Appendix E: Optimizing FCC Class A Channel Selective (channelized) Signal boosters

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The FCC signal booster Classes, A and B, are operational designations and should not be confused with the commonly used technical classifications of amplifier designs used within the signal booster. For example, FCC Class B signal boosters usually use technical class A amplifier circuits to provide high linearity. FCC Class A signal boosters may be using any of the technical classes of amplifier circuits. Reference: FCC part 90.219.

The Code of Federal Regulations part 47 section 90.7 and 90.219 details the definitions and limits for the use of RF signal boosters in Land Mobile Radio networks. These rules are included in Section V of this Best Practices paper.

Within this paper FCC Class A signal boosters are called 'channelized' amplifiers
for better clarity.

Types of Class A signal boosters

Class A signal boosters have been available for over 15 years with different, newer technologies and bands appearing over the years. There are four types available today and because of operational differences each type may require different configurations and optimizations. The following is a very minimal description of the different types.

These types will be cited throughout this document when the types has different characteristics relative to the subject being discussed.

Type 1: Crystal filter type: This is the original type and it is only available currently at VHF frequencies. These are not programmable and generally limited to 4 channels per signal booster. Except for bandwidth these are the same as Class B signal boosters. Since the signal booster only passes one channel the composite power effect in broadband signal boosters does not exist. These types are the most economical of all channelized amplifiers.

Type 2: Single Channel heterodyne. These are perhaps the most programmable of all Class A signal boosters. These are always channelized as the passband bandwidth is restricted and cannot be reprogrammed to operate as a Class B broadband signal booster. Selectivity is achieved by down converting the input to a narrow IF filter then up converting the output back to the input frequency. These closely resemble a standard repeater, with good input sensitivity and fixed output power regardless of input level. Repeater activation thresholds are programmable and squelch operation can be none, CTCSS or Digital squelch activated. This type is capable of up to approximately 30 watts output per channel. The number of channels are unlimited as each channel is a stand alone rack mounted module and scaleable as required. Remote status monitoring, alarming and complete programmability capability is standard.

Type 3: Multiple channel heterodyne. This design uses a wideband down conversion of the input band (i.e. block conversion) into a bank of multiple parallel "IF" sections, combines the IF outputs into a composite output, then up coverts the composite signal into a common output power amplifier. Each IF is programmable so each may select an individual channel. The number of channels per signal booster is determined by the number of Ifs used, with 4 and 8 channel versions being most common.

Due to the common input amplification and common output power amplifier this type does exhibit the composite power effect common to Class B signal boosters. (a discussion of composite power and optimization of composite power effects can be found in Addendum E, Optimizing Class B Signal Boosters) The potential output power per channel varies greatly from model to model due to many output power amplifier choices. Remote alarming and channel programmability is available as an option in some models. Since this type does not use baseband demodulation, CTCSS or Digital squelch control is not currently offered.

Type 4: Functionally, this type is similar to Type 3 but uses digital signal processing to perform the channel bandwidth and frequency selection. This is sometimes referred to as 'digital filtering'. Current standard models have 4 to 8 channel capacity per signal booster. This type can allow programmability of gain per channel, which may be beneficial when input signals are from different remote sites. The output power per channel varies from model to model and high power (25 to 60 watt) amplifiers are available. Note the power amplifier is amplifying the composite power of the number of active channels, therefore the power per channels is less than the overall power rating of the output amplifier.
Remote status monitoring, alarming and complete programmability capability is standard. Since this type does not have normally include baseband demodulation, CTCSS or Digital squelch control is not currently offered.

Note: Type 4 has passband programmability which allows the passband to be more than one channel's bandwidth. When operating in this mode, the signal booster becomes a FCC Class B, broadband signal booster and has more composite power effects.

Number of Channels:
Type 1 is limited to approximately 4 VHF channels and is typically 1 channel.

Type 2 has no limits on the number of channels, however conventional low power transmit combiners are required and that places practical limits on how many channels can be combined while retaining adequate power per channel. In in-building applications where low power distribution is preferred the combining loses are more acceptable.

Most current Type 3 and type 4 models have hardware limitations of up to 8 channels per signal booster. (up to 16 channel capacity is under development)
When the primary system utilizes more channels than the capacity of one signal booster additional signal booster inputs and outputs may be combined using hybrid combiners or other commonly available devices. Normal combining losses will reduce the power per channel accordingly.

Interoperability Considerations:

The number of channels in a Class A signal booster is intentionally fixed to those specific channels used by the system it normally communicate with. The main function of a Class A signal booster is to prevent other undesired channels from interacting with the desired channels passing through the signal booster.

The system planner should consider the channel requirements when the signal booster should also serve mutual aid and other outside agencies during an emergency event. This is an extension of interoperability.

When additional channels should be processed by a channelized signal booster temporarily, one or more approaches may be used to accommodate them.

(a) The Class A signal booster is installed with all the expected interoperability channels in addition to the normal channels being used. If the number of channels exceed the capacity of one Class A signal booster, more are added in parallel until a sufficient number of channels is provided. The system designer must also anticipate the composite power effects if the 'emergency' channels are only activated during an event.

(b) The channels within the Class A signal booster are reprogrammed to accommodate interoperability channels. In this method the system designer must predetermine what normally processed channels within the signal booster will be made inactive during the event. The channel change is most effectively implemented using remote programming access circuits.

(c) If the new channels are close to existing channels, the passband bandwidth of one or more channels may be widened. When this approach is used, the system designer should prepare a plan then, based on the levels of all the channels that will pass through each window, recalculate the output power. This is because the composite power effect comes into play when any passband allows more than input channel to be amplified by the same output amplifier. The passband bandwidth change is most effectively implemented using remote programming access circuits. This choice is currently limited to type 4 signal boosters.

In scenarios (b) and (c) preplanning is required to have fast reprogramming response capability during the emergency. It would not be practical to dispatch a trained person to each structure to implement changes at the signal booster's physical location. A centralized remote site is optimal. The requires the system designer to include circuits for remote control to the appropriate structures. There are many circuit options available to the system designer, such internal data networks, dedicated or dial up telephone circuits, etc. Naturally the most dependable method is preferred and the public internet is never recommended.

The remote reprogramming effort is similar to the methods used in 'dynamic regrouping' methodology. As many emergency scenarios as possible are matched with the radio channel changes that would be required in each scenario, limited by the channel capacity of the Class A signal booster(s). The results are entered into a program that allows non-technical personnel to activate the reprogramming based on the event type.

Propagation Delay

When signals pass through a signal booster they are delayed by the signal boosters internal circuits. The amount of delay varies with design but overall is relative to the passband bandwidth. The narrower the passband, the greater the propagation delay.

Propagation delay becomes a consideration in public safety applications where the direct signals from the repeater site and the delayed signals from the signal booster overlap. When the signal booster delay is small it has no effect on system operation.

Manufacturers experience with overlap (or multipath) in simulcast system designs has established maximum signal booster delays relative to the type or brand of radio system used. Digital modulations have reduced the acceptable signal booster delay and the system designer should anticipate the worse case to facilitate current and future system requirements without replacing or reprogramming signal boosters.

Currently, the most severe digital modulation type radio system delay recommendation is 15 microseconds or less. Analog systems may operate with longer delays, dependent upon each radio each system design.
Current Class A signal boosters cannot achieve much less than 50 microseconds propagation delay while maintaining a single channel passband bandwidth.

If deployed in a tunnel or other situation where no overlap with the outside signal can exist, signal booster propagation delay is not a consideration. (Although not part of this in-building discussion, delay is a major problem when using a signal booster to fill-in for an outdoor area.)

It has also been established when a stronger signal 'captures' the receiver there will be no communication degradation caused by the lesser signal(s), regardless of delay. Again, digital modulations generate the most demanding specification. Recent evaluation has established digital receivers are captured by the signal that is 16 dB or greater than any other signal at the receiver input. The system designer can overcome the propagation delay challenge of Class A signal boosters by designing each in-building installation so as there are no overlap areas with less than 16 dB dominance of a signal from either the direct or delayed signal path.

Obviously, at some point the signals must approach equal levels and delay becomes detrimental to the operation of the system. The system designer should calculate the various looses to identify where the 16 dB rule is violated and make sure these locations are not in areas where communications is needed. This can be a complex issue because the effect wall and floor attenuations must be considered. As the signals pass through additional walls and floors the levels can change considerably in a few feet.

Reducing Class A signal booster delay:

Since delay is dominated by the passband bandwidth, the delay can be reduced by simply widening the passband bandwidth. At some point, usually 200 KHz or greater bandwidth, the delay in a Class A is reduced to an acceptable level. As the bandwidth is increased the Class A signal booster delay becomes closer to being a Class B signal booster, which has propagation delays of less than 5 microseconds.

When using a channelized signal booster with more than one channel passband in a trunked radio system, all the passbands should be increased equally to prevent unpredictable operation.

When operating as a Class B signal booster the composite power effects apply and the system engineer should anticipate the highest possible input levels from undesired signals that appear within the widened passbands. Margins to accommodate the potential output signal variations must be added. The system designer may also have to reprogram the ACG circuits to accommodate the effect of high level undesired signals on an AGC circuit normally handing one channel instead of many channels at the same time.

Output power considerations

Many Class A signal boosters have the capability of providing 5 watts or more output power per channel. While this may be desired, additional considerations arise at these power levels.

First, the FCC 90.219 rules for signal boosters limit the ERP per channel to 5 watts maximum under any conditions.

With gain roof top (donor) antennas it is easy to exceed this level on the uplink path. Since directional antennas with inherent high gain are desirable on the roof, the uplink output power should be reduced accordingly. For example, a net 10 dB antenna/coax gain roof antenna system, an input level of 500 milliwatts (+ 27 dBm) is maximum signal booster output under the FCC signal booster rules.

The limitation on power delivered to inside antennas is more compliance to OSHA Human RF Exposure limits than the FCC 5 watt ERP limit. It is easy to exceed these limits with high power output signal boosts, and, if allowed to occur, open civil liability issues in the event of a complaint. The system designer should establish the ERP for the highest ERP antenna and, using OSHA guidelines, adjust the signal booster power accordingly.

Although not endorsed here, the common compliance practice is to use cellular handsets as an acceptable power level reference, or 600 milliwatts (+27 dBm) maximum ERP at any indoor antenna. Remember, for exposure measurements, this is the maximum composite power measure and the power per channel in a multichannel system will be less. For example, the 600 mW composite power ERP for a 10 channel trunked system results in 60 mW (+17 dBm) maximum ERP per radio channel at any indoor antenna. This reduces the signal boosters output power requirements considerably.

Naturally, the system designer must also consider balance between the uplink and downlink coverage within the structure to prevent one sided communication attempts. In at trunked system this effect is usually caused by excessive downlink power levels.

Alternately, an ERP of over 5 watts is legal when each signal booster installation is coordinated and licensed as a separate fixed location base station. This may be desirable for outdoor fill-in applications of high power signal boosters but less suitable for in-door applications due to the human exposure limitations.

Power Consumption

Many in-building system specifications include some form of back-up power. In This is usually addressed using battery based DC power back-up devices and the most common requirement is 12 hours operation.

The system designer must anticipate the back-up power requirement, which can be considerable with high powered signal boosters. The system designer may use a lower operating power level but at the risk of someone later increasing power consumption beyond the back-up's capability. Alternately, ask the manufacturer for a lower powered unit to reduce the size and cost of the back-up system.

Conclusion

Class A signal boosters offer reduction of interactions caused by undesired channels and may provide higher power per channel in the finished system design as compared to Class B signal boosters. However, these benefits may come at additional cost. There are many considerations and trade-offs the system designer must handle when planning and installing a public safety in-building system, whether class A or B.