NEXTIVITY
Smarter by Design

Technology Advances in Public Safety Communications

By Victor Mejia, Product Manager at Nextivity

For first responders, reliable communication is essential to the safety of operations at incidents. In fact, it can be a matter of life or death.

Unfortunately, it is common for obstructions to block the signals between the radio towers (or high sites) which broadcast the emergency radio signals and the Land-Mobile-Radios (LMRs) used by emergency responders when inside a building.

Results from a National Institute of Standards and Technology (NIST) survey of first responders on public safety communication problems highlight this issue (NISTIR 8245 updated June 2021). Reliability was ranked among the top three, along with usability and interoperability. Respondents cited dead zones as one of the biggest issues they face in emergency situations. Dead zones can occur due to geographical interference (e.g., valleys and canyons) and structural interference (e.g., high rise buildings, basements, tunnels, and subways).

As LMR network towers are outdoors, signal penetration through challenging radio frequency (RF) environments and building materials such as concrete is problematic. Low-emission certified (LEED) buildings are particularly challenging due to the high radio signal attenuation properties of the materials used to make the buildings energy efficient. These and other environmental or building construction obstacles cause dead zones, dropped calls, poor reception, and prevent first responders from connecting over LMRs for vital communications.

To address this problem, the concept of the Emergency Responder Communications Enhancement Systems (ERCES) for in-building LMR coverage was first introduced into the International Fire Code, section 510, in 2009. This code is used by jurisdictions to standardize the processes and equipment used by first responders. Jurisdictions also reference the code in their laws and require compliance before a Certificate of Occupancy (CO) is issued for most new buildings over 30K ft^2, and it is generally required for annual CO renewal.

An ERCES is deployed to transmit emergency radio signal between the high site and LMR equipment inside a facility, using antennas, cabling and electronics, regardless of environmental or construction obstructions. Traditionally, Distributed Antenna Systems (DAS) and wideband Bi-Directional Antennas (BDA) solutions have been used to meet public safety communications codes and enable emergency responders to talk with the command post and one another. However, the inherent limitations of these legacy technologies can also cause the communication problems cited by first responders.

Limitations of Legacy Public Safety Communications Equipment

Legacy public safety communications equipment typically uses wideband bi-directional amplifiers (BDAs) to send and receive signals that are broadcast from the high site. As wideband BDAs are designed to pick up all radio signals within the frequency range of the BDA, including bands that do not carry emergency communications, this often results in distorted, muffled, or interrupted communication on the two-way radios used by emergency responders.

Another frequent problem is the incorrect setting of the uplink gain of the BDA. If the uplink gain is set too low, the signal won't reach the high site and communication won't be established. If the uplink gain is set too high and the signal reaches the high site with too much power, this will cause interference for the high site receiver and disrupt communications. To avoid the situation, the local Fire Marshal or Authority Having Jurisdiction (AHJ) may require system integrators to create a link budget report prior to the deployment of the ERCES to be sure the high site is reached with an optimal signal level. Furthermore, small changes in uplink gain settings to the BDA may be used to try and resolve remaining in-building dead spots, which can cause operation outside the approved link budget and may lead to degraded communication performance.

Further communication degradation can occur due to interference between the donor and server antennas inside the facility, causing problems like feedback oscillation. To prevent this, NFPA 1221 – 2019 and IFC 510 require 20 dB isolation above system gain between donor and server antennas. Usually, the process to calculate and set compliant gain values is a complex process that requires highly skilled technicians' on-site RF gear such as signal generators and spectrum analyzers. The full process may take two to four hours of work and, if the RF conditions change in the future, this process needs to be re-done. This takes constant diligence and can require repeated truck rolls to ensure the system is ready for any emergency.

Key Technology Elements in Public Safety Communication Systems

Before discussing ERCES innovations, it's important to first understand the key technology elements that make up public safety communications systems and the factors that need to be considered when selecting technologies to meet in-building code compliance.

Radios — Every jurisdiction has a communications plan that includes a set of predefined frequencies licensed by the FCC and which encompass LMR bands, cellular bands such as FirstNet, or a combination of both. Unfortunately, not all solutions or vendors support all radio types, which limits options.

Booster Class — An important distinction is the Class A or Class B classification. Class A devices typically perform better, with narrow filters that reduce the amount of noise bleeding into other channels and systems. Class B equipment has wider filters, meaning it can transmit into unintended or unwanted channels and create unnecessary noise and potential interference with other systems. Class B systems have an advantage over Class A systems in that the delay of a signal through the system is lower. This eases system design for simulcast networks and reduces Time Domain Interference (TDI) that may reduce system performance.

Pathway Survivability — This defines the duration and requirements for conduits and risers, and system components, to survive a fire. There are typically specifications relating to circuit integrity, cable integrity, fire-rated enclosures, and some sort of alternative method approved by the AHJ to interpret and enforce local codes. Pathway survivability requirements have a huge impact on cost, with the difference in cost between fire-rated and non-fire-rated gear as high as 10x or more. For example, fire retardant wrapped, fire-rated coaxial cable can cost a building owner up to $300 per linear foot, or more. A variety of research and development efforts are however underway in the industry to produce more cost- effective fire-safe cables.

Battery Backup — There is an extremely important difference between commercial-grade and public safety-grade systems. Often, the fire department cuts power to the building during an incident. Systems that are expected to continue working during an incident are required to have battery backup. Currently, 12-hour backup is most common, but some jurisdictions or AHJs may require 24-hour battery backup. In contrast, commercial systems do not require or offer battery backup and may be eliminated as a potential public safety system. Many vendors overlook this requirement and lead system integrators and property technology managers down a misleading path with their commercial gear. Although not as common, a given jurisdiction may also allow for generator-based backup. With this in mind, it's a good idea to check the requirements carefully, or work with a partner that has intimate knowledge of the local codes and local code interpreters.

NEMA Rating — All public safety equipment is required to be NEMA-rated to protect in-building systems from the effects of water from hoses and sprinkler systems. There can be variations in the specific NEMA requirement from one jurisdiction to another. Most jurisdictions require some version of NEMA 4, although some call out 3x or 4x. Even though equipment may be marketed as "public safety," it may not come with a NEMA rating. Installers must then invest in NEMA-rated off-the-shelf housings, which add to the cost, size, and complexity of the system.

Monitoring — ERCES are required to provide standard alarms when certain fault conditions are met. These alarms are attached to the Fire Alarm Control Unit (FACU) on site and will trigger action from building owners and local first responders if the alarm is activated.

Maintenance — Most jurisdictions have ERCES maintenance provisions, and typically an annual check-up is required. Modern ERCES solutions may feature remote monitoring above and beyond the basic alarms required by code. Monitoring is an area that is often underserved and overlooked. Over time an installed system can be unknowingly compromised, sometimes by something as simple as a cut cable or an unplugged component. When systems are not properly monitored when not in use, they may fail in times of an emergency. As a result, some jurisdictions now require system monitoring, enabled by alarms, alerts, and reporting. It's expected over time that monitoring may become a standard requirement.

The Standardization Picture

The NFPA 1221 standard, widely adopted in the United States, defines the proper design, installation, maintenance, and use of emergency services communications systems. Many jurisdictions now require NFPA or IFC (International Fire Code)-compliant public safety and emergency responder coverage (ERCES) as a prerequisite for getting an occupancy permit.

For a given building to be deemed safe for occupancy, for sale, rent, or lease, it must be inspected and given a CO. Every location has its own rules and regulations that are required to obtain a CO. Most CO requirements are based on established standards, like NFPA 1221 and IFC 510, but each jurisdiction is free to improvise and interpret.

Disruptive Innovations: Cel-Fi RED Public Safety ERCES Solutions

Nextivity has introduced a line of public safety solutions that address the issues and concerns that have been expressed by the public safety community with disruptive innovations that resolve the technical limitations of legacy equipment traditionally used.

Faster Signal Processing

Faster, hardware-based signal processors are used in these innovative systems in order to process signals in real time. For example, these hardware signal processing elements responds to changing signals in less than 1.2 milliseconds which is faster than the guard time between transmissions in a P25 digital systems. This makes response instantaneous: one radio keys up and sends a signal while the second radio also keys up and sends a signal at almost the same time with the correct amount of attenuation or gain, automatically reaching the high site with the correct transmit power. This guarantees that the communication channel will be available regardless of when or where the communication needs to be established.

Built-in Grid Testing

As part of the acceptance test done by an AHJ, a minimum signal level of –95 dBm or DAQ of 3.4 at 95% of the target coverage area is required for an ERCES to pass. To perform this test, an AHJ coordinates with the dispatch center to set a maintenance window that enables a designated frequency channel to be used during the test without conflicting with other first responder operations. This represents a significant cost in time, resources, and money for the AHJ and the building owner. If the system does not perform as expected, the test must be re-scheduled, incrementally increasing the budget assigned for the project and delaying the certificate of occupancy issuance.

In contrast, Nextivity's innovative public safety solutions feature built-in grid test functionality that generates a full signal report, in both uplink and downlink direction. This can make a significant difference in how rapidly a CO is issued. Historically, the data delivered in this report has only been available for system integrators prior to the AHJ acceptance test with access to expensive equipment (with costs as high as $35,000). Now – using Cel-Fi RED Public Safety ERCES software, components, and a consumer two-way radio (walkie-talkie) – an integrator can test the performance of the uplink and downlink channels and generate a visual report of the signal levels at various locations inside the building rapidly before the AJH test, ensuring a pass the first time.

With the Cel-Fi COMPASS and Cel-Fi WAVE PRO App, integrators can perform Cel-Fi's built-in grid test to guarantee peak system operation.

Automatic Calculation and Setting of Isolation Between Donor and Server Antennas

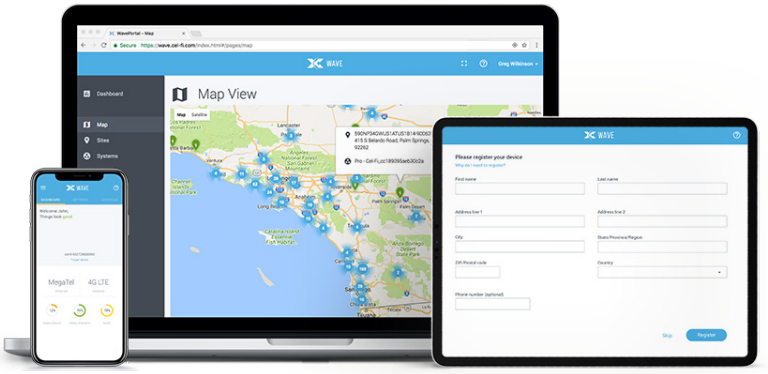
Leveraging the advanced signal processing capabilities of the Cel-Fi RED systems, the integrator only needs to enter the desired isolation value in the Cel-Fi WAVE PRO mobile app for Cel-Fi RED systems to evaluate the RF conditions inside and outside the building and adjust the system gain until the specified isolation value is achieved. The calculation and setting of this parameter take less than a minute and does not require any additional RF measurement tool other than a cell phone with the WAVE PRO app installed. If the RF environment changes over time, the system will adapt to the new conditions and ensure that the required isolation target is always met.

Automatic Calculation and Set of Uplink Transmit Power

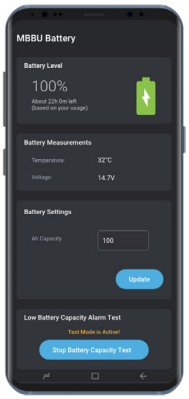
Human error and extensive manpower time are eliminated with automatic calculations of the link budget and setting of uplink transmit power. Using the high site location, site location, antenna data and satellite terrain models, the WAVE cloud platform calculates the necessary uplink transmit power to hit the remote site with the required power level.

Remote Monitoring and Management

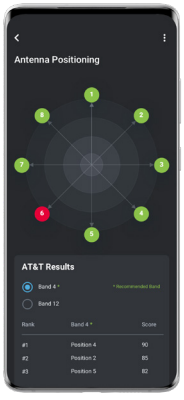
Built-in end-to-end remote monitoring and management using the Cel-Fi WAVE Portal and WAVE PRO app is another essential Nextivity innovation that allows for customized real-time monitoring of the high site-to-server antenna, as well as notifications that help ensure the system is operating up to code – without needing a truck roll.



Grid Test



Battery Settings



Antenna Positioning

ERCES Systems

The Cel-Fi QUATRA RED integrated ERCES public safety DAS was named **Safer Building Coalition's 2021 Safe Inside Product of the Year.**

Cel-Fi QUATRA RED — Public Safety DAS ERCES System

Cel-Fi QUATRA RED includes all the ERCES components referenced above and is ETL listed to UL2524. The system is modular and comprised of the following:

- **Network Unit (NU):** Also referred to as the Head End. This is where the external LMR and FirstNet donor signals are ingested and converted to digital signals for distribution.
- **Coverage Unit (CU):** Commonly referred to as a Remote Unit. The CU is where the digital signal is converted back to analog RF, boosted, and retransmitted through an antenna to provide coverage.
- **Management Unit (MU): T**he MU houses the communications capability for the entire system and facilitates Internet connectivity to Nextivity's cloud-based WAVE Portal where all Cel-Fi systems are monitored. Dry contacts for the Fire Alarm Control Unit (FACU- also known as the Main Alarm Control Panel) are produced through the MU.

Cel-Fi SOLO RED — Public Safety BDA ERCES System

Cel-Fi SOLO RED includes all the ERCES components referenced above and is ETL listed to UL2524. SOLO RED is available in Class A and Class B configurations. Unlike traditional wideband BDAs, SOLO RED Class B is channelized, so it only relays the appropriate radio signals and frequencies with a no noise guarantee. The system is also modular and compromised of the BDA and accessories listed below.

- **Public Safety BDA:** This is where the external LMR donor signals are distributed, converted back to analog RF, boosted, and retransmitted through an antenna to provide coverage. The BDA houses the communications capability for the entire system and facilitates Internet connectivity to Nextivity's cloud-based WAVE Portal where all Cel-Fi systems are monitored. Dry contacts for the FACU are produced through the BDA.

Cel-Fi RED — Additional Public Safety Components for ERCES Systems

Cel-Fi QUATRA RED and Cel-Fi SOLO RED need additional components to complete the ERCES setup requirements. The systems require their respective battery backup unit and are compatible with the following Cel-Fi RED or third-party components:

QUATRA RED Battery Backup Unit (BBU)

SOLO RED Battery Backup Unit (BBU)

Remote Annunciator (RA)

Emergency Power-Off Switch (EPO)

Active Server Antenna (ASA)

- **Battery Backup Unit (BBU):** The flexible battery backup systems and 12-24 hour requirements dictate the type of battery configuration needed. Third party BBUs are also supported.
- **Remote Annunciator:** Some jurisdictions want the ERCES Annunciator to be physically next to the FACU. Cel-Fi RED's Remote Annunciator has dry contacts for alarming and can be powered and remotely connected to the MU via Category (Ethernet) cable
- **Emergency Power-Off Switch (EPO):** Cel-Fi RED supports a separate EPO switch, using Power over Ethernet (PoE), that can be installed with the main system in the fire room or placed remotely and connected via Category cable. Third party EPO switches are also supported.
- **Active Server Antenna:** The Cel-Fi RED Active Server Antenna allows for monitoring and alarming of each individual antenna in the system.

Ease of Deployment

An individual Cel-Fi QUATRA RED system can be deployed like a simple 1W BDA or like a fiber DAS, up to 6W per NU, depending on the needs on site. The head end (NU) takes in the RF donor signal from the high site, digitizes the signal, and distributes it over Category (Ethernet) cable to each Remote Unit (CU).

Each CU supplies 1W RF power per band, with a single RF output that delivers the combined FirstNet and LMR signals. A DAS field can be attached to the CU, or an omni-directional antenna can be attached to provide coverage. A CU can be positioned next to the NU, with a short jumper cable between the two units to support a "BDA-like" deployment. The CU could also be positioned up to 150m away from the NU, in the style of a fiber DAS. A single NU can support up to six CUs in a star configuration, providing the flexibility of up to a 6W system with a single donor.

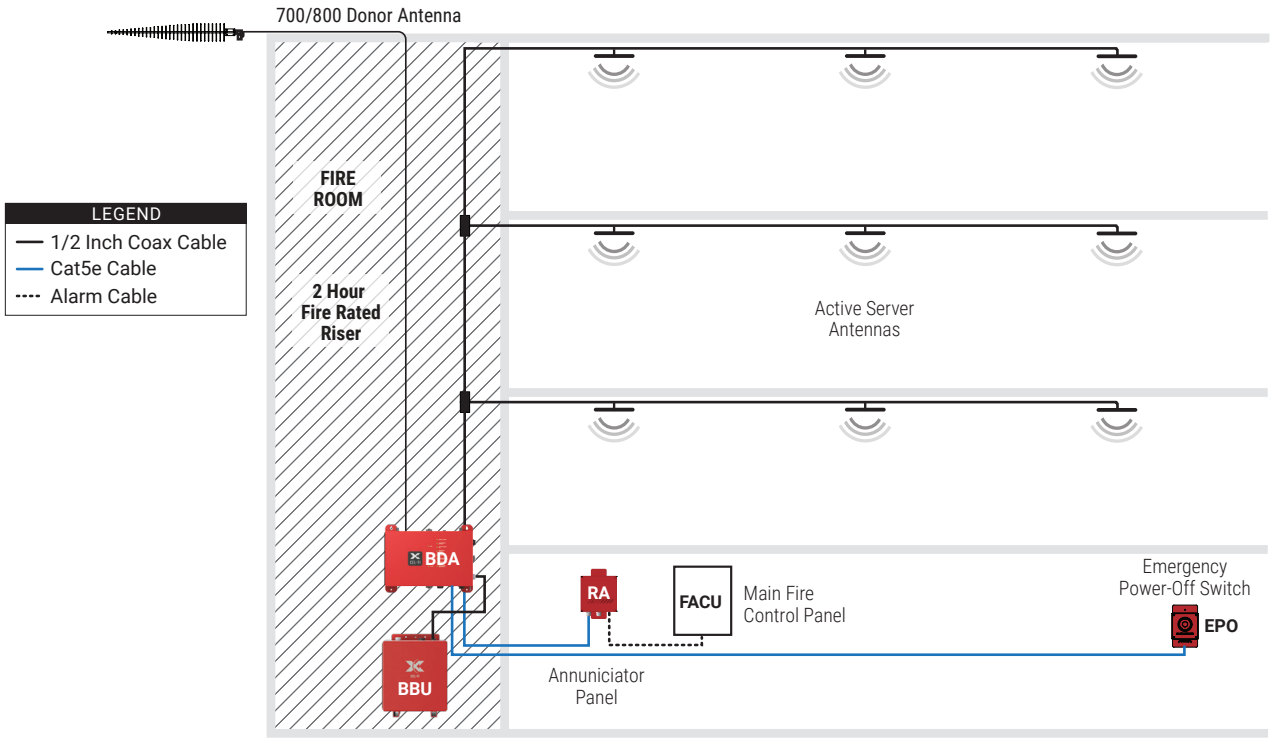
Because each remote unit (CU) is powered over Ethernet, the battery backup is aggregated in a single point at the head end, which dramatically reduces systems costs and install complexity. If any individual CU cable is cut, the rest of the system is unaffected.

Distributing the signal throughout the building using Category cable significantly reduces the complexity and difficulty versus a coaxial cable-based system. Cel-Fi's Category cable methodology is "lossless" meaning that each CU (each point where the signal is retransmitted) is at full power. This makes the planning process much easier for installers and reduces costs, time to market, and time to CO.

Public Safety

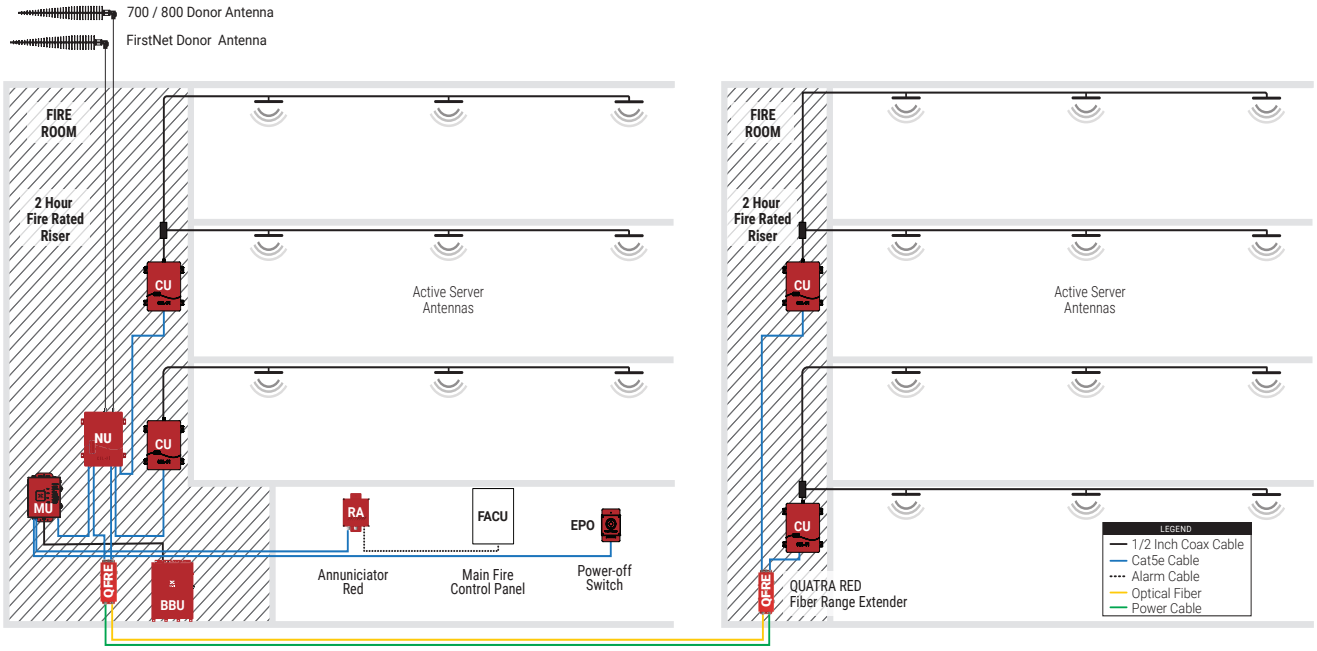
Public Safety BDA Configuration

The Cel-Fi SOLO RED 0.5-Watt Public Safety BDA is a selectable Class A or Class B ERCES for small-to-mid-sized structures.



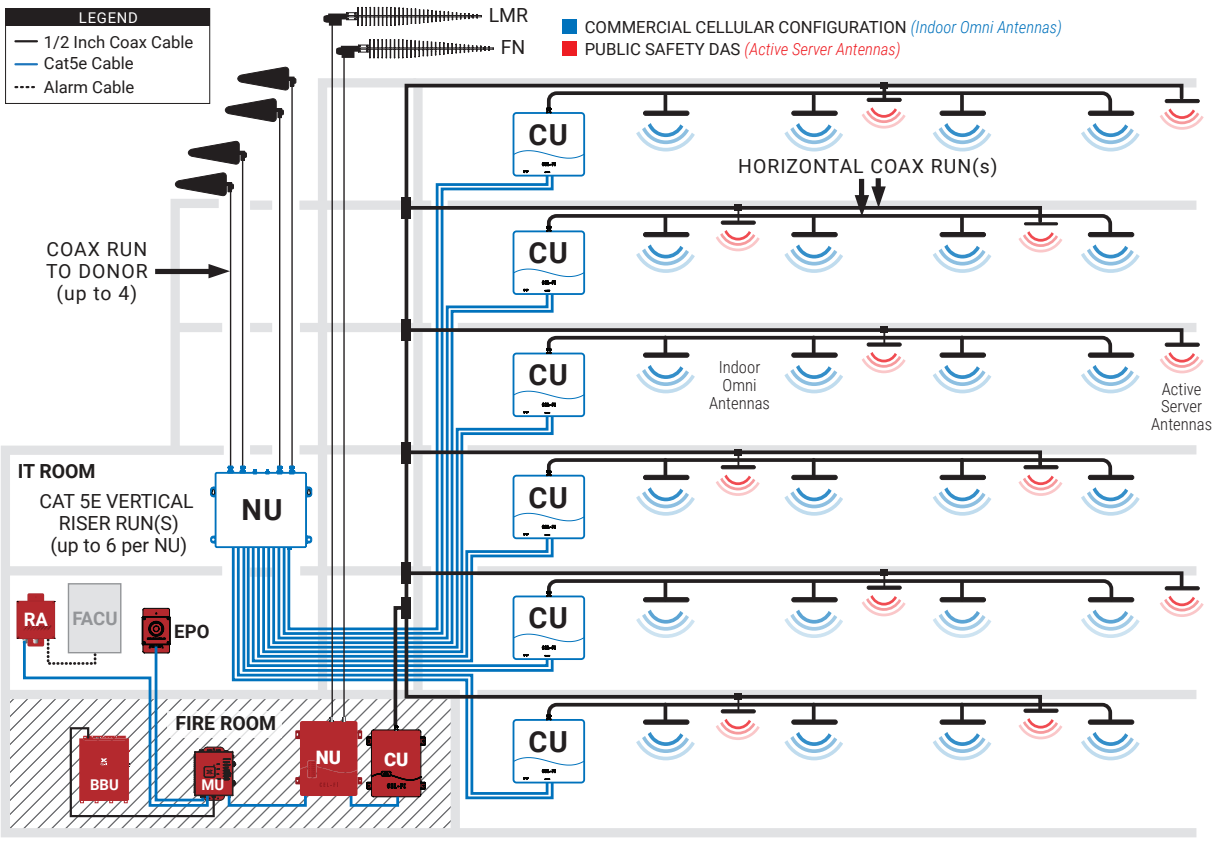
Public Safety DAS Configuration

The Cel-Fi QUATRA RED Public Safety DAS ERCES is scalable from 1 to 6 Watts, including full campus solution or skyscrapers that reach up to 1.9M ft^2 for Class A and B, with integrated FirstNet. The Cel-Fi QUATRA RED Fiber Range Extender extends the distance between the Network Unit and Coverage Unit to roughly one mile.



Public Safety DAS + Commercial Cellular Configuration

There is often an opportunity to deliver both Public Safety and Cellular communications within a building. In some cases, it may even be possible to share some passive infrastructure. The Cel-Fi systems require no specialized filters to facilitate such deployments.



FirstNet Bands

Many in the industry think of FirstNet as being limited to Band 14 (700 MHz) when, in fact, AT&T delivers FirstNet service across all of its bands. Cel-Fi QUATRA RED relays Band 14, as well as bands 4, 12, and 2, depending on the band AT&T is broadcasting at the specific site. This provides for much more reliable FirstNet coverage and can even provide FirstNet service where band 14 is not available.

Superior Automatic Gain Control

Gain is an area where many ERCES get in trouble. Cel-Fi QUATRA RED emerges from a technology platform that has been battle-tested globally over LTE networks with extremely stringent requirements for gain control. As such, it delivers innovations never seen before in the public safety market.

Gain settings in conventional BDAs and BDA-fed fiber-DAS systems can be difficult to get exactly right. Too little gain results in pockets within the system where voice quality may suffer or could result in dead zones with no coverage. Too much gain could swamp the network, drowning out either the high site or other neighboring systems. For these reasons, setting gain in conventional ERCES typically requires highly skilled engineers, and plenty of trial and error.

Because of the intelligence built-in to the Cel-Fi QUATRA RED system and the ability for the system's components to sense each other and understand their state of operation, gain can be set automatically by the installer at the touch of a button to simplify the process and eliminate the issues noted above. In addition, systems can be connected to the WAVE cloud and monitored. So, in the case of any post-installation issues, alarms will be triggered in the cloud and response can be initiated.

Donor Antenna Intelligence

Cel-Fi QUATRA RED supports both FirstNet and LMR. It is likely that the location of those donor signals will be different, so QUATRA RED has an RF donor port for each. This allows each donor antenna to be individually optimized and pointed. The challenge with a directional antenna is pointing it in the right direction. To exacerbate the problem, it's not always the closest tower or strongest signal that should be used. There can be wide variation in the signals from different towers, impacted by frequency use, loading, location, power, technology version, and many other factors.

Nextivity solves this through its Antenna Pointing application, which is available in the Cel-Fi WAVE PRO app. All an installer needs to do is aim the antenna and click on the test button. Once signal quality results are reported, the installer can rotate the antenna 45 degrees and test again. The installer can then simply fix the antenna to the direction with the best results.

This approach is very different to other systems currently available in the market that only test for signal strength. Strength is an insufficient metric, as the amount of noise, signal type, or quality is not measured. Quite often, the strongest signal is not the best signal.

For LMR antenna positioning, the Cel-Fi WAVE Portal automatically calculates the distance and direction of the high site. Once an installer sets the geographical coordinates of the high site, the WAVE Portal provides the optimum LMR antenna aiming direction.

Extensive Filters

Public safety radios need to be set up with specific frequency configurations and channels based on licensing and implementation within the area covered by the radio. These configurations can get quite complicated and extensive, particularly within large metro areas or in locations where jurisdictions are bordering each other and therefore use (and want to accommodate) resources from both areas. This can lead to complexity at a given site, where a repeater may not support enough frequencies or combinations to satisfy all of the local requirements. In that case, wider filters or multiple BDAs may be used. Cel-Fi QUATRA RED supports 56 filters in its Class A version and 28 channels in the Class B variation – the most in the industry. Each filter can be individually programmed. Once the system has been set up properly, the configuration can be saved and instantly reloaded into any new system going into the area.

The Cel-Fi Difference

Nextivity has been delivering cellular coverage solutions globally for more than 10 years. The requirements from a commercial cellular system for switching and gain control are more onerous than that of public safety due to the number of users a commercial system has to support. Nextivity has developed best-in-class automatic slot-to-slot gain control, which guarantees the best talk-in and talk-out performance in the industry. This proprietary technology has been incorporated into Cel-Fi RED solutions, resulting in optimal Delivered Audio Quality (DAQ) scores.

The Cel-Fi RED solutions were also designed from the ground up to be modular to solve one of the biggest challenges in the public safety ERCES market – i.e., the ability for each individual jurisdiction to interpret and enforce safety codes. This requirement creates a substantial amount of variation from location to location, not just in frequencies but also how specific standards are implemented. The modularity of Cel-Fi RED solutions support the deployment of all safety codes in a configurable manner.

A Flexible Approach to Public Safety Communication

As the public safety community transitions to a 4G LTE infrastructure, Nextivity is well positioned to meet the growing need for flexible solutions that enable uninterrupted communications and meet diverse industry standards and jurisdictional requirements. Cel-Fi RED Public Safety In-Building ERCES support P25 / LMR channels in the 700 MHz and 800 MHz spectrum, with Class A and B variants available. The DAS version includes dedicated FirstNet 4G LTE bands for more advanced data driven applications, such as body cameras, drones, and monitoring equipment.

Public Safety: #1 Driver by Audience

BUILDING OWNER:
Certificate of Occupancy

INTEGRATOR GOAL:
Speed of Installation for Owner

LOCAL AUTHORITY:
Keep Public Safety Officials and Building Safe

Cel-Fi RED is the first technology to bridge the challenges experienced in public safety communications. Built on Nextivity's market leading and proven technology that has been deployed globally, Cel-Fi QUATRA RED is designed to serve both LMR and FirstNet environments and ensure the safety of emergency workers and the citizens they serve. These public safety communication solutions provide a flexible, one-stop approach to addressing the complexity of existing environments, while meeting the evolving standards around network performance and NEMA 4 ratings.

As easy-to-install, integrated solutions for in-building environments, Cel-Fi RED helps developers and building owners resolve the communications obstacles public safety professionals face today, while future-proofing their systems.

Cel-Fi RED Public Safety ERCES solutions are available through distributors around the globe.
For more information, **visit www.cel-fi.com/solutions/public-safety.**

NEXTIVITY
Nextivity Inc.
16550 West Bernardo Drive, Bldg. 5, Suite 550, San Diego, CA 92127
cel-fi.com