ABA Engineering Academy Continuing Educational Series: "What is a bootstrap and what does it do"

As ATSC 3.0 continues to gain momentum with television stations, engineers are seeking information about how it works and what will be required to implement at their station.

Most readers know that ATSC 3.0 uses OFDM (orthogonal frequency division multiplexing), which divides data among thousands of carriers (8K, 16K or 32K); versus the legacy ATSC standard that uses 8-VSB (eight-level vestigial sideband modulation), which puts all the data on a single carrier.

ATSC 3.0 provides an improvement over existing OFDM-based DTV standards through use of the latest LDPC FEC (low-density parity-check forward error correction) codes and optimized constellations ranging from QPSK (quadrature phase shift keying) through 4096QAM (quadrature amplitude modulation).

Different combinations of codes, pilot patterns and constellations can be selected to allow data rates ranging from less than 1 Mbps in an extremely robust mode working at less than zero dB SNR (signal-to-noise ratio) to over 57 Mbps when a much higher SNR is available.

A key requirement for ATSC 3.0 is the ability to change the transmission format while continuing to support legacy receivers. This is accomplished through a framing structure that includes a "System Discovery and Signaling" signal, referred to as the "bootstrap" signal before each frame. This signal has a fixed physical configuration, but carries data identifying the version of the frame following it. This could be ATSC 3.0, a future ATSC 3.1 or some other variation; even one using a different waveform.

Frames carrying ATSC 3.0 data and those with different formats can be combined in the same RF channel. When it is time to transition to a new standard, the bootstrap will allow older receivers to ignore the new ATSC 3.1 frames but continue to demodulate the ATSC 3.0 frames.

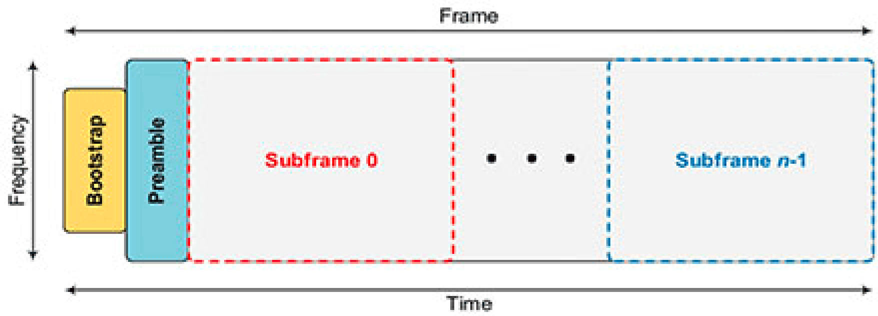

Figure 7.10 from "A/322: ATSC Candidate Standard – Physical Layer Protocol" shows the frame structure of an ATSC 3.0 frame. The bootstrap at the start of the frame provides the information necessary to demodulate the preamble, which in turn provides the information necessary to demodulate the rest of the data in the frame and its subframes.

The bootstrap is the most robust part of the signal. The preamble is less robust than the bootstrap, but more robust than the data in the frame.

The bootstrap signal uses a Zadoff-Chu sequence combined with a PN (pseudo-noise) sequence to create a robust signal that allows detection and decoding at a SNR of around –10 dB or less. The Zadoff-Chu root defines the major version number and the PN sequence defines the minor version number. Once this frequency domain sequence is translated to the time domain using a 2048-point IFFT (inverse fast fourier transform), cyclic shifts can be applied in the time domain to encode information in the bootstrap symbol.

The bootstrap signal has a fixed bandwidth of 4.5 MHz, regardless of the actual RF channel bandwidth. The sampling rate is fixed at 6.144 Msamples per second with an FFT size of 2048, resulting subcarrier spacing of 3 kHz.

Each bootstrap symbol has a duration of 500 microseconds. The number of bootstrap symbols is set at four. The first is a synchronization symbol. Symbols that follow contain emergency alert wake-up information, system bandwidth, the minimum time to the next frame with the same major and minor version, and a value for one of the defined preamble structures. Annex K of "A/322" defines 119 different preamble structures.

BOOTSTRAP BENEFITS

Mathematics, beyond the scope of this article, is required to fully describe the bootstrap signal. To learn more, search Google "Zadoff Chu." See "A/321 Part 1—ATSC Candidate Standard: System Discovery and Signaling" for a mathematical description of how the signal is generated in ATSC 3.0. Zadoff-Chu sequences are also used in LTE cellular transmissions.

The ATSC bootstrap signal provides benefits beyond those mentioned earlier. In addition to providing a universal entry point to the ATSC 3.0 waveform and any future waveform, the robust signal gives the receiver a head start on frequency offset and RF channel estimation, making it easier to decode the preamble and the rest of the frame. The bootstrap is integral to reception. The time required to complete a DTV channel scan is a major frustration for viewers. Worse, channel scans often must be repeated if the desired signal wasn't received on the first scan and the antenna is relocated. The bootstrap signal should help solve both issues. The receiver only has to detect the bootstrap signal to know there is a DTV signal on a channel. The bootstrap signal is much more robust than the payload data, so antenna positioning isn't likely to be a problem.

The spacing of the frames will determine how long a receiver will have to remain on a channel to detect the presence of an ATSC 3.0 signal. Although the ATSC 3.0 standard will allow frame lengths up to about 5 seconds, such long frames are not likely to be used for conventional broadcasting because it will greatly slow the time required to change programs, even on the same channel.

A more realistic frame length is around 250 ms. At this frame length, a scan of 49 channels would take less than 15 seconds! While this won't provide the call letters or program information on available stations, that information can be easily obtained after the identified channel is selected, on a more detailed follow-up scan, or from a listing of stations in an area transmitted by one or more of the stations.

The bootstrap signal also will play a key role in emergency alerting. For example, a portable receiver in a tablet or cellphone only has to turn its receiver on long enough to pick up the bootstrap signal (2 ms). The receiver does not need to decode the preamble or the rest of the frame or turn on additional demodulation circuitry until the bootstrap signals that an emergency alert is available, reducing power consumption and thus providing longer battery life. When an alert is received, it can switch on the demodulator and receive and display the emergency message and supplemental data.