Anywave gap fillers – a powerful tool for SFNs and coverage optimization – ATSC 3.0 and other standards

David Neff, General Manager, Anywave Communication Technologies, Inc.

Gap fillers, also known as on-channel repeaters or boosters have been around for a long time, but recent developments in regulations and technology have made them a critically important tool that you should consider in your broadcast coverage planning – especially for ATSC 3.0.

Gap filler basics

A gap filler in its simplest form is an amplifier. After all, the purpose of a gap filler is to increase or "boost" the signal level of a transmitted RF signal, so that coverage can be improved. However, a simple amplifier has limitations. It adds additional distortion, usually with no provisions to equalize it, and does not have a way to deal with the feedback of the output signal that can appear at the input. At worst, this can result in oscillations and a destroyed amplifier. At best, the feedback signal can degrade the signal quality of the amplifier output, possibly resulting in unacceptable MER. Physical isolation and/or shielding of the receive antenna from the emissions of the transmit antenna, and the use of highly directional antennas are always recommended if possible, but in many cases, that is not enough.

Gap fillers have evolved over the years. To improve the degradation caused by the feedback signal, methods to cancel or reduce the effect of the feedback have been developed. "Echo cancellation" – called that because the feedback signal resembles a signal that was received from a reflection (it is the same signal, just different in amplitude and time delayed), is what many call their technology. Today's gap fillers include echo cancellation that can handle situations even when the feedback (undesired) signal at the gap filler input is many times larger than the incoming (desired) signal.

In addition, methods to provide automatic (adaptive) equalization of linear and non-linear distortions caused by the power amplifier and output filter in gap fillers have been developed, so that output signal quality can be further optimized. Typically, such equalization of RF power amplifiers is done by demodulating to baseband signals, and comparing these signals to ideal references. This is not practical in the gap filler case, as time delay through the gap filler is important. Demodulation to baseband causes time delays in the milliseconds range – far too long for receiver equalizers in single carrier systems such as ATSC 1.0, and also far too long for the guard intervals that exist in OFDM signals like ATSC 3.0. Practical gap fillers should have insertion delays in the 5 microsecond range, or less. Thus a different type of low delay RF equalization has been developed.

Other factors that can affect gap filler performance are the input signal level, antenna sway, strong adjacent channel signals, power fluctuation, multipath, and intermodulation products (shoulder level) of the incoming signal.

Regulatory environment

The key technical issues of echo cancellation, adaptive correction, and low insertion delay have been achieved, and improvements continue. The regulatory framework for gap fillers has also evolved recently. In the US, the FCC issued a Report and Order FCC 21-21 on January 19, 2021 that set up rules to govern the use of distributed transmission systems (DTS), also known as single frequency networks (SFNs). While not explicitly mentioning gap fillers in the Report and Order, gap fillers are on channel radiators, and are covered by these new rules. The FCC has also authorized LPTV, Class A, and television translator stations to use DTS – previously this was only possible on an experimental basis. So a process now exists for licensing and deployment of DTS, including gap fillers.

ATSC 3.0, with its OFDM signal format, is also a key enabler of DTS and gap fillers, given its superior performance in successful reception of an RF signal along with a co-channel, time delayed, coherent signal. This is very similar to multipath effects at the receiver.

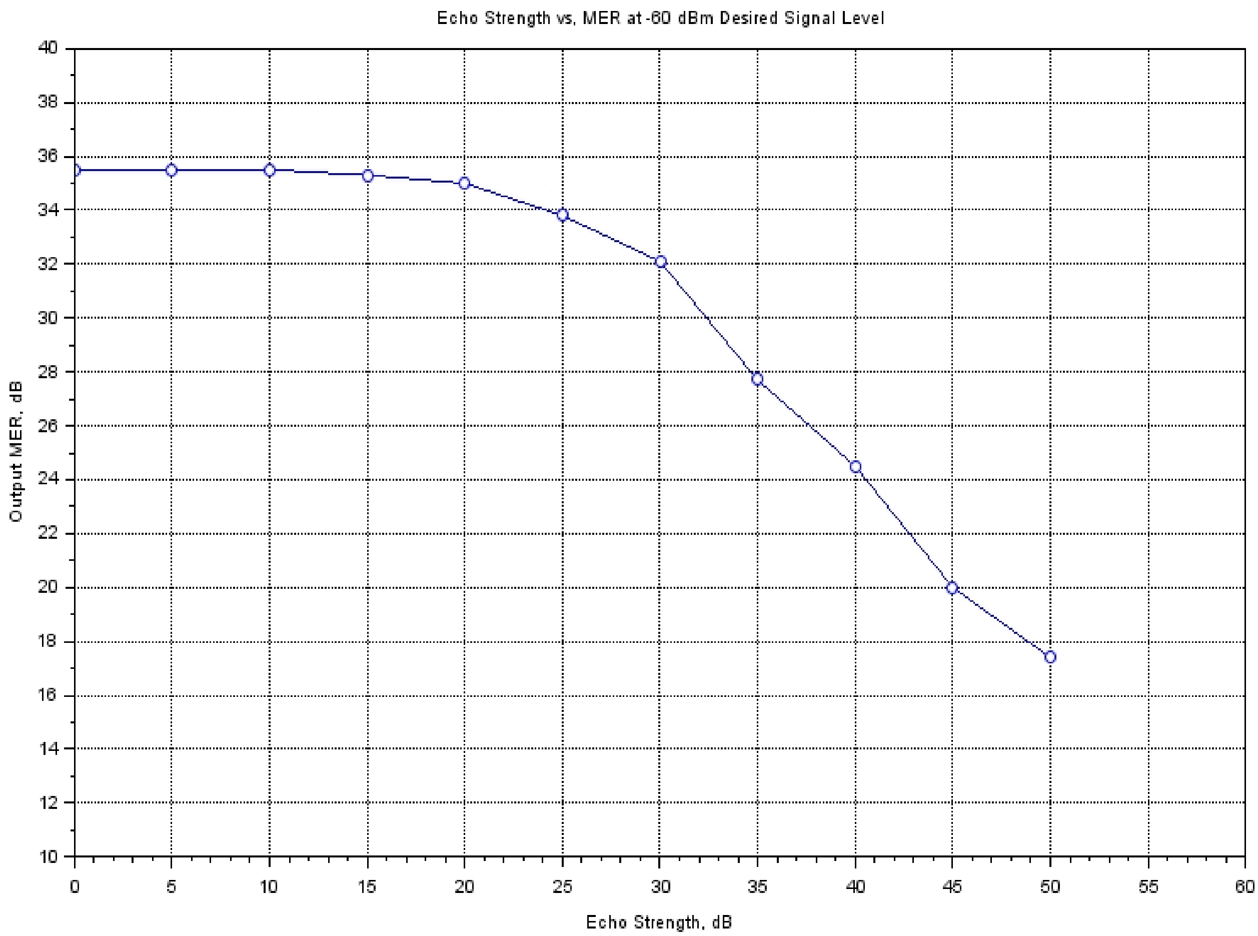
Comparison to synchronized SFN transmitters

Traditionally, SFN network deployments are considered with multiple synchronized transmitters. These transmitters are fed with baseband signals from an STL (studio to transmitter link) like most transmitters, but are also synchronized via timing signals that are delivered by the link. This allows all of the transmitters (which are on the same channel) in the network to be synchronized to emit the same information at approximately the same time. Given that there is no feedback issue like a gap filler (the input to the SFN transmitter is baseband, not on-channel RF), SFN transmitters may generally be operated at higher power levels than gap fillers. In addition, SFN transmitters can provide normal adaptive precorrection to equalize amplifier and filter distortions, and the signal quality from an SFN transmitter can be as good as, or better than the signal quality of any other transmitter in the network. With a gap filler, since the signal is received and retransmitted from the main transmitter without demodulation, the output of a gap filler can only be lower in signal quality than the main signal. It is not "regenerative" in that sense.

On the other hand, gap fillers are much less costly and easier to implement than synchronized SFN transmitters. No STL, SFN Adapter, or synchronization are required, so the need for fiber, microwave, or other equipment is eliminated. Gap fillers are often available in outdoor, tower-mounted enclosures, so deployment can happen very quickly. Power levels of gap fillers have historically been very low, but with recent advancements in echo cancellation technology, along with good engineering and antenna isolation, gap fillers of significant power levels can now be achieved.

Anywave gap fillers

The Anywave gap fillers have all of the advanced technology to provide a powerful solution for broadcasters looking to fill in coverage gaps in their broadcast signal, or as a key tool in deploying a single frequency network. As mentioned, one of the most important features of a gap filler is the ability to cancel "echoes" – the unwanted signals fed back from the output of the gap filler to the input. Anywave has pioneered and patented a unique multi-stage system for cancelling these echoes. A graph of the effects of this superior echo cancellation is below.



This graph shows the MER measured at the gap filler output (vertical axis), vs. the echo strength (horizontal axis) compared to the desired incoming signal. Looking at the 30 dB echo strength value, that corresponds to an output MER of 32 dB. That means that with a feedback signal at the input of the gap filler that is 30 dB (1000 times) higher than the desired incoming signal, the gap filler can still output a very respectable 32 dB MER signal! Note that the tests above were made with an incoming signal of >35 dB MER; lower values would also degrade the output MER.

This strong echo cancellation is critically important for successful operation, especially given the new FCC DTS rules. These rules define the "spillover" beyond the stations defined coverage contour. In most cases, a broadcaster will deploy a gap filler with a directional antenna, with the main lobe of the antenna pattern pointed back towards the main transmitter. This is necessary to prevent spillover, but it may exacerbate the echo level fed back to the gap filler input. So a superior echo cancellation and good antenna isolation is critical to most gap-filler requirements.

A summary of the key features of the Anywave gap fillers:

- Available in both indoor and outdoor versions
- All frequencies – VHF band I and III, UHF
- Works with any signal format – ATSC 1.0, ATSC 3.0, DVB-T/T2, ISDBT, and more
- Industry-leading, multi-stage, patented echo cancellation – provides significant rejection of unwanted signal fed back from output to input. Can provide high quality output signal even when feedback signal at the input is 1000 times larger than desired receive signal
- Gap filler is available in power output levels of 400 watts or higher, depending on site characteristics.
- Gap filler includes exceptional automatic and adaptive signal correction to minimize distortion from output amplifier and filter
- Very low insertion delay for signal – typically around 5 uS - important for good receiver performance
- Highly efficient and linear power amplifiers, including ultra-efficient Doherty technology for UHF and band III VHF
- Works directly from off-air received signal – no STL needed, no transmitter synchronization as with typical SFN networks

Conclusion

Gap fillers, which have been available for many years, but largely ignored because of their limitations and regulatory issues, have significantly evolved in their capabilities and authorization. As ATSC 3.0 deployments continue to accelerate in the US, and strong signals in all areas of the stations coverage contour (to allow deep indoor penetration, mobility, etc.) are demanded, gap fillers have now become a powerful tool for optimizing a station's coverage, and should be considered in any DTS/SFN planning.