapping structure defined in the dual link standard (SMPTE ST 372).

Each link describes a 10-bit virtual interface operating at a nominal rate of 148.5 MHz (or 148.5/1.001 MHz), containing timing reference code words (SAV/EAV), line numbers (SMPTE ST 372),line based CRCs (SMPTE ST 292-1), payload ID and optional ANC data such as audio data etc.

ANC data insertion follows the same conventions adopted for the 1.5 Gbit/s interface. For HANC data, the C data channel, of each Link A and Link B interface is the preferred channel for general HANC data with the Y data channel, being reserved for specialised ANC data such as audio control packets and timecode etc.

ANC data is mapped onto link A first; any remaining data is then mapped onto link B.

Link A and Link B of the virtual interface are multiplexed word-by-word into a single 10-bit parallel stream as shown in Figure B1.

The 4 different mapping structures identified in Table B1 describe the specific mapping of the video data into the active lines of the virtual interface.

For Y'C'BC'R 4:2:2 10-bit formats, the active pixels are distributed line-by-line into two data streams (i.e. Link A, Link B) that produce the same data structure of the 1.5G-SDI interface (SMPTE ST 292-1).

For Y'C'BC'R 4:2:2 12-bit formats, and all 4:4:4 and 4:4:4:4 formats the active pixels are distributed across Link A and Link B of the virtual interface in a manner that assigns 422 signal to Link A.

Mapping into Link A and Link B is defined in the Dual Link standard (SMPTE ST 372).

B1.4 Alpha Channel

An auxiliary component signal (Alpha channel) may accompany the R'G'B', R'FS G'FS B'FS or Y'C'BC'R video signal. If present it has the same characteristics as the Y' or G' channel as defined for the source image formatting interface. Interfaces containing the auxiliary component are denoted as R'G'B' +A and Y'C'BC'R +A.

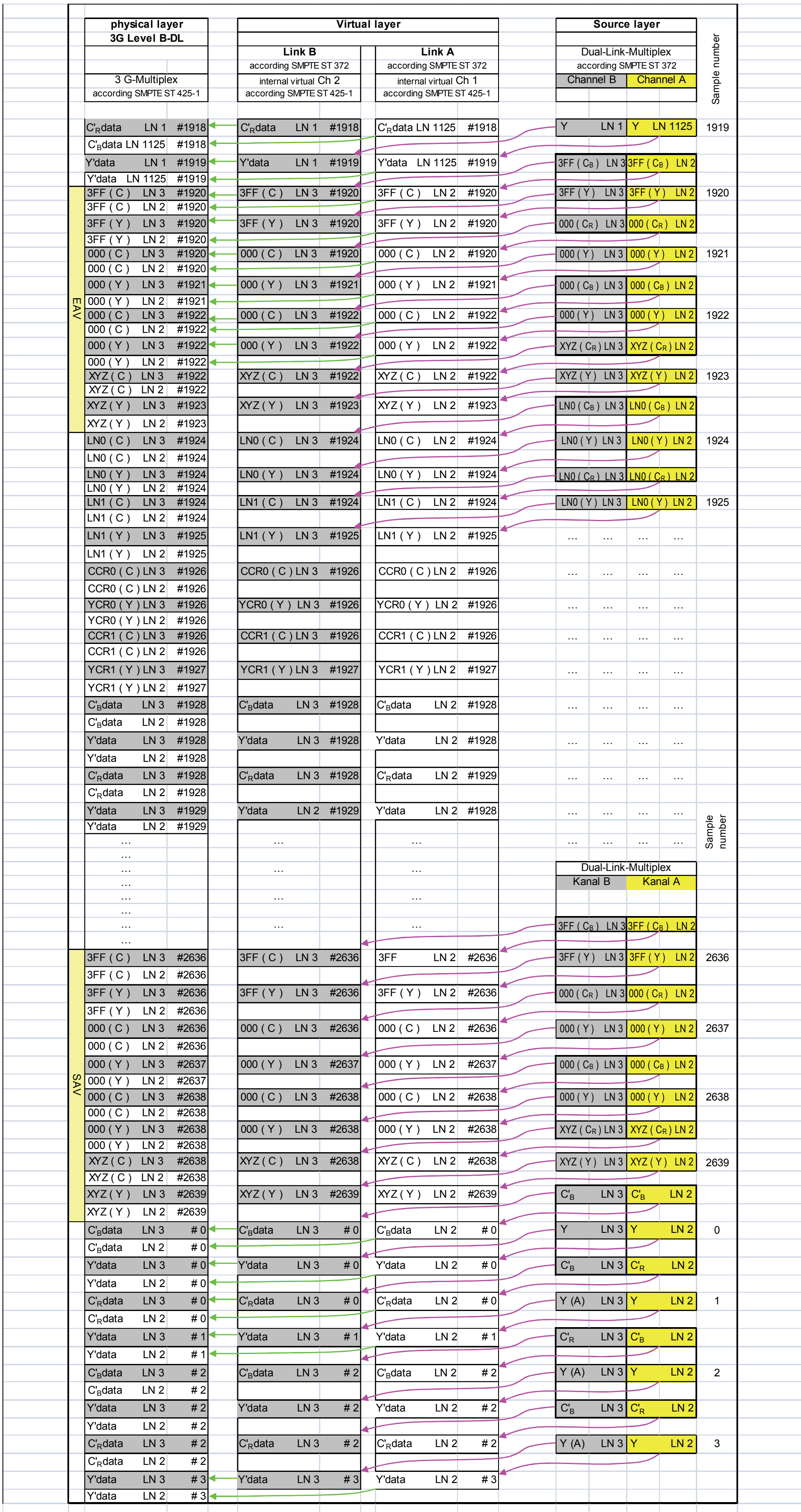

Figure B1: Link A / Link B Mapping

B1.5 Audio

Up to 32 audio channels sampled at 32 kHz, 44.1 kHz or 48 kHz (16 channels at 96 kHz sampling) may be carried in total.

Up to 16 audio channels sampled at may be mapped into the horizontal ancillary data space of the C multiplex of each of the two Links, Link A and Link B, which are transported via data stream one and data stream two of the virtual interface respectively. The 1.5G-SDI standard (SMPTE ST 299-1:2009) defines the mapping of the 16 embedded audio channels into each link.

The maximum number of audio channels that can be mapped into the available horizontal ancillary data space varies in accordance with the video format and the video frame rate.

Table B2:
(SMPTE ST 425-1:2011): Maximum number of audio channels in horizontal ancillary data space

Image Format	Frame/Field Rates	Max. number of audio channels:	
		32 kHz, 44.1 kHz or 48 kHz sampling	96 kHz sampling
1920 x 1080	60, 60/1.001 and 50 Frames Progressive	Up to 32 channels	Up to 16 channels
	60, 60/1.001 and 50 Fields Interlaced		
	30, 30/1.001, 25, 24 and 24/1.001 Frames Progressive		
SMPTE ST 2048-2 2048 x 1080	60, 60/1.001, 30 and 30/1.001, Frames Progressive, 30 and 30/1.001 PsF	Up to 16 channels	Up to 8 channels
	50, 48, 48/1.001, 25, 24 and 24/1.001 Frames Progressive, 25, 24 and 24/1.001 PsF	Up to 32 channels	Up to 16 channels
SMPTE ST 428-9 2048 x 1080	24 Frames Progressive and 24 Frames PsF	Up to 32 channels	Up to 16 channels
SMPTE ST 428-19 2048 x 1080	30 Frames Progressive and 30 Frames PsF	Up to 16 channels	Up to 8 channels
	25 Frames Progressive and 25 Frames PsF	Up to 32 channels	Up to 16 channels
1280 x 720	60, 60/1.001 and 50 Frames Progressive	Up to 32 channels	Up to 16 channels
	30, 30/1.001, 25, 24 and 24/1.001 Frames Progressive		

B1.6 Payload ID

The payload ID is inserted into Link A and Link B to identify the video format payload and interface.

The channel assignment in bit b6 of byte 4 is set to ‘0’ for Link A and to ‘1’for Link B.

Annex C: Level B-DS (Dual Stream)

C1.1 Overview

Level B-DS specifies the Dual Stream mapping of various television and cinematography signals along with the carriage of embedded audio, ancillary data and the payload ID, in a serial digital interface operating at a nominal rate of 3 Gbit/s.

C1.2 Mapping

Level B-DS provides a mapping structure for the carriage of two bit synchronised 1.5G-SDI compliant interfaces over the nominal 3 Gbit/s SDI. Any two formats supported by 1.5G-SDI interface may be carried on the 3 Gbit/s SDI, as long as they have the same vertical line structure and frame rate.

These include the HD rasters of 1920 x 1080, 1280 x 720 and the 2k cinematography raster of 2048 x 1080 that can be transported through Single-link 1.5G-SDI as shown in Table C1 below.

Note: SMPTE ST 348 (High Data-Rate Serial Data Transport Interface (HD-SDTI) and SMPTE ST 349 (Transport of Alternate Source Image Formats through SMPTE ST 292-1) can also be applied to the Level B-DS mapping mode.

Table C1: Source image formats supported carried by SMPTE ST 292-1

Mapping Structure	Image Format	Signal Format Sampling Structure/Pixel Depth	Frame/Field Rates	Transport
SMPTE ST 274	1920 x 1080	4:2:2 (Y'C'BC'R)/10-bit	60, 60/1.001 and 50 Fields Interlaced	Interlaced
			30, 30/1.001, 25, 24 and 24/1.001 Frames Progressive	Progressive
			30, 30/1.001, 25, 24 and 24/1.001 PsF	PsF
SMPTE ST 2048-2	2048 x 1080	4:2:2 (Y’C’BC’R)/10-bit	60, 60/1.001 and 50 Fields Interlaced	Interlaced
			30, 30/1.001, 25, 24 and 24/1.001 Progressive	Progressive
			30, 30/1.001, 25, 24 and 24/1.001 PsF	PsF
SMPTE ST 296	1280 x 720	4:2:2 (Y'C'BC'R)/10-bit	60, 60/1.001, 50, 30, 30/1.001, 25, 24 and 24/1.001 Frames Progressive	Progressive

C1.3 Virtual Interface

Two 1.5 Gbit/s parallel, 10-bit interfaces of the same line and frame structure, are mapped into data stream one and data stream two of the 20-bit virtual interface defined in the 3G-SDI standard.

The 10-bit virtual interfaces contain timing reference code words (SAV/EAV), line numbers, line based CRCs (see SMPTE ST 292-1), payload ID and optional ANC data such as audio data etc.

Each 10-bit virtual interface is line and word aligned, having an interface frequency of 148.5 MHz or 148.5/1.001 MHz as shown in Figure C1. It should be noted that if the two streams are not frame aligned, video switching could be adversely affected.

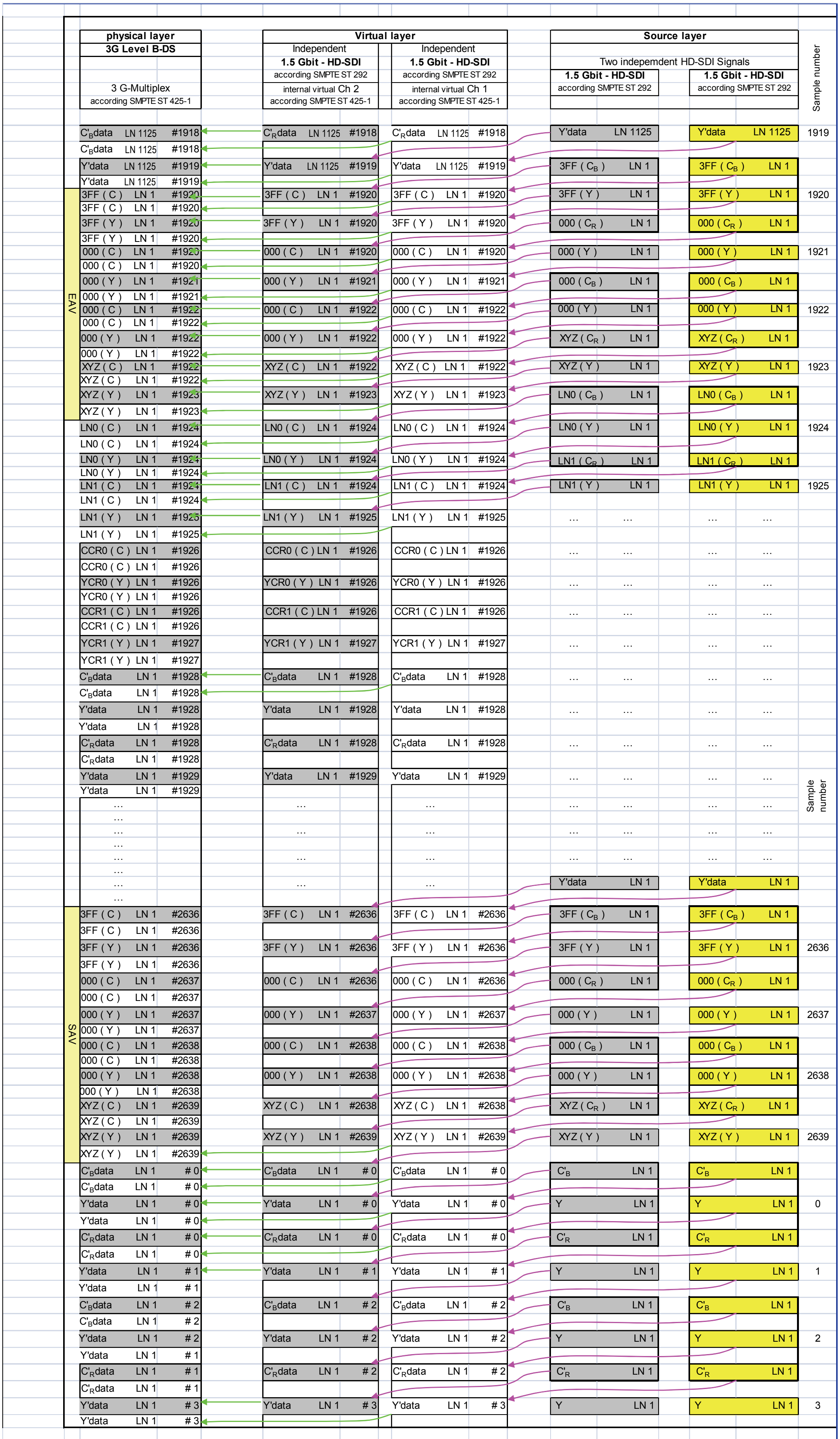

Figure C1: Dual Stream Mapping

The source data for each 10-bit virtual interface may be packetized data, or an uncompressed video source.

C1.4 Alpha Channel

There is no alpha channel on 1.5G-SDI and therefore an alpha channel is not available to Level B-DS mapping

C1.5 Audio

Two streams of up to 16 audio channels sampled at 32 kHz, 44.1 kHz or 48 kHz (8 channels at 96 kHz sampling) may be carried in Level B-DS. Audio channels may be mapped into the horizontal ancillary data space of the C multiplex of each 1.5G-SDI stream, which are transported via data stream one and data stream two of the virtual interface respectively.

The 1.5G-SDI standard (SMPTE ST 299-1) defines the mapping of the 16 embedded audio channels into each stream

The maximum number of audio channels that can be mapped into the available horizontal ancillary data space varies in accordance with the video format and the video frame rate.

C1.6 Payload

The payload ID is inserted into data stream one and two to identify the video format payload and interface.

Annex D: Bibliography and Comparison Table

D1.1 Bibliography

ITU R BT-601 First published in 1982, it describes the exchange of standard definition signals via a serial digital interface now often described as SD-SDI

ITU R BT-709 First published in 1990, it describes the HD common image format of 1920 x 1080 and was the first international standard for the exchange of high-resolution imagery. This standard included the definition of full High Definition signals at 60 (59.94) and 50 progressive frames per second but it is only recently that practical implementation of these standards has become practicable

SMPTE ST 121:2008 Transmission of Time Code in the Ancillary Data Space

SMPTE ST 274:2008 1920 x 1080 Image Sample Structure, Digital Representation and Digital Timing Reference Sequences for Multiple Picture Rates

SMPTE ST 291:2006 Ancillary Data Packet and Space Formatting

SMPTE ST 292-1:2010 The 1.5 Gbit/s Signal/Data Serial Interface was originally developed to provide a serial digital connection between HDTV equipment operating largely with 10-bit Y'C'BC'R 4:2:2 signals to a maximum frame rate of 30 frames per second. Over time, SMPTE ST 292-1 applications were expanded to include larger picture formats, higher refresh rates and to provide support for R'G'B' and 12-bit source signal formats together with the carriage of packetized data

SMPTE ST 296:2001 1280 x 720 Progressive Image Sample Structure - Analogue and Digital Representation and Analogue Interface

SMPTE ST 299-1:2009 24-Bit Digital Audio Format for SMPTE ST 292-1 Bit-Serial Interface

SMPTE ST 299-2:2010 Extension of the 24-Bit Digital Audio Format to 3 Gbit/s Bit-Serial Interfaces.

SMPTE ST 348:2005 (Archived 2006) – High Data Rate Serial Data Transport Interface (HD-SDTI)

SMPTE ST 349:2001 (Archived 2006) – Transport of Alternate Source Image Formats through SMPTE ST 292-1M

SMPTE ST 352:2011 Video Payload Identification for Digital Interfaces

SMPTE ST 372:2011 Describes the use of twin 1.5 Gbit/s (SMPTE ST 292-1) links to transport a 3 Gbit/s signal, the original practice in studios for supporting 1920 × 1080 and 2048 × 1080 formats. Dual-link

connections require twice the number of cables as single-link connections, resulting in increased equipment cost and increased complexity within the studio facility

SMPTE ST 424-2006: 3 Gbit/s Signal/Data Serial Interface

SMPTE ST 425-1:2011 Describes the transmission of several image formats from 2048 x 1080 production format down to 720 line 4:4:4 over a single coaxial cable at 3 Gbit/s, eliminating some of the practical drawbacks of dual-link, especially for live events and outside broadcast installations

SMPTE ST 428-1:2006: D-Cinema Distribution Master — Image Characteristics

SMPTE ST 428-9:2008: D-Cinema Distribution Master — Image Pixel Structure Level 3 — Serial Digital Interface Signal Formatting

SMPTE ST 428-11:2009: Additional Frame Rates for D-Cinema

SMPTE ST 428-19:2010 D-Cinema – Serial Digital Interface signal formatting for Additional Frame Rates level AFR2 and level AFR4

SMPTE ST 2048-1:2011 2048 x 1080 Digital Cinematography Production Image FS/709 Formatting – for Serial Digital Interface

SMPTE ST 2051-2010 Two-Frame Marker for 50 Hz and 60(/1.001) Hz Progressive Digital Video Signals on 1.5 Gbit/s and 3 Gbit/s Interfaces

D1.2 Comparison of Standards Documents

Table D1: SMPTE and ITU Standards

<table>
<tr><th rowspan="2">Image Format</th><th rowspan="2">Level & Audio</th><th colspan="5">Ref. SMPTE Standard</th><th colspan="5">Ref. ITU-R Standard</th></tr>
<tr><th>Image</th><th>Audio</th><th>I/F (Map-ping)</th><th>ANC</th><th>PID</th><th>Image</th><th>Audio</th><th>I/F (Map-ping)</th><th>ANC</th><th>PID</th></tr>
<tr><td rowspan="3">1920 x 1080</td><td>A 16 ch.</td><td rowspan="3">ST 274</td><td>ST 299-1</td><td rowspan="9">ST 425-1</td><td rowspan="9">ST 291</td><td rowspan="9">ST 352</td><td rowspan="3">BT.709</td><td>BT.1365</td><td rowspan="3">BT.1120</td><td rowspan="6">BT.1364</td><td rowspan="2">BT.1614</td></tr>
<tr><td>A 32 ch.</td><td>ST 299-2</td><td>-</td></tr>
<tr><td>B 32 ch.</td><td>ST 299-1</td><td>BT.1365</td><td rowspan="7">-</td></tr>
<tr><td rowspan="3">1280 x 720</td><td>A 16 ch.</td><td rowspan="3">ST 296</td><td>ST 299-1</td><td rowspan="3">BT.1847</td><td rowspan="6">-</td><td rowspan="6">-</td></tr>
<tr><td>A 32 ch.</td><td>ST 299-2</td></tr>
<tr><td>B 32 ch.</td><td>ST 299-1</td></tr>
<tr><td rowspan="3">2048 x 1080</td><td>A 16 ch.</td><td rowspan="3">ST 2048-1</td><td>ST 299-1</td><td rowspan="3">-</td><td rowspan="3">-</td></tr>
<tr><td>A 32 ch.</td><td>ST 299-2</td></tr>
<tr><td>B 32 ch.</td><td>ST 299-1</td></tr>
</table>

Annex E: Glossary

3G HD-SDI	This is the SMPTE ST 424 implementation of a professional high-definition serial digital interface which expands upon SMPTE ST 259, SMPTE ST 344, and SMPTE ST 292 allowing for bit-rates of 2.970 Gbit/s over a single-link coaxial cable. 1080p HDTV signals can be accommodated
720p	Type of high-definition television (HDTV) image that is 720 vertical lines by 1280 horizontal pixels wide, displayed in progressive format. (It has a 16:9 aspect ratio and its frame rate varies depending on where it is used)
1080i	Type of high-definition television (HDTV) image that is 1080 vertical lines by 1920 horizontal pixels wide, displayed in an interlaced format. (It has a 16:9 aspect ratio and is used at 25 or 29.97 Hz frame rate, depending on where it is used.)
1080p	Type of high-definition television (HDTV) image that is 1080 vertical lines by 1920 horizontal pixels wide, displayed in a progressive format. (It has a 16:9 aspect ratio and is used at 50 or 59.94 Hz frame rate, depending on where it is used.)
Ancillary data	Data that represents anything but the video data in a serial data interface. The most significant ancillary data is audio, also termed embedded audio.
Bandwidth	A measure of the capacity of a circuit or channel -- the amount of information transferred between points within a specified time period.
BNC connector	Bayonet Neill-Concelman connector. This is a common type of hf/rf coaxial connector that is used extensively in the broadcasting industry for applications at frequencies up to 3 GHz. In SDI applications the 75Ω rather than the 50Ω version is used.
Coaxial cable	An asymmetrical cable consisting of a central conductor surrounded by a concentric tubular screen. An electrically insulating dielectric separates these two conductors. The characteristic impedance of the coax cable used for (HD) SDI is 75 Ω.
DCDM	Digital Cinema Distribution Master (SMPTE ST 428). This defines the characteristics of the image and audio to be used for Digital Cinema.
DID	Data Identifier
Dual Link HD-SDI	This is the SMPTE ST 372 implementation of a pair of (ST 292) links (1 & 2) operating in parallel to provide a 2.970 Gbit/s interface capable of sustaining a 1080p HDTV signal.
EBU	European Broadcasting Union. Founded in 1950 in Switzerland, it is a professional association of 75 Public Service Broadcasters in the European Broadcasting Area with 35 associate members around the world. It works closely with standards bodies to promote technologies that are of benefit to broadcasters.
Embedded audio	Audio that is embedded as ancillary data in the SDI family of interfaces.

HD-SDI	This is a standard published by the SMPTE (ST 292) which expands upon SMPTE ST 259 and SMPTE ST 344 allowing for bit-rates of 1.485 Gbit/s. These bit-rates are sufficient for and often used to transfer uncompressed High Definition video (720p, 1080i).
Interlaced scanning	A scanning technique in a video system where odd and even horizontal lines of a video frame are displayed during alternating update cycles. Lines 1, 3, 5, etc., are displayed during the first cycle, creating one field. Lines 2, 4, 6, etc., are displayed on the second cycle, creating the next field. Two fields combine to make one frame. This is effectively an obsolete technique.
ITU	International Telecommunications Union. A Treaty organisation founded in 1865 in France. It became a Special Agency of the United Nations in 1949. It produces international telecommunications standards.
NRK	NorskRikskringkasting AS, the Norwegian Broadcasting Corporation – a founding Member of the EBU.
Packetized data	This is data that is organised into discrete units (packets) of data that are processed individually. Communications protocols are used to transmit packets in the correct order so that the data they contain can be accessed as contiguous data at the reception point. Packetised data lends itself to multiplexing in interfaces such as the SDI family of interfaces.
PCB	Printed circuit board.
Progressive scanning	A picture-scanning process where all the lines of the image are scanned by every vertical scan. All modern flat panel displays employ progressive scanning.
Ps	Picosecond, 10-12s or 0.000000000001s. A unit frequently encountered in jitter measurements in SDI.
PsF	Progressive segmented Frame is a scheme designed to process progressive scan video using an interlaced transmission channel and media. With PsF a frame is divided into two segments with odd lines in one segment and even lines in the other. The crucial difference between this arrangement and interlaced scanning is that there is no motion between the two segments that make up the complete video frame; both fields (segments) represent the same instant in time. Frame rates of 24 and 25 Hz are common.
SDI	Serial digital interface (SDI) refers to a family of video interfaces standardised by the SMPTE and used for broadcast-grade standard definition video. Bitrates of up to 360 Mbit/s can be accommodated.
SMPTE	Society of Motion Picture and Television Engineers. A Standards Body founded in 1916 in America that defines standards for television and film production.
UI	Unit Interval. This is commonly encountered in jitter measurements and it quantifies the jitter in terms of the fraction of the ideal period of a bit. It is useful because it scales with clock frequency. Absolute units such as picoseconds (ps) are also encountered.