S32: Specialist Group on Physical Layer

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S32 Chairman
Sony

Tune In to the Future
ATSC 3.0 Physical Layer

- Organization
- Architecture
- Key Features
- Document status
- Summary
S32 - Organization

S32: PHY Layer
(Luke Fay)

S32-1: Common Elements

S32-2: Modulation & Coding
(Lachlan Michael)

S32-3: Waveform
(Nejib Ammar)

S32-4: Core Broadcast Services
(Jim Kutzner)
Physical Layer architecture

**PHY (Studio)**

- **Scrambler**
- **FEC**
- **Bit Int’l Mapper**
- **Time Int’l Mapper**
- **Freq Int’l Mapper**
- **OFDM Framer / Preamble**
- **IFFT**
- **GI**
- **Bootstrap / Spectrum Shaping**
- **D/A**
- **PAPR**
- **Formatting**
- **BICM / LDM**

**SFN Interface (STL)**

Carries Baseband Description

**Output (Broadband)**

- **Planned PLP**
- **Unicast IP**

**Output (broadcast)**

- **Broadcast PHY**
- **Broadband PHY**

**uplink**

- **Output (Broadband)**
- **Planned PLP**
- **Unicast IP**

**downlink**

- **QoS (L2)**
- **Scheduler**
- **Encapsulated packets (L2)**

**OFDM Gen**

- **Framer**
- **DFT**
- **BICM**

1. Timestamp to measure Time Advance
2. Reserved timeslot in real time PLP for interactivity in a frame with unfixed length
Forward error correction

- Inner Code (LDPC with code lengths 16200, 64800 bits)
  - Structure A
    - Quasi-cyclic structure with parallel factor = 360
    - Dual Diagonal parity matrix
    - Applies to coderates {6,8..13}/15 for 64K (6…13)/15 for 16K
  - Structure B
    - Quasi-cyclic structure with parallel factor = 30 or 360
    - Dual diagonal parity matrix + identity matrix
    - Applies to coderates {2…5,7}/15 for 64k codes {2…5)/15 for 16k
- Outer Code (selectable)
  - BCH (K+192, K) or (K+168,K) 12bit correctable code
  - CRC (32 bit)
Constellations

- 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
Low Capacity, Robust

High Capacity, Less Robust
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
Network Flexibility

Radio Horizon

Spill-over into adjacent market
Network Flexibility (2)

TU Series - Deltawing Panel
Broadband Transmission

Radio Horizon

> Indoor penetration

No spill-over into adjacent market

C2
Directivity = 3.0
## What is Guard Interval?

<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>
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<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>
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<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>
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<td>#4</td>
<td>111.11µsec</td>
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<td>X</td>
<td>X</td>
<td>X</td>
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<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>296.30µsec</td>
<td>253.97µsec</td>
<td>222.22µsec</td>
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<td>X</td>
<td>X</td>
<td>X</td>
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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>
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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>
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<td>X</td>
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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
• Zadoff Chu sequence with various roots modulated by PN sequence with certain seeds in the frequency domain retains desired Constant Amplitude Zero Auto-Correlation (CAZAC) properties

• Sync detect/service discovery based on cross-correlation with a known preamble sequence (ZC root and PN seed)

• Parameter selection conveyed post initial synchronization through cyclic shifts of the detected preamble sequence...starting at 22bits
Bootstrap Time Domain

- Alternating structures after 2048 point inverse-FFT
  - A has 2048 samples
  - B has 504 freq shifted samples of A
  - C has 520 freq shifted samples of A
Channel bonding
(optional: conditional mandatory)

• Realized by separate RF channels
  – E.g. 12MHz as 2 separate 6MHz channels
  – Total bandwidth is any sum of 6, 7, 8MHz: 12, 13, 14, 15, 16MHz
  – Different OFDM parameters for different channels are possible
  – Channels can be adjacent or separated
• Allows to reuse standard signals, incl. preamble, framing etc.
• Standard tuners (e.g. 6MHz)
• Possible to mix channels from VHF and UHF
Working Draft Status

• **System Discovery and Signaling document**
  – Bootstrap symbol definition
  – Signaling structure
  – Signaling syntax
  – Status: currently a Candidate Standard

• **PHY Standard with Parts**
  – Full details of downlink
  – Status: drafting

• **PHY Return channel Standard**
  – Full details of uplink
  – Status: drafting
Summary

- ATSC 3.0 standard enables system options for broadcasting industry (not just system parameter options)
- High robustness, spectrally efficient operating points
- Flexible configuration of operating modes with large SNR range
- Very robust synchronization with signaling of basic system parameters to allow for future technology advances
- Channel bonding options for spectrum sharing
- Many flexible functions for optimization per broadcaster
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