S32-3: AHG on Waveform Generation and Framing

Nejib Ammar,
S32-3 Chairman
Zenith
Outline

- S32-3 Work Area
- Waveform Parameters
  - BW, FFT
  - Guard Interval
  - Pilots
  - PAPR Reduction
- Layer Division Multiplexing (LDM)
- Bootstrap
- Framing
- Summary
Physical Layer Architecture

1. Timestamp to measure Time Advance
2. Reserved timeslot in real time PLP for interactivity in a frame with unfixed length
**Structure and Waveform Blocks**

**Signaling**

- **LDM Injection**
  - Combines multiple layers of data streams with different BICM

- **OFDM Framer**
  - Combines multiple inputs into single stream and formats it in frames

- **Pilots Insertion**
  - Inserts pilots and reserved tones for channel estimation, synchronization

- **IFFT**
  - Generates OFDM waveform

- **PAPR**
  - Reduces peak-to-average power ratio

- **Guard Int. Insertion**
  - Inserts GI to combat multipath effects

- **Bootstrap Insertion**
  - Inserts the bootstrap for service discovery, initial synchronization and core signaling

---

**Structure**

- Orange

**Waveform Generator**

- Blue

---

Tune In to the Future
Key Considerations

- **Flexibility** to support a variety of network types, network sizes and service types
  - Different combinations of FFT sizes, guard intervals, scattered pilot patterns, different frame types
- **Robustness**
  - Increased signaling data robustness
- **Reduced overhead** to increase payload
  - Optimized pilots patterns for channel BW and propagation conditions
- **Power savings**
  - Time Division Multiplexing (TDM) of data frames
- **Reduced complexity** for fast deployment
  - H/W implementation and Testing
- **World standard**
  - Support for different channel BWs
- **Extensibility** to support future needs
  - Future extension frame parts
Waveform Parameters

- Baseline supports three channel BWs
  - 6MHz (e.g. US, South America)
  - 7MHz (Typical VHF band)
  - 8MHz (Typical UHF band)
- FFT sizes
- Adjustable Number of Carriers (NoC)
  - Maximum capacity under various Masks
  - Adaptable to RF environment changes

<table>
<thead>
<tr>
<th></th>
<th>8K</th>
<th>16K</th>
<th>32K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carriers Spacing (Hz)*</td>
<td>837.1</td>
<td>418.5</td>
<td>209.3</td>
</tr>
<tr>
<td>Symbol Duration Tu (µs)*</td>
<td>1194.7</td>
<td>2389.3</td>
<td>4778.7</td>
</tr>
</tbody>
</table>

(*) 6 MHz Channel
Guard Interval (GI)

- Flexible set to support different networks from pure MFN to large SFN sizes
- Balanced and optimized for 6, 7 & 8 MHz channel bandwidths
- Optimized overhead based on channel estimation extent

<table>
<thead>
<tr>
<th>GI</th>
<th>6 MHz</th>
<th>7 MHz</th>
<th>8 MHz</th>
<th>Dx Basis</th>
<th>FFT 8K</th>
<th>16K</th>
<th>32K</th>
<th># Samples</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>28</td>
<td>24</td>
<td>21</td>
<td>4</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>192</td>
</tr>
<tr>
<td>#2</td>
<td>56</td>
<td>48</td>
<td>42</td>
<td>4</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>384</td>
</tr>
<tr>
<td>#3</td>
<td>75</td>
<td>64</td>
<td>56</td>
<td>3</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>512</td>
</tr>
<tr>
<td>#4</td>
<td>112</td>
<td>96</td>
<td>84</td>
<td>4</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>768</td>
</tr>
<tr>
<td>#5</td>
<td>149</td>
<td>128</td>
<td>112</td>
<td>3</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>1024</td>
</tr>
<tr>
<td>#6</td>
<td>224</td>
<td>192</td>
<td>168</td>
<td>4</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>1536</td>
</tr>
<tr>
<td>#7</td>
<td>299</td>
<td>256</td>
<td>224</td>
<td>3</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>2048</td>
</tr>
<tr>
<td>#8</td>
<td>355</td>
<td>304</td>
<td>266</td>
<td>3</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>2432</td>
</tr>
<tr>
<td>#9</td>
<td>448</td>
<td>384</td>
<td>336</td>
<td>4</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>3072</td>
</tr>
<tr>
<td>#10</td>
<td>532</td>
<td>456</td>
<td>399</td>
<td>4</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>3648</td>
</tr>
<tr>
<td>#11</td>
<td>597</td>
<td>512</td>
<td>448</td>
<td>3</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>4096</td>
</tr>
<tr>
<td>#12</td>
<td>709</td>
<td>608</td>
<td>532</td>
<td>3</td>
<td>X</td>
<td></td>
<td></td>
<td>4864</td>
</tr>
</tbody>
</table>
Pilots (1/2)

- **Scattered Pilots (SP)**
  - Used mainly for channel estimation
  - Flexibility of choices with respect to echo range and mobile speed
  - **Dx** values trade-off echo range and overhead
    - Basic set for max GI utilization (75%~90%)
    - Extended set for post-GI equalization (38%~45%)
  - **Dy=2** optimized for high mobility (~200km/h@695MHz)
  - **Dy=4** optimized for fixed service
Continual Pilots (CP)
- Used for estimation, compensation and tracking of carrier frequency and timing offsets
- CP reference indices
  - Random and evenly distributed for robust synchronization under frequency selective fading
  - Reduced capacity overhead (~0.7%)
  - Nested CP tables for different FFT modes to reduced memory requirements
Peak-to-Average Power Ratio (PAPR) Reduction Techniques

- PAPR reduction techniques used to reduce high peaks of OFDM signal
  - Two complementary (optional) techniques are recommended for ATSC3.0 baseline
- Tone Reservation (TR): dedicated tones (subcarriers) are modulated and utilized to cancel peaks in time domain
  - Small capacity overhead (~1%) is required
  - Good performance especially for high constellation order
- Active Constellation Extension (ACE): Boundary constellation points are extended to predefined sectors (mask) to reduce peaks in time domain
  - Good performance especially for low constellation order
Layered Division Multiplexing (LDM)

- LDM is a new transmission technology to super-impose two (or more) PHY data streams with different power levels, channel coding and modulation types
  - Upper Layer (UL): Very robust. well suited for HD portable, indoor, mobile reception
  - Lower Layer (LL): High data rates. Well suited for multiple-HD and 4k-UHD high data rate fixed reception
- Injection Level parameter determines the distribution of total power among two layers
  - Can be varied between 3dB and 10dB is steps of 0.5 dB
  - Example: 5 dB injection level allocates 24% transmission power to LL and 76% to UL
- Receiver decodes UL first, cancels it from the receive signal to get LL

<table>
<thead>
<tr>
<th>Example of LDM Transmission</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 MHz RF Channel (-4 dB Lower Layer Injection)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Data rate</th>
<th>SNR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper layer (robust-mod)</td>
<td>2.0 Mbps QPSK 3/15</td>
<td>-2.0 dB</td>
</tr>
<tr>
<td>Upper layer (mid-rate)</td>
<td>2.7 Mbps QPSK 4/15</td>
<td>-0.3 dB</td>
</tr>
<tr>
<td>Upper layer (high-rate)</td>
<td>4.1 Mbps QPSK 6/15</td>
<td>2.7 dB</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Low layer with -4 dB injection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-rate</td>
</tr>
<tr>
<td>Mid-rate1</td>
</tr>
<tr>
<td>Mid-rate2</td>
</tr>
<tr>
<td>High-rate</td>
</tr>
</tbody>
</table>
Bootstrap

• Quick and robust detection of ATSC signal
• Fast initial synchronization and channel estimation
• Signaling of system versioning, EAS wake-up and core L1 signaling
Bootstrap: Time Domain Signal

- Mixing C-A-B and B-C-A structures
  - Resilience to interference and adverse channel effects
  - Ease of estimation of fractional frequency offsets
  - Robust detection performance

A: IFFT of frequency structure
B: cyclic prefix (postfix) with phase shift
C: cyclic prefix
Bootstrap: Frequency Domain Signal

- Frequency domain signal (A portion in time domain) is a Zadoff-Chu (ZF) sequence, modulated by a PN sequence and mapped to 2K symbol
  - Sync detection/service discovery based on correlation of ZC sequence with one among prescribed sequences
  - Channel estimation based on cross correlation with detected PN sequence
- Four bootstrap symbols carry 22 signaling bits using cyclic shifts of the detected root sequence. Signaling fields include
  - EAS wake-up
  - Core system parameters such as BW, BSR, preamble structure
Frame Structure

- Recommendation of general framing and L1 structure
  - Bootstrap: four symbols to provide ATSC signal versioning and preamble configuration
  - Preamble: variable number of symbols to deliver L1 signaling (static + dynamic) indicating payload configuration
  - Data symbols carry arranged PLP payload
- Work is ongoing to define details of PHY signaling and PLP mapping with provision for
  - Flexibility to support a variety service rates, multiplexing, resource allocation etc.
  - Extensibility to enable new needs in the future
  - Maximum layer independence
  - Enable power saving for mobile devices
  - Enable management of change time between services
Summary

- The baseline waveform parameters offer broadcasters a rich toolset to enable their specific network and service needs
  - Large set of GI to optimize their network set-up
  - Different FFT sizes to enable static and nomadic services
  - Rich and efficient sets of pilots to deal with different reception environments
- Bootstrap provides a robust and quick entry to ATSC signal
  - Quick synchronization
  - Fast and reliable EAS wake-up
  - Delivery of core signaling and system versioning for extensibility
- Framing structure is being defined to enable delivery of mobile and fixed services within a single RF channel
  - Flexibility to support resource allocations for different types of services
  - Power savings for mobile receivers
  - Extensibility to support future and changing RF environments
ATSC 3.0, Technology Marches On

Tune In to the Future
Thanks to our Sponsors

LG, zenith, DOLBY, BTS, CEA, COX MEDIA, Fraunhofer, NAB LABS, NERCO DTV, ONE Media, pearl, SAMSUNG, SONY, triveni DIGITAL, VERANCE, PBS, bim