Can’t have one without the other. Well, maybe you can, but you may fall out of grace with your AHJ. Both NFPA & IFC fire codes require system gain to be set 20dB lower than system isolation. Why is isolation so important? Ever look at the output of a BDA that begins to oscillate? It’s not pretty.

Let’s start by explaining what we mean by isolation. Practically all Public Safety in-building coverage enhancement systems require a Bi-Directional Amplifier (BDA), also defined by the FCC as a Signal Booster device. These devices amplify weak signals received from the repeater site and reradiate them indoors. The challenging part is that they reradiate the same frequencies as they receive. To give an analogy, have you ever sat in an auditorium and the person giving the speech walks too close to the monitor with the mic causing an awful squeal that gets louder and louder until he moves farther away, or the sound guy reduces gain on that mic channel? That kind of feedback can happen in a BDA system as well and is known as oscillation. If an in-building system lacks isolation, it will begin to oscillate, or feedback into itself. As it oscillates, the BDA will get “louder” and “louder” until it either protects itself by reducing gain, shutting down, or burns up. What I mean by louder here is that the amplitude of the RF signal being re-radiated continues to increase until the BDA amplifier is driven into saturation. An amplifier operating in this non-linear region will produce ugly intermodulation products and unwanted noise that can seriously degrade the Public Safety repeater site performance and even interfere with adjacent cellular systems.

Where did the value 20dB come from?

Previous Code only required 15dB greater isolation than Gain. Changes to the 2016 NFPA 1221 code increased that value to 20dB. So why the change? Depending on the manufacturer and technology used, some BDAs can exhibit stable operation with only 10 or 15 dB less gain than isolation. It’s what we can’t control that may have lead code writers to revisit this value. For example, let’s say an office environment uses aluminum blinds that just happened to be closed during the AHJ walk-around testing and the system passes. Now the building becomes occupied and the new tenants open the blinds and in this 4-story L-shaped building we now have line-of-sight between in-building antenna and Donor antenna on building rooftop.

Let’s assume that we have lost 10dB isolation with the blinds open and the BDA automatically reduces its’ gain to avoid oscillation. If gain gets reduced, then it’s likely that your system will no longer comply with code. This reduction in coverage may go undetected until the next scheduled system test, or worse, during an actual life-threatening incident. Increasing the isolation requirement adds more margin to help absorb some of the changing RF environment factors that are difficult to emulate during AHJ testing. This is just one basic example of how isolation can be affected by something so seemingly trivial. Other scenarios affecting isolation could be: shipping dock doors opened, using donor antennas that lack sufficient directionality, poorly assembled/connectorized cables near the BDA or donor antenna, the use of multiple BDAs looping back on each other, reflective surfaces, ducting from vents, and possibly the most common is lack of RF attenuation between the donor antenna on the roof and indoor antennas one floor below.

Protecting Gain

Since many modern BDAs incorporate circuitry that helps prevent the ugly by-products resulting from oscillation, why worry about isolation at all? Unfortunately, It’s nearly impossible to predict how much isolation a system will achieve until it is installed. During the design phase we tend to design using a BDA’s maximum gain and maximum power values. However, a word of caution, with many BDAs on the market spec’d at 90 or 95 dB of gain, especially in the 700/800 MHz bands, achieving isolation of 110 to 115dB may prove challenging.

Let’s highlight the importance of isolation using actual numbers. Consider the case where a field tech measured the 800 MHz control channel at the rooftop during a site survey and determined that the RSSI into the BDA will be -65dBm. You, as the system designer, determine that a 20-channel simulcast system results in a 20dBm output power per channel level, this assumes the use of a 2W BDA (10*log(20 Ch’ls) – 33dBm = 20dBm). Therefore, the actual gain needed in order to reach the per-channel power is 85dB (20dBm-(-65dBm)=85dB). You submitted your design based on 20dBm per channel and you learn that you’ve been awarded the project. A short time later installation is completed and now it’s your turn to shine. You arrive at the site to optimize the system. You proceed to commission the system using Comba’s cool built-in system isolation measurement feature and the software displays 90dB of isolation. According to code, the gain must be set to 20dB less than isolation. In this case, your max gain can only be set to 70dB. If we add 70dB of gain to our -65dBm input signal, our output is only +5dBm, or 15dB less than our original design parameter. So now you’re in panic mode knowing you’ll never achieve necessary coverage at this level. What gives? Is there something wrong with the BDA? Or is it simply isolation issue?
You can easily confirm isolation by shutting off the BDA, disconnecting the donor and DAS cables from BDA and perform your own test by injecting signal from Signal generator into either the donor or passive DAS systems and monitoring the other side with spectrum analyzer. Sure enough, you've confirmed the accuracy of Comba's built-in signal generator feature to be spot-on and next step is to resolve isolation issue.

Start by using the same signal generator & analyzer configuration and methodically disconnect each floor until isolation improves. Once you've determined which floor(s) are causing the problem, you may be able to narrow down to a specific antenna. Adding an attenuator pad to an antenna or entire branch circuit may get isolation back to where it needs to be.

Bear in mind that while adding attenuation may fix isolation issues, degraded coverage might become collateral damage. Furthermore, if a Class A BDA is being used, Time Delay Interference (TDI) issues may surface when indoor signals no longer dominate donor signals.

**Improving Isolation**

If you suspect your application may have isolation issues, you might try the following:

1. Use a high isolation donor antenna. Even though your donor site may be close and antenna gain is not needed, the use of a highly directional antenna, and thus high gain, offers the benefit of narrow beamwidth. Narrow beamwidth means more signal is directed away from the building rather than leaked into the building. The improvement in beamwidth alone may afford us 10-20dB more isolation and hence 10-20dB more gain.

Another bonus is the antenna gain. Inherently, high isolation antennas have more gain due in part to the more focused beam. In the example above, our RSSI was measured to be -65dBm. At this input level we determined that 85dB of gain is needed to reach max power-per-channel of 20dBm However, we could only achieve 70dB gain due to insufficient isolation. Using this same example, if we swap the donor antenna with a high isolation antenna having 10 dB more gain, the new RSSI into BDA becomes -55dBm. With -55dBm input, we now only require 75dB of gain to hit target output of 20dBm/channel. Reducing BDA gain means less isolation is required. Our new isolation requirement of 95dB (75dB gain + 20dB margin= 95dB target isolation) is 5dB over the previously measured value of 90dB. But wait. Once you’ve swapped the donor antenna for the high isolation antenna, re-run the isolation test and you’ll likely find that your isolation increased by 10-20dB. The resulting increased isolation combined with the need for lower gain may completely erase the isolation issue. There are true benefits to using high isolation antennas, however one tradeoff is cost. These high isolation antennas can be 5 to 10 times the cost of the more common 7-10dBi yagi antenna.

2. If coverage is required throughout the top floors near the donor antenna location, then try designing using more antennas at lower power. More antennas mean more passive loss which ultimately improves isolation.

3. As a last resort, try relocating the Donor Antenna to create more physical separation between the offending indoor antenna and Donor Antenna. If a maintenance or mechanical room exists on the rooftop, try mounting the Donor Antenna to facility walls in a manner that would increase isolation.

In summary, if you can’t meet the gain reflected in your link budget, suspect lack of isolation as the culprit. Better yet, if you suspect up front that your application may be a good candidate for isolation problems, bite the bullet and design in that high isolation antenna and add a few more antennas to those top floors. A few extra dollars spent on the front end may save you even more on the tail end.

…and if you’re in a pinch, call Comba. Public Safety in-building system solutions is what we do.