The transition to ATSC 3.0

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Making the ATSC 3.0 transition

- The need for channel sharing
- ATSC 1.0 Channel Sharing
- ATSC 3.0 Channel Sharing
- The basics of statistical multiplexing

Channel Sharing: Lighthouses and Nightlights

- ATSC 3.0 will require extensive channel sharing
- Most stations will need at least two shares: ATSC 1.0 and ATSC 3.0
- Bit rate agreements are difficult and often reflect a lack of knowledge of how statistical multiplexing works
- Fair agreements need to address time as well as rate
- The interconnection between stations is often overlooked until its too late…..
  - The interconnection often drives both cost and video quality (for good or bad)
  - Reusing an ATSC 1.0 signal for ATSC 3.0 defeats the whole purpose of ATSC 3.0
  - Poor channel share implementations degrade quality and reduce useable channel count

How can we make ATSC 1.0 work for the nightlights?

ATSC 1.0 Channel Sharing

- The ATSC conversion is driven by channel sharing

- During each phase ATSC 1.0 will usually be the limiting factor

- The FCC requires that ATSC 1.0 coverage must retain 95% of the audience
  - Applies to the primary channel
  - This may eliminate some hosts if their coverage is less

- Most stations want to retain all of their existing channels

- ATSC 3.0 can (usually) carry more channels than ATSC 1.0

- Spreading shared ATSC 1.0 channels across several stations can optimize VQ

- A market wide approach is best
  - station pairing offers too little ATSC 1.0 capacity

- The ATSC 1.0 Nightlight will evolve as the 3.0 audience grows

MPEG 2 Efficiency Improvements

- MPEG codecs, MPEG2, AVC, HEVC all specify the <u>decoder</u>

- MPEG 2 encoders are <u>still</u> improving

- HD has improved more than SD
  - Within MPEG2
  - AVC and HEVC also favor higher resolutions

- MPEG 2 HD encoding efficiency is about double what it was in 1999

- Improvements generally fall into categories:
  - Codec, Statmux, Filtering

- Major leaps are rare, but there have been several:
  - Optimized Variable GOP (Codec)
  - Lookahead and multiple lookahead (Statmux & Filters)
  - MCTF (motion compensated temporal) (filter)
  - Single slice (codec)

- But….Most improvements are small but cumulative: 1% or 2% at a time

What bitrate do I need?

- ## There is no real answer!

  - Basic parameters:
    - minimum
    - maximum
    - priority
    - total pool size / # of services

  - The bitrate for a given quality level depends on:
    - Video format (1080i, 720p etc.)
    - Content: Sports, Entertainment, Film, Hand animated, Computer animated…
    - Your taste
    - The market size

  - In ATSC 1.0 the number of channels considered to have acceptable quality (by their management) varies widely

    – Examples:

      - Small market channel share (3 way, 2 independent + Public TV): 3 HD + 7 SD

      - Large market (O&O): 2 HD + 5 SD (limited sports)

      - Large market (O&O): 2 HD + 2 SD (Sports on both HD's)

  - In the end the quality must be appropriate for the content

  - It must serve the interests of the staion(s) and the public

Making the ATSC 1.0 share work

- More stations = more opportunity to optimize the mix of channels on the 1.0 stations

- The primary HD channel shares represent opportunity for Public and Independent stations
  - These stations often don't carry sports
  - Bitrate agreements are difficult, often its more productive to treat bitrates as a fallback
  - The primary agreement should allow optimization of the encoding system,
    i.e. maximize overall VQ first

- It is possible to fit two HD channels even with simultaneous sporting events
  - There are many examples from the spectrum auction
  - Controlling the rate of any accompanying SD channels is critical
  - HD sharing with HD is often more efficient than a mix of HD and SD

- Rather than try to specify SD bitrates, it is often better to treat them as equal, but with less priority than the primary channels

Things to consider in a contract

- Never specify a "minimum" bitrate. This = CBR

- Average is better
  - Average over what time frame?
    - Consider a day, or a week to allow for sporting events
    - Tools are available to log bitrates
    - It is possible to have deterministic average bitrates
      But letting the encoder decide often offers better performance

- Specifying equal settings is often more efficient than trying to specify bitrates
  - Equal settings should provide equal VQ if the encoder is well designed
  - The contract can contain language based on bitrates to settle disputes if necessary

- Split the channels into groups, settings for the primary channels, other settings for the secondary channels

- Bitrate logging with adjustment good faith agreement can allow higher quality for all
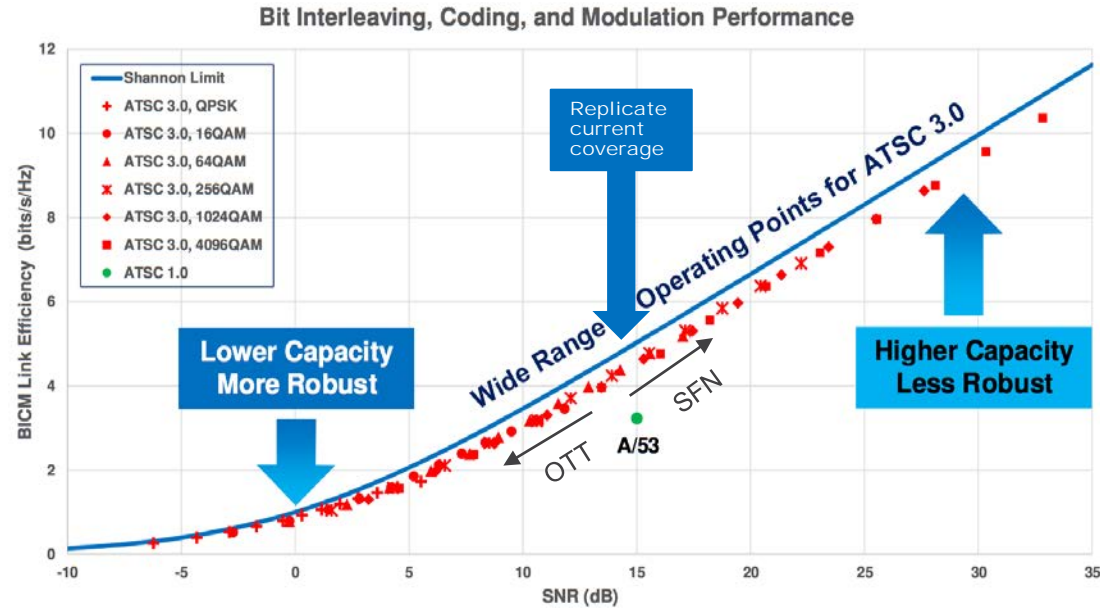
ATSC 3.0 Rollout

ATSC 3.0 transition over time

- The initial rollout period (2019 – late 2020)
  - Few 3.0 TV's
  - Service is required to kick start the consumer market
  - Occasional UHD / HDR special programming will become available

- Full service (2021 2022)
  - Quality and services must clearly distinguish 3.0 as an improvement over 1.0
  - Network programming should be available 1080p HDR
  - SFN and OTT hybrid transmissions can improve quality and quantity of services

- Crossover
  - The number of 3.0 households will eventually crossover 1.0
  - MVPD's will eventually carry 3.0 services
  - Some of the 1.0 stations will convert, placing new demands on the remaining nightlights
  - Eventually 1.0 service will be reduced as stations reach the 5 year timeout, assuming 3.0 is more profitable

PLP's: A lot of choices

- Physical Layer Pipes
  - Use up to 4 PLP's
  - Each PLP can have different modulation and bandwidth
  - The parameters for each PLP are chosen for specific services
  - Indoor, mobile, portable services require robust modulation
  - UHD or high channel count HD may require less robust modulation in order to carry enough bits
  - Single Frequency Networks may support different choices than a single transmitter
  - A robust PLP for service announcement can extend OTT availability
- A single PLP in the middle of the range will yield 24 to 26 Mb/s

Bit Interleaving, Coding, and Modulation Performance

Legend:
- Shannon Limit
- ATSC 3.0, QPSK
- ATSC 3.0, 16QAM
- ATSC 3.0, 64QAM
- ATSC 3.0, 256QAM
- ATSC 3.0, 1024QAM
- ATSC 3.0, 4096QAM
- ATSC 1.0

Y-axis: BICM Link Efficiency (bits/s/Hz)
X-axis: SNR (dB)

Replicate current coverage

Wide Range Operating Points for ATSC 3.0

Lower Capacity More Robust

Higher Capacity Less Robust

OTT   SFN   A/53

ATSC 3.0 Lighthouse

- Assumptions:
  - 25 Mb/s
  - Stations transmit 1080p59.9
  - Statistical multiplexing is used
  - Capacity for a single transmitter will likely be 4 to 6 primary channels
  - 720p59.9 for some stations would increase this capacity

- In the initial rollout the goal is likely to replicate the primary ATSC 1.0 services
  - The goal should be to very quickly achieve better quality than the ATSC 1.0 services
  - This is the time to eliminate Interlace
  - Reusing the ATSC 1.0 transmission is only OK until there are TV's available

- UHD will be an issue
  - Useful bitrates for UHD are 2 to 3 times the 1080p rates
  - Typical transmitter configurations will not allow for UHD along with full carriage of 3 or 4 1080p59.9

Why you may need Hybrid sooner than later

- Some networks will have occasional UHD content as early as 2020
  - Consumer electronics manufacturers will advertise UHD TV's
  - Local Electronics stores and chains will advertise with cooperative dollars
  - A shared transmitter will probably not have enough bandwidth for UHD, certainly not two
  - OTT delivery can provide the necessary bandwidth without equipment budget
- Many shared transmitters will not have space for secondary channels
  - These channels can be transmit OTT with **no** transmitter bandwidth
  - Secondary channels can be in HD when delivered via OTT
- Early adaptor consumers will set the tone for the rollout
  - Early adopters need to see a difference between ATSC 1.0 and 3.0

Hybrid Broadcast / Broadband
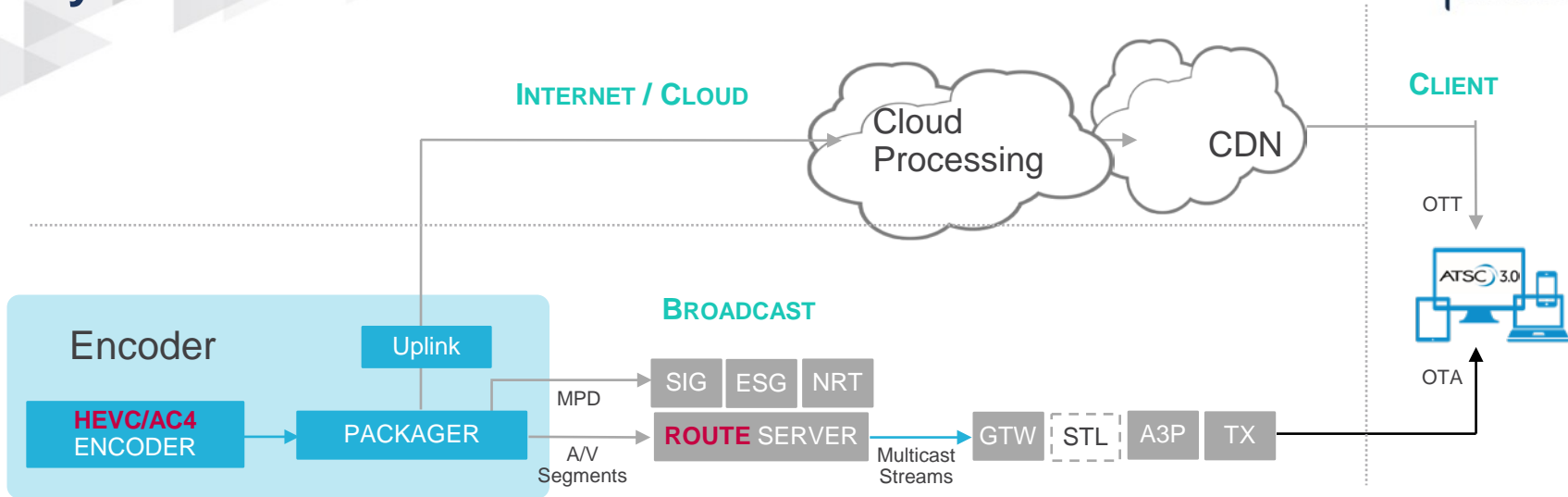
- A single Media Presentation Description (MPD) is used to signal A/V on broadcast and broadband
- The receiver can seamlessly switch between OTA and OTT
- OTT reception is only possible if OTA is present
- Examples of hybrid delivery of A/V streams:
  - Same service over broadcast and broadband but with different qualities (HD OTA, UHD OTT)
  - Enhanced tuning time
  - OTT error correction / recovery for OTA
  - Main service over broadcast: DVR, Pause, Start Over, Rewind OTT
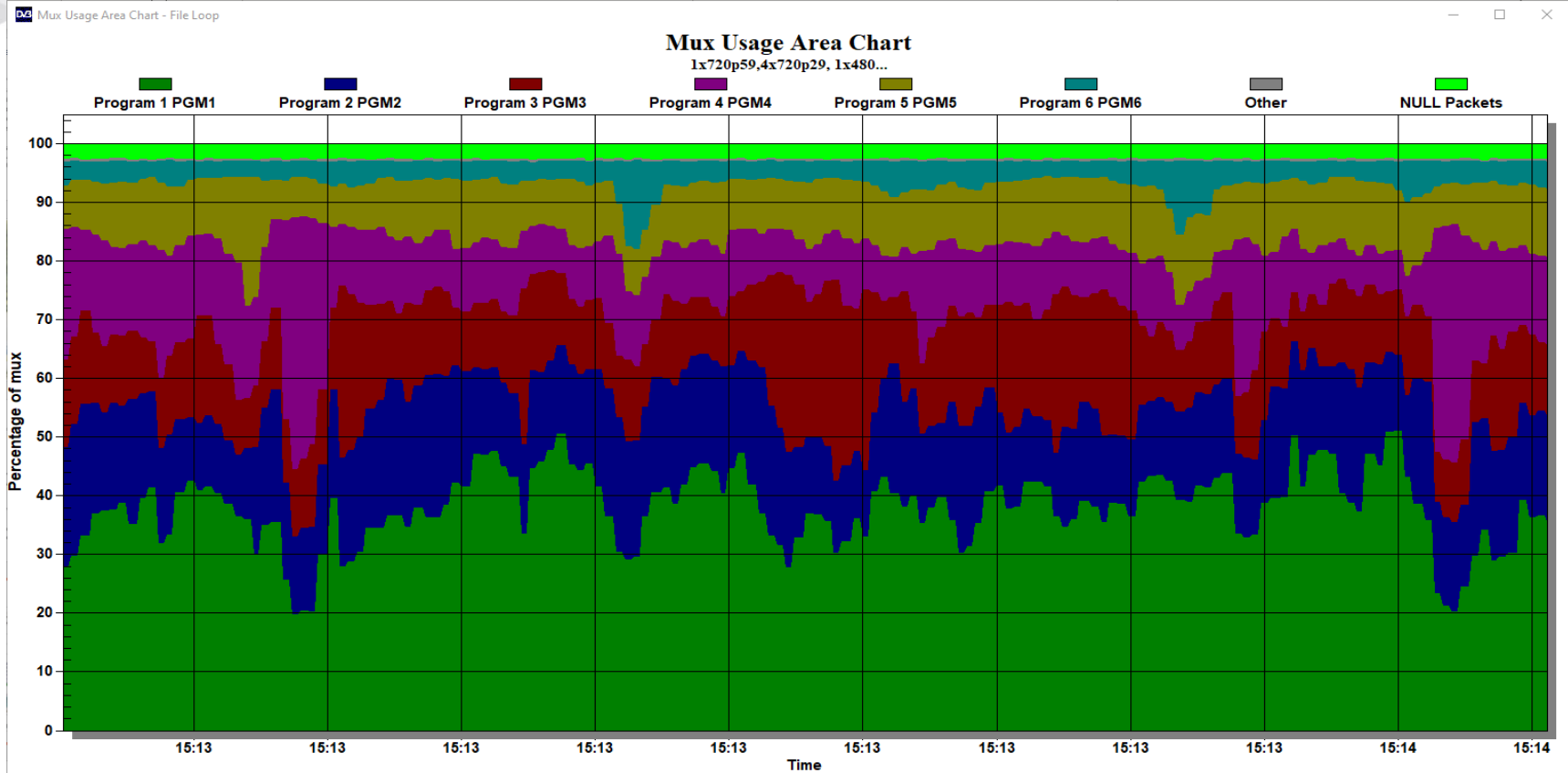
About Statistical Multiplexing

Statistical Multiplexing

- Statistical Multiplexing is **STATISTICAL**
  - i.e. it's not **ALWAYS** going to work the way you want
  - Constant Bitrate = Variable Quality
  - Variable Bitrate = Constant Quality
  - The actual instantenous quality is determined by total pool complexity
  - The complexity varies continuously
  - It works because some channels have light complexity while others have high complexity
  - It doesn't work when all channels have high complex simultaneously
  - The more channels there are the more likely that the statistics will balance out for consistent quality
  - The quality will vary with time, one measure of quality is the percentage of time the picture is unacceptable
  - With few channels there is efficiency gain, but the quality will be more variable

Statistical Multiplexing

- The instantenous bitrate for each channel is determined by the required bits to achieve the target quality

- The sum of the channel bitrates must equal a constant bitrate, otherwise null packets will be needed to fill between peaks

- The target quality is determined by:
  - Channels with equal priority should have equal quality
  - Channels with lower or higher priority will have adjusted quality, lower or higher

- It is possible to target a given bitrate, but the required bitrate is fundamentally determined by:
  - Video format: Pixels per second   H x V x FR
  - HD uses fewer bits per pixel than SD, UHD less than HD…
  - Complexity: Motion x Detail
  - Nearby pictures: scene, transitions, pan, flash, fade, camera shake, film registration
  - Noise: camera noise, film grain, existing encode artifacts

Statistical Multiplex Example

Statistical Multiplex Example

About Bitrates
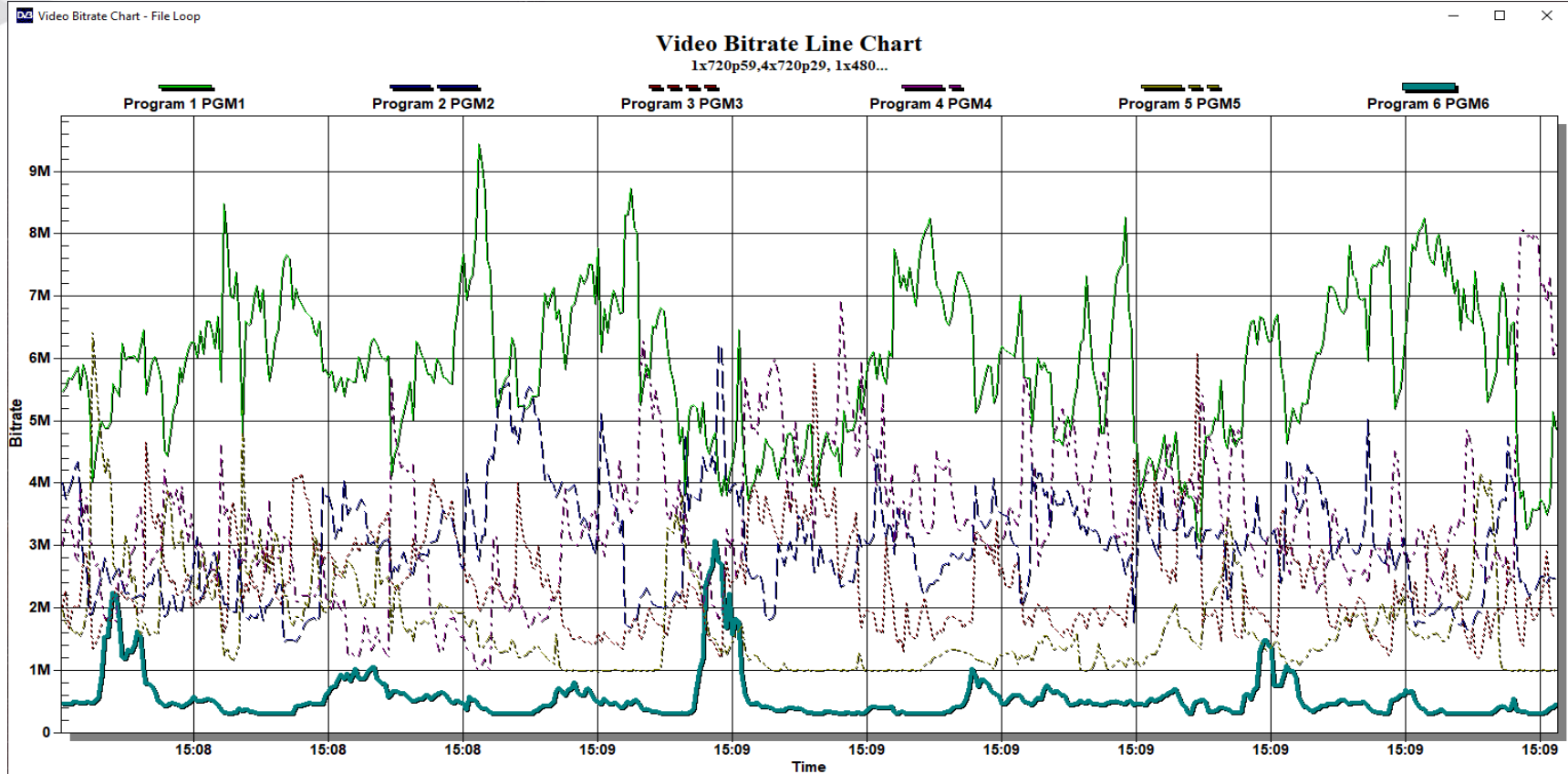
- Factors which determine video quality:
  - Maximum bitrate that's available to a channel
  - Average bitrate (pool / channels)
  - The content present on the other channels

- In a large pool the quality is more closely related to the maximum bitrate than the average
  - Max = Pool – (sum of mins)   OR the max setting, whichever is lower

- The average bitrate should be determined by the encoder, not forced upon the channel
  - Modern encoders are smart, they will balance the channels naturally
  - Forcing an average per program reduces overall video quality
  - But a forcing an average makes contracts easier to write

- The minimum bitrate has very little to do with quality
  - High minimum bitrates will degrade other channels more than they improve the target channel
  - If every stream has a high minimum it is no longer a statmux: it will be CBR
  - Overall quality is improved when there are more bits that can be "moved"
  - A good encoder has lookahead to ensure there are enough bits available around scene change and transitions

- HD requires fewer bits per pixel, but SD allows for higher statmux gain

Sample bitrate as Run (in Excel)

harmonic

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Date	Time	SI	Ghost	NULL	WXXX HD	WXXY HD	WXXX SD1	WXXX SD2	WXXY SD1	WXXY SD2	Total		
2	10/15/2019	19:26:31	51136	0	514368	5534720	3806624	2051456	5844544	1526560	788096	20117504		
3	10/15/2019	19:26:32	51136	0	494816	5608416	3284736	2447008	4713536	1747648	741472	19088768		
4	10/15/2019	19:26:33	48128	0	484288	6157376	3328352	2803456	2651552	2230432	858784	18562368		
5	10/15/2019	19:26:34	48128	0	499328	6769504	3779552	2204864	3011008	2042432	918944	19273760		
6	10/15/2019	19:26:35	51136	0	512864	7470368	2812480	2335712	3552448	2123648	741472	19600128		
7	10/15/2019	19:26:36	51136	0	512864	6883808	2647040	2929792	2854592	2386848	1567168	19833248		
8	10/15/2019	19:26:37	54144	0	527904	6916896	3322336	2898208	3368960	2326688	1045280	20460416		
9	10/15/2019	19:26:38	45120	0	452704	6298752	2394368	2612448	3140352	1834880	709888	17488512		
10	10/15/2019	19:26:39	48128	0	505344	6930432	2419936	3902880	3092224	1744640	673792	19317376		
11	10/15/2019	19:26:40	51136	0	499328	6276192	2522208	3384000	3695328	2004832	815168	19248192		
12	10/15/2019	19:26:41	51136	0	505344	5400864	4193152	3047104	4205184	1761184	565504	19729472		
13	10/15/2019	19:26:42	51136	0	517376	7049248	3424608	2665088	3546432	1744640	661760	19660288		
14	10/15/2019	19:26:43	48128	0	482784	6752960	3301280	2988448	2851584	1508512	697856	18631552		
15	10/15/2019	19:26:44	48128	0	497824	4770688	3364448	3448672	4618784	1741632	827200	19317376		
16	10/15/2019	19:26:45	51136	0	514368	6172416	3781056	2092064	4829344	1717568	730944	19888896		
17	10/15/2019	19:26:46	49632	0	490304	7706496	3356928	1479936	3501312	1528064	633184	18745856		
18	10/15/2019	19:26:47	49632	0	508352	7322976	2594400	1953696	4521024	2104096	606112	19660288		
19	10/15/2019	19:26:48	51136	0	491808	7715520	2487616	2243968	3484768	1923616	576032	18974464		
20	10/15/2019	19:26:49	48128	0	500832	7235744	2774880	1968736	4120960	1911584	756512	19317376		
21	10/15/2019	19:26:50	51136	0	517376	7341024	2764352	1955200	4690976	1899552	669280	19888896		
22	10/15/2019	19:26:51	51136	0	502336	4754144	3696832	2410912	5497120	1529568	875328	19317376		
23	10/15/2019	19:26:52	78208	0	792608	8434432	6396512	3044096	6191968	2628992	2952352	30519168		
24	10/15/2019	19:26:53	21056	0	186496	2517696	1391200	1158080	1194176	682816	248160	7399680		
25	10/15/2019	19:26:54	48128	0	497824	6697312	3934464	2813984	2979424	1658912	625664	19255712		
26	10/15/2019	19:26:55	51136	0	508352	6328832	3767520	4066816	2744800	1442336	613632	19523424		
27	10/15/2019	19:26:56	49632	0	520384	7607232	2659072	3185472	3738944	1451360	625664	19837760		
28	10/15/2019	19:26:57	49632	0	502336	6038560	2445504	2636512	4778208	2262016	604608	19317376		
29	10/15/2019	19:26:58	48128	0	481280	5363264	3095232	1898048	4179616	2911744	554976	18532288		
30	10/15/2019	19:26:59	51136	0	499328	6486752	3784064	2419936	3329856	2343232	628672	19542976		

Forgotten ATSC 1.0 Formats

Vertical	Horizontal	Aspect	Frame Rate	
1080	**1920**	**16x9 (square)**	24, 30	Progressive
			30	**Interlaced**
720	**1280**	**16x9 (square)**	24, **30**, **60**	**Progressive**
480	**704**	**4x3, 16x9**	24, **30**, 60	**Progressive**
			30	**Interlaced**
480	604	4x3 (square)	24, 30, 60	Progressive
			30	Interlaced

- Of the original A53 formats, only 3 are widely used
- 2 currently unused formats have promise for reintroduction
- 720p30 offers HD at half the current HD bitrates
- 480p30 offers clearer pictures for SD, but at similar bitrates

Final Thoughts

Final Thoughts

- The ATSC 3.0 transition will require unpresented cooperation between broadcasters
- The greatest challenge is going to be channel sharing
- Getting a station on the air in 3.0 is less of a challenge than keeping 1.0 service alive
- The challenges are legal as well as technical
- There is intense focus on legal agreements based on bitrates
- BUT continuity and quality of service are not defined just by bitrates

Thank You

MPEG 2 VQ: Making the Nightlight work