High-Definition Television

Was bringt die Zukunft?

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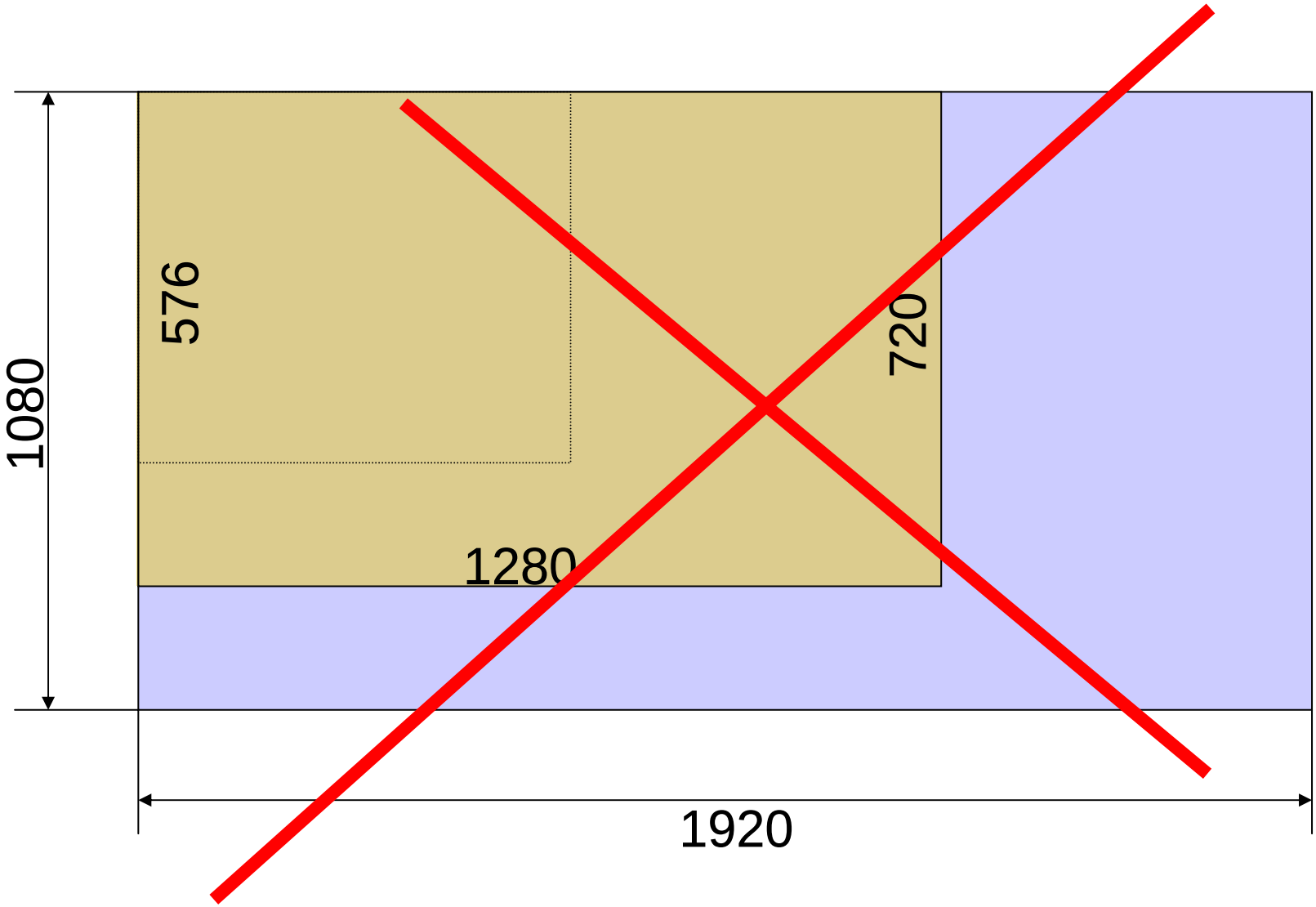
Agenda

- Part 1
  - HD Broadcasts
  - Consumer situation
  - What should broadcasters do?
  - New technology offers in production
- Part 2
  - Subjective tests of the EBU and 1080p/50
- Part 3
  - Future developments

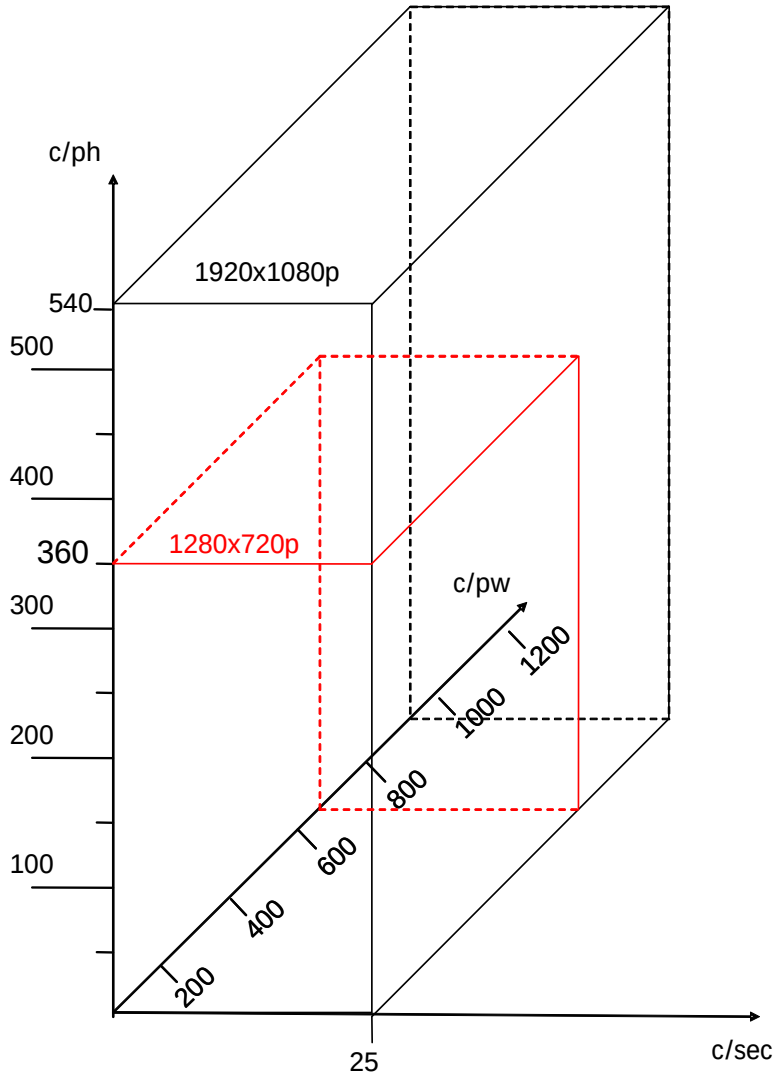
Recapitulation HDTV formats

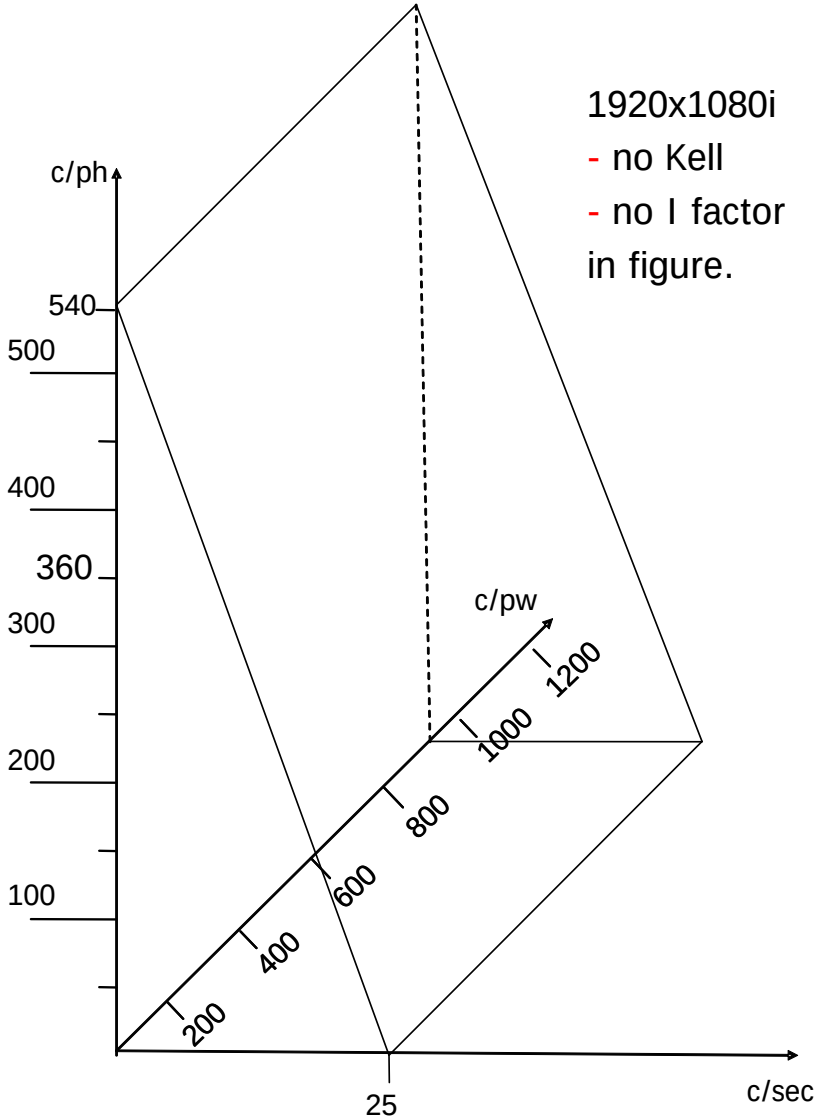
- 720p/50:
  - 1280 x 720 progressive scanning 50 frames/second
  - 4:2:2 10 Bit resolution about 0.98 Gbit/s (net)
  - Utilize 1.485 GBit/s HD-SDI infrastructur in the studio
- 1080i/25:
  - 1920 x 1080 interlaced scanning 25 frames/second or 50 fields
  - 4:2:2 10 bit resolution about 1.036 Gbit/s (net)
  - Utilize 1.485 GBit/s HD-SDI infrastructur in the studio
- 1080p/50:
  - 1920 x 1080 progressive scanning 50 frames/second
  - 4:2:2 10 bit resolution about 2.072 Gbit/s (net)
  - Utilize dual link HD-SDI infrastructur or new 3 Gbit/s HD SDI

I don‘t like that figure.....



Idealised Spectrum for 1080i/25, 720p/50 and 1080p/50

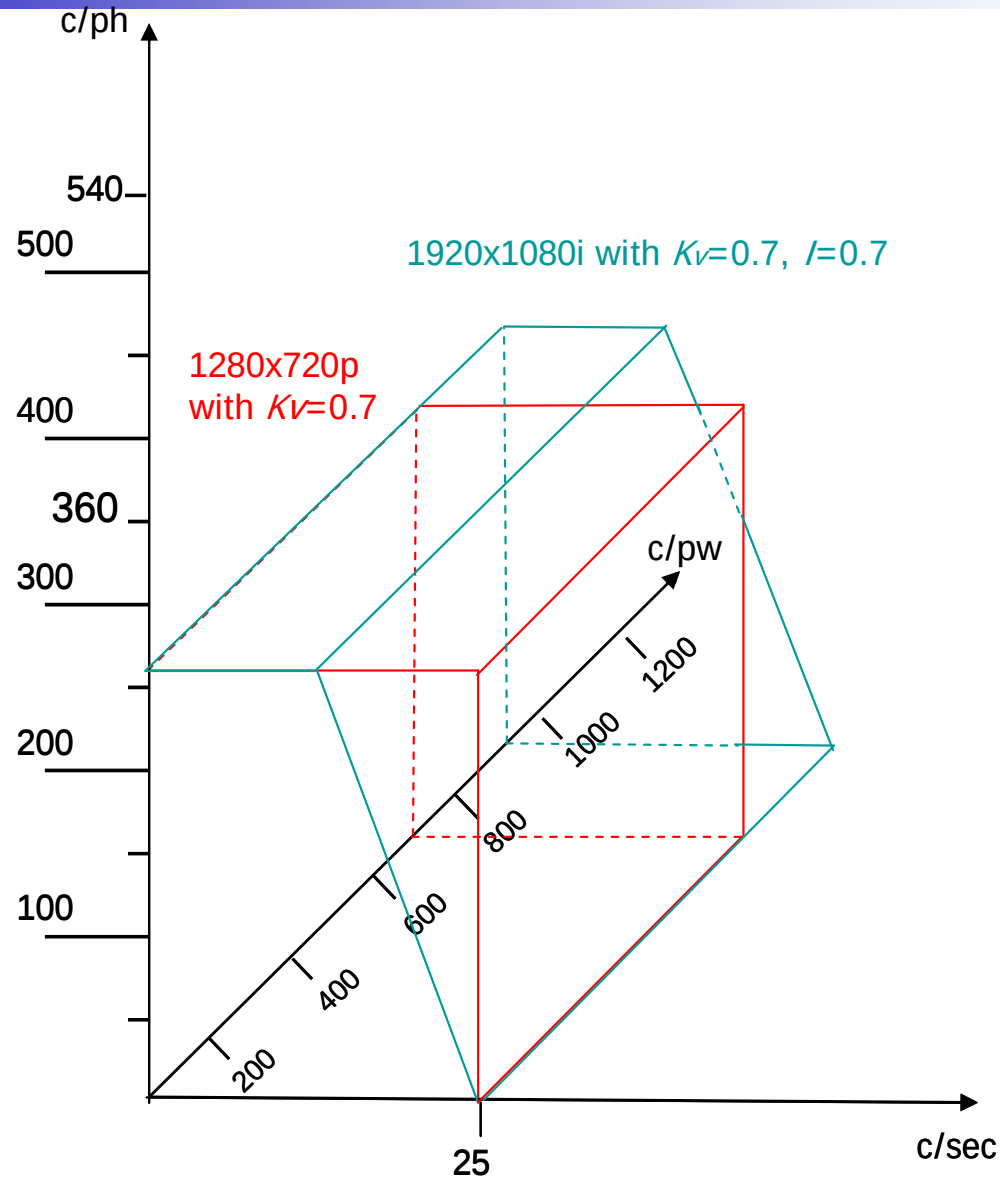




1920x1080i
- no Kell
- no I factor

in figure.

Idealised Spectrum – both „spectrum volumes“ are about equal



Broadcasts

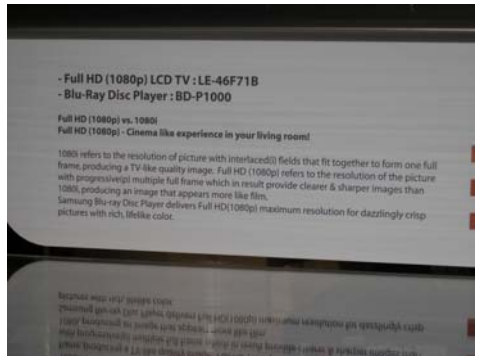
- Pan-European:
  - Euro1080 (HD1...)
- Pay-TV/Private
  - Canal+
  - BSKYB (UK); SKY Italia;
  - Premiere
  - NTL (cable)
  - TPS
  - SAT1 / Pro7 /Anixe HD
- Public Broadcaster - Satellite:
  - BBC (Test)
  - SVT
  - TF1
  - SRG ab 2008 (Eurofoot)
  - TV Catalunya
- Public Broadcaster - DTT:
  - BBC (Tests)
    - HD for all group
  - SVT (perhaps)
  - France (Tests in Lyon, Marseille, Paris)
  - Norway?

Broadcasts

- Summary of the BBC trails during worldcup:
  - provided the best HDTV quality!
  - convincing HDTV quality requires good and careful planning of the whole digital chain
  - MPEG-4 AVC with 19Mbit/s (1080i/25) in broadcasting
  - In contribution up to 80 Mbit/s and very careful planning of re-codings along the chain

Driving factors for consumers

- Displays
  - Fashion factor
  - HD-Ready, Full-HD,
- Content
  - Event driven
  - Movies (BluRay, HD-DVD, download)
  - Game Consoles



HD Ready – what does the consumer label tell us, and what does it not tell us?

- HD Ready:
  - Interface specification
    - Y, Pb,Pr, DVI or HDMI
  - Vertical min. resolution 720 pixel
  - Wide aspect ratio
  - Copy protection
- No guarantee for certain display image quality
- We have already heard complaints about missing guidelines for minimum display characteristics

What is the headache for broadcasters?

- Increasing variants of display technologies
  - including ideas of wide colour gamut.....
- If displays in the home differ significantly in image quality presentation then what is the final quality check criteria for the broadcaster?
  - according to existing CRT specifications?
  - if there is no grade 1 CRT in the future broadcaster cannot check!
- Consequence:
  - perceived image quality might not be predictable

EBU activity on displays

- Production:
  - 4 application spaces (reference, control, observation and special use)
  - Specification/Parameter document
  - Measurement guidelines
- Consumer
  - Guidelines on how broadcaster wish that theis signal is presented on consumer displays
  - Guideline for test magazines.....

Broadcasters questions on HDTV

- When, how much does it cost, do we have a (good) plan?
- What is a suitable mainstream HDTV production format for IT based environments?
- What is our target consumer quality over different distribution channels?
  - Target display size.....
- What happens if we show 720p/50 on a “full-HD” display?
- Status on 720p/50 and 1080i/25 equipment?
- Why have so many chosen 1080i/25?
- What’s about the 1080p/50 rumors?

Mainstream production UR

- HDTV Mainstream production – an equivalent to our 50 Mbit/s SDTV environment
- Fundamental:
  - cost adequate for “many system investments”
  - standardised compression algorithm, open!
  - If target display size is XX then production quality is YY
- System aspects:
  - progressive scanning support plus legacy inter
  - support of IT based production ideas and archiv
  - MXF mappings
  - no overload of network infrastructures
  - no overload of storage systems

CONFLICTING REQUIREMENTS?

- Quality:
  - image quality criteria (4th and 7th gene adroom
  - 10bit-8bit issue, sampling, horizontal sub-sampling, bit-rate, GOP
  - what contribution-link impairments can we expect
  - how many different compression algorithm will be cascaded

Mainstream HDTV production - EBU approach

- Test of the following systems in the EBU project P/HDTP
  - AVID DNxHD
  - Sony (HDCAM, HDCAM-SR), and XDCAM type Long-GOP MPEG-2 compression system
  - GVG Thomson JPEG 2000
  - Panasonic (DVCPRO HD), MPEG-4 Studio Profile
- Biggest technical issue
  - adequate test material
- Results ? (June, for EBU members: seminar on Codecs)

Mainstream HDTV production – MPEG-4 Encoder

- EBU project group B/HDC will conduct test of a variety of encoders
  - Time frame 6 month
  - The results can only be a snapshot in time because of continuous improvements of the implemented algorithm
- Generally it is reported that progressive signals encode better than interlaced signals
- More, when B/HDC tests are concluded.

Summary (part 1)

- HDTV is event and content driven
  - introduced by all major broadcasters between 2008-2012
- Display manufactures will continue to invent new technologies
  - Consequences for broadcasters
- IT-based HDTV production is a real challenge
  - Trade off between HDTV quality and network/storage demands
  - Archive question unclear
- The variety of new compression formats in production leads to system design and interoperation issues
  - for SDTV we had 2 competing compression systems
  - for HDTV we have JPEG2000, H.264SP, Long GOP MPEG-2, DNxHD, and.....
- MPEG-4 AVC encoder performance seems to improve to make bit-rates around 10 Mbit/s possible in the next years (at least with 720p/50)

Demo 1 – uncompressed HDTV

- EBU test material for codec tests
- Camera HDC1500
  - HQ lenses, very careful conditions
- Capture in 1080p/50, 720p/50, 1080i/25, (1080p25, 1080p25 with shutter)
- 1080p/50 is shown on the projector and the right screen

- Part 2
- Subjective Test of the EBU
- Question: what HDTV format can we recommend to our members in production and emission, short term and in the future?

Pros and Cons

- 50p: progressive scanning
  - good motion portrayal
  - more temporal information consequently good for sport genre
  - better to compress with modern compression systems such as MPEG-4 AVC and VC1
  - Matrix displays work ideal with progressive input signals
- 25i: interlaced scanning
  - industry has a long experience with it
  - cheap way of data compression in the past
  - CRT's can use interlaced very well
  - Content with little motion may not suffer from interlaced artefacts
  - Matrix displays require de-interlacer
  - 1080p/50 requires double base-band bandwidth than 1080i/25

1080p/50 in production

- Camera sensors operate already with (at least) 1920x1080 pixel progressive scanning at 24, 25, 50, 60...300 frames per second
  - Usually cameras provide a down-sampled output (1080i/25, 720p/50, 1080p/25)
  - Some provide dual link output with native 1080p/50
- Some VTRs or servers can record 1080p/50
- BBC idea for a mezzanine compression of 1080p/50 to use 1.485 Gbit/s HD-SDI links, or even to use SDI for 720p/50 and 1080i/25
- But: 1080p/50 is a huge challenge and finally requires developments and investments, so there must be a “case” for it

1080p/50 advantages (production)

- Suitable for fast action genre (sport) and for drama, nature, etc.
- Provides high spatial and temporal resolution
- “Close” to one of the Digital Cinema formats
- Ideal multipurpose high end HDTV format
- Provides very good down-sampled 720p/50 and 1080i/25
- Unite the 1080i/25 and 720p/50 world

- Drawback: no 24p / 25p film judder

1080p/50 emission and consumer side

- DVB has only MPEG-4 AVC Level 4, but 1080p/50 would require MPEG-4 AVC Level 4.2
- HDTV Ready logo (STB) only 1080i/25 and 720p/50
- More and more displays with 1920x1080 pixel enter the market (“full-HD”)
- DVI and HDMI already support 1080p/50-60
- Game stations provide 1080p/50-60
- BluRay player provides 1080p/50-60

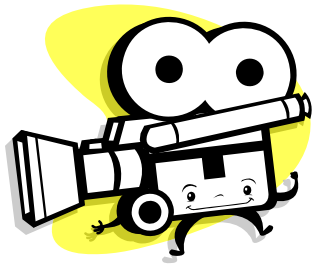
Critical questions

- Is 1080p/50 a suitable emission format?
  - what are the required bit-rates
  - are there any advantages in image quality compared to the existing HDTV formats at the same bit rate?
  - what happens if we show 720p/50 on a “full-HD” display?
  - if 1080p/50 is used in high-end productions, would it make sense to broadcast it or rather to down-sample to 720p/50 or 1080i/25?
  - what guideline can we give to EBU members?

Our research approach

- We believe only in subjective testing
- Traditional methods:
  - Double Stimulus Impairment Scale
  - Shortcomings:
    - we compare a reference against the impaired image of the same format
    - we can only determine the failure characteristics of each format individually
    - a comparison of the different HDTV formats is only indicative
- A better subjective method?

Experimental broadcast chain and impact factors



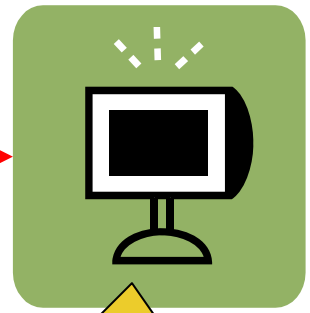
Need for content that
is identical
in all three HD formats

1080p/50
1080i/25
720p/50

Encoder
MPEG-4
AVC

Decoder
MPEG-4
AVC

1920x1080 pixel
Matrix Display



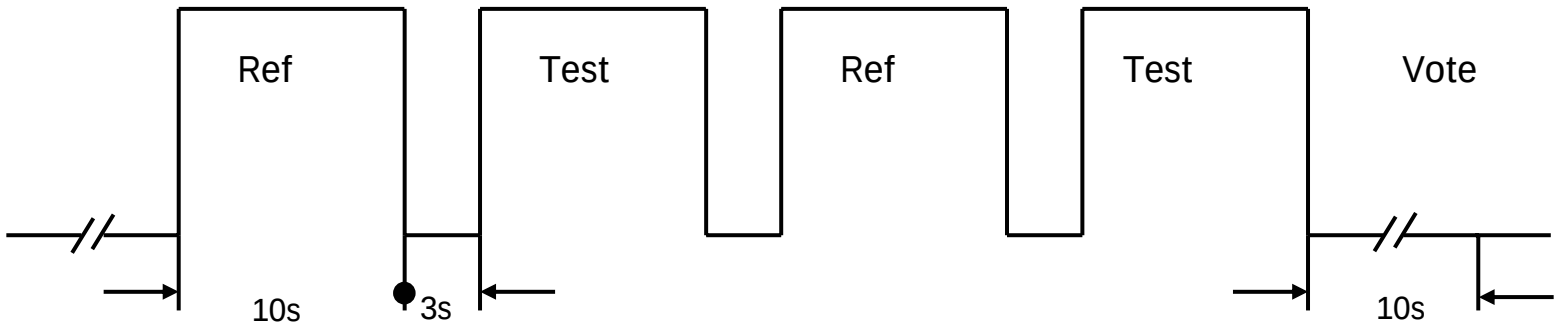
1080p/50 encoder?
What parameters?

Display issues:
-no grade 1 display available
-what display to chose
-scaler (720p/50 case)
-de-interlacer (1080i/25)

Set up for the first tests

- 21 non experts (male/female average age)
- Viewing conditions according to ITU-R BT.500 for room and display
- 6 persons per session at 3h and 4h (half-half)
- 50 inch PDP display with 1920x1080 pixel
- Display as good as possible aligned to D65k

Method: Double Stimulus Impairment Scale (DSIS)



Vote: difference between reference and test

- 5. imperceptible
- 4. perceptible but not annoying
- 3. slightly annoying
- 2. annoying
- 1. very annoying

Content for the first test

- Content – SVT Sweden:
  - 65 mm film 50 fps scanned to 3840x2160p/50
  - downsampled to 1080p/50, 1080i/25, 720p/50
  - method of downsampling and interlacing typical to camera functions
  - “oversampled” quality
  - critical but not unduly so
  - published by VQEG and EBU

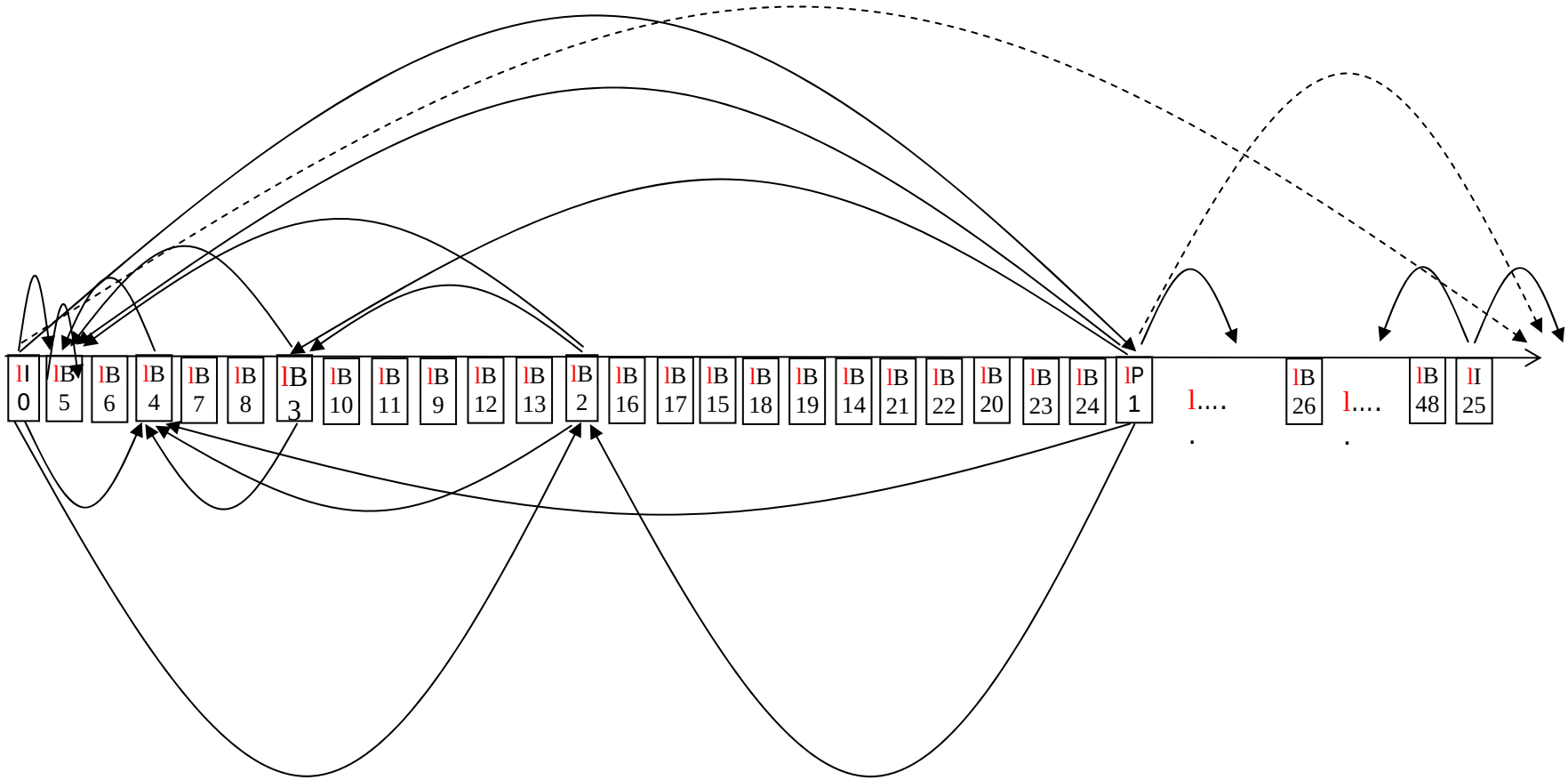
Content presentation

- In randomized form **per** HDTV format
- Viewers did not know what HDTV format and what bit-rate they were looking at
- Training sequence
- First 4 votes disregarded in analysis
- Votes were checked regarding sensibility

MPEG-4-AVC encoding

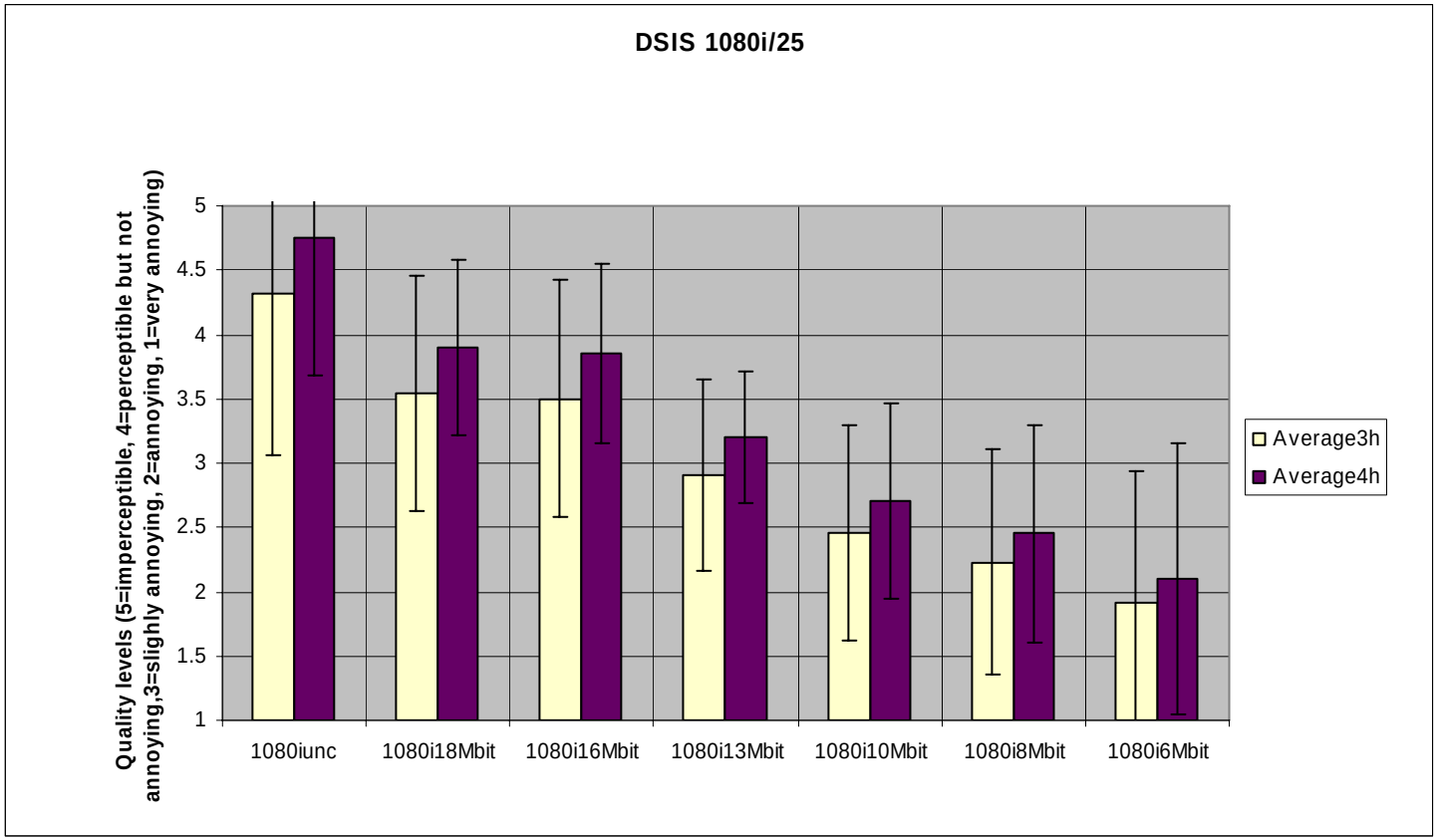
- In software by HHI-Berlin, because there is no hardware encoder for 1080p/50
- We wanted to get an impression on where hardware codecs will be in about 2-3 years
- Level 4 for 720p/50 and 1080i/25; Level 5 for 1080p/50
- Rate control via quantisation parameters (+/- 3% accuracy for bit-rate)
- Hierarchical coding structure, today difficult in hardware, but in 1 – 2 years.....

“Advanced” GOP Structure

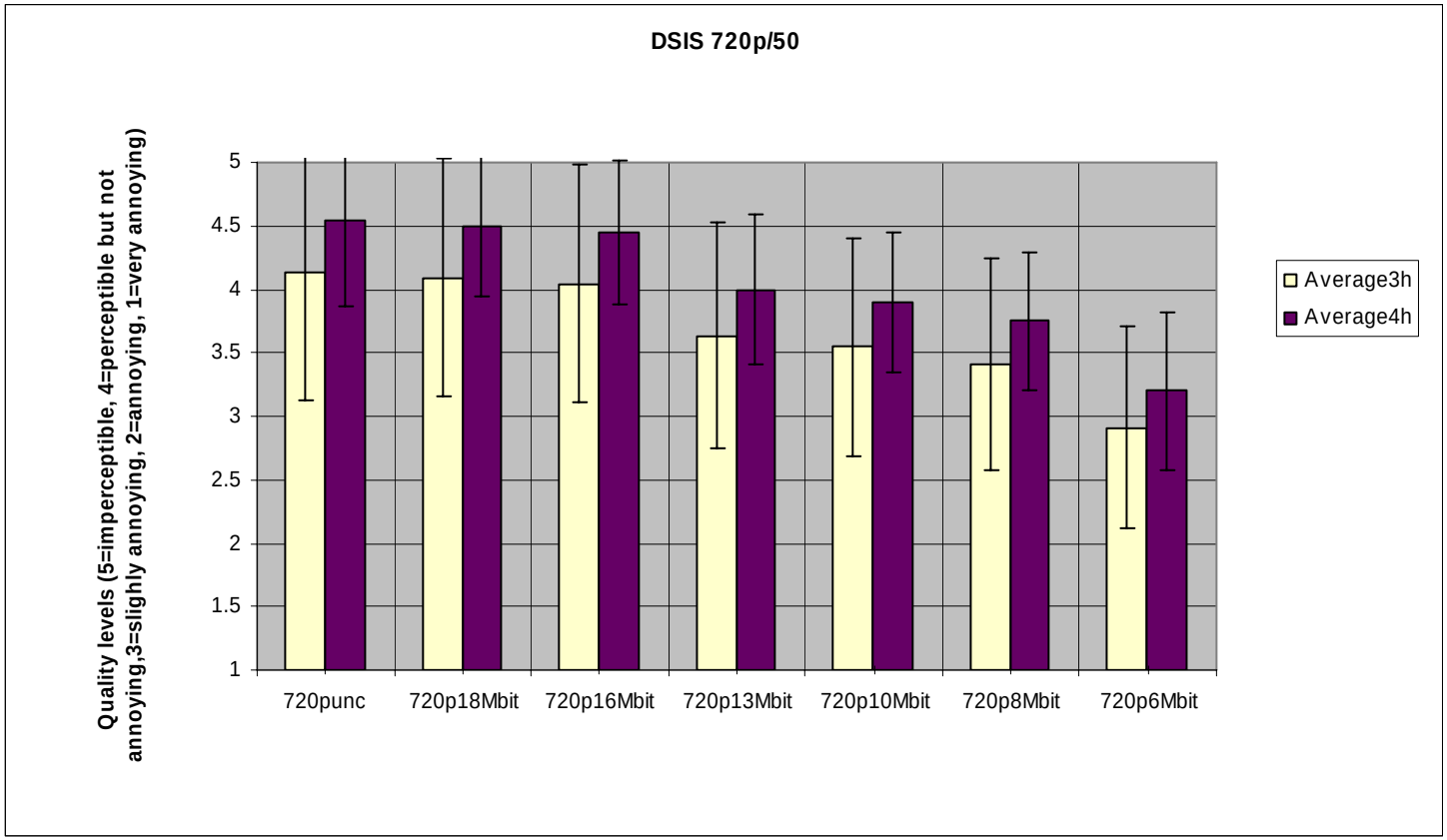


1080p/50 streamGOP structure analysed by Y. Nishida (NHK)

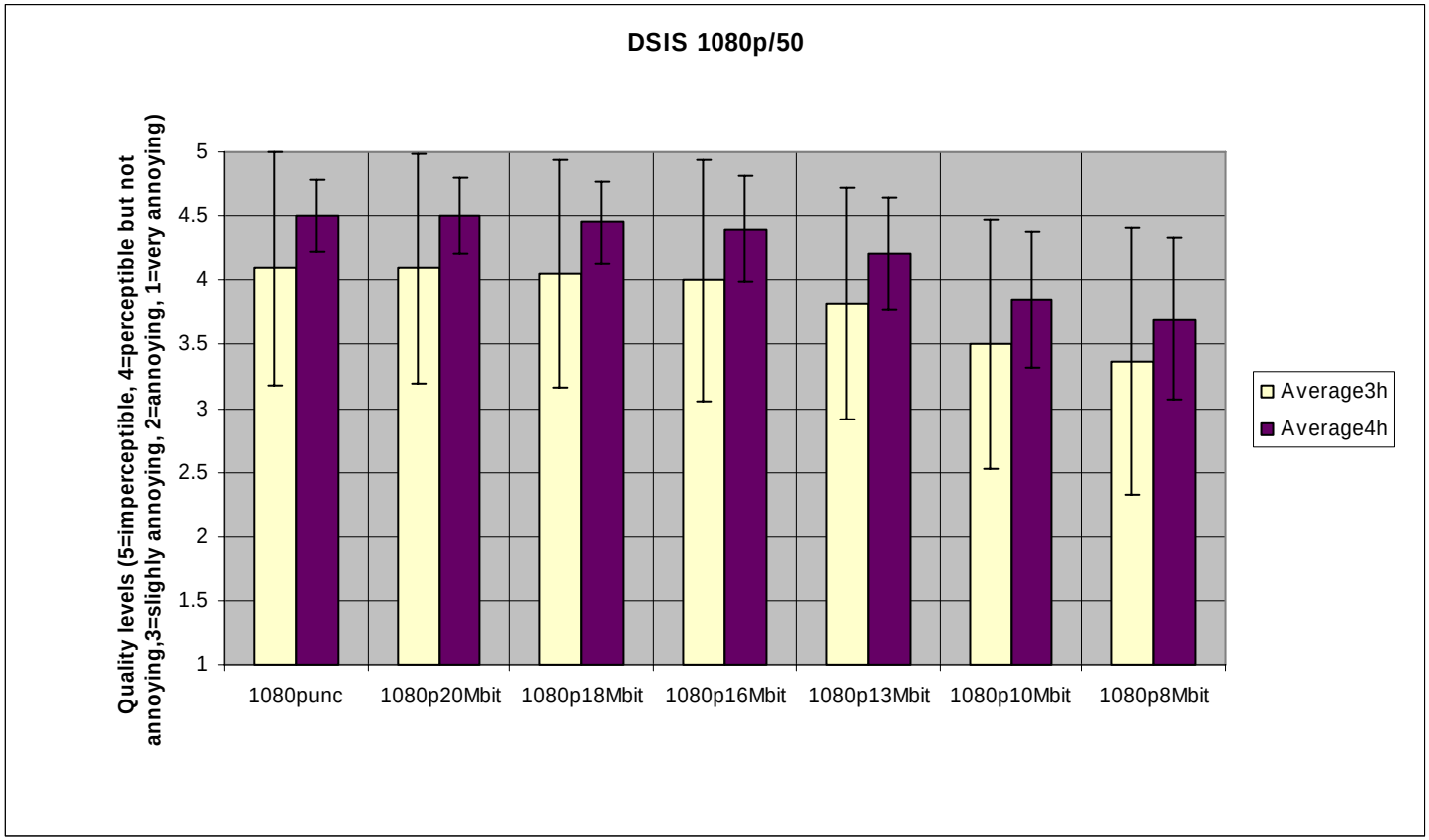
Results for 1080i/25



Results for 720p/50



Results for 1080p/50



Surprising results with these test conditions, content and settings

- 720p/50 enters the region of « slightly annoying » between 8 and 6 Mbit/s
- 1080i/25 enters the region of « slightly annoying » between 16 and 13 Mbit/s
- 1080p/50 enters the region of « slightly annoying » at < 8 Mbit/s
- The results of 1080p/50 are astonishing
  - At first sight we would have expected that 1080p/50 would require about 20% more bitrate than 1080i/25
- We need further testing with different content

Further DSIS tests

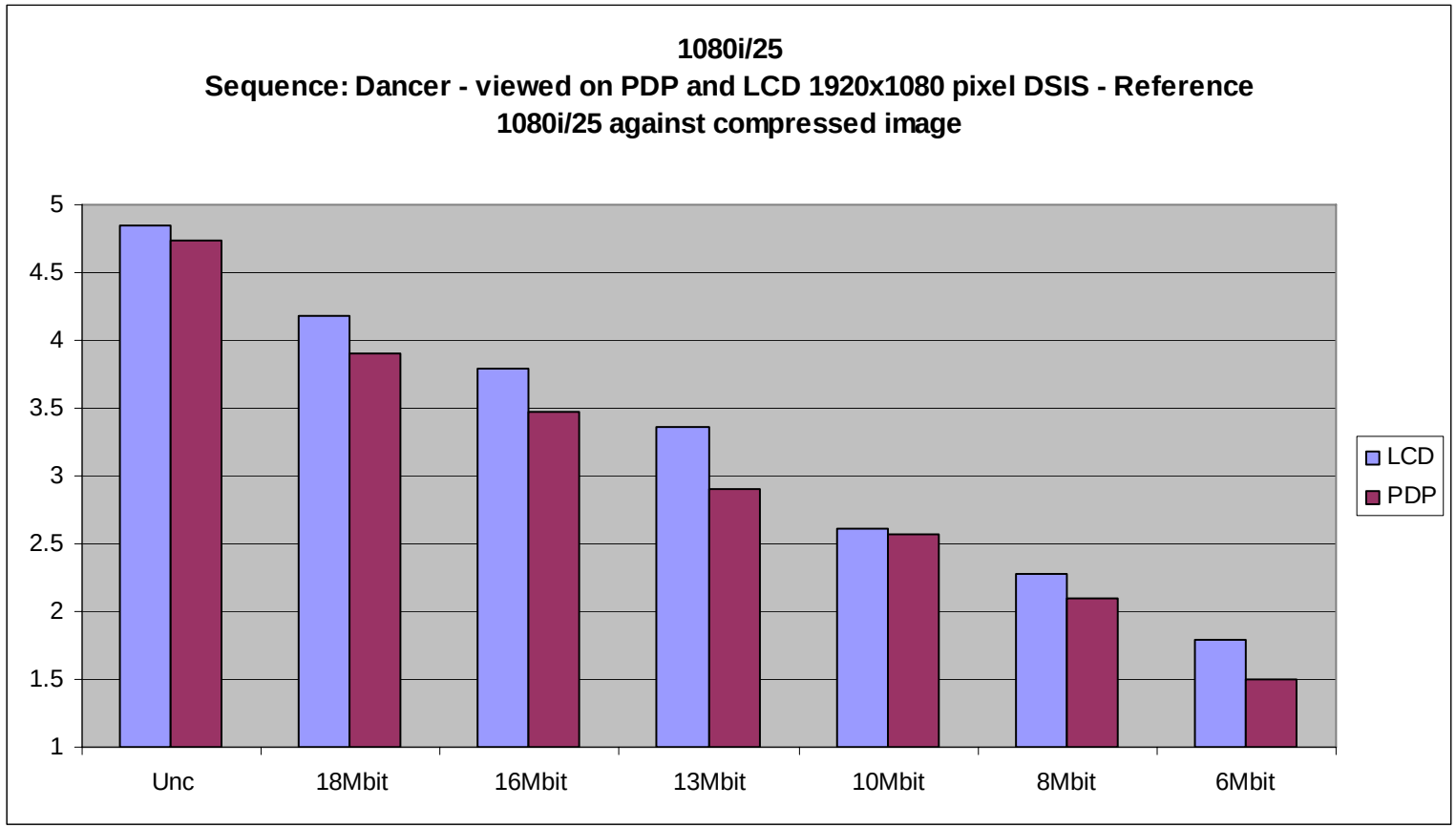
- About 72 students at the FH Wiesbaden
- Different content
  - another SVT sequence (scanned 2160p/50)
  - native 1080p/50 sequence shot with a 1080p/50 CCD camera
- DSIS on Full-HD PDP (50 inch) and LCD (52 inch)

Sequences

1080p/50 CCD

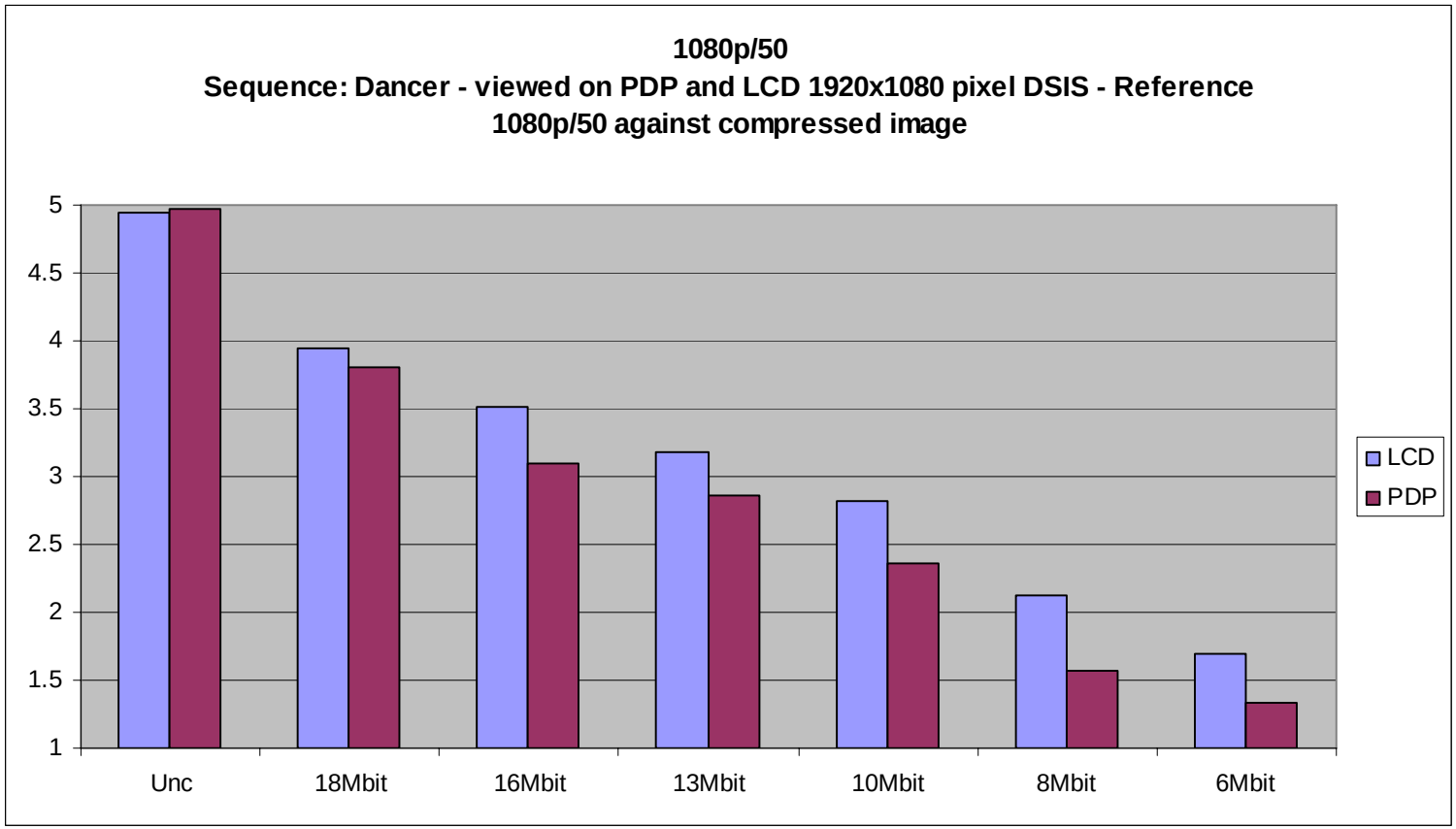
2160p/50

Results for 1080i/25 (Dancer)



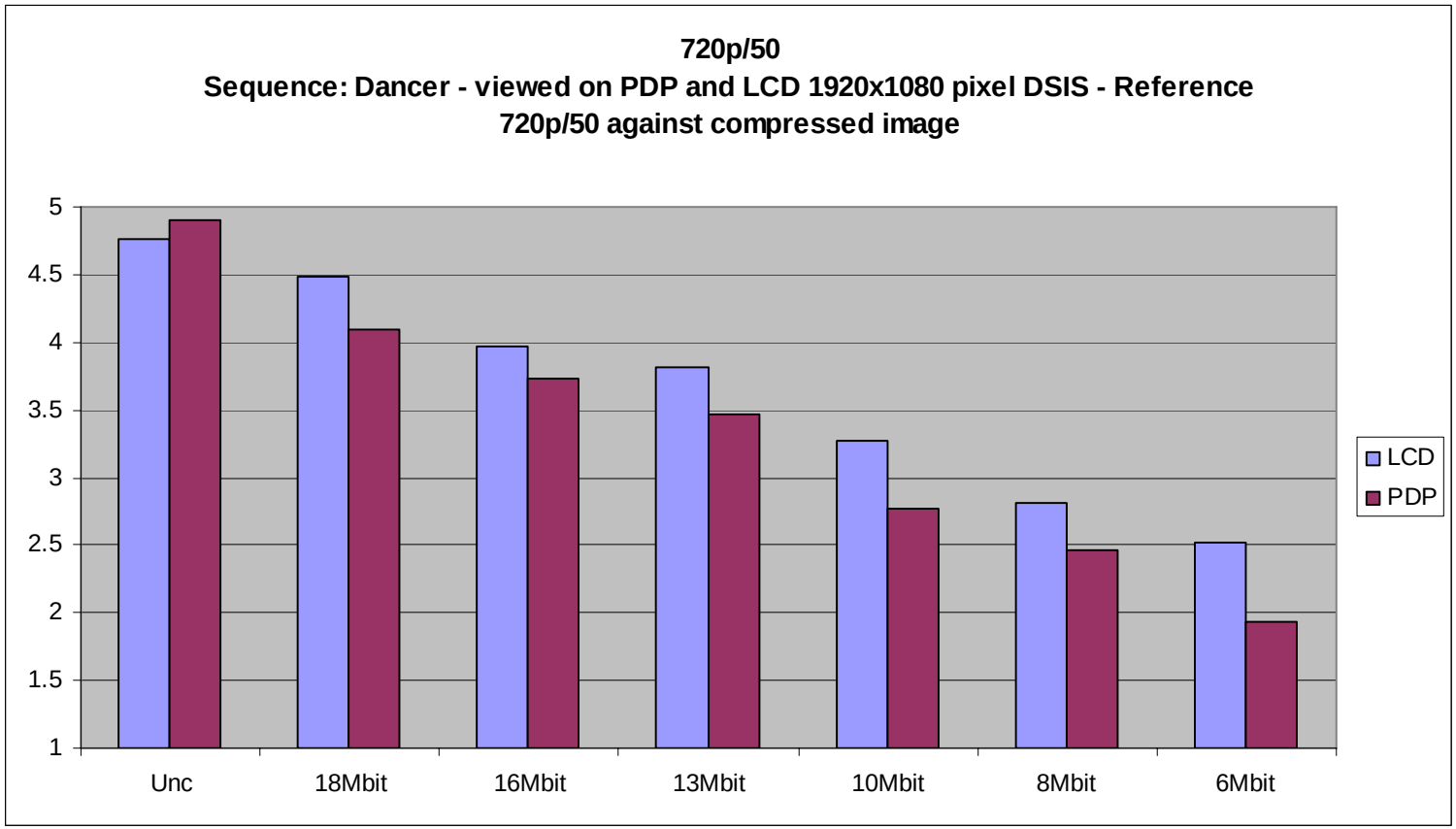
Average of 3h&4h

Results for 1080p/50 (Dancer)



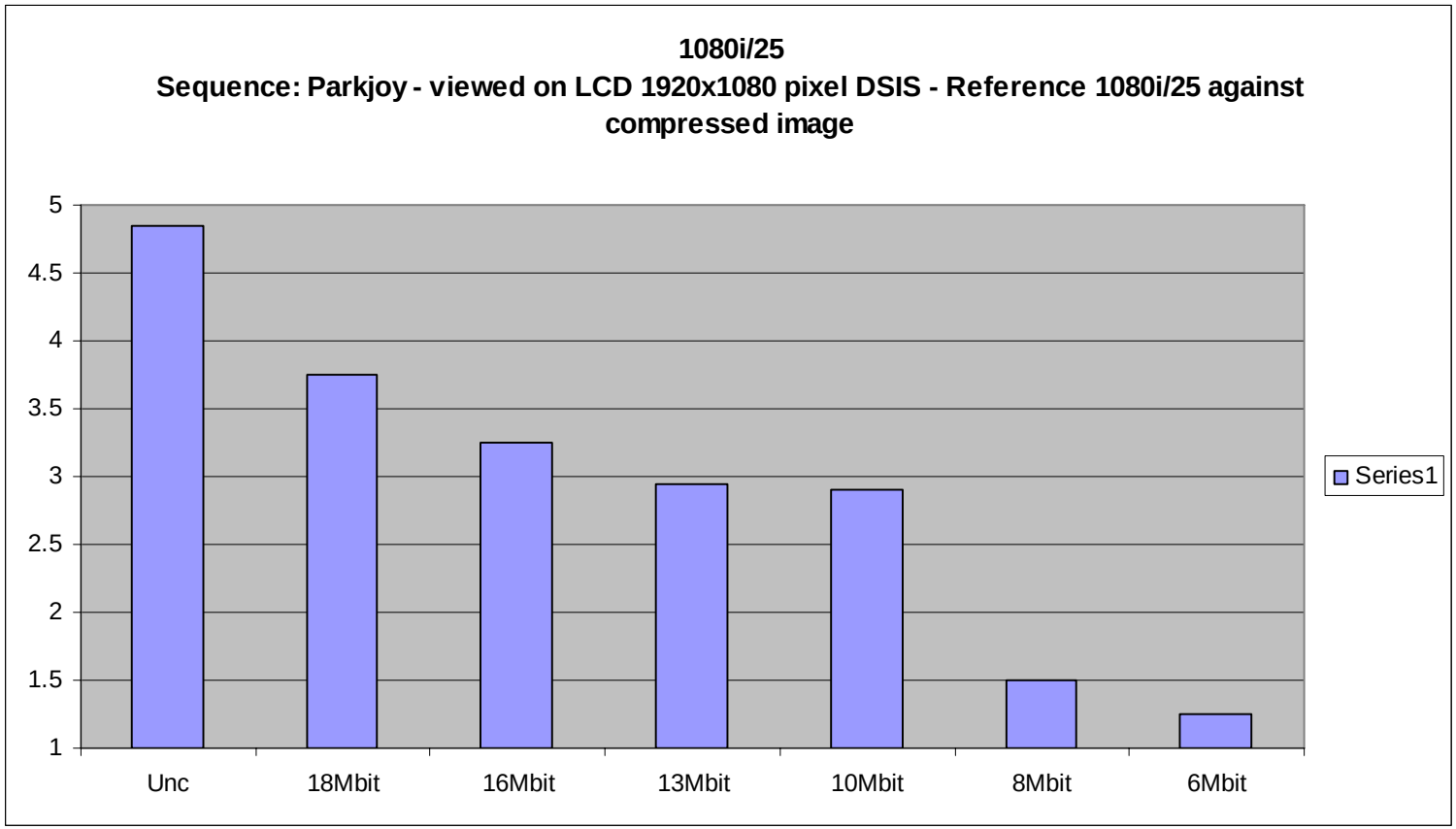
Average of 3h&4h

Results for 720p/50 (Dancer)



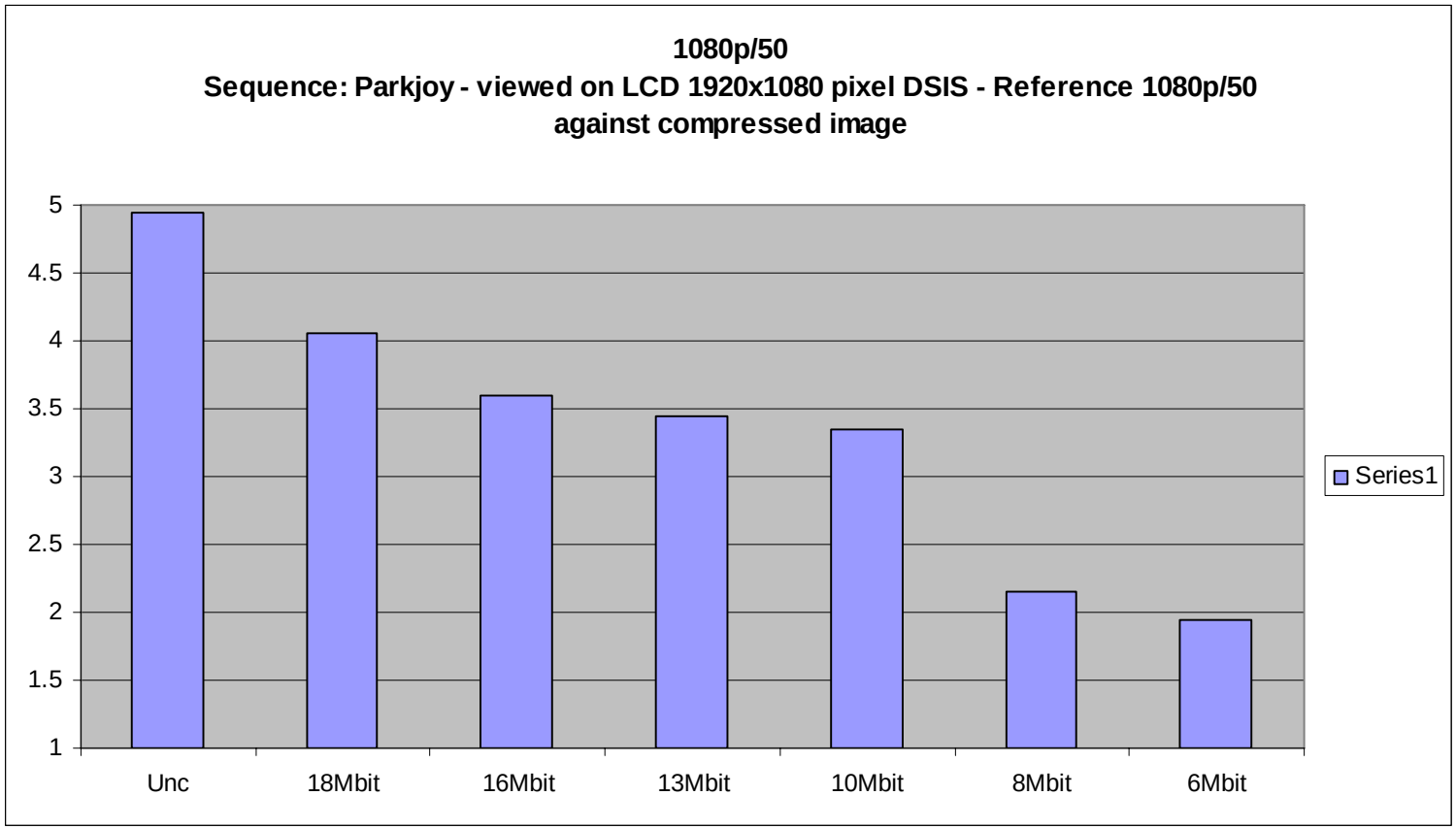
Average of 3h&4h

Results for 1080i/25 (Parkjoy)



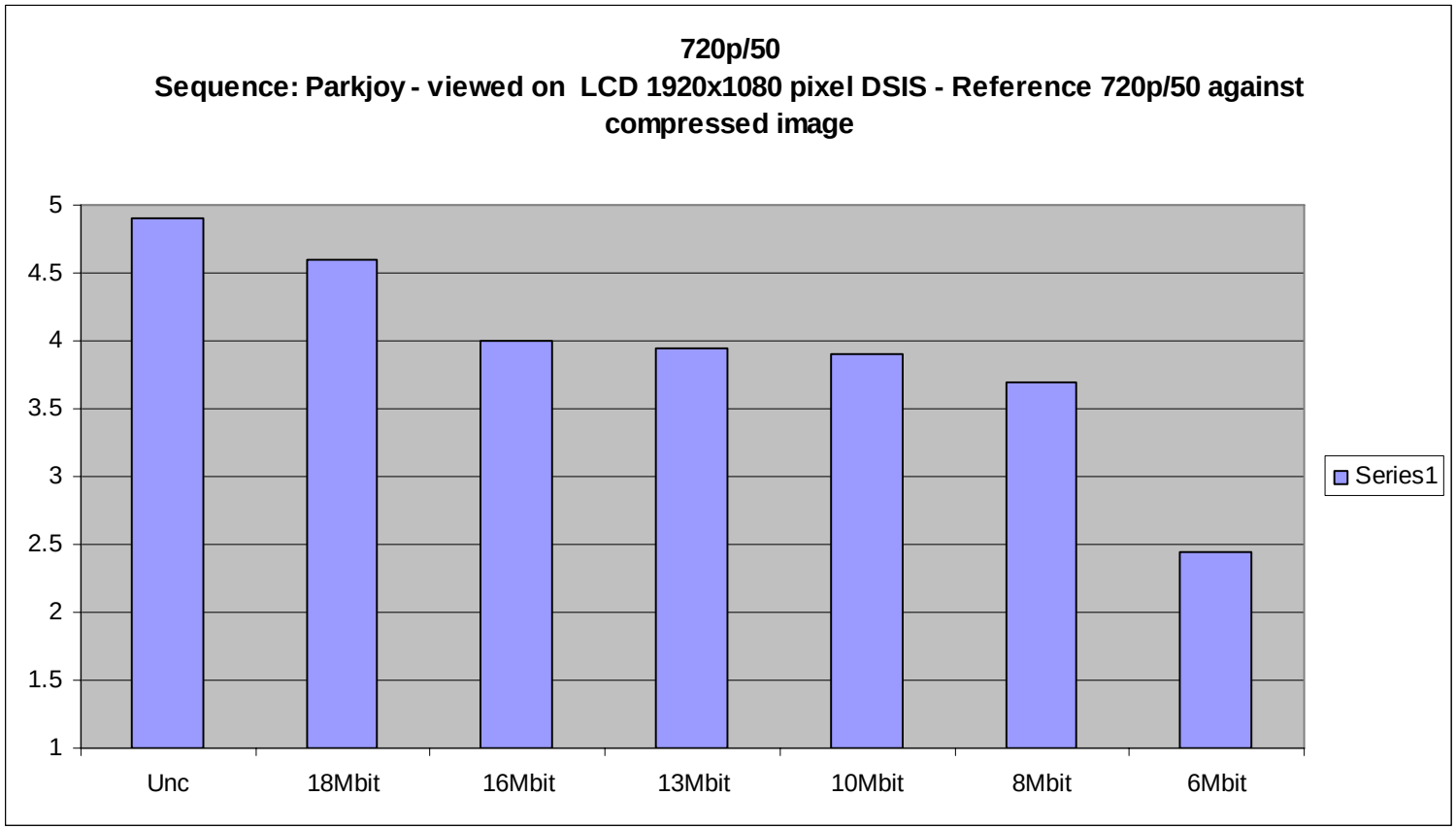
Average of 3h&4h

Results for 1080p/50 (Parkjoy)



Average of 3h&4h

Results for 720p/50 (Parkjoy)



Average of 3h&4h

Results of DSIS testing on 2nd and 3rd generation HDTV formats

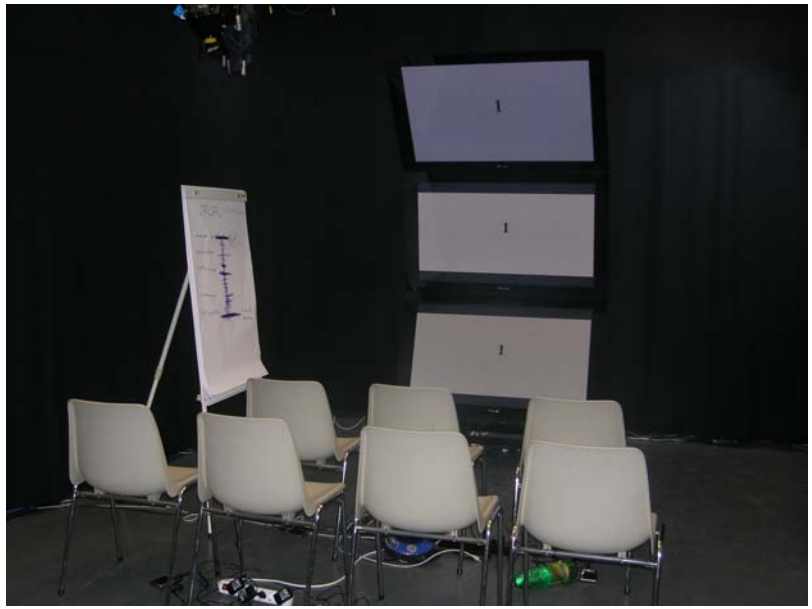
- For Dancer sequence (shot in 1080p/50)
  - 720p/50 failure characteristic performed best
  - 1080i/25 - 1080p/50 similar failure characteristics
- For SVT sequence ParkJoy (scanned 2160p/50)
  - Impact of oversampling of the source format became obvious
  - 720p/50 and 1080p/50 failure characteristics similar, but 720p was better for lower bit rates
  - 1080i/25 worst

Results of DSIS testing on 2nd and 3rd generation HDTV formats

- Issues:
  - The results are extremely content dependent
  - Failure characteristics of DSIS do not tell what format is better!!
  - we want a method where we can directly compare the different formats, because DSIS does always require that you compare to the uncompressed reference within the same HDTV format

New method for picture quality assessment (EBU II)

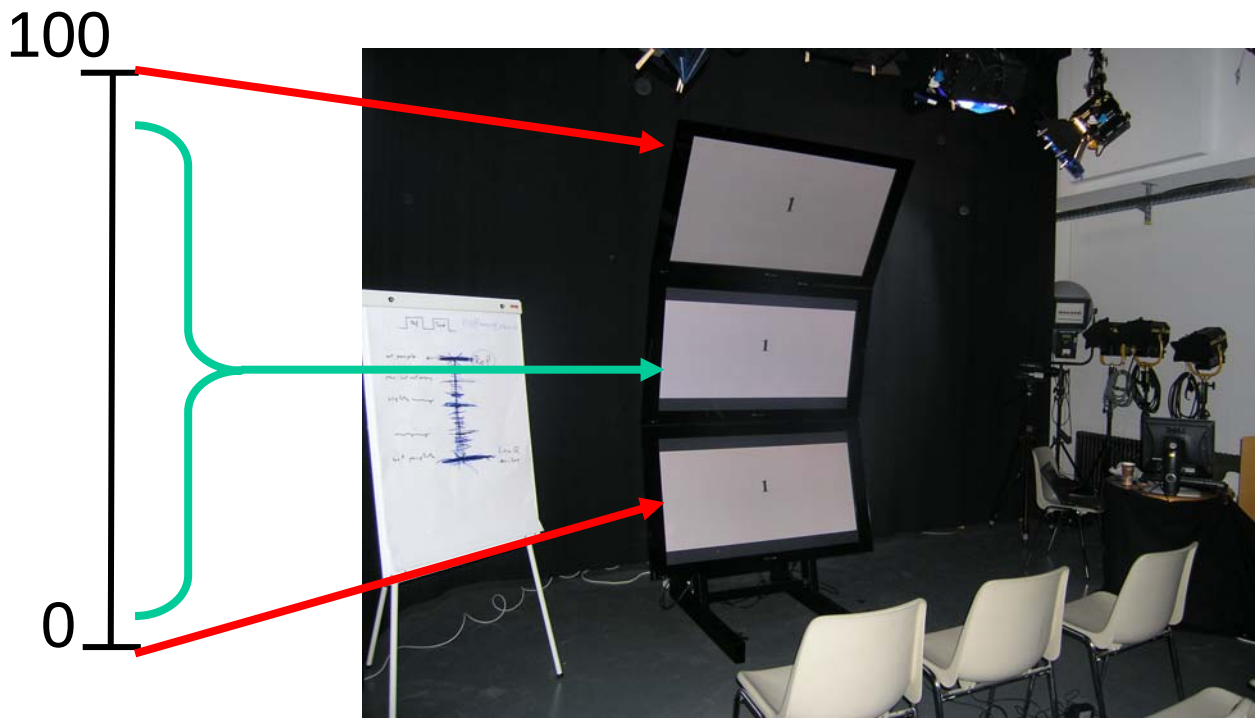
- Three display configuration with upper and lower anchor
- Upper anchor: 1080p/50 uncompressed
- Lower anchor: SDTV with defined impairment
- Middle display: pictures under test in various bit rates and orders and formats



Results of a test with EBU II
(Triple Stimulus Continuos Evaluation Scale)

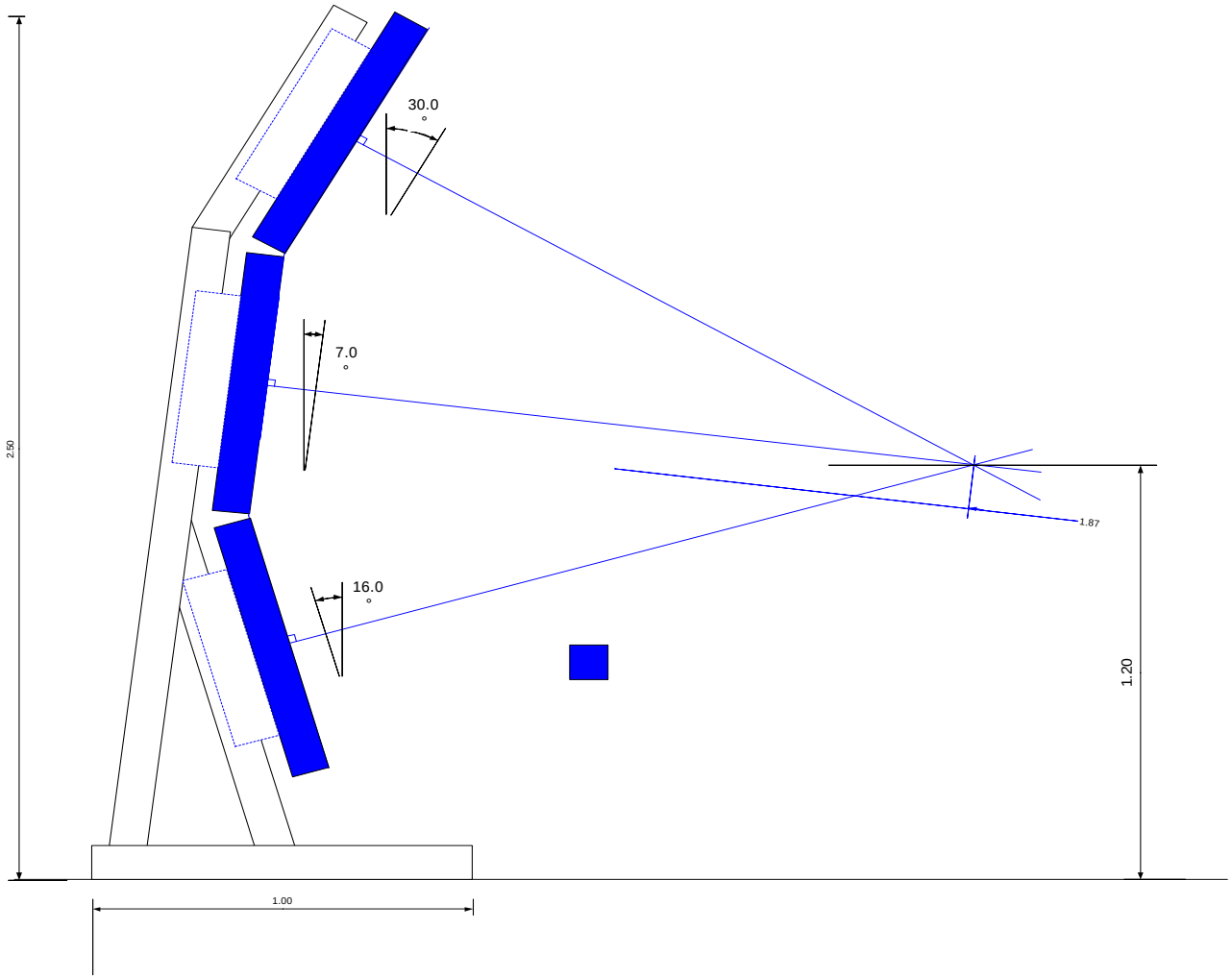
100 = 1080p/50 uncompressed

voting



0 = SDTV 3Mbit/s (todays TV)

Design and set-up for EBU II
(Triple Stimulus Continuos Evaluation Scale)

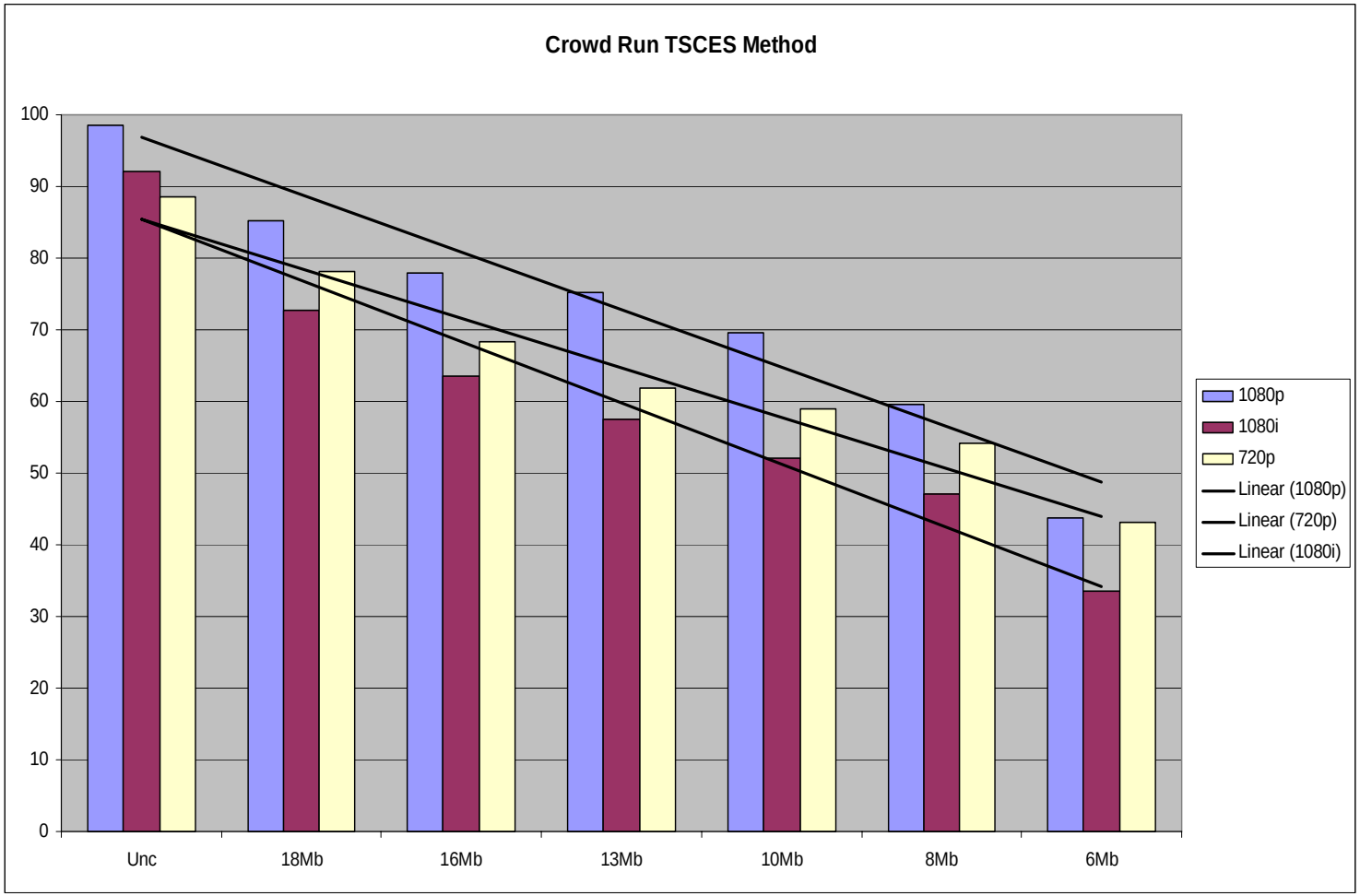


Technical drawing by Edgar Wilson EBU

Tests with TSCES Method – EBU II

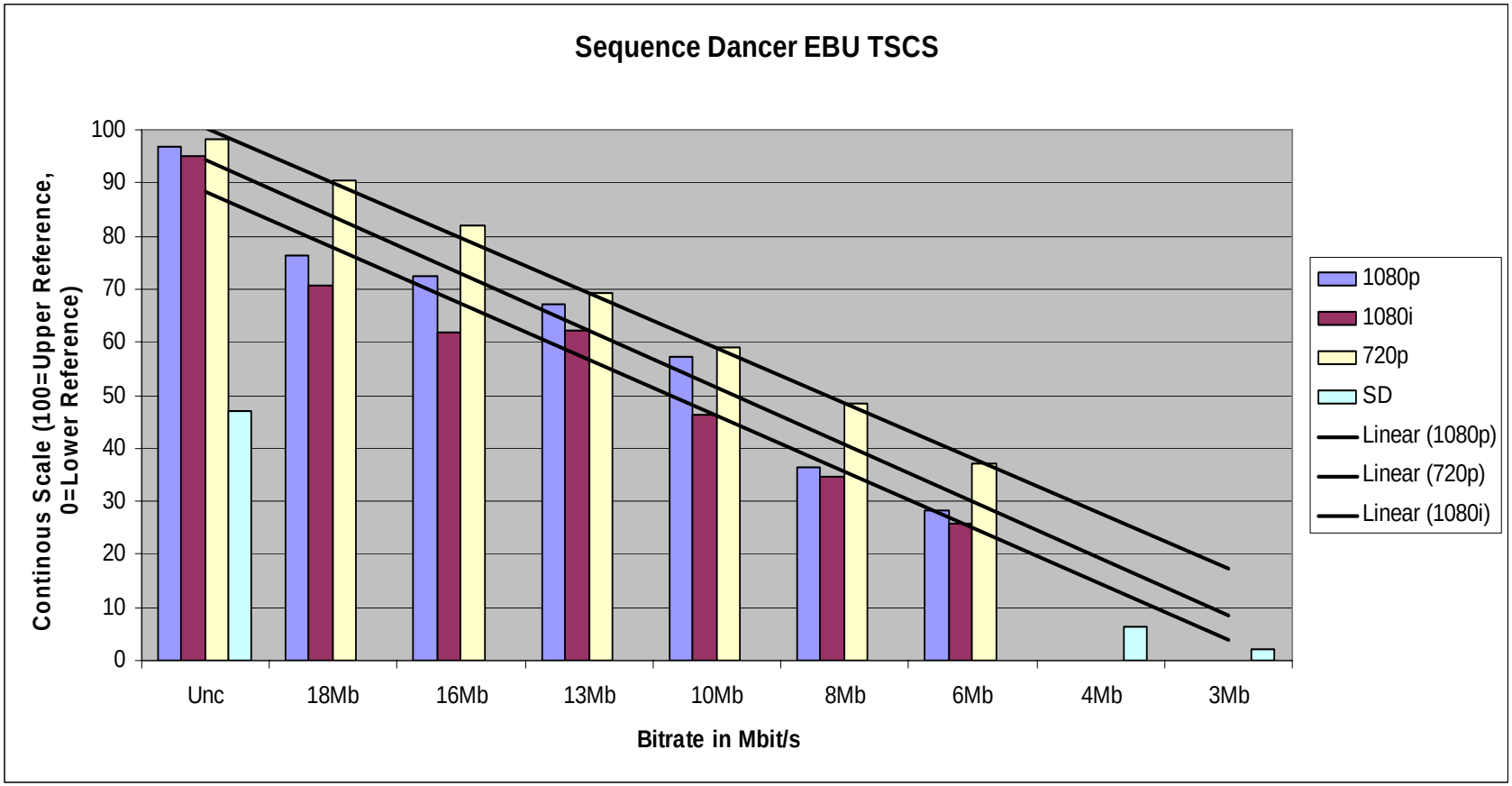
- 178 students at the FH Wiesbaden
- 173 valid votes
- standard deviation ~ 12% (half a grade of an ITU-R grade) on the raw data
- test of seven different content with different criticalities
  - originated on a HDC1500 CCD camera
  - originated on film 65mm/50fps and scanned to 2160p/50
- Raw data are presented (arithmetic mean), over all participants
- Hidden upper/lower anchor included

Individual sequence results with triple stimulus method – Crowd Run



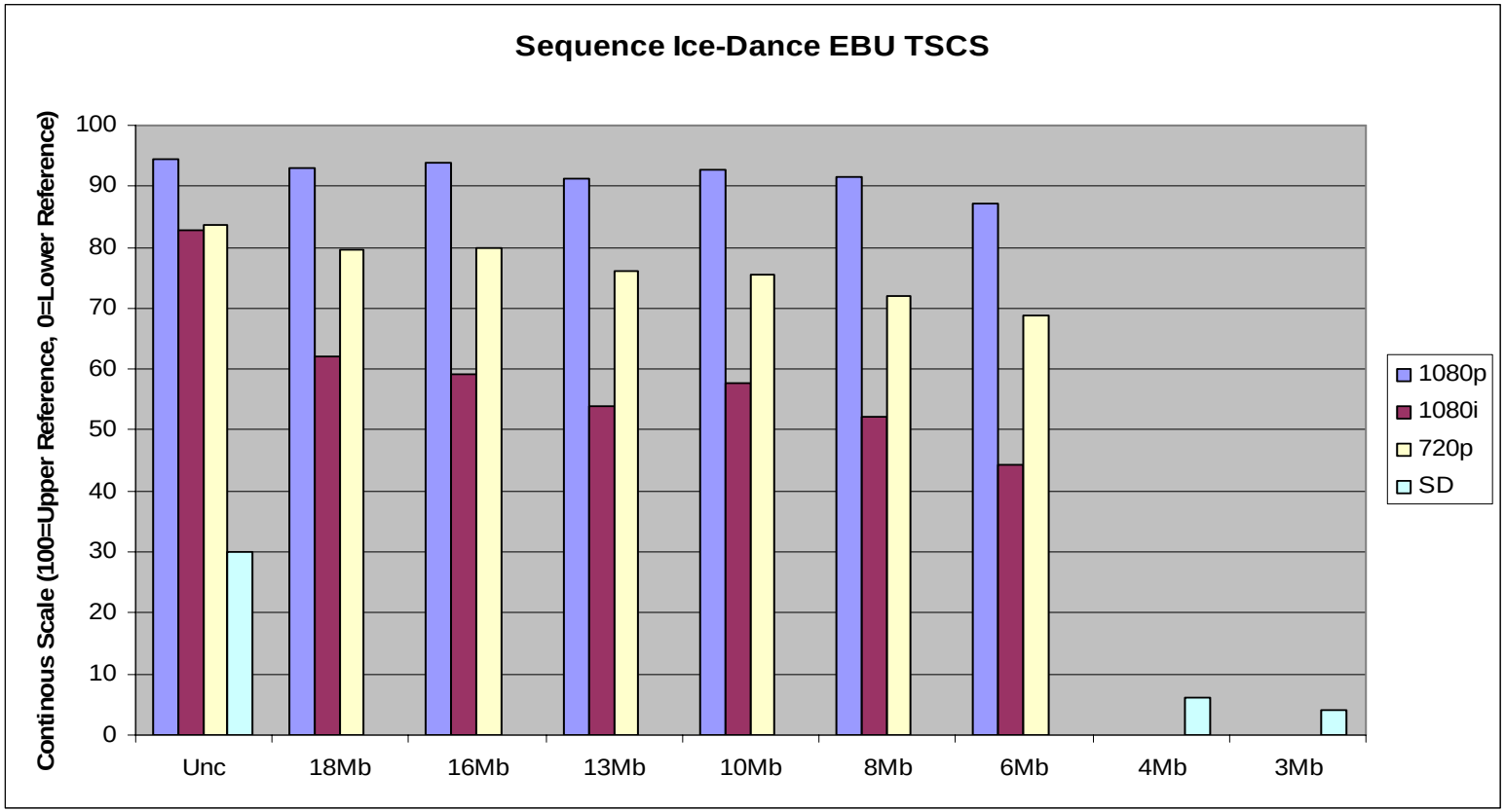
- Running crowd, no camera pan

Individual sequence results with triple stimulus method – Dancer



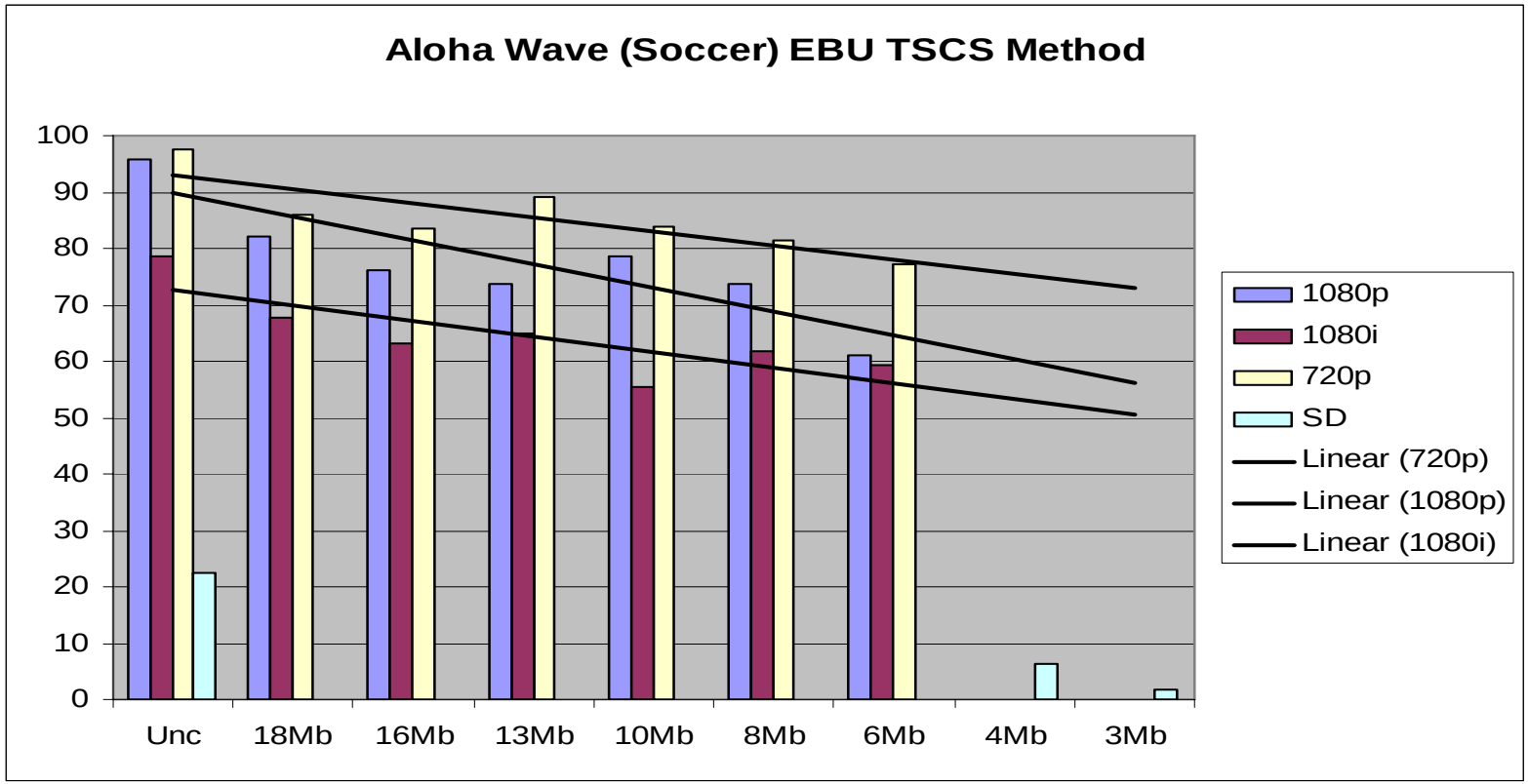
- Very critical sequence, but realistic TV programme

Individual sequence results with triple stimulus method – Ice-Dance



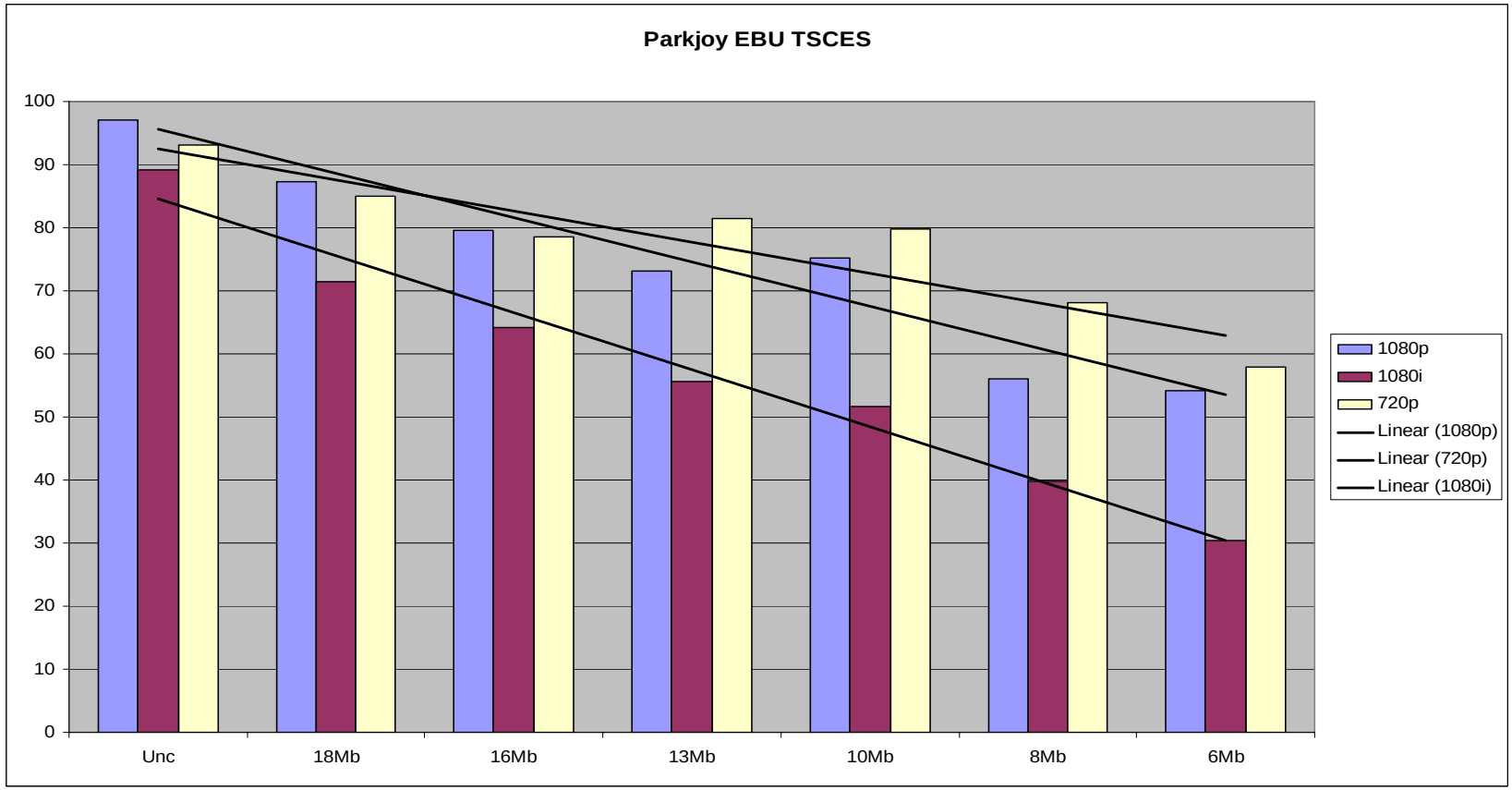
- Relative uncritical sequence, controlled environment type

Individual sequence results with triple stimulus method – Soccer Aloha



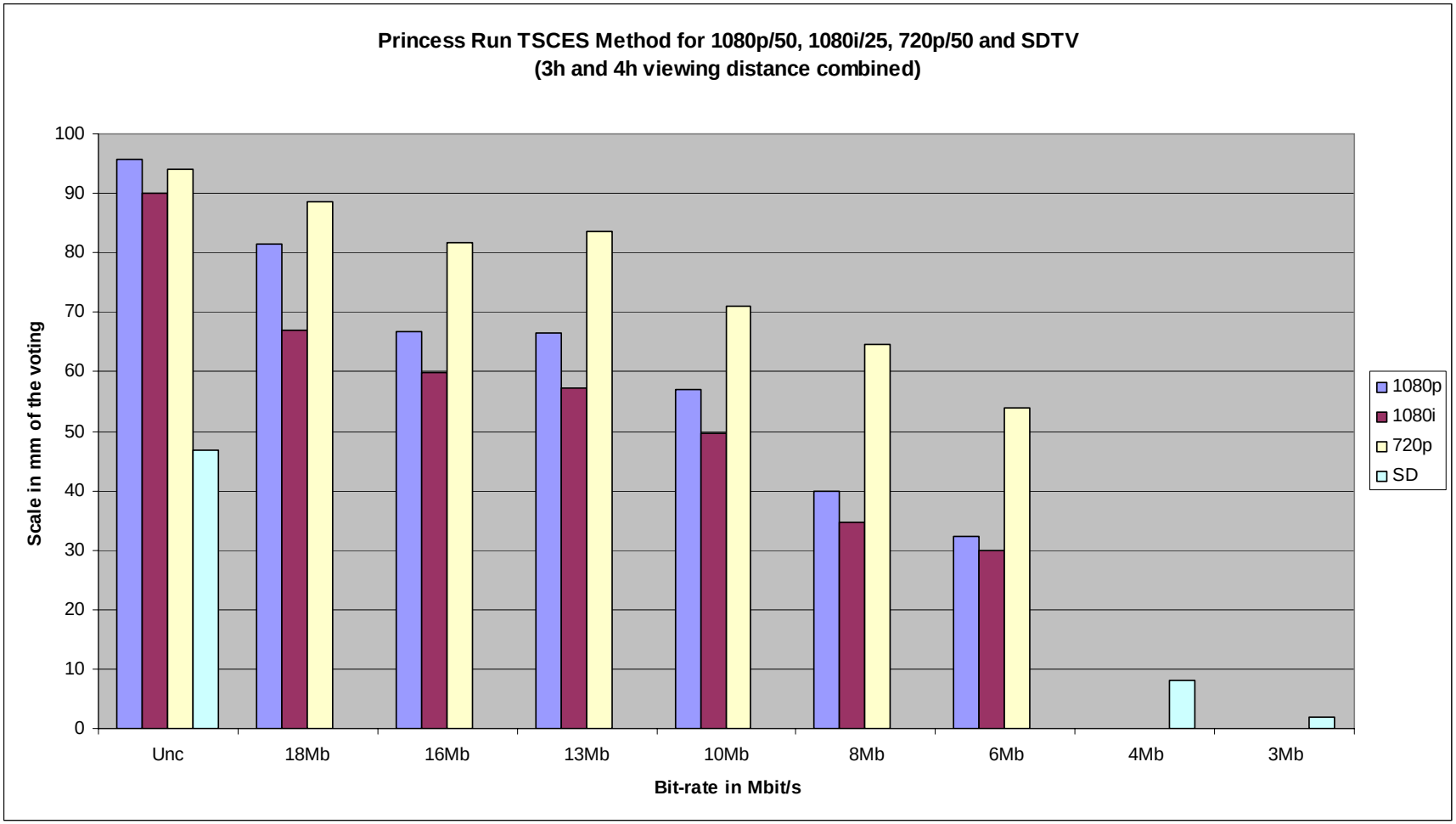
- Soccer – wide angle – aloha-wave in audience, not too critical

Individual sequence results with triple stimulus method – Parkjoy



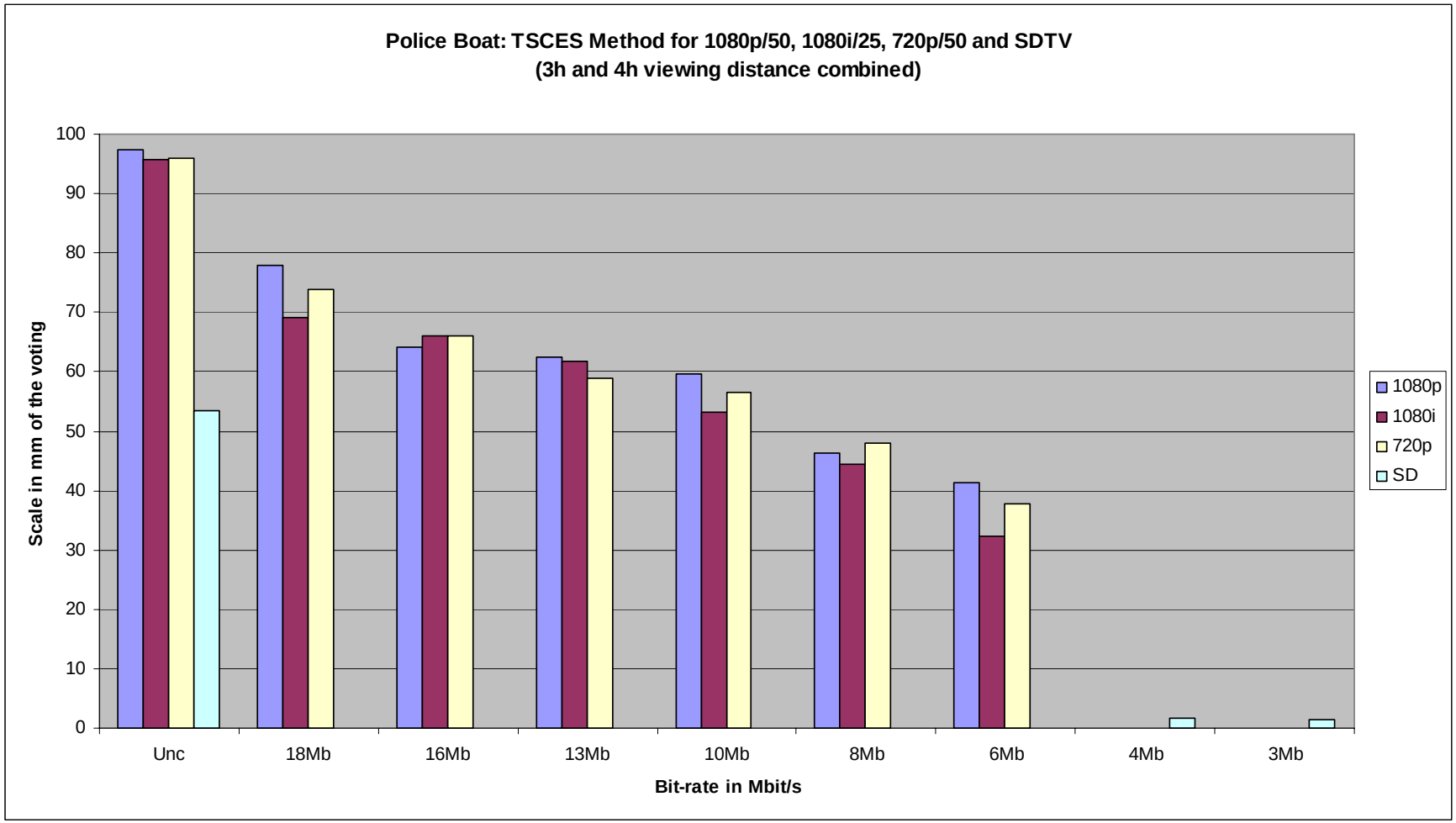
- See cross over point

Individual sequence results with triple stimulus method – Princess Run



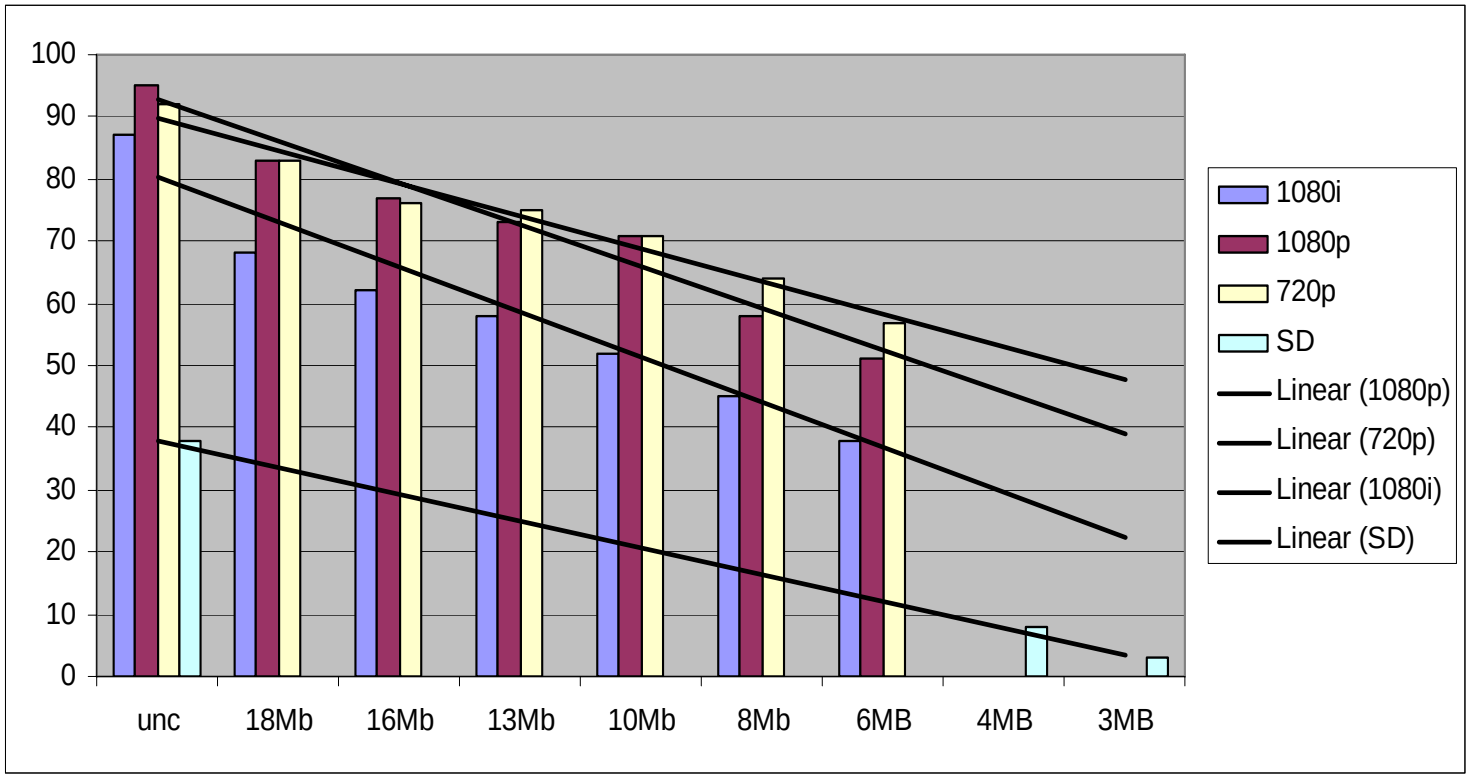
- Difficult to code

Individual sequence results with triple stimulus method – Police Boat



- Water, difficult to code and to rate
  – only sequence where all formats are close.

Over all 7 sequences



Demo 2 – compressed HDTV

- AVC software coding by the HHI Berlin
- 6, 10, 16 Mbit/s
- Source: HDC1500 CCD in 1080p/50 and SVT material 2160p/50 original
- 1080i25, 720p/50 and 1080p50
- Pay attention to sequences when the encoder becomes overloaded with information with the 1080p/50 format
- Try to find upscaling artefacts for 720p/50
- See artefacts caused by 1080i/25

Test conclusions (I)

- We should avoid interlaced in production and emission for HDTV – baseline requirement!
- Today, 720p/50 in emission provides the best bandwidth-quality trade-off for your £, $, € and for displays up to 50” (target for public?)
- Why not 1080p/50, yet ?
  - With higher criticality of the image the encoder becomes “overloaded” and the compression artefacts mask the advantages of higher resolution
  - Up-scaling at the display from 720p/50 to Full-HD does not lead to a significant visibility of impairments at 3h

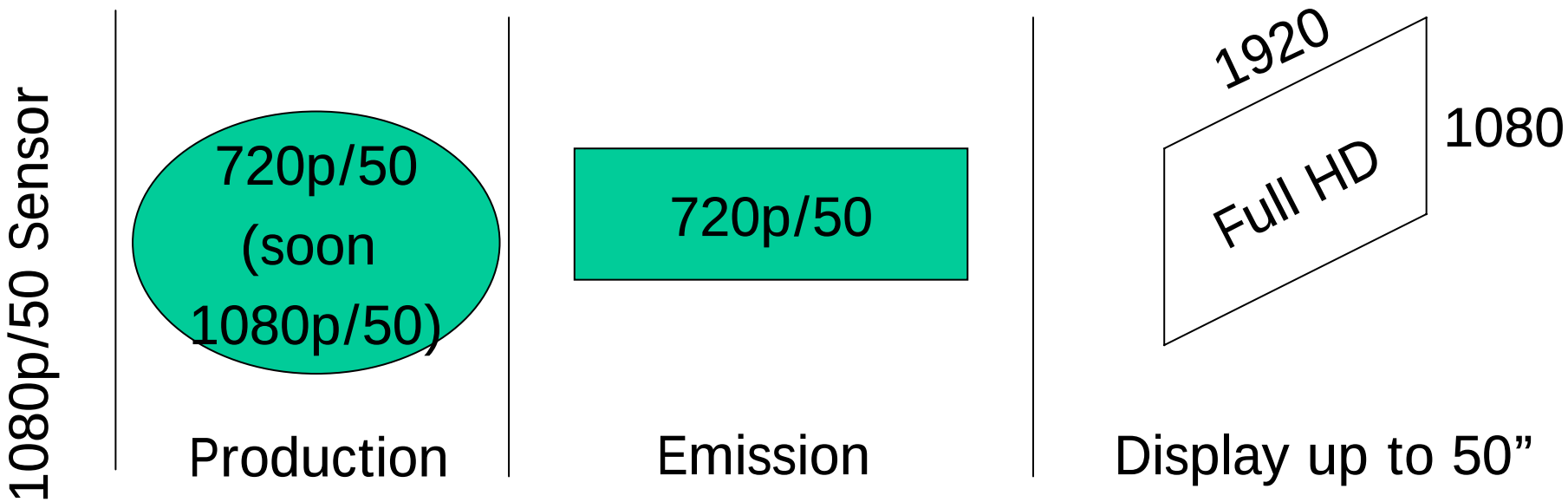
Test conclusions (I)

- With lower content criticality, we found that 1080p/50 can provide the best quality
- More work is required on the 1080p/50 coding - there is potential!

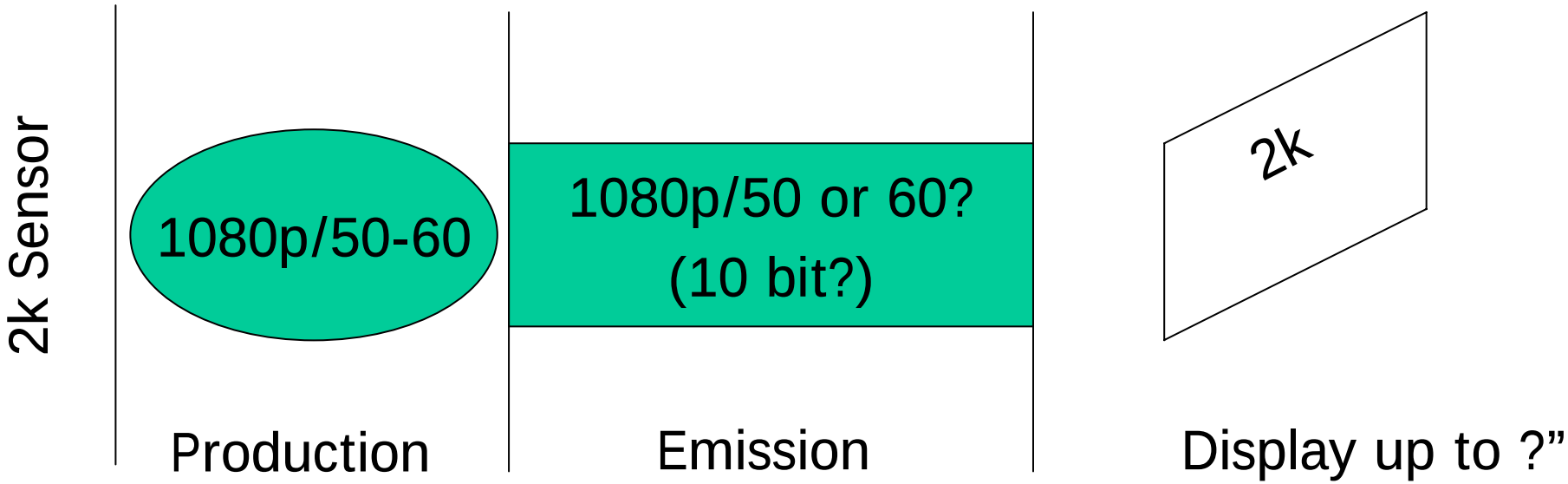
- Rule of thumb:
  - High spatial resolution at the capturing point
  - Spatial downsample for emission (or in production if not avoidable)
  - Spatial upsample at the display

Test conclusion (II)

- Best match **today** according to our results



For the day after tomorrow



Summary (Part 2)

- We presented initial research
- It would be good if others, independently could conduct similar investigations
- We need to study methods for 1080p/50 that are backward compatible in emission
- There is strong interest by several users
- Europe is a green field site with respect to HDTV
  - there is still a window of opportunity for a 3rd generation HDTV system in a time frame of about 5++ years
  - we can do better than the rest of the world!!!
- Personal advice: start with 720p/50 to gather experience with progressive productions at 50p and migrate to 1080p/50 when time comes

Part 3 – the future

- Ultra High Definition Television
- Stereoscopic Television – 3D stuff

3D Televsion

3D – digital Chain

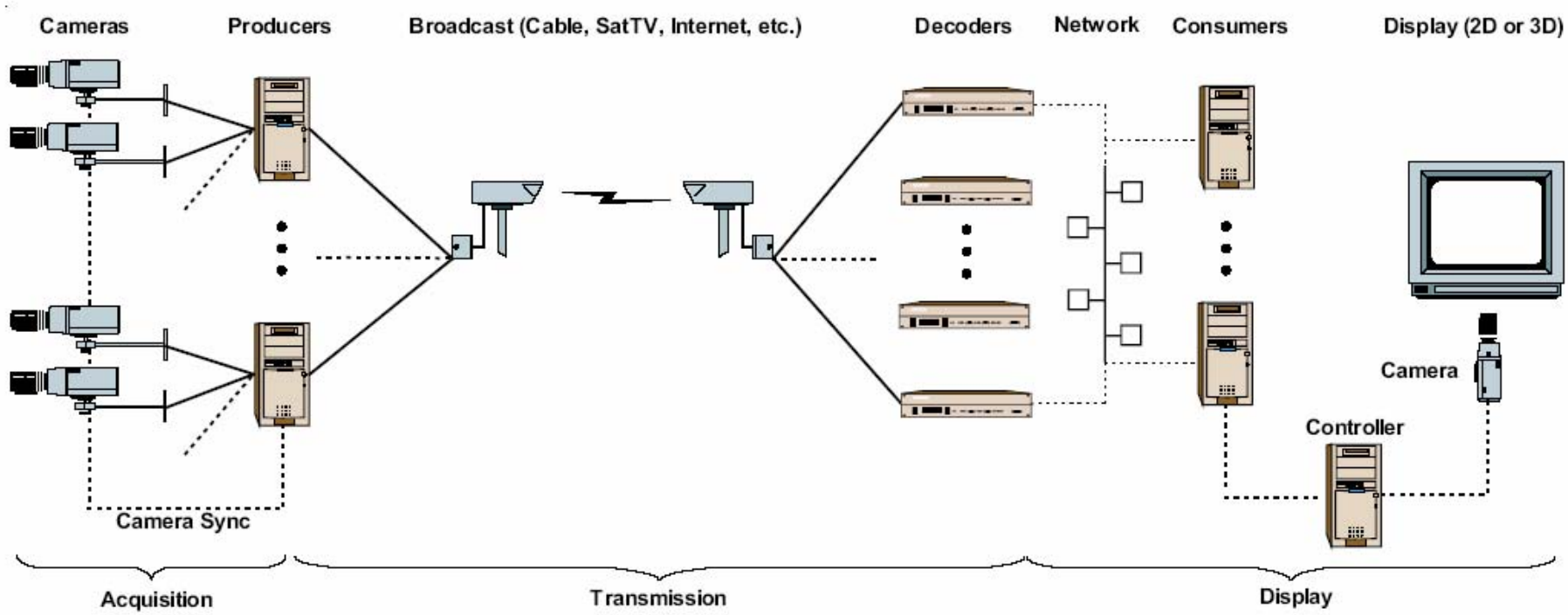


Fig. 1. *A scalable end-to-end 3D TV system.*

Anthony Vetro, Wojciech Matusik, Hanspeter Pfister, Jun Xin

Mitsubishi Electric Research Laboratories, Cambridge, MA

3D – Display issues

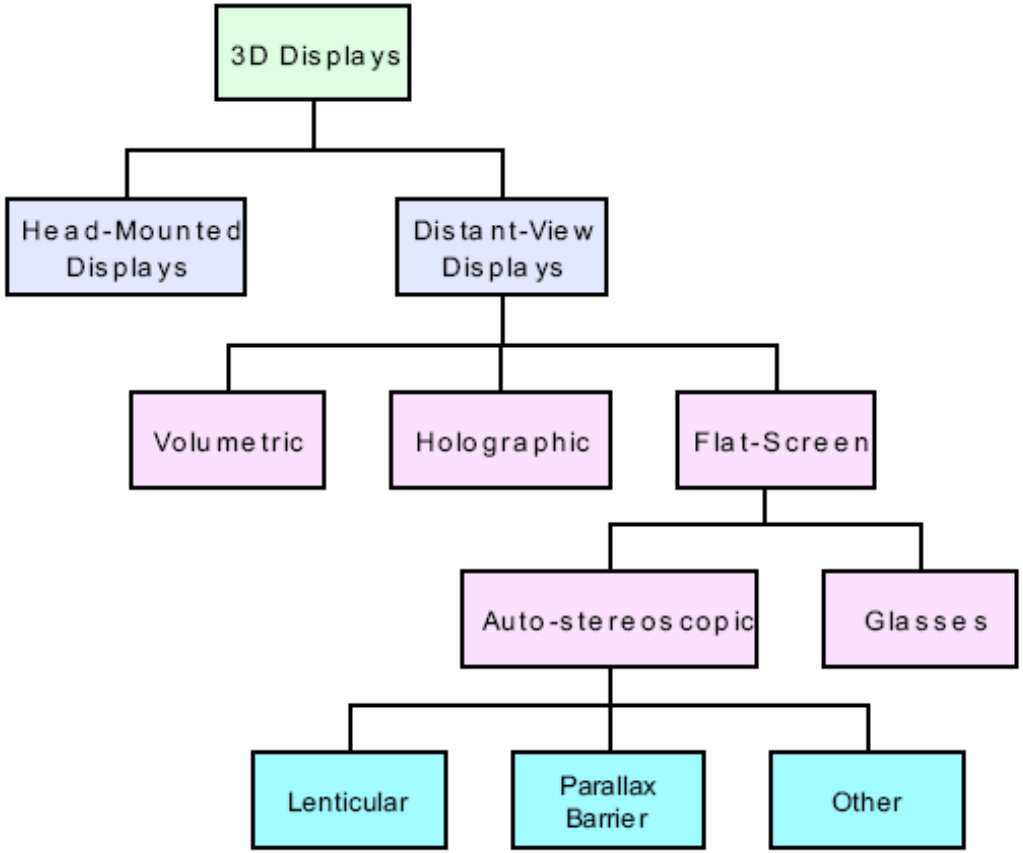


Fig. 2. *Overview of 3D display technologies.*

Anthony Vetro, Wojciech Matusik, Hanspeter Pfister, Jun Xin

Mitsubishi Electric Research Laboratories, Cambridge, MA

Opinion on 3D

- Depends strongly on the display side!
- How much 3D will consumer want for daily TV consumption?
- Game consoles soon
- Cinemas will follow
- Broadcasting?

Ultra High Definition Television

- Approach the limit of visual sensation
  - UHDTV: 100° x 85°
  - 1920x1080: 30° x 20°
- Resolution

UHDTV	7680x4320	Progressive 60p
DC formats	1920x1080 3840x2160 5760x3240 7680x4320	DC frame rates (new discussion in SMPTE DC groups)
HDTV	1920x1080	Progressive 50/60p (interlaced 25i)
HDTV	1280x720	Progressive 50/60p

Other issues on UHDTV

- Hierarchical system: multiple of 1080p
- Might use 1080p50/60 as emission format (speculation)
- According to Masayuki Sugawara (NHK):
  - 20-25 years from Nov. 2007 on

Summary

- Today's issues on HDTV have been presented
  - it is a challenge for broadcasters to move to HDTV productions whilst maintaining the HDTV quality – (danger: no HDTV light)
  - progressive scan with 50p is the way forward
  - avoid interlaced, avoid interlaced, avoid interlaced (and don't get it into the archives)
- 1080p/50 is an option for future productions (5++ years)
  - we need research for emission applications
- The question on what comes next is open
  - 3D and UHDTV or something in between.....
  - why is nobody looking into higher frame-rates.....