ANALYSIS OF POTENTIAL INTERFERENCE ISSUES RELATED TO FCC ORDER 20-48

Committee to Review FCC Order 20-48 Authorizing Operation of a Terrestrial Radio Network Near the GPS Frequency Bands

Computer Science and Telecommunications Board
Air Force Studies Board

NATIONAL ACADEMIES
Sciences
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Updated Nov 8, 2022

A Cautionary Note

This study provides a National Academies review and analysis of certain technical considerations regarding a spectrum allocation decision that was under debate and process for nearly twenty years. Significant and complex economic, legal and regulatory issues have been and are at play. It is not unreasonable to expect that various stakeholders will extract portions of this study to provide support for previously argued positions and to undercut certain opposing positions. It is important that this study be taken as a whole and that conclusions be drawn from the full report and not from a selective reading of only those points which might be used to support a given position.

Note added November 8, 2022:

As detailed in the committee's report and in the comments made verbally during the public briefing at which this slide deck was used, the committee makes an explicit distinction between the FCC-defined regulatory term 'Harmful Interference' and the committee's use of the term 'harmful interference' in describing its task and in its conclusions.

To avoid any confusion that might come from only looking at the slide deck and not having access to the verbal delivery, these slides have been annotated to clearly indicate which term is being used in each circumstance.

Study Origin

- Section 1663 of the FY2021 NDAA
- “[A]n independent technical review of the order and authorization adopted by the Federal Communications Commission on April 19, 2020 (FCC 20-48),” which authorized Ligado Networks LLC to operate a low-power terrestrial radio network adjacent to the Global Positioning System (GPS) frequency band.

Study Tasks

1. Assess which of two commonly used approaches to evaluating interference that might cause harm to GPS services would most effectively mitigate the risks of harmful interference to GPS services and DoD operations and activities.
2. Assess the likelihood that the authorized Ligado service will create harmful interference to GPS, mobile satellite services, and other commercial or DoD services and operations.
3. Assess the feasibility, practicality, and effectiveness of the measures in the FCC order to mitigate harmful interference effects on DoD devices, operations, and activities.

Study Output

- Report(s) on these three issues as well as other related issues the study committee determines relevant.
- Bulk of the technical analysis is expected to be performed based on public reports and open science and engineering literature and practice and result in an entirely unclassified report.
- Classified annex as needed.

Study Committee

Michael McQuade	Carnegie Mellon University (Chair)
Jennifer Alvarez	Aurora Insight Inc.
Kristine Larson, NAS	University of Colorado Boulder
John Manferdelli	VMware
Preston Marshall	Google
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Richard Reaser, Jr.	Independent Consultant
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Nambi Seshadri, NAE	University of California San Diego
Scott Stadler	MIT Lincoln Laboratory
Stephen Stafford	Johns Hopkins University Applied Physics Laboratory

Presentations to the Committee

DOD CIO

Ligado Networks

National Telecommunications and Information Administration, Dept. of Commerce

Roberson and Associates

Volpe Center, Department of Transportation

National Advanced Spectrum and Communications Test Network

Brad Parkinson, Stanford University

Garmin International

Trimble, Inc.

Iridium

Resilient Navigation and Timing Foundation

AMS Committee on Radio Frequency Allocation

National Society of Professional Surveyors

Air Line Pilots Association

Aviation Spectrum Resources, Inc.

Collins Aerospace

Helicopter Association International

National Agricultural Aviation Association

Office of Engineering and Technology, Federal Communications Commission

Written Comments

Aviation Spectrum Resources, Inc.

Brad Parkinson, Stanford University

CNH Industrial

Volpe Center, Department of Transportation

Federal Communications Commission

Garmin International

GPS Innovation Alliance

Iridium Communications, Inc.

Ligado Networks

Narayan Strategies

National Advanced Spectrum and Communications Test Network

Michael Marcus, Northeastern University

National Society of Professional Surveyors

Office of Spectrum Management, National Telecommunications and Information Administration, U.S. Department of Commerce

Office of the Chief Information Officer, Department of Defense

Resilient Navigation and Timing Foundation

Roberson and Associates

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UNAVCO

WBK Law on Behalf of Garmin Ltd.

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Approaches to Predicting Interference

- Signal-to-Noise interference protection criterion

  This approach tests GPS receivers at various interference levels that could be attributed to Ligado transmissions and measures the resulting degradation in reported C/N_0. Many key receiver functions can be mapped to C/N_0 thresholds. This metric commonly proposes a 1 dB loss (or less) as precluding harm to any of these functions.

- Measurement of the GPS position error

  This approach tests GPS receivers under two scenarios, the first without the Ligado signals present and the second with them. Truth surveyed position is known in both cases. Any increase in the average position error and related position error statistics for the second scenario relative to the first are deemed measures of interference by the Ligado signals.

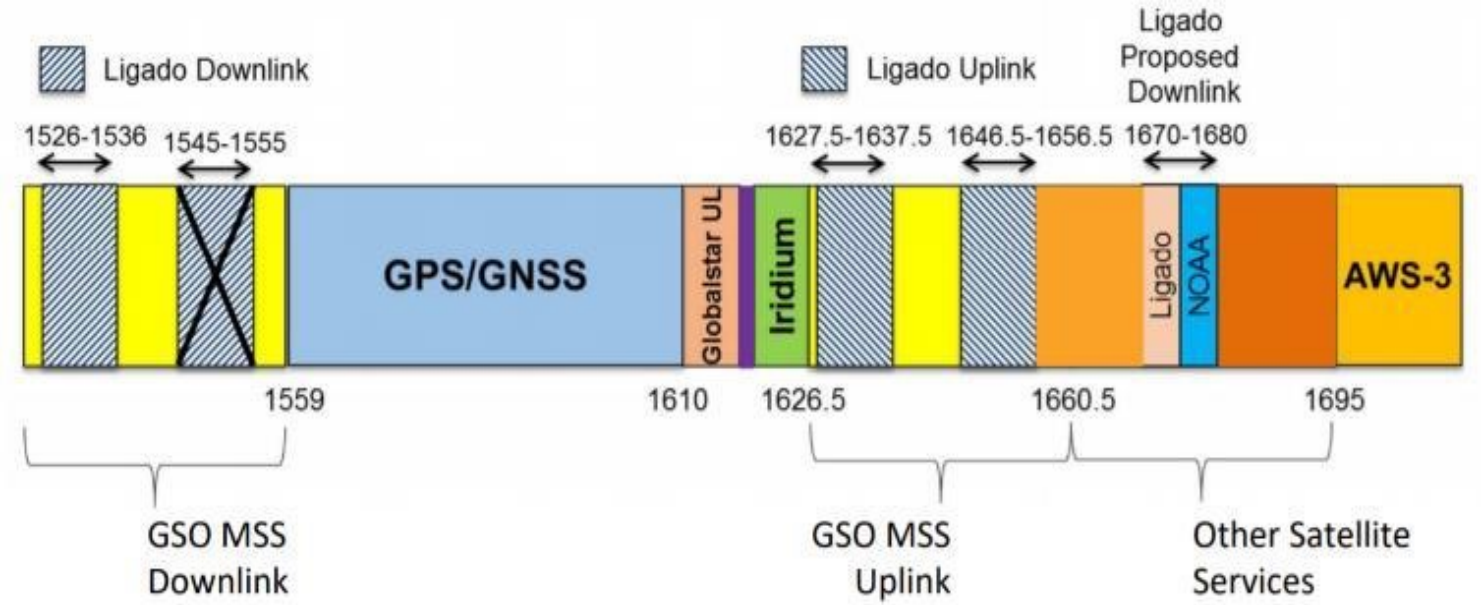
FCC Definition of ‘Harmful Interference’

- “[i]nterference which endangers the functioning of a radionavigation service or of other safety services or seriously degrades, obstructs, or repeatedly interrupts a radiocommunication service operating in accordance with [the ITU] Radio Regulations.”
- This implies two conditions:
  - The emission, radiation or induction must (a) endanger the functioning of the radio navigation or safety service or (b) seriously degrade, obstruct or repeatedly interrupt any other radiocommunication service and
  - The service claiming Harmful Interference must be operating in accordance with regulations (as in United States Code (USC), Title 47 Telecommunications, Chapter 1, Subchapter A, Part 15, Section 15.3)).

This Report's Use of 'interference'

- The general term 'interference' describes what happens in a receiver when some other signal affects the intended received signal in a way that reduces the effective received signal-to-noise ratio.
- Report uses the uncapitalized term 'harmful interference' in a more general sense to imply degraded receiver operations without assessing whether such degradation is actually causing a degradation of function or whether the receiver is operating in accordance with FCC rules.

The Frequency Bands of Interest



- RF transmitters do not operate with arbitrarily sharp cutoff frequencies and thus, depending on how rapidly (as a function of frequency) their emitted power spectrum falls off, may emit power beyond their authorized spectral bands.
- RF receivers do not ‘listen’ only within a band defined with arbitrarily sharp boundaries and thus may receive power from frequencies outside their designed band.

Conclusion Regarding Task One

Approaches to evaluating 'harmful interference' concerns

Conclusion 1: Neither of the prevailing approaches to evaluating harmful interference concerns effectively mitigates the risk of harmful interference.

- Neither approach provides analytical, repeatable, or straightforward criteria to evaluate new entrants. Both approaches depend on sampling a subset of the many and varied GPS receivers in the marketplace. Both approaches have a role to play in evaluating harmful interference to existing receivers.
- The signal-to-noise approach is inflexible as a determinant or threshold, providing what in some circumstances may be an overly conservative emission limit because no single value for signal-to-noise degradation determines when the various types of possible harm to receiver performance will become significant.
- The position measurement approach is too narrow in its applicability to the many and varied uses of the GPS system.

Additional Commentary on Task One

Approaches to evaluating ‘harmful interference’ concerns

Conclusion 1: Neither of the prevailing approaches to evaluating harmful interference concerns effectively mitigates the risk of harmful interference.

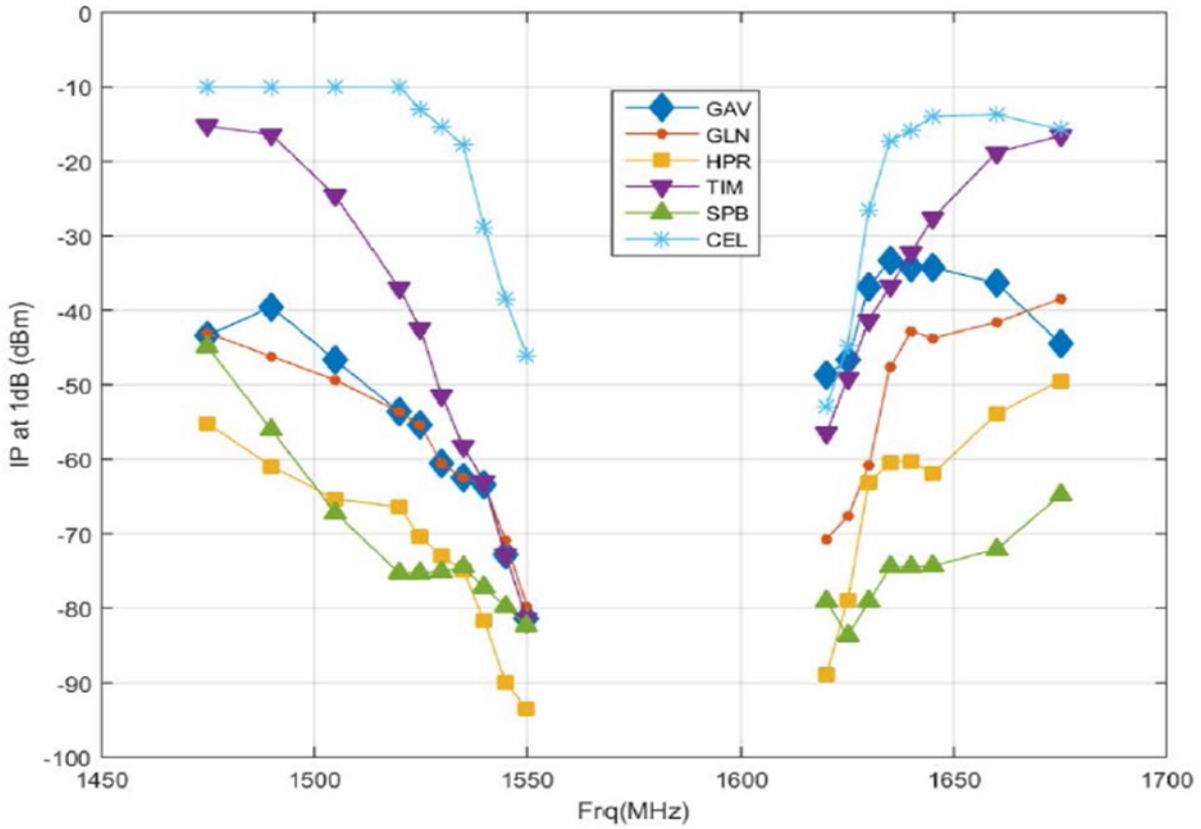
- While commonly argued in the FCC proceedings and in input to the committee the committee does not believe that a 1 dB Interference Protection Criteria is appropriate as a general standard. Often receivers can tolerate 6-15 times this level of interfering power before the objective performance of a receiver is degraded. The 1 dB criterion is prophylactic, but conservative.
- With more well-defined receiver standards, and frequency masks for potentially interfering signals, a straightforward SNR standard could be highly predictive of harmful interference and hence inform emitter characteristics that are calculated to prevent such interference.
- This SNR standard will likely be higher than 1dB signal degradation and the standard may change over time as technology improves.

Conclusions Regarding Task Two

‘harmful interference’ to GPS and Mobile Satellite Services

- Susceptibility spans up to 60 dB.
- GPS receivers encountering a different environment from when they were designed.

GPS Receiver Sensitivity to Interference



Source: United States Department of Transportation Global Positioning System (GPS) Adjacent Band Compatibility Assessment.

Conclusions Regarding Task Two

‘harmful interference’ to GPS and Mobile Satellite Services

Conclusion 2:

- **Most commercially produced general navigation, timing, cellular or certified aviation GPS receivers will not experience significant harmful interference from Ligado emissions as authorized by the FCC.**
- **High precision receivers are the most vulnerable receiver class, with the largest proportion of units tested that will experience significant harmful interference from Ligado operations as authorized by the FCC.**

Conclusion 3: It is within the state-of-the-practice of current technology to build a receiver that is robust to Ligado signals for any GPS application, and all GPS receiver manufacturers could field new designs that could coexist with the authorized Ligado signals and achieve good performance even if their existing designs cannot.

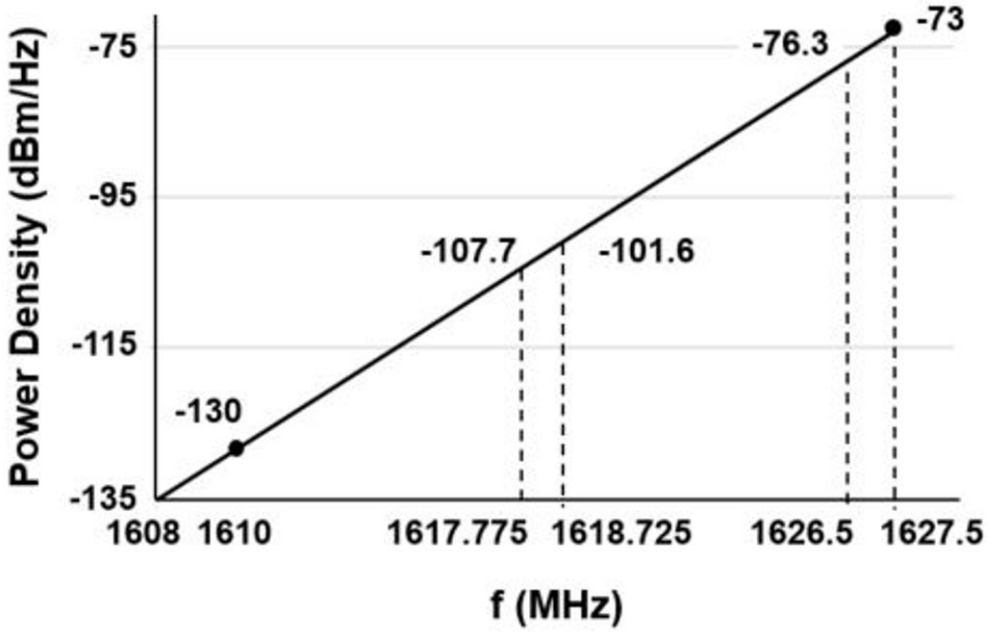
Conclusion 4: Iridium terminals will experience harmful interference on their downlink caused by Ligado user terminals operating in the UL1 band while those Iridium terminals are within a significant range of a Ligado emitter — up to 732 meters.

Conclusions Regarding Task Two

‘harmful interference’ to GPS and Mobile Satellite Services

Interference with Iridium downlink

- Iridium has stated their noise floor is -170 dBm/Hz, which is consistent with a noise-limited system.
- At the high side of the Iridium band, channels will see an interference level of -76 dBm/Hz from a single user.
  - Requires 94 dB of attenuation to be reduced to the noise floor.
  - This will occur at a distance of 732 m (free space path loss) or 51 m (non-line-of-sight).



Out-of-band emissions spectral mask

Conclusions Regarding Task Two

For DOD Systems

In a briefing to the committee, DOD asserted based on nonpublic data that:

‘DoD and interagency partners conducted testing to determine the impacts to GPS (captures FCC Order 20-48’s authorized deployment). The tests demonstrated that the proposed signal introduces harmful interference to critical national security mission capabilities.’

‘The terrestrial network authorized by FCC Order 20-48 will create unacceptable harmful interference for DoD missions. The mitigation techniques and other regulatory provisions in FCC Order 20-48 are insufficient to protect national security missions.’

The committee discusses these issues in a classified annex to this report.

Conclusions Regarding Task Three

Feasibility, practicality, and effectiveness of mitigation measures

Conclusion 5:

- **Although the mitigation procedures proposed in the order may be effective, in many cases such mitigation may be impractical without the extensive dialog among the affected parties presumed in the Order.**
- **In some cases, mitigation may not be practical at operationally relevant timescales or at reasonable cost.**

Additional Considerations

Better means of assessing 'harmful interference'

- The committee believes that a sensible criterion for harmful interference could be developed that accounts for position error effects, acquisition and tracking challenges, and continuity of service.
- Such a criterion might be based on a maximum limit for degradation of C/N_0 in the designated frequency range *for a reasonably well-designed receiver*.
- This analysis would then dictate an adjacent-band power mask that the FCC would guarantee going forward *for a given period of time*.

Additional Considerations

Managing future controversies - Receiver standards

Many of the current spectrum controversies arise from receiver designs that were predicated on different environments than would emerge after FCC rulemakings.

Assumptions about receiver performance would be highly beneficial in focusing the discussion, without impacting the marketplace or equipment cost and performance of future receiver designs.

Additional Considerations

Managing future controversies - Spectrum succession

It is essential that all spectrum decisions recognize that, at some point in time, they will be adjusted or changed completely.

A cohesive policy about rights of current users, the impact of equipment lifetime, business models, and all other considerations is essential, and should be established outside the pressures of any one spectrum decision.

Additional Considerations

Managing future controversies - Administrative processes

FCC regulatory decisions have both a policy component, and a technical fact finding one.

The process appeared to the committee to be resolving questions of fact, e.g., ‘Will Ligado interfere with GPS,’ through administrative and/or procedural processes rather than a technical one. While it is keenly aware of the constraints inherent in the Administrative Procedures Act, it is the committee's opinion that selecting from specific filings may not be an appropriate technique to answer questions of fact. This proceeding might have had a more accepted outcome if the FCC was in a position to provide its own positions on factual questions.

Additional Considerations

Managing future controversies - Increased collaboration

A useful step to meeting the U.S. Government objectives (as compared to the individual objectives of the FCC and NTIA) would be to jointly study and test the impact of proposed regimes. Criteria would be agreed in advance, experiments agreed by all parties to be the relevant and inclusive cases.

Thank You

Report is available for download from National Academies Press at www.nap.edu