cable
National Cable & Telecommunications Association
25 Massachusetts Avenue, NW, Suite 100
Washington, DC 20001-1431
(202) 222-2300

Rick Chessen
Senior Vice President
Law and Regulatory Policy

(202) 222-2445
(202) 222-2448 Fax
rchessen@ncta.com

January 22, 2014

BY ELECTRONIC FILING

Julius Knapp
Chief
Office of Engineering and Technology
Federal Communications Commission
Office of the Secretary
445 12th Street, SW
Washington, DC 20554

Re: Revision of Part 15 of the Commission's Rules to Permit Unlicensed National Information Infrastructure (U-NII) Devices in the 5 GHz Band, ET Docket No. 13-49

Dear Mr. Knapp:

Access to additional spectrum for Wi-Fi is critical to economic growth and innovation. But as Americans rapidly increase their use of and dependence on Wi-Fi technologies, existing unlicensed spectrum resources are becoming dangerously congested. Consumers already experience the impact of the unlicensed spectrum shortage in homes, offices, and public areas across the country. If we do not designate additional unlicensed frequencies suitable for Wi-Fi soon, this problem will become acute. Furthermore, the new IEEE 802.11ac "Gigabit" Wi-Fi standard offers Americans unprecedented wireless broadband capacity. But the standard can only deliver on this promise if the Commission provides access to the 160-MHz channels on which full Gigabit Wi-Fi depends. Without additional Wi-Fi spectrum, American consumers, schools, and hospitals will not benefit from Gigabit Wi-Fi, while it becomes available elsewhere around the world.

Fortunately, the Commission recognizes these risks and opportunities, and has initiated a proceeding to designate additional frequencies for Wi-Fi use in the 5 GHz band. The 5 GHz band is the country's single best, and perhaps only, opportunity to rapidly bring additional Wi-Fi channels into use and to thereby address consumer demand and empower Gigabit Wi-Fi. And the U-NII-1 portion of this band – *100 MHz of spectrum perfectly suited to Wi-Fi* – is the country's best chance for additional 5 GHz access in the near term.

Adding 100 MHz of usable Wi-Fi spectrum at U-NII-1 by allowing for increased power and outdoor operation, while maintaining the requirement that unlicensed devices must not cause harmful interference to incumbents, would have a tremendous positive impact on the country. It would support expansion of consumer broadband, advance the Commission's connected schools program, empower additional mobile health systems, and allow technological innovation harnessing the new Gigabit Wi-Fi standard. And because U-NII-1 is already designated for unlicensed use, service providers could bring it online very quickly through modest changes to existing equipment. Much of the existing consumer equipment ecosystem already contains U-NII-1-enabled Wi-Fi chips.[1] This means that consumers would see the benefits of updated rules almost immediately. To be sure, U-NII-1 is ideal for rapidly adding 100 MHz to the President's commitment of 500 MHz of new broadband spectrum.

Only one company opposed the FCC's U-NII-1 proposal – Globalstar. The FCC proposed to permit mobile satellite services ("MSS") companies like Globalstar to use this band for their feeder links in the 1990s.[2] Around the same time, the Commission created its initial rules for unlicensed access to U-NII-1 based on 1990s predictions about demand for MSS operations. Expecting intensive use of the U-NII-1 band by multiple MSS operators serving millions of customers, the FCC set very low power levels for unlicensed devices and adopted an indoor-use restriction as extremely conservative protections for MSS.[3] But today Globalstar is the only MSS operator using the band. Every other company has gone bankrupt or uses different frequencies. And rather than the millions of customers that the FCC predicted many years ago,[4] Globalstar uses the vast 100 MHz U-NII-1 band – over 1.5x more spectrum than the entire core

---

1 *See, e.g.*, TCB Grant of Equipment Authorization, Apple Inc., FCC ID BCGA1458 (granted Oct. 23, 2012) (Apple iPad 4); TCB Grant of Equipment Authorization, Kilpatrick LLC, FCC ID S2F-8560 (granted Sept. 24, 2013) (Amazon Kindle Fire HDX 7); TCB Grant of Equipment Authorization, HTC Corporation, FCC ID NM8PM23300 (granted Oct. 5, 2012) (HTC 8X); TCB Grant of Equipment Authorization, LG Electronics MobileComm USA, Inc., FCC ID ZNFD820 (granted Oct. 31, 2013) (LG Nexus 5); TCB Grant of Equipment Authorization, Motorola Mobility LLC, FCC ID IHDT56PE2 (granted July 3, 2013) (Motorola Droid Ultra); TCB Grant of Equipment Authorization, Nokia Corporation, FCC ID PYARM-825 (granted Oct. 18, 2012) (Nokia Lumia 820); TCB Grant of Equipment Authorization, Samsung Electronics Co Ltd, FCC ID A3LGTP6800 (granted Nov. 21, 2011) (Samsung Galaxy Tab 7.7).

2 *Amendment of Parts 2, 25, and 97 of the Commission's Rules with Regard to the Mobile-Satellite Service Above 1 GHz*, ET Docket No. 98-142, Notice of Proposed Rulemaking, 13 FCC Rcd 17107 ¶¶ 1, 5 (1998) (proposing to authorize Big LEO systems to utilize the 5091-5250 MHz band for feeder uplinks); *see also Amendment of Parts 2, 25, and 97 of the Commission's Rules with Regard to the Mobile-Satellite Service Above 1 GHz*, ET Docket No. 98-142, Report and Order, 17 FCC Rcd 2658, 2667 ¶ 16 (2002) (authorizing Big LEO systems to utilize the 5091-5250 MHz band for feeder uplinks).

3 *See Amendment of the Commission's Rules to Provide for Operation of Unlicensed NII Devices in the 5 GHz Frequency Range*, ET Docket No. 96-102, Report and Order, 12 FCC Rcd 1576, 1595-96 ¶¶ 43-44 (1997) (establishing rules for U-NII devices operating in U-NII-1).

4 *Amendment of the Commission's Rules to Establish Rules and Policies Pertaining to a Mobile Satellite Service in the 1610-1626.5/2483.5-2500 MHz Frequency Bands*, CC Docket No. 92-166, Report and Order, 9 FCC Rcd 5936 ¶¶ 4, 10, 44 (1994) (noting one MSS license applicant's estimate that by 2001 the demand for MSS user transceivers would be 1.3 million in the United States and 4.7 million worldwide).

2.4 GHz Wi-Fi band – for four U.S. feeder link stations serving fewer than 85,000 duplex customers worldwide, only a subset of which are U.S.-based.[5]

Despite the fact that these changed circumstances make the assumptions on which the FCC's rules depend untenable,[6] and despite the nationwide demand for sharing and improved spectrum efficiency, Globalstar insists that sharing U-NII-1 with outdoor Wi-Fi operations is impossible and will cause harmful interference to its system. The record overwhelmingly proves, however, that Wi-Fi and Globalstar can share the band without harmful interference.[7] In fact, experts from CableLabs and the University of Colorado submitted a detailed study in July 2013 demonstrating that outdoor Wi-Fi operations at the 1 Watt maximum power level permitted in the U-NII-3 band would not cause harmful interference to Globalstar's feeder link operations, and that Globalstar's technical argument was unreliable because it was based on a set of invalid assumptions and inputs. By correcting these assumptions, the study showed that Globalstar customers would not experience service degradation even when analyzing peak expected interference.[8]

To be sure, NCTA is committed to the fundamental principle that unlicensed devices must not cause harmful interference to Globalstar.

Nonetheless, in a final attempt to delay an FCC decision, Globalstar filed a second technical paper on November 29, 2013 (the "Roberson Paper"), largely repeating the arguments contained in its first paper. To establish once and for all that there is nothing in either of the Globalstar filings that should delay Commission action – and that outdoor Wi-Fi use of the band will not cause harmful interference to Globalstar's feeder links – CableLabs and the experts from the University of Colorado have conducted a second, more comprehensive analysis of U-NII-1 sharing, which we have attached to this letter ("CableLabs/CU Further Analysis").[9]

---

5 *See* Globalstar, Inc., 2012 Annual Report (Form 10-K) at 30, 33 (Mar. 15, 2013), *available at* http://www.sec.gov/Archives/edgar/data/1366868/000114420413015324/v335533_10k.htm.

6 "[T]he FCC is *obligated* to reevaluate its policies when circumstances affecting its rulemaking proceedings change." *California v. Fed. Commc'ns Comm'n*, 905 F.2d 1217, 1230 (9th Cir. 1990) (emphasis added) (citing *Geller v. Fed. Commc'ns Comm'n*, 610 F.2d 973, 980 n.59 (D.C. Cir. 1979)).

7 *See* Reply Comments of the National Cable & Telecommunications Association at 12 & n.46 (filed July 24, 2013) ("NCTA Reply Comments") (collecting citations demonstrating record support for permitting outdoor, 1 Watt operations in U-NII-1). Unless otherwise noted, all comment citations herein are to ET Docket No. 13-49.

8 Rob Alderfer, Dirk Grunwald, and Kenneth Baker, *Toward Expanded Wi-Fi Access in the 5 GHz Band*, CableLabs, at 17-35 (July 2013) ("July 2013 Study") (attached to NCTA Reply Comments).

9 Dirk Grunwald, Rob Alderfer, and Kenneth Baker, *5 GHz UNII-1: Wi-Fi and Globalstar Sharing Analysis*, CableLabs (January 2014) (attached) ("2014 CableLabs/CU Further Analysis").

With this new study, the Commission has all the information it needs to complete its U-NII-1 interference analysis. Specifically, the record now makes clear that:

- The FCC should use a whole-system analysis rather than a single-link analysis. Both Wi-Fi proponents' studies and Globalstar's new study agree with this approach. Only a whole-system analysis answers the key question – the amount of interference a satellite user experiences – rather than measuring power levels at a midpoint in the system.

- A conservative whole-system analysis of peak interference risk, based on valid Wi-Fi density levels, including a reasonable assumption about the percentage of outdoor access points, and normal Wi-Fi duty cycles, channelization, and elevation angles, results in a finding that outdoor Wi-Fi operations will not cause harmful interference to Globalstar's feeder link operations.

- Utilizing a dynamic simulation as opposed to a static study, even with very conservative assumptions, confirms that commercial Wi-Fi operations will not cause harmful interference to Globalstar feeder link operations. A dynamic study provides the FCC with a thorough analytical approach that examines the interactions of every individual Globalstar satellite with Wi-Fi access points using real antenna patterns at different times and on different days.

- The Commission must account for Globalstar's exceptionally light use of U-NII-1 – the company uses the huge 100 MHz band for only four feeder links in the United States serving merely 85,000 duplex customers worldwide. With so few simultaneous duplex calls, Globalstar's system can manage far more interference than Wi-Fi operations could ever produce, without any customer impact. Nonetheless, NCTA supports FCC rules that mandate that Wi-Fi networks protect these Globalstar customers from harmful interference.

With the attached CableLabs/CU Further Analysis, the U-NII-1 record is complete. After a comprehensive notice and comment process, and the submission of multiple detailed technical studies, nothing stands in the way of moving ahead with U-NII-1 immediately. In response to the FCC's Notice of Proposed Rulemaking last year, a wide cross-section of the broadband economy expressed its strong support for permitting higher power operations and outdoor use – including IEEE, Cisco, Google, Microsoft, the Wi-Fi Alliance, the New America Foundation, and Public Knowledge, along with cable companies like Cablevision, Comcast, and Time Warner Cable.[10] Importantly, the Department of Defense also weighed in, explaining to the FCC

---

[10] Comments of IEEE 802 at 4 (filed May 28, 2013); Comments of Cisco Systems, Inc. at 54-55 (filed May 28, 2013); Comments of Google Inc. and Microsoft Corporation at 5-6 (filed May 28, 2013); *see also* Letter from Harold Feld, Senior Vice President, Public Knowledge, to Marlene H. Dortch, Secretary, Federal Communications Commission at 1-2 (filed Dec. 20, 2013); Comments of Cablevision Systems Corporation at 5-6 (filed May 28, 2013);

that it no longer required access to U-NII-1 for future systems, stating that those frequencies were therefore available for unlicensed services.[11]

Given the state of the record and the urgency of the matter, the time for Commission action is now. Chairman Wheeler recently demonstrated his strong support for quick action, stating "that if you take a look at the five gigahertz [band], and you look at block U-NII-1 . . . we should be moving to ruling on that."[12] Commissioner Rosenworcel has similarly stated that the 5150-5250 MHz band "deserves immediate attention,"[13] and she has urged the Commission to "take the flexible rules that have been the script for an unlicensed success story in the 5.725-5.825 GHz [U-NII-3] band and expand them to this lower portion of the 5 GHz band."[14] Commissioner Pai also supports moving "promptly to modify the service rules for the U-NII-1 band,"[15] and has stated that "[b]y raising the power limits on the U-NII-1 band and allowing for outdoor use, we can make this band attractive for commercial Wi-Fi while safeguarding incumbent users."[16] Most recently, Senator Pryor wrote to Chairman Wheeler on December 20, 2013 noting that "the Commission has already gathered a significant amount of technical data on whether and how to open up the U-NII-1 band for enhanced unlicensed operations. I encourage the Commission to review this data carefully to make an informed decision whether it can move forward on the U-NII-1 band in the near term."[17] All the pieces are in place and the time to act is now.

Comments of Comcast Corporation at 3-4 (filed May 28, 2013); Comments of Time Warner Cable Inc. at 10-11 (filed May 28, 2013).

[11] Letter from Karl B. Nebbia, Associate Administrator, Office of Spectrum Management, National Telecommunications and Information Administration, to Julius P. Knapp, Chief, Office of Engineering and Technology, Federal Communications Commission, GN Docket No. 13-85, at Attachment, p.1 (filed July 24, 2013).

[12] *Oversight of the Fed. Commc'ns Comm'n: Hearing Before the H. Comm. Energy & Commerce, Subcomm. on Commc'ns & Tech.*, 113th Cong., 2013 WL 6518248 (Dec. 12, 2013) (response of Thomas Wheeler, Chairman of the Fed. Commc'ns Comm'n, to a question by Doris Matsui, Representative).

[13] *Rosenworcel Seeking Foreign Broadcast Ownership Fresh Look, Favors IP Transition Trials* at 1, COMMUNICATIONS DAILY (Oct. 30, 2013).

[14] Statement of Jessica Rosenworcel, Comm'r, Fed. Commc'ns Comm'n, Revision of Part 15 of the Comm'n's Rules Regarding Operation in the 57-64 GHz Band (Aug. 9, 2013), http://transition.fcc.gov/Daily_Releases/Daily_Business/2013/db0809/FCC-13-112A3.pdf.

[15] *Commissioner Ajit Pai Applauds U.S. House of Representatives Committee on Energy and Commerce for Highlighting Promise of 5 GHz Band for Unlicensed Use and Calls for Prompt FCC Action to Facilitate Greater Use of 5 GHz Band* at 1 (Nov. 13, 2013), *available at* http://www.fcc.gov/document/pai-statement-house-5-ghz-hearing.

[16] *Id.*

[17] Letter from Senator Mark Pryor to The Hon. Tom Wheeler (Dec. 20. 2013).

1. ***The CableLabs/University of Colorado analysis demonstrates that the Roberson Paper depends on invalid assumptions and inputs that render it unreliable – correcting these mistakes shows that Wi-Fi will not cause harmful interference to Globalstar.***

The attached CableLabs/CU Further Analysis begins by examining the most recent technical paper drafted on behalf of Globalstar by Roberson and Associates, LLC.[18] It confirms the conclusion articulated in the CableLabs/CU July analysis that U-NII devices can operate outdoors at higher power levels up to 1 Watt without causing harmful interference to Globalstar's U-NII-1 operations, even considering peak interference.

First, it is important to note that the Roberson Paper accepts that an accurate model of the interference risk to Globalstar's operations must be evaluated on a whole-system basis, as CableLabs/CU explained.[19] The first Globalstar technical analysis, appended to Globalstar's opening comments, looked only at the potential impact of interference in the satellite uplink signal, without considering the system as a whole, or how interference in the uplink would impact the downlink that ultimately delivers the signal to the end user.[20] The Roberson Paper therefore marks agreement among U-NII-1 stakeholders that the interference analysis must take into account the whole Globalstar system.

The parties also now agree that an accurate interference analysis must account for Wi-Fi density, the percentage of outdoor access points, duty cycles, signal attenuation due to clutter, and channelization.[21] The CableLabs/CU Further Study shows, however, that Globalstar used invalid assumptions about each of these inputs in its most recent filing and therefore does not provide a reliable evaluation of the potential for interference to Globalstar's system.[22]

Specifically, Globalstar would have the Commission believe that *every single* Wi-Fi access point in the United States will (1) operate outdoors, (2) simultaneously operate twenty-four hours a day, (3) only use the U-NII-1 band (essentially abandoning the 2.4 GHz and U-NII-3 bands), and (4) operate at a constant 30-degree elevation angle to the satellite with virtually no signal attenuation due to clutter. As explained in the CableLabs/CU analysis, and summarized below, these assumptions strain all credulity.

---

[18] Supplemental Comments of Globalstar, Inc., at Attachment A (filed Nov. 29, 2013) ("Roberson Paper").

[19] *See*, *e.g.*, Roberson Paper at 5, 12-14 (discussing Roberson's approach used to estimate the effect of U-NII access points on Globalstar's downlink capacity); 2014 CableLabs/CU Further Analysis at 6-7.

[20] Comments of Globalstar, Inc., at App'x (filed May 28, 2013).

[21] July 2013 Study at 25-27; *see* Roberson Paper at 9 (Wi-Fi duty cycles), 15 (channelization), 8 (clutter, antenna gain, elevation angle).

[22] 2014 CableLabs/CU Further Analysis at 7-15.

Wi-Fi density and outdoor use errors. Globalstar assumes that every urban area will have a Wi-Fi deployment density equal to that on Google's Mountain View campus,[23] and that every Wi-Fi access point will operate outdoors.[24] Both assumptions are incorrect. In fact, Wi-Fi deployments will differ significantly in urban and rural areas. Moreover, relying on existing cable deployments as a proxy (a reasonable assumption given the number of outdoor access points deployed by cable operators), much less than half of all Wi-Fi deployments are likely to be outdoors. But for the sake of being extremely conservative, CableLabs/CU's calculations are based on a 50 percent deployment of outdoor access points.[25] Correcting this one Roberson error reduces Globalstar's interference estimates by at least half.[26]

Duty cycle errors. Globalstar erroneously assumes that all Wi-Fi access points will transmit simultaneously twenty-four hours a day.[27] CableLabs/CU corrects this mistake, noting that previous studies estimate that Wi-Fi access points actively transmit between 1 percent and 10 percent of the time.[28] Even the most conservative interference analysis, therefore, would assume that there is only a 10 percent chance that a particular access point will be transmitting at any given point in time. Because it fails to recognize this fact, Globalstar overstates the total Wi-Fi noise level by a factor of at least ten.[29]

Channelization errors. Globalstar erroneously assumes that all Wi-Fi access points will suddenly operate exclusively in U-NII-1 channels without considering other unlicensed channels.[30] In fact, access points will use all available Wi-Fi channels, including those available in the U-NII-3 and 2.4 GHz bands, a total of 240 MHz of spectrum.[31] This amounts to three times more spectrum than assumed by Globalstar.[32] Globalstar therefore overstates noise by at least three times.[33]

Elevation angle errors. Globalstar also incorrectly assumes a constant 30 degree elevation angle to the satellite across all Wi-Fi access points and a uniformly low level of Wi-Fi signal attenuation due to clutter.[34] CableLabs/CU previously demonstrated that the elevation

---

[23] Roberson Paper at 7.

[24] *See id.*

[25] 2014 CableLabs/CU Further Analysis at 9-10, 15 n.20.

[26] *See id.* at 10.

[27] *Id.* at 10-12.

[28] *Id.* at 11.

[29] *Id.*

[30] *Id.* at 12-13.

[31] *Id.* at 12.

[32] *Id.*

[33] *Id.*

[34] Roberson Paper at 8; 2014 CableLabs/CU Further Analysis at 13.

angle to a Globalstar satellite will actually vary from 30 to 60 degrees,[35] and that an accurate analysis must take account of varying signal path loss due to obstacles like buildings and foliage.[36]

While any one of the errors described above is problematic, the cumulative impact of all of the errors is staggering. Making basic adjustments to Roberson's flawed analysis demonstrates that *even in a peak interference scenario, the capacity of Globalstar's system would likely be reduced by less than 1.5 percent; not by 56 percent as concluded by Roberson*.[37]

In other words, even accepting Globalstar's own parameters, but adjusting the inputs to reflect more accurate assumptions regarding Wi-Fi operations, the impact to Globalstar's system from higher power, outdoor unlicensed operations in U-NII-1 will be *de minimis*. Importantly, the CableLabs/CU analysis considers peak expected interference, and is therefore a conservative outer bound. The Commission's own conclusions should be based on actual interference levels that will typically be even lower than the *de minimis* levels identified by the conservative CableLabs/CU analyses.

Moreover, as the CableLabs/CU analysis notes, a 1.5 percent capacity reduction poses even less of a problem for Globalstar in light of the small number of subscribers to its duplex (satellite phone) service.[38] Capacity impairment in the context of Globalstar's system would mean an outer limit on the number of subscribers the system could serve at any one time. With only 85,000 duplex subscribers worldwide, a number that has consistently declined since 2008, it is unlikely that Globalstar operates its system at anywhere near full subscriber capacity.[39] As a result, even far more than a 1.5 percent reduction in capacity would have no perceivable impact on a Globalstar customer's experience.

The Commission can act here to allow higher power, outdoor Wi-Fi with confidence. Such a finding would rely on an analysis consistent with the conservative, but real-world, interference analyses the Commission has used in recent proceedings, including the review of interference issues in the AWS-3 band and the H Block. The simulation model presented by CableLabs and described above employs realistic assumptions regarding access point deployment patterns, ground elevations, antenna patterns, duty cycle, and channel selection. Furthermore, the simulation described in the next section considers the movement of satellites across the sky and factors in the resulting changes in distances and elevation angles between access points and satellites.

---

35 July 2013 Study at 25. ("One study demonstrated that 88% of the time a Globalstar satellite will be observed between 30° to 60° elevation angle above the horizon at Earth latitude of 41.9° (the approximate latitude of Denver, CO.)").

36 *See id.*

37 2014 CableLabs/CU Further Analysis at 14-15.

38 *Id.* at 5, 8.

39 *See id.* at 8.

Similarly, in the AWS-3 notice of proposed rulemaking adopted last year, the FCC relied on an NTIA working group report that contained a more refined analysis that "more accurately depict[s] *real world operation* of LTE networks and their interaction with the incumbent systems," thereby allowing a significant reduction of the potential interference range.[40] And, as the Commission found in last year's *H Block Order*, when the relationship between interferer and target receiver is variable, it is essential to avoid interference calculations based on "overly conservative" assumptions; instead, the FCC's findings should account for the "low probability of . . . interference actually occurring."[41] Here, the Commission should base its analysis on realistic assumptions about the Wi-Fi operating environment, not a hypothetical and unrealistic scenario conjured by Globalstar.

2. CableLabs/CU's comprehensive dynamic simulation of U-NII-1 sharing confirms that Wi-Fi will not cause harmful interference to Globalstar feeder link operations.

To further confirm the accuracy of the analysis, the CableLabs/CU Further Analysis also studied the interference question from a different angle. Rather than merely relying on a static calculation based on relatively simple system attributes, this new approach constructs a comprehensive simulation of the interaction between Wi-Fi access points and Globalstar satellites. As with the earlier static analysis, it uses conservative assumptions, and then takes the next step by accounting for the dynamic nature of Wi-Fi/satellite interactions – using much more accurate geographic and temporal information to examine interactions between Wi-Fi access points and actual Globalstar satellites over time. The new analysis takes into account the orbital movement of Globalstar's satellites, provides a more accurate estimate of where Wi-Fi access points are likely to be deployed geographically, and accounts for how Wi-Fi use fluctuates throughout the day in the United States. The result is a dynamic simulation tool that allows the Commission to understand peak interference to Globalstar's system more effectively.

CableLabs/CU used this new tool to simulate the impact of each access point on each of Globalstar's twenty-four satellites over a week-long period, accounting for peak hours of Wi-Fi usage and each satellite's orbit.[42] The study found that the average increase in the noise visible to all Globalstar satellites throughout the week was only 0.14 dB, while the peak increase in noise – coinciding with the times of day when the satellite is closest to the access points and Wi-Fi usage is at its highest – was a mere 1.12 dB.[43] *In other words, the total additional noise in*

---

[40] *Amendment of the Comm'n's Rules with Regard to Commercial Operations in the 1695-1710 MHz, 1755-1780 MHz, and 2155-2180 MHz Bands*, GN Docket No. 13-185, Notice of Proposed Rulemaking and Order on Reconsideration, 28 FCC Rcd 11479, 11505 ¶ 58 (2013) (emphasis added).

[41] *Service Rules for Advanced Wireless Services H Block—Implementing Section 6401 of the Middle Class Tax Relief and Job Creation Act of 2012 Related to the 1915-1920 MHz and 1995-2000 MHz Bands*, WT Docket No. 12-357, Report and Order, 28 FCC Rcd 9483, 9494 ¶ 23, 9526-27 ¶ 111 (2013).

[42] 2014 CableLabs/CU Further Analysis at 23-29.

[43] *Id.* at 26-27.

Globalstar's uplink signal as a result of outdoor, 1 Watt unlicensed operations is approximately 1 dB, even at peak interference levels.

The CableLabs simulation also considered how the additional noise in Globalstar's satellite uplink signals would impact Globalstar's end users. To do so, CableLabs used the link budget information described in the Roberson Paper, which provides a ratio for understanding the impact of additional noise on the capacity of Globalstar's system.[44] *CableLabs found that Globalstar's capacity would be reduced by a maximum of 1.82 percent and an average of 0.21 percent – as measured by Globalstar's own metric – not by 56 percent as Globalstar claims.*[45]

The fact that the traditional static model and the new dynamic simulation both predict similarly low levels of interference conclusively demonstrates that outdoor unlicensed operations at powers up to 1 Watt would have no noticeable impact on Globalstar's satellite customers. A peak increase in the noise floor of approximately 1 dB, and a corresponding decrease in Globalstar's capacity of less than 2 percent simply do not constitute harmful interference.

* * *

The FCC has collected a voluminous record in this proceeding that fully explains the exceptional value of expanding Wi-Fi operations in U-NII-1. The recommended rule changes needed to accomplish this goal – increasing maximum power to 1 Watt and allowing outdoor Wi-Fi – are straightforward and do not require any additional work to design. The overwhelming majority of commenters support these two changes.[46]

Only Globalstar opposes the Commission's proposal based on a highly flawed interference claim. The record now includes multiple detailed interference studies that ensure that the Commission has all the information that it needs to resolve this technical question.

Facing today's spectrum scarcity, the FCC has insisted on maximizing the efficiency and intensity with which every licensee uses its assigned frequency. It has asked broadcasters, government users, and mobile phone operators to tighten their belts and find ways to share. Given this exceptional push toward sharing and efficiency, the Commission must not allow Globalstar to refuse to share and to hoard 100 MHz of valuable spectrum in such an inefficient manner.

---

44 That ratio assumes that a 10 dB increase in uplink noise translates to a 55.4 percent reduction in capacity. *Id.* at 28 n.39.

45 *Id.* at 27-29.

46 *See* NCTA Reply Comments at 12 & n.46 (collecting citations demonstrating record support for permitting outdoor, 1 Watt operations in U-NII-1).

Respectfully submitted,

/s/ Rick Chessen

Rick Chessen

cc: Chairman Tom Wheeler
Commissioner Mignon Clyburn
Commissioner Jessica Rosenworcel
Commissioner Ajit Pai
Commissioner Michael O'Rielly
Geraldine Matise
Mark Settle

Attachment

5 GHz UNII-1: Wi-Fi and Globalstar Sharing Analysis

Dirk Grunwald, University of Colorado
Rob Alderfer, CableLabs
Kenneth Baker, University of Colorado

Abstract

Wi-Fi use of the 5 GHz band is important for sustaining the growth of wireless broadband and enabling next-generation wireless technology. However, outdated FCC rules designed to protect mobile satellite service (MSS) from harmful interference render Wi-Fi access to 100 megahertz of the band, known as UNII-1, unsuitable for wide-scale deployment. Today, only one MSS company, Globalstar, occupies this entire 100 megahertz, and a far lower level of MSS utilization exists than what the FCC assumed when establishing rules many years ago. Nonetheless, Globalstar has repeatedly argued that updating UNII-1 technical rules to allow for outdoor use and higher power levels would cause harmful interference to its satellite phone system.

This paper demonstrates that Globalstar's technical arguments are unreliable through two approaches. We first explain a set of flaws in Globalstar's recently proffered interference model. We then develop a sophisticated coexistence simulation, which shows that satellite phone users are extremely unlikely to experience any service diminution (harmful interference) as a result of expanded Wi-Fi access to UNII-1. This paper therefore confirms the findings of a July 2013 study by the authors that was submitted into the FCC record.

CableLabs® University of Colorado Boulder

About the Authors

Dirk Grunwald is the Wilfred and Caroline Slade Endowed Professor at University of Colorado at Boulder, in the Department of Computer Science. He received his Ph.D. from the University of Illinois, Urbana-Champaign in the Department of Computer Science. He has been a member of the faculty of the Department of Computer Science at the University of Colorado since 1989 and holds joint appointments in the Dept. of Electrical and Computer Engineering and the Interdisciplinary Telecommunications Program. His research background includes computer architecture, systems, networking and wireless networking including cognitive radio systems.

Rob Alderfer is a Strategic Analyst for CableLabs, the cable industry research and development consortium. He served as Chief Data Officer of the Wireless Telecommunications Bureau at the Federal Communications Commission from 2010 to 2012. Prior to that, he was responsible for communications policy at the White House Office of Management and Budget.

Kenneth Baker is a Scholar in Residence at the Interdisciplinary Telecommunications Program at University of Colorado at Boulder, and holds a PhD, MS, and BS in EE. Prior to joining the faculty at CU, he has held various positions related to RF network planning and new product research and development at both Nortel and Qualcomm Inc. In addition he has participated in the rollout and optimization of CDMA networks worldwide. His background also includes wireless industry consulting and training. He holds twelve patents in CDMA communication system technology.

This paper was made possible with support from CableLabs. Founded in 1988 by cable operating companies, Cable Television Laboratories, Inc. (CableLabs®) is a non-profit research and development consortium that is dedicated to pursuing new cable telecommunications technologies and to helping its cable operator members integrate those technical advancements into their business objectives.

Table of Contents

1 Executive Summary 4

2 Analytic Context 5

3 A Critique of the Globalstar Analysis 7

3.1 Density of Access Points 8

3.2 Duty Cycles 10

3.3 Channelization 12

3.4 Elevation Angle / Wi-Fi Signal Loss 13

3.5 Summarizing and Quantifying the Critique 13

4 A Dynamic Simulation of UNII-1 Coexistence 16

4.1 Overview of the Dynamic Method 16

4.2 Components of the Simulation 17

4.2.1 Tracking the Globalstar Constellation 17

4.2.2 Simulating Wi-Fi Deployment 19

4.2.3 Characterizing the Wi-Fi Signal 20

4.3 Putting the Components Together: Simulating Wi-Fi “Noise” 23

4.4 Results: Translating Wi-Fi “Noise” to Globalstar Capacity 27

4.5 Sensitivity of Results 29

5 Conclusion 30

1 Executive Summary

Wi-Fi now carries the majority of Internet traffic and is therefore crucial to the functioning of modern economies. Yet the resource that enables Wi-Fi use – wireless spectrum – is scarce. Additional spectrum capacity is required to sustain wireless growth and enable new technologies like 802.11ac, the next-generation mass market Wi-Fi standard that is designed for gigabit speeds.

The FCC has proposed to expand Wi-Fi access in the 5 GHz band, which is the global home to 802.11ac technology. Doing so will require sharing wireless frequencies with other users, as Wi-Fi has done since its inception. However, in one portion of the 5 GHz band, known as Unlicensed National Information Infrastructure-1 (UNII-1), the sole incumbent spectrum licensee, a provider of mobile satellite service (MSS) known as Globalstar, has repeatedly maintained that there could be potential harmful interference resulting from expansion of Wi-Fi to permit outdoor use and higher power levels, despite contrary technical showings from the Wi-Fi community, including the authors.

This paper demonstrates through two independent approaches that Wi-Fi and Globalstar can share the 5 GHz UNII-1 band under updated technical rules that remove current limitations on Wi-Fi, such as outdoor use restrictions and onerous power limitations.

We first explain that Globalstar's recently proffered interference model contains a set of important flaws that render it unreliable. Simple adjustments that more accurately reflect Wi-Fi usage reduce Globalstar's core claims of harm, which they characterize as "capacity degradation," from the 56% they claim to less than 1.5%.

Next, we provide a more accurate picture of interference risk to Globalstar's duplex satellite system, using a dynamic simulation that accounts for both satellite system and Wi-Fi system variables. This simulation better portrays real-world coexistence by determining the likely level of noise experienced by each of the 24 active satellites in the Globalstar constellation as they orbit the Earth at over 15,000 miles per hour, accounting for the geographic deployment of access points, antennae characteristics, and the temporal nature of Wi-Fi use, among other factors.

This approach establishes a reliable real-time estimate of the peak level of Wi-Fi "noise" into Globalstar's duplex system, which is the main driver of any potential impact to satellite phone users. The approach offers the FCC a far more accurate mechanism for interference analysis.

The simulation finds that the peak level of Wi-Fi "noise" likely to be seen by Globalstar's constellation is minimal, at approximately 1 dB, which we translate to end-user impact using link budget information provided by Globalstar. Using Globalstar's metric of "capacity degradation," we find a peak impact of a *de minimus* 1.8% or less, which is highly unlikely to cause any satellite phone service diminution, especially in light of the small subscribership of the Globalstar duplex system. In other words, harmful interference into Globalstar's satellite system as a result of expanded Wi-Fi access is found to be very unlikely. We take care in this presentation to be conservative and avoid understating interference risk.

Through these two independent approaches – a basic critique of Globalstar's latest analysis, and a sophisticated coexistence simulation – we remain confident that Wi-Fi access can be expanded in UNII-1 using updated technical rules without meaningful risk of harmful interference to Globalstar, as we have concluded in previous analysis. These findings support the FCC's proposal to enable outdoor, higher-power Wi-Fi access in UNII-1.

2 Analytic Context

The FCC has proposed to expand access for Wi-Fi in the 5 GHz band as a means to ensure adequate capacity for this increasingly important element of the wireless broadband ecosystem, and to fully enable the next generation of Wi-Fi technology, known as 802.11ac or "gigabit Wi-Fi."[1]

A component of the FCC's proposal involves updating the terms of access for Wi-Fi in the 5150-5250 MHz band, known as UNII-1. The restrictions placed on Wi-Fi in this band were specified over 15 years ago, and were intended to provide conservative protections to the nascent Mobile Satellite Service (MSS) that uses the band for its ground station feeder uplinks, which are one link in their duplex (satellite phone) system. Since that time, wireless broadband has become central to economic activity in much of the world, with Wi-Fi serving as the primary means to connect online.[2] In addition, the past 15 years have provided a basis for assessing the technical and economic role of MSS. Given the disparity between expectations and reality about the usage of MSS, the FCC has deemed it appropriate to reassess its rules in the UNII-1 band.[3]

---

[1] For a discussion of Wi-Fi capacity trends and 802.11ac spectrum needs, see *The Need for Wi-Fi Spectrum*, section 2 of Alderfer et al., "Toward Expanded Wi-Fi Access in the 5 GHz Band", July 2013, appended to *Reply Comments of the National Cable and Telecommunications Association* in Federal Communications Commission ET Docket No. 13-49.

[2] According to the 2013 Cisco Visual Networking Index, Wi-Fi now carries almost half (49%) of all Internet Protocol traffic worldwide, compared to 48% over fixed lines and 3% over mobile.

[3] Federal Communications Commission ET Docket No. 13-49, "In the Matter of Revision of Part 15 of the Commission's Rules to Permit Unlicensed National Information Infrastructure (U-NII) Devices in the 5 GHz Band", February 20, 2013.

However, Globalstar, the sole remaining MSS operator using 5 GHz, has repeatedly asserted that expanding Wi-Fi access will result in harmful interference to its duplex system, which serves approximately 85,000 customers globally.[4] These concerns have taken several forms.

In May 2013, Globalstar submitted technical analysis to the FCC indicating that as few as 201 Wi-Fi access points could harm their duplex system.[5] This claim entailed an inappropriate definition of interference, premised on a generic ITU-developed standard for noise as measured at the satellite. As described in our July, 2013 paper, this approach does not appropriately account for the technical characteristics of the Globalstar system, and does not seek to forecast the outcome of central policymaking importance, which is the potential impact to satellite phone users.

In response, CableLabs and the University of Colorado (CU) demonstrated how a more holistic approach to modeling interference risk, which accounts for any potential impact on satellite phone users by examining both the uplink and the downlink in Globalstar's duplex system, would yield more accurate results than those proffered by Globalstar.[6] This analysis showed that hundreds of millions, or even billions, of Wi-Fi access points could operate in the UNII-1 band simultaneously before increasing the noise in Globalstar's system by even a small amount that would likely to be imperceptible to end users.

Others in the Wi-Fi community – including Intel, Cisco, and the IEEE[7] – have subsequently confirmed our analytic approach and conclusions. Only Globalstar contends that the FCC's proposed technical rule changes would cause harmful interference.

Recently, Globalstar filed a second technical analysis at the FCC seeking to justify its opposition to expansion of Wi-Fi access.[8] Significantly, Globalstar has newly adopted the CableLabs / CU method for analyzing the risk to the system as a whole, rather than a generic, single-link, ITU-specified noise floor recommendation.[9] This is

---

[4] Note that a simple subscriber count implicitly overstates the actual usage of Globalstar's duplex system; most subscribers will generally use the service when out of range of terrestrial communications, so simultaneous usage is likely to be much lower than total subscriber counts.

[5] *Comments of Globalstar Inc.*, ET Docket No. 13-49, May 28, 2013.

[6] Alderfer et al., July 2013.

[7] *See, e.g., Reply Comments of IEEE 802*, ET Docket No. 13-49, at 17-19, July 23, 2013; *Reply Comments of Wi-Fi Alliance*, ET Docket No. 13-49, at 20-21, July 24, 2013.

[8] *Supplemental Comments of Globalstar Inc.*, ET Docket No. 13-49, November 29, 2013.

[9] See p.10 of the "Roberson Report", appended to Supplemental Comments of Globalstar Inc., November 29, 2013, wherein an expression of total system carrier to noise ratio is documented.

important and the correct framework for analyzing Globalstar's bent-pipe satellite system.

However, the assumptions used in Globalstar's implementation of this analytic method are significantly flawed and lead to inaccurate conclusions with regard to sharing with Wi-Fi in UNII-1. Section 3 of this paper provides an analysis of Globalstar's latest submission, which demonstrates that it is unreliable as a basis for policy and does not disprove the validity of the July, 2013 CableLabs / CU analysis.

Nonetheless, to supplement our conclusions, we provide an additional and nuanced approach to understanding true interference risk to Globalstar's duplex system. In Section 4, we move the technical debate from the static parameters employed to date, where modeling is simplified and key parameters are portrayed as unmoving, to a more dynamic understanding of how Wi-Fi may interact with Globalstar's duplex system in the real world.

This dynamic, state-of-the-art simulation of coexistence leads us to confirm our July, 2013 conclusion that UNII-1 technical rules can be updated without significant risk of harmful interference to Globalstar.

3 A Critique of the Globalstar Analysis

The main driver of Globalstar's unsupportable conclusions about interference risk from Wi-Fi in UNII-1, which they offer in a recent FCC filing,[10] is the company's unrealistic calibration of what constitutes the "worst case" of Wi-Fi deployment parameters. However, importantly, Globalstar's analysis does accept the premise, put forward by CableLabs and CU, that such risk should be modeled with the impact to the total system and its users in mind, rather than using a generic ITU-based noise floor limit for a single link, as Globalstar had previously contended.

The common understanding that holistic system considerations are paramount provides a basis for a nuanced analysis of interference risks. Nevertheless, the implementation of this "whole-system" analysis approach taken by Globalstar in its most recent technical report (hereafter referred to the "Roberson Report" in reference to its outside consultant authorship) is not a reliable basis for policy. Specifically, the assumptions used in the Roberson Report represent a "worst case" that is outside the bounds of what is technically possible or observable in the real world.

Since our primary aim in this paper is to reach a realistic understanding of interference risk, it is worthwhile to examine how basic adjustments to Roberson's

[10] *Supplemental Comments of Globalstar Inc.*, ET Docket No. 13-49, November 29, 2013.

analytic inputs – made to reflect a minimum standard of plausibility – can vastly change conclusions. Our goal here is not to show what may be observed in the real world, which we cover in a later section of this paper, but rather to make some basic corrections to Globalstar's analysis that show its conclusions to be unreliable.

The Roberson Report's primary claim of potential harm is that the downlink capacity of the Globalstar duplex system could be reduced by more than one-half if Wi-Fi access is expanded in UNII-1. To reach this conclusion the authors assume, among other things: 1) An extremely dense deployment of outdoor Wi-Fi access points; 2) All of which use only the UNII-1 band (ignoring all other Wi-Fi channels); 3) At 100% duty cycle (continuous maximum utilization); 4) With significant gain at (energy directed toward) the satellite, a clear line of sight to the sky and no Wi-Fi signal blockage by buildings and other ground clutter. Taken individually and collectively, these assumptions do not present a realistic picture interference risk, or even a plausible "worst case."

A few basic adjustments to the Roberson method will reveal that the maximum level of interference risk is much lower than claimed. The major drivers of interference risk in the Roberson Report are explored in turn below.

It is important to understand, however, that it is not clear that even the exaggerated claims of duplex system capacity impact made in the Roberson Report would cause diminution of service to satellite phone users, in light of the very low subscribership to Globalstar's duplex service. Since downlink bandwidth is limited to end users,[11] and quality of service is maintained in user sessions,[12] capacity impairment will manifest as a limitation on the number of subscribers that can be served simultaneously. Globalstar has made no claim that it operates its system at anywhere close to the maximum number of simultaneous subscribers that could be supported. Indeed, the number of subscribers to its duplex service has declined each year since Globalstar first began reporting service-specific subscription numbers in 2008.[13]

3.1 Density of Access Points

[11] Most Globalstar users are limited to 9.6 kpbs.

[12] According to the description of the Globalstar duplex system in the Roberson Report.

[13] See Globalstar, Inc., 2010 Annual Report (Form 10-K) at 33, 35 (Mar. 31, 2011), available at http://www.sec.gov/Archives/edgar/data/1366868/000114420411019122/v214676_10k.htm; Globalstar, Inc., 2012 Annual Report (Form 10-K) at 30, 33 (Mar. 15, 2013), available at http://www.sec.gov/Archives/edgar/data/1366868/000114420413015324/v335533_10k.htm

Access point density is an important component of the Roberson Report since it provides the total number of outdoor Wi-Fi hotspots, from which the other elements of the model are built.[14]

The Roberson analysis assumes that 4.4 million Wi-Fi access points will be operational outdoors. This figure is based on Google's free Wi-Fi deployment in Mountain View, California, from which network density is calculated – 16 access points per square kilometer - and is then extrapolated to all "urban" areas in the United States, which provides the estimate of 4.4 million outdoor access points.

This level of outdoor Wi-Fi density is extremely high, and would represent significant market demand for Wi-Fi services. We do not dispute that Wi-Fi is in high demand and is highly valued by consumers. However, Roberson's estimation method reveals a fundamental misunderstanding of Wi-Fi deployment.

While Google's Mountain View Wi-Fi deployment is designed to provide near-ubiquitous coverage, it is unlikely that such a design will take root across all urban areas using 5 GHz spectrum that entails relatively high path loss. Indeed, Google uses the 2.4 GHz ISM band as the access network, not 5 GHz, and intends the network for use both indoors and outdoors, which drives an extremely dense architecture.

In contrast, cable operators, wireless carriers, and others are deploying Wi-Fi not for ubiquitous coverage, but rather for strategic capacity where customers gather. For example, the CableWiFi consortium now operates well-over 200,000 Wi-Fi access points, and around half are deployed indoors in retail establishments, schools, and airports. The broader population of access point deployments is even more likely to be indoors, in retail establishments or residences. This is reflected in commonly accepted interference analyses, where over 95% of access points are assumed to be located indoors.[15]

Since Wi-Fi is well suited as an extension of fixed network assets, it is highly unlikely that an "outdoor-in" coverage model will predominate the 5 GHz Wi-Fi deployments of the future. This is relevant because indoor access points pose no risk to Globalstar's system. Yet, in the Roberson analysis, little to no "blocking" of Wi-Fi signals (which would represent indoor deployment) was incorporated. Thus, the full projected population of 4.4 million access points was assumed to be outdoors, impacting Globalstar's system in generating interference risk estimates.

---

[14] Globalstar examines only outdoor Wi-Fi access points since signals from indoor deployments will not result in significant noise to their satellite system.

[15] See, for example, "Cisco Systems: A Baseline RLAN Deployment Model and Sharing Analysis Between EESS (Active) and RLAN In The 5350-5470 MHz Band", *Document 4-5-6-7/CG-Cisco*, ITU-R Study Groups, October 2, 2013.

In addition, Roberson's definition of "urban" incorporates broad areas with significant diversity in population density; for example, the Census-defined urbanized areas used in the study incorporate both the urban cores and surrounding suburbs. A more granular approach would more accurately reflect likely Wi-Fi deployment, and we take such an approach in the simulation described in Section 4.

Even if one were to accept Globalstar's estimate of 4.4 million 5 GHz access points, a simple adjustment for the proportion that are likely to be deployed outdoors, and thus be relevant for interference analysis, would reduce this key parameter significantly. This is not to undermine the importance of an ability to deploy outdoor APs – a critical element of any network – but rather to characterize the Roberson Report's assumptions relative to realistic parameters. An adjustment for Globalstar's access point density parameter based on the reality of the CableWiFi consortium experience -- a conservative approach that likely over-states the proportion of total APs that would be deployed outdoors -- reveals an overstatement of interference risk by at least two times.

3.2 Duty Cycles

Wi-Fi duty cycles, or the proportion of time that access points will be transmitting, is relevant to determining the likelihood that the population of access points will be transmitting simultaneously. This, in turn, drives the total signal level from the population of Wi-Fi access points at any given time. This is an essential consideration in interference modeling, since the primary concern is the total noise level at any given point in time and its resulting impact to end users of the Globalstar duplex system.

The Roberson Report uses a 100% duty cycle assumption in its core statement of interference risk, meaning that the entire assumed population of 4.4 million access points will all be transmitting at the same time, and simultaneously adding noise to the satellite system.

This is a level of utilization that is not technically possible in the operation of Wi-Fi; indeed, a study that the Roberson Report relied upon showed an 80% theoretical maximum.[16] However, using even an 80% duty cycle assumption in this analysis is unrealistic.

Empirical measurement shows a much lower utilization level than theoretical maximum. One recent study examining human exposure to radiation found that the

---

[16] Nickolas LaSorte, Dan Bloom, et al., "Comparison of Duty Cycle Measurement Techniques of 802.11b/g in the Frequency and Time Domain", *Instrumentation and Measurement Technology Conference*, 2013.

median duty cycle was just over 1%. At the 95th percentile – a true statistical "worst case" -- duty cycles were just over 10%.[17]

Table 2
Number of locations per environment and 50th and 95th percentile of the duty cycle in different environments.

Environment	Number of locations	p_{50} (D) (%)	p_{95} (D) (%)	SD (D) (%)
Industrial	17	1.35	10.50	3.16
Rural	3	–	–	–
Suburban	30	1.18	4.55	7.37
Urban	82	1.43	11.05	7.14
Office	41	1.24	6.08	5.27
Residential	6	1.85	–	–
All environments	179	1.36	10.44	6.35

–: Not available, not enough values for accurate estimate; SD = standard deviation.

Duty Cycles Observed in Different Wi-Fi Environments

If we take a 10% duty cycle to approximate the likely extreme of interference risk based on these empirical measurements, we see that Roberson's core conclusions of interference risk, which relied on a 100% duty cycle assumption, are overstated by a factor of ten times on this parameter alone. Adjusting this factor for the most likely observed duty cycle of 1% would mean an overstatement of interference risk by 99 times - again, solely as a function of assumed duty cycles, without incorporating other adjustments.

While a relatively simple adjustment for duty cycle assumptions changes the output of the Roberson model significantly, even the above construct over-simplifies – and overstates – interference risk, because it does not incorporate any information about the probability of simultaneous transmission of access points.

Simultaneous transmission is a function of both the duty cycle for each access point, and a function of the probability that a significant number of access points will be transmitting at the same time. A 10% duty cycle assumption does not mean that 10% of the universe of access points will be transmitting at the same time, as the logic employed by Globalstar would imply. A 10% duty cycle means that there is a 10% chance that any given access point will be transmitting at any given point in time. The probability that all (or a significant number of) access points will be transmitting at the same time, and thus all collectively adding noise to Globalstar's system as they suggest, is extremely small. This probability can be expressed

[17] Joseph et al., "Determination of the duty cycle of WLAN for realistic radio frequency electromagnetic field exposure assessment", *Progress in Biophysics and Molecular Biology*, 2012.

statistically. Assuming a very high 80% duty cycle, the chance that 4.4 million access points will all be transmitting at the same time is less than one thousandth of one percent (<0.000001).[18] In other words, laws of probabilities dictate that Globalstar's "worst case" scenario is extremely unlikely to occur.

3.3 Channelization

Channelization – or the amount of spectrum assumed in modeling – is also a key element of interference analysis. In the present context, it is relevant for determining how much Wi-Fi signal will be concentrated in UNII-1.

In the Roberson Report it is assumed that Wi-Fi access points will use UNII-1 exclusively, without regard for other available Wi-Fi spectrum. This has the effect of erroneously concentrating interference entirely into Globalstar's system.

In reality, access points will use all available Wi-Fi channels and traffic will be spread across a wide range of channels. Conservatively, we can quantify this by accounting for the three non-overlapping 20 MHz channels in the 2.4 GHz ISM band, as well as the five 20 MHz channels available at 5.8 GHz (UNII-3) – all of which are allocated for Wi-Fi and used today. Including the four 20 MHz channels in UNII-1, that means a total of 240 MHz of Wi-Fi spectrum – three times the amount assumed by Roberson.

By assuming that all Wi-Fi traffic will be concentrated into UNII-1, Roberson overstates the amount of Wi-Fi signal concentrated in their system by three times. (Again, only for the channelization parameter, without incorporating other adjustments.)

It would be reasonable to incorporate even more spectrum into the analysis. There are fifteen additional channels allocated today in UNII-2 (a and c); the FCC has also proposed expanding Wi-Fi access into new UNII-2b and UNII-4 bands, which would provide another twelve channels. Therefore, in the future it is possible that thirty-nine Wi-Fi channels may be available in the 5 GHz and 2.4 GHz bands.[19] By accounting for this spectrum, we can provide a range of interference risk. We do this in the simulation described in Section 4, and we find that greater Wi-Fi spectrum access directly reduces peak noise in UNII-1.

---

[18] Using a binomial probability function. For more information on binomial probabilities, see: http://stattrek.com/probability-distributions/binomial.aspx. Calculations rely on http://vassarstats.net/

[19] It is also possible that another 100 to 150 MHz of spectrum is available for Wi-Fi like services in the 3.5 GHz band. This would further diminish the impact to Globalstar's system beyond what is estimated here. Also note that current UNII-2 rules entail restrictions on Wi-Fi use, such as dynamic frequency selection mandates; therefore, we do not incorporate them into our base accounting of Wi-Fi channel availability.

3.4 Elevation Angle / Wi-Fi Signal Loss

Outdoor Wi-Fi deployments take many forms, and many specific parameters will influence the level of signal generated into Globalstar's system. Wi-Fi access points may be omnidirectional or may be sectorized. They may be positioned with a clear line of sight to the sky, or they may be in an urban cavern. They may be geared toward range maximization and tuned to maximum transmit power, or they may be capacity-focused, with lower transmit power. And at any given point in time, each access point will have a different angle to Globalstar's satellites, given the non-geostationary nature of MSS and its continuous orbit of the Earth.

Roberson ignores the complex nature of Wi-Fi deployment parameters in generating conclusions about interference risk. Instead, the model assumes a static world, with a constant angle to the satellite across all access points, a uniformly low level of Wi-Fi signal loss through clutter, a single access point transmit power level, and a number of other simplified assumptions that would be impossible to observe in the real world.

While the Roberson Report clearly overstates interference risk because of its failure to account for these factors, we do not attempt here to quantify the effect of these simplifications. Instead, in Section 4 we will simulate Wi-Fi deployment and its dynamic interaction with Globalstar's duplex system.

3.5 Summarizing and Quantifying the Critique

This section has sought to identify the Roberson Report's unrealistic interference assumptions, in order to provide a directional indication of how conclusions may change if modeling assumptions are anchored to a reality-based assessment of peak interference risk.

We have reviewed how basic adjustments for indoor access points, duty cycles, channelization, and elevation angle / Wi-Fi signal losses should be amended, and we have estimated the quantified effect of these amendments for the first three of these parameters. Each quantified estimate provided above has been in isolation, however. A summary is provided in the below table.

Parameter	*Roberson Report Worst-Case*	*Actual Worst-Case*
Density	4.4m public APs, all outdoor	Half of public APs may be indoor (conservatively)
Duty Cycles	100% duty cycle (constant utilization)	10% duty cycle (at the 95th percentile – i.e., "worst case")
Channelization	All APs use only UNII-1	8 to 35 additional channels available
Elevation Angle / Wi-Fi Signal Loss	Static, uniform	Dynamic (explored in next section)

Summary of Basic Adjustments to Roberson Report

To estimate the cumulative impact of reality-based adjustments to a worst-case scenario, we can use Table 7 of the Roberson Report as a reference. Table 7 showed a roughly 56% satellite downlink capacity impairment resulting from 1.1 million access points using one of the four 20 MHz channels in UNII-1 (corresponding to the total 4.4 million access points assumed in the core model), as seen in the figure below.

Table 7. Calculation of Relative Capacity as a Function of Number of Access Points

Number of Access Points U-NII-2 Rules Outdoor (6 dB antenna elevation loss) in 20 MHz BW	Uplink Degradation (dB)	Uplink Eb/(No+Io+Ia) (dB)	Required Downlink Eb/(No+Io,red) (dB)	Overall Eb/No+Io) (dB) Required [Eb/(No+Io)min]	Incr = Increase in downlink (Eb/No+Io) needed to maintain Eb/(No+Io)MIN, ovr (db)	Io, downlink dBW/Hz	Reducs in Downlink Io (dB) Required	Relative Capacity
.-	0	19.9	1.063	1.01	0	-209.60	0.00	1
32,000	1	18.9	1.077	1.01	0.0145	-209.67	0.07	0.985
72,000	2	17.9	1.095	1.01	0.0325	-209.75	0.16	0.965
185,000	4	15.9	1.150	1.01	0.0875	-210.03	0.43	0.906
365,000	6	13.9	1.235	1.01	0.1725	-210.48	0.88	0.816
650,000	8	11.9	1.375	1.01	0.3125	-211.32	1.72	0.673
1,100,000	10	9.9	1.610	1.01	0.5475	-213.15	3.55	0.442
1,820,000	12	7.9	2.000	1.01	0.9375	-220.32	10.72	0.085

Impact estimated by Globalstar: 1.1 million access points in each 20 MHz UNII-1 channel will lead to ~56% diminution of duplex system capacity

Roberson Model of Duplex System Capacity Impact

We can estimate the cumulative impact of our adjustments, therefore, by multiplying the 1.1 million AP figure by the overstatement of risk for each parameter, which provides an approximation of the level of interference associated with a true worst-case scenario, expressed as access point equivalents. We can then use the appropriate access point equivalent number to estimate the impact by examining the "Relative Capacity" column of Roberson's Table 7.

The formula used for this estimate is as follows:

$$1{,}100{,}000_{APs} * 0.5_{outdoor} * 0.1_{duty\ cycle} * 0.33_{channels} = 18{,}150_{AP\ equivalents}$$ [20]

In Roberson's Table 7, 18,150 access points corresponds to somewhere between 0% and 1.5% capacity diminution. This is not to say that 18,150 APs is the likely population of 5 GHz hotspots – rather, we use the number to translate our corrections to a metric that is normalized to Roberson's model of capacity impact.

Table 7. Calculation of Relative Capacity as a Function of Number of Access Points

Number of Access Points U-NII-2 Rules Outdoor (6 dB antenna elevation loss) in 20 MHz BW	Uplink Degradation (dB)	Uplink Eb/(No+Io+Ia) (dB)	Required Downlink Eb/(No+Io,red) (dB)	Overall Eb/No+Io) (dB) Required [Eb/(No+Io)min]	Incr = Increase in downlink (Eb/No+Io) needed to maintain Eb/(No+Io)MIN, ovr (db)	Io, downlink dBW/Hz	Reducs in Downlink Io (dB) Required	Relative Capacity
.-	0	19.9	1.063	1.01	0	-209.60	0.00	1
32,000	1	18.9	1.077	1.01	0.0145	-209.67	0.07	0.985
72,000	2	17.9	1.095	1.01	0.0325	-209.75	0.16	0.965
185,000	4	15.9	1.150	1.01	0.0875	-210.03	0.43	0.906
365,000	6	13.9	1.235	1.01	0.1725	-210.48	0.88	0.816
650,000	8	11.9	1.375	1.01	0.3125	-211.32	1.72	0.673
1,100,000	10	9.9	1.610	1.01	0.5475	-213.15	3.55	0.442
1,820,000	12	7.9	2.000	1.01	0.9375	-220.32	10.72	0.085

Adjustment for Globalstar's errors of assumption: duplex system capacity impact likely less than 1.5%.

Effect of Adjustments to Roberson Model of Duplex System Capacity Impact

Through these basic adjustments to the Roberson Report's unrealistic scenario, we can see that the estimated capacity impact on the Globalstar duplex system goes from 56% to not more than 1.5%. This better represents a worst-case scenario, as it is anchored to reality-based values for relevant parameters that drive interference risk. Furthermore, these findings demonstrate the continued validity of our main conclusion in July - that there is very little risk to Globalstar's duplex system from the expansion of Wi-Fi access in UNII-1.

We could stop here, since it is highly unlikely that a 1.5% diminution of capacity of Globalstar's duplex system will have any impact to satellite phone users. Unless Globalstar regularly runs its duplex system at 98% capacity – highly unlikely given its low number of subscribers – no meaningful impact will manifest.

However, to supplement our conclusions, we go a step further and provide additional analysis to support data-driven policy. In Section 4, we detail an innovative approach to interference analysis, simulating interference risk through a dynamic accounting of how MSS and Wi-Fi parameters may coexist in UNII-1.

---

[20] This adjustment formula assumes that 50% of access points are installed indoors, that duty cycles average 10%, and that access points use twelve 20 MHz channels (three at 2.4 GHz, four at UNII-1, and five at UNII-3).

4 A Dynamic Simulation of UNII-1 Coexistence

The radio frequency environment in which all wireless communication takes place is complex and ever changing. Definitive statements of interference risk therefore by nature rely on a simplified understanding of the wireless environment. Wireless policy is optimally developed with a more nuanced understanding of interference risk.

For this reason, we endeavor in this section to present a careful simulation of real-world coexistence between Globalstar's duplex system and Wi-Fi use of UNII-1. Such a simulation moves beyond Roberson's static presentation, and toward a dynamic understanding of how key parameters change over time.

In the context of UNII-1 coexistence, this means accounting for the impact to each of Globalstar's 24 active satellites,[21] individually and collectively, by determining their orbital position and sensitivity to Wi-Fi access points at any given time, with a realistic understanding of how Wi-Fi is deployed geographically and used temporally, among other factors. This is a complex undertaking, but one that is necessary for understanding the true risk of interference to Globalstar's duplex system, upon which a framework for coexistence can be built. This approach represents a progression in the state of the art of interference analysis, beyond simplistic models and toward an understanding of realistic interactions. Through this simulation we find further confirmation of our conclusions that UNII-1 technical rules can be updated to enable greater Wi-Fi use without significant risk to Globalstar.

4.1 Overview of the Dynamic Method

Our goal in this analysis is to determine a real-world upper-bound level of interference risk to Globalstar's duplex system, in order to gauge the likelihood of an impact to satellite phone users.[22]

To facilitate this, we track the path of each of the 24 satellites in Globalstar's constellation as they orbit the Earth, which enables us to know how many Wi-Fi access points each satellite "sees" at any given point in time. With information about Wi-Fi deployment, both in total number and in geographic distribution, we calculate the distance of each access point to each satellite at any given time to obtain a true understanding of Wi-Fi signal path loss, and integrate information about the likelihood of signal losses due to ground clutter. We can account for characteristics

---

[21] Globalstar has 84 total satellites, but we incorporate only the 24 that we believe are currently in use for duplex service.

[22] We also explore both peak and average levels of interference risk; we find average levels to be significantly lower than peak.

of Wi-Fi antennae, and for the episodic usage of Wi-Fi by consumers. In this manner we characterize the level of Wi-Fi "noise" added to Globalstar's constellation.

Next, we translate this simulation to duplex system capacity impact using the link budget provided in the Roberson Report. This provides a framework for estimating the impact to end users of the satellite system. We note, however, that we have no basis for judging the accuracy of the link budget provided by Roberson. It is possible that the duplex system has more margin for noise than estimated using this framework, and therefore the capacity impact estimates we present here may overstate what might be realized in the real world.

We present a means of simulating real-world coexistence in UNII-1, though we do make several simplifying assumptions in the presentation to avoid arbitrary precision. Where simplifying assumptions have been made, they are clearly identified and calibrated to avoid understating interference risk. For example, we assume that all access points transmit at 1-watt power, which is highly unlikely to be observed across all deployments even if allowed by FCC rules. In calibrating our parameters to the upper end of the possible, we note that even our simulation may be interpreted as an overstatement of interference risk. We acknowledge this and do not intend to set precedent for assumption calibration in other interference analyses. Rather, we conduct a thought experiment to determine the upper bound of interference risk in the real world.

This simulation involves several large and dynamic data sets, as well as significant computation. IPython was used as the software tool to bring this data together in the simulation and produce results.[23]

4.2 Components of the Simulation

We now describe the key components of the simulation and the values we associate with each driver in our presentation.

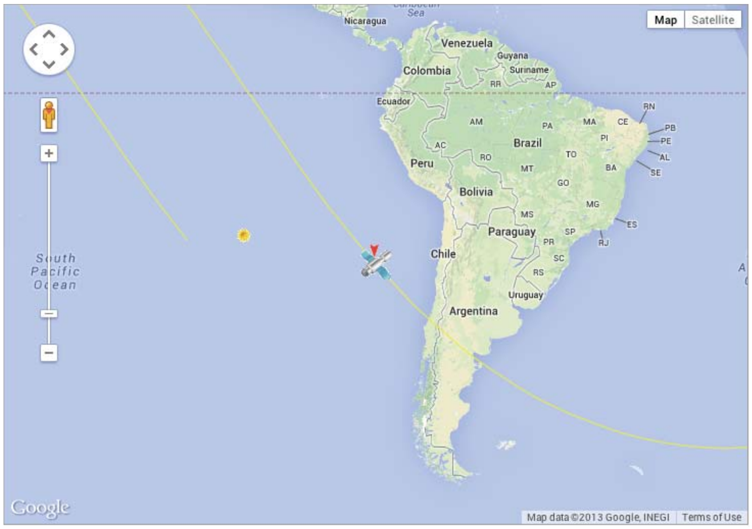
4.2.1 Tracking the Globalstar Constellation

We begin with an inventory of the Globalstar constellation of non-geostationary, low Earth orbit satellites. Each of Globalstar's 24 satellites can be tracked in real time using publicly available information.[24] For example, at approximately 19:00 UTC on

[23] IPython is a powerful open source computing resource, supported in part by Microsoft and the Sloan Foundation. See: http://ipython.org

[24] Found at: http://www.n2yo.com/satellites/?c=17

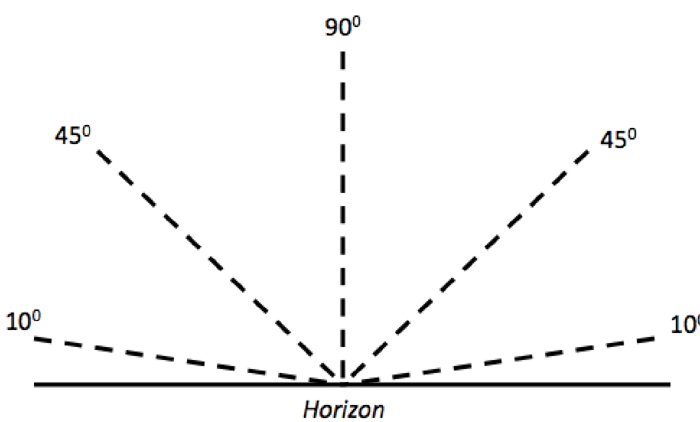
December 31st, 2013, Globalstar satellite M097 was orbiting off the Pacific coast of South America at 1422 km altitude, as seen below.



GLOBALSTAR M097	
LOCAL TIME:	12:06:28
UTC:	19:06:28
LATITUDE:	-29.41
LONGITUDE:	-80.82
ALTITUDE [km]:	1422.66
ALTITUDE [mi]:	884
SPEED [km/s]:	6.82
SPEED [mi/s]:	4.24
AZIMUTH:	157.8 SSE
ELEVATION:	-28.7
RIGHT ASCENSION:	23h 6m 25s
DECLINATION:	-69° 40' 50"
Local Sidereal Time:	18h 47m 46s

Snapshot of A Satellite in the Globalstar Constellation

Globalstar has described each satellite in the constellation as having a 5800 km wide spot (diameter) for receiving signals from Earth. Satellite phone signals at the edges of this spot are unlikely to complete a reliable link; in general, an elevation angle above 10 degrees is needed to communicate with the satellite.[25]



Angles Above Horizon: Illustrative Reference

For this reason it would be reasonable to assume that Wi-Fi access points at an elevation angle lower than 10 degrees would not generate noise into a Globalstar

---

[25] For more information on Globalstar's system characteristics, see "Description of the Globalstar System", December 7, 2000, at: http://gsproductsupport.files.wordpress.com/2009/04/description-of-the-globalstar-system-gs-tr-94-0001-rev-e-2000-12-07.pdf

satellite. However, to ensure that we are not understating the potential risk of interference, in our presentation we will assume that all access points within the 5800 km spot of a satellite will be seen.

4.2.2 Simulating Wi-Fi Deployment

We then gather an estimate of the number of outdoor Wi-Fi access points that will be deployed, and where they will be deployed. Our critique of Globalstar's static model earlier noted that a significant number of access points will be deployed indoors, where there is no risk to Globalstar's system. However, for purposes of our current presentation, and again to avoid understating risk, we will carry forward Globalstar's base assumption of outdoor access point density, but refine it for greater geographic granularity.

Globalstar assumed approximately 16 access points per square kilometer for every urban area in the United States. However, an entire urban statistical area[26] was used to define urbanicity, despite variation in population density throughout. For example, the suburbs surrounding urban cores are included in the defined urban area, and in Globalstar's analysis a uniform access point density would apply throughout that area. In addition, Globalstar's analysis did not assume any access points were deployed outside of these areas (e.g., in rural areas).

Our simulation enables greater granularity in access point density by using zip code tabulation areas (ZCTAs) from the US Postal Service and Census Bureau.[27] ZCTA data entails both population and area data at a much more detailed level than broader urban areas used by Roberson – there are 33,120 ZCTAs across the United States, whereas there are only 486 urban statistical areas.

Using ZCTAs, we can distribute access points across the nation according to population density. To do so, we will use an urban / suburban / rural breakdown, with 16 APs per square km in urban areas (Roberson's estimate), 10 APs per square km in suburban areas, and 1 AP per square km in rural areas.

This more granular approach to estimating access point density yields a total number of approximately 3,120,000 APs. As noted earlier, our simulation accounts for the specific geographic distribution of these APs by ZCTA – therefore, we know the angle and distance of each AP to every Globalstar satellite at any given point in

---

[26] For more information on how urban areas are defined, see US Census Bureau, "Growth in Urban Population Outpaces Rest of Nation, Census Bureau Reports", March 26, 2012, at: http://www.census.gov/newsroom/releases/archives/2010_census/cb12-50.html

[27] ZCTA data available at: http://www.census.gov/geo/reference/zctas.html

time. To enhance accuracy in distance calculations, we account for ground elevation in each ZCTA as well.[28]

While 3.12 million APs is less than the 4.4 million assumed in the Roberson Report, we observe that no adjustment has been made for the significant proportion that are likely to be deployed indoors (and thus pose no risk to Globalstar). This factor is significant; for example, industry-consensus interference modeling generally assumes approximately 95% of APs are deployed indoors.[29] In effect, therefore, our simulated population of APs deployed has significant allowance for Wi-Fi growth.

4.2.3 Characterizing the Wi-Fi Signal

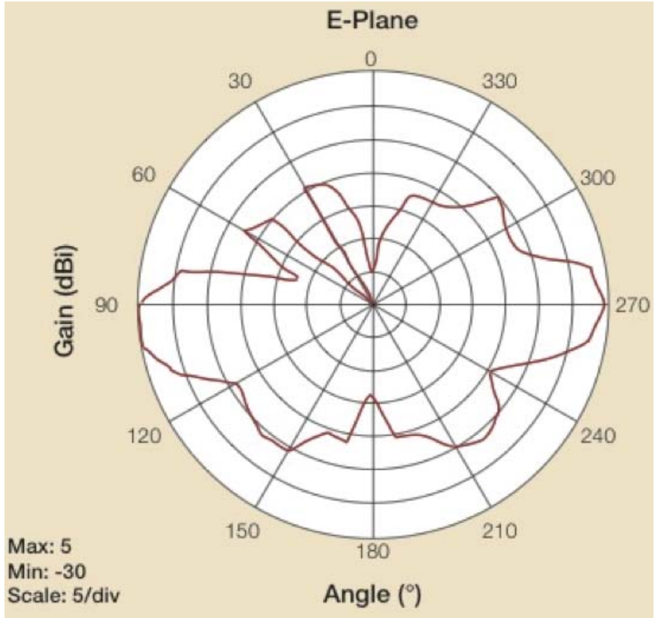
There are several discrete considerations in characterizing the Wi-Fi signal. First and most straightforward is the assumed transmit power. For purposes of our simulation, we will assume that every one of the 3,120,000 APs is transmitting at 1 watt. While this is not a realistic scenario – even if FCC rules allowed for 1 watt transmit power, many access points would operate well below that level – we use this base parameter to avoid understating interference risk.

Also relevant to determining the level of Wi-Fi signal seen at the satellite is the antenna pattern, or the amount of gain from the AP in different directions. For this parameter, we will use a common antenna pattern as seen in a Ruckus AT-0636-VP access point.[30] As shown in the diagram below, most signal is directed outward and downward, to serve users on the ground. At nadir (zero degrees in the figure below), the signal is reduced by 25 dBi. This antenna pattern helps us determine the level of signal directed at each Globalstar satellite as it makes its orbit and positions itself at different angles to each AP.

[28] Elevation data from the US Geological Service, found at: http://gisdata.usgs.net/xmlwebservices2/elevation_service.asmx

[29] *Document 4-5-6-7/CG-Cisco*, ITU-R Study Groups, October 2, 2013.

[30] The Ruckus AT-0636-VP has an omnidirectional antenna. Specs are available here: http://www.ruckuswireless.com/products/external-antenna-options



Representative 5 GHz Wi-Fi Antenna Pattern

In addition to transmit power and antenna pattern, another factor impacting the Wi-Fi signal seen at the satellite is the level of ground clutter. At low elevation angles of below 10 degrees, ground clutter may reduce the Wi-Fi signal by 10 dB. As the satellite reaches higher elevation angles clutter will have less impact on the Wi-Fi signal, and we assume that angles of 30 degrees or higher will have no associated clutter losses.[31] This is a relatively conservative clutter loss construct; outdoor deployments in areas with tall buildings will entail greater losses and will experience them at much higher angles.

Also of importance to characterizing the Wi-Fi signal is the duty cycle, or the proportion of time that access points will be transmitting. As noted in Section 3, empirical studies have observed peak duty cycles of 10% at the 95th percentile.[32] The impact to Globalstar's duplex system will be driven not by a static duty cycle number, but by human usage of Wi-Fi in real time.[33] For this reason it is appropriate to characterize duty cycles over a 24-hour period that depict higher usage at peak periods, which will vary by time zone. Again, to be conservative we will chose a higher peak than empirical observations suggest – 40%, rather than 10%, as shown below. In addition, we note again that the simultaneous use of APs is driven by

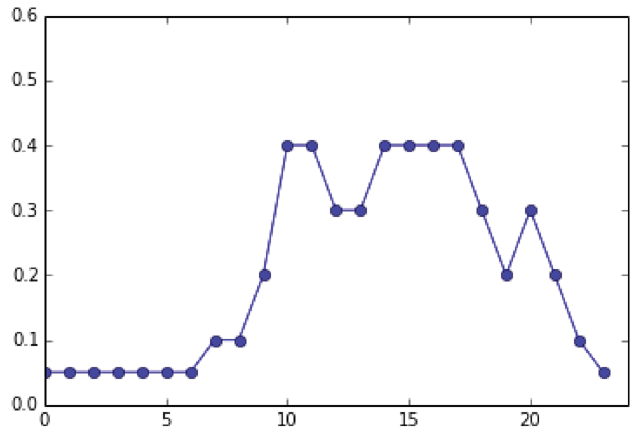
---

31 Yoshikawa & Kagohara, "Propagation characteristics in land mobile satellite systems", IEEE 39th Vehicular Technology Conference, 1989.
http://ieeexplore.ieee.org/xpl/articleDetails.jsp?arnumber=40130

32 Joseph et al., 2012.

33 Hourly activity based on usage patterns depicted by Rodrig et al., "Measurement-based Characterization of 802.11 in a Hotspot Setting", presented at SIGCOMM, 2005. Note that measurements were taken indoors in a conference setting with high demand that is not representative of outdoor usage levels, but temporal patterns provide a basis for analysis.

probability; even the temporal depiction of Wi-Fi duty cycles shown here likely overstates the actual simultaneous use that will drive interference risk.



Wi-Fi Duty Cycles Over A 24-Hour Period

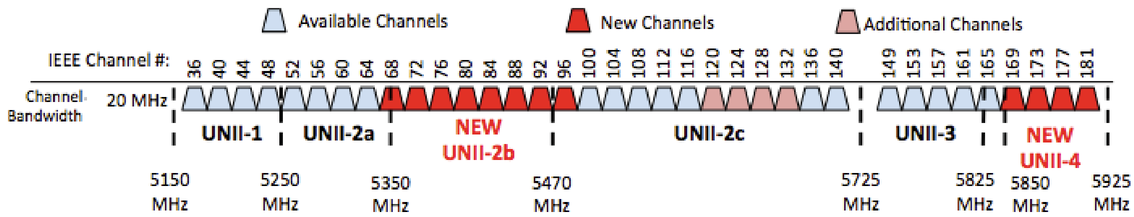
Finally, we must also know how many channels are in use by the access point, in order to determine the possible concentration of Wi-Fi signal in the UNII-1 band that is shared with Globalstar. Most APs that use the 5 GHz band rely primarily on the UNII-3 sub-band in light of its favorable access rules; in addition, APs also use the 2.4 GHz ISM band. Recognizing that the FCC is considering how best to expand Wi-Fi access, we will use a range of channels in our presentation.

In our base case, twelve 20 MHz channels are in use, consisting of the three non-overlapping channels in the 2.4 GHz band, as well as UNII-1 and UNII-3 in 5 GHz. Currently available UNII-2 channels (UNII-2 a and c) are not included in our base case because of the unique restrictions that apply to their use; however, these channels are authorized for use outdoors, so we do incorporate them into the upper bound of our range of channel availability.[34] In addition, the FCC may make other Wi-Fi spectrum available – another eight channels in UNII-2b, and four more channels in UNII-4 -- which we also include in the upper bound of our range. This provides a range of spectrum availability between twelve and thirty-nine 20 MHz channels.[35] The 5 GHz IEEE Wi-Fi band plan is shown below for reference.

---

[34] UNII-2 channels require the use of Dynamic Frequency Selection protocols.

[35] Again, this does not include the up to 150 megahertz of spectrum that the FCC has proposed to make available for Wi-Fi-like service at 3.5 GHz; including that spectrum as well would further reduce Wi-Fi “noise” in UNII-1.



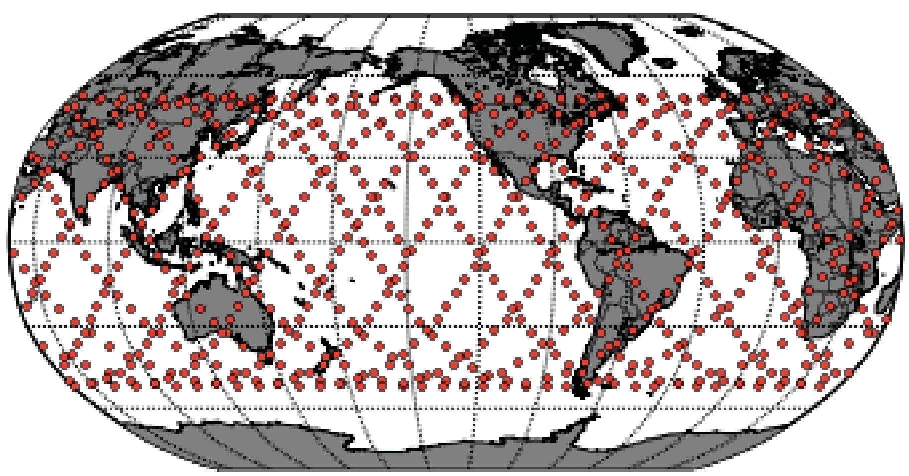
Wi-Fi Band Plan at 5 GHz

4.3 Putting the Components Together: Simulating Wi-Fi "Noise"

With the above components, we are able to simulate the level of Wi-Fi interference to each Globalstar satellite at any given point in time from any access point on the ground, accounting for how Wi-Fi use at different times of the day and in different locations will impact a satellite orbiting the Earth at over 15,000 miles per hour.

To do this, we begin by choosing a specific satellite to track, a specific period of observation, and a specific location on the ground.

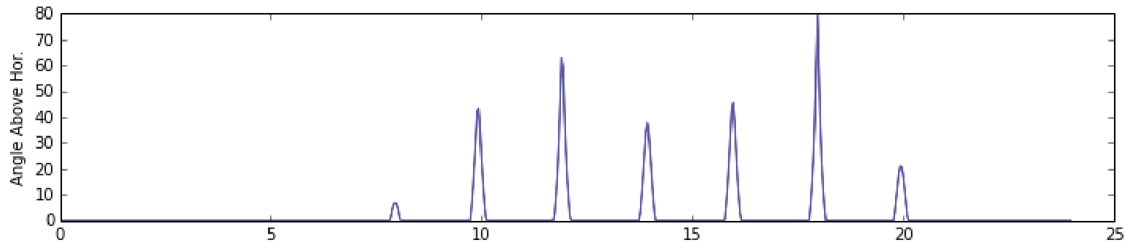
In our presentation we begin by tracking Globalstar satellite M088; the path of which over a 24-hour period is as follows:



24-Hour Path of Globalstar Satellite M088

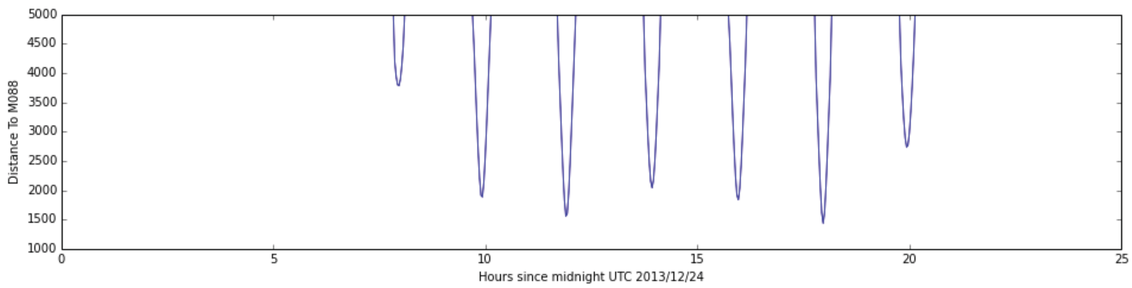
We will observe M088 from Lebanon, Kansas, the geographic midpoint of the United States. This will enable the satellite to see the entire contiguous states – and all APs within it -- when the satellite is close overhead.

On any given day, the angle from Lebanon to the satellite will change rapidly as the satellite orbits. The following figure shows the angle of M088 to the ground throughout the day. Note that for most of the day, the angle is zero (or lower) and the satellite is out of sight. For brief periods the satellite moves overhead of our chosen location; at its closest point, around 17:00 UTC, the satellite is 80 degrees to Lebanon.



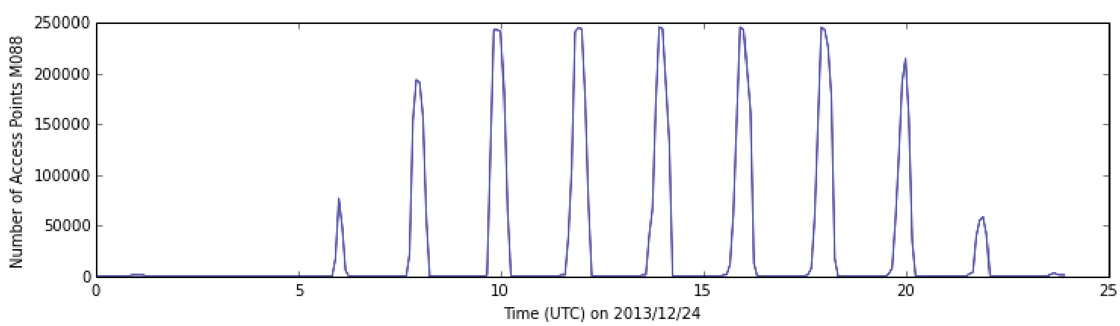
Angle of M088 to Lebanon, Kansas Throughout the Day

As M088 approaches Lebanon, the distance varies inversely with the angle, as shown in the figure below. At 17:00 UTC, M088 is at its closest point to Lebanon, at approximately 1800 km.



Distance of M088 to Lebanon, Kansas Throughout the Day

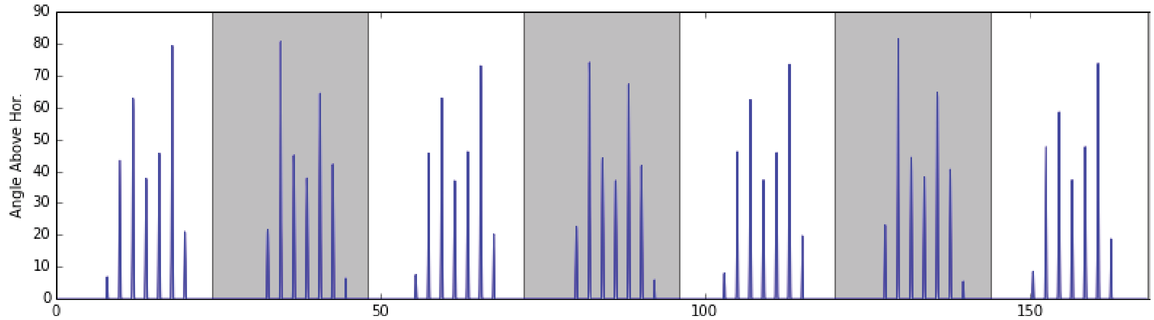
Coincident with its orbit over Lebanon, M088 is able to see Wi-Fi access points throughout the United States. The following figure shows the number of APs in view of M088 throughout the day, normalized to each of the twelve 20 MHz Wi-Fi channels in use today.



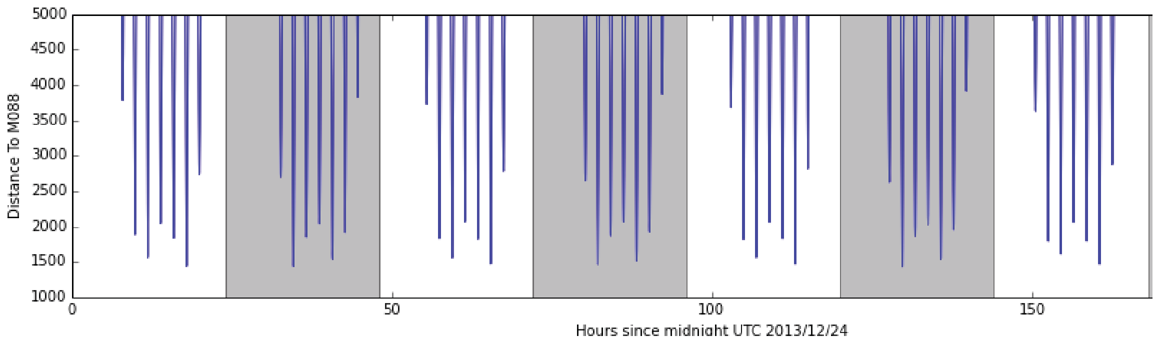
Number of APs seen by M088 As It Orbits Lebanon Throughout the Day[36]

[36] In this figure the peak number of APs by 20 MHz channel of 250,000 translates to 3 million total APs across all Wi-Fi channels.

To ensure that we are not choosing an unrepresentative 24-hour period of observation, we also observe the satellite over the course of a week. As shown in the below rendering of elevation angles and distances, the 24-hour periods are similar. This therefore means that the number of access points seen by the satellite is relatively consistent from day to day.



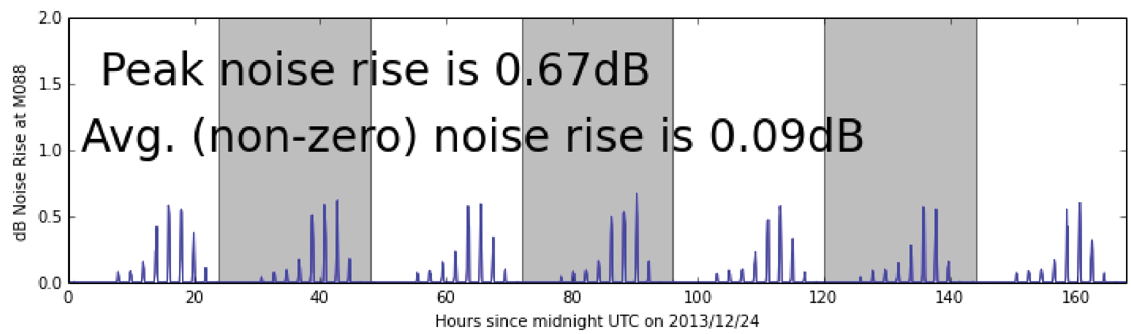
Angle of M088 to Lebanon Over A Week[37]



Distance of M088 to Lebanon Over A Week

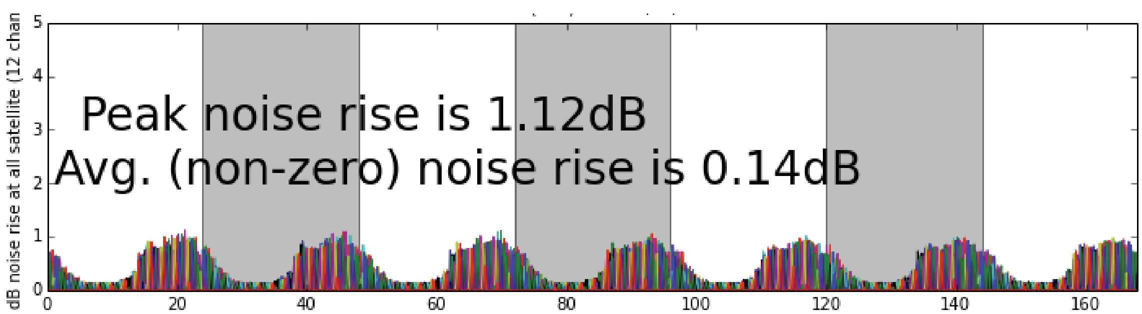
We can then estimate the Wi-Fi noise added to Globalstar's uplink as seen at M088 by accounting for the characteristics of the Wi-Fi signal specified earlier, such as the antennae pattern, duty cycle, and transmit power. As shown in the following figure, when the satellite is closest to Lebanon (nearly overhead), and Wi-Fi usage is highest, the level of noise seen at the satellite peaks. This noise level is relatively low, however, reaching only 0.67 dB.

[37] In graphics depicting week-long periods, 24-hour intervals indicated by shades.



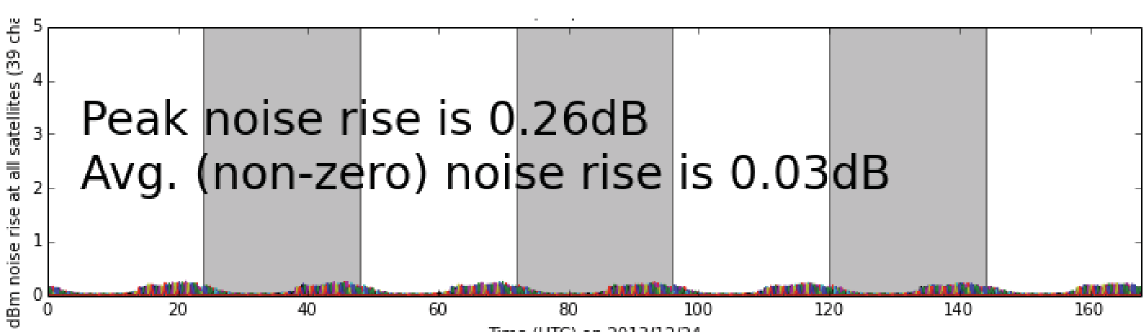
Uplink Noise Rise to M088 Over A Week

This analytic process can be repeated for all satellites in the Globalstar constellation to obtain a sense of the system-wide impact. This is depicted below, with each color representing a different satellite in the constellation. Note that the level of impact across all satellites is relatively uniform, and the peak uplink noise rise is approximately 1 dB.



Uplink Noise Rise to the Entire Globalstar Constellation Over A Week (12 Wi-Fi Channels in Use)

One can also obtain a sense of the impact if additional spectrum is available for Wi-Fi, which may be the case as the FCC expands Wi-Fi access across the 5 GHz band, and if currently available UNII-2 channels are considered. The effect would be to spread the signal across a greater range of bandwidth and further reduce the level of noise in Globalstar's uplink. This is shown below, where the peak noise rise is reduced by 75%, relative to the 12-channel scenario shown above.



Uplink Noise Rise to the Entire Globalstar Constellation Over A Week (39 Wi-Fi Channels in Use)

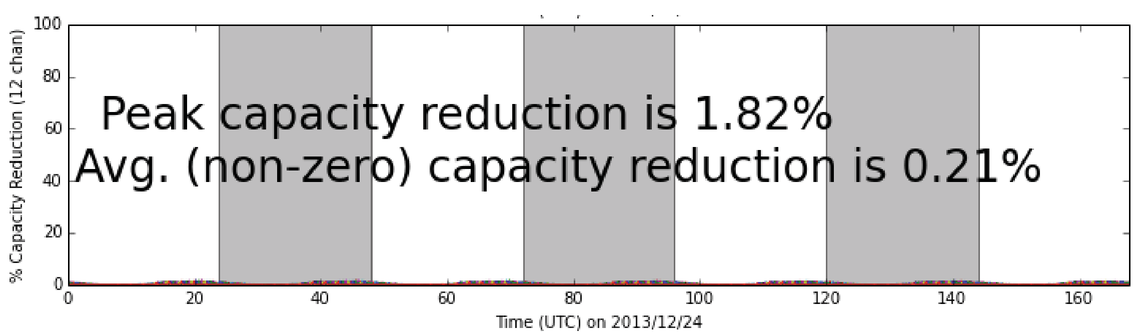
4.4 Results: Translating Wi-Fi "Noise" to Globalstar Capacity

The observations noted above are compelling: Millions of Wi-Fi access points deployed across the United States are likely to yield a very small amount of noise to the uplink in Globalstar's duplex system. We will now translate the simulated uplink noise rise to an estimate of impact on end users, using the link budget provided in the Roberson Report. Our approach takes Roberson's link budget information on its face, without judgment as to its validity.

The Roberson Report states that the combined carrier-to-noise level (C/N, also expressed as Eb/No+Io) with no additional interference from Wi-Fi is 1.01, which occurs when the downlink is 209.6 dBW/Hz.

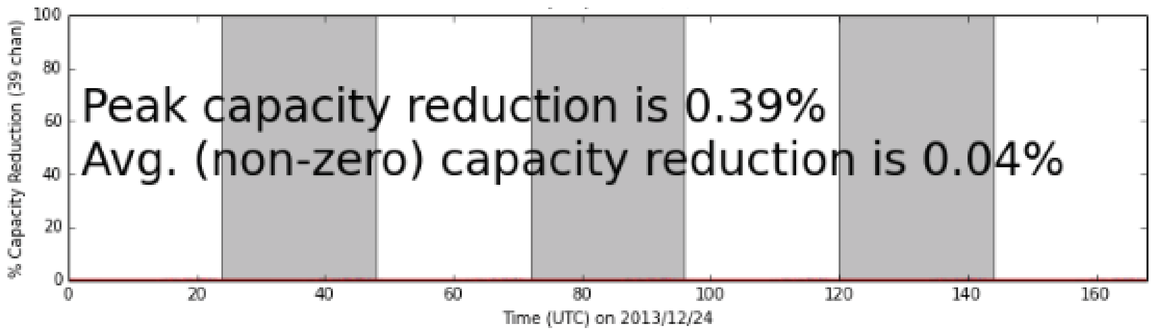
The implication is that the Globalstar duplex system will increase uplink power to adjust for new Wi-Fi noise in order to maintain a C/N of 1.01, which then causes a reduction in capacity. We make no judgment on the validity of this claim, but we use the framework to estimate the amount of capacity that would be sacrificed by Wi-Fi deployment in our simulation.[38]

We find that the peak amount of "capacity reduction", as the Roberson Report frames the metric, is 1.82% with twelve Wi-Fi channels in use, or 0.39% with thirty nine Wi-Fi channels in use. This is shown in the following figures, again over the period of a week as satellites orbit and Wi-Fi use waxes and wanes.



Capacity Impact to Globalstar Constellation (12 Wi-Fi Channels in Use)

[38] The Roberson Report states that a 10 dB uplink noise rise translates to a 55.4% reduction in capacity. (See Table 2 of Roberson Report, p.15.) We use this ratio as the basis for our estimates.



Capacity Impact to Globalstar Constellation (39 Wi-Fi Channels in Use)

These simulation results confirm our initial critique of the Roberson Report, and reveal how the implausible assumptions therein drive an unrealistic (and overly pessimistic) assessment of interference risk and its potential impact.

As demonstrated through a dynamic simulation of satellite system functioning and real-world Wi-Fi deployment parameters and signal characteristics, the risk to Globalstar's duplex system from expanding Wi-Fi use of UNII-1 is extremely small. The potential impact to duplex capacity, as judged by Globalstar's own link budget, is a de minimus 1.82% at peak, or less. Indeed, given the extremely conservative parameters of this simulation, which are reviewed in section 4.5 of this paper, one might reasonably expect that the average capacity effects – which are substantially lower than peak numbers – to be the more instructive output of the simulation.[39] In any case, unless Globalstar runs its system at 98% capacity regularly – again, unlikely given low subscribership – satellite phone users will experience no service diminution.[40]

Therefore, through two independent approaches – a basic critique of Globalstar's latest analysis, and a sophisticated simulation of coexistence – we find confirmation of our July conclusion that there is little to no risk of harmful interference to Globalstar's duplex system in expanding Wi-Fi access to UNII-1.

---

[39] We report *non-zero* averages of capacity impacts, which accounts only for the period of time in which the satellite is within site. This metric therefore avoids understating average impacts by including periods of time when the satellite is orbiting elsewhere.

[40] The Roberson Report also claims potential harm resulting from small coverage reductions and satellite battery usage. Insufficient information has been provided by Globalstar to verify these claims or assess them relative to the simulation presented here. We do however note that in Globalstar's petition for rulemaking in the 2.4 GHz Terrestrial Low Power Service proceeding, relief was requested from coverage requirements associated with its satellite licenses; therefore, it is unclear what value Globalstar places on satellite service coverage. See *Petition for Rulemaking of Globalstar Inc.*, November 13, 2012, at http://www.globalstar.com/en/ir/docs/FCC12-Petition_for_Rule_Making_Nov_13th.pdf.

4.5 Sensitivity of Results

It is worth reviewing the many conservative parameters we have used in our presentation to avoid understating interference risk.

We have made no adjustment for the proportion of access points that may be deployed indoors, whereas well-over half of CableWiFi access points, for instance, are deployed indoors, and the broader population of access points are likely to heavily skew toward indoor deployment. In commonly accepted interference analyses, 95% of APs are assumed to be located indoors, so our presentation here is extremely conservative, and has significant allowance for Wi-Fi growth. Incorporating a proportion of indoor access points to the presentation would further reduce the impact of Wi-Fi on the Globalstar system.

In our simulation all APs transmit at 1 watt, which is at the upper end of what the FCC may permit in the band. Even if FCC rules allowed for 1 watt transmit power on access points, many APs would operate below the maximum threshold, as they do today for a number of network engineering reasons.

Our simulation also enabled Globalstar satellites to "see" APs anywhere above the horizon, rather than to cut off Wi-Fi signals below 10 degrees to correspond with the normal sight of satellite user terminals. In addition, we do not incorporate terrain information that would further reduce Wi-Fi signals.[41] In effect, our simulation intentionally over-estimates the proportion of access points that any satellite is likely to "see" in actuality.

Also, we do not adjust for the extremely low probability that APs will experience simultaneous use at significant levels. As described earlier, peak interference risk is in large part a function of simultaneous use of Wi-Fi at any given moment. Simultaneous use is, in turn, a function of both duty cycle (the proportion of time that a single AP transmits) and probability (the likelihood that many APs will be transmitting at the same time). Simultaneous use is likely to be low, even with high duty cycles, due to probabilities. We do not factor probability effects in our simulation, but rather take the simpler duty cycle parameter alone.

All of these factors combine to a conservative simulation, and are presented here to demonstrate that a real-world simulation, even one that may be "worst case," yields favorable prospects for coexistence.

We are confident that any reasonable set of inputs will yield the same conclusions we have reached. For instance, in our research we have run a version of the simulation that more closely adheres to the implausible assumptions of the

[41] For example, Boulder, Colorado lies directly east of the Rocky Mountain foothills; Wi-Fi signals from Boulder are not likely to be visible to a satellite until it is well overhead.

Roberson Report[42] and we achieved results that are not materially different, varying from our main capacity impact findings by only a percentage point or two.

In addition, we must also reiterate that the “capacity reduction” estimates we provide here rely on the link budget depicted in the Roberson Report, and we have undertaken no independent assessment of the validity of that link budget. We have used the Roberson noise to capacity ratio[43] and applied it to our simulation of uplink noise generation. Since capacity and coverage (range) are interrelated, valid questions may exist about the baseline from which the Roberson Report estimates capacity impacts.

5 Conclusion

This paper has demonstrated that Wi-Fi and Globalstar can share the 5 GHz UNII-1 band under updated technical rules that remove current limitations on Wi-Fi, such as outdoor use restrictions and onerous power limitations. This conclusion is consistent with our earlier work, which was submitted to the FCC in July, 2013.

As we have reviewed in detail, the pessimistic coexistence outlook offered by Globalstar relies on an implausible set of assumptions pertaining to Wi-Fi deployment. Simple adjustments – such as accounting for all available Wi-Fi spectrum, and the fact that Wi-Fi access points do not continuously transmit – would change Globalstar’s analytic conclusions dramatically. Instead of a capacity diminution of 56% as Globalstar projects, these simple adjustments indicate that a less than 1.5% impact is a more likely result under its proffered framework.

This conclusion is consistent with both our July, 2013 analysis and our newly developed dynamic simulation of coexistence in UNII-1, which we offer in this paper to fully inform the policy process and account for the real-world complexities of the radio frequency environment. We have simulated the upper-bound level of Wi-Fi noise that could be experienced by each of Globalstar’s 24 satellites as they orbit the Earth at over 15,000 miles per hour, accounting for their view of Wi-Fi access points at any given moment and the related signal characteristics that will impact a Globalstar user’s experience.

In this sophisticated approach, we find confirmation of our initial observation that the impacts to capacity of Globalstar’s duplex system – as judged by its own link budget – is likely to be a *de minimus* 1.8% or less, even with several conservative parameters in our presentation. Since Globalstar’s duplex service has less than

---

[42] Such as 80% peak duty cycle and density of 16 access points per square kilometer across both suburban and urban areas.

[43] 10 dB addition of uplink noise = 55.4% capacity diminution. See Table 2 of Roberson Report, p.15.

85,000 subscribers globally, satellite phone users are extremely unlikely to experience any service diminution as a result of Wi-Fi deployment in UNII-1.

These results confirm previous showings of little to no risk of harmful interference to Globalstar's satellite system, including previous findings by the authors, and support the FCC's proposal to expand Wi-Fi access in 5 GHz.