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Editing & Mastering UHDTV: Studio Lossless or NearLossless Compression

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Editing & Mastering UHDTV: Studio Lossless or near Lossless Compression

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Mr MXF Ltd.

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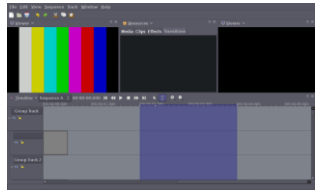
Overview

- UHD Compression for editing & mastering
  - Which UHD?
  - TIFF & DPX
- JPEG2000
- ProRes
- SStP
- AVC
  - XAVC
  - AVCUltra
- TICO
- VC-3
- VC-2
- VC-5

UHD “lossless” compression – what’s the problem?



Acquire

Produce

Master

Distribute

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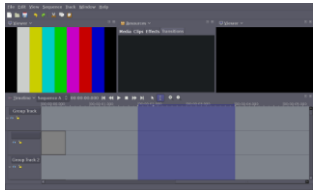
UHD “lossless” compression – what’s the problem?

1916-2016

Might be UHD1
Might be HDR HFR WCG
From compressed to Raw

- Might be:
  - One version
  - HD + SDR + HDR



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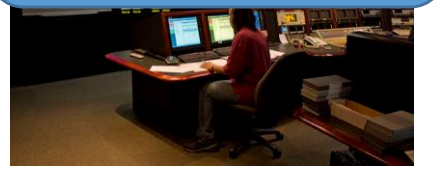

- Might be:
  - One version of UHD
  - HD + SDR + HDR as simulcast or side channels

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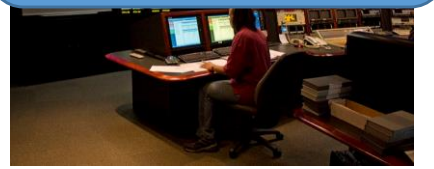

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You are here

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UHDTV is more than higher resolution

4K is not all there is to UHDTV

In search of the "Wow Factor"

Higher Spatial Resolution

Wider Field of View

Higher Frame Rate

Enhanced Color Gamut

Increased Bit-Depth

Enhanced Dynamic Range

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Which UHD

- 8k vs 4k vs UHD1
  - 3840 x 2160 → 4 x 1920 x 1080
  - 4096 x 2160 → 4 x 2048 x 1080
  - 7680 x 4320 → 16 x 1920 x 1080
- More pixels or more wow?
  - Chroma 4:2:2 (maybe even 4:2:0) or 4:4:4 or 4:4:4:4
  - High Frame Rate (HFR)
  - High Dynamic Range (HDR)
  - Wide Color Gamut (WCG) BT.2020

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Simple maths – UHDTV

- HD
  - 1920 x 1080 x 25 fps x SDR
  - Y, Cb, Cr 4:2:2 10b int
  - =1.1 Gbps to transmit
  - =25Mbps to 150Mbps to move
  - =1TB/hr to 4TB/hr to store
  - = 67 MB/frame to process
- Applies to
  - Server backplanes
  - CPU caches
  - GPU buses
- UHDTV
  - 3840 x 2160 x 25 fps x SDR
  - Y, Cb, Cr 4:2:2 10b int
  - =4.1Gbps to transmit
  - =100Mbs to 500Mbps to move
  - =3TB/hr to 14TB/hr to store
  - =270 MB/frame to process
- Operating points
  - Are important
  - This is just one possible UHDTV point

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Simple maths – “heavy” UHDTV

- HD
  - 1920 x 1080 x 25 fps x SDR
  - Y, Cb, Cr 4:2:2 10b int
  - =1.1 Gbps to transmit
  - =25Mbps to 150Mbps to move
  - =1TB/hr to 4TB/hr to store
  - = 67 MB/frame to process
- Applies to
  - Server backplanes
  - CPU caches
  - GPU buses
- UHDTV
  - 3840 x 2160 x 100 fps x HDR
  - Y, Dz, Dx 4:4:4 16b float
  - =40Gbps to transmit
  - =250Mbs to 1500Mbps to move
  - =7TB/hr to 40TB/hr to store
  - =270 MB/frame to process

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Simple maths – “ultra-heavy” UHDTV2

- HD
  - 1920 x 1080 x 25 fps x SDR
  - Y, Cb, Cr 4:2:2 10b int
  - =1.1 Gbps to transmit
  - =25Mbps to 150Mbps to move
  - =1TB/hr to 4TB/hr to store
  - = 67 MB/frame to process
- Applies to
  - Server backplanes
  - CPU caches
  - GPU buses
- UHDTV
  - 7680 x 4320 x 300 fps x HDR
  - X’ Y’ Z’ 4:4:4 64b float
  - =477 Gbps to transmit
  - =400Mbps to 1750Mbps to move
  - =12TB/hr to 50TB/hr to store
  - = 1 GB/frame to process

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Just put it on a display

- HDMI 1.4 maximum data rate is 10.2 Gb/s (including blanking)
- HDMI 2.0 maximum data rate is 18 Gb/s (including blanking)
- Calculations for RGB (4:4:4) color:
  - 3840x2160 × 30Hz × 3 × 10 = 7.46 Gb/s (8-bit color) ✓
  - 3840x2160 × 60Hz × 3 × 10 = 14.9 Gb/s (8-bit color) ✗
  - 3840x2160 × 60Hz × 3 × 12 = 17.9 Gb/s (10-bit color) ✗
- So for 2160p60 @10b you need HDMI 2.0
  - Includes HDR support
- So for 2160p60 @12b you need HDMI 2.1 – not released yet
  - Will include dynamic metadata support

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Uncompressed – TIFF & DPX

- The “old” workhorse standards
- TIFF
  - A proprietary specification originating from Aldus corporation
  - “Latest” stable version from Adobe in 1994
  - Uncompressed + metadata and sometimes uses JPEG compression
- DPX or SMPTE ST 268
  - Widely used for uncompressed pixel carriage
  - Many proprietary mechanism for providing metadata
  - Metadata describes what the pixels mean
    - Is it RGB, XYZ, Bayer mask etc.
    - What format is the underlying data

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JPEG 2000 - ISO/IEC 15444

- Probably the most mature and standardised “lossless” codec
- Widely used in Digital Cinema
  - Production processes
  - Mastering
  - Archive
- What is “lossless”?
  - Mathematically lossless
    - perfect reconstruction but variable bitrate
    - From 2:1 to around 8:1 compression depending on content
  - Visually lossless
    - A more subjective measure but often around 10:1 compression – depending on content

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JPEG 2000

- Wavelet based (not DCT)
- Algorithm is standardised and stable
- Algorithm implements EBCOT
  - Embedded Block Coding with optimised Truncation
  - This means different implementations are free to truncate in different ways
  - The measure of rate distortion is not standardised and implementers choose
- Extensions provide metadata for Broadcast Profile signalling
- Extra specification such as D-Cinema IMF provide extra constraints

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JPEG 2000

- The visual bump problem
  - Applies to all visually lossless codecs
  - Using JPEG 2000 as an example
    (because I made the picture for an IMF talk)

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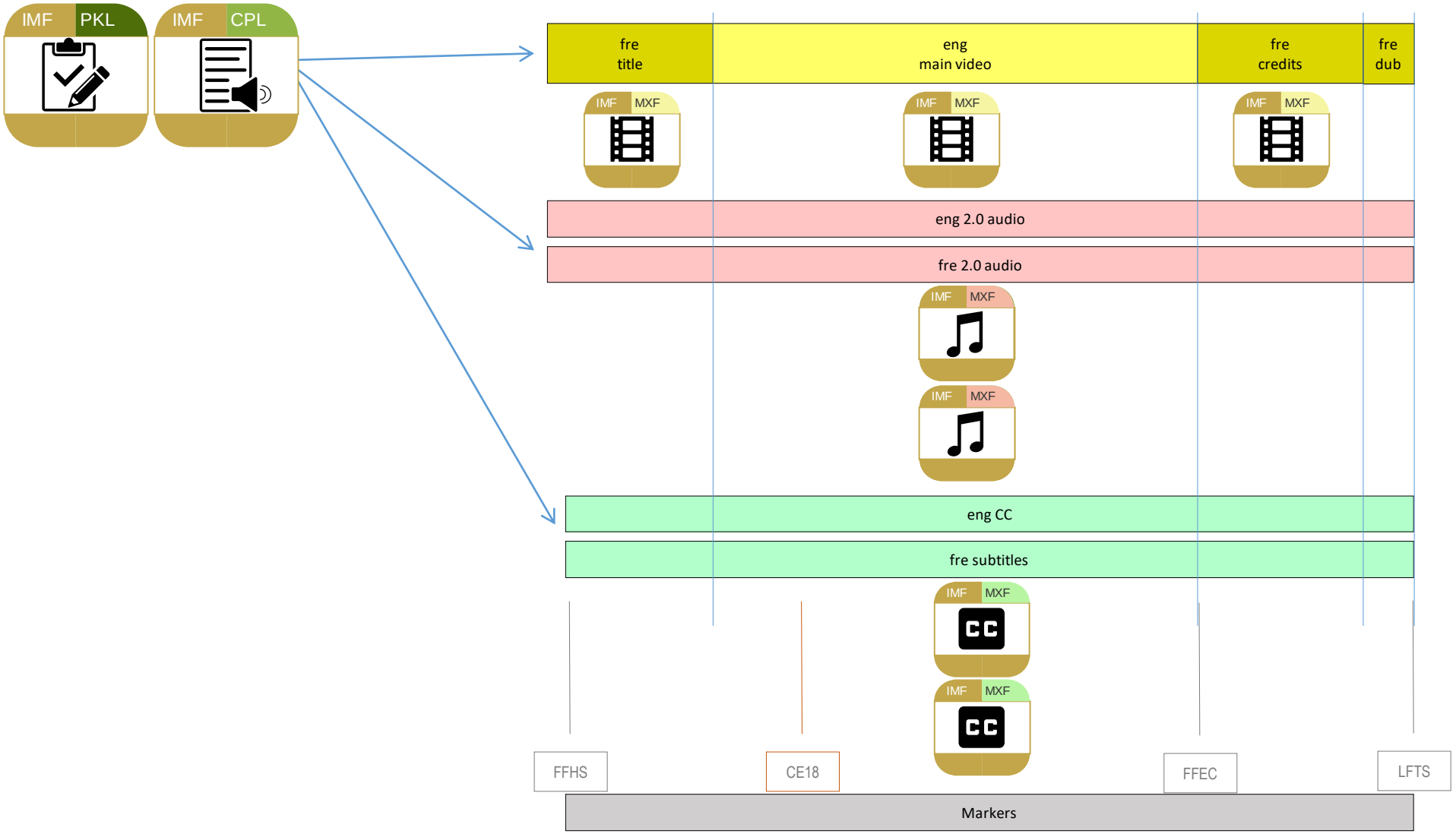
The visual bump problem



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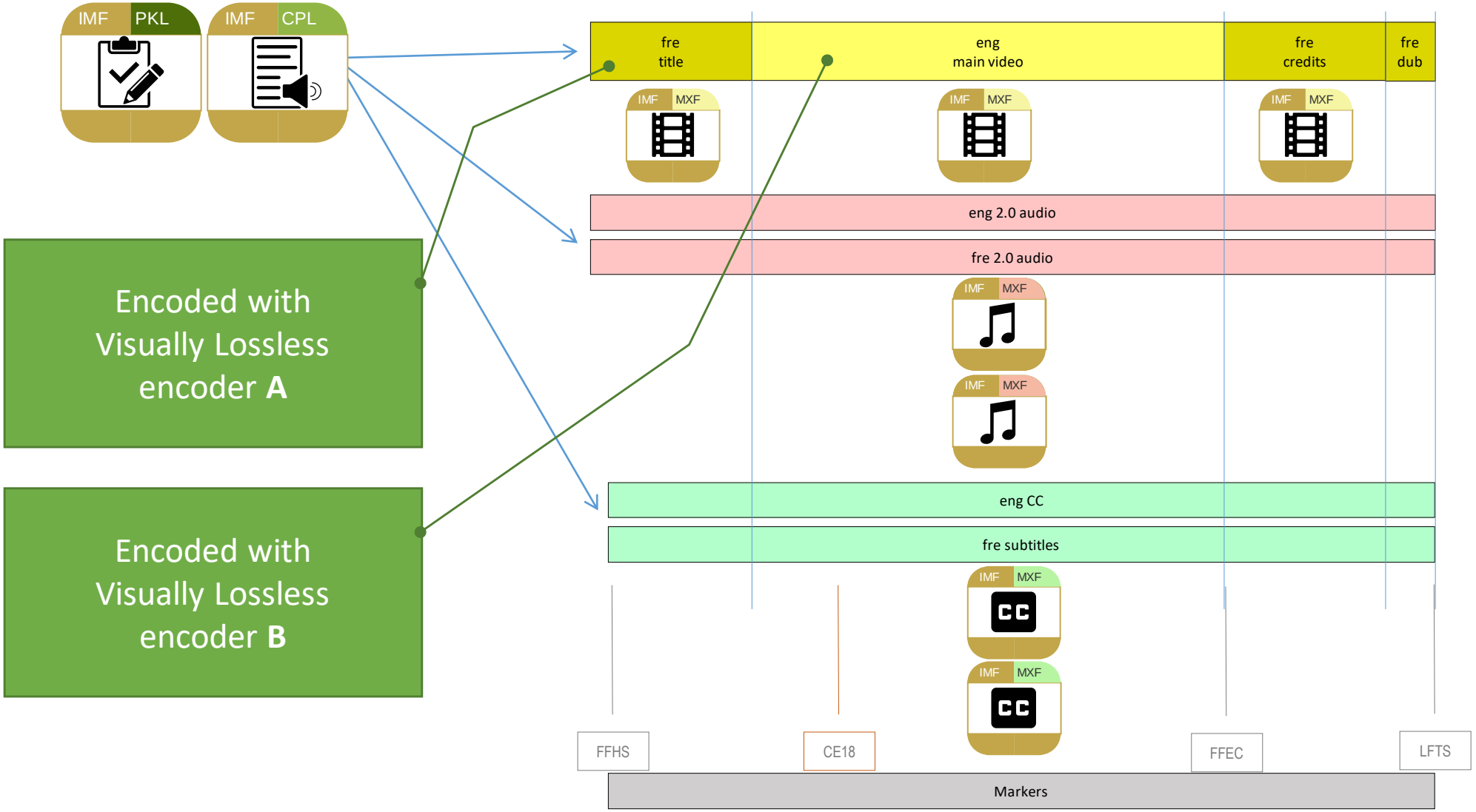
The visual bump problem



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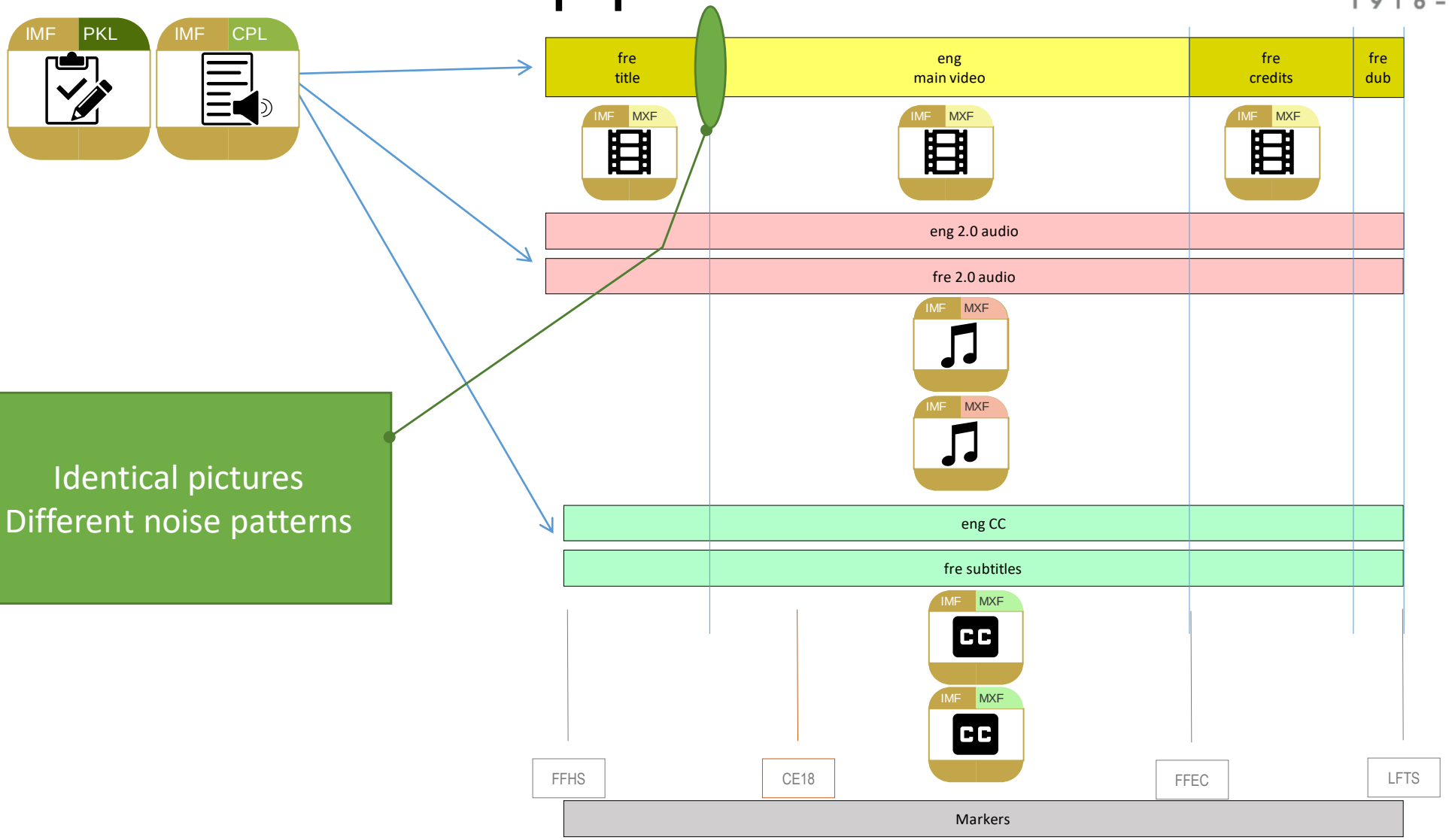
The visual bump problem



Identical pictures
Different noise patterns

The visual bump problem

- Operating point bitrates need good headroom
- The quality & consistency of background areas is important
- The cascade performance of the codec is important
  - Is the bump visible after 1 generation? 2 generations?

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ProRes

- Apple's codec – RDD36
  - Apple ProRes 4444 XQ
    - Visually Lossless with Good multi-generation performance
    - High Dynamic Range & Wide Color Gamut support
    - Highest Quality 12bpp/ch 16b alpha – approx. 500Mbps for 1920x1080 4:4:4 30fps
  - Apple ProRes 4444
    - Visually Lossless with Good multi-generation performance and low complexity
    - Very High Quality 12bpp/ch 16b alpha – approx. 330Mbps for 1920x1080 4:4:4 30fps
  - Apple ProRes 422 HQ
    - Visually Lossless with Good multi-generation performance
    - Very High Quality 12bpp/ch 16b alpha – approx. 330Mbps for 1920x1080 4:4:4 30fps
- Tools available licensed by Apple who run a QC program
- Common wrapper Quicktime (MXF in the pipeline)

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SStP – MPEG4-2

- ISO/IEC 14496-2:2004/Amd 5:2009, Simple Studio Profile Levels 5 and 6
- Widely deploy as a high quality master for many years
- ST 2067-3 IMF Application #3
  - HD progressive & Interlaced operating points
    - at common Frame rates
    - At 422 and 444 YUV colorimetry and RGB
    - 10 or 12 bits
  - UHD (2K, UHD1, 4K) operating points
    - Progressive at common frame rates
    - At 422 and 444 YUV colorimetry and RGB and X'Y'Z'
    - 10 or 12 bits
  - 300Mbps to 3.6Gbps
- Common wrappers - MXF & Quicktime

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AVC

- The work-horse ISO codec
- Trade names include XAVC, AVC Ultra
- Operating points often defined by Camera or Distribution requirements
  - Resolutions: HD, 2K, QFHD, 4K
  - All common frame rates
  - YUV, RGB color spaces
  - Intra coding only for this application (News and others use Long GoP variants)
  - “Classes” often relate to bitrates and are defined by vendors
    - XAVC 4K Class 480 CBG (XAVC-I 4K 480) for 4096 x 2160p images
    - AVC Ultra Class 4K 4:4:4 compression
- UHD interoperability good for one specification but not between specifications
- Common containers MXF, Quicktime, MP4

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VC-2

- Also known as Dirac SMPTE ST 2042
  - Also known as Cineform
    - Wavelet based scheme
    - Intra frame compression with ratios similar to AVC
    - Operating points at all common resolutions and frame rates
    - Low complexity with open source implementations
    - Good multigeneration performance
    - Royalty and patent free
- Samples and conformance specified in SMPTE
- Tools @ diracvideo.org
- Common containers MXF, AVI, Ogg, Matroska

VC-3

- Avid's Codec SMPTE ST2019
  - Also known as DnxHD
    - DCT based scheme
    - Operating points at all common resolutions and frame rates
    - Good interoperability with low complexity
    - Good multigeneration performance
  - DNxHR
    - New quality levels, Alpha channel, HDR support, WCG support
    - DNxHR 444 – high quality correction and finishing
    - DNxHR HQX – high quality extended
    - DNxHR HQ – high quality
    - DNxHR SQ – standard quality
    - DNxHR LB – low bandwidth
- Toolkits Licensed by AVID
- Common containers MXF, Quicktime

VC-5 SMPTE ST 2073

- GoPro's Codec
  - Also known as Cineform
    - Wavelet based scheme
    - Support for any color space or color difference or direct encoding of a camera sensor
    - Operating points at all common resolutions and frame rates
    - Good interoperability with low complexity
    - Good multigeneration performance
- Samples and conformance specified in SMPTE
- Common containers MXF, Quicktime

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Other Compressions in the Chain

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RAW

- By definition it is the raw format from the camera sensor
- By definition RAW formats are proprietary
- RAW formats often
  - Compress the pixel arrays
  - Carry camera metadata to “fix in Post Production” exposures and dynamic range
  - Carry extra metadata about the capture / lens etc

- RAW formats are specific to a device
- Converting to an interoperable mezzanine often INCREASES file size!

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SMPTE RDD35 TICO

- Visually lossless compression up to 4:1
  - Even Mathematically Lossless at lower compression ratio
- Robust to multiple encoding generations
- Robust to error
- Fixed & Pixel lines-based latency
- Extremely light in FPGA (no external DDR memory)
- Fast & efficient in software
- Resolutions from HDTV to UHDTV 4K/8K
- Smart mapping on SDI or IP

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Conclusions

- There is no single codec standard that is “right”
- Editing and Mastering often depend on the genre
- IMF (ST 2067) has recognised this
  - IMF applications constrain operating points such as image codecs
  - Image codecs are constrained tightly to give good interoperability
- No single vendor supports every operating point of every codec (I think)

- All the codecs mentioned are SMPTE ST, RP or RDD documents
- SMPTE is going to be busy