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High-Power Broadband Devices for FirstNet and First Responders

Andrew M. Seybold

FirstNet Public-Safety Broadband Authorized to Use High-Power User Equipment (HPUE)

Executive Summary

For many years, the public-safety community struggled with the many land mobile radio systems being spread out over various portions of the radio spectrum, which resulted in the inability for neighboring agencies to communicate directly with each other when needed. This lack of interoperability led the public-safety community to call for a single, nationwide, public-safety broadband network that would provide full interoperability. This network became a reality in 2012 when Congress passed and the then-President signed a bill to establish this new network and provide some basic funding to start the project.

Once radio spectrum was allocated to what is now The FirstNet Authority, the Federal Communications Commission (FCC) issued a nationwide license under the rules that govern public-safety spectrum. It further authorized exclusive use of higher-power field devices within this spectrum for the purpose of providing enhanced coverage and higher data rates for the public-safety community. The FirstNet Authority did not award the contract to build and operate this network until 2017. In January 2021, the network was ready to support high-power devices.

In the interim, several companies were investigating and experimenting with building field devices capable of operating at this higher power. Results of their efforts were made public in January 2021, when AT&T Wireless, the network contractor, announced the availability of high-power mobile devices for use exclusively on public-safety spectrum (20 MHz of spectrum in the 700-MHz band).

This increase in transmitter power from field devices has been described as a game changer for everyone who is permitted to use this spectrum: first responders and extended primary users defined as those who work with the public-safety community during incidents and emergency situations. Public-safety spectrum may also be used by commercial broadband customers but only on a secondary basis when spectrum in a given area is not needed by public safety.

The announcement from FirstNet (Built with AT&T) that the network is ready for high-power mobile devices also named two vendors that have been approved to provide these devices. While this paper is devoted to one vendor's high-power products, its products incorporate the high-power module developed by the other approved high-power field-unit vendor.

This paper walks readers through a short history of FirstNet and then takes a deep dive into high-power products provided by Airgain, Inc., including results of extensive drive testing using the Airgain high-power device. While both approved companies have devices that are available today, the Airgain offering has a decided advantage due to its design.

High-power field devices available for in-vehicle use provide extended FirstNet coverage for all users qualified to operate on public-safety broadband spectrum. These devices are approved by FirstNet (Built with AT&T), the FCC, and the 3GPP LTE, or 4G, standards body. Use of high-power devices is restricted to the FirstNet network within the 20 MHz of public-safety broadband spectrum known as Band 14.

Brief FirstNet History

After many years of the public-safety community's efforts to establish a nationwide broadband network, the Middle-Class Tax Relief and Job Creation Act of 2012 was ratified. Within that law was a section granting public safety an additional 10 MHz of broadband spectrum adjacent to the 10 MHz of spectrum in the 700-MHz band that had already been licensed to the Public-Safety Spectrum Trust (PSST). This Act created what is now known as The FirstNet Authority, which is an independent authority under the auspices of the National Telecommunications and Information Agency (NTIA) within the U.S. Department of Commerce (DOC).

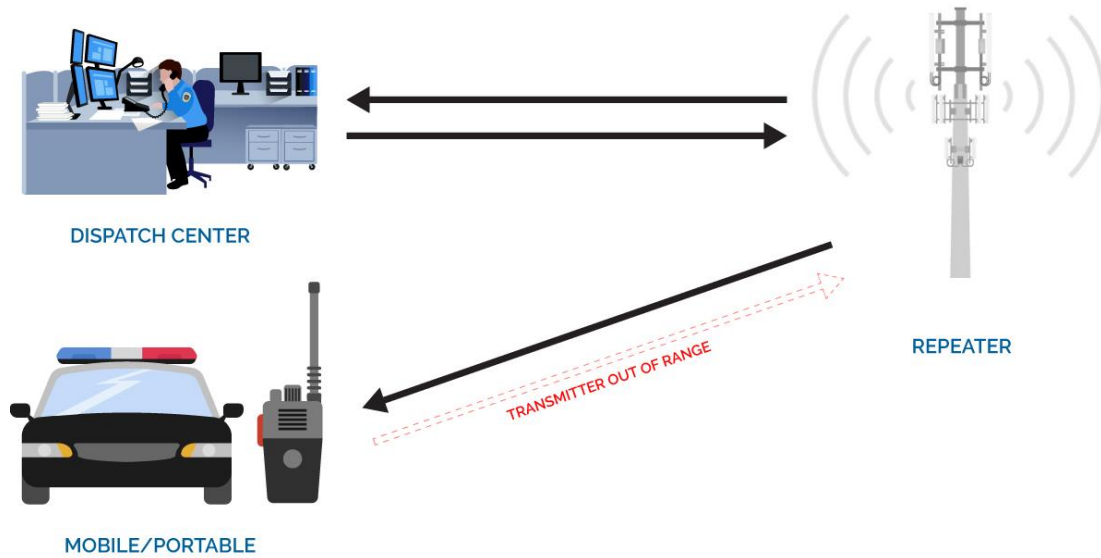
The FCC was instructed to license this 20-MHz swath of 700-MHz spectrum to The FirstNet Authority for the purpose of providing the spectrum needed for the Nationwide Public-Safety Broadband Network (NPSBN) for which the public-safety community had worked so tirelessly. On October 28, 2013, the FCC passed Docket No. 12-94 to set service rules for public-safety broadband spectrum. The FCC differentiated this 20 MHz of spectrum, now licensed to The FirstNet Authority, as public-safety spectrum. As such, it fell under the rules (FCC Part 90) that govern all public-safety spectrum authorized by the FCC. Most noteworthy is that this FCC Report and Order permits the use of higher power levels for user devices within this 20 MHz of public-safety spectrum known as Band 14.

Following this FCC action, the 3GPP standards body, which is responsible for Long-Term Evolution (LTE) worldwide standards, authorized "class 1 power," commonly known as "high power," that is designated for use exclusively within public-safety Band 14 in the United States.

Why High Power Is Important

The use of higher power makes a significant difference in Land Mobile Radio (LMR) systems. With LMR, field devices and the network are not reliant on each other. As a result, networks often "out-talk" user devices' ability to respond. When public safety uses LMR, as it has since the 1930s, the network (radio base station) often transmits farther than the mobile and/or handheld devices. High-Power User Equipment (HPUE) extends the range of the cellular field devices to enable them to respond to the network.

With cellular broadband, user devices and the network must communicate with each other for users in the field to be able to receive and send voice, text, and data. If the user device (e.g., cell phone, tablet, mobile router) cannot communicate with the network, it will be disconnected from the network. If a user device is near the edge of a cell site or shadowed by terrain or buildings and the network can no longer hear the phone, communications are not possible until the field unit is back within its transmit range.



With LMR, the downlink stays connected when the uplink is disconnected.



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With cellular, the downlink disconnects when the uplink is disconnected.

High-Power User Equipment

“High-Power User Equipment (HPUE)” is the official 3GPP¹ designation for this high-power capability and FirstNet (Built with AT&T) has trademarked the term MegaRange™ to describe what high-power devices offer the public-safety community. The idea is to extend the distance public-safety Band-14 user devices can be from a cell center and remain connected to the network. In addition to extending coverage with a stronger signal, MegaRange devices deliver faster and more consistent data rates in challenging or remote coverage areas.

Many public-safety communications professionals consider the availability of higher-power user equipment to be a game changer for the public-safety community. HPUE not only benefits public-safety users in the more rural areas of the United States, it provides improved communications in suburban and metro areas as well. The power difference is significant. A standard broadband device such as a tablet or smartphone transmits at a maximum power level of 0.2 watts while high-power devices (currently limited to mobile devices) can transmit at power levels up to 1.26 watts, which is a significant increase in transmit power.

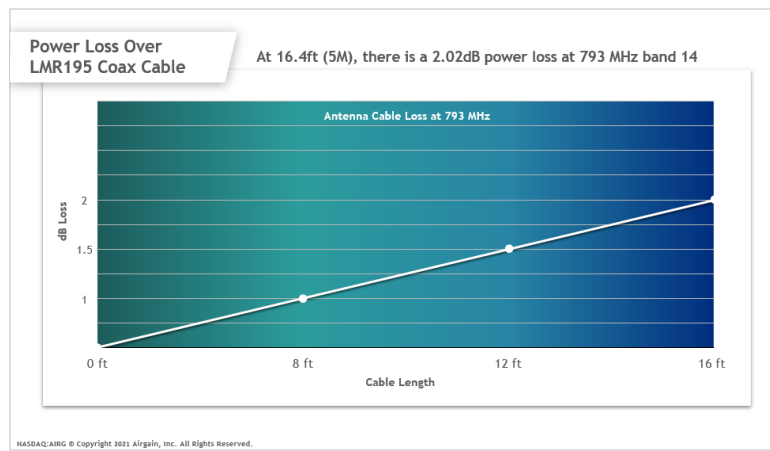
FirstNet (Built with AT&T) announced that MegaRange™ devices would be available starting in January of 2021. Today, there are two approved MegaRange equipment vendors: Assured Wireless Corporation and Airgain, Inc.® The AirgainConnect® AC-HPUE uses a customized high-power module supplied by Assured Wireless. AirgainConnect and Airgain technology have been patented by Airgain.

AirgainConnect

Airgain, Inc., specializes in wireless connectivity solutions and technologies designed to enable wireless networking for a broad range of devices and holds many patents for its antenna solutions and wireless connectivity products. An industry leader in carrier-class embedded antenna systems, Airgain also has a twenty-plus year history in delivering aftermarket antenna systems for public-safety vehicles in the United States and abroad. By visiting Airgain.com and selecting “Products,” you will see that Airgain’s products provide solutions for consumer, enterprise, and automotive markets. When you select “Technology,” you will learn that Airgain’s expertise includes antenna technologies for all 802.11 Wi-Fi variants including Wi-Fi 6, Wi-Fi 6E, 5G CBRS, 3G and LTE, LPWAN (Lower-Power Wide-Area Network used for IoT), Bluetooth, ZigBee, and Z-Wave.

Airgain has been developing and shipping antennas to a broad range of clients including public safety for more than twenty-five years. When Assured Wireless introduced its HPUE module, Airgain saw an opportunity to tightly integrate the module with the antenna components to further improve the coverage benefits of HPUE. Since the high-power module resides in the antenna, there is no need to run coax cables from the trunk-mounted router to the vehicle roof-mounted shark-fin antenna. Airgain calls this new solution an “antenna-modem.” This new category of equipment is connected via a Local-Area Network (LAN) connection and this eliminates typical losses in receive and transmit signals that are inherent with the use of coax cables.

¹https://www.etsi.org/deliver/etsi_ts/136100_136199/136101/10.03.00_60/ts_136101v100300p.pdf



The diagram above shows that the power loss of a typical roof-mount antenna connected to a vehicle-mounted device using an LMR195 coax cable approximately sixteen feet long creates a signal loss of 2 dB² (37 percent). This loss has been mitigated by building the high-power module directly into the antenna housing. The high-power module includes both Band 14 public-safety LTE and all AT&T LTE bands that have been made available to the public-safety community. Mitigation of cable loss results in better transmit and receive signals for both the Band-14 high-power portion of the antenna-modem and the FirstNet (Built with AT&T) LTE bands.

Airgain has been awarded a number of patents for its antenna designs and it was not a surprise that it has multiple issued and pending patents for the AirgainConnect AC-HPUE high-power antenna-modem. While the antenna-modem is designed to be permanently mounted on the roof or rear deck of a vehicle, Airgain has also designed a magnet-mount accessory to enable AirgainConnect to be used in trials to determine its effectiveness so an agency can see for itself how much difference AirgainConnect makes in both extended coverage and high data rates (more information below) without having to install it permanently.

AirgainConnect

In mid-December, Airgain provided me with an AirgainConnect AC-HPUE, which I then had installed on the roof of my SUV. I have been using a Sierra Wireless MG90 router in my vehicle for the past two years and have run extensive drive tests to collect coverage data.

² <https://www.timesmicrowave.com/Calculator>

AirgainConnect

High Power Band 14
Plus all FirstNet LTE Bands
GPS, Wi-Fi

**Both Connect to
Sierra Wireless MG90 Router**

Airgain Centurion 9-in-1

4X Wideband Cellular (600 to 6MHz)
4 Wi-Fi MIMO and GPS



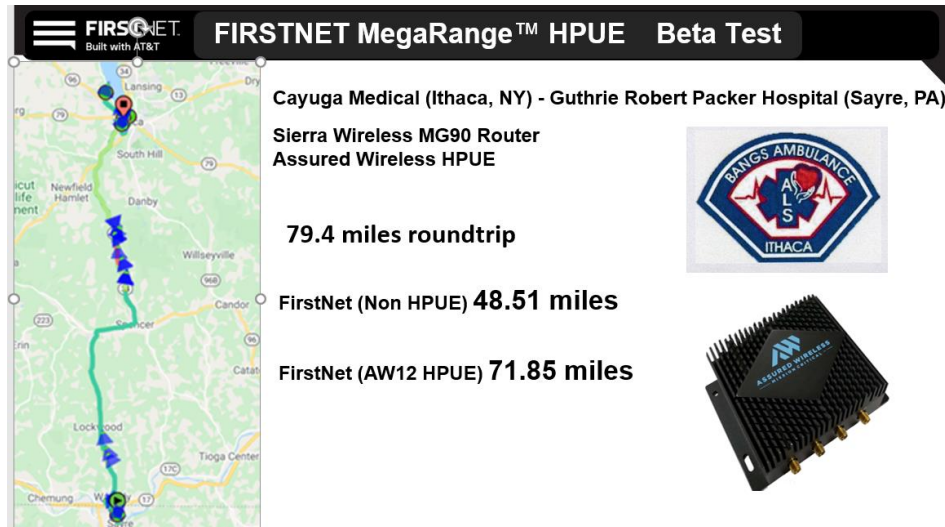
The MG90 was set up to record data for both the FirstNet (Built with AT&T) public-safety network and the Verizon network while running my drive tests, mostly around Phoenix and Maricopa County. After installation of AirgainConnect, I have repeated these drive tests for local agencies and it is obvious that FirstNet has been installing a large number of Band-14 cell sites and/or adding Band 14 to its existing cell sites.

While most of Phoenix and Maricopa County have Band 14 coverage, signal levels indicated there were places where Band-14 signals were too low to be considered useful for high-speed data or video transmissions. After AirgainConnect was installed, I drove the same routes within the city and county and found that in areas where I previously had Band-14 coverage, AirgainConnect significantly increased uplink data rates, and I had coverage in areas where previously I had not been able to detect coverage.

Drive Tests

In up-state New York, FirstNet ran a beta test with Cayuga Medical in Ithaca, NY using Bangs Ambulance. This test did not include AirgainConnect but it was conducted using the Assured Wireless version of the high-power device connected to a Sierra Wireless MG90 and a standard roof-mount shark-fin antenna.

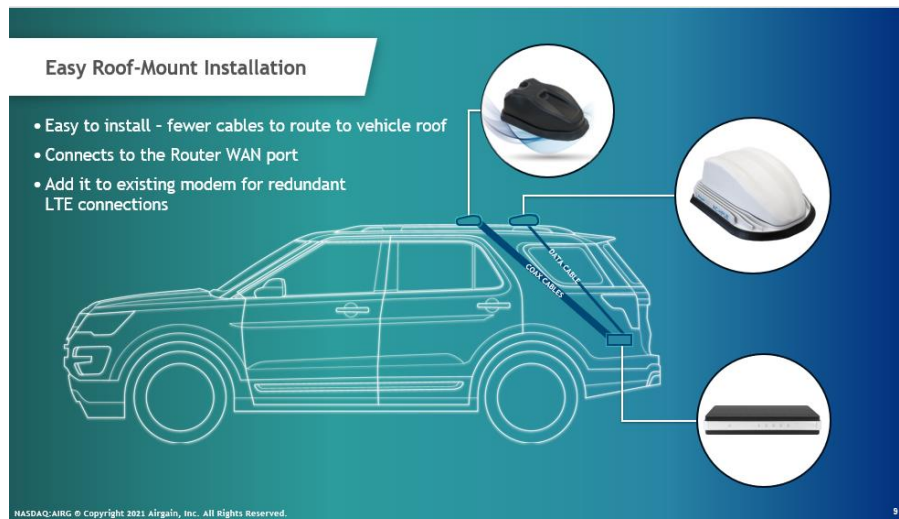
This test was run from Cayuga Medical's service area south to Guthrie Robert Packer Hospital in Sayre, PA. The round trip for this test was 79.4 miles. During this test, the ambulance reported it was in standard FirstNet coverage for 48.51 of those miles. However, with the Assured Wireless AW12, it was connected to FirstNet for 71.85 miles, which is a significant difference of more than 23 miles.



After this test, Chief Harlin McEwen (Ret), the driving force behind winning federal approval for what is now FirstNet, received an AirgainConnect and had it installed in his private vehicle. Like mine, it was connected to a Sierra Wireless MG90. After installation of the AirgainConnect antenna-modem, Chief McEwen drove the same route and reported the following results:

- Recently did drive test to compare Bangs Ambulance coverage results and my results over same route with the Airgain antenna-modem showed:
 - Bangs Ambulance: Total roundtrip miles **79.40**
 - FirstNet Coverage (Non HPUE) miles 48.51
 - First Net Coverage (AW12 HPUE) miles 71.85
 - Chief HRM:
 - First Net Coverage (Airgain AC-HPUE) miles . . . 78.957

As can be seen, the difference in FirstNet coverage with the Assured Wireless solution and AirgainConnect was a little more than seven miles, or a 10-percent additional increase in coverage. Again, this increase in coverage can be attributed to the design of AirgainConnect and that it does not require devices to be connected with coax cable.



Drive Tests

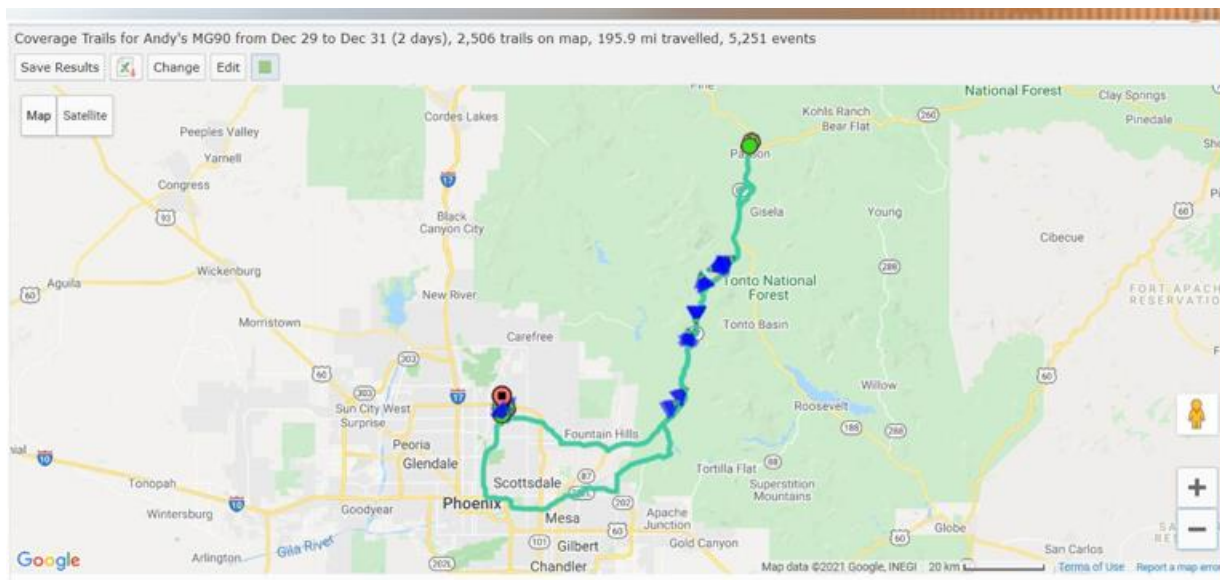
My drive tests using AirgainConnect began in late December 2020, before FirstNet announced High-Power User Equipment (now referred to as FirstNet® MegaRange™). So far, I have driven 1,685 miles in Arizona and from Phoenix to Las Vegas and back. During all these drives, my MG90 was reporting to the Sierra Wireless Airlink Mobility Manager cloud. The cumulative results show that of the 1,685 miles driven, I was in FirstNet range using AirgainConnect for 1,638.1 miles. The system also reported that during these drives I was within standard FirstNet coverage for 1,538.4 miles. This indicates AirgainConnect provided six-percent better overall coverage for the 1,685 miles.

In rural areas, the use of HPUE dramatically increased coverage. However, as you will see below, within urban areas included in the drive tests, there were places where even though the MG90 reported I was in standard FirstNet coverage, signal levels in some of these areas indicated only marginal coverage. AirgainConnect also provided an increase in coverage levels in these areas.

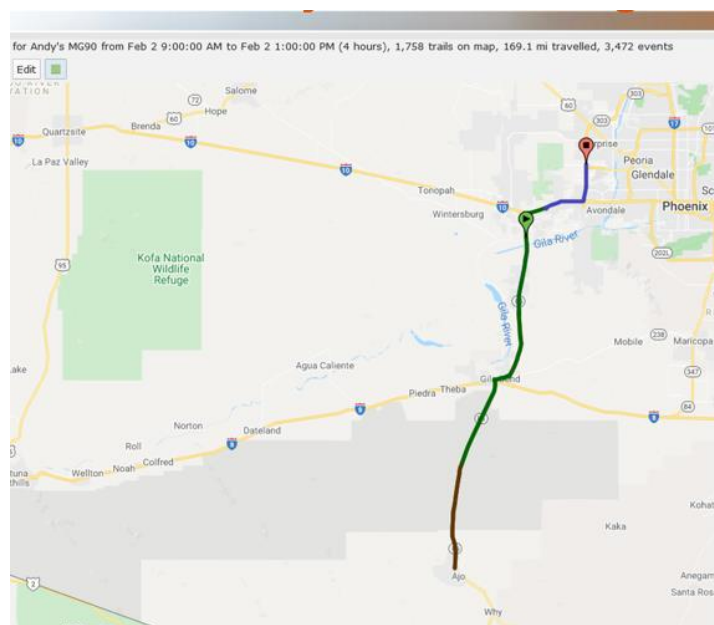
Below you will find a break-out of some of my trips and data for each. I drove within the cities of Phoenix, Scottsdale, and Mesa, as well as many rural and less-populated areas.

Phoenix to Payson, Arizona

This drive was 195.9 miles round trip on a highway and in mountainous terrain, and it included a side trip through Tonto National Park recreational areas. Elevations went from about 1,400 feet to more than 4,000 feet and back several times. AC-HPUE connected mileage totaled 193.9 miles and standard FirstNet mileage was 193.0 miles. However, standard FirstNet coverage in many areas was at the edge of usability. Even so, the network was usable for most of the drive with AirgainConnect.



The next drive test took me almost due south and close to the Mexican border. The route is along a flat highway with mountains on both sides during some of the drive. I lost FirstNet coverage at Ajo, AZ at the south end of the drive and was connected to FirstNet (AT&T) partner Comnet Wireless, which does not support Band 14 but does support some FirstNet LTE bands. The round trip was 169.1 miles. AirgainConnect shows it was connected for 168.2 of those miles while standard FirstNet was connected 154.7 miles.



These tests are indicative of urban, suburban, and rural coverage gains when AirgainConnect is compared to standard FirstNet coverage. Again, while some drive tests don't show a significant difference when using AirgainConnect, there are differences in signal strength. When connected to AirgainConnect or the Assured Wireless device, all FirstNet (AT&T) LTE bands are included in the high-power device (high power permitted only on Band 14). It is not possible to tell which portion of the LTE

spectrum has been selected by the high-power device. HPUE is set for Band-14 priority, which means high-power devices will be communicating with a Band-14 cell site if one is available. That the router cannot tell which band segment the high-power device has selected is of little consequence to public-safety users since the high-power device will remain connected to a FirstNet LTE band. However, for our tests, I wanted to determine when and for how long the router was connected to the cellular network through the AirgainConnect and how much of the time it was connected to Band 14. This information is not normally available and, as mentioned, it really does not make a difference to public safety.

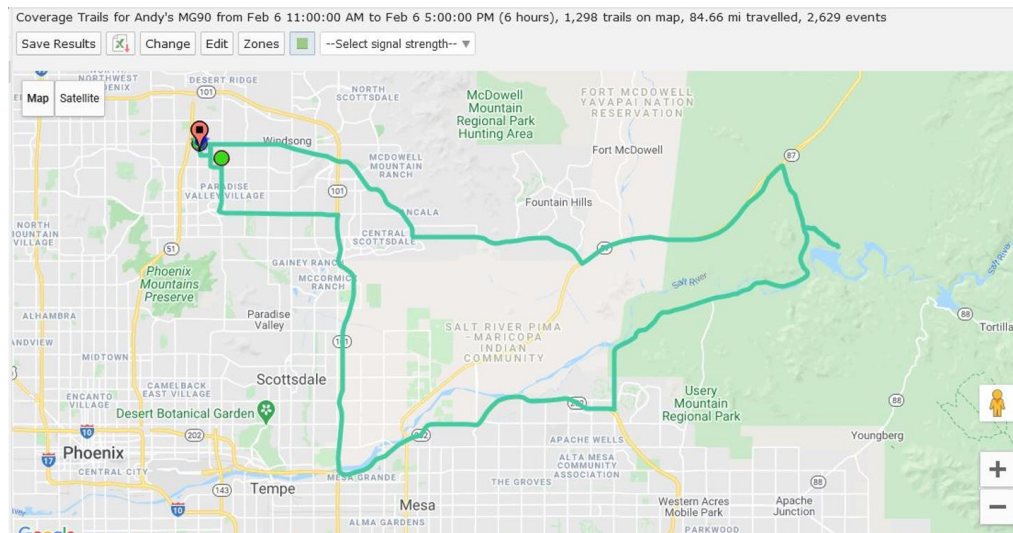
In discussions with both Airgain and Assured Wireless, I learned that if I had a different Ethernet Injector, I could see the band changes. (The Ethernet Injector is the device that powers AirgainConnect and provides the AirgainConnect Ethernet WAN connection). The new injector required new software to be written to indicate times when AirgainConnect was using which band. I replaced the standard injector with the new injector, made sure it was working properly, and then conducted the drive test described below.

Once I finished the drive test, I received an Excel spreadsheet that showed, minute-by-minute, which LTE band AirgainConnect had selected. The following is a sample of the information I received:

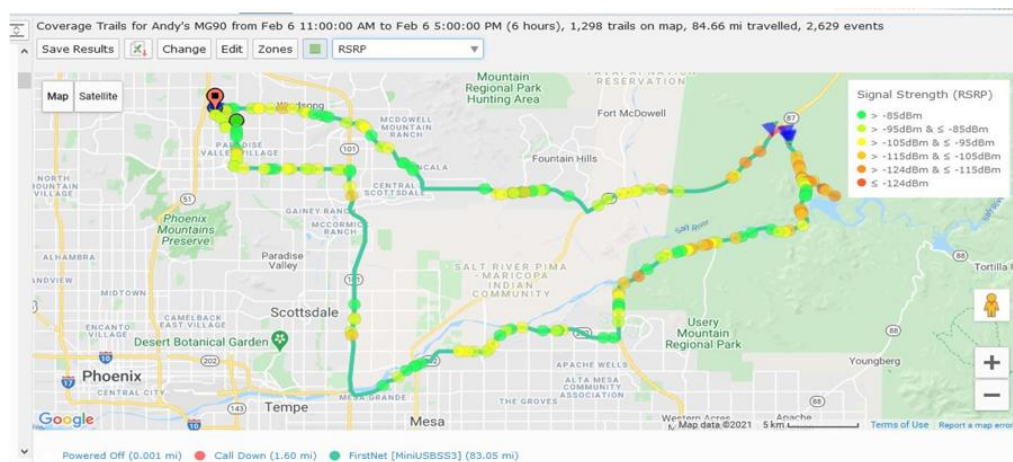
2021-02-06T11:37:30-08:00	30
2021-02-06T11:38:30-08:00	2
2021-02-06T11:39:00-08:00	2
2021-02-06T11:40:00-08:00	2
2021-02-06T11:42:30-08:00	14
2021-02-06T11:43:30-08:00	14
2021-02-06T11:44:30-08:00	14
2021-02-06T11:45:30-08:00	14
2021-02-06T11:46:00-08:00	14
2021-02-06T11:47:00-08:00	14
2021-02-06T11:48:00-08:00	30
2021-02-06T11:49:00-08:00	2
2021-02-06T11:49:30-08:00	14
2021-02-06T11:50:30-08:00	14
2021-02-06T11:51:30-08:00	14
2021-02-06T11:52:30-08:00	14
2021-02-06T11:53:00-08:00	14
2021-02-06T11:54:00-08:00	14
2021-02-06T11:55:00-08:00	14
2021-02-06T11:56:00-08:00	14
2021-02-06T11:56:30-08:00	14
2021-02-06T11:57:30-08:00	14
2021-02-06T11:58:30-08:00	14
2021-02-06T11:59:30-08:00	14
2021-02-06T12:00:00-08:00	14
2021-02-06T12:01:00-08:00	14

I tried to match the times and bands listed with the drive test map and found it was not an easy task. So, I turned to the Sierra Wireless engineers and after a few days, they gave me the information I needed to successfully compare locations with bands in use during the test, and they also provided the signal strength of standard FirstNet coverage.

The results shown below include the total trip mileage: 84.66, AirgainConnect coverage for 84.54 miles (almost perfect), and standard FirstNet coverage for 83.05 miles. The difference here does not appear to be significant, and when you look at the maps below you will see that standard FirstNet coverage was almost as good as AirgainConnect coverage. However, reviewing the FirstNet coverage map with signal strength, it is clear that in a number of areas where FirstNet was connected, the signal strength was not sufficient to provide adequate two-way communications, especially to upload data or video. The takeaway here is that while the router stayed connected to standard FirstNet, coverage remained fairly consistent and AirgainConnect provided far better coverage. The last drive-test diagram uses Google Maps with a legend showing which FirstNet LTE band AirgainConnect had selected.



Total Trip Miles: 84.66; Total AirgainConnect Miles 84.54

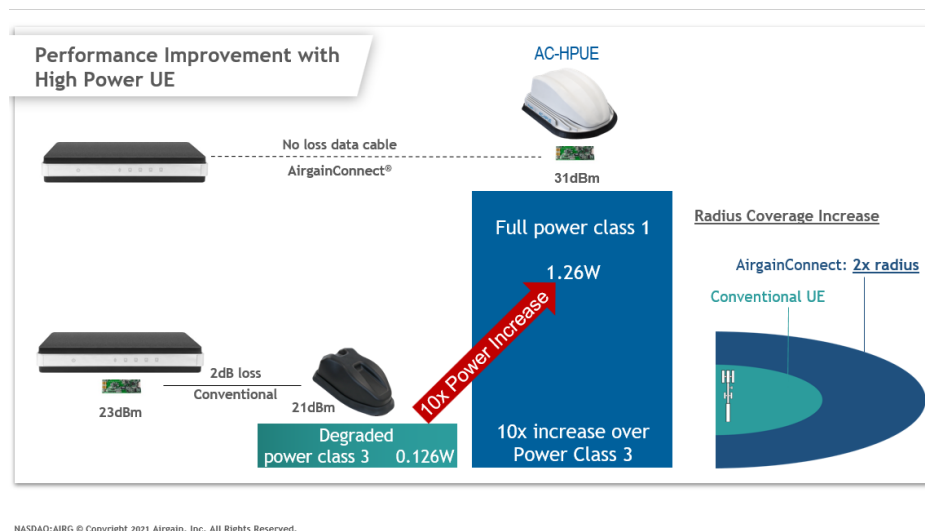


Standard FirstNet Coverage; Note Low Signal Areas (> -115dBm)



Google Earth Plot Showing Where FirstNet LTE Band 14 Was Selected by AirgainConnect During Tests

These tests show conclusively that there are a number of advantages to using high-power devices, especially AirgainConnect since it provides additional transmit and receive gain on every FirstNet LTE band. Below is a diagram showing that compared to standard class-3 FirstNet devices that operate at a maximum power level of 0.126 watts after cable loss, the AirgainConnect antenna-modem system provides up to ten times more power. Further, because AirgainConnect does not use coax cables to connect to mobile devices, transmit and receive gain is increased on *ALL* FirstNet LTE bands.



Tests conducted by others also indicate that AirgainConnect can provide improved coverage inside parking structures, in underground tunnels, and in metropolitan areas.



While I have yet to conduct tests in an urban canyon setting, parking structure, or underground tunnel, those who have report significant improvements. High-power devices have only been on the market for a few months, but as more public-safety agencies run tests and sign up for the service, we will learn more about how effective the AirgainConnect method of extending coverage for LTE Band 14 and the other public-safety bands and improving data rates from the field. This information will be available to anyone considering using high-power devices, especially Airgain's high-power antenna system with the built-in antenna-modem module that eliminates additional losses related to use of coax cables.

Mobile Devices and AirgainConnect

Again, high-power devices are currently available primarily for mobile routers, laptops, tablets, and any vehicle-mounted device that has a LAN/WAN connection. I have determined AirgainConnect to be best matched with any FirstNet-approved vehicular router that supports a Wi-Fi bubble around the vehicle. Not only does this increase coverage and data capacity for the vehicle, it increases coverage for handhelds and tablets within range the vehicle's Wi-Fi hotspot. Generally speaking, when creating a hotspot around a vehicle, it should be in the 2.4-GHz Wi-Fi band since this band provides the best coverage from field devices to and from the AirgainConnect AC-HPUE. (Airgain offers AirgainConnect with optional built-in Wi-Fi and GPS antennas for connecting to a router.) AirgainConnect can also be connected directly to a laptop or via a docking station or tablet.

If the vehicle-mounted router is also connected to other devices in the vehicle, e.g., dash cams, alarms, and/or sensors, the addition of the AirgainConnect high-power system will enhance their capabilities and extend their range beyond the normal limits of the FirstNet network.

Conclusion

While we are still learning about high-power device capabilities on FirstNet public-safety broadband spectrum, we will find out more as drive tests are conducted by authorized public-safety and extended primary FirstNet users across the United States. More data specific to AirgainConnect will become available as devices are installed in vehicles authorized to operate on FirstNet Band 14. High-power devices are designed to increase range and data capabilities in more rural environments and in suburban and metro areas. AirgainConnect antenna-modem tests continue to be conducted in parking garages, tunnels, and other areas where typical broadband coverage is not available.

Airgain has integrated an existing high-power module into an external-mount antenna, thus eliminating coax antenna cables traditionally used to connect antennas to in-vehicle devices. Further, Airgain has been able to increase both the transmit and receive range of mobile routers, laptops, and tablets, even on non-Band 14 FirstNet spectrum. As many have concluded, the AirgainConnect antenna-modem is truly a game changer with its ability to increase radio coverage and data speeds for the public-safety community over FirstNet.

For more information about AirgainConnect and the rest of Airgain's broad antenna product line, visit the Airgain website at Airgain.com.

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