How Upgrading Tower Top Amplifier Specification Has Improved First-Responder Radio Communications

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A new specification for Tower Top Amplifiers (TTA) has delivered greater consistency, audio quality and reliability for first-responder radio communications. The updated specification—introduced in in 2018 by one of North America's leading manufacturers of critical communication equipment—has now become its sole specification of TTA for new or replacement installations in critical communications network base stations throughout the nation's land mobile radio (LMR) network. This article explains the rationale for the changes, including their benefits for public-safety communications, and describes how Filtronic worked closely with the OEM in developing a TTA product to meet the new specification.

Background: Public-safety communications in North America

The current public-safety communications network was established in the 1980s and early 1990s. The network of base stations aims to give 100% area coverage across North America, providing guaranteed communications connections for police and other emergency responders using land mobile radios in any location.

When the network was initially designed and implemented, it was based predominantly on analog radio technologies, which were state-of-the-art at the time. Although very effective, the system was insecure, allowing new, easily obtainable radio scanners to pick up signals and listen in to police radio and other first-responder communications. Over the next decade or so, the radios were gradually updated to use digital modulation schemes and eventually the data was encrypted, making them secure and preventing casual eavesdropping. At the same time, channel bandwidths were reduced to enable more channels to be accommodated. More recently, the individual communication channel bandwidth is being halved again in order to double the number of channels—so the evolution continues.

However, while the radios themselves have been constantly upgraded, the radio frequency (RF) components and base stations that support the communications network have not substantially altered since the 1990s. This means that some components installed in base stations, such as power amplifiers, power combiners, filters, antennas and other RF conditioning products, have remained unchanged since their installation almost 30 years ago.

Technology: The role of Tower Top Amplifiers

A crucial subsystem deployed in the majority of network base stations is the Tower Top Amplifier, which is used to improve receiver performance. TTAs incorporate a low-noise amplifier installed at the top of the mast and a control/distribution unit installed at the base. The tower-top element incorporates a low-loss, bandpass filter to protect the receiver from out-of-band interference and a low-noise amplifier to boost the received signal. The control/distribution unit at the base amplifies and splits the output signal to feed multiple different radio receivers. The tower top and base units are connected by a coaxial feeder cable running down the mast.

Over the years, many different companies have made the components for tower-top and base units, and there was some level of interoperability between them. But, over time, manufacturers opted to produce both the tower top and base elements together, meaning they had to be purchased as a pair which helped improve reliability and system performance.

An important feature of the original TTA specification was that the gain of the receive signal could be set to achieve the desired performance. That meant using attenuators to adjust the level of amplification and prevent the receiver from being overloaded. So, for example, in a dense urban environment where there is a lot of signal traffic, the gain can be reduced to prevent the receiver from picking up too many signals. This higher level of attenuation can also reduce system performance as well as restrict the range of the receiver. Conversely, for base stations in sparsely populated areas, the receiver needs to be far more sensitive so it can pick up signals from far away – so the attenuation would be reduced to achieve higher gain. At each base station, the gain would be set at the point of installation, according to the location of the site and its application.

Challenges: Complications caused by dual attenuators

The problem with the original specification for TTAs was that they featured two separate attenuators, providing two locations at which gain could be set. Both were housed in the control/distribution unit. The first 'Reserve Gain Attenuator' was located before the amplifier, and the second 'Distribution Attenuator' was located after the amplifier. As there are two locations for setting the gain, there are almost infinite possibilities for altering the ratio between them to achieve the same required level of overall gain. So, while the overall gain achieved might be the same, system performance would differ depending on the balance between the settings of the two attenuators.

The Reserve Gain Attenuator influences the sensitivity and noise figure of the system and its performance in the presence of high-power interfering signals. The Distribution Attenuator effects the system linearity. So, setting the first attenuator high and the second attenuator low, produces poor noise figure, poor range, but high immunity to interference. The other extreme is to have little or no attenuation at the input and all the attenuation after the distribution amplifier. In this case, the overall gain achieved would be the same as the above scenario, with very good noise figure and increased range, but with greater susceptibility to interference.

Because there were multiple ways to set the two attenuators to achieve the same level of gain, different installers could set up sites differently. Each manufacturer provided guidance on how to set attenuation levels for different locations, but there was a lack of consistency between the different products, meaning that individual installers could achieve the required gain levels for each site by setting the attenuators in whatever way they chose. This meant that once the base stations were operational, it was sometimes difficult to diagnose the cause of any under performance, since the attenuators could have been set in many different ways. Any problems, such as audio drop-outs or poor call quality, were difficult to rectify without knowing how the two attenuators at each base station had been configured.

The new TTA specification

The potential problems caused by this uncertainty were one of the reasons why the OEM requested changes to the TTA specifications. The most significant changes were:

a. The removal of the second attenuator, relying instead on a single adjustable attenuator located in front of the amplifier in the control/distribution unit to give installers a single control point to adjust gain for the whole system.

b. Improvements to the low noise amplifier in the tower top to making it more linear and to reduce the noise figure.

The new specification for Tower Top Amplifiers however proved particularly challenging to achieve, and several RF suppliers attempted to fulfill it before a successful product was eventually developed.

TTAs had conventionally incorporated stand-alone filters, amplifiers and other connectorized components, which were cabled together in a waterproof housing. In the new product, all components are fully integrated into a single cast housing. As well as meeting all the performance standards stipulated by the OEM, this new product provides a lighter-weight solution in a smaller footprint, enabling better utilization of space at the communication tower.

Benefits: Improved performance, control and reliability

There are significant benefits of the new TTA specification for installers, end users and—ultimately—the American public. Each base station can now be set up very simply via a single control to optimize gain levels for the site, according to its location and the density of base stations in the region. Having a single attenuator means there is only one point of adjustment to set the overall gain for the site. This immediately removes any ambiguity about how gain levels should be achieved. It makes setting gain levels far simpler and more consistent across the entire network—in a remote rural area, the attenuator can be set to achieve a high system gain of 15dB, while in an urban area it can be set to a low gain of 5dB. This eliminates variations in the way different installers set up gain levels at different base stations.

To compensate for the loss of an attenuator, the specification for the amplifier at the tower top has been significantly improved. This means there is no loss of performance, despite only having a single attenuator in the base unit. It combines the best of both worlds, with the benefit of a tower-mounted amplifier that has its gain effectively set to maximum, while providing the control simplicity of using a single attenuator to set the overall gain level for the site.

Better communications for public safety

The new TTA specification has been demonstrated to support improved LMR performance for all emergency service providers. It gives radio system operators the confidence that their mission-critical networks will operate reliably with resilient connections and higher quality audio, especially in congested urban environments.

Ultimately, this means greater peace of mind and security for the citizens who rely on these vital rapid-response services.