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# Transmission Site Planning for ATSC 3.0

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**Abstract -** *ATSC 3.0 is an advanced, new-generation, over-the-air transmission standard. With it comes a wealth of creative technologically advanced capabilities, which have the potential to enable some significant and exciting new business models. Because the physical layer (PHY) of ATSC 3.0 is based on OFDM modulation, rather that 8VSB, several items in the current transmission chain may be affected. TV broadcasters, who may already be contemplating the conversion to ATSC 3.0, have by now likely realized that they will be forced to make changes to their existing transmitter plant. Items subject to change may include the transmitter (including exciters and power amplifiers), inside RF plant (line, mask filter, combiners), and outside transmission line and antenna. This paper provides insight into the key differences between the current ATSC 8VSB and the new ATSC 3.0 standard, along with an overview of how these differences may impact the transmitter plant. A review of Peak-to-Average Power Ratio (PAR) differences between 8VSB and OFDM, along with power amplifier characteristics will be reviewed. Lastly, some recommendations for planning a smooth transition path from ATSC 8VSB transmission over to ATSC 3.0 will be discussed.*

## Key Differences: ATSC 1.0 & ATSC 3.0

ATSC 1.0 (8-VSB) is a fixed digital TV modulation standard, with little flexibility or scalability. It uses 8-level Vestigial Sideband (8-VSB) modulation. The transmitted data rate is fixed at 19.39Mb/s and the receive C/N threshold is 15dB. The standard is already more than 20 years old and has proven itself to be a very robust digital transmission method for over-the-air delivery. It provides the platform for excellent quality HD and SD multicast transmissions. The benefits over the analog NTSC standard that it replaced in the USA were tremendous and provided the biggest change since color television was first broadcast in 1953. Compared to some other digital TV standards of today, ATSC 1.0 has a few disadvantages, some of which are listed here:

- Fixed data rate / payload
- Fixed modulation format
- Fixed interleaver
- Fixed coding / error correction
- Difficult reception in high echo areas
- Marginal/difficult SFN implementation
- Mobile reception difficult

ATSC 3.0 is built around OFDM modulation and utilizes much more modern techniques for error correction, along with a host of variable parameters and constellations. With introduction of ATSC 3.0, broadcasting becomes part of the wireless internet. Essentially, broadband and broadcasting have now been merged. It also allows interactive and hybrid TV using standard internet protocols. It also provides data rates ranging from <2Mb/s to >50Mbps over 6MHz bandwidth. This provides far more flexibility for the broadcaster and certainly opens up the opportunity for 4K UHD transmission, along with HD and SD and other services.

In summary, here are five key features of ATSC 3.0, all of which are significant differentiators over ATSC 1.0:

- Robust mobile reception
- Ultra-High Definition (UHD, or 4K) TV
- Immersive high quality audio
- IP Transport
- Advanced Emergency Alerting (EAS)

## Peak-to-Average Power Ratio

When one compares the ATSC 1.0 and 3.0 physical layer, the biggest impact on the RF waveform and by far the biggest factor affecting the transmitter system is the Peak-to-Average Power Ratio (PAPR, or PAR). One advantage of the 8-VSB standard used for ATSC 1.0 is that the transmitted PAR was close to 6dB [1]. In comparison, an OFDM waveform, such as DVB-T or ATSC 3.0, has a transmitted PAR of around 8dB [1]. This 2dB difference in PAR can affect the transmitter average power rating, which in turn can impact cost, physical size and performance.

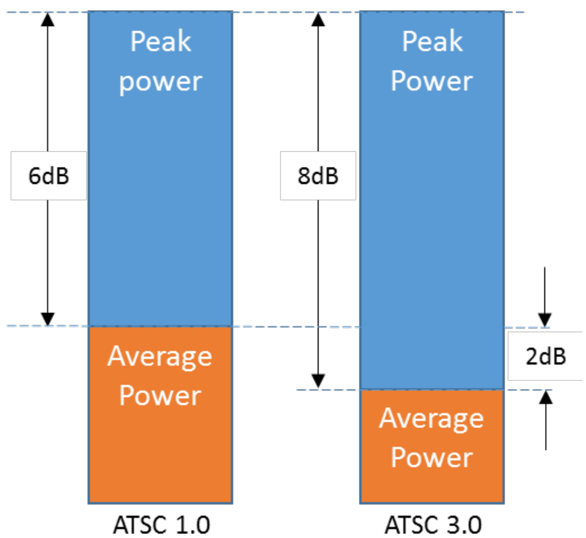


FIGURE 1 - PAR DIFFERENCE BETWEEN ATSC 1.0 & 3.0

Figure 1 shows the difference in average power between ATSC 1.0 and 3.0, for a constant peak RF power level.

If a television transmitter was originally designed and optimized specifically for 8-VSB transmission, it will probably have components sized appropriately for a 6dB PAR. This includes the power amplifiers, power supplies, cooling system, RF components (filters, line, test load) and other items. It is known that transmitters in ATSC 1.0 service today were optimized for best performance and efficiency with a 6dB transmitted PAR figure.

Clearly, if an ATSC 1.0 transmitter is already operating at, or close to, its maximum peak RF power capability, it must be operated a similar peak power level with ATSC 3.0 modulation. Any attempt to raise the peak power will result in distortions and clipping, which manifests itself in degraded RF performance, especially for Third Order Intermodulation Distortion (IMD, or "shoulder" level) and Modulation Error Ratio (MER). Figure 2 depicts the effect of increasing peak power through an amplifier, hard into clipping and beyond its useful operating range. At this point, even the best pre-correction techniques may not be successful in providing a mask compliant signal.

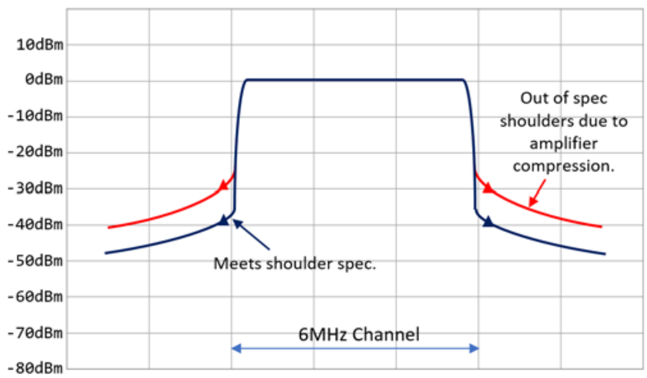


FIGURE 2 - EFFECT OF AMPLIFIER COMPRESSION ON SHOULDER LEVEL

## TRANSMITTER POWER FOR ATSC 3.0

In the broadcast transmitter business, a question that we are asked frequently is: "*What transmitter power will I need for my future ATSC 3.0 service*?". A simple question indeed, but one that may not have a simple answer. Due to the very flexible nature of the ATSC 3.0 physical layer standard, there are a lot of variables and many different scenarios. Some industry leaders have stated that it could be the same average power as for the 1.0 transmission. However, a pure side-by-side, apples-to-apples, comparison with 15dB C/N rooftop reception and a data payload of 19.39Mb/s will result in a lower ERP requirement for 3.0 versus 1.0. This is attributable to the better coding efficiency and advanced error correction capabilities built into the new standard. This does not even consider the significant improvements in video compression that HEVC offers, which will increase the effective number and/or quality of programs that can be squeezed into a given bit-rate. Each broadcaster needs to evaluate its plans as far as what will be passed through the transmitter – the number of programs, SD, HD or UHD quality, type of reception being planned (rooftop vs. indoor, vs. mobile/portable device), etc. To add complexity to this, 3.0 can accommodate multiple PLP's, where each PLP can be individually tailored to best match the type of service that may be needed. Add LDM and SFN and it becomes even more complex.

Figure 3 illustrates six operating models that were developed by a group of broadcast engineering experts, using use case models that have been selected by broadcasters. This illustrates the type and number of each service, the target type of reception, the modulation parameters of each PLP and the payload capability of each PLP [4].

| Config. | Opportunity | Multiplex Capacity | Targeted Receivers | Service Assignments | Channel Loading (BCH On) | PLP Capacity (Mb/s) |
|---|---|---|---|---|---|---|
| 1 | UHD from Single Stick TDM Audio Services | Lots more HD/SD services space available | Fixed (similar to today) | 1 UHD + 1-12 HD or 1 UHD + 3-6 SD | PLP 1: FFT 32K, GI 148uS, 64QAM, LDPC 64800, FEC 11/15, Frame 250mS | 20.03 |
| | | | | | PLP 2: FFT 32K, GI 148uS, QPSK, LDPC 64800, FEC 5/15, Frame 250mS | 0.66 |
| 2 | Multicast HD/SD from single stick TDM | 5-12 | Fixed (similar to today) | 2-4 HD or 8-10 SD in a single video stat mux pool | PLP 1: FFT 32K, GI 148uS, 64QAM, LDPC 64800, FEC 11/15, Frame 250mS | 17.59 |
| | | | | | PLP 2: FFT 32K, GI 148uS, QPSK, LDPC 64800, FEC 5/15, Frame 250mS | 1.03 |
| 3 | UHD + Mobile HD | 2-5 | Fixed | 1 UHD (+ audio) | PLP 1: FFT 32K, GI 148uS, 256QAM, LDPC 64800, FEC 11/15, Frame 250mS | 20.8 |
| | | | Mobile & Indoor | 4 SD or qHD Mobile + audio | PLP 2: FFT 8K, GI 148uS, 16QAM, LDPC 64800, FEC 5/15, Frame 250mS | 2.23 |
| 4 | Multicast HD/SD Robust Core SFN | 5-7 | Fixed | 2 HD in video stat mux pool | PLP 1: FFT 16K, GI 148uS, 64QAM, LDPC 64800, FEC 5/15, Frame 250mS | 8.7 |
| | | | + Robust Services | +3-5 SD in video stat mux pool | PLP 2: FFT 16K, GI 148mS, 16QAM, LDPC 64800, FEC 5/15, Frame 250mS | 2.97 |
| | | | | + audio | PLP 3: FFT 16K, GI 148uS, QPSK, LDPC 64800, FEC 5/15, Frame 250mS | 0.66 |
| 5 | Deep Indoor HD Core + Mobile Single Stick | 6-8 | Fixed + portable deep indoor receivers | 2 HD in video stat mux pool (+ audio) | PLP 1: FFT 16K, GI 148uS, 64QAM, LDPC 64800, FEC 7/15, Frame 250mS | 5.38 |
| | | | | 4-6 SD in video stat mux pool (+ audio) | PLP 2: FFT 16K, GI 148uS, QPSK, LDPC 64800, FEC 7/15, Frame 250mS | 2.13 |
| | | | | + audio | PLP 3: FFT 16K, GI 148uS, QPSK, LDPC 64800, FEC 5/15, Frame 250mS | 0.;66 |
| 6 | Deep Indoor & Mobile SFN TDM | Roughly 5 | Portable receivers indoor and high-speed Mobile | 4-5 SD or qHD in a video stat mux pool (+ audio) | PLP: FFT 8K, GI 222uS, 16QAM, LDPC 64800, FEC 5/15, Frame 250mS | 5.74 |

FIGURE 3 – SIX USE CASE EXAMPLES FOR ATSC 3.0

## TRANSMITTER TECHNOLOGY AND ATSC 3.0

Newer transmitters for both UHF and VHF transmission have emerged in the market over the past 2 or 3 years. These designs bring vastly improved AC to RF efficiency, along with much better system level redundancy than many earlier designs. Improved RF devices and Doherty implementations for the final amplifier have played a dramatic role in providing large increases in efficiency.

The newest generation of "Asymmetrical Doherty" 50 Volt LDMOS RF transistors are rated at OFDM power levels of up to 150W across the UHF-TV spectrum and can provide efficiencies approaching 55% at the pallet (board) level. When coupled with other efficiency improvements and optimizations in AC to DC power supplies and "smart" liquid cooling systems, the result is an overall transmitter efficiency which can exceed 40%.

Asymmetrical Doherty LDMOS Characteristics (Example Ampleon BLF-888E) [2]:

- Voltage (Vds, Drain/Source): 50 Volts
- Average Power: 150W (OFDM TV)
- Efficiency (žd): 52%
- RF Gain: 17dB
- Doherty back-off (peak/main) 7.96dB
- Excellent ruggedness (VSWR > 40:1)
- Excellent thermal stability
- Three circuit designs can cover all UHF Band

A key and significant advantage given by the asymmetrical Doherty device is the back-off. This is the difference between the operating points of the main (carrier) amplifier and the peaking amplifier. It should be noted that standard 2-stage Doherty devices provide a 6dB back-off. The Asymmetrical Doherty device back-off is 7.96dB, which is very close to ideal, since the transmitted PAR for OFDM TV is close to 8dB.

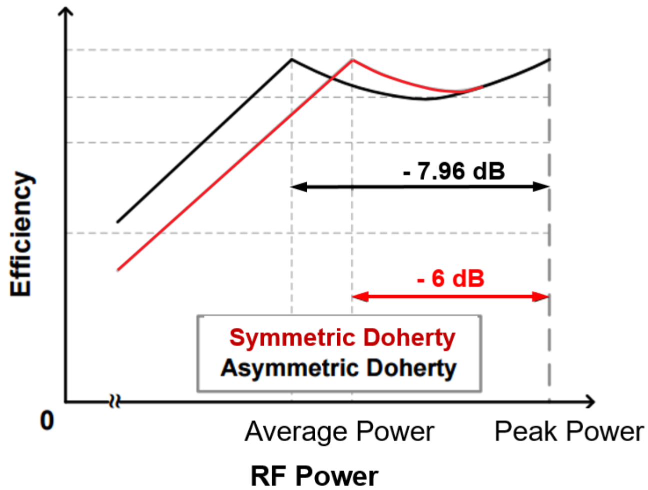


FIGURE 4 - ASYMMETRICAL VS. SYMMETRICAL DOHERTY

## TRANSITION SCENARIOS FOR ATSC 3.0 MIGRATION

While looking ahead towards the possibility of transmitting ATSC 3.0 in the near future, there are number of areas that a broadcaster can consider now. Because 3.0 is not compatible with 1.0 and, and therefore, any TV sets in use today, various transition schemes have been suggested, with the main point that viewers will see little or no disruption. Most transition scenarios [3] involve slowly introducing 3.0 signals, while weaning consumers from their ATSC 1.0 signals. Let's look at two possible 1.0 to 3.0 transition scenarios:

### *I. Single Owner, Two Stations in Same Market*

In a market where one owner has two stations, the following scenario might be possible [4]. The programming from both stations would be transmitted in ATSC 1.0 on one station and ATSC 3.0 on the other. Due to the improved efficiency of ATSC 3.0, both stations should be able to provide all their program streams at today's quality on the ATSC 3.0 channel and likely gain some robustness (improved service) on lower bit-rate streams. Unfortunately, it is unlikely that most stations will be able to use this method.

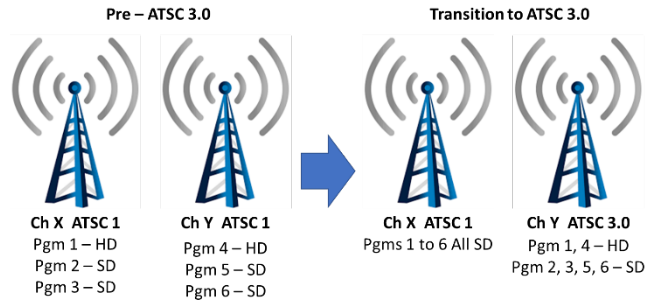


FIGURE 5 - SINGLE OWNER 2-STATION SCENARIO FOR ATSC 3.0 TRANSITION

### *II. The "Lighthouse" Station Transition Concept*

Since most major markets will have several stations, each with a different owner, the previous scenario may prove to be unusable. Another idea being proposed by several industry experts and highlighted in a recent industry publication [5] suggests a temporary channel-sharing partnership featuring a "Lighthouse" Station. In this scenario, one station (i.e. the "Lighthouse") would seed the market with ATSC 3.0 signals for all the TV stations in each market, while the other stations make unused capacity collectively available to replicate the Lighthouse station's ATSC 1.0 signal, as well as their own ATSC 1.0 signals. Over time, as audiences migrate their viewing over to the new ATSC 3.0 services, these stations will elect to convert all their respective transmissions to ATSC 3.0, and no longer transmit an ATSC 1.0 signal. The current ATSC 1.0 PSIP system can support this channel sharing by preserving the stations' branding and recognition of the virtual channel. It will, however, require that consumers rescan their receiving devices when a station shares its ATSC 1.0 stream for the first time.

Of course, this idea might only work with the exceptional cooperation and planning between stations who may otherwise be business rivals.

Regardless of the approach taken to make the move from 1.0 to 3.0, it seems very likely that eventually, your station will need to transition its RF plant (Transmitter, RF system, RF line and Antenna) over to ATSC 3.0 in the coming few years.

## PLANNING NOW FOR FUTURE

You may be thinking – "*Why should I worry about ATSC 3.0 today? I have enough headaches as it is and this Spectrum Repack is certainly going to take up a lot of time and resources over the next few years*". The opportunity here is very clear – If your station is going to be Repacked, you may well need new equipment at the Transmission site. Items that are likely to be affected have been discussed at various industry events, conferences, webinars, meetings, etc. for the past three years. Clearly, if a new transmitter must be purchased, it would be very wise to start planning now for 3.0.

### I. *New Transmitter Considerations For 3.0*

Items to consider now:

- Can the new transmitter that I am purchasing be easily and inexpensively upgraded from ATSC 1.0 operation to 3.0 at a later date?
- Will the 3.0 upgrade be simply a Software/Firmware change, or will you need new hardware?
- What about the average power level? How much power will you need?
- Will your average power need to be reduced by 2dB because of limited peak power headroom, or will it be able to operate at the same average power?
- What about increased power for ATSC 3.0? Perhaps your station is planning on providing a mobile service. Coverage for mobile devices has been shown to improve if some vertical polarization is included in the signal. Optimum levels of V-Pol are likely to be in the 25% to 50% range [6]. This therefore would necessitate a transmitter power increase of the same amount (between 25% and 50%) in order to maintain licensed H-Pol ERP.
- Finally, check that your preferred transmitter supplier is willing to guarantee in writing that the new transmitter can be upgraded simply and easily (to 3.0) and ask for a price for the conversion.

### II. *Existing Transmitter Considerations For 3.0*

What if your station is already on a lower UHF channel and it looks like there will be no channel change needed during the upcoming Repack? Perhaps your existing transmitter will be fine for conversion to 3.0 later.

In evaluating the capability and usability of the existing transmitter, take a close look at the following items:

- Is your existing transmitter capable of being converted to 3.0?
- If so, would it just need a new exciter, or will it require some additional modifications?
- Will it provide enough RF power for your service/coverage planning?
- Is the transmitter still supported by the manufacturer?
- Is the original manufacturer still in business?

If the transmitter can be converted to 3.0, it would be prudent to obtain a price quote for the conversion and compare it to the price of a new transmitter, taking into consideration the cost of operation and ROI. Since new transmitters tend to be far more energy efficient (often by >50%) than the old system, the ROI may show a very short breakeven period, sometimes in the 3 to 5-year range.

## BEYOND THE TRANSMITTER

Besides the transmitter, there are several other items that you will need to look at in the transmitter facility. The existing RF system is also potentially a Repack replacement item. If it is, then it can be re-sized to match the expected ATSC 3.0 average and peak power levels. This includes any RF line, patch panels, test loads, mask filters, combiners that are in the system. Even if you aren't going to be changing channels, it would be wise to inspect every item in the RF path and verify its suitability for future 3.0 service. Most RF components inside the transmitter room will likely have the required 2dB headroom expected to be needed. If considering V-Pol add another 1dB to that for a total of around a 3dB (100%) power increase.

## RF LINE & ANTENNA

Perhaps even more daunting will be the outside RF Line and Antenna. Many consulting firms and manufacturers with vast experience are available and I recommend that you start a conversation today. There are so many variables to juggle, it's going to be a challenge. RF line in general should be okay (although you may be changing or modifying it for re-pack anyway) but it needs to be checked for the anticipated average /peak power levels for the future 3.0 service. The antenna is probably the most difficult item. If a channel change for re-pack is in the mix, your station may elect to up-size it and/or add V-Pol at the time that the re-pack antenna is specified. While you won't get reimbursed for the 3.0 specific changes, the upcharge for changing the antenna specs now will obviously be less than replacing it for Repack and then replacing it a second time when 3.0 arrives.

The antenna gain (and ERP) also impacts the transmitter power rating, as well as other factors such as the type of coverage being planned (indoor, mobile, rooftop, etc.). While there are many variables, a good rule of thumb for today is to plan for the same average ERP as your current ATSC signal and then possibly add between 25% and 50% for V-Pol.

It should be stated that the existing TV antenna will almost certainly "work" for 3.0, it just may not provide the ideal, or planned coverage that is needed in your market.

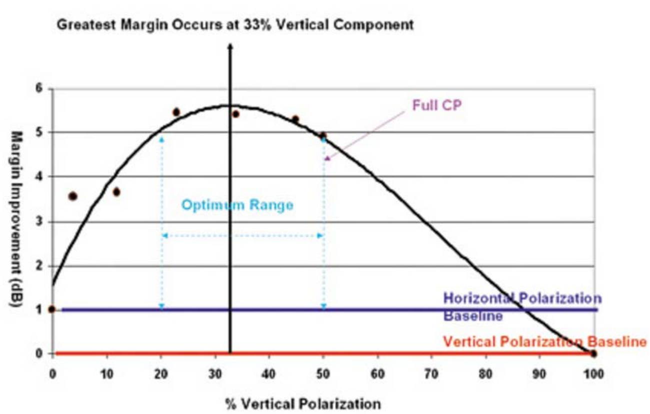


FIGURE 6 - IMPROVING MOBILE RECEPTION WITH V-POL [7]

## The Tower

On top of all the Transmitter, RF system and Antenna issues, don't forget the Transmission Tower. Again, if Repack is in your near future, a tower study to evaluate its current loading and condition is an absolute must. Also, once a new antenna is specified this can be included into the calculations. It is already becoming clear that many TV towers in service today do not meet the newest EIA wind-loading requirements. Some stations and group owners have already begun getting their existing towers inspected, in order to avoid any surprises later. Much has been said already about the cost involved to modify towers and the availability of qualified personnel to make the changes needed.

## Final thoughts And Conclusions

ATSC 3.0 is moving along quickly in terms of standards development testing and public interest. Some time spent now to plan your transition path will likely be time very well spent. To emphasize that point, any changes needed for Repack may be the trigger to also implement some additional changes for future 3.0 transmission. It is realized that there is much more involved than just the transmission site. Many other items will be needed, especially if 4K UHD delivery is in your plans.

One additional item to consider now may be how your transport Stream is delivered to your transmitter. While you are probably transporting your content as SMPTE-310 or ASI today, this also will change. The new ATSC 3.0 standard employs IP Transport (no ASI or SMPTE into the transmitter). While you could simple convert the existing transport stream into the IP stream at the transmitter facility, it might be great time to consider changing the STL over to IP. This is likely to result in some cost savings also.

Now is the time to begin planning your station's transition from ATSC 1.0 to 3.0. There are many resources and industry experts available, including consulting firms, manufacturers, installation and site inspection teams ready to serve you.

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