

**A Report To The
Corporation for Public Broadcasting
Regarding
ATSC 3 Digital Television
Implementation for Public Television**



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January 31, 2018

Executive Summary

The firm of Meintel, Sgrignoli, and Wallace, LLC (MSW) is pleased to provide the following report to the Corporation for Public Broadcasting (CPB) regarding the adoption and implementation of the ATSC 3 television standard. Specifically, MSW was tasked with studying the potential impacts and opportunities for public television (PTV) stations as the new ATSC 3 television standard is implemented by broadcasters.

The purpose of this report is to highlight some of the technological advances and focus on some of the potential opportunities and business considerations, as well as to generally outline the transition plan for TV broadcasters to transition to ATSC 3 in their respective markets.

PTV broadcasters are particularly interested in ATSC 3 as an opportunity to provide new and innovative services to their audiences and communities, as well as to explore new revenue models that may be attractive in today's environment. Additionally, PTV broadcasters, with their specific missions, are particularly well suited to benefit from the advances available in ATSC 3.

However, with all the excitement of new services, new highly-efficient technologies, and new potential business models, PTV stations must also approach ATSC 3 with feasible business plans while minimizing financial risk to their organizations. As ATSC 3 is deployed and implemented across the United States, stations must also safeguard their existing operations, organizational missions, and financial resources in order to take full advantage of ATSC 3 once it is fully deployed and viable.

On November 16, 2017, the Federal Communications Commission (FCC) adopted a Report and Order (R&O) authorizing the use of the "Next Generation Television Standard" and also issued a Further Notice of Proposed Rulemaking (FNPRM) (GN Docket No. 16-142).

Television stations may now voluntarily use the Advanced Television Systems Committee (ATSC) 3 standard for over-the-air transmissions in their service areas subject to the rules adopted by the FCC. Those rules include a simulcast requirement as well as procedures that stations must follow in order to initiate ATSC 3 transmissions or to consummate a channel sharing arrangement in their market to facilitate the sharing of ATSC 1 or ATSC 3 signals.

Broadcasters and consumer electronics manufacturers have been working diligently over the last few years on the development of the ATSC 3 television standard (A/300). This new standard will allow TV broadcasters to implement a whole host of cutting-edge technologies including more efficient audio and video encoding, hybrid delivery of content and services, as well as a number of other technologies.

ATSC 3 Business Considerations

TV broadcasters deploying ATSC 3 will have a variety of business opportunities in which they may engage and potential new services which they may offer to their audiences and communities.

One new opportunity that may appeal to PTV broadcasters is the ability to utilize the hybrid delivery (over the air and over the Internet) for content and other services (see **Figure 1 below**). The ability to offer “customization” of content may be of particular appeal to PTV audiences as they would be able to setup preferences for genres of programming or particular content areas in which they are interested.

This additional new content, that would be integrated with the ATSC 3 TV Application and delivered via the Internet connection, could enable new instructional or educational programming content and interactivity to enhance learning by all audiences. The ATSC 3 TV application would provide a consumer experience that would not necessarily differentiate between OTA linear content and linear or non-linear (Video On Demand) content delivered via the internet connection. Consumers would experience a seamless integration of content from a variety of sources; and this would lead to additional content discovery, as well as better engagement with viewers. In addition, by using the hybrid delivery capabilities of ATSC 3, stations may provide additional multi-cast channels in linear or non-linear feeds that are delivered via the Internet connection to the ATSC 3 receiver. Thus, the addition of new “channels” to the “station” is no longer constrained by the over-the-air bandwidth limitations since this content would be delivered via the internet.

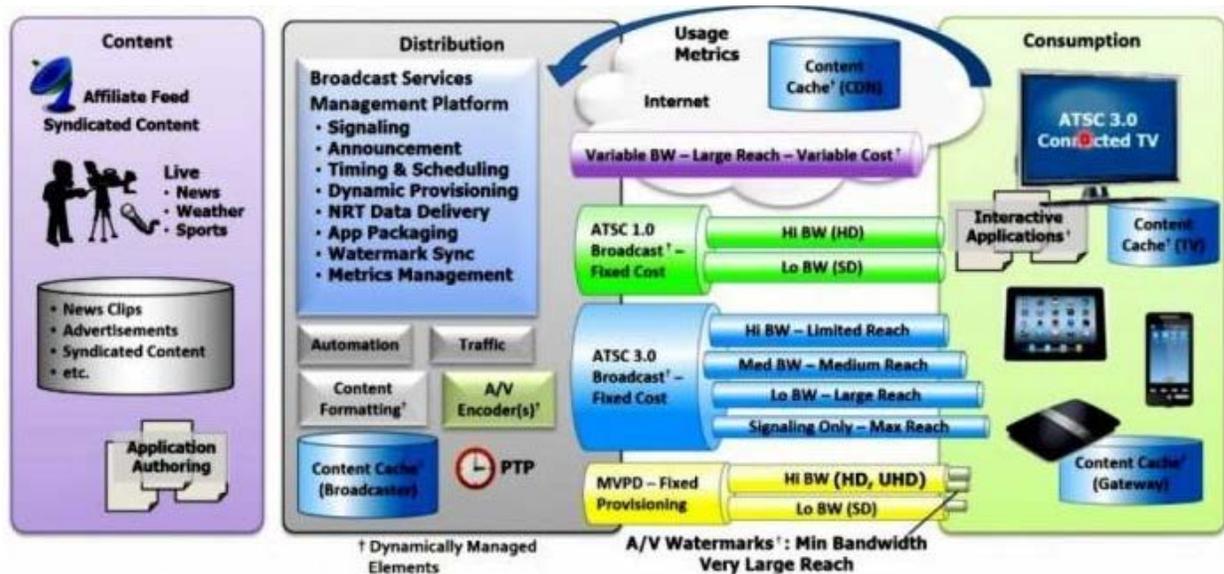


Figure 1 (Courtesy of Triveni)

One often cited example that has possible implications for PTV stations would be “pledge-free” content during pledge drives for stations’ members. Another is the ability to offer video on demand (VOD) type services such as previous episodes of multi-episode content (An example may be “catching-up” on previous episodes of a documentary series).

Non-Real Time Video / Video On Demand:

Another possibility would be the delivery of non-real-time files to ATSC 3 receivers to enhance educational materials and other content. As an example, this content may include guidebooks or other materials related to an instructional video. One might imagine a foreign language instructional series where the app makes available to the viewer workbooks or interactive vocabulary lessons. Or, perhaps a DIY type quilting show that makes a pattern available to viewers so they can make the same quilt. Or, another example may be a cooking show with recipes that are available on-screen by accessing them through a TV app.

Public Safety:

Delivery of data and files for emergency services is another opportunity that may be particularly interesting to state network entities, as well as other PTV stations that are actively involved in their local EAS operations, or the delivery of warnings and other content during emergency situations. The ATSC 3 standard enables the delivery of content to viewers such as evacuation route maps, instructions on sheltering in place for a tornado, or other situation that can be geo-targeted or localized for specific areas. PTV stations have a unique opportunity to develop partnerships with local first responders and other governmental organizations to fully develop these types of content and file delivery to disseminate information to their communities.

Cross Platform Content Discovery:

For joint licensees, delivering audio-only content to ATSC 3 receivers would also be possible. The possibility to integrate their radio operations with the ATSC 3 TV App would allow seamless access to streaming audio services, podcasts (Audio On Demand), and other content. The cross-promotional opportunities of an integrated platform may be very beneficial to stations in this multi-platform delivery world. In particular for licensees with multiple radio formats, the integration with the TV App may provide additional audience content discovery.

Mobile Content:

Mobile video and audio services enabled by ATSC 3 would allow PTV stations to broadcast content to mobile devices such as tablets or automobiles that have ATSC 3 reception capability. A PTV station may choose to provide very robust RF signals that will reach deep indoor and mobile receivers. By targeting these types of receivers, PTV stations may be able to deliver content targeted for specific use cases, such as kids’

content for backseat viewers in a mini-van while mobile. Content could also be delivered to a tablet device that would allow viewers to access news content during their commute on public transit.

Audience Measurement/Verification:

PTV stations may be able to use some of these ATSC 3 system features to generate additional underwriting or membership revenues, as well as to build their brand and image with their audiences.

For PTV underwriters, the ability to verify audience measurement data may enhance the value of underwriting sponsorships. Although the implementation of the audience measurement features of ATSC 3 has many issues to resolve, the technology holds promise for both commercial and non-commercial stations.

There are several broadcast and consumer electronics industry activities that are on-going to explore this capability of the ATSC 3 system, and to develop best practices that will ensure compliance with privacy requirements. These activities will investigate several approaches to gathering audience data and are focused on developing implementations that will work well for consumers, TV manufacturers, and broadcasters.

The demographics of “typical” PTV viewers may be a more highly targetable audience for certain underwriters and, when coupled with audience measurement data, may place a higher value on underwriting sponsorships. In this way, stations may be able to better value their underwriting sponsorships and provide underwriters with key demographic data which substantiates the value to underwriters.

Personalization/Targeted Content:

Local content insertion enabled in ATSC 3 will certainly have applications for State Networks and other PTV stations operating over broad geographic areas. This technology would allow content to be targeted at specific audiences, and local content to be inserted into network content during specific times. For example, providing a localized weather forecast or other localized content for various geographic locations in a state network would be possible using the content insertion features of ATSC 3.

Personalization of content can be implemented in a variety of ways. Consumers can personalize their ATSC 3 receiver with preferences for certain types. Alternatively, targeted content can be delivered to the specific IP address of an ATSC 3 receiver if it is registered with the content provider. Testing of targeted content delivery and best practices approaches that are compliant with privacy requirements are currently under development.

Likewise, a PTV station may choose to insert local content aimed at very specific audiences. For example, station members may receive a “Thank You” message instead of a “Please Pledge” message during fund raising events. Or, station members may have

access to specific content that non-members do not. There are a variety of opportunities for PTV stations to explore and deploy that may enhance the business of PTV.

ATSC 3 Applications

It is important to consider that many people in today's audiences are used to an environment such as Netflix or Hulu that provides easy navigation to content as well as other features. ATSC 3 was developed with this environment in mind. Consequently, it may be useful for broadcasters to think of ATSC 3 in the context of a TV Application ("App").

As noted above, ATSC 3 enables the TV viewer to access additional deep-linking and other content via the App running on the ATSC 3 receiver. This App also integrates the content delivered over-the-air with the content delivered over the Internet to present a seamless integration of both over-the-air (OTA) and over-the-top (OTT) content to the viewer.

Furthermore, integration with various PTV services (such as OTT or E-commerce) may provide PTV with the ability to offer a variety of content and services to viewers based upon their preferences, and not limited to the over-the-air TV content schedule.

There are several broadcast industry initiatives that are focused on various aspects of the development of the App for ATSC 3. It is desired that broadcasters develop apps that are generally alike in terms of function and layouts in order to minimize consumer confusion and to enhance the user experience.

There are a number of new opportunities that arise with the concept of a App. Public media should consider the implications of this opportunity and how it can be used to enhance audience and member experiences, content discovery, and other important considerations. Hence, public media organizations should engage with these industry initiatives to collaborate on best practices for ATSC 3 App development and deployment.

Deployment Schedule

As the FCC recently adopted the voluntary use of ATSC 3 transmissions by broadcasters, some early-adopter broadcasters are developing plans for their initial foray into ATSC 3. However, as discussed later in this document, developing relationships with other stations within the same DMA to facilitate channel-sharing and ATSC 3 deployment may take some time.

In the short term, stations may find it useful to initiate discussions with other broadcasters within their market to discuss potential ATSC 3 deployment scenarios. However, much of the roll-out of ATSC 3 by broadcasters will likely be driven, to some extent, by the spectrum repacking and the various transition dates for various markets.

Therefore, market deployment of ATSC 3 transmissions will likely be somewhat aligned to the FCC's spectrum repack phase assignment schedule for the various markets. In other words, markets with stations scheduled to transition in early phases are likely to initiate ATSC 3 transmission earlier than those stations in later phases.

In the long term, it is likely to take several years for broadcasters to fully deploy ATSC 3 transmissions and develop agreements with all the broadcasters in each market. Hence, stations should take a cautious approach and carefully evaluate the various scenarios for deployment in their individual market prior to making firm commitments for ATSC 3 transmission or ATSC 1 channel-sharing.

Regulatory Considerations

As noted previously, the FCC recently released a Report and Order (R&O) and Further Notice of Proposed Rulemaking (FNPRM) regarding the voluntary deployment of Next Generation Television (ATSC 3) for Television Broadcasters in the US.

The FNPRM was issued in order to address some of the channel-sharing and coverage requirements that are particularly important to PTV stations. It is anticipated that this activity will conclude in late 2018. Some of the topics included in the FCC's FNPRM include the following:

1. Local Simulcasting Waivers and Exceptions
2. Temporary Use of Vacant Channels
3. Significantly Viewed Status of Next Gen TV Stations

Some of the key regulatory considerations and requirements for ATSC 3 deployment by TV stations as outlined and adopted in the FCC's R&O are listed below.

Voluntary Use:

The FCC will allow stations to voluntarily operate with ATSC 3 transmissions, but is not requiring stations to convert to ATSC 3 at this time. The FCC agreed that a market place and consumer driven adoption of ATSC 3 would be appropriate and declined to adopt the requirement for stations to convert to ATSC 3 or that TV sets include an ATSC 3 tuner. Consequently, the deployment time-line for stations and consumer receivers are not mandated and will be driven by market demand.

Local Simulcasting:

The FCC also adopted rules to require simulcasting of "substantially similar" content of the station's "primary video programming" on stations' ATSC 1 and ATSC 3 signals.

This is primarily to protect consumers from not being able to receive content in ATSC 1 as stations migrate to ATSC 3. It is the expectation that stations' programming will generally be simulcast in ATSC 1 and ATSC 3 at least during the initial launch and roll-out of ATSC 3. However, this requirement will sunset in approximately five years from the adoption of the standard. Thus, the simulcast requirement may not be permanent and stations may want to consider the potential implications to any channel-sharing agreements that they may execute with other stations to facilitate their launch of ATSC 3 transmissions during this period.

Furthermore, the FCC is conducting a FNPRM to more clearly define these rules and to develop criteria for stations to request waivers of the simulcast requirement. And, more importantly for NCE stations, whether the simulcasting requirements would have a presumptive waiver for NCE and LPTV/TV Translators stations. Currently, the FCC has

proposed that LPTV/TV Translator stations would not have to simulcast in ATSC 1 and ATSC 3 and may flash-cut to ATSC 3 without an ATSC 1 simulcast.

Coverage Requirements:

The FCC did adopt rules regarding the coverage requirements for stations transitioning to ATSC 3. There are two different scenarios considered by the FCC.

First, stations that are relocating its ATSC 1 signal will have a higher requirement in terms of minimizing the loss of existing coverage and population covered. The FCC has stated that it would look “more favorably” at arrangements that yielded a loss of not more than five percent of the existing coverage population. Stations proposing scenarios that will have less than 95% coverage of their existing audience will need to provide more detailed showings with the applications.

Secondly, for stations establishing ATSC 3 signals on a host station, the FCC requires only that they are within the same Designated Market Area (DMA) as the existing station. However, the population covered by ATSC 3 is not considered.

These requirements may be problematic in certain circumstances for a few PTV stations that are not located within a primary DMA coverage area. For example, stations that were located in order to achieve universal coverage of a particular state may find that their transmitter locations are not ideal for channel-sharing and ATSC 3 transmissions. Thus, the FCC FNPRM on these requirements may provide some relief for PTV stations in this circumstance.

Licensed Simulcasting:

The FCC will license stations with “temporary second channels” in order to facilitate the required channel sharing of ATSC 1 and ATSC 3 signals. Therefore, both the ATSC 1 and ATSC 3 signals of a TV broadcaster will be two separately authorized companion channels under the broadcaster’s single, unified license.

The two partner “host” and “guest” stations that are in a simulcast arrangement will continue to be licensed separately, and each station will have its own call sign.

Each licensee will be independently subject to all of the Commission’s obligations, rules, and policies. The Commission retains the right to enforce any violation of these requirements against one, more than one, or all parties to a simulcast agreement. Consequently, in order to minimize risk, stations should be sure to carefully consider various scenarios as part of their channel sharing agreements with other broadcasters.

Licensing Procedure:

Stations must file with, and receive approval from, the FCC prior to: (1) moving its ATSC 1 signal to a host station, moving its ATSC 1 simulcast to a different host station,

or discontinuing an ATSC 1 guest signal; (2) commencing the airing of an ATSC 3 channel on an ATSC 3 host station (that has already converted to ATSC 3 operation), moving its ATSC 3 channel to a different host station, or discontinuing an ATSC 3 guest signal; or (3) converting its existing station from ATSC 1 to ATSC 3 operation or from ATSC 3 back to ATSC 1.

For all these scenarios, the FCC has adopted a streamlined process that requires the filing of an application for Modification of License (without the need to file for a construction permit provided that no technical changes are proposed). However, as explained above, various showings or exhibits may be required as part of the FCC filing if more than 5% of the currently covered population would no longer be covered by a host/guest station.

Multichannel Video Programming Distributor (MVPD) Carriage:

It is important to distinguish between the channel-sharing cable carriage requirements for stations that are channel-sharing pursuant to the FCC Incentive Auction and spectrum repacking versus the carriage requirements for channel-sharing stations that are transitioning to ATSC 3.

With respect to ATSC 3 transitioning, the FCC rules require that a TV broadcaster's ATSC 1 simulcast channel will retain mandatory carriage rights on cable and satellite systems, but that its ATSC 3 signal will not have mandatory carriage rights while the local simulcasting requirement is in effect.

Thus, a station operating both in ATSC 1 and ATSC 3 may choose between must-carry and retransmission consent for its ATSC 1 signal, but may only pursue carriage via retransmission consent for its ATSC 3 signal. Therefore, the FCC makes clear that an ATSC 3 station will not be able to exercise mandatory carriage rights with respect to its ATSC 3 signal instead of its ATSC 1 signal, nor will it have mandatory carriage rights even if its ATSC 3 signal is the only signal being broadcast.

In addition, a TV station relocating its ATSC 1 signal to a host facility will not be permitted to gain new mandatory carriage rights if they were not previously held and exercised by the ATSC 1 station as a result of its new location. Furthermore, in order to assert the ATSC 1 mandatory carriage rights, the ATSC 1 channel must continue to qualify for such rights at the temporary host location from which it will transmit its ATSC 1 signal. So, stations may need to carefully evaluate the cable carriage coverage afforded by the host ATSC 1 transmitter.

Consequently, it is important to note that NCE, Class A, and LPTV stations may be affected if, for example, an NCE station that qualifies for carriage based on its existing ATSC 1 contour encompassing a cable headend cannot continue to qualify for carriage rights at the ATSC 1 host facility location if the shift in contour means the station can no longer cover the cable headend with the required signal level or signal quality.

ATSC 3 stations with must-carry rights relocating their ATSC 1 simulcast channel must provide notice to affected MVPDs at least 90 days in advance of the move, and 120 days in advance if the move occurs during the incentive auction repacking period.

Consumer Issues:

All stations that relocate their ATSC 1 signals (e.g., moving to a host station's facility, subsequently moving to a different host station's facility, or returning to their original facility), must air daily on-air consumer education PSAs, or crawls, beginning 30 days prior to the date that the stations will terminate ATSC 1 operations on their existing facilities.

In most cases, Consumers will need to re-scan their existing ATSC 1 television sets in order to update the channel mapping in the set for new ATSC 1 channel-sharing stations. Thus, stations should plan appropriate outreach and viewer education programs in order to minimize consumer confusion and disenfranchisement when commencing a channel-sharing arrangement with another station.

With regard to consumer adoption of ATSC 3 television sets, it is anticipated that new ATSC 3 tuner/demodulator chips will be included with new ATSC 1 sets. In this way, new sets will be capable of receiving both ATSC 1 and ATSC 3 signals. Many of the well-known brands of television receivers have announced that they will follow this strategy.

Thus, new television sets will be able to receive both ATSC 1 and ATSC 3 signals. Over time, as sets are replaced in course of the normal replacement cycle, a significant base of ATSC 3 sets will be deployed. At some point in the future, when the majority of viewing is on ATSC 3 channels, broadcasters and regulators will determine an appropriate cessation schedule for ATSC 1 transmissions. However, it is anticipated that this will not be for quite some time in the future.

Some of the initial ATSC 3 receivers to the market, specifically targeted toward early-adopters, will likely be dongles and other devices that are designed to receive ATSC 3 signals and convert them for display on existing devices through a variety of interfaces (Wifi, HDMI, USB, etc.). These devices are likely to be available in the market starting in the second quarter of 2018.

Market Based Transition

As previously noted, the adoption of ATSC 3 will be a market-driven roll-out with no mandate or requirement for stations to convert to ATSC 3. However, this transition is different from the transition from analog to digital. In many respects this is a transition from one digital technology to another, which is common-place in the wireless industry.

The FCC adoption of ATSC 3 was largely premised upon the concept of channel sharing. In order to facilitate stations' migration from ATSC 1 to ATSC 3, there needs to be some simulcast of the signals in both formats. Consequently, with no new spectrum available with which to launch ATSC 3 services, stations must cooperatively work together in their local markets to develop channel-sharing arrangements to enable stations to launch ATSC 3 broadcasts while also maintaining their ATSC 1 signal.

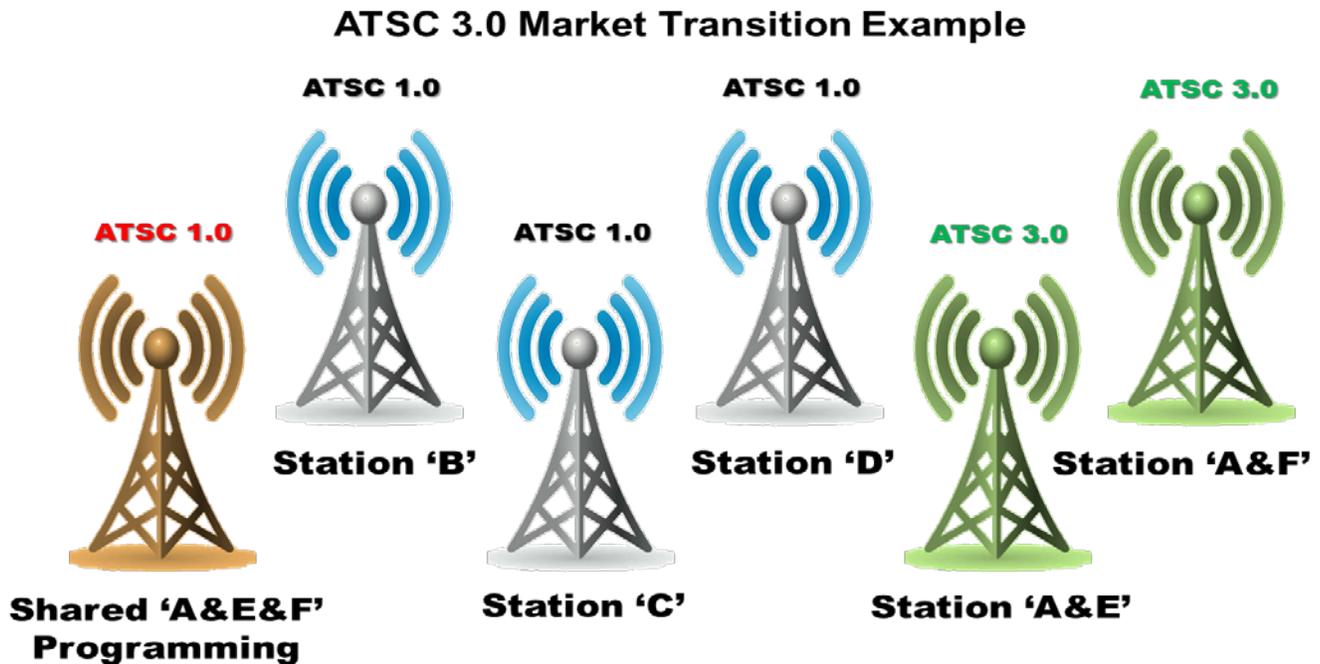
Another consideration for the implementation of ATSC 3 and the deployment by stations is that it may coincide with the FCC's post-auction repacking of the TV spectrum. As such, stations may be able to minimize disruption to consumers by reducing the number of TV set channel re-scans required. By launching ATSC 3 stations and ATSC 1 channel shares along with the channel repacking, the number of rescans required by consumers will be minimized.

Furthermore, to the extent that repack stations in a market purchase new ATSC 3 ready transmitters, the costs for conversion from ATSC 1 to ATSC 3 will be somewhat mitigated as previously discussed.

One of the first steps in the transition in a market would be the selection and launch of the first ATSC 3 station in the market (the so-called "lighthouse").

The launching of the "lighthouse" station in the market enables access to ATSC 3 content for consumers as they purchase new ATSC 3 capable TV sets, while also maintaining access to the existing ATSC 1 content of the ATSC 3 lighthouse station as it is hosted on another station's ATSC 1 signal. The "lighthouse" station provides the "beacon" of ATSC 3 content to draw consumers to the new ATSC 3 signal.

Then, in successive transitions, additional stations are converted to ATSC 3 transmission and their corresponding ATSC 1 signals are carried by another "host" station within the market. As shown in **Figure 2** below, this transition progresses as consumers purchase more sets, and stations determine it's feasible to launch additional ATSC 3 services.



This process would continue until the marketplace has been seeded with ATSC 3 capable TV sets and very few ATSC 1 only TV sets remain in service. At that time, the FCC may determine it's feasible to terminate the operation of ATSC 1 signals and all stations would convert to ATSC 3 transmissions.

The timeline for adoption is not clear at this time because it is market driven. However, it is likely that some markets will initialize their ATSC 3 transmissions to be coincident with the FCC's post-auction repacking schedule, which is currently scheduled to occur over the next approximately three years. Hence, initial ATSC 3 transmissions in some markets are likely to commence during this three year period.

The organization of channel sharing arrangements and the accompanying contractual agreements, along with the equipment procurement and installation, is likely to be a fairly large undertaking and is not likely to occur immediately upon the adoption of the FCC's ATSC 3 rules.

As noted above, it is anticipated that consumers will purchase new sets over time, which will include both ATSC 1 and ATSC 3 reception capability. First generation ATSC 1 / ATSC 3 receivers will likely reach the mass consumer market in 2019 or 2020. Consequently, a significant base of installed ATSC 3 capable receivers will seed the market as new sets are purchased. Eventually, a significant majority of sets in use will include ATSC 3 reception capability. At that time, the FCC and broadcasters may evaluate the usefulness of continued ATSC 1 transmissions and determine a cessation schedule for ATSC 1 services.

Deployment Risk Mitigation

All of the innovation, potential new business opportunities and technological advances, however, do come with some risk. The adoption of ATSC 3 is a voluntary transition for both broadcasters and consumers. It is likely that it will take many years for solid business models and consumer receivers to be available in the market. There is some risk that the ATSC 3 deployment is slowed down or stalled by a variety of possible events or scenarios.

Consequently, stations should be thoughtful and deliberate about their deployment plans for ATSC 3. Due to the long time-horizon for the full deployment of ATSC 3, stations should not feel that they need to lock-down partnerships without looking at all the possible options. Stations should view ATSC 3 as a long-term business plan and develop both short-term and long-term plans that encompass the transition and business arrangements in the short term as well as over the long-term 5 to 15 year period.

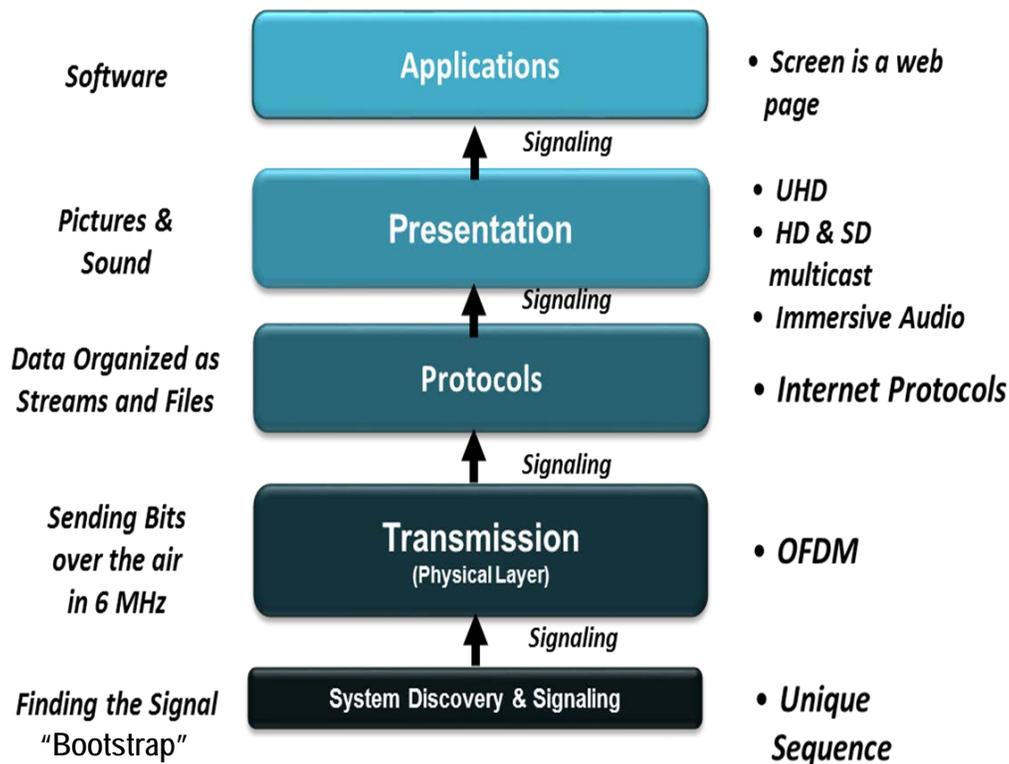
As noted above, a market-by-market transition and roll-out plan will be highly dependent upon broadcasters working together in each TV market to roll-out ATSC 3 and develop channel sharing arrangements for both the ATSC 1 and ATSC 3 content in their respective markets. Consequently, having working relationships with all TV broadcasters in the market will be critical for developing a successful transition plan for the market. Developing these relationships may pose different challenges to state networks or other public media entities that operate in multiple markets. In these cases, plans for each market may not necessarily be the same across an entire network. It is likely a separate agreement and plan will be required for each market.

Stations may be well served to examine a variety of possible deployment and transition scenarios for their stations, as well as examining a variety of potential partners and channel sharing scenarios. This is particularly important as the second, third, and fourth stations in a market are transitioned to ATSC 3, and the capacity to carry programs in ATSC 1 is reduced and limited.

Overview of Core ATSC 3 Technologies

The ATSC 3 Standard (A/300) is a suite of standards including documents relating to specific core technologies implemented in ATSC 3. These technologies cover a variety of components that make up the overall system (available at www.atsc.org).

As shown in the **Figure 3** below, ATSC 3 is a layered system including signaling that allows a receiver to properly receive and decode the various component of the ATSC 3 signal.



This hierarchical signaling design will enable broadcasters to change specific component layers in the system as technologies change without the need for a wholesale replacement of the entire system. In other words, the system is designed to be extensible and “upgradeable” as new advances enable component layer replacement. The following is a brief overview of some of the core technologies for various components of the system.

Physical (RF) Layers: (A/322)

The bottom two layers shown in Figure 1 above are commonly referred to as the Physical or Radio Frequency (RF) layers. These two layers are setup to be hierarchical in nature. An ATSC 3 receiver will find the System Discovery & Signaling layer first in order to synchronize the receiver. In addition, information carried in the system discovery signal

(“Bootstrap”) instructs the receiver how to find and decode the next signal in the transmission (Physical) layer, which is the Preamble. Decoding the Preamble enables the receiver to decode the subsequent signaling and payload information that is transmitted.

There are a few unique characteristics of the Physical Layer of the ATSC 3 standard that are different than the current ATSC 1 standard, which make ATSC 3 and ATSC 1 transmissions incompatible. Unlike ATSC 1, the new ATSC 3 standard uses OFDM (Orthogonal Frequency Division Multiplexing) modulation. This means that the system uses multiple RF carriers simultaneously to broadcast information as opposed to the current ATSC 1 system which is a single carrier system (8-VSB).

The Physical layer in ATSC 3 is also unique in that a variety of modulation constellations, Forward Error Correction (FEC) coding settings, the number of RF carriers or FFT size, as well as numerous other RF parameters are dynamically variable at the selection of the TV broadcaster. In contrast, the existing ATSC 1 signal has a single fixed RF parameter setting and is not changeable.

This flexibility allows a TV broadcaster to trade-off the robustness of the RF signal delivered to an ATSC 3 receiver with the total data throughput or payload (MB/sec) depending upon the settings or parameters chosen by the TV station.

Furthermore, the ATSC 3 Physical Layer includes a number of technologies that enables broadcasters to setup a variety of use cases. These additional physical layer features include:

- Low Density Parity Check Codes (LDPC)
- Multiple Forward Error Correction Codes (FEC)
- Three options for Outer Coding (BCH, CRC, None)
- Six Modulation Constellations (QPSK, 16QAM, 64QAM, 256QAM, 1024QAM, 4096QAM)
- 16 Pilot Patterns
- 12 Guard Interval Settings (27.78 μ Sec -703.7 μ Sec)
- Three FFT Choices (8K, 16K, 32K)
- Interleaver Options (Convolutional, Hybrid)
- Multiple Physical Layer Pipes (PLP's)
- Layer Division Multiplexing (LDM)
- Multiple Framing Options:
 - Time Division Multiplexing (TDM)
 - Frequency Division Multiplexing (FDM)
 - Hybrid Time and Frequency Division Multiplexing

As noted above, there are multiple possible operating points for the TV broadcaster to choose from depending upon the robustness level desired and the data rate of the payload required to deliver the desired services to a particular target receiver. This flexibility is of paramount importance to TV broadcasters as it allows them to customize their system configurations based upon the use case or business model that they choose to deploy and

is changeable on a dynamic basis. The system is designed to allow maximum flexibility for broadcasters to take advantage of current and future business needs.

As shown in **Figure 4** below, the ATSC 3 system has multiple operating points and may be changed dynamically. It is noted that the current ATSC 1 (ATSC A/53) system is denoted by the single black star near the 15dB SNR line for comparison.

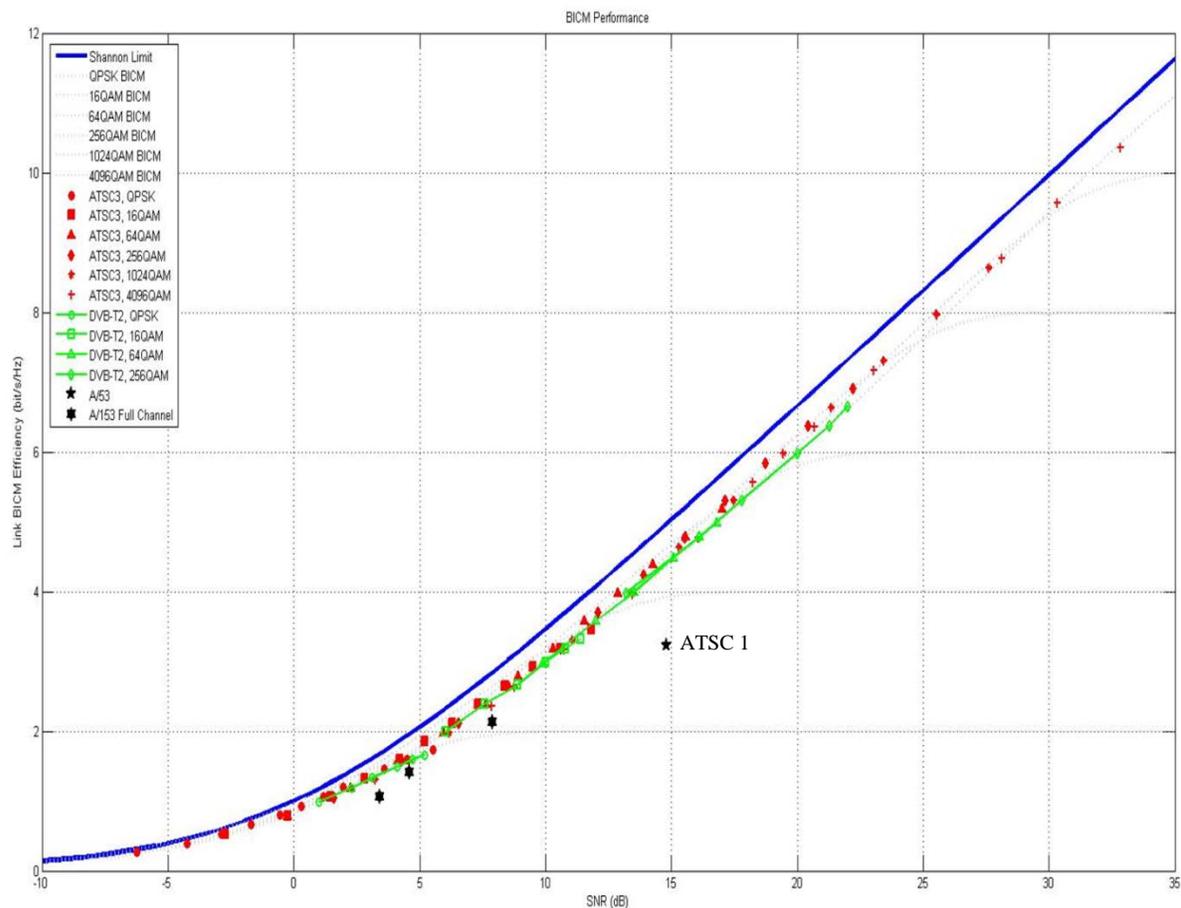


Figure 4 - ATSC 3 Physical Layer (RF) Operating Points

IP Protocols:

One of the most important technologies in ATSC 3 is the extensive use of Internet Protocol (IP) as the core “transport” of content. The use of IP is particularly advantageous as it allows one of the most important features of ATSC 3, which is the ability to integrate content delivered via an Internet connection (IP) and over-the-air (OTA) content, known as “Hybrid” delivery.

In addition, non-real-time files may also be delivered as part of the IP delivery protocol. By utilizing IP technology in the ATSC 3 standard, interoperability with other delivery mechanisms is enabled. This interoperability allows ATSC 3 devices to make use of

multiple connections for the delivery of content, files, data, and other services. Also, the integration of the various delivery methods in ATSC 3 makes it possible to integrate the various sources in a manner that is seamless to the viewer or device user.

Audio/Video CODECS:

The use of new, more efficient audio and video codecs is another important core technology for ATSC 3. It requires much less data (payload) to deliver the same audio/video quality using the AC-4 audio codec and the HEVC video codec (encoder/decoder).

The efficiency gains of the new audio and video codecs used for ATSC 3 are one of the largest benefits of the system to broadcasters. For example, the new HEVC codec uses only approximately 2.5-4.5Mb/S to deliver HD content (such as 720p or 1080i) compared with the 7-10Mb/S required for the current ATSC 1 system utilizing new optimized MPEG2 codecs with statistical multiplexing.

As a result, broadcasters will be able to deliver substantially more content within the existing 6MHz RF channel, such as multiple HD channels, or provide much higher quality content (higher resolution, wide color gamut, high frame rate, and high dynamic range) than is provided today with equivalent bitrates to today's codecs.

The new audio codec for ATSC 3 in the US will be the Dolby AC-4 standard. This standard is particularly exciting for content producers as it allows for "object-based" audio control. For example, the viewer may determine that they want to have the "dialogue" channel at a higher volume than the score or other channels. Users will have the ability to control various components of the audio content. And, the capability for a fully-immersive 7.1.4 audio experience for consumers will likely be one of the most sought after features by consumers in the adoption of ATSC 3.

The large efficiency gains of the new audio and video codecs are one of the core technologies that make ATSC 3 so attractive for broadcasters to launch ATSC 3 transmissions.

Presentation Layer:

The ability to deliver new higher resolution video such as 4K, or High Dynamic Range (HDR), or Wide Color Gamut (WCG) video will likely drive consumer adoption of new ATSC 3 TV sets. These new technologies will provide audiences with much better quality video and audio content. Additionally, broadcasters will be able to remain competitive with other content distributors by being able to deliver these formats to their audiences. It is noted that some content distributors are already delivering these higher quality formats to consumers.

The enhancements in the audio presentation utilizing AC-4 and its object-oriented audio system will also drive adoption of ATSC 3 receivers by consumers. The enhanced audio

experiences, including immersive sound, will be a key feature for content producers to utilize as they develop content for distribution in the new ATSC 3 world. PTV content producers, in particular, may find a variety of new uses and techniques that utilize the capabilities of the AC-4 audio system.

Application Layer:

One of the most important features and functionality of ATSC 3 receivers is the addition of an Application Layer that enables the receiver to run software applications. These applications are envisioned to be tightly integrated with TV broadcast content to enable a host of additional functionality including interactive and other types of features such as non-real-time file delivery as well as integration of OTT content.

Many view the TV Application as a key driver of audience viewing habits and content discovery, as well as providing a “portal” to additional content and services offered by the ATSC 3 broadcaster. Certainly, a variety of TV Applications are likely to develop and will enable stations to establish a unique “look, feel, and brand” for their station and content.

ATSC 3 Equipment Requirements

As with any new technology migration, there will be a need to acquire new equipment and integrate that new equipment into an existing operational TV broadcast plant. As outlined above, there are a variety of new technologies being adopted in ATSC 3 that are not “backward-compatible” with existing infrastructure at a “typical” TV station.

As a consequence, stations are likely to deploy ATSC 3 in a variety of phases or steps to enable various ATSC 3 functionality as equipment becomes available and affordable.

Therefore, the components required to enable ATSC 3 operation at any particular PTV station will greatly depend upon the existing infrastructure the station currently has in operation, as well as other factors including the potential channel-sharing partnerships and whether master control or origination of content resides locally or originates from a central-cast hub or other system.

Also, the distribution of the signals and content out to the transmitter site will differ substantially depending upon the nature of the station (state network versus single station) as well as the current STL (Studio to Transmitter Link) infrastructure (fiber or microwave).

However, to enable the minimum core TV service there are a few components that stations will likely require, which are listed as follows.

Studio/Master Control Equipment:

The studio or master control equipment required for an ATSC 3 deployment will likely include new audio and video encoding equipment in order to encode the content with the new AC-4 and HEVC codecs. In addition, stations will likely need the appropriate multiplexers, electronic service guide generators, and a Broadcast Gateway or Scheduler that is the “output” of the studio before the STL connection.

Also, in order to transmit the existing content in ATSC 3, stations will need to provide content from a server or other source in the format desired. Or, alternatively, stations will need to up-convert content (much like we did in the analog to digital conversion) from the existing format to the new format desired for ATSC 3 transmission.

This is a particularly important consideration for stations that participate in a Joint Master Control (JMC). Stations will need to work with their JMC provider in order to facilitate the appropriate equipment upgrades and integration. Furthermore, JMCs may need to provide separate ATSC 1 and ATSC 3 streams to the local station. The provisioning of the program content streams may become complicated with channel-sharing considerations regarding both ATSC 1 and ATSC 3 streams. Thus, special consideration of the impact on JMC operations should be a high priority before moving forward with ATSC 3 deployment planning.

Example list of equipment likely needed for ATSC 3 at studio/master Control

- New Studio/Master Control Equipment for ATSC 3:
 - New HEVC Video Compression, Video Encoders, Statistical Multiplexing
 - High Efficiency Video Coding allows Ultra HD (4k), High Dynamic Range, Wide Color Gamut, High Frame Rate, etc.
 - Multiple Encoders, as required for multiple services (each TV service)
 - New AC-4 Audio Compression and Audio Encoders (may be integrated with video encoder)
 - “Up-converters” to convert existing signals to new formats
 - Service Multiplexing
 - New Signaling (PSIP and/or Metadata) Equipment
 - Broadcast Gateway (“Scheduler/Framer”) controls data payload, framing and provides transmitter exciter RF Parameters (STL/SFN Interface)
 - Advanced EAS support
 - Closed Captioning Equipment
 - Hybrid Content Streaming Infrastructure (content and web services etc.)

It is also noted that the location of this equipment will need to be determined in cooperation with the other stations in the market that are channel sharing the ATSC 3 transmitter. It may be that a consolidated “headend” location for the market would provide some efficiency for signal interconnection. Or, stations may house their own equipment and deliver content to the ATSC 3 Gateway location for scheduling and framing into the ATSC 3 signal.

Studio to Transmitter Link:

The existing ATSC 1 STL will likely require some modification or replacement, particularly if the link is not currently an IP link. The new ATSC 3 standard includes an STL Protocol (A/324) to enable the functionality of the Gateway/Scheduler interface to the transmitter exciter as well as other functions. Some of the important considerations for the STL link are:

- New system is all IP Transport. Existing Transport Stream STL’s likely to require replacement.
 - Systems designed for ATSC 1 and a constant data rate of 19.39Mb/s
 - Existing ATSC 1 systems mostly SMPTE-310M or ASI Transport Stream
 - For ATSC 3, higher data rates up to \cong 30-60 Mb/s may mean that the original STL may not be suitable

- IP transport opens the door to alternative STL methods including:
 - IP Microwave
 - Fiber Interconnection (various methods)
 - IP via private networks and possibly satellite
- Early evaluation of access options at the transmitter site provides for flexibility.
- New IP transport methods provide the means to add significantly improved error mitigation and redundancy.

As discussed above, it is important to consider all the signal routing and interconnection required for both the ATSC 1 and ATSC 3 channel sharing and signal delivery to the various “host” stations. As a consequence, it is likely that various STL links will require modification, replacement, or path re-alignment to another location to enable the various channel sharing scenarios required for a market. Stations using JMCs should pay particular attention to the details of delivering ATSC 1 and ATSC 3 streams to various host stations within their market.

Transmitter Facility:

One frequent question is what modifications are required for the transmitter facility. The scope of changes or modifications required for a transmitter facility to transmit ATSC 3 will vary significantly across facilities depending upon the existing equipment and the degree to which stations wish to optimize their transmission facilities for ATSC 3.

Stations that are repacking as part of the FCC’s Post-Incentive Auction Repacking process may be purchasing new transmitters as part of their channel relocation project. In this case, it is very likely that the new transmitter will be ATSC 3 “ready”, meaning that the ATSC 1 exciter may be upgraded to ATSC 3 with software or firmware upgrades and very little changes to the actual hardware.

Obviously, the design of the transmitter will dictate if this is possible. However, transmitter manufacturers are generally following the path of ATSC 3 upgradeable equipment. One design consideration will be the peak power handling capability of the power amplifier in the transmitter. In general, newer designs that have been implemented to accommodate DVB-T or OFDM signals, and they will be capable of transmitting ATSC 3 signals with minimal distortion and good performance.

Older transmitters are generally capable of being converted to ATSC 3 from ATSC 1. However, the power amplifiers may not be capable of the higher peak to average power ratios required for ATSC 3, will be limited in output power, and may not be able to

achieve the appropriate transmitter output power rating when operating in ATSC 3. Therefore, an evaluation of the existing transmitter and facilities will likely be the best approach in order to develop a transition plan and appropriate equipment replacements or modifications necessary at the transmitter facility.

It is noted that the FCC's rules regarding transitioning to ATSC 3 are based upon the same Effective Radiated Power (ERP) levels that stations operate in their current ATSC 1 mode. Therefore, replacement of older transmitters not capable of meeting the higher power requirements may be needed in those cases where stations are not repacking and have an older transmitter that is not designed for the transmission of OFDM signals at the rated output power.

Also, the FCC in its rules regarding ATSC 3 transmissions adopted the same emission mask requirements for ATSC 3 as for ATSC 1. So, existing mask filters should be appropriate for ATSC 3 operations. The few exceptions may be "sharp-tuned" mask filters that have notches at the edge of the transmission channel due to the limited non-linear pre-correction capabilities of early DTV transmitters. It is recommended to have a qualified RF engineer evaluate any existing equipment that is to be re-purposed and not replaced as part of an ATSC 3 conversion project.

It is noted that the existing ATSC 1 system has an occupied bandwidth of 5.38MHz and the new ATSC 3 signal has an occupied bandwidth of 5.83MHz. Therefore, the ATSC 3 signal is slightly wider than ATSC 1 transmissions, but still contained within the allotted 6MHz RF channel. This is important for any older generation mask filters that were tuned "narrow" in order to meet shoulder requirements of the DTV emission mask requirement.

Another frequently asked question related to transmission facilities is if the station should replace its antenna with an antenna that incorporates some vertical radiation component. Of course, the addition of a vertical radiation component should improve reception within a station's coverage area, particularly indoor reception, regardless if the transmission is ATSC 1 or ATSC 3.

So, adding a vertical radiation component may be a good idea regardless if the station plans to convert to ATSC 3 or not since a higher signal power density within the coverage area should improve station reception in ATSC 1 as well as ATSC 3.

Another consideration regarding adding a vertical radiation component is whether the station plans to offer mobile services. Adding a vertical radiation component is also generally a good idea in order to improve the robustness of mobile reception that may be

desired with ATSC 3. Of course, there are capital and operational expense considerations with adding a vertical component to the radiated signal, as it does require larger transmitter output power. So, stations may find they need to replace their transmitter with a much larger power rated unit in order to add the vertical component. This may be a significant capital investment for a station to undertake. Also, there may be significant operational cost considerations with higher electrical usage and commensurate increases in costs for electricity for the larger transmitter.

It is noted that stations that retain a horizontally-polarized (Hpol) antenna will still be able to operate in these various ATSC 3 modes, but they may not deliver the required signal strength for a highly reliable service under difficult propagation conditions. Therefore, while replacement of the antenna is not required, the station may find that the Hpol only antenna exhibits some performance limitations. This decision will likely be driven by a cost/benefit analysis conducted on the replacement costs of the antenna and the stations' financial circumstances.

Single Frequency Networks (SFN):

The ATSC 3 system is designed to take advantage of Single Frequency Networks (SFN). SFNs offer two specific advantages to ATSC 3 stations that choose to deploy them.

First, a SFN allows a station to maintain a higher and more consistent RF signal density across its market. By adding additional transmitters, the "average" RF signal level will be higher in various locations across the market when compared with a single transmitter facility.

Secondly, by adding additional SFN transmitters, there are now multiple RF paths from the transmitters to the receiver. The path diversity that this enables is another big benefit of SFN deployment, as the statistics of having a completely blocked path between the transmitter and receiver are considerably less if there are multiple transmitters that are operating simultaneously and can deliver a signal to a given receiver.

However, SFNs are not required for the deployment of ATSC 3. Certainly SFNs offer advantages for certain use cases and propagation environments. However, they are not required for successful ATSC 3 deployment. Consequently, it is very likely that large-scale SFN deployment would occur several years later in the transition to ATSC 3.

It is important to note that the SFN deployment costs can be defrayed or managed by utilizing a shared infrastructure among several stations in the market sharing the same SFN transmitting sites, antennas, and other assets. Thus, working with other stations in

the market on an SFN design and deployment would be critical in order to manage the both the capital and operational costs associated with an SFN deployment.

The recently released FCC ATSC 3 rules allow stations to utilize SFNs using the current DTS (Distributed Transmission System) rules. Therefore, stations may deploy SFNs for ATSC 3 but must adhere to the current DTS rules. It is noted that some broadcasters would like to modify the existing DTS rules in order to facilitate better ATSC 3 network designs. It is anticipated that there will be some broadcast industry activities related to modification of the existing DTS rules in the near future.

Conclusions

Public television stations should understand the potential new opportunities, as well as the potential impacts to their operations, that ATSC 3 presents to their organizations. Stations are encouraged to develop a plan on how to accommodate those impacts, as well as develop a budget for the potential costs involved in rolling out ATSC 3.

In addition, stations should understand the importance of working with other stations within their markets or DMAs to develop a market-wide plan for the deployment of ATSC 3. The channel sharing scenarios as well as deployment framework will likely vary from market to market depending upon the stations involved, their ownership, and other factors. Thus, PTV stations should engage with all the other stations in their markets to determine the likely channel sharing and ATSC 3 deployment scenarios.

It is clear that many broadcasters are excited about the new opportunities provided by the transition at ATSC 3. Thus, stations should consider developing both short-term and long-term plans and strategies for their ATSC 3 deployment.

However, PTV broadcasters also have to balance these new opportunities and potential new services with their existing operational environments at the stations, consider the risks associated with each potential business partner, and adopt appropriate safeguards to ensure there is a minimal risk to the stations' ongoing operations, mission, and financial conditions.