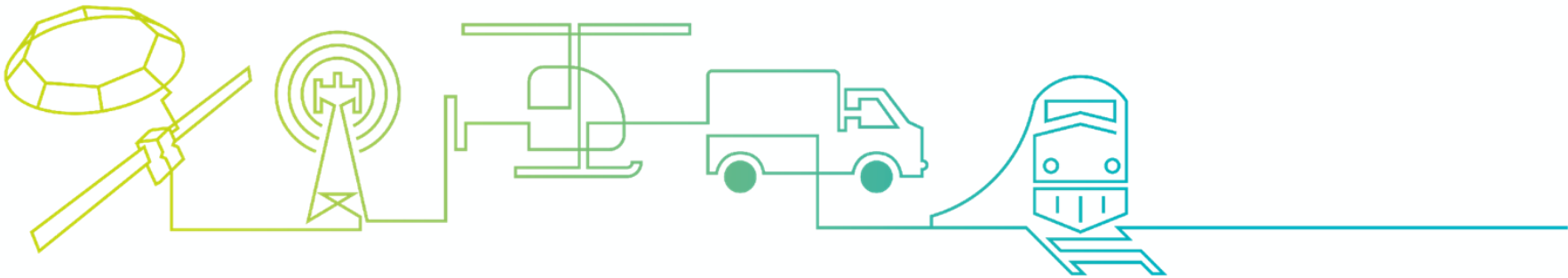
Ligado Network's Mobile Terrestrial Services Plan & the Protection of GNSS Service

NOVEMBER 15, 2017



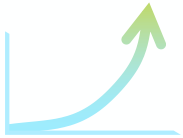
ligado NETWORKS | Making Stronger Connections

Ligado Networks Overview

Company Overview

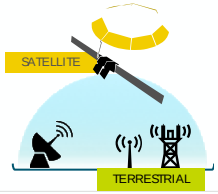
Ligado Networks is a new company with new owners, a new board, new management, and a new plan to deliver advanced connectivity while protecting GPS

Market Focus



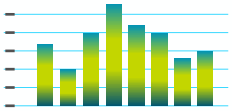
Ligado is targeting the Industrial IoT market, which has critical communications needs that are unmet by today's broadband and narrowband wireless networks

Advanced Private Networks



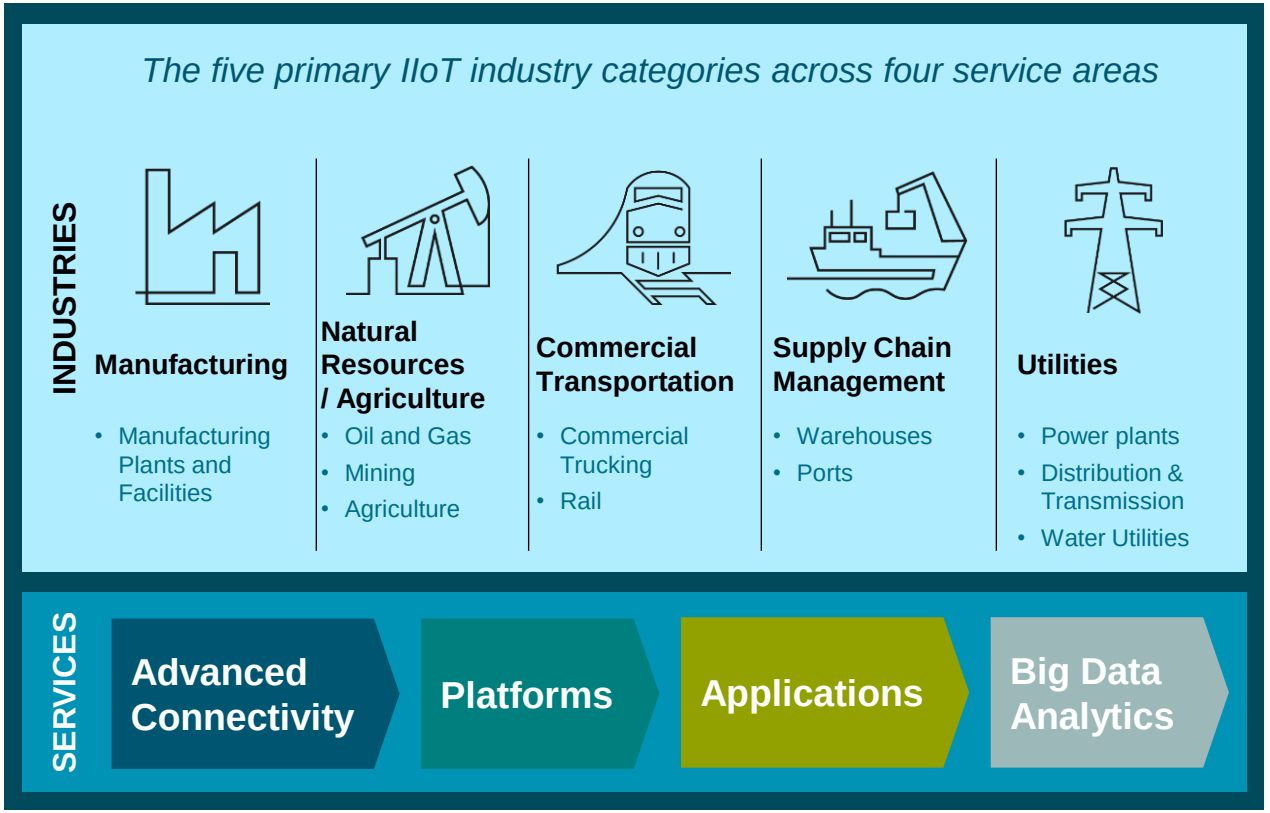
Our strategy is to enable and accelerate private network deployments that deliver pervasive, highly secure, and ultra-reliable connectivity for emerging 5G and critical IoT use cases

Spectrum



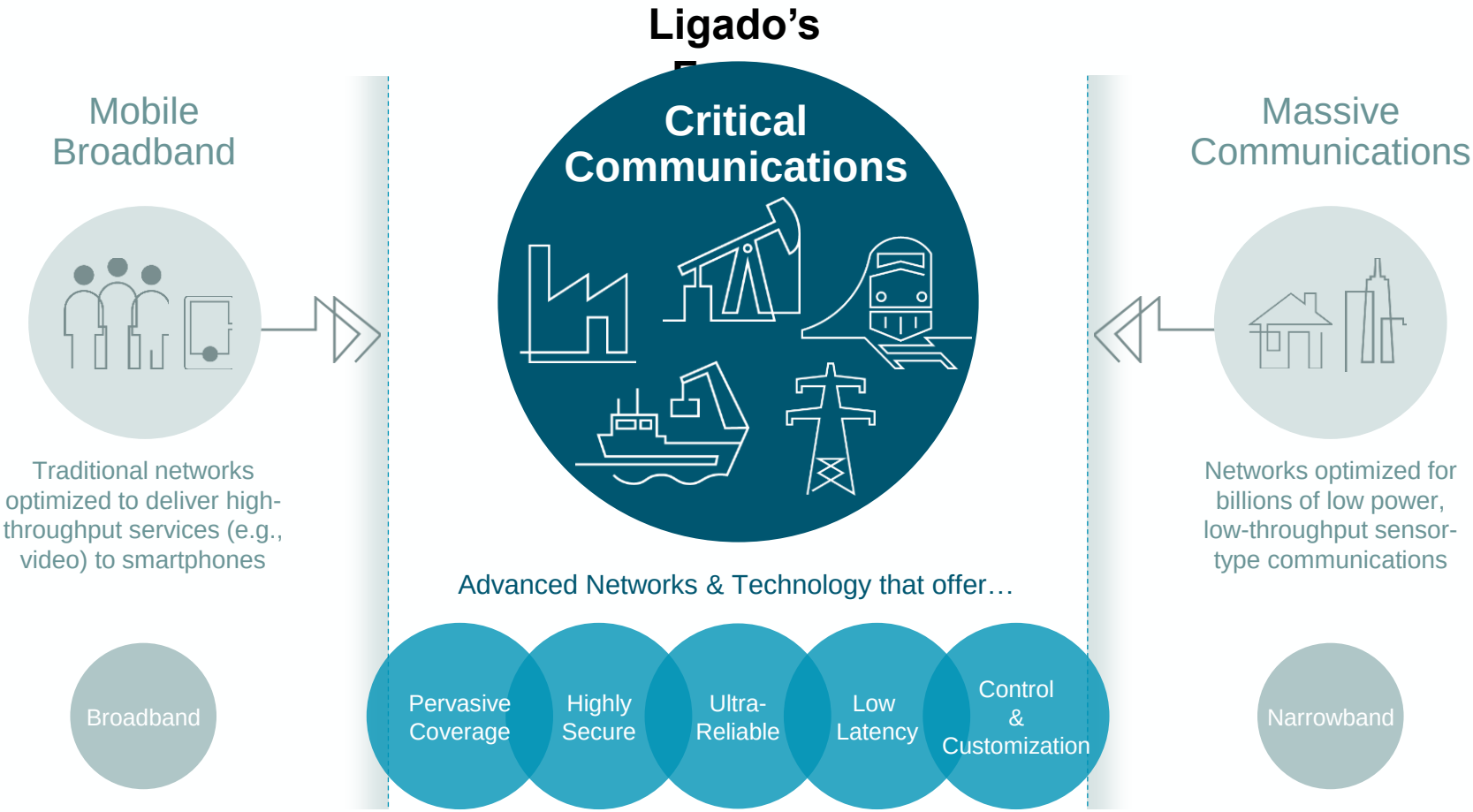
Our plan is based on mid-band ATC spectrum that can be flexibly deployed to support an array of advanced network requirements

The Industrial IoT (IIoT) Market



Serving the Industrial IoT market will require advanced connectivity to meet robust performance requirements that permit tight integration with applications, platforms, and big data solutions in critical business operations

Ligado's Network Can Meet the Unique Requirements of the IIoT Market



Our combined approach to technology and network deployment can accelerate advanced capabilities for emerging 5G and critical IoT use cases

IIoT Networks: Commercial Transportation Case Study

Extended Coverage & Value-Added Services

Industrial infrastructure with extended coverage needs

Class-1 Rail Freight Operator

- Factory to port delivery
- Over 21,000 miles of track
- 30% of rail miles lack terrestrial wireless coverage (dark territories)(1)

CUSTOMER CHALLENGE:
Transportation providers face continued pressure to deliver and maintain operational efficiency while improving safety system-wide (*including dark territories*)

USE CASES:

- Positive Train Control
- Track inspection
- Situational awareness and worker safety
- Equipment and cargo tracking
- Wayside station monitoring
- Voice, PTT, and LMR communications

OUR SOLUTION:

Pervasive support from point-to-point with connectivity throughout

EXPERTISE:

Planning: Defining rail solutions and build-to-suit terrestrial instances

COVERAGE:

- Rail yard terrestrial solutions with system-wide satellite support
- Private or shared terrestrial networks on licensed spectrum in key terminals and rail yards
- Pervasive coverage via Satellite
- Roaming with public or private networks

TECHNOLOGY:

Network design, architecture & deployment: RAN & Core

OPERATION:

Fully managed network: Monitoring, Maintenance, SLA compliance

VALUE-ADDED SERVICES:

High Precision Location Services (10cm accuracy) supporting safety, PTC and asset tracking

Commercial BVLOS UAS for linear rail inspection

Sources: PTC; TPSC; Association of American Railroads
(1) USDOT Federal Rail Administration, Dark Territory Working Group

IIoT Networks: Power Generation and Distribution Case Study

Private Single Tenant Network

Power Generation Plant and Power Grid

Natural Gas Power Plant

- 100+ acre facility
- 1,100 MW plant serving 850,000 homes and businesses
- Integrated water intake, gas pipelines and high tension power lines

CUSTOMER CHALLENGE:

Power plant operators must meet consumption needs with greater flexibility and efficiency while reducing emissions. They must manage a complete set of systems and operations while maintaining worker safety and protecting the smart grid

USE CASES:

- Equipment management and monitoring
- Machine automation
- Workforce management
- Materials/Asset Management
- Data prioritization and teleprotection
- Security (Access Control & CCTV)
- Transmission and gas line inspection
- Unified communications (voice, PTT, LMR integration)

OUR SOLUTION:

Highly reliable support for complex systems and a secure, dedicated heterogeneous network

EXPERTISE:

Planning: Network & solution technologies

COVERAGE:

- Full plant and campus coverage with extended satellite support

Dedicated Licensed spectrum: Highly secure, ultra-reliable with comprehensive redundancy

Interoperability: Heterogeneous deployment connecting disparate equipment and protocols

TECHNOLOGY:

Network design, architecture & deployment: RAN & Core (full, partial, customer provided)

OPERATION:

Fully managed network: Monitoring, Maintenance, SLA compliance

VALUE-ADDED SERVICES:

Commercial BVLOS UAS for linear transmission line and gas pipeline inspection

High Precision Location for pinpoint accuracy (10cm) to support inspection results

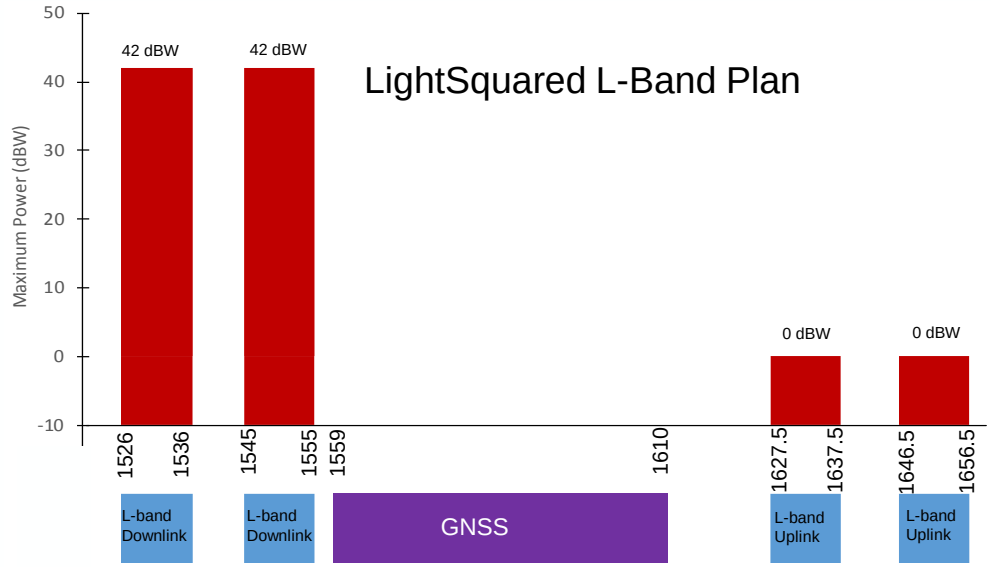
Sources: Gartner; Heavy Reading, General Electric, McKinsey

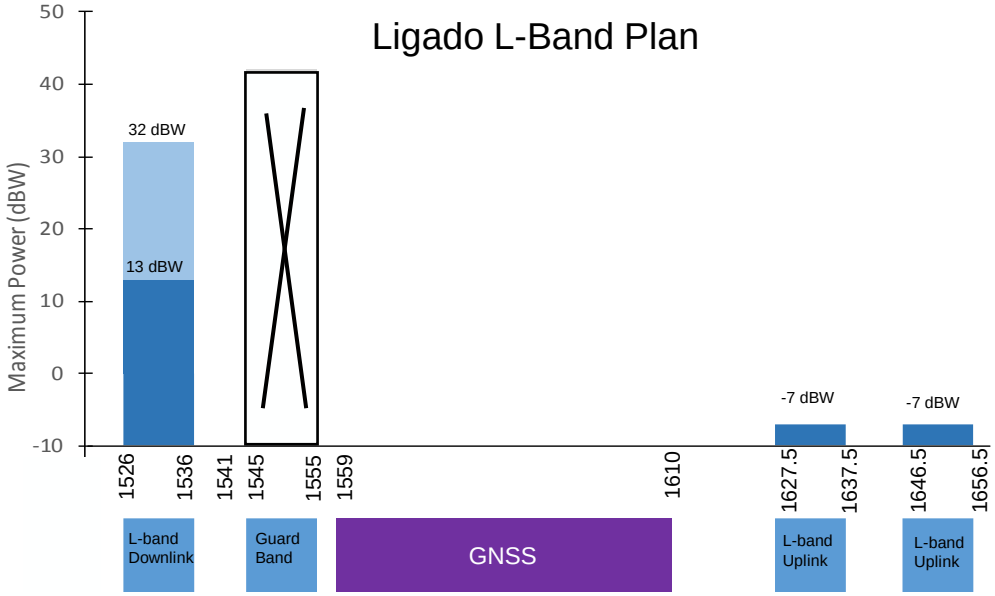
Our Spectrum Plan Offers Significant Public Benefits

Deploying this spectrum is a WIN for U.S. consumers and our nation's economy. This plan will:

- Advance American innovation in 5G and the Industrial Internet of Things by unlocking 30 MHz of underutilized spectrum and continuing U.S. leadership in spectrum policy
  - America has led the world economy in spectrum technology and innovation, creating tremendous value and jobs
  - The spectrum frontier is 5G and Industrial IoT, and America needs spectrum to maintain that leadership
  - A satellite-terrestrial network is an essential piece of ensuring the U.S. will lead the world in the IIoT future
- Generate billions of dollars in new, private investment through the build-out and deployment of a new network
  - With the IIoT in place, the U.S. could see its cumulative GDP increase by $7.1 trillion by 2030 – a 2.3 percent increase from trend projections
- Create at least 8,000 new jobs and hundreds of thousands more indirect jobs to operationalize the national plan
- Every month this spectrum goes unused, American consumers lose up to ~$2 billion in consumer value
  - This means the U.S. economy forgoes up to $24 billion per year in potential economic activity

Our Plan is NOT the LightSquared Plan; It Was Designed to Protect GNSS





Distances Between Spectrum Bands Are Not To Scale

Our Downlink Proposal Is Fundamentally Changed from LightSquared's Proposal

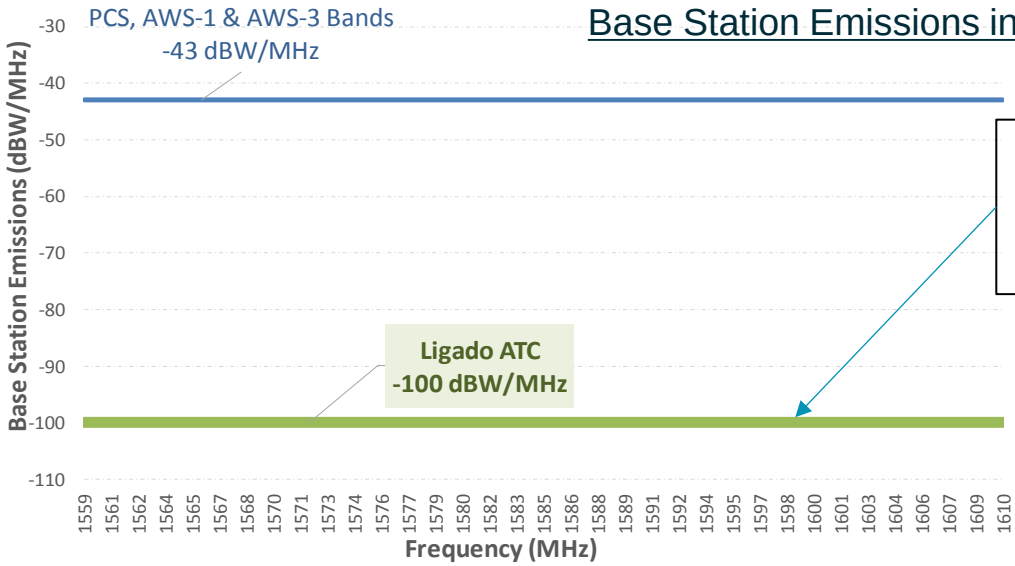
- Surrenders 10 MHz of Ligado spectrum to GNSS: no terrestrial use of the downlink channel (1545–1555 MHz) closest to the GPS band
  - Allows continued coexistence of GNSS operations in an additional 10 MHz of spectrum
  - Effectively creates a 23 MHz guard band for GNSS
- Lowers Power Levels:
  - Power levels for the lower downlink channel will be in the range of 9-13 dBW to protect certified aviation GPS devices
  - 1/800th of LightSquared's power
- Reduces Out of Channel Emissions: old emissions were -39.4 dBW/MHz to 32 dBW/MHz within 1541-1559 MHz; new limit will be -85 dBW/MHz in that band segment
- Lowest OOBE of any FCC Licensee in GNSS band: -100 dBW/MHz OOBE inside the GNSS band from our base stations

Our Uplink Proposal Is Fundamentally Changed from LightSquared's Proposal

- Lowers In-Band Power Levels:
  - Dramatically lowers power levels for the uplink channels (1627.5-1637.5 MHz; 1646.5-1656.5 MHz)
    - Maximum power reduced from 0 dBW to -7 dBW EIRP
  - 1627.5-1632.5 MHz uplink channel has an additional power limitation that ramps from -31 dBW to -7 dBW EIRP; this segment will revert to -7 dBW EIRP across the band after 2020
- Reductions in Out-of-Band Emissions Solve Stated Concerns:
  - OOBE limit of -105 dBW/MHz was requested
  - Ligado met this limit
  - Doing so was technically challenging and costly to implement

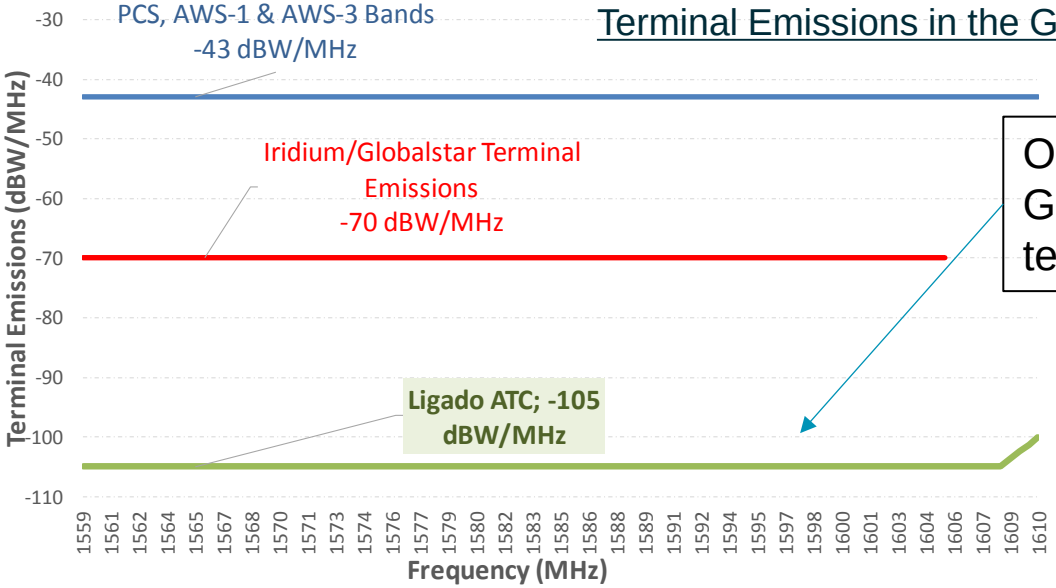
Our Out-of-Band Emissions are Far Below Those of Neighboring Spectrum Users

Base Station Emissions in the GNSS Band



Our base station emissions into the GNSS band are significantly lower than base station emissions from other band users

Terminal Emissions in the GNSS Band



Our user terminal emissions into the GNSS band are significantly lower than terminal emissions from other band users

Our Plan Complies with FAA Safety Standards

- The FCC will impose a condition on use of the 1526-1536 MHz band:

  Whatever reduction in power is necessary to achieve compatibility of each terrestrial transmitter operating in the lower downlink with current and future technical standards for certified aviation devices.

- Compliance with FAA standards: The power level in 1526-1536 MHz will be set to protect certified aviation GPS devices and to comply with all applicable FAA TSOs and MOPs
- Nationwide power limitations: Consultation with the FAA on compliance with their standards and masks has led to a determination that the safe power level in the 1526-1536 MHz channel ranges from 9 to 13 dBW EIRP nationwide – not just near airports
- Tower-specific protections: Ligado will be required to determine the safe power for each and every tower specifically to comply with FAA standards
- Considers aggregate effects: Power levels were reduced to account for the aggregate effect of a network of towers
- Uplinks: RTCA evaluated Ligado's uplinks and did not raise any issues with the proposed operations of those channels

Our Ongoing Commitments to Protect and Coordinate with GPS

Commitments to the GPS Manufacturers:

- The GPS manufacturers and the FCC will receive test measurements and other data demonstrating compliance with OOBE limits
- The GPS manufacturers will receive:
  - 6 months advance notice of activation of base stations transmitting in the 1526-1536 MHz band;
  - a coverage map showing, by county, the existing and anticipated coverage of our terrestrial network; and
  - sample handsets for testing purposes

Commitments to the FCC and the FAA:

- The FCC and the FAA will receive base station parameters at least 30 days before transmissions commence in the 1526-1536 MHz band at each location
- For the first two years, the FCC will receive an independent audit of the calculation of the transmit EIRP limit for each proposed base station antenna sector in the 1526-1536 MHz band
- Ligado will maintain Network Operations Center procedures for continuous monitoring of the transmit power setting for each base station antenna in the 1526-1536 MHz band

The GPS Companies Recognize that the Ligado Plan Protects GPS

GARMIN	"Garmin spokeswoman Carly Hysell said [Ligado's] agreement to cut out-of-band emissions and power levels in the spectrum band closest to the GPS signal protects the interests of GPS users, and the company doesn't anticipate any performance-degradation issues for those using GPS technologies." Wall Street Journal (Dec. 17, 2015)
JOHN DEERE	"Deere herein confirms that it does not oppose grant of the Modification Application, as proposed, that would incorporate the full set of technical parameters and licensing conditions…." Deere Reply Comments (June 21, 2016)
Trimble	"Trimble continues to support the adoption of the Agreed License Conditions …. Taken as a whole, the Agreed License Conditions represent a compromise which balances the competing public policy interests raised by Ligado's proposed use of its licensed spectrum." Trimble Reply Comments (June 21, 2016)
NovAtel	"We are pleased to report that after considerable discussion and analysis [NovAtel and Ligado] have reached a co-existence agreement which calls for future coordination…. On the basis of this understanding, NovAtel supports Commission granting of the modification applications." Joint NovAtel/Ligado Ex Parte Filing (June 27, 2016)
TOPCON	"Over the past many months, we've worked closely with Ligado to conduct a thorough analysis. We've agreed that the parties will cooperate in the future if their proposal impacts TopCon's operations in any way. Our agreement is a positive step forward for both companies, and we look forward to coordinating with Ligado over the coming years as it deploys a ground network." Chief Strategy Officer Ivan Di Federico, Press Release (Dec. 6, 2016)

This Spectrum Has Been Definitively Tested

- TWG (2011)
  - Tested LightSquared proposal
  - Over 130 receivers tested over 3 months
  - HPL, GLN and Timing testing did not test for impact on position or timing accuracy but only C/N_0
- National Space-Based PNT Systems Engineering Forum (NPEF) (2012)
  - Tested only Lower Downlink only at 32 dBW
  - Tested 101 GLN devices over two non-consecutive weeks
  - Did not test for impact on position accuracy but only for 1 dB C/N_0
- Roberson & Associates (2016)
  - Tested Ligado's new proposal
  - Tested 27 devices across five categories over nine months
  - Tested for the impact of Ligado's proposed network on both C/N_0 and actual position accuracy
- NASCTN (2017)
  - Tested Ligado's new proposal over thousands of lab hours
  - Conducted by a DOD, NIST and NTIA sponsored lab
  - Collected and analyzed data regarding the position and timing accuracy as well as C/N_0 for 19 GPS devices in three categories (GLN, HPL and Timing)
- ABC Compatibility (OST-R) (2017)
  - Focused on collecting data about a 1 dB change in C/N_0
  - Other data (like position accuracy) collected but excluded from report
  - Tested 80 devices across six categories in one week in the lab

Next Steps – We Can Have a Robust GPS and Spectrum for 5G and IIoT

- Testing is complete and data has been provided to the regulators
  - Multiple public and private entities have performed exhaustive testing
  - ABC Study report is complete
- Discussions with FAA are complete and a proposal to protect certified aviation GPS receivers has been developed
- Thorough and transparent public process has yielded comprehensive recommendations and inputs
- Value of putting this spectrum to good use is clear
- Ligado is committed to protecting GPS: How can we work together to achieve our goals and resolve any remaining issues?