THE NEW ATSC 3.0 TELEVISION STANDARD

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DENNIS WALLACE
MANAGING PARTNER

Meintel, Sgrignoli, & Wallace
AGENDA

1. Overview of ATSC 3.0 Standard
2. Unique System Characteristics of ATSC 3.0
3. Upper Layers of System
4. RF (Physical) Layer of ATSC 3.0 System
5. Market Transition From ATSC 1.0 to ATSC 3.0
ATSC 1.0 IN RETROSPECT

Advanced Digital HDTV System

2M Pixels – 5x VGA
16M colors – 1,000,000x

Computer
DOS … Windows 3.1

19.4 Mbps
1000x faster

Dial-up Modem
19.2 kbps

Cell Phone
Analog 2G

VCR - analog

Compressed Digital Video

Mobile TV

• The HDTV Grand Alliance was a Revolution in 1993
THE “MODERN” DIGITAL WORLD

• Rapid Advances and Ongoing Disruptions

- Cable & DSL Modem
  Up to 100 Mbps

- HDTV - Digital – Smart TVs
  LED / LCD displays

- 4G Networks
  12 Mbps

- WiFi 802.11ac 1300 Mbps

- Computer
  1999: 802.11b (11 Mbps)
  2009: 802.11n (600 Mbps)
  2013: 802.11ac (1300 Mbps)

- Tablets
  2010: iPad (16 Gbytes)
  2014: iPad Air 2 (128 Gbytes)

- Wearables
  2007: iPhone (4Gbytes)
  2014: iPhone 6 (128 Gbytes)

- 4G Networks
  12 Mbps
NEXT GENERATION TV
– BROADCAST BENEFITS

Big advances in core technologies

- Video compression: MPEG HEVC
- Audio compression: Immersive Audio
- Robust modulation: OFDM

World’s first all IP standard

- New competitive IP based hybrid broadcast/broadband service
- Ultra HD TV plus HDR at home and on the go (mobile IP TV)
- More efficient video distribution model
- More content via multiple streams
- Interactivity and addressable advertising
- Ancillary service capabilities enabling new business models
- Enhanced EAS

Flexible, extensible, and scalable - graceful migration
ATSC 3.0 LAYER STACK

- Screen is a web page
- UHD
- HD & SD multicast
- Immersive Audio
- Internet Protocols
- OFDM
- Unique Sequence

Software

Pictures & Sound

Data Organized as Streams and Files

Sending Bits over the air in 6 MHz

Finding the Signal

Applications

Presentation

Protocols

Transmission (Physical Layer)

System Discovery & Signaling

Signaling
“TRANSPORT” (M&P) LAYER STACK

Media Processing Unit (MPU)

MPU mode payload

MPEG Media Transport Protocol (MMTP)

ROUTE (ALC/LCT)

HTTP

TCP

UDP

IP

Data Link Layer (e.g. GSE or TLV or ALP)

Physical Layer (e.g. ATSC 3.0)

Broadcast

Broadband
TRANSMISSION

ATSC 1.0

- One bit rate – 19.39 Mbps
- One coverage area
- Service flexibility – HDTV, multicast, data *(see next slide)*
TRANSMISSION

**ATSC 1.0**

- One bit rate – 19.39 Mbps
- One coverage area
- Service flexibility – HDTV, multicast, data *(see next slide)*

**ATSC 3.0**

- Flexible bit rate & coverage area choices
- Optional on-channel repeaters for robust indoor & mobile reception over entire DMA
- Multiple simultaneous “bit pipes” – different choices for different broadcast services
  - Physical Layer Pipes (time)
  - Layer Division Multiplexing (power)
  - Channel Bonding

*More Bits To More Places*
**PRESENTATION LAYER**

**ATSC 1.0**
- Allows HDTV & SD multicast
  - HDTV – MPEG-2 (12 – 18 Mbps)
  - SDTV – MPEG-2 (3 – 5 Mbps)
  - 5.1 Dolby Digital surround sound

**ATSC 3.0**
- Allows UHD and/or HD multicast
  - Super-4k – HEVC (18 – 30 Mbps)
  - Super-HD – HEVC (8 – 12 Mbps)
  - HD – HEVC (3 – 8 Mbps)
  - SD – HEVC (1 – 2 Mbps)
  - Immersive Audio

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Standard Dynamic Range and Color
100-nit color grading, Rec. 709 color, 8 bits/pixel

High Dynamic Range, Faster Framerates and Wide Color Gamut
1000-nit color grading, Rec. 2020 color, 10 bits/pixel

Better Pictures & Sound
BETTER PICTURES?
BETTER EXPERIENCE?

UHD
Ultra High Definition
3840×2160 resolution

WCG
Wide Color Gamut
10 or 12-bit color depth
Rec 2020 / BT.2020

HDR
High Dynamic Range
up to 4K nits

HFR
High Frame Rate
60fps – 120fps
HIGHER RESOLUTION? –OR– MORE CHANNELS?

8K - UHDTV
7680x4320

- DVD 720x480
- HDTV 1280x720
- FullHD 1920x1080
- 4K 3840x2160
## VIDEO COMPRESSION COMPARISON

### FOR SIMILAR PICTURE QUALITY

<table>
<thead>
<tr>
<th></th>
<th>ATSC 1.0 (MPEG-2 Video)</th>
<th>ATSC 3.0 (MPEG-H HEVC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SD</td>
<td>3 - 5 Mbps</td>
<td>1 - 1.8 Mbps</td>
</tr>
<tr>
<td>HD</td>
<td>10 - 18 Mbps</td>
<td>2.5 - 4.5 Mbps</td>
</tr>
<tr>
<td>4K UHDTV (2160p60 10b)</td>
<td>N/A</td>
<td>8 – 15 Mbps*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>15 – 25 Mbps**</td>
</tr>
</tbody>
</table>

*For typical PQ comparisons  
**For higher PQ expectations

As with all bitrate projections, these ranges are subject to PQ expectations & content complexity

Bitrate table courtesy of Matthew Goldman, Ericsson
## AUDIO COMPRESSION COMPARISON
FOR SIMILAR AUDIO QUALITY

<table>
<thead>
<tr>
<th></th>
<th>ATSC 1.0 (Dolby AC-3)</th>
<th>ATSC 3.0 (Dolby AC-4 or MPEG-H Audio)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stereo</td>
<td>192 kbps</td>
<td>32 – 96 kbps</td>
</tr>
<tr>
<td>Surround (5.1)</td>
<td>384 kbps</td>
<td>80 – 208 kbps</td>
</tr>
<tr>
<td>Immersive (&gt;7.1+4 ch. + objects) &amp; Personalizable</td>
<td>N/A</td>
<td>144 – 384 kbps*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>288 – 768 kbps**</td>
</tr>
</tbody>
</table>

*For “basic” immersive  
**For “advanced” immersive

As with all bitrate projections, these ranges are subject to audio quality expectations & content complexity.
ATSC 3.0 BROADCASTING

~ Six-Eight 1080 ‘fixed’ HDTV Services*

* 2TB of storage = 1,300 hours

~ Twelve 720 ‘fixed’ HDTV Services**

** 2TB of storage = 2,000 hours
ATSC 3.0
BROADCASTING

Fifteen or more 480p “Nomadic” Services*

Thirty or more 360p “Nomadic” fully mobile Services**

...or variety of combined “fixed & Mobile” video services

* 2TB of storage = 6,000 hours
** 2TB of storage = 10,000 hours
UHDTV is only possible with a new broadcast platform.
SCALABLE VIDEO CODING

Allows multiple devices to decode various picture quality/resolutions from video stream

- Robust HDTV Stream
- Less Robust Enhancement Layer Video Stream

Business motivation to utilize SVC as well as quality and service motivations.
LINEAR CHANNEL VIEWING

‘Free-to-air’

Next Gen Broadcast Gateway

HDMI

Live Streaming

Wifi

Transition Device: Gateway no need for Set Top Box
MULTIPLE CHANNELS AND FORMATS

'Free-to-air'

Next Gen Broadcast Gateway

Live Streaming

Wifi

UHD

HDMI

HD

MULTIPLE CHANNELS AND FORMATS
NRT AND DVR

‘Free-to-air’

Pause/Forward/Rewind
Manage and play stored content

Next Gen
Broadcast Gateway

DVR

Streaming of stored content

Wifi

HDMI

Video On Demand – CDN Connectivity
Non-Real-Time File Transfer to Gateway
APPLICATIONS

ATSC 1.0

- Pictures, Graphics and Sound are “burned in”
- Same experience for entire audience

ATSC 3.0

- HTML5/Internet overlay graphics
- Hybrid delivery - merge broadcast & internet
- Dynamic Ad Insertion
- Personalized Graphics
- Interactivity
- Synchronized second-screen applications
- Immersive Audio - user control of tracks and mix
- Audience Measurement capabilities

Internet Experience
Personalized & Dynamic
NEW PUBLIC SERVICE CAPABILITIES

• Emergency Alerting
  • Extremely robust EAS “wake up” signaling
  • Advanced EAS messaging capabilities
  • Ability to reach indoor, battery-powered receivers

• Robust Audio and Closed-Caption delivery even when picture fails

• Improved audio intelligibility for the hearing impaired
  • New capabilities for improved dialog/narrative intelligibility (track – specific volume control)
  • Continued support for Video Description Services
OVERVIEW AND KEY TECHNOLOGIES

ATSC 3.0
PHYSICAL LAYER
ATSC 1.0 TRANSMISSION MODE

- Single Set of Transmission Parameters for Over the Air Broadcasting
- 8-VSB Used for Terrestrial TV (2VSB, 4VSB, 16VSB generally not in use)
  - Vestigial Sideband AM
  - One Carrier
  - 8 Amplitude Levels
  - ~15dB Threshold for AWGN
  - 2/3 FEC
  - One Fixed Data Rate 19.39MB/Sec Payload
  - Framing Based upon MPEG TS Packets
  - Echo Cancellation in Receiver ~ 100uSec
  - Small Pilot Carrier
  - One Interleaver
  - Single Purpose Transmission System
    - Fixed antenna TV service
    - “Replacement” for Analog Fixed Service
ATSC 3.0 TRANSMISSION MODES

• Low Density Parity Check Codes – Long / Short
• Forward Error Correction Code Rates (Inner)
  • 12 Code Rates – 2/15 thru 13/15
• Three Choices for Outer Code BCH, CRC, None
• Modulation Constellations – 6 Choices
  • One Uniform Constellation
    • QPSK
  • Five Non-Uniform Constellations
    • 16QAM 2D NUC
    • 64QAM 2D NUC
    • 256QAM 2D NUC
    • 1024QAM 1D NUC
    • 4096QAM 1D NUC
• Three FFT Choices
  • 8K, 16K, 32K
• Pilot Patterns
  • 16 Pilot Patterns
• Guard Intervals
  • 12 Guard Intervals (7 for all FFT’s and 5 for 16K/32K FFT Only)
    • Range from 27.78uSec to 703.7uSec
• Time Interleavers
  • Convolutional Interleaver (S-PLP)
  • Hybrid Interleaver (M-PLP)
• Framing – Frame Length Variable 50mSec – 5Sec
  • Time Division Multiplexing
  • Layer Division Multiplexing
  • Frequency Division Multiplexing

The Ultimate Swiss Army Knife
ATSC 3.0 RANGE OF PERFORMANCE

- System Synchronization and Signaling (Bootstrap)
  - AWGN SNR Threshold ~ -10dB
  - Rayleigh Channel SNR ~ -6dB

- Preamble and Payload Data Threshold Dependent Upon Parameter Choices
  - AWGN SNR Threshold Variable -6dB to +32dB
  - Rayleigh Channel SNR Approximately -5dB to +36dB

- Payload Data Rate Dependent Upon Parameter Choices
  - QPSK – Most Robust Mode ~ 1MB/Sec
    - 2/15 FEC; 8K FFT
  - 4096 QAM – Least Robust Mode ~ 57MB/Sec
    - 13/15 FEC; 32K FFT
Low Capacity, Robust

High Capacity, Less Robust
Required A/322 Mod/Cod Combinations

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<table>
<thead>
<tr>
<th>Code-Rate/Constellation</th>
<th>2/3</th>
<th>3/4</th>
<th>4/5</th>
<th>5/6</th>
<th>6/7</th>
<th>7/8</th>
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Mandatory Mod/Cods = 46 + 28 = 74 Mod/Cod Combinations

Multiply by 3 FFT sizes (8K, 16K, 32K) = 74 * 3 = 222

Multiply 222 by 7 Guard Interval Choices = 1,554 Combinations

Multiply Outer Code Choices; Pilot Pattern, and you have over 74,592 Combinations
Enable multiple constellation types

- Non-uniform 16/64/256/1024/4096 point constellations + QPSK
- Non-uniform constellations
  - can give more than 1dB gain vs. uniform constellations
MODULATION CHOICES

MODULATION CONSTELLATIONS

- QPSK (Uniform)
- 16QAM (2D Non-Uniform)
- 64QAM (2D Non-Uniform)
- 256QAM (2D Non-Uniform)
- 1024QAM (1D Non-Uniform)
- 4096QAM (1D Non-Uniform)
FORWARD ERROR CORRECTION

Inner Code (LDPC with code lengths 16200, 64800bits)

- Structure A
  - Quasi-cyclic structure with parallel factor = 360
  - Dual Diagonal parity matrix
  - Applies to coderates \(\{6,8\ldots13\}/15\) for 64K \((6\ldots13)/15\) for 16K

- Structure B
  - Quasi-cyclic structure with parallel factor = 30 or 360
  - Dual diagonal parity matrix + identity matrix
  - Applies to coderates \(\{2\ldots5,7\}/15\) for 64k codes \(\{2\ldots5\}/15\) for 16k

Outer Code (selectable)

- BCH \((K+192, K)\) or \((K+168,K)\) 12bit correctable code
- CRC (32 bit)
Layered Division Multiplexing (LDM)

- LDM is a new transmission scheme that uses **spectrum overlay technology** to super-impose multiple physical layer data streams with different power levels, error correction codes and modulations for different services and reception environments;
- For each LDM layer, **100% of the RF bandwidth and 100% of the time** are used to transmit the multi-layered signals for spectrum efficiency and flexible use of the spectrum;
- **Signal cancellation** can be used to retrieve the robust upper layer signal first, cancel it from the received signal, and then start the decoding of lower layer signal;
- The **upper layer (UL)** is ultra-robust and well suited for HD portable, indoor, mobile reception. The **high data rate lower layer (LL)** transmission system is well suited for multiple-HD and 4k-UHD high data rate fixed reception.
- **Future Extension Layer (FEL)** can be added later with full backward compatibility.
MIXO CHANNELS CAPACITY

• MISO, SIMO
  • SFN operation
    • Gap fillers, increase service area
  • Antenna diversity
    • Better performance coupled with time interleaving

• MIMO
  • Low SNR region
    • Mobile reception
    • Relatively small MIMO gain
  • High SNR region
    • Roof-top reception
    • Increased MIMO gain

\[ C = \log_2 \left( \det \left[ I + \frac{P}{\sigma^2 N_T} HH^H \right] \right) \]
\[ C = \log_2 \left( 1 + |\det H|^2 \left( \frac{\text{SNR}}{2} \right)^2 + \|H\|^2 \left( \frac{\text{SNR}}{2} \right) \right) \]

- Multiplexing gain
- Diversity gain

\[ P: \text{ total power} \]
\[ N_T: \text{ no of transmit antennas} \]
\[ \sigma^2: \text{ noise variance} \]
Perfect CSI at Rx

High MIMO gain
A frame consists of bootstrap, preamble, and data portions.

A frame allows multiple FFT sizes (one per sub-frame).

A frame can be divided into sub-frames.

The maximum frame length will be 5 sec. Range is 50msec to 5000msec in 5msec increments.
BOOTSTRAP SYNCHRONIZATION SYMBOLS

Robust synchronization
- Service discovery
- Coarse time, freq ACQ
- Initial CH estimation
- 5MHz bandwidth
- <=6dB SNR performance
  - with FER = 1E-2

22 signaling bits
- Sampling frequency
- Channel BW
- EAS, Preamble selection
- Time to next similar frame
SUB-FRAME TYPES

- The sub-frame is a set of OFDM symbols with the same waveform attributes.
- The waveform attributes of a sub-frame constitute a \textit{sub-frame type} and are defined as:
  - FFT Size
  - GI Duration
  - Pilot Pattern
  - SISO/MIMO
  - Frequency INTL
  - NoC

- In one frame,
  - Multiple Sub-frames of different \textit{sub-frame type} are allowed
  - Multiple Sub-frames of the same \textit{sub-frame type} are allowed
## SUB-FRAME PLP MULTIPLEXING OPTIONS

### Time Division Multiplexing

| A00 | A01 | A02 | A03 | A04 | A05 | A06 | A07 | A08 | A09 | A10 | B00 | B01 | B02 | B03 | B04 | B05 | B06 | B07 | B08 | B09 | B10 | B11 | B12 | B13 | B14 | B15 | B16 | B17 | B18 | B19 | B20 | B21 | B22 | B23 | C00 | C01 | C02 | C03 | C04 | C05 | C06 | C07 | C08 | C09 | C10 | C11 | C12 | C13 | C14 | C15 | C16 | C17 | C18 | C19 | C20 | C21 | C22 | C23 | C24 | C25 | D00 | D01 | D02 | D03 | D04 | D05 | D06 | D07 | D08 | D09 | D10 | D11 | D12 | D13 | D14 | D15 | D16 | D17 | D18 | D19 | D20 | D21 | D22 | D23 | D24 | D25 | D26 | D27 | D28 | D29 | E00 | E01 | E02 | E03 | E04 | E05 | E06 | E07 | E08 | E09 | E10 | E11 | E12 | E13 | E14 | E15 | E16 | E17 | E18 | E19 | E20 | E21 | E22 | E23 | E24 | E25 | E26 | E27 | E28 | E29 | F00 | F01 | F02 | F03 | F04 | F05 | F06 | F07 | F08 | F09 | F10 | F11 | F12 | F13 | F14 | F15 | F16 | F17 | F18 | F19 | F20 | F21 | F22 | F23 | F24 | F25 | F26 | F27 | F28 | F29 | F30 | F31 |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|

### Frequency Division Multiplexing

| A00 | A01 | A02 | A03 | A04 | A05 | A06 | A07 | A08 | A09 | A10 | B00 | B01 | B02 | B03 | B04 | B05 | B06 | B07 | B08 | B09 | B10 | B11 | B12 | B13 | B14 | B15 | B16 | B17 | B18 | B19 | B20 | B21 | B22 | B23 | C00 | C01 | C02 | C03 | C04 | C05 | C06 | C07 | C08 | C09 | C10 | C11 | C12 | C13 | C14 | C15 | C16 | C17 | C18 | C19 | C20 | C21 | C22 | C23 | C24 | C25 | D00 | D01 | D02 | D03 | D04 | D05 | D06 | D07 | D08 | D09 | D10 | D11 | D12 | D13 | D14 | D15 | D16 | D17 | D18 | D19 | D20 | D21 | D22 | D23 | D24 | D25 | D26 | D27 | D28 | D29 | E00 | E01 | E02 | E03 | E04 | E05 | E06 | E07 | E08 | E09 | E10 | E11 | E12 | E13 | E14 | E15 | E16 | E17 | E18 | E19 | E20 | E21 | E22 | E23 | E24 | E25 | E26 | E27 | E28 | E29 | F00 | F01 | F02 | F03 | F04 | F05 | F06 | F07 | F08 | F09 | F10 | F11 | F12 | F13 | F14 | F15 | F16 | F17 | F18 | F19 | F20 | F21 | F22 | F23 | F24 | F25 | F26 | F27 | F28 | F29 | F30 | F31 |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|

### Time and Frequency Division Multiplexing

| A00 | A01 | A02 | A03 | A04 | A05 | A06 | A07 | A08 | A09 | A10 | B00 | B01 | B02 | B03 | B04 | B05 | B06 | B07 | B08 | B09 | B10 | B11 | B12 | B13 | B14 | B15 | B16 | B17 | B18 | B19 | B20 | B21 | B22 | B23 | C00 | C01 | C02 | C03 | C04 | C05 | C06 | C07 | C08 | C09 | C10 | C11 | C12 | C13 | C14 | C15 | C16 | C17 | C18 | C19 | C20 | C21 | C22 | C23 | C24 | C25 | D00 | D01 | D02 | D03 | D04 | D05 | D06 | D07 | D08 | D09 | D10 | D11 | D12 | D13 | D14 | D15 | D16 | D17 | D18 | D19 | D20 | D21 | D22 | D23 | D24 | D25 | D26 | D27 | D28 | D29 | E00 | E01 | E02 | E03 | E04 | E05 | E06 | E07 | E08 | E09 | E10 | E11 | E12 | E13 | E14 | E15 | E16 | E17 | E18 | E19 | E20 | E21 | E22 | E23 | E24 | E25 | E26 | E27 | E28 | E29 | F00 | F01 | F02 | F03 | F04 | F05 | F06 | F07 | F08 | F09 | F10 | F11 | F12 | F13 | F14 | F15 | F16 | F17 | F18 | F19 | F20 | F21 | F22 | F23 | F24 | F25 | F26 | F27 | F28 | F29 | F30 | F31 |
|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|

* Each PLP has a separate modulation and coding combination
## WHAT IS GUARD INTERVAL?

**OFDM Symbol**

(Natural resilience to echoes)

<table>
<thead>
<tr>
<th>GI</th>
<th>6 MHz channel</th>
<th>7 MHz channel</th>
<th>8 MHz channel</th>
<th>Dx Basis</th>
<th>FFT 8K</th>
<th>FFT 16K</th>
<th>FFT 32K</th>
<th># Samples</th>
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<tr>
<td>#1</td>
<td>27.78µsec</td>
<td>23.81µsec</td>
<td>20.83µsec</td>
<td>4</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>192</td>
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<tr>
<td>#2</td>
<td>55.56µsec</td>
<td>47.62µsec</td>
<td>41.67µsec</td>
<td>4</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>384</td>
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<tr>
<td>#3</td>
<td>74.07µsec</td>
<td>63.49µsec</td>
<td>55.56µsec</td>
<td>3</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>512</td>
</tr>
<tr>
<td>#4</td>
<td>111.11µsec</td>
<td>95.24µsec</td>
<td>83.33µsec</td>
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<td>X</td>
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<tr>
<td>#5</td>
<td>148.15µsec</td>
<td>126.98µsec</td>
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<td>X</td>
<td>X</td>
<td>1024</td>
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<tr>
<td>#6</td>
<td>222.22µsec</td>
<td>190.48µsec</td>
<td>166.67µsec</td>
<td>4</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>1536</td>
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<td>#7</td>
<td>296.30µsec</td>
<td>253.97µsec</td>
<td>222.22µsec</td>
<td>3</td>
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<tr>
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<td>351.85µsec</td>
<td>301.59µsec</td>
<td>263.89µsec</td>
<td>3</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>2432</td>
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<tr>
<td>#9</td>
<td>444.44µsec</td>
<td>380.95µsec</td>
<td>333.33µsec</td>
<td>4</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>#10</td>
<td>527.78µsec</td>
<td>452.38µsec</td>
<td>395.83µsec</td>
<td>4</td>
<td>X</td>
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<td>X</td>
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<tr>
<td>#11</td>
<td>592.59µsec</td>
<td>507.94µsec</td>
<td>444.44µsec</td>
<td>3</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>4096</td>
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<tr>
<td>#12</td>
<td>703.70µsec</td>
<td>603.17µsec</td>
<td>527.78µsec</td>
<td>3</td>
<td>X</td>
<td>X</td>
<td></td>
<td>4864</td>
</tr>
</tbody>
</table>
SFN BENEFITS

ATSC 3.0 SINGLE FREQUENCY NETWORKS
SFN FOR ATSC 3.0

ATSC 3.0 will support a SFN (Single Frequency Network) infrastructure

- Sparse and Dense Networks are possible

SFN is a broadcast network planning strategy that allows efficient utilization of spectrum by expanding coverage/service without additional frequency allotment
IMPACT OF SFN ON SERVICE

Total received signal strength may increase coverage in overlapping region providing ‘SFN Gain’

- Indoor reception with simple receivers and antennas
  - Better service inside of coverage contours including deep building penetration
- Geographic (SFN zoned) services
- Interference mitigation
- Rx Path Diversity is biggest component of gain
SFN GAIN AND SPATIAL DIVERSITY PROVIDE IMPROVED QOS

SFN provides increased service area for services

- Pedestrian, Mobile, Indoor
- Increased gains possible with MISO/receiver diversity
- Path Diversity provides real system gain
MAXIMUM TX DIVERSITY SFN

- “Sparse” SFN using 3-5 Transmitters
- Provides Path Diversity for Rx
- Increased Field Strength throughout coverage area
- Supports Targeted Ad Business Models
- Shared (Co-Located) Stations makes concept financially viable
- ATSC 3.0 includes Filter Code Set for best performance in Rx
HOW TO TRANSITION TO ATSC 3.0?

IP upgrade to Next Gen TV (3.0) – Fundamentally different than the earlier DTV transition:

- Digital to digital upgrade
- No request for a second channel
- No request for government funded set-top-box converter
- Propose initial voluntary update: no government mandate and marketplace will decide
- Optional for the consumer to upgrade to Next Gen TV
- New sets will support both 1.0 and 3.0 for a limited time
- Will coexist with the current 1.0 standard (utilizing channel sharing) so no disruption to consumer viewing on current 1.0 sets
- Last transition
MARKET TRANSITION TO ATSC 3.0

- FCC Rules for Broadcasters November 16th
- “Voluntary” Operation of ATSC 3.0
  - Adoption of ATSC 3.0 will be Market Driven
  - No Governmental Tuner Mandates
  - TV set manufacturers have pledged to make sets ATSC 1/3 compatible
- Transition requires unprecedented cooperation among broadcasters in each TV Market
  - Key to transition is “Channel Sharing”
  - Industry Consolidation & Joint Ventures are key drivers
STATION TRANSITION CONCEPT

- FCC will not provide additional spectrum to manage transition (unlike analog to digital transition)

- Congress will not provide subsidy for converter boxes (unlike analog to digital transition)

- Industry will ask FCC to allow broadcasters to begin ATSC 3.0 on their own timetable—initially, all voluntary and market driven
  - Will Coincide with Auction Re-Pack

- Stations will partner with each other to share spectrum

- Commercial launch and growth of ATSC 3.0 services while maintaining a limited service to ATSC 1.0 legacy viewers
INITIAL MARKET – ALL TRANSMIT ATSC 1.0

Station ‘A’

Station ‘B’

Station ‘C’

Station ‘D’

Station ‘E’

Station ‘F’
TRANSITION MARKET – SHARED 1.0 AND 3.0

Shared ‘A&E&F’ Programming

Station ‘B’
ATSC 1.0

Station ‘C’
ATSC 1.0

Station ‘D’
ATSC 1.0

Station ‘A&F’
ATSC 3.0

Station ‘A&E’
ATSC 3.0
TRANSITION MARKET – ATSC 1.0 ‘SUNSET’

Shared ‘A,B,C,D&E&F’ Programming

Station ‘B’

Station ‘C’

Station ‘A&E’

Station ‘A&F’
END TRANSITION – ALL ATSC 3.0

Station ‘A’

Station ‘B’

Station ‘C’

Station ‘D’

Station ‘E’

Station ‘F’
SUMMARY

• ATSC 3.0 HIGHLIGHTS:
  • Entirely IP system (not MPEG Transport Stream)
  • OFDM Modulation (not 8-VSB)
    • Many choices depending upon broadcasters choice
  • Hybrid System Integrates Over the Air and Internet Connectivity for a seamless experience for the viewer
  • Bootstrap Hierarchical Signaling enables future upgrades
  • Advanced Emergency Alerting Capabilities
  • New Audio and Video Compression (CODEC)
  • Higher Resolution Video, High Dynamic Range, Wide Color Gamut, High Frame Rate, all supported
  • Voluntary Standard (not mandated by FCC/Gov’t)
  • Simulcast 1.0/3.0 with Channel Sharing will enable transition
CONTACT INFORMATION

Dennis Wallace, C.B.T.E.
Managing Partner
Meintel, Sgrignoli, & Wallace, LLC
1282 Smallwood Drive
Suite 372
Waldorf, Maryland 20603
(202) 251-7589
Email: Dennis.Wallace@mswdtv.com
Web Site: www.mswdtv.com