The Power of Antenna-Modem Integrated HPUE

Optimizing Public Safety FirstNet Vehicle Performance

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FirstNet™ is in operation today

FirstNet is now operational across the United States, with public safety agencies embracing its high-speed mobile broadband data capabilities to improve emergency response and drive operational efficiencies. Arising from the ashes and anguish of 9/11, FirstNet enables life-saving situational awareness by boosting communications functionality used by emergency responders.

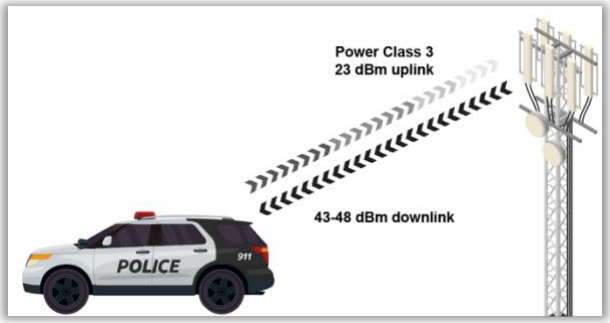
LTE, as a digital data service, brings a different set of challenges than older land mobile radio (LMR) technologies. Ensuring the broadest reach of an LTE cell site offering a FirstNet Band 14 signal is a tall order that demands excellent service from the cell site and the deployment of high-performance user equipment (UE) in the field. New approaches to boost the return signal from distant UEs offer an opportunity to extend the cell coverage area.

This paper reviews these innovations that can be applied to vehicle-based radio devices, from the new High Power UE (HPUE) technology to full integration of HPUE functionality into a combination of antenna with radio. By equipping fleets with mobile routers and LMR/LTE mobile radios supporting optimized HPUE technology tightly coupled with external antennas, public safety agencies create the best possible environment for successful emergency communications and field operations.

The importance of a FirstNet uplink signal

LTE networks support large numbers of end-user devices such as smartphones, tablets, vehicle routers, and Internet of Things (IoT) connectivity. Making the most of this dense high-performance network requires careful choreography between devices, a dance orchestrated by network radio systems located on cell sites distributed around the region. This orchestration relies upon a feedback loop between the base station and individual devices. If the synchronized flow fails because the signal from the device to the base station is too weak, then the channel to the device goes silent.

The amount of power a base station can transmit on the downlink versus the amount of power a device can transmit on an uplink is not equal. Base stations typically broadcast at high power levels that can range from 20 to 69 Watts, producing a signal that can boom across the landscape and penetrate deep into buildings. Device uplink power, on the other hand, must remain much lower. The lower levels enforced for devices help keep the signal within emissions levels established for human safety while also helping protect battery life. Furthermore, LTE radio technology is interference-limited. This characteristic means that network capacity goes down as the noise from devices in the field goes up. As a consequence, the LTE devices are designed to operate with the lowest uplink power level possible.



In the LTE standards produced by the international standards body 3GPP, the typical smartphone LTE device operates as a Power Class 3 UE. This default handset power class permits a maximum uplink power level of 0.2 Watts, a stark contrast to the downlink power of the base station. As a result, a

device can frequently "hear" a base station, even distant base stations, but not have sufficient power to send messages to the base station. When this uplink connection fails, the synchronized message flow with the base station halts, and the UE is out of range even with a strong base station signal.

The tight synchronization between LTE base stations and devices places a premium on uplink coverage and provides a sharp contrast with older analog land mobile radio technology. In an analog radio system, the distant mobile radio may fade in and out as its location changes. Even a weak and scratchy voice signal may remain understandable, though only portions of the speech can be heard. No such opportunity to understand information from a weak signal is possible with LTE. If the uplink power is insufficient, no information will flow, and the channel is dead.

As a consequence, the operational impact of LTE device uplink signal limitations in rural and remote suburban areas is tangible. While FirstNet works to quickly fill in remaining gaps as much as possible, the challenges will persist for many areas that have tough terrain that blocks radio signals. Even with a fully deployed cell site grid, problems can arise. Cell site failures due to disaster or mechanical faults happen, and mobile vehicles must be able to connect to a distant cell site that remains available.

Operationally, these coverage limitations mean that public safety agencies operating in these areas will struggle to add the benefits of modern cloud-based applications to the mission delivery model. Without consistent access to these powerful applications, emergency responders are forced to shape daily operations around the lowest common denominator. By optimizing FirstNet device uplink performance, the full benefit of FirstNet is delivered to all regions of the country, not just those areas in densely populated cities and towns.

NIST to the rescue

In the years leading up to FirstNet becoming a reality, public safety communications research experts at the National Institutes of Standards and Technology (NIST) identified the value in boosting the uplink device power as a way to extend coverage range. In response, the NIST and FirstNet Authority representatives to the 3GPP standards body worked to expand the uplink power options available to devices transmitting on Band 14.

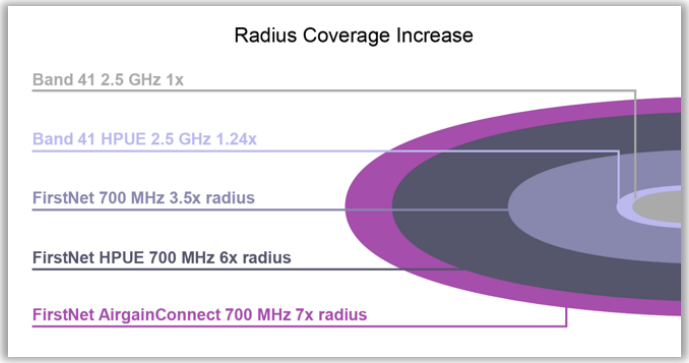
The result was Power Class 1, a new designation used to coordinate power control between the base station and an LTE UE. Commonly referred to as High Power UE (HPUE), the new power level enables vehicle-mounted LTE device transmission using uplink signals as high as 1.25 Watts. The difference in uplink output power compared to Power Class 3 devices is substantial, as the typical smartphone is limited to 0.2 Watts. Mobile vehicle devices that operate HPUE gain a remarkable 630% boost in power, an increased power budget that becomes available when needed.

By capturing the unique requirements for increased uplink power in international 3GPP standards, the NIST and FirstNet teams ensured that network base station and device implementations would work in harmony. These standards establish the messages exchanged between the device and network to indicate the power class options supported by the device. The concerted efforts by NIST and FirstNet Authority to capture these requirements in 3GPP standards served as an essential step in making consistent high-performance LTE a practical reality across the US.

Innovation powers uplink performance

High Power User Equipment (HPUE) systems are now ready for the market. Basic HPUE implementations incorporate a digital modem and an analog radio front-end that is capable of supporting Power Class 1 transmissions. The package can appear as a module that takes the place of current Band 14 radio modules used in mobile routers or mobile LMR/LTE radio systems. These traditional integrations use a shielded coaxial cable to take the radio output power from the module to an external vehicle antenna mounted on the vehicle.

Unfortunately, signal strength fades as the power flows over the shielded cable. And the loss is significant. As an example, a typical 16-foot cable run in a vehicle will sap 2.02 dBm of power. Recovering this lost power is only possible by taking an innovative approach to integrating radio components directly into an assembly that contains an external antenna. For purposes of this paper, this design approach is called an antenna-modem integrated HPUE solution.



An effective antenna-modem integrated HPUE design eliminates all cable loss and contributes a 60% boost in signal power exiting the vehicle. Where HPUE alone improves output power performance by 630%, adding the additional gain of antenna-modem integration yields a total improvement of 1000% over a legacy Band 14 mobile router radio module and antenna restricted to lower Power Class 3 levels. An example of a new product that closely couples HPUE functionality with the antenna is the AirgainConnect from Airgain. This company's offer is the first integrated antenna-modem approach Omdia has found that incorporates HPUE capability.

Antenna-modem integrated HPUE installations have the potential to eliminate large portions of uncovered footprint across a public safety agency's territory. Just as important, antenna-modem integrated HPUE provides increased LTE resilience in the event of cell site outages. While adjacent cell sites will increase downlink signal power and alter base station antenna tilt to compensate for a failed site, vehicles in the field will require higher output power to complete the link. Antenna-modem integrated HPUE will be instrumental in ensuring consistent operation in the event of site failures.

As already noted, the elimination of a shield coaxial cable run between the radio and antenna delivers a 60% boost in power output at the antenna. The direct benefit of that increased uplink power is extended range. But a secondary benefit comes as well as heat generation produced by an LTE radio module in an enclosed compartment is eliminated.

As a case in point, the interior of a parked police cruiser with the engine shutdown will quickly heat up when exposed to the hot summer sun. When engine ignition occurs, an HPUE radio module located in the mobile router will energize and cast-off waste heat inside the already hot compartment. By moving the HPUE radio functions to an external antenna assembly, agencies can reduce thermal stress impacting electronics installed in the vehicle compartments.

Operational impact: Why optimized HPUE matters

LTE systems deliver high-performance mobile broadband services with the potential to transform public safety operations. To ensure consistent access to high-quality mobile broadband services, public safety agencies must take action to optimize FirstNet Band 14 performance by leveraging the benefits of antenna-modem integrated HPUE. Delivering ubiquitous access to cloud-based applications across a jurisdiction's service area enables powerful tools that improve daily operations in law enforcement, emergency medical services, and fire operations.

The chief enabler for useful operational impact is access consistency. By expanding the broad coverage reach of a FirstNet cell site, antenna-modem integrated HPUE devices make operational use of cloud-based applications the rule rather than the exception. These new mechanisms impact each agency differently.

Law enforcement agencies prize consistent access to high-performance LTE service because of both enhancements to officer safety and efficiencies gained in the day-to-day process workflow. For officer safety, uniform reliable access to broadband across the agency's service area enables rapid identification of wanted or dangerous subjects following a traffic stop. Without LTE, vehicle and license checks require voice communications with a dispatcher, with a subsequent lag until the database inquiry completes and a dispatcher communicates the response. In contrast, officer-initiated inquiries via a mobile data terminal or smartphone are nearly instantaneous.

Beyond protecting the officer, LTE-based systems create the needed foundation to keep a mobile field force in the field. Instead of lengthy trips out of a patrol area to file paperwork, patrol officers can use mobile devices in the cruiser to create case documentation, check email, and use the agency's intranet resources for training and information. By maximizing the amount of time in the field, the agency delivers better service to the citizens it protects for the lowest cost possible.

Emergency medical services (EMS) systems are increasingly turning to digital technology to connect the ambulance with receiving medical institutions. Consistent high-quality FirstNet coverage allows broader use of patient monitoring tools and reporting tools that improve physician consults. For EMS systems that bill a patient's insurance company for transport and treatment, the use of connected ambulance technology can sharply reduce the amount of time before payment is received.

In the fire service, the mobile data terminal supplying up-to-date incident and premises information to responding units serves as the starting point for fire unit officers as they formulate a plan-of-attack while en route to the scene. But the fire service can do much more with the growing availability of rich LTE-enabled tools. As an example, video streaming from drones hovering over a fireground can feed unmatched situational awareness to incident commanders. Likewise, innovation in wildland-urban interface (WUI) protection can tap remote LTE-enabled cameras and sensors to detect and rapidly evaluate fire growth across a broad landscape. Getting the precious intelligence

from these analytical models to the incident commander in the field is made possible with optimized HPUE devices that combine radio and antenna elements into a single unit.

Public safety operations benefit from consistent wireless services, regardless of where a public safety vehicle is in the service area. Spotty, occasional, or unreliable service forces agency leadership to design day-to-day operational practices around a lowest-common-denominator that avoids potentially valuable cloud-powered innovation. Mobile routers, radios, and IoT devices equipped with antenna-modem integrated HPUE provide public safety agencies with the highest degree of readiness possible.

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