Channelized versus Broadband BDAs

In Public Safety Applications

A discussion and comparison

Presented by The Jack Daniel Company
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Introduction
The use of signal boosters (aka Bi-Directional Amplifiers or BDAs) in primary Public Safety wireless systems has become an accepted method of resolving in-building, subway and even shadowed area outdoor coverage.

The recent entry of a proprietary channelized type signal booster has given rise to extensive discussion of the benefits of selecting specific individual channels over the broadband, all channels, approach used extensively by public safety. Other channelized signal booster designs have been available for many years.

This paper is a discussion of what the author believes are pertinent details public safety system designers should consider in making a technology selection. Others may have differing view points.

Related information may be found at www.RFSoliutions.com web site.

Definitions

FCC signal booster class definitions (47CFR90.219 rule) :
A signal booster may be either narrowband (Class A), in which case the booster amplifies only those discrete channels intended to be retransmitted, or broadband (Class B), in which case all signals within the passband of the signal booster filter are amplified. The FCC rules specifically limit Class A (channelized) to amplifying ONLY one narrowband channel per passband;

> 90.219 (c) Class A narrowband boosters must meet the out-of-band emission limits of § 90.210 for each **narrowband channel** that the booster is designed to amplify.

Industry signal booster type definitions:

Bi-directional amplifier (aka "BDA") is another name for signal boosters. One way signal boosters are also sometimes referred to as BDAs.

Channelized: A signal booster that is capable of single channel selectivity. Some may have multiple channels in the same package. These are capable of meeting the FCC Class A signal booster definition. *NOTE: Variable bandwidth Digital BDAs are NOT always programmed to be FCC Class A signal boosters.*

Broadband: A signal booster that amplifies a group of channels that fall within a given bandpass range, usually many kilohertz or megahertz wide. Some may have multiple band passes in the same package. Generally operated as FCC Class B signal boosters. *However if the bandpass is set to amplify only the licensees adjacent channels, the signal booster meets the FCC Class A signal booster requirements.*

Digital programmed bi-directional amplifier: A signal booster using digital filtering that has bandpass bandwidths can be varied by programming.
- When the bandwidth(s) are programmed to ONLY pass one licensees channels, it is operating as a FCC Class A Class A signal booster .

- When the bandwidth(s) are programmed to pass the licensees channels as well as non-licensee channels between the licensee's channels, it is a FCC Class B signal booster.

Therefore, a signal booster with programmable bandwidth may legally be EITHER a FCC Class A or FCC Class B signal booster, which is determined by the operating passband not the technology used. This is supported by a FCC signal booster rules clarification below issued on 8-3-07.

Question 1: Is a Class A signal booster still a Class A signal booster when the bandwidth is great enough to amplify adjacent channels which aren't licensed to the user?

Answer: No, a Class A signal booster must be designed to meet only the booster amplification requirements of the assigned channel(s) per 90.219(a). Because licensees may be authorized to transmit on multiple nonadjacent channels, a Class A booster would need to either be designed to select specific channels or connect directly to the radio so that only the channels transmitted by the licensed radio are boosted. Obviously, various deployment scenarios and bandwidth choices for Part 90 services can complicate the class designation. Therefore, the equipment authorization process may analyze each signal booster individually to determine how it is designed to operate and whether it would fall within the Class A or Class B categories.

Question 2: If a signal booster does remain a Class A signal booster with wider bandwidths, at what bandwidth does a Class B signal booster definition begin to apply?

Answer: There is no black and white answer to this question because it depends on the configuration of the device and how it is designed to operate. A Class A signal booster that can amplify multiple discrete authorized channels is still a Class A amplifier. However, clearly a Class B signal booster would not be designed to discriminate which Part 90 channels are permitted under an individual authorization, but instead amplify a range of Part 90 frequencies consistent with the requirements of 90.209.

Question 3: Conversely, if all the channels within the bandwidth of the signal booster are licensed to the same licensee, would that signal booster be classified as a Class A even though the signal boosters bandwidth is greater than one channel as defined by 90.209?

Answer: Without specific details for the signal booster you are referring to, it is difficult to answer this question. When equipment is submitted for approval, the details regarding what license it will operate under are not provided. However, it is usually clear how the device is intended to operate and the range of frequencies it is capable of amplifying. If a device is submitted with the capability of amplifying a wide range of frequencies with no apparent means of channel selectivity, it would be considered a Class B signal booster.

(Comment: FCC certification procedures have no mechanism to delineate between a Class A and a Class B signal booster. Signal boosters do not even have their won equipment class in Part 2 of the FCC rules, but are classified as an ' Amplifier' or 'Non-Broadcast Transmitter' depending upon the design and certification application.)

Question 4: Does (sic) the emission mask rules in Part 90.210 apply to Class A signal boosters?

Answer: Yes.

Note the answer to Question 4 limits the passband(s) to one single channel each.

Characteristics of specific signal booster designs:

Class B Broadband: Uses broadband amplifiers with common output power amplifiers. Composite output power, ALC (OLC), broadband noise emissions, Moderate output power per channel, moderate gain. Very low digital group distortion and propagation delay. (< 5 microseconds)

Class A channelized types:

1. Complete module per channel type: Discrete input and output amplifiers per channel. Programmed functions. Stable output power per channel, Keyed = no on-channel noise, high power per channel (1 – 25 watts), high gain. Moderate to high group delay.

2. Digital filter type designs : Broadband input and/or output amplifiers with discrete channelized "digital filters". Composite output power, ALC, broadband noise emissions, Moderate output power per channel, moderate gain. Moderate to high group delay.

3. Hybrid type designs: Broadband input and/or output amplifiers with discrete channelized intermediate amplifier(s). Composite output power, ALC, broadband noise emissions, Moderate output power per channel, moderate gain. Moderate group delay.

NOTE 1: Class A signal booster output powers that results in over 5 watts ERP per channel are NOT authorized under Part 90.219 signal booster rules. ***If the signal booster ERP exceeds 5 watts (+37 dBm) the installation(s) must be licensed as individual base station sites.***

Note 2: Signal boosters must also comply with Human RF Exposure limits (FCC 1.1310, et al). Accepted practice is to limit ERP of any single in-building antenna to 600 milliwatts (+28 dBm) maximum ***composite*** *power. Example: For a 10 channel system, this is approximately +18 dBm max. per channel.*

Common characteristics of signal booster system implementation.
These are common to all signal boosters regardless of the signal booster technology used.

- Feedback, antenna-to-antenna isolation:

99% of all feedback problems are due to (1) inferior, unstable hardware designs or (2) improper installation.

All installations can have feedback oscillation regardless of what product design is used. There is only one sure prevention: proper system design and installation.

The accepted practice to design a system where the outside-to-inside antenna isolation (loss) is at least 15 dB more than the gain setting of the signal booster.

Channelized systems often have higher gain than broadband signal boosters making the antenna-to-antenna isolation more difficult to maintain and, due to their higher output power per channel, the oscillation interference level can be much greater than from a lower power broadband signal booster.

Most signal boosters use some form of automatic gain control to maintain operation within the FCC's -13 dB limitation on out-of-band emissions. This is usually near the 1 dB compression point of the amplifiers.

It is a common characteristic that the signal booster output power will be at the maximum capability of the amplifiers used when the system is in oscillation. Oscillations may occur anywhere within the passband(s) and may vary in frequency over time. Due to the non-linearity of the amplifiers during oscillation, out-of-band emissions (i.e. noise) will also increase.

Some designs attempt to solve the feedback problem of improper installations by incorporating some form of a gain reduction scheme when the output amplifier level has exceeded some preset limit.. When activated these 'anti-oscillation' or 'anti-feedback' circuits must either reduce the signal booster gain (1) permanently or (2) for some predetermined period of time.

If the gain or shutdown is permanent, then some action (locally or remotely) must be taken by a person to restore the system to its prior condition. If the problem persists the antenna installation must be improved or the system gain reduced permanently.

If the gain is restored automatically after some period of time and the feedback problem still exists, the system will go into oscillation again and the shut down action will occur again. The result can be random 'bursts' of high level oscillation interference signals that are very difficult to locate and correct. Again, the solution is to rework the installation and reset fixed gain levels properly.

It should also be noted that a mobile or portable operating abnormally near an antenna (i.e. input overloading) may appear the same as an oscillation to some gain control and anti-oscillation circuits. During an emergency this may occur. It is obvious any anti-oscillation circuit could interrupt continued communications.

If there is no anti-oscillation circuit the system will return to normal operation immediately after a temporary large input incident. A short burst of overdrive, which may generate very brief out-of-band interference is preferable over a system that shuts down when it is most needed.

High performance broadband signal boosters now have the capability to store and report excessive output excursions. These reports may also be used as alarms of oscillations. This data, combined with the option of remote controlled fixed gain adjustments, allow a system to easily be optimized for long term operation.

Output Noise:
The FCC standard for out-of-band output emissions is the same for all signal booster technology : -13 dBm.

The usual concern over output noise is in the uplink direction, where excessive noise could impact on receivers in the same general direction as the desired, distant repeater site.

All designs can desense nearby uplink receivers under the -13 dBm FCC standard. There is very little possibility of interference with adjacent downlink receivers in the UHF and 800 MHz bands due to the duplex frequency separation.

The power density of noise on adjacent channel frequencies (as close as 12.5 KHz) is generally greater from channelized signal boosters than broadband signal boosters. The power density of the broadband signal boosters is distributed over a wider spectrum, potentially making the impact on adjacent channels less.

Practical Considerations:

Channelized signal boosters have a finite number of channels they can process. The most common models range from one channel to eight. Larger numbers of channels can be accommodated at greater expense. Most public safety metro trunking systems utilize over 10 channels and often many more.

Broadband signal boosters can process one or more 'bands', each being approximately 100 KHz to 20 MHz wide.

Some channelized signal boosters can be programmed for more than one channel bandwidth; one to eight 12.5 KHz to 150 KHz windows. When a 'band selective' signal booster passes more than one channel within a passband, it is technically and operationally a broadband or FCC class B signal booster.

Higher power signal boosters may also require external combiners and multicouplers similar to a base station site.

Channelized signal boosters also require more operating power, increasing the cost and size of back-up power systems.

The most compelling use for channelized signal boosters is when desired channels are closely intermixed with undesired channels, such as exists in the current 800 MHz band.

However very comparable performance can be obtained when there are closely spaced groups of desired channels that can be selectively amplified using high performance bandpass filters. Additional enhancement can be accomplished with adjacent frequency notch filters.

In any case, the driving need for channelized signal boosters will be greatly diminished when the 800 retuning effort that is already underway is completed. By relocating public safety channels to narrower passbands and removing interleaved undesired channels, broadband signal boosters are the obvious solution. Most existing quality signal boosters can be 'retuned' to protect the users investment.

There is a much larger need for Class A channelized signal boosters in the VHF bands due to close transmit-receive duplex channel pairing and to implement simplex systems.

Interoperability
For public safety systems, interoperability is an important requirement. Interoperability capability arises during an event where others operating in the same band need in-building coverage. This is called 'mutual aid' and while there may be channels set aside for mutual aid operations there is an inadequate number of channels for a major incident.

It is possible the number of channels required to be amplified could double or triple the non-emergency capacity.

A channelized system by its very nature limits the usable channels to some fixed quantity. A channelized system could be designed to (1) activate additional channels on demand or (2) increase channel passband bandwidths on demand. Both these approaches require considerable pre-planning, remote control and personnel training to be successful and even then the capacity of a channelized signal booster may be exceeded in an emergency.

A properly designed broadband system requires no user intervention during an emergency, which is the ideal solution for the users.

It should be noted that when a channelized bandwidth is increased the operational characteristics become similar to a broadband signal booster.
The power per channel becomes variable due to the composite effect of multiple carriers passing through a common output amplifier. Increased non-linearities and IM's become a concern.

Number of Channels and Composite power
In broadband system designs it is accepted and well proven practice to anticipate the worse case scenario when dealing with multiple carriers in the same amplifiers. While some may feel the variability of channel power is unacceptable in good engineering practice, the opposite is the real case. For example, the largest user of signal boosters in the US, Sprint Nextel, uses broadband signal boosters even though their channels are interleaved with many other licensees. Broadband signal boosters have been successfully deployed for over 15 years in all environments including downtown Los Angeles, NYC. etc.

The effect of additional channels within the passband of a broadband signal booster is not as extreme as imagined in real systems. The most severe implementations with urban areas may have as many as 20 to 40 carriers within the passband. When the system is designed for many channels up front the system will perform reliably. The impact on per channel power can be minimal in good designs. For example, if an urban system is designed for 40 potential channels, it would take another 40 channels to reduce the power per channel by 3 dB.

Public safety applications are more predictable because the channel licensing coordination within public safety only bands is very strict. This coordination minimizes nearby co-channel and adjacent channel usage. The use of local public safety coordination also resolves most interference and other technical issues among public safety users, including signal booster interactions.

The current interleaved interaction 800 MHz band between Sprint-Nextel and public safety is a temporary situation that is being resolved by "rebanding", a mandatory relocation of channels to eliminate this interference.

The current situation has been used by some to advocate using channelized signal boosters over broadband signal boosters even though the use of broadband technology has been proven appropriate.

Propagation delay
True Class A channelized (one channel per passband) signal boosters have much greater propagation delay than Class B broadband signal boosters. Typical values are 50 microseconds versus 5 microseconds, respectively.

In outdoor fill-in signal booster applications, it is universally recognized longer delays will produce areas of overlap that causes intermittent and unreliable communications. Manufacturers delay standards range from 15 to 36 microseconds. This effect is especially present in simulcast and digital systems. In digital systems, the limiting factor is the equalization possible in the digital voice decoder circuitry (VOCODER), which is limited to 32 to 36 microseconds.

(Outdoor use is fully discussed in a paper at: http://rfsolutions.com/outdoor.pdf)

There is considerable debate as to the impact of delay on in-building systems. Many installations present conditions that enable receiver capture in the areas of concern. Most recently, a 16 dB differential in signal levels is the desired non-interfering level. In high rise structures it is difficult to maintain this differential as both the outside and inside signals pass through various attenuating mediums, such as wall. There is usually some location where the differential between the outside and the delayed inside signals is less than 16 dB and coverage dead zones result in these areas.

It has long been accepted that the very low delay of a broadband signal booster produces in-building signals that are, in effect, simulcast signals. Interaction between outside and inside signals is insignificant because there is no need for receiver capture between the two signals.

Given the choice of a more expensive channelized system with real or potential delay problems and a lower cost broadband system with no delay problems, experienced system designers usually select the broadband approach.

Conclusion;
There are situations where the use of channelized signal boosters is the best solution. However, the majority of public safety requirements can be met with a properly designed broadband signal booster system. It is noteworthy that broadband signal booster manufacturers offer 'public safety rated' products designed specifically for high reliability, dependability and serviceability.