SMPTE Engineering Guideline

4:2:2 / 4:2:0 Format Conversion Minimizing Color Difference Signal Degradation in Concatenated Operations — Application

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Foreword

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SMPTE EG 2050-2 was prepared by Technology Committee 32NF.

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1 Scope

This engineering guideline provides details on a possible implementation of the filter defined in SMPTE RP 2050-1. See the introduction of SMPTE RP 2050-1 for information on how the filter is used.

2 Guideline of the Implementation

2.1 General

2.1.1 Definitions

The following nomenclature is used in this guideline.

F0[-3]…F[4]: Filter coefficients for conversion from 4:2:2 to 4:2:0. The value of each coefficient is defined in SMPTE RP 2050-1. The filter normalizing divisor is 1024.

F1e[-1]…F1e[2], F1o[-1]…F1o[2]: Filter coefficients from 4:2:0 to 4:2:2. The value of each coefficient is defined in SMPTE RP 2050-1. The filter normalizing divisor is 1024.

NumLS: Number of luminance samples per active line in a 4:2:2 image sampled system.

NumAL: Number of active lines per frame for progressive systems, or per field for interlaced systems using 4:2:2 image sampling.

$Y'[x,y]$ / $C_B'[x,y]$ / $C_R'[x,y]$: Luminance and color-difference samples of color encoding and digital representation in a 4:2:2 image sampled system.

$Y''[x,y]$ / $C_B''[x,y]$ / $C_R''[x,y]$: Luminance and color-difference samples of color encoding and digital representation in a 4:2:0 image sampled system.

Limit(y, V): Mathematical notation for limiting of position. This process is defined in the following pseudo C-code function:

```
int Limit(y, V)
{
if(y < 0) return (0);
else if (y > V) return (V);
 else return y;
}
```

Clip(v, Min, Max): Mathematical notation for clipping of value. This process is defined in the following pseudo C-code function:

```
int Clip(v, Min, Max)
{
  if(v<Min) return (Min);
  else if(v > Max) return (Max);
  else return(v);
}
```

2.1.2 4:2:2 image format

Table 1 indicates the applicable 4:2:2 image formats for this engineering guideline. For each system nomenclature, the constant NumLS and NumAL are used for the 4:2:2/4:2:0 and 4:2:0/4:2:2 conversion processes defined in the Section 2.2.

Table 1 – 4:2:2 Image format

No.	System Nomenclature (for all frame rates defined in ST 274M and ST 296M)	Luminance samples per active line (NumLS)	Active lines per frame	Scanning format	Active lines per frame for progressive, or per field for Interlace (NumAL)	Reference standards
1	1920 × 1080/P	1920	1080	Progressive	1080	SMPTE ST 274
2	1920 × 1080/I	1920	1080	Interlace	540	SMPTE ST 274
3	1280 × 720/P	1280	720	Progressive	720	SMPTE ST 296

2.2 Filter Implementation for 4:2:2 and 4:2:0 Conversion

2.2.1 Mapping of samples

2.2.1.1 Mapping of samples in progressive image formats

Figure 1 illustrates the mapping of Y′[x,y] / C_B′[x,y] / C_R′[x,y] and Y″[x,y] / C_B″[x,y] / C_R″[x,y] in a progressive image. This figure also illustrates the relative position of color difference samples between 4:2:2 and 4:2:0.

Y′[x,y] / C_B′[x,y] / C_R′[x,y] are the x-th sample position in the y-th active line of a frame with 4:2:2 sampling.

For Y′[x,y], the range of x is from 0 to (NumLS - 1), and the range of y is from 0 to (NumAL -1).

For C_B′[x,y] and C_R′[x,y], the range of x is from 0 to (NumLS / 2 - 1), and the range of y is from 0 to (NumAL - 1).

Y″[x,y] / C_B″[x,y] / C_R″[x,y] are the x-th sample position in the y-th active line of a frame with 4:2:0 sampling.

For Y″[x,y], the range of x is from 0 to (NumLS - 1), and the range of y is from 0 to (NumAL -1).

For C_B″[x,y] and C_R″[x,y], the range of x is from 0 to (NumLS/2 - 1), and the range of y is from 0 to (NumAL/2 -1).

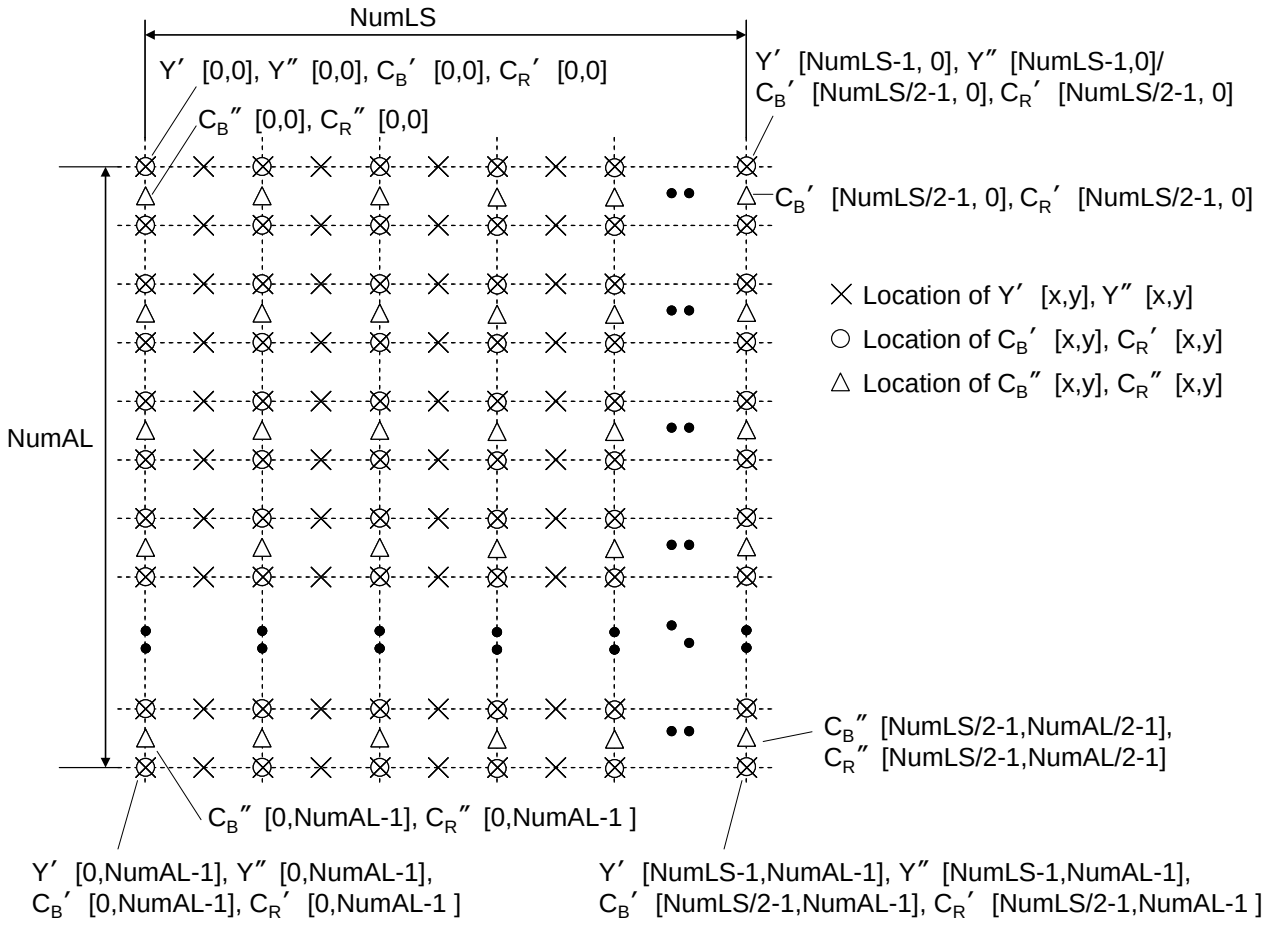

Figure 1 – Mapping of 4:2:2 and 4:2:0 samples to Y′[x,y] / C_B′[x,y] / C_R′[x,y] and Y″[x,y] / C_B″[x,y] / C_R″[x,y] for the progressive image formats

2.2.1.2 Mapping of samples in interlaced image formats

Figure 2 llustrates the mapping of Y′[x,y] / C_B′[x,y] / C_R′[x,y] and Y″[x,y] / C_B″[x,y] / C_R″[x,y] in the first field of an interlaced image. This figure also illustrates the relative position of color difference samples between 4:2:2 and 4:2:0.

Y′[x,y] / C_B′[x,y] / C_R′[x,y] are the x-th sample position in the y-th active line of the first field of an interlaced image with 4:2:2 sampling.

For Y′[x,y], the range of x is from 0 to (NumLS - 1), and the range of y is from 0 to (NumAL -1).

For C_B′[x,y] and C_R′[x,y], the range of x is from 0 to (NumLS / 2 - 1), and the range of y is from 0 to (NumAL - 1).

Y″[x,y] / C_B″[x,y] / C_R″[x,y] are the x-th sample position in the y-th active line of the first field of an interlaced image with 4:2:0 sampling.

For Y″[x,y], the range of x is from 0 to (NumLS - 1), and the range of y is from 0 to (NumAL -1).

For $C_B''[x,y]$ and $C_R''[x,y]$, the range of x is from 0 to (NumLS/2 - 1), and the range of y is from 0 to (NumAL/2 -1).

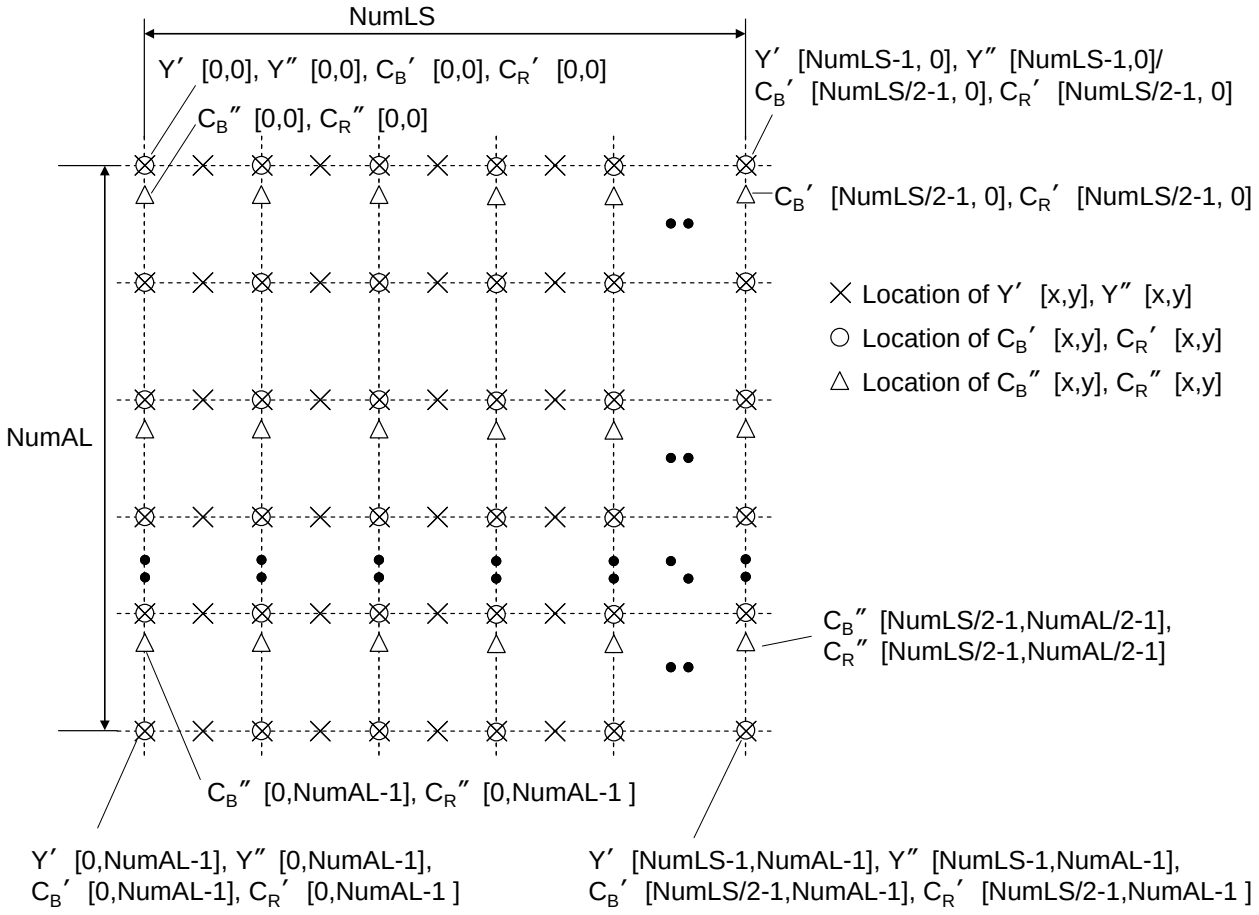

Figure 2 – Mapping of 4:2:2 and 4:2:0 samples to Y′[x,y] / C_B′[x,y] / C_R′[x,y] and Y″[x,y] / C_B″[x,y] / C_R″[x,y] for the first field of interlaced image formats

Figure 3 illustrates the mapping of Y′[x,y] / C_B′[x,y] / C_R′[x,y] and Y″[x,y] / C_B″[x,y] / C_R″[x,y] in the second field of an interlaced image. This figure also illustrates the relative position of color difference samples between 4:2:2 and 4:2:0.

Y′[x,y] / C_B′[x,y] / C_R′[x,y] are the x-th sample position in the y-th active line of the second field of an interlaced image with 4:2:2 sampling.

For Y′[x,y], the range of x is from 0 to (NumLS - 1), and the range of y is from 0 to (NumAL -1).

For $C_B'[x,y]$ and $C_R'[x,y]$, the range of x is from 0 to (NumLS / 2 - 1), and the range of y is from 0 to (NumAL - 1).

Y″[x,y] / C_B″[x,y] / C_R″[x,y] are the x-th sample position in the y-th active line of the second field of an interlaced image with 4:2:0 sampling.

For Y″[x,y], the range of x is from 0 to (NumLS - 1), and the range of y is from 0 to (NumAL -1).

For $C_B''[x,y]$ and $C_R''[x,y]$, the range of x is from 0 to (NumLS/2 - 1), and the range of y is from 0 to (NumAL/2 -1).

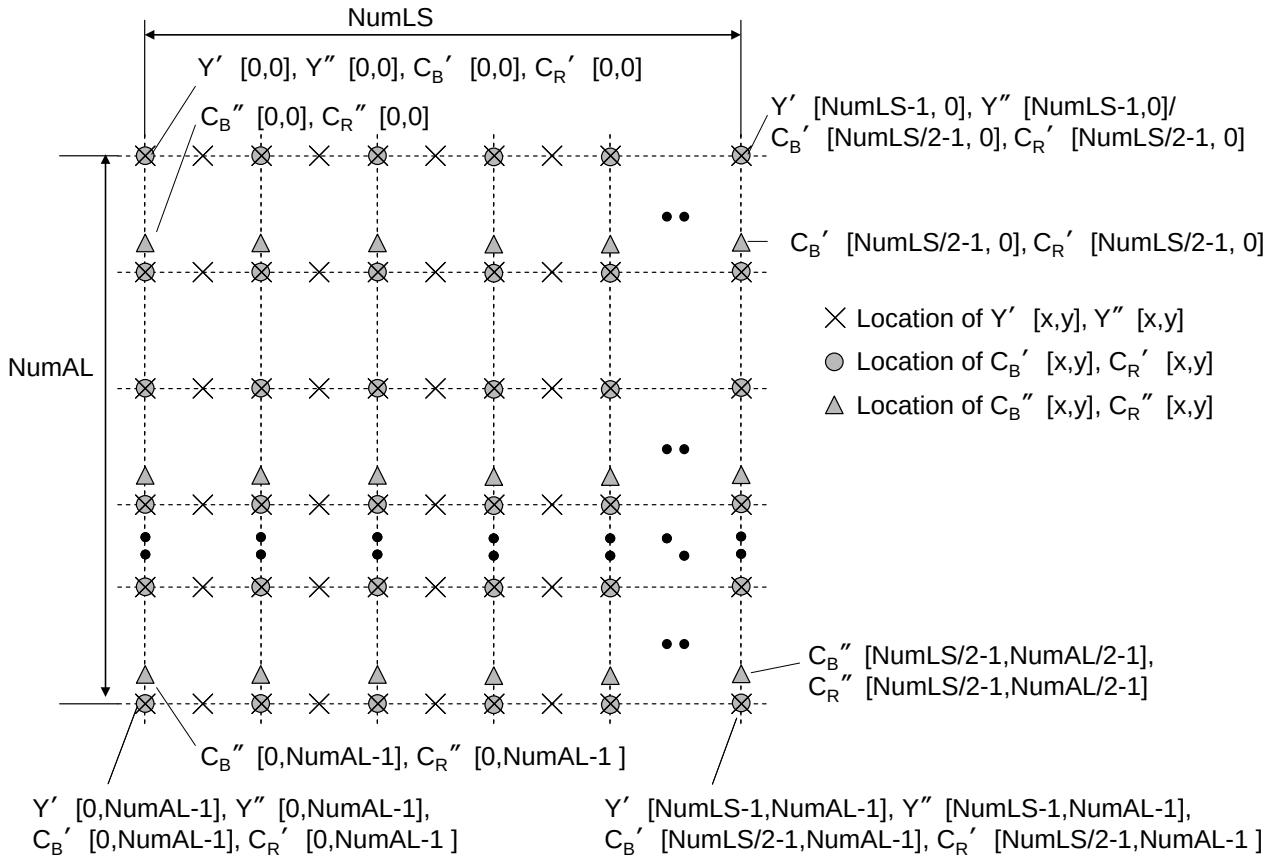

Figure 3 – Mapping of 4:2:2 and 4:2:0 samples to $Y'[x,y] / C_B'[x,y] / C_R'[x,y]$ and $Y''[x,y] / C_B''[x,y] / C_R''[x,y]$ for the second field of interlaced image formats

2.2.2 Conversion Process

This section describes the conversion process for 4:2:2 to 4:2:0 and 4:2:0 to 4:2:2.

2.2.2.1 4:2:2 / 4:2:0 conversion process

This sub-section describes the conversion process from 4:2:2 sampling to 4:2:0 sampling.

In the process of 4:2:2 / 4:2:0 conversion, coefficients defined in SMPTE RP 2050-1 and constants defined in Table 2 are to be used according to the bit-depth of 4:2:2 sampling and 4:2:0 sampling.

Table 2 – Constant Values for 4:2:2/4:2:0 conversion process

No.	Bit Depth of 4:2:2 Sampling	Bit Depth of 4:2:0 Sampling	C_a	C_b	C_c	C_d	C_e	C_f	C_g
1	8	8	1	0	1	512	1024	0	255
2	8	10	4	0	1	128	256	0	1023
3	10	8	1	2	4	2048	4096	0	255
4	10	10	1	0	1	512	1024	0	1023

For Luminance samples, the process defined in Eq. 1 is applied wherein x is from 0 to (NumLS – 1) and y is from 0 to (NumAL – 1).

$$Y''[x,y] = floor\left((C_a \cdot Y'[x,y] + C_b)/C_c\right) \qquad \textbf{Eq. 1}$$

For color difference samples, the processes defined in Eq.2 and Eq.3 are applied wherein x is from 0 to (NumLS/2 – 1) and y is from 0 to (NumAL/2 – 1).

$$C_B''[x,y] = clip\left(floor\left(\left(\left(\sum_{k=-3}^{4} F0[k] \bullet C_B'[x, Limit(2\cdot y + k, NumAL - 1)]\right) + C_d\right) \Big/ C_e\right), C_f, C_g\right) \qquad \textbf{Eq. 2}$$

$$C_R''[x,y] = clip\left(floor\left(\left(\left(\sum_{k=-3}^{4} F0[k] \bullet C_R'[x, Limit(2\cdot y + k, NumAL - 1)]\right) + C_d\right) \Big/ C_e\right), C_f, C_g\right) \qquad \textbf{Eq. 3}$$

2.2.2.2 4:2:0 / 4:2:2 conversion process

This sub-section describes the conversion process from 4:2:0 sampling to 4:2:2 sampling.

In the process of 4:2:0 / 4:2:2 conversion, coefficients defined in SMPTE RP 2050-1 and constants defined in Table 3 are to be used according to the bit-depth of 4:2:0 sampling and 4:2:2 sampling.

Table 3 – Constant Values for 4:2:0/4:2:2 conversion process

No.	Bit Depth of 4:2:0 Sampling	Bit Depth of 4:2:2 Sampling	C_h	C_i	C_j	C_k	C_l	C_m	C_n
1	8	8	1	0	1	512	1024	1	254
2	8	10	4	0	1	128	256	4	1019
3	10	8	1	2	4	2048	4096	1	254
4	10	10	1	0	1	512	1024	4	1019

For Luminance samples, the process defined in Eq.4 is applied wherein x is from 0 to (NumLS – 1) and y is from 0 to (NumAL – 1).

$$Y'[x,y] = floor\left(C_h \cdot \left(Y''[x,y] + C_i\right) / C_j\right) \quad \textbf{Eq. 4}$$

For color difference samples, the process defined in Eq.5, Eq.6, Eq.7, and Eq.8 are applied wherein x is from 0 to (NumLS/2 – 1) and y is from 0 to (NumAL/2 – 1).

$$C_B'[x,2y] = Clip\left(floor\left(\left(\left(\sum_{k=-2}^{1} F1e[k] \bullet C_B''[x, Limit(y+k, NumAL/2-1)]\right) + C_k\right) \Big/ C_l\right), C_m, C_n\right) \quad \textbf{Eq. 5}$$

$$C_B'[x,2y+1] = Clip\left(floor\left(\left(\left(\sum_{k=-1}^{2} F1o[k] \bullet C_B''[x, Limit(y+k, NumAL/2-1)]\right) + C_k\right) \Big/ C_l\right), C_m, C_n\right) \quad \textbf{Eq. 6}$$

$$C_R'[x,2y] = Clip\left(floor\left(\left(\left(\sum_{k=-2}^{1} F1e[k] \bullet C_R''[x, Limit(y+k, NumAL/2-1)]\right) + C_k\right) \Big/ C_l\right), C_m, C_n\right) \quad \textbf{Eq. 7}$$

$$C_R'[x,2y+1] = Clip\left(floor\left(\left(\left(\sum_{k=-1}^{2} F1o[k] \bullet C_R''[x, Limit(y+k, NumAL/2-1)]\right) + C_k\right) \Big/ C_l\right), C_m, C_n\right) \quad \textbf{Eq. 8}$$

Clipping can be applied to Y″[x,y]/C_B″[x,y]/C_R″[x,y] before mapping to interface signal to avoid prohibited values.

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Annex A Bibliography (Informative)

Note: All references in this document to other SMPTE documents use the current numbering style (e.g. SMPTE ST 274:2008) although, during a transitional phase, the document as published (printed or PDF) may bear an older designation (such as SMPTE 274M-2008). Documents with the same root number (e.g. 274) and publication year (e.g. 2008) are functionally identical.

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

SMPTE ST 292-1:2012, 1.5 Gb/s Signal / Data Serial Interface

SMPTE ST 296:2011, 1280 × 720 Progressive Image Sample Structure — Analog and Digital Representation and Analog Interface

SMPTE ST 372:2011, Dual Link 1.5 Gb/s Digital Interface for 1920 × 1080 and 2048 × 1080 Picture Formats

SMPTE ST 421:2006, VC-1 Compressed Video Bitstream Format and Decoding Process

Amendment 1:2007 to SMPTE ST 421:2006

Amendment 2:2011 to SMPTE ST 421:2006

SMPTE ST 424:2006, Television — 3 Gb/s Signal / Data Serial Interface

SMPTE RP 2050-1:2012, 4:2:2 / 4:2:0 Format Conversion Minimizing Color Difference Signal Degradation in Concatenated Operations — Filtering

ISO/IEC 13818-2:2000, Information Technology — Generic Coding of Moving Pictures and Associated Audio Information: Video

ITU-T Recommendation H.264, Advanced Video Coding for Generic Audiovisual Services

“The 4:2:2/4:2:0 perfect reconstruction filter set and its application in HD-SNG”, SMPTE Motion Imaging Journal, pp29-39, July/August 2009