THE BROADCAST BRIDGE
Connecting IT to Broadcast

A Practical Guide To RF In Broadcast :

Part 4 - Codecs, Facilities & The Future

By Ned Soseman

A Themed Content Collection from The Broadcast Bridge

Themed Content Collection

Contents

Introduction

By Tony Orme. The Broadcast Bridge.

This is the third of a multi-part series which serves as a reference resource for broadcast engineers. It covers the science and practical applications of RF technology in broadcast.

Broadcasting has encountered more technology change over the past thirty years than many of us care to think about. Analog has changed to digital delivery, SD has changed to HD and 4K, and sound is transitioning to deliver higher levels of immersive experience through object and surround sound. But the one consistent technology that has stood the test of time is RF.

RF differs from most other broadcast technology as it's fundamentally analog. As the laws of physics haven't changed in the past hundred years, then the underlying rules that govern all RF systems haven't changed either. But what has changed is how we use RF in the context of modern broadcasting along with our understanding of how waves propagate through the universe.

Broadcasting has always driven technology to its limits, and this is certainly the case with RF. Morse devised the first channel coding system ninety years before Shannon formalized his achievements through information theory. And this in turn led to the development of the highly efficient coding systems that we use in modern broadcasting such as CODFM and 5G-NS.

Our RF understanding is sure to improve for as long as users continue to use mobile devices.

A Practical Guide To RF In Broadcast is a four part series with three articles per part.

Available now:

Part 1. History, Modulation & Regulation

Part 2. Bands, Designs & Radiation

Part 3. Planning, Tuning & Monitoring

Part 4. Codecs, Facilities & The Future

Codecs & Encoding

By Ned Soseman. *The Broadcast Bridge.*

Here we look at codecs and encoding for digital RF modulation such as ATSC 3.0, DVB and other digital OTA standards, and network requirements for encoding and delivering streaming internet video.

The idea of compressing analog video by transmitting only the portions of the scene that changed frame-to-frame was proposed by R.D. Kell in 1929. Bell Labs proposed Differential Pulse Code Modulation (DPCM) for digital video compression in 1952.

A codec is software (often running on dedicated hardware) that encodes or decodes a digital data stream. Understanding codecs is an essential part of the life of an RF engineer.

Most video coding aka 'compression' formats are written and approved by standardization organizations and committees such as JPEG, MPEG, SMPTE, ATSC and others.

Most video compression is based on Discrete Cosine Transform (DCT) coding and motion compensation.

Video content, encoded using an approved format, is typically bundled with an Advanced Audio Coding (AAC) encoded audio stream, and delivered inside a multimedia container format such as AVI, QuickTime, MOV and MP4, containing H.264 or H.265 files.

A Little Codec History

The first digital video coding standard was H.120, introduced by the ITU-T in 1984, and it was not efficient enough for video at 1984 processor and network speeds. H.261 debuted in 1988. MPEG-1 was developed by the Motion Pictures Expert Group (MPEG) in 1991 to compress VHS-quality video. QuickTime was also created in 1991 and in 1998 the ISO approved the QuickTime file format as the basis of the MPEG-4 standard.

MPEG-2/H.262 was introduced in 1994 and became the standard for DVDs and SD DTV. MPEG-2 is a DCT algorithm that can deliver up to 100:1 compression. In 1999, MPEG-4/H.263 was introduced. In 2003, MPEG-4/H.264/AVC was introduced. H.264 is the standard for Blu-ray disc players, YouTube, Netflix Vimeo and the iTunes Store. In 2013, High Efficiency Video Coding HEVC/H265/ MPEG-H was introduced for UHD Blu-ray, UHD streaming, DVB, ATSC 3.0, macOS High Sierra and iOS11.

Transport Streams

Today, nearly all video is a 'stream' in one form or another, some in coaxial cable such as SDI and some in Gb Cat 5 IP such as NDI. Both are high-bandwidth digital video transmission standards for production.

An MPEG transport stream (MPEG-TS) is a digital container for audio, video, and Program and System Information Protocol (PSIP) data over an IP connection. A transport stream wraps numerous sub-streams which are often packetized elementary streams (PESs). It wraps the main data stream using the MPEG codec or a non-MPEG video codec such as JPEG 2000.

Each MPEG-TS stream is divided into 188-byte or less packets and interleaved together. Network packets are typically 188-bytes that begin with a sync byte and a header, but the communication medium may add additional information. The packet size was originally compatible with Asynchronous Transfer Mode Systems (ATM) defined by the American National Standards Institute (ANSI) and ITU-T.

Many MPEG-TS streams such as multiple TV channels can be mixed. Other containers such as AVI, MOV, and MP4 usually wrap each frame into a single packet. MPEG-TS streams are typically constant bitrate (CBR). ATSC 1 strictly requires CBR on the transport stream by using null packets (all zeros) to fill in bit gaps.

ATSC 3.0

ATSC 1.0 supports one bit rate of 19.4 Mbps. ATSC 3.0 can use both CBR and Variable Bit Rate (VBR) encoding. ATSC 1.0 uses 8VSB modulation to deliver TV and data separately to viewers or customers. All ATSC 3.0 content is delivered using standard internet IP. It also delivers more bits/Hz by using Orthogonal Frequency-Division Multiplexing (OFDM) modulation. Within a 6 MHz TV channel, ATSC 3.0 can deliver from 1-57 Mbit/s at 10 bits/pixel with a total of 64 physical layer pipes (PLPs).

A PLP is a separate channel that has its own robustness and bit rate. A maximum of four simultaneous PLPs per channel provides maximum bandwidth. PLPs allow separate TV channels on the same RF channel. The PLP originated with DVB-T2 using OFDM modulation with forward error correction and interleaving known as concatenated channel coding.

Also, ATSC 3.0 uses a bootstrap signal to allow a receiver to discover and identify all the ATSC 3.0 signals being transmitted. The bootstrap signal can also wake up an ATSC 3.0 receiver to bring critical emergency information into homes. Beyond the bootstrap, ATSC 3.0 is a highly detailed suite of standards, recommended practices, and protocols, all of which are available in detail at Technical Documents - ATSC : NextGen TV.

For TV station engineers and transmitter engineers performing their daily duties, ATSC 3.0 is simply a new way to modulate a broadcast TV RF signal with some additional features and channels such as a broadcast group's unique NextGen TV app. In some ways, transmitting an ATSC 3.0 signal is like transmitting an ATSC 1.0 signal. The difference between the two is how the ATSC 3.0 signal is built as it is multiplexed and distributed. In terms of TV transmission, like always there's not much to worry about so long as everything is working fine. When something goes wrong, an engineer must find the problem and fix it, hopefully before viewers notice, by identifying what data is being transmitted, how well or not, and why not. It's not something that can be easily fixed by evaluating a TV video monitor display.

Easier Than They Look

Resolving ATSC 3.0 issues requires specialized T&M gear capable of displaying and analyzing the data in every stream and pipe. You're not going to see anything helpful on a waveform monitor or vector scope.

Many ATSC 3.0 T&M gear manufacturers were also key contributors in the creation of ATSC 3.0 format standards and practices. They wrote and understand ATSC 3.0 and make monitoring it and managing it with MPEG analyzers, MPEG -TS monitors, and ATSC 3.0 analyzers and engineering alarms much easier to use for station troubleshooters. In some ways there's much more to monitor, but manufacturers are working on easier ways to monitor it all in real time 24/7.

ATSC 3.0 is loaded with data and is likely to contain significantly more data as it moves forward. However, 'loaded' is nothing close to the data required for a 4K/60 video signal. On the other hand, digital data may be the future of TV broadcasting revenue. The 'Broadcast Internet' may put broadcast 'high towers and high power' to a more profitable use. A future The Broadcast Bridge chapter on 'The future of OTA TV' will investigate group-owned, tall tower, high power, broadcast internet plans. The only way to compete with ISPs is to provide the best service to many customers at a lower price.

Other Radios In TV Stations

By Ned Soseman. The Broadcast Bridge.

Why keeping control of wi-fi and other devices within a broadcast facility to ensure there is no interference with critical devices is essential.

The first, battery-operated, low-frequency, wireless, consumer electronics, remote control radio transmitter was the 1939 Philco Mystery Control.

Pulse-count modulation (note the rotary dial) made it the first digital wireless remote control.

During the first half of broadcast TV history there were only five sources of program and commercial content: Live in-studio, live broadcast microwave, film, videotape, or a national network via ATT telephone (telco) lines that needed an on-site daily ATT telco crew to equalize as telco network performance changed. Early video-capable satellites were only affordable for world-class, live rock concerts. Syndicated film and videotape programs were shipped overnight. Walkie talkies were the only portable communication.

Fast forward to the post-analog, digital nirvana era. Videotape and film are expensive and virtually obsolete. Nearly everything historically important has been digitally archived. Everybody has a cellphone, high-speed internet access, and more than a few know how to live stream to social media. Most TV content is transported digitally and much of that activity is wireless, as is nearly everything else in the world today.

Q: How many wireless devices are within your reach right now? Which might be transmitting? RF management in a facility built on RF has become as mission critical as transmitting the broadcast TV signal itself. Interference is unacceptable.

In the '80s the TV industry widely adopted infrared controls which were somewhat compatible within each manufacturers' standards. Compatibility between different models can be iffy, but the problem with IR display remotes is when you want to control only one of several similar models on a video wall or control room from a distance. Radio remote controls are targeted so don't have the same problem.

Radio (RF) does not require line-of-sight between the transmitter and receiver as infrared does, and transmitters are usually matched to receivers. Uses for radio remote control can be handy and sophisticated, ranging from electric garage door or gate openers, automatic barrier systems, and burglar alarms to Wi-Fi, Bluetooth, cellphones, and smartphones. Typical RF remote control standards are Bluetooth with Audio/Video Remote Control Profile (AVRCP), Zigbee (based on IEEE 802.15.4), or Z-Wave mesh networks. Modern garage door opener transmitters operate on 310, 315 and 390 MHz. Older garage openers can transmit between 300-400 MHz. Modern car key fob remote frequencies are 315 MHz in the USA, and 433.92 MHz in Europe. Nearly all car key fobs operate somewhere within 275 to 450 MHz. Roku remotes use 2.4 GHz Wi-Fi. Rogue RF signals from myriad sources can be on nearly any frequency. Receiver beware!

One Way to Two?

Traditionally, broadcasters have always communicated with their audience in a single direction. Audience feedback was by mail, phone calls, letters to the local newspaper, and services such as Nielsen ratings. Stations transmit on their licensed broadcast channel and often use private broadcast auxiliary service (BAS) channels for studio-transmitter links (STL) and remote studio links. Most early remote-control technology for links was by dual-tone multi-frequency (DTMF) touch-tones on a dial-up telephone line or a dedicated 2-way system. Some systems counted pulses from a rotary dial for commands. It was crude but broadcast engineers made available technology work.

In the late 2000s, the internet became fast, simple, and ubiquitous as did iPhones and Androids, and by design they could all connect wirelessly to all kinds of broadcast gear by a GUI via cellular digital data or local Wi-Fi. The smartphone became the new engineering tweaking tool, more powerful and repeatable than screwdriver adjustments.

In a typical, brick and mortar TV facility, digital IP data over RF remains easy to manage thanks to static IP addresses. If all wireless gear in a station uses static IP addresses, a rogue cell phone entering the building with Dynamic IP turned on shouldn't interfere with network devices, right? That is, until one of the static devices in the facility happens to be offline for one reason or another.

That situation caused a couple of hours of grief during a production I was engineering when one device was temporarily unplugged during setup and a part time crew member walked in the studio with a phone set to DHCP that knew our usual Wi-Fi login. It logged onto the temporarily unused static device address our TV gear was assigned. When we plugged our static IP TV gear back in, it was blocked due to the address conflict.

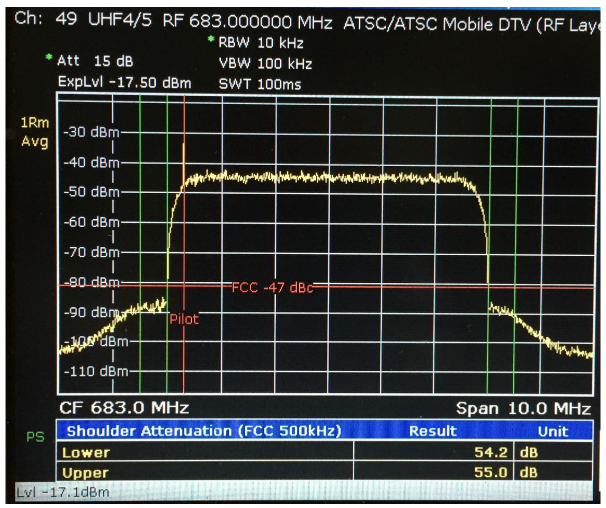
In the field, such as in OB or live news events where gear may need to be reconfigured for specific circumstances and events, IP addresses can change and more rogue cellphones scanning for Wi-Fi networks to log onto may wonder into range. Often the problem can be a phone set to dynamic IP carried by a part-time crew member who has logged onto the OB or newsroom Wi-Fi system before. Any production system IP address beginning with 192.168.x.x is asking for trouble.

Of course, the most significant change to consumer TV consumption is streaming video and the internet. ATSC 3.0 is designed to take advantage of all this with IP protocol and two-way communication between TV stations, viewers, and others. ATSC 3.0, aka NextGenTV, will be the topic of the next chapter.

Spectrum Analyzers

Spectrum management is a complicated issue at world-championship events. Every broadcast device that transmits radio waves, such as a wireless mic or video transmitter, must be registered and its antenna physically tagged before it is allowed into the stadium. Local broadcast groups such as the Society of Broadcast Engineers (SBE) use local frequency coordinators to help oversee and manage the concentrated deluge of RF transmissions in such a tight space. The primary electronic tool used before and during the broadcast to monitor the RF spectrum in a world-championship stadium are RF signal analyzers with directional antennas.

Benchtop and handheld spectrum analyzers are as popular as they are different in frequency ranges, analysis bandwidths, and displayed average noise levels (DANL). Some spectrum analyzers are specifically designed to be 'broadcast analyzers.' They receive and analyze a particular FM or TV signal, a video and MPEG TS, and also function as a general-purpose spectrum analyzer, all in one device.



When not analyzing ATSC 1.0 Shoulder Attenuation, a spectrum analyzer can be a useful RF security monitor.

The Future Of OTA TV In The US

By Ned Soseman. The Broadcast Bridge.

History is usually written by the victors, but at the moment it is far from clear exactly who the winners will be with OTA TV in the US over the next few years.

Isn't it curious that an industry dedicated to marching forward with ever-improving technology and more stimulating displays in homes and TV studios, has yet to find a better local news format than news – weather – sports? In so many subtle ways, the more TV broadcasting technology changes the more the content remains the same, from local live shot quotas and weather set chroma keys to operating room-clean anchor desks. Those of us behind the cameras know that most of the anchors are hiding shorts and canvas shoes behind the big desk. That part of TV anchorman Ron Burgundy movies is true.

Who remembers touring NAB exhibits when an earthshaking new TV technology was 'the buzz' of the floor? One company or another nearly always debuted a game changer, from incremental to enormous, which could be about as big and heavy as it was hugely expensive. Some new technology was from long-time industry leaders, and some came from companies few had heard of before. Some succeeded, some flopped. Last year's coolest gear, like 3DTV displays and special glasses, could be bought dirt cheap in the back of some NAB Show exhibits after broadcasters dropped it. When smartphones and PC chips surpassed HDTV quality requirements while falling in price, off-the-shelf computer products bumped the production equipment expense pendulum in the opposite direction.

RF & Contour Maps

Over recent years broadcast TV audience shares have significantly diminished. In 2021, Nielsen reported households spent more time watching streams than watching TV. In November 2022, broadcast TV accounted for about 25% of TV viewing time, compared to nearly 32% for cable. Nexstar recently reported 2Q23 ad revenues down $87 million USD from 2Q22.

Decades ago, a local affiliate could get a 50+ share on its local late news if it followed a huge network rating hit. Producers, programmers, and sales gurus can argue about why the broadcast TV audience is fractured, but transmitter engineers know that the number one, most obvious tangible advantage TV broadcasters have over all other industries is 'Tall towers and high power.'

TV stations blanket a market with a strong signal that doesn't necessarily end at the FCC contour line. The station contour map is more for checking for potential interference with nearby stations rather than to verify market coverage. Tall towers and high power are a substantially more efficient wireless digital communications strategy to move large amounts of one-to-many data, than using hundreds of one-to-one cell phone towers, spaced about a mile apart in metropolitan markets, to singularly move massive data to individual accounts.

The foundation of radio and TV broadcasting is RF, but more recently both delivery systems have shared audience delivery functions with satellites, cable, streams, and internet providers. The transition to digital ATSC 1.0 began in the late 1990s. In about 2006, the US federal government funded a very inexpensive consumer digital television adaptor device to convert the ATSC 1.0 digital signal to analog NTSC for viewing on a standard analog TV. Analog TV transmission in the US ended in 2009. In 2023, ATSC 3.0 stations continue signing on in smaller markets. The FCC and NAB want to set a mandatory ATSC 1.0 signoff in 5 years. What's the plan? Where is the adaptor? Is mandating technology that doesn't exist a good idea?

NextGen TV

NextGenTV is known as ATSC 3.0 when transmitted and NextGen TV when received, which seems very confusing to average people shopping for a new TV at Walmart. It's two distinct marketing names for the same technology. When's the last time you heard 5G called "New Radio, or NR," which was its original name? Marketing issues like this are what can happen when brilliant engineers try marketing.

No Questions, No problems

I worked for Sony Video Products Company in the late 1970s and one of its premier inventions at that time was the "Random Access Betamax", aka Sony SLP-300 industrial Betamax with a wired RM-300 "Auto Search" control. It was the first commercial, random-access video playback device, and Fiat Motor Company bought a fleet of them with TV monitors on rolling kiosks for all their dealerships to help sell cars. As it turned out, sales prospects often lost interest waiting for the one-hour Betamax tape to shuttle between new Fiat models. Ho hum.

Watching TV is one of the safest and most passive human activities ever, short of napping. Viewers don't put up with questions, wait times or special glasses. Tracking the whereabouts of the remote control is about the only viewing challenge worth the effort. Other than wireless remotes, interactive TV has failed every time it's been tried. If TV content doesn't appeal to a viewer, it can rapidly become a near-satisfying, near-sleep experience. Isn't the idea of broadcasting to engage and communicate with the broadest audience?

Who remembers the so-called 'second screen?' The concept debuted at an NAB Show a decade ago that was designed for instant viewer feedback between a station's website and a tablet or smart phone at home. The idea also touted occasional unique program-related content such as isolated camera shots. It was another ho hum because it required more thought and input than to dial a certain phone number to register an opinion. Interesting how reversing that technology translated into safe-distanced, news anchor and interview backhauls during the pandemic.

NextGen TV delivery can be linear, on demand, or a mixture of both. Without an internet connection, the viewer's NextGen TV experience looks and works much like ATSC 1.0. What will people want to watch? The ultimate viewer interaction tool is the remote control, and it seems there are as many new ideas for NextGen TV apps and content as there are major US TV station groups. Each group appears to be developing its own ideas of how to monetize NextGen TV, mostly centered on the power and creativity of their broadcast app and targeted audiences.

Dreams, Opportunities, & Risks

At the 2023 NAB Show, the NAB announced a new task force partnership with the FCC called "The Future of Television," to "help ensure a smoother roll-out of the next generation broadcast standard known as ATSC 3.0." Sunsetting ATSC 1.0 signals is a key area of engagement for the task force, which appears more focused on regulatory issues than marketing. Some are saying the ATSC 1.0 sunset should occur in five years, and that then broadcasters can reuse that spectrum for other purposes. Nice dream, but not so fast. Spectrum is money.

For NextGen TV to succeed, there must be enough affordable NextGen TVs available for most viewers to adopt it. Currently, few TVs sets or tuners support NextGen TV and some of them don't support all the latest updates within ATSC 3.0. Some blame the receiver shortfall on supply lines and chip shortages. A number of leading TV manufacturers have announced that they will not support NextGen TV in 2024 models. Some receivers and 'NextGen TV home gateway devices' have fizzled and returned customer's money. Clearly, if mobile NextGen TV services succeed as anticipated, it's going to take huge numbers of built-in NextGen TV receivers to provide data and entertainment services to the vehicle market, for example.

The good news is that you can't buy a new TV or monitor without HDMI connections, and ATSC 3.0 is easy to convert to HDMI. A home gateway device can connect to almost anything by Wi-Fi or HDMI like a ROKU device. The problem with early home gateways is changing ATSC 3.0 DRM technologies and standards. DRM is more stable today, but the early product solutions couldn't keep up with the changes and continue to make money.

Back when most markets offered only three or four commercial TV stations, TV call letters and outrageous ad rates were considered a 'license to print money.' Meanwhile, everyone watched TV for free. Those days are long gone, but some seasoned broadcasters remember the 'good old days' of printing money. Some emerging trends indicate the Broadcast Internet may be a completely different new way to monetize NextGen TV.

ATSC 3.0 is based on Internet Protocol (IP), so it can carry internet content or services simultaneously with TV program content. The beauty of the Broadcast Internet is that it can be networked between stations across the country making it available virtually anywhere. Several station groups are experimenting with it, and there is no reason groups can't connect their Broadcast Internet networks and SFNs together to increase coverage. The Broadcast Internet is a one-to-many data distribution technology, as opposed to one-to-one cellular technology. Cellphone data will be used to confirm the success of Broadcast Internet downloads.

5G TV & DRM

The FCC recently granted special temporary authority (STA) for a broadcast TV station to try out 5G broadcasting on 5G Channel 108 (5.5 GHz). Station WWOO-LD, Boston will be the first 5G TV station in the US. WWOO is currently licensed for low power ATSC broadcasting on Channel 28. Because there are no devices able to receive 5G broadcast signals in UHF, the trial will use special 5G devices custom produced by Qualcomm specifically for these proof-of-concept tests in the 5 GHz, 5G band. These trials bear a striking resemblance to a number of field trials conducted in Europe over the last few years, trials which were deemed successful enough to prompt some European national broadcasters to progress towards wider adoption.

The beauty of 5G TV is that it is one-to-many, meaning it is as technically simple to simultaneously distribute content to the entire audience inside a major league sports venue as it is to broadcast it on TV. 5G TV is a one-way transmission moving content from the transmitter to the viewer, just like TV. When cellular data is transferred from the ISP to a cell phone user, somebody is charged for every bit of data sent to every phone. The cost-of-scale benefits between one-to-one private data compared to 5G public distribution are the opposite ends of the cost-per-bit spectrum.

Possibly the murkiest area in NextGen TV is Digital Rights Management (DRM). DRM is available for ATSC 1.0 but little used. The ATSC recently said, "This security upgrade for television broadcasters is important since unprotected signals can easily be intercepted, "deep faked" and redistributed without permission." Are deep faked memes from Bonanza or Batman a problem? In fact, NextGen TV needs serious content protection like all ISPs do, for private data security such as the Broadcast Internet for banking. DRM raises many questions about controlled live viewing and DVRs that TV viewers aren't accustomed to asking.

In a world where free TV seems headed the way of fossil fuel, DRM can be a double-edged sword. Item 41 of the FCC's THIRD REPORT AND ORDER AND FOURTH FURTHER NOTICE OF PROPOSED RULEMAKING, Adopted June 20, 2023, says "Next Gen TV broadcasters would be free to air the most desirable programming, including popular existing programming and new program offerings that could reasonably be provided in 1.0 format, only on their 3.0 primary programming stream. This could create two different tiers of free, OTA television service, which we find would not be in the public interest." Me neither.

With NextGen TV activity, the Broadcast Internet, ML, AI, and quantum computing clearly in our futures, broadcast TV is poised to revise and redefine itself more than any time in its history. Prepare for change, hang on for the ride, and make the future happen as seamlessly as possible for viewers. Tall towers and high-power RF are the key to maintaining commercial and public broadcast TV's future success and engineers keep them transmitting.