Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band	GN Docket No. 12-354

REPLY COMMENTS OF GOOGLE INC. ON THE FURTHER NOTICE OF PROPOSED RULEMAKING

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August 15, 2014

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I. INTRODUCTION AND SUMMARY.

Comments on the Further Notice of Proposed Rulemaking ("FNPRM")[1] demonstrate that the Commission has an opportunity to transform the 3.5 GHz band into a platform for innovation and a resource for economic growth. Google agrees with other commenters that, to seize this opportunity, the FCC should:

1. Implement smaller, dynamic exclusion zones rather than those identified in the National Telecommunications and Information Administration's ("NTIA") Fast Track Report.

2. Adopt operating and licensing rules that take full advantage of Spectrum Access System ("SAS") capabilities. In particular, the Commission should:

    - Finalize flexible rules that enable a wide range of small cell operations rather than tailoring its regulations to a narrow set of uses;

    - Adopt its proposed three-tier licensing framework and assign spectrum dynamically;

    - Create Priority Access License ("PAL") areas based on interference protection criteria rather than ill-fitting geographic boundaries; and

    - Protect incumbent satellite earth stations efficiently by using real-world information rather than worst-case interference assumptions.

3. Ensure impartial SAS administration without undermining service competition.

The following reply comments and accompanying technical declarations focus on these three critical points.

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[1] *Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band*, Further Notice of Proposed Rulemaking, FCC 14-49, 29 FCC Rcd. 4273 (2014) ("FNPRM").

II. SMALL, DYNAMIC EXCLUSION ZONES WILL PROTECT INCUMBENTS WHILE ENCOURAGING INVESTMENT IN THE 3.5 GHZ BAND.

The record leaves no doubt that the Commission must revise its proposed exclusion zones for incumbent federal radar systems.[2] Not a single commenter supports the Commission's plan to codify the exclusion zones set forth in the NTIA Fast Track Report, even as a "starting point" for a possible reduction of those zones in the future.[3]

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[2] *See, e.g.*, Comments of 4G Americas at 2-3; Comments of Alcatel-Lucent at 7 ("[T]he current exclusion zone proposal in no way represents the type of innovative sharing mechanisms needed to combat our growing spectrum crunch.") ("Alcatel-Lucent Comments"); Comments of American Petroleum Institute at 11 (proposed exclusion zones "will constrain investment and hamper equipment development, particularly for the oil and gas industry") ("American Petroleum Institute Comments"); Comments of AT&T at 34 ("AT&T Comments"); Comments of CTIA at 11 (proposed exclusion zones would render the band "essentially non-viable for commercial purposes") ("CTIA Comments"); Comments of Dynamic Spectrum Alliance, WhiteSpace Alliance, and Public Interest Spectrum Coalition at 1 ("Coalition Letter"); Comments of Ericsson at 10-11 ("Ericsson Comments"); Comments of Federated Wireless, Inc. at 6 ("Federated Wireless Comments"); Comments of Iberdrola USA Networks at 6; Comments of Microsoft Corporation at 6-7 ("Microsoft Comments"); Comments of Mobile Future at 6 ("Mobile Future Comments"); Comments of Motorola Mobility LLC at 12-13; Comments of National Cable & Telecommunications Association at 6 ("Operating rules for a wireless service that deny access to most Americans simply will not attract the investment needed for widespread network deployments.") ("NCTA Comments"); Comments of Nokia Solutions and Networks US LLC at 20-21 ("Nokia Comments"); Comments of Qualcomm Incorporated at 7 (proposed exclusion zones "will cripple the usefulness and value of the band to support mobile broadband") ("Qualcomm Comments"); Comments of Shure Incorporated at 5; Comments of Southern Company Services, Inc. at 2-3; Comments of Telcordia Technologies, Inc. d/b/a iconectiv at 6 ("[T]he size of the Exclusion Zones for protecting federal incumbents along the coasts of the U.S. as proposed in the *Further Notice* is currently so large as to discourage use of this spectrum by commercial entities."); Comments of Telecommunications Industry Association at 4; Comments of T-Mobile USA, Inc. at 6 ("[T]he currently proposed Exclusion Zones effectively make the band unusable.") ("T-Mobile Comments"); Comments of Verizon at 5 ("Verizon Comments"); Comments of Wi-Fi Alliance at 14 ("WFA Comments"); Comments of Wireless Internet Service Providers Association at 17 ("WISPA Comments"). Unless otherwise noted, all comment citations herein are to comments filed on July 14, 2014 in GN Docket No. 12-354.

[3] *See* FNPRM ¶ 141.

First, it is unnecessary and inappropriate for the Commission to use exclusion zones to protect commercial operations from federal users in this band.[4] This would be contrary to the Commission's longstanding rule that lower-tier operations must accept interference from higher-tier users. Therefore, in contrast to NTIA's approach,[5] the Commission should consider only the potential for harmful interference to federal systems when determining appropriate exclusion zones. Doing otherwise would set a dangerous precedent in spectrum management, render the 3.5 GHz band unattractive for investors, and deter innovation by restricting commercial operations based on speculative predictions about the amount of interference they will be able to tolerate.[6]

Second, even if the Commission considers interference from federal users to commercial users when calculating exclusion zones, Google's recent tests independently confirm that the

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[4] *See, e.g.*, Alcatel-Lucent Comments at 7 ("PAL and GAA users should be permitted to assume the risk of such interference [from federal incumbents], without the federal government paternalistically prohibiting commercial operations due to the federal government's interference into the new commercial service."); Ericsson Comments at 11; Federated Wireless Comments at 10-11; Coalition Letter at 1; Microsoft Comments at 9 ("Technology may have to be developed to protect GAA (and PA) CBSD and end user devices from the peak field strength emitted by federal incumbents operations [*sic*], but that is an activity that the private sector will have every incentive to address."); NCTA Comments at 8 (enabling operators to decide whether to deploy in a particular spectrum environment "may well lead to significant innovation in device performance and spectrum utilization, just as occurred after the Commission opened up the 2.4 GHz band, formerly regarded as a 'junk' band, for wireless broadband use"); WFA Comments at 15; Wireless Innovation Forum Comments at 4-5 (noting that exclusion zones designed exclusively to protect primary systems from secondary systems have been successful in TV bands).

[5] *See* NTIA, *An Assessment of the Near-Term Viability of Accommodating Wireless Broadband Systems in the 1675-1710 MHz, 1755-1780 MHz, 3500-3650 MHz, and 4200-4220 MHz, 4380-4400 MHz Bands* at 1-7 (rel. October 2010) ("Fast Track Report").

[6] *See* Executive Office of the President, President's Council of Advisors on Science and Technology, *Report to the President: Realizing the Full Potential of Government-Held Spectrum to Spur Economic Growth* at 8-9 (July 2012) ("PCAST Report").

FNPRM's proposed exclusion zones are excessive. The FCC bases the proposed exclusion zones on those suggested by NTIA, which drew its zones in part to protect commercial base stations from military radar systems.[7] The distance at which radar will cause interference into small cell networks, however, is much smaller than that calculated in the Fast Track Report. For example, the Fast Track Report predicted interference from the primary incumbent radar into a wireless network at a distance of up to 361 kilometers.[8] As shown in Appendix A, however, real-world tests using an actual incumbent radar and an LTE picocell demonstrate that co-channel LTE/radar operation is possible *with no discernible impact on the LTE network at a distance of only 4 kilometers*.[9] This results in exclusion zones about 90 times smaller in distance and over 8,000 times smaller in area than those calculated in the Fast Track Report.[10] Laboratory testing suggests that LTE performance can remain strong with separation distances from the radar of as little as 0.6-1.4 kilometers.[11] Laboratory testing of Wi-Fi devices produces similar results for operations that are not co-channel with radar.[12] Google's previous test results also showed that the large exclusion zones originally proposed by NTIA are not necessary to protect

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7 *See* Fast Track Report at 1-7.

8 *Id.* at 4-66, 4-72 (calculating East Coast exclusion zone for "Shipborne Radar – 1" as 361 kilometers).

9 Appendix A, Declaration of Andrew W. Clegg, Ph.D. ¶ 24 (August 14, 2014) ("Clegg Declaration").

10 *Id.*

11 *Id.* ¶ 23.

12 *Id.* ¶¶ 32-33.

federal operations against interference from small cell deployments.[13] These findings complement analyses submitted by other commenters.[14]

Third, the Commission should adopt an engineering-based protection standard for federal incumbents rather than static, fixed exclusion zones.[15] As Federated Wireless has observed, "fixed geographic frequency assignments [would] lead[] to significant spectrum and market inefficiencies."[16] This is because incumbent ship-borne radar systems are not static or fixed. The incumbent systems are quintessentially mobile, and have "highly varying spectrum usage patterns."[17] Moreover, fixed exclusion zones do not take into account deployment conditions for commercial operations at a specific location, such as local terrain and whether a Citizens Broadband Radio Service ("CBRS") network is operating indoors or outdoors.[18]

As noted in prior comments, Google has deployed a prototype Dedicated Listening Device ("DLD") to identify the presence of incumbent radar systems so that a SAS can determine dynamically when and where an exclusion zone is necessary.[19] This research indicates that it is straightforward to detect the presence of ship-borne radar operations even

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[13] *Id.* ¶¶ 37-39.

[14] *See*, *e.g.*, Comments of Interdigital Inc. at 4, GN Docket No. 12-354 (filed Feb. 20, 2013) (exclusion zone distances can be cut dramatically); Qualcomm Comments at 2, 17, GN Docket No. 12-354 (filed Feb. 20, 2013) (exclusion zones can be reduced from hundreds of miles to tens of miles); Reply Comments of T-Mobile USA, Inc. at 10, GN Docket No. 12-354 (filed Apr. 5, 2013) (urging the Commission to reduce exclusion zones proposed by the NTIA after verifying Qualcomm's analysis).

[15] *See* Federated Wireless Comments at 1-16; Comments of Google Inc. at 10 ("Google Comments").

[16] Federated Wireless Comments at 13.

[17] *Id.*

[18] Google Comments at 10.

[19] *Id.* at Appendix A ¶ 10.

beyond the visual horizon, at a distance of more than 50 kilometers.[20] At that distance, even scores of CBRS devices operating at full power from a high-rise located directly on the shore, each using an outdoor antenna pointed directly back at the radar, would not create aggregate interference above the -10 dB I/N objective of the radar.[21] In short, a DLD is able to detect incumbent operations and inform a SAS of the need to protect the frequency long before the incumbent receives harmful interference from secondary devices. Even if incumbent operations begin suddenly, close to land, the DLD will detect the operations, and the SAS will be able to command local devices to avoid the frequency.[22]

Several commenters have proposed re-conceptualizing exclusion zones as "coordination zones."[23] This is not necessary. As explained above, the zones established to protect incumbents should change dynamically based on when and where federal incumbent systems are in use. If the Commission adopts this approach, federal operators would not be at risk of harmful interference anywhere they operate, so there would be no need for a time-consuming, mutually burdensome coordination process in which each user seeks permission from federal operators to access a static exclusion zone.[24] To be sure, the Commission's rules should *allow* federal

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[20] *Id.* ¶ 11.

[21] *Id.* ¶¶ 11-12.

[22] *See id.* ¶ 12. Further, Google understands that the principal operations supported by the incumbent radar—flight operations on large-deck amphibious ships—generally are not conducted close to shore, and therefore near-shore operations are likely to be related to tests and maintenance of the incumbent radar. Clegg Declaration at ¶ 39.

[23] *See, e.g.*, T-Mobile Comments at 7-8; Ericsson Comments at 12; Mobile Future Comments at 6-7.

[24] *Cf.* Verizon Comments at 6 (advocating protective zones in which licensees could operate "if the government incumbent has determined that the licensee has in place the security and control protocols needed to adequately protect the incumbent from harmful interference"); Mobile Future Comments at 6 (arguing that "parties may be able to voluntarily coordinate to increase operations and mitigate any interference concerns through practical solutions").

operators to coordinate with commercial entities if they wish to do so. In such cases, a SAS could record such agreements and make spectrum available accordingly. The Commission should not, however, permit the possibility of voluntary coordination with federal users to obscure the critical need to avoid over-protection of federal incumbents, nor should it revert to the sort of resource-intensive, unpredictable coordination process that the SAS was conceived to replace.

III. RULES THAT TAKE FULL ADVANTAGE OF SAS CAPABILITIES WILL ENABLE INNOVATION.

As the PCAST Report concluded, "[a] well-designed [f]ederal spectrum policy opens up opportunities for innovation and growth in sectors that are barely imagined, much less well-defined, when the policy choice is made."[25] In order to implement such a policy, the Commission should prioritize flexibility for a range of CBRS operations and resist calls to force a traditional, macrocell licensing framework onto shared, small cell use of the 3.5 GHz band.

A. The Commission Should Adopt Flexible Rules To Enable Diverse, Efficient Small Cell Operations.

The Commission has recognized the opportunity small cells present to "turn some of the perceived disadvantages" of the 3.5 GHz band, such as limited signal propagation, "into advantages."[26] Accordingly, the Commission should reject calls to allow excessive power levels,

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[25] PCAST Report at 39.

[26] *Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band*, Notice of Proposed Rulemaking, FCC 12-148, 27 FCC Rcd. 15594 ¶ 20 (2012); *see also* FNPRM ¶ 12 ("The combination of small cells and spectrum sharing technologies could vastly increase the usability of the 3.5 GHz Band for wireless broadband and serve as a model for future coexistence among services in other spectrum bands.").

oversized license areas,[27] and other operating parameters that are inappropriate for small cell operations.[28] The power levels currently in use for femtocells and unlicensed consumer access points are appropriate for the 3.5 GHz band. A limit of 36 dBm for these devices has proven to be high enough to allow network operators to achieve dense operation in other bands, while also permitting efficient reuse of spectrum by nearby transmitters. Since making vast amounts of additional spectrum available for macrocell-type network deployments is not realistic, spectrum reuse is necessary to address the huge demand for more wireless capacity. And, as found by the PCAST and the Commission, the 3.5 GHz band is an ideal location for developing rules that facilitate reuse.[29] The Commission therefore should adopt rules that are geared to achieving the spectrum reuse that is essential to meeting wireless demand.

Within the framework of small cell operations, the Commission should accommodate a wide range of Priority Access and General Authorized Access ("GAA") operations and approaches instead of catering to any particular existing technology. Thus, while incumbent mobile carriers and their suppliers largely envision this band as a home for heterogeneous networks ("HetNets") and other conventional licensed network deployments using LTE

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[27] Small cells generally have a range of 10 meters to several hundred meters. Small Cell Forum, *Small cells – what's the big idea* at 2 (Feb. 15, 2012), *available at* http://www.smallcellforum.org/Files/File/SCF-Small_Cells_White_Paper.pdf. As discussed below, large geographic units like census tracts or counties are a poor proxy for the coverage provided by small cells. *See* Section III.D, *infra*.

[28] *See, e.g.*, CTIA Comments at 9 (urging the Commission to allow higher power levels for outdoor PAL use); Ericsson Comments at 10 (arguing that the proposed power limits should support a range of uses, including macrocells); Verizon Comments at 8 (arguing that at least +30 dBm maximum power limitation with a maximum antenna gain of 17 dBi—EIRP of approximately 47 dBm—is required "to support outdoor wide area coverage 'base station' uses").

[29] *See* PCAST Report at 51, 82; FNPRM ¶¶ 3, 12.

technology,[30] the Commission should decline to pick winning technologies or business models. Flexible rules should make available sufficient spectrum for PAL deployments by traditional mobile operators and other interested licensees with different plans, while also allowing GAA users to access designated spectrum as well as any PAL spectrum that otherwise would lie fallow.[31]

Even if failing to tailor the rules to promote expansion of major carriers' networks does make the band somewhat less attractive for a few established operators in the short term, the long-term benefits of using the band to "promote a diverse array of network technologies" far outweigh that consequence.[32] The FCC's experience with unlicensed bands demonstrates the point. Because the Commission insisted on neutral rules, a wide array of unlicensed spectrum technologies now contribute over $200 billion to the U.S. economy each year, and that number is increasing at an astounding rate.[33] The Commission's neutral rules in the 2.4 GHz and 5 GHz bands allowed innovators to make investments in new, risky, and lower-cost technologies that

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[30] *See* AT&T Comments at 18 ("Given the difficulties associated with real-time interference coordination and cancellation, AT&T submits that PALs should have specific frequency assignments within a defined service area and frequency assignments should not be dynamically controlled by the SAS. As indicated above, PALs in the 3.5 GHz band could play an important role in carriers' deployment of HetNets."); Ericsson Comments at 1-2; Qualcomm Comments at iii ("[B]y using a simpler two tier spectrum access framework, such as ASA, and relying on an existing cellular technology such as LTE, the 3.5 GHz band can be put to use quickly to help expand mobile network capacity for American consumers."); *see generally* T-Mobile Comments.

[31] *See* Comments of Google Inc. at 10, GN Docket No. 12-354 (filed Feb. 20, 2013).

[32] FNPRM ¶ 2.

[33] Raul Katz, *Assessment of the Economic Value of Unlicensed Spectrum in the United States*, at 8-9 (Feb. 2014), *available at* http://www.wififorward.org/wp-content/uploads/2014/01/Value-of-Unlicensed-Spectrum-to-the-US-Economy-Full-Report.pdf.

are driving the tech economy today. The Commission should not undermine the potential of the 3.5 GHz band to provide similar opportunities.

Several commenters maintain either that the Commission should not apply the new CBRS rules to the 3650-3700 MHz band, or that users operating in the band under Part 90 Subpart Z should be entitled to operate under those rules indefinitely, even after the Commission applies the new rules to this portion of the spectrum.[34] These approaches, too, would favor some operations over others. As Google has noted, incorporating a full 150 MHz of spectrum increases the attractiveness and functionality of the band for a diverse array of wireless operations, and will give all CBRS users greater flexibility to operate in the presence of incumbent federal operations.[35] The Commission should grandfather existing fixed wireless uses in the 3650-3700 MHz band for a transition period,[36] and otherwise prioritize regulatory simplicity, flexibility, and neutrality – and certainly should not carve up the band by adopting different rules for different frequencies.

B. A Three-Tier Framework with Dynamically Assigned PAL and GAA Channels Will Maximize the Utility of the 3.5 GHz Band.

Some commenters suggest that the Commission should abandon its proposed three-tier sharing framework. These commenters seek either a permanent two-tier approach or a

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[34] *See* American Petroleum Institute Comments at ii; Utilities Telecom Council Comments at 11; Western WiMAX LLC Comments at 3. Indeed, the American Petroleum Institute maintains that, "[o]nce grandfathered, existing 3.65 GHz band licensees should retain the ability to update their licenses to add or modify sites." American Petroleum Institute Comments at 7.

[35] Google Comments at 19.

[36] FNPRM ¶ 166; Reply Comments of Google Inc. at 11, GN Docket No. 12-354 (filed Dec. 20, 2013); *see also* Comments of Motorola Solutions, Inc. at 2 ("The grandfather period for such a transition should not be longer than 5 years to encourage investment in new spectrum sharing technologies.").

"transitional approach" in which GAA users would share spectrum with Priority Access licensees only at some uncertain time in the future.[37] The FCC's three-tier framework will serve the Commission's goals more effectively than these alternatives.[38]

Critics of the three-tier framework mistakenly assume that a SAS cannot manage the interactions between PAL and GAA users while protecting incumbents.[39] But as Spectrum Bridge explains, "[e]xpanding upon the functionality currently implemented in the TV bands (for TVWS) to enable three (3) tier access is well within the technical capabilities of an SAS."[40] Indeed, Google has developed a working prototype SAS that it presented at the Commission's SAS workshop.[41] That prototype provides all the functionality required in the FNPRM, including protection of PAL users from other PAL users, protection of federal users from aggregate PAL and GAA operations, protection of PAL users from GAA users, and relocation of GAA users when necessary to permit deployment of PAL devices.[42] The prototype can readily be scaled to meet the needs of CBRS operators nationwide.[43]

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[37] Qualcomm Comments at 1; *see also* Ericsson Comments at 4-6; Nokia Comments at 14-15; Verizon Comments at 12-13.

[38] For example, Qualcomm argues that the Commission should restrict its efforts in this proceeding to "implement[ing] tried and true spectrum management tools." *See* Qualcomm Comments at 1.

[39] *See, e.g.*, CTIA Comments at 4 (calling a SAS that manages multiple tiers of users "a concept ripe with uncertainty"); AT&T Comments at 11 (calling the SAS proposed by the Commission "novel").

[40] Comments of Spectrum Bridge, Inc. at 1.

[41] Appendix B, Declaration of Preston Marshall, Ph.D. ¶¶ 4-5 ("Marshall Declaration").

[42] *See* Preston Marshall, Principal Wireless Architect, Google Inc., *Spectrum Access System: Managing Three Tiers of Users in the 3550-3700 GHz Band* at 2 (Jan. 14, 2014), *available at* http://wireless.fcc.gov/workshops/sas_01-14-2014/panel-1/Marshall-Google.pdf ("Google SAS Presentation"); *see generally* Marshall Declaration.

[43] *See* Marshall Declaration at ¶ 9.

Several commenters claim that SASs will impede their ability to manage LTE networks.[44] They are mistaken. The role of a SAS is limited to protecting higher-in-right users and helping implement the Commission's minimum standards for CBRS operations, while assisting efficient network deployments. As the Commission has explained, SASs "would . . . take into consideration any channel requests submitted by [devices] as well as geographic and spectral efficiency considerations."[45] Similarly, SASs will aid in optimizing use of the band for operators holding PALs in adjacent areas or multiple licenses within the same area.[46]

SASs would not set power levels for devices in the band, but would merely "[d]etermine the maximum permissible radiated transmission power level for [devices] at a given location and communicate that information to the [devices]."[47] Operators retain discretion to control their

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[44] *See, e.g.*, CTIA Comments at 14-15 (arguing that SASs should not be responsible for issuing dynamic frequency assignments or making determinations about operating power, since PAL operators should have the flexibility to determine how best to deploy their 3.5 GHz operations and sometimes need to adjust their operations on a real-time basis); Ericsson Comments at 14 ("[E]xternal intervention with an individual cell within a managed network will impact the carrier service quality, coverage, and mobility."); Verizon Comments at 10 ("Moreover, many of the features that make LTE a robust and highly efficient platform would be obviated because interference management, resource management, and inter-cell coordination become moot points if the cells are not contiguous. It is highly undesirable to give a third-party SAS Manager control over these types of network-impacting parameters because it makes precise engineering of the Radio Access Network impossible.").

[45] FNPRM ¶ 103.

[46] *Id.* ¶ 48 ("To the extent a licensee has PALs in adjacent census tracts, we propose that the SAS should endeavor to assign contiguous frequencies across geographic boundaries. In addition, consistent with the dynamic nature of the proposed channel assignments, we encourage SAS Administrators to make reasonable efforts to assign adjacent frequencies to licensees with access rights to multiple channels in a single census tract.").

[47] *Id.* ¶ 95.

own LTE networks, so long as their preferences do not interfere with higher-in-right users or hamper the efficient allocation of the band.[48]

SASs also would not prevent PALs with large aggregations of adjoining (spatial or spectral) licenses from operating on common frequencies throughout their contiguous license holdings, and in contiguous spectrum, to the extent possible. As explained in the accompanying declaration of Dr. Preston Marshall, SASs can accommodate such operation by statically assigning PAL reservations to contiguous logical channels.[49] Existing LTE management services can accommodate these conditions inasmuch as they will be similar to the conditions on exclusively licensed spectrum, except that in the 3.5 GHz band, PALs must avoid causing harmful interference to incumbent users.

Far from being an impediment to managing LTE networks,[50] dynamic frequency assignment is a tool for providing the consistent service that LTE customers seek.[51] Some

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[48] This flexibility should extend to how operators design their networks to enable communications with a SAS. As Google has previously noted, while it is important that CBRS devices send information to a SAS and implement instructions from a SAS in a timely manner, it is not necessary that devices operating in the band communicate directly with a SAS. Google Comments at 27. Google understands that the FNPRM's proposed rules permit indirect communication with a SAS by defining a CBRS Device as "Fixed or Portable Base stations, *or networks of such base stations*, that operate on a Priority Access or General Authorized Access basis in the Citizens Broadband Radio Service consistent with this rule part." FNPRM ¶ 65 (emphasis added). The Commission should confirm in its final order that this is the case.

[49] Marshall Declaration at ¶ 10.

[50] *See, e.g.*, Ericsson Comments at i (arguing that dynamic frequency assignments would "circumvent efficient spectrum planning and usage" and noting that "[w]ireless network operators carefully manage the use of assigned frequencies from multiple bands to ensure availability when and where spectrum is needed throughout a system for coverage or for capacity, to maintain a level of service their customers demand").

[51] *See* Google Comments at 28; Comments of Wireless Internet Service Providers Association at 11, GN Docket No. 12-354 (filed Dec. 5, 2013) (SAS that dynamically assigns PAL and

commenters argue that this approach creates risk. But quite the opposite is true. Dynamic frequency assignment provides greater certainty because the loss of any specific channel in any specific locations does not result in the loss of PAL rights due to federal or FSS operations. Dynamic assignment ensures that operators have access to the best available spectrum channel and, by relocating operations when higher-tier users claim their spectrum, minimizes disruptions to service.[52] Dynamic assignment allows protection of federal incumbent and Priority Access operations while enabling a seamless experience for end users of CBRS services. As discussed in Dr. Marshall's declaration, Google has developed a proposed framework that protects incumbents' ongoing and episodic operations, while minimizing disruption to carriers.[53] As Dr. Marshall explains, SASs should be designed to minimize the degree of dynamic, or changing assignments.[54] They should only use dynamic features to avoid situations in which PAL users would otherwise lose access to PAL spectrum.

C. A Two-Tier Framework Would Not Eliminate the Need for SASs.

Some commenters have suggested that in a two-tier framework, CBRS operations could be implemented with primitive SASs or without any SAS at all.[55] These commenters disregard

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GAA frequencies will ensure that "as the operating environment changes over time, users will be able to continue operating while avoiding co-channel interference").

[52] Google Comments at 28; Comments of Google Inc. at 11, GN Docket No. 12-354 (filed Dec. 5, 2013) ("Ensuring that users have access to the best available channel will benefit PAL and GAA operations alike. Accordingly, FCC rules should give SASs the flexibility to dynamically assign spectrum blocks at any time—even during a Priority Access license period.").

[53] Marshall Declaration at ¶ 5.a-b.

[54] *Id.*

[55] *See, e.g.*, AT&T Comments at 22; CTIA Comments at 4-5; Ericsson Comments at 5 ("With PALs and GAA users in separate frequency blocks, a much simpler SAS can be employed to

the entire thrust of this proceeding. The Commission proposes to determine interference conditions based on the total aggregate interference from all users because this will dramatically increase the utility of the 3.5 GHz band.[56] Such an approach enables devices to make dynamic use of the spectrum, rather than unnecessarily limiting the capabilities of each individual device. Implementing this approach requires both knowledge of all relevant devices in the band, regardless of tier, and the ability to ensure that the aggregate activities of the devices are not harming higher-in-right users.

Whether in a two-tier framework or a three-tier framework, a robust SAS is needed to implement this efficient sharing by CBRS operators. Including the 3650-3700 MHz band, CBRS devices will have access to fifteen different 10 MHz channels.[57] So long as multiple PAL holders are permitted to operate in the same geographic area, no individual PAL holder will be aware of the emissions of all other Priority Access licensees in the same band. Without a SAS, PAL holders would not be capable of ensuring that their incremental contribution to aggregate emissions is below the level that would trigger protection of incumbents. The Commission would need to limit PAL operations based on worst-case interference modeling, thus dramatically limiting the utility of the band for commercial services.

Google demonstrated the functionality of its SAS at the Commission's SAS Workshop on January 14, 2014. Below are two figures excerpted from the presentation:

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prevent their causing harmful interference to incumbent operations."); Qualcomm Comments at 9.

[56] *See* FNPRM ¶ 79.

[57] *See id.* ¶ 47 (proposing to establish unpaired 10 MHz channels).

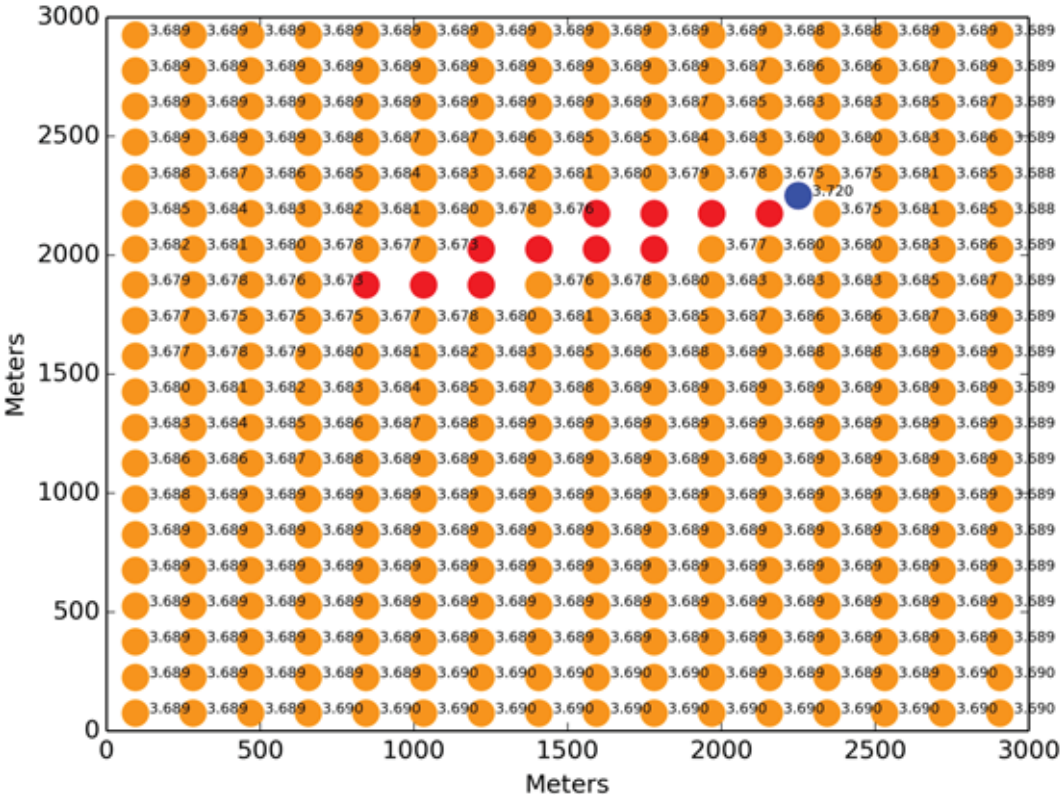
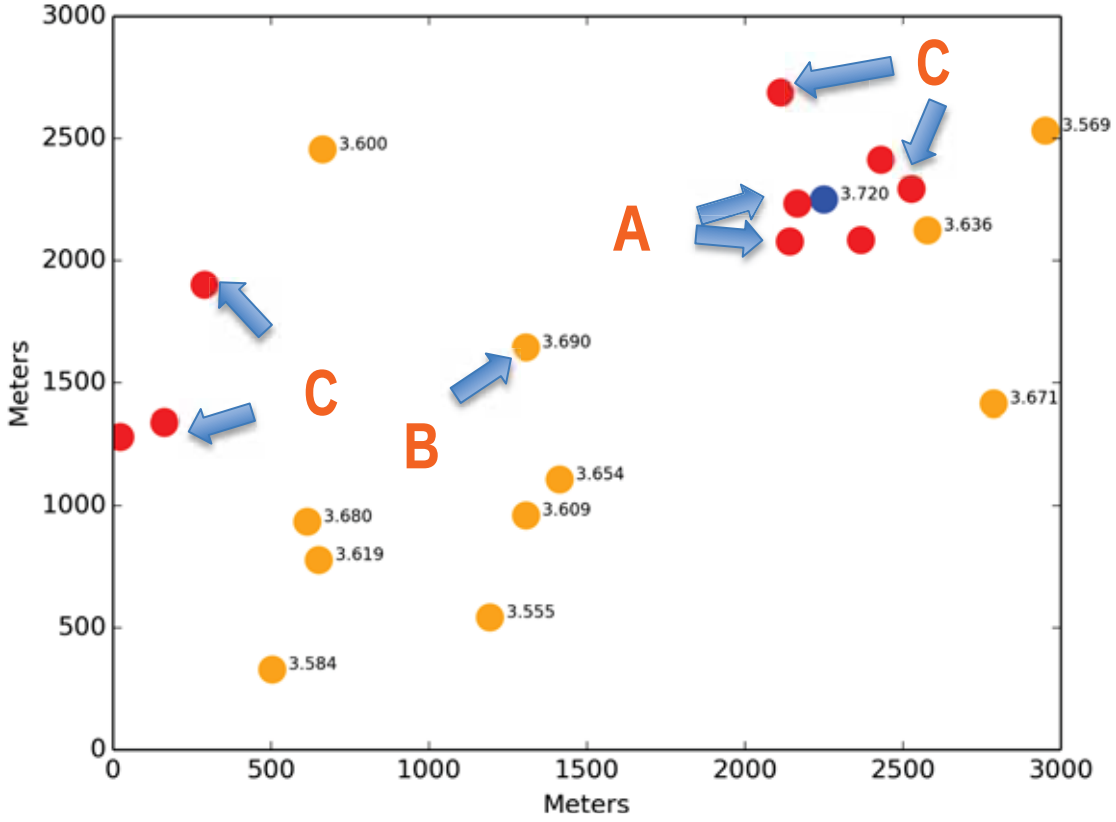


Figure 1

The blue dot in Figure 1 represents an incumbent Fixed Satellite Service ("FSS") earth station, and the red dots represent areas where full-power CBRS operation is categorically prohibited in order to protect that earth station. The orange dots show the permissible areas for placement of a single CBRS device in the absence of any other devices in the vicinity.

Although the exclusion zone required for a single device is quite small, the interference margin is "consumed" by those existing devices as additional CBRS devices enter service, and there is less and less opportunity for additional CBRS devices.



- Devices labeled A would not have been permitted, even singly.
- Device B consumed most of the incumbent out-of-band interference tolerance, so devices labeled C are excluded, protecting the incumbent.

Figure 2

Figure 2 depicts the SAS view of the same area as more devices enter. Operational CBRS devices are shown in orange. Devices that the SAS did not permit to transmit are shown in red. As noted above, only a system with knowledge of all users in the CBRS band can accurately determine the extent to which interference margins have been affected by existing devices and assess whether additional devices should be permitted. In the absence of such a SAS, each CBRS operator would need to restrict its own use formulaically, in order to ensure

protection of incumbent operations based on mere assumptions about what other CBRS users might be doing.

Similarly, efficient management of Priority Access operations to accommodate federal needs or to avoid interference with FSS requires awareness of other PAL and GAA users. In particular, if federal incumbents displace a PAL holder on a given channel, the coordination provided by SAS will allow seamless relocation of GAA users to free up another channel for the licensee's Priority Access use. As a result, a robust SAS is critical to managing the 3.5 GHz band efficiently.

D. Basing PAL Areas on Interference Protection Needs Will Avoid Waste.

Geographic units like census tracts are a poor fit for small cell operations because their boundaries bear no relationship to the edges of wireless network coverage; this mismatch will lead to substantial under-use of available spectrum.[58] If the FCC uses census-tract-based license areas, an operator that obtains a license to deploy a small cell network to cover a building or group of buildings will block any other Priority Access use of that channel throughout the entire census tract, regardless of how little of the tract the licensee is using.[59] Some census tracts cover tens of thousands of square miles.[60] Given growing demand for limited spectrum resources, the Commission cannot afford such waste.

The Commission should reject calls by some commenters to compound this problem by adopting even larger geographic license areas, such as counties.[61] While census tracts have

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[58] *See* Google Comments at 11-14; Comments of Federated Wireless at 17-18, GN Docket No. 12-354 (filed Dec. 5, 2013).

[59] Google Comments at 11.

[60] *Id.*

[61] *See* T-Mobile Comments at 9; CTIA Comments at 7-8.

serious drawbacks as license areas, they are axiomatically largest in geographic size (and most inappropriate as a PAL licensing unit) in those areas with the lowest population density. Thus, census tracts are worst where the need for additional commercial wireless spectrum is least. Counties, by contrast, are frequently enormous even in populous areas. For example, eight of the ten largest cities in the United States are within a single county. Los Angeles County alone covers more than 4,000 square miles and is home to more than 10 million people.[62] To assign a single license for small cell CBRS operations across the entirety of Los Angeles County—excluding other Priority Access operations on the same channel everywhere in L.A.—would be profligate use of spectrum resources.

As the PCAST Report correctly recognized, large license areas effectively deny smaller potential users an opportunity for protected spectrum rights.[63] For example, only the largest entities would have the means to secure a 10 MHz band of spectrum across a large city. In contrast, smaller license areas will lower barriers to entry and tend to increase the number of participants in the market, which in turn will foster deployment of new technologies and business models.[64]

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[62] U.S. Census Bureau, STATE AND COUNTY QUICKFACTS, LOS ANGELES COUNTY CALIFORNIA, *available at* http://quickfacts.census.gov/qfd/states/06/06037.html.

[63] *See* PCAST Report at ix.

[64] *See id.*; *see also Commission Seeks Comment on Licensing Models and Technical Requirements in the 3550-3650 MHz Band*, Public Notice, FCC 13-144, 28 FCC Rcd. 15,300, 15,306 ¶ 14 (2013) (noting the Commission's goal of enabling "flexible, micro-targeted network deployments, promoting intensive and efficient use of . . . spectrum").

E. SASs Should Use Real-World Information to Protect Incumbent Satellite Earth Stations.

Numerous commenters agree with the Commission's assessment that SASs can use information about devices, earth stations, and operating environments to maximize the spectrum available for CBRS networks while protecting FSS earth stations.[65] Nevertheless, some FSS users continue to argue that the Commission should base its protection of FSS earth stations on generic assumptions that over-protect the incumbent service, rather than taking full advantage of SASs' capability to establish protection zones that are correctly sized for the real-world environment.[66] This inefficient approach would unnecessarily constrain commercial use of the 3.5 GHz band.

For example, the Satellite Industry Association ("SIA") recommends over-sized exclusion zones based on two factually flawed premises: (1) that SASs will not be able to conduct the required propagation modeling, and (2) that determining aggregate interference will be unworkable.[67] In addition, SIA's technical analyses use unrealistic worst-case scenarios and unsubstantiated assumptions to justify overbroad protections.

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[65] *See, e.g.*, Comments of Pierre de Vries at 21 ("an analytic model of expected aggregate power-flux density could be used by SASs to authorize operations that would protect FSS earth stations"); Comments of Sony Electronics, Inc. at 5 and Annex (a Complementary Cumulative Distribution Function of aggregate power flux density can mitigate exclusion zones for FSS earth stations); WFA Comments at 13 ("Instead of a uniform protection area, the Commission should consider each of these [incumbent FSS earth station] users individually, and develop criteria that reflect the actual satellite and transponder usage, any site specific protection needs, and actual link conditions…"); WISPA Comments at 20 (rules for grandfathered FSS earth stations "should take into account the protective effects of terrain and other factors to create 'real-world' protection zones").

[66] *See generally* Comments of the Satellite Industry Association ("SIA Comments"); *see also* Comments of National Public Radio at 11 (recommending that the Commission confine GAA operations to spectrum below 3620 MHz) ("NPR Comments").

[67] SIA Comments at i-ii.

With regard to SIA's assertion that propagation modeling will be challenging, the Commission's own rules demonstrate that such modeling is feasible. As Google already has shown in this proceeding, nearly ten years ago the Commission provided an analytic framework for determining interference to C-band downlinks from in-band operations.[68] The same methodology can be used to compute both adjacent channel interference and out-of-band emissions to FSS operations above 3.7 GHz. The Commission should rely on this well-established approach in addressing interference protection requirements, although the framework should be modified slightly to constrain the range of protected azimuth/elevations to those occupied by domestic FSS services above 3.7 GHz and actual satellite usage below 3.7 GHz. Moreover, this methodology can be applied using baseline information regarding the FSS services, such as FSS site locations, actually occupied domestic satellite slots, and commercial filter and receiver noise performance, as well as baseline information regarding CBRS devices, such as their locations, power, and directionality. While FSS operators and device manufacturers should be free to provide additional data that may improve protection modeling, these basic requirements will provide sufficient information for SASs to calculate appropriate protection without great complexity.

SASs can also account for aggregate interference. Google demonstrated this functionality at the FCC's SAS workshop on January 14, 2014.[69] As noted above and in the accompanying declaration of Dr. Preston Marshall, moreover, modern computing technology is

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[68] *See generally Wireless Operations in the 3650-3700 MHz Band*, Report and Order and Memorandum Opinion and Order, FCC 05-56, 20 FCC Rcd. 6502, 6554 (2005).

[69] *See* Google SAS Presentation at 4-5.

more than capable of scaling this functionality to account for millions of CBRS devices.[70] To the extent that SIA relies substantially on the assumption that most CBRS devices will be mobile,[71] its assumption is erroneous; it is more likely that most devices will be fixed access points, while end user devices will operate in client mode only. End user equipment will have to communicate with one of these access points in order to gain permission to operate, while the SAS will interact directly only with the access points. Even if access devices move, the accuracy requirements proposed by the Commission will likely require that the devices re-register and request authorization. Therefore, device mobility should not create a significant issue in protecting FSS or any other service.

SIA's analysis also relies on a number of flawed and unsupported technical assumptions. First, SIA assumes that FSS operations have little margin to interact with CBRS devices, because they are receiving substantial interference from existing federal uses.[72] But SIA provides no evidence or reasoning to substantiate its argument that half of its proposed interference margin should be allocated to federal users. SIA's approach, therefore, unjustifiably reduces the proposed SAS interference margin by 3 dB.[73]

Second, SIA's proposed protection contour in section 1.4 of its Technical Annex conflates worst-case and average scenarios. As SIA concedes, the recommended protection area represents "the maximum envelope" above all of the tested scenarios.[74] By applying the maximum envelope to *all* FSS sites, SIA's analysis admittedly overprotects all but one FSS site

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[70] *See* section III.B, *supra*; *see also* Marshall Declaration at ¶ 9.

[71] *See* SIA Comments at 8, 10.

[72] *Id.* at 5, 17, Technical Annex at 1.

[73] *Id.* at 17.

[74] *Id.* at Technical Annex at 4.

in the country. Such protection is absolutely unnecessary, as the location of each protected FSS site is known, and satellite positions are fixed.

Relatedly, SIA's analysis fails to account for the effects of actual antenna gain, directionality, and elevation angles that are specific to each site. In most locations in the United States, elevation angles are high enough that the antenna gain will be no more than the front-to-back ratio of the antenna. The front-to-back ratio of an antenna is defined as the difference in dB between the maximum gain or front of the antenna (usually 0 degrees) and a point exactly 180 degrees behind the front. Relying on these front-to-back ratios reduces the power by more than 30 dB as compared to SIA's analysis. Even in locations with low elevation angles, the resulting geographic restrictions are minimal because the excluded area is likely to be long but very narrow in shape as a result of the directionality. Lastly, in most cases, any directional antennas used would not be pointed squarely at the FSS site, as SIA unrealistically assumes in its filing by relying on high EIRPs that can only be achieved using significant directionality.[75] The SAS should be informed of antenna directionality when CBRS assignments are requested so that the SAS can evaluate these impacts, thereby eliminating the need to restrict the operation of all devices based on hypothetical or unlikely worst-case deployments.

Finally, SIA compounds these technical errors with a policy argument that turns spectrum rights upside down: that the Commission should preclude CBRS operation to guard against "disappoint[ment]" by Priority Access operators.[76] PAL operators will establish their networks knowing that they lack interference protection from incumbent FSS and federal operations

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[75] *Id.*

[76] *See id.* at 12.

alike.[77] Because adjacent band FSS locations are relatively stable, and in-band operations are fixed as a result of the Commission's freeze on new FSS operations in the 3550-3700 MHz band, Priority Access users will have full visibility of potential restrictions to protect these sites before investing in deployments. There is no reason to believe that due diligence on the part of potential Priority Access operators would not identify those regions at risk of constraints on deployment. The FCC regulations need not protect against "disappointment" on the part of any CBRS user.

Satellite interests also understate the effectiveness of mitigation techniques that can reduce the need for large exclusion zones. For example, National Public Radio ("NPR") argues that earth station filters would only be partially effective in reducing interference from CBRS operations.[78] NPR appears to base this claim on its characterization of the performance of a single low noise block filter.[79] As Google has previously explained, however, numerous filter

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[77] *Cf.* Section II, *supra* (making the same point with respect to federal incumbents).

[78] NPR Comments at 3-5.

[79] NPR cites its experience with the Norsat BPF-C-1 filter. *See id.* at 4. Given NPR's choice of filters, its failure at preventing interference is not surprising. According to its data sheet, this filter has a -20 dB rejection at approximately 3.60 GHz, providing minimal rejection in the range of many signals that were referenced as likely causing interference, such as authorized in the 3650 to 3700 MHz band. *See, e.g.*, Norsat International Inc., *Microwave Component C-Band Pass Filter* (2011), *available at* www.norsat.com/wp-content/uploads/bpf_c_mc.pdf. However, the relative ineffectiveness of the Norsat BPF-C-1 filter does not support the conclusion that filters are inherently ineffective. The filters cited in Google's technical analysis of C-Band interference, which can be purchased off the shelf and are used in all Google Fiber C-Band dishes, are effective immediately below the 3.7 GHz boundary, and would be a suitable baseline for usage in this band. *See* Letter from Aparna Sridhar, Telecom Policy Counsel, Google Inc., to Marlene H. Dortch, Secretary, FCC, at Appendix ¶¶ 7-11, GN Docket No. 12-354 (filed Sept. 3, 2013) ("Google FSS Earth Station Ex Parte"). Use of these filters is already a "best practice" for C-Band reception in the United States, and the use of inferior technology by some operators is not a valid reason to impede innovation in the band, particularly when more effective filtering technology is readily available at a reasonable cost.

vendors have developed the "radar elimination filters" intended to protect FSS earth stations against existing high-powered military radar systems in the 3.5-3.7 GHz band.[80] This equipment, which is widely available for less than $500, can be used to filter out interference from small cell operations.[81] The Commission should take account of available filter performance when creating final rules to protect FSS operations—certainly before imposing a restriction that would dramatically reduce the value of the CBRS band.

F. Requiring SASs to Account for the Geolocation Abilities of Different Devices Will Permit Technological Flexibility and Promote Efficiency.

The Commission's proposal to require devices to detect location within 50 meters horizontally and 3 meters vertically is unreasonable and unnecessary to protect incumbent operations. Instead of establishing a bright-line rule that requires every device to meet this accuracy requirement, the Commission should allow location accuracy to be a characteristic of each device, and allow SASs to calculate worst-case interference based upon the location capabilities of the device. This will allow technological flexibility while creating incentives to invest in developing devices with improved geolocation capability.

The FCC's inquiry into indoor location accuracy in the 911 context demonstrates that 50-meter horizontal accuracy is not technologically reasonable today, and the 3-meter vertical accuracy requirement even less so. There, the Commission proposed rules that would require horizontal location within 50 meters of the caller for 67 percent of calls within two years, and for 80 percent of calls within five years, plus vertical location estimates within 3 meters of the caller

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[80] Google FSS Earth Station Ex Parte at 2.

[81] *Id*. at 2-3.

for 67 percent of calls within three years, and for 80 percent of calls within five years.[82] But the record in that proceeding is clear that these proposed benchmarks cannot be met. Although some emerging technologies have shown promise in tests,[83] none can comprehensively meet a 50 meter/3 meter requirement today.[84] This is equally true for the 3.5 GHz band, and perhaps even more so because 3.5 GHz devices will generally not include the large variety of receiver and transmitter bands that are available in cell phones to assist with geolocation.

Fortunately, the Commission need not establish a bright-line 50-meter/3-meter accuracy requirement for 3.5 GHz devices in order to protect incumbent operations. The role of location accuracy in the 3.5 GHz band context is different than in the 911 context. Here, the goal is to ensure that a commercial device does not operate at a geographic point that will result in harmful interference, rather than to allow public safety personnel to determine the exact location of an individual. A device that cannot provide 50-meter/3-meter accuracy can still operate effectively in the repurposed 3.5 GHz band, as long as it protects higher-priority users by operating consistent with its location capabilities. This approach would continue to protect incumbents but allow less precise devices to operate in all the areas that are consistent with the devices' location-

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82 *Wireless E911 Location Accuracy Requirements*, Third Further Notice of Proposed Rulemaking, FCC 14-13, 29 FCC Rcd. 2374, 2376 ¶ 3 (2014).

83 *See* The Communications Security, Reliability, and Interoperability Council III, Working Group 3, *Indoor Location Test Bed Report* (March 2013) (reporting on the results of an indoor test bed for existing and emerging location technologies).

84 *See id.* at 39; *see also* Comments of AT&T at 5-9, PS Docket No. 07-114 (filed May 12, 2014); Comments of Cisco Systems, Inc. at 3, PS Docket No. 07-114 (filed May 12, 2014); Comments of CTIA at 4-7, PS Docket No. 07-114 (filed May 12, 2014); Comments of Motorola Mobility at 7-9, PS Docket No. 07-114 (filed May 12, 2014); Comments of Qualcomm at 1, 7, PS Docket No. 07-114 (filed May 12, 2014); Comments of Sprint Corporation at 4-5, PS Docket No. 07-114 (filed May 12, 2014); Comments of T-Mobile at 11-17, PS Docket No. 07-114 (filed May 12, 2014); Comments of the Telecommunications Industry Association at 2, PS Docket No. 07-114 (filed May 12, 2014); Comments of Verizon and Verizon Wireless at 15, PS Docket No. 07-114 (filed May 12, 2014).

determination capabilities—increasing flexibility, incentivizing efficiency, and improved device performance, all while accounting for the realities of today's available technologies.

Relatedly, the Commission should establish a confidence interval for reporting location information. The Commission has taken a similar approach in the *Wireless E911 Location Accuracy Requirements* proceeding by proposing that 67 percent of calls must meet horizontal accuracy requirements within two years and 80 percent of calls must meet those requirements within five years. While the FCC's proposed accuracy requirements in that proceeding are not reasonable, its use of a confidence interval is the right approach. The Commission should assign a similar probabilistic requirement in the 3.5 GHz band in order to avoid harmful interference, because meeting a specific location accuracy requirement with absolute certainty under every conceivable circumstance simply is not physically possible.

IV. THE COMMISSION SHOULD ESTABLISH RULES THAT ENSURE IMPARTIAL SERVICE BY SAS ADMINISTRATORS, BUT SHOULD NOT PROHIBIT ADMINISTRATORS FROM OBTAINING PALS.

Competition among multiple administrators is the best way to ensure that SASs provide high quality service. Competition will drive SAS administrators to innovate and improve their performance.[85] The proposed rules require each administrator to "make its services available on a non-discriminatory basis."[86] Moreover, with competitive SAS administration, customers who are dissatisfied with the service offered by their current SAS administrator can go elsewhere. A Commission rule that prohibits SAS administrators from obtaining PALs, as suggested by

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[85] FNPRM ¶ 98.

[86] *Id.* ¶ 106.

Microsoft,[87] would only discourage parties from investing to design and manage a SAS, thus *reducing* competition-based protection against discriminatory SAS administration.

The Commission rightly declined to impose that sort of restriction in its TV white space proceeding. Although the FCC requires white space database administrators to make their services available on a non-discriminatory basis, administrators are not prohibited from using white spaces.[88] Microsoft itself opposed a rule that would bar TV white space database administrators from having "the right to use the spectrum their database administered," noting that such a rule would lessen beneficial competition.[89] Microsoft explained that the Commission's ban on discriminatory treatment of customers was sufficient.[90] Microsoft was right.

V. CONCLUSION.

For the reasons stated above, the Commission should: (1) adopt right-sized, dynamic exclusion zones to protect federal incumbent operations; (2) take full advantage of SAS capabilities to promote efficient spectrum use; and (3) prohibit discrimination by SAS administrators without preventing administrators from obtaining PALs. By doing so, the

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87 Microsoft Comments at 12.

88 47 C.F.R. § 15.715(g). In its comments, Microsoft notes that the North American Numbering Plan has rules similar to those it seeks here. Microsoft Comments at 12 n.22. But there is only one North American Numbering Plan administrator, Neustar, Inc., and therefore there is no concern about discouraging competition. In the 3.5 GHz band, in contrast, the Commission's goal of improving SAS service depends on having a number of approved administrators who compete for customers.

89 Letter from Paula Boyd et al., Microsoft Corporation, to Chairman Julius Genachowski, FCC, at 3, GN Docket No. 02-380 (filed Sept. 15, 2010).

90 *Id.*

Commission will best advance its goals of supporting innovation and maximizing the utility of the 3.5 GHz band.

Respectfully submitted,

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August 15, 2014

Appendix A

Declaration of Andrew W. Clegg, Ph.D.

Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band	GN Docket No. 12-354

DECLARATION OF ANDREW W. CLEGG, Ph.D.

I) Introduction

1. My name is Andrew W. Clegg. I am a spectrum engineering lead for Google Inc. Before joining Google, I served as electromagnetic spectrum manager at the National Science Foundation. In addition, I worked for several years in senior engineering positions at companies that are today part of AT&T Mobility, and at Comsearch. I received my Ph.D. in radio astronomy, with a minor in electrical engineering, from Cornell University, and a B.A. in physics and astronomy from the University of Virginia.

2. I have reviewed the Further Notice of Proposed Rulemaking (FNPRM) in the above-captioned proceeding, including the Commission's request for parties to submit additional analysis that could support a reduction in the exclusion zones the Commission has proposed to accommodate Federal Incumbent Access Tier Users, which were based on recommendations made by the National Telecommunications and Information Administration (NTIA) in its 2010 Fast Track Report.[1] I have also reviewed

[1] NTIA, *An Assessment of the Near-Term Viability of Accommodating Wireless Broadband Systems in the 1675-1710 MHz, 1755-1780 MHz, 3500-3650 MHz, 4200 4220 MHz, and 4380-4400 MHz Bands* (rel. October 2010) (Fast Track Report);

the Fast Track Report itself. The information contained in this declaration expands upon information previously submitted by me in this proceeding.[2]

3. As detailed in this declaration, our laboratory and field tests show that an LTE picocell can be operated co-channel with an incumbent radar, with no discernible impact to the LTE system, when closer than 4 km to the radar. This result clearly demonstrates that the several-hundred-kilometer exclusion zones proposed in the FNPRM are unnecessary and unwarranted.

II) Interference from the Principal Incumbent Radar to Wireless Networks

a) Incumbent Radar Characteristics

4. The principal incumbent shipborne radar in the 3550-3650 MHz band is the U.S. Navy's AN/SPN-43C air traffic control radar (the SPN-43 radar). In addition to air traffic control, the radar can be used for weather observations. The SPN-43 radar is capable of operating over the range 3500-3700 MHz, but shipborne use within 44 nautical miles (approximately 81 km) of the coast is limited by NTIA's regulations to 3500-3650 MHz.[3]

5. The technical characteristics of the SPN-43 radar have been widely published in publicly available literature[4] although some of the information in the various

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Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band, Further Notice of Proposed Rulemaking, FCC 14-49, 29 FCC Rcd. 4273 ¶ 138 (2014) (FNPRM).

[2] Comments of Google Inc., GN Docket No. 12-354, Appendix A, Declaration of Andrew W. Clegg, Ph.D. (filed July 14, 2014).

[3] NTIA, "Manual of Regulations and Procedures for Federal Radio Frequency Management," Chapter 4 (Frequency Allocations), footnote US349, May 2013.

[4] Fast Track Report at 3-31; International Telecommunication Union, Recommendation ITU-R M.1465, "Characteristics of and Protection Criteria for Radars Operating in the Radiodetermination Service in the Frequency Band 3100-3700 MHz," March

publications is not consistent. The table below is based upon a combination of published characteristics and over-the-air measurements of the SPN-43 radar's emissions conducted by Google in the vicinity of Norfolk, Virginia:

Table 1: SPN-43 Radar Characteristics	
Tuning Range	3500 – 3700 MHz
Pulse Repetition Rate	1,000 Hz
Pulse Width	1 microsecond
Duty Cycle	0.1%
-3 dB Bandwidth	~1 MHz
Bandwidth between first spectral nulls	~1.9 MHz
Transmit Power (peak/average)	1 MW/ 1 kW (60/30 dBW)
Antenna Gain	32 dBi
EIRP (peak/average)	1.6 GW/1.6 MW (92/62 dBW)
Antenna Beamwidth (H/V)	1.75/4.4 degrees
Antenna Polarization	Horizontal (typical) or circular
Antenna Rotation Period	4 seconds

6. The SPN-43 radar is used aboard aircraft carriers (hull classification CVN) and amphibious assault ships (hull classifications LHA and LHD). Based on the Navy's list of ships,[5] there are 22 vessels of these types in service, under construction, or planned for service. The majority of these vessels have as their homeport either Norfolk (9) or San Diego (7), while two of the 22 ships are forward deployed in Japan.[6] Two additional SPN-43 radars are installed on land, one at St. Inigoes, Maryland, and one at Pensacola,

2007; NTIA, Technical Report 14-500, "Spectrum Occupancy Measurements of the 3550-3650 Megahertz Maritime Radar Band Near San Diego, California," January 2014; NTIA, "Federal Government Spectrum Use Reports 225 MHz to 5 GHz," 3500-3650 MHz Report, April 2014.

[5] http://www.navy.mil/navydata/ships/lists/shipalpha.asp.

[6] *Id.*

Florida.[7] Based on these counts, the maximum number of U.S.-based SPN-43 radars is 22, and the maximum number of U.S.-operated SPN-43 radars worldwide is 24.

7. The exclusion zones calculated in the Fast Track Report – which formed the basis of the proposed exclusion zones in the FNPRM – are based on theoretical calculations of interference from radar systems into wireless networks. The Fast Track Report studied five separate radar signal types. The characteristics of the SPN-43 radar (as listed in the Fast Track Report) match the characteristics of "Shipborne Radar – 1" used in the report's exclusion zone calculations. To our knowledge, and consistent with our observations in Norfolk, the SPN-43 radar is the primary incumbent government system currently operating in the 3550-3650 MHz band. The Fast Track Report calculated that "Shipborne Radar – 1" (the SPN-43 radar) would produce interference hundreds of kilometers away, and saturation (receiver overload) or even physical damage to wireless devices at substantial distances:

Table 2: Distances over which a SPN-43 radar is calculated to produce the specified effect according to the Fast Track Report [8]	
Interference	361 km
Saturation of wireless device receiver	51 km
Burnout of wireless device	15 km

8. To better understand actual interference effects of the radar, as opposed to the theoretical analysis underlying the Fast Track Report's assessment, Google has conducted tests of interference from the SPN-43 radar into wireless networks. We

[7] National Telecommunications and Information Administration, "Manual of Regulations and Procedures for Federal Radio Frequency Management," Chapter 4 (Frequency Allocations), footnote US109, May 2013.

[8] Fast Track Report, table 4-66, p. 4-72, and table 4-67, p. 4-78.

performed laboratory tests using simulated radar signals, and field tests using an actual SPN-43 radar and an LTE picocell. We studied the radar's impact on an LTE system, and also conducted laboratory testing of the radar's impact on Wi-Fi. While the Fast Track Report assumed that the theoretical wireless network would use WiMAX technology, we expect that actual deployments in this band will utilize the tested LTE or Wi-Fi technologies, as WiMAX has not seen substantial uptake in the U.S. market.

9. The measurement procedures employed in the tests and the results of the tests, particularly as they apply to the distance at which radars will impact secondary users, are documented here. In this declaration, we focus on the results of the laboratory tests. The field tests were conducted by a consortium consisting of Google, Virginia Polytechnic Institute and State University (Virginia Tech), Federated Wireless, and Rohde and Schwarz, in collaboration with the U.S. Navy and the U.S. Naval Academy. Virginia Tech plans to file results of the field tests in this proceeding when it obtains clearance from the Navy to do so. In general, results of the field tests were consistent with the laboratory tests.

b) Laboratory Tests of Radar Interference into LTE

i) Setup

10. The purpose of the laboratory tests was to assess the impact of radar interference on downlink data throughput of an LTE system. We used this metric because typical wireless use (for example, streaming music or video, or downloading search results) is most dependent on downlink data speeds.

11. The laboratory tests were performed with direct wired connections among all components, which allowed us to carefully control and measure both desired (LTE)

and undesired (radar) signal levels. It also allowed us to insure that the measurements were not affected by ambient radio signals. A simplified diagram of the test setup is presented in Figure A-1 in the Appendix.

12. The LTE system consisted of an Airspan AirSynergy 2000 eNodeB (eNB) communicating with a Qualcomm test handset as the User Equipment (UE). The eNB and UE were capable of 2x2 MIMO (Multi-In Multi-Out) operation, but the second antenna ports on both were terminated with 50-ohm loads, forcing the LTE system to operate in Single-In Single-Out (SISO) mode. This approach results in a conservative measurement (i.e., an overestimate) of interference impact, since an important feature of MIMO technology is its ability to reduce the effects of interference on a wireless channel.

13. The laboratory tests were conducted under an experimental license in Mountain View, CA, using an LTE center frequency of 2600 MHz.[9] LTE characteristics are not frequency-dependent, and all devices used in the tests were connected with cables instead of relying on over-the-air propagation, so the use of a 2600 MHz center frequency instead of 3600 MHz did not have any impact on the results. The LTE bandwidth was set to 10 MHz, which is consistent with the Priority Access license bandwidth proposed in the FNPRM.[10]

14. The interfering radar signal was simulated using the "Radar Pulses/Chirps" feature of the *iqtools* toolbox in MATLAB.[11] We used the published and

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[9] Callsign WG2XOT, issued January 17, 2013.

[10] *See* FNPRM ¶ 29.

[11] MATLAB is software for the development of mathematical algorithms, and *iqtools* is an Agilent-supplied plug-in for MATLAB that provides for the creation of numeric data to simulate wireless signals in conjunction with Agilent's arbitrary waveform generators.

measured characteristics of the SPN-43 radar pulse as inputs to *iqtools*, and fed the resulting IQ waveform into an Agilent M8190A arbitrary waveform generator (AWG) to create the simulated radar signal at any desired radio frequency. With this setup, the radar pulse magnitude is constant, and therefore we did not simulate the effect of radar antenna rotation. Adding the effect of the rotation would decrease the impact of radar interference. In actual deployments, the radar rotates every four seconds, and the main beam is pointed at any given receiver for only 20 milliseconds of that period. As a result, the radar's signal strength as observed by a victim receiver is significantly reduced for 99.5% of the time.

15. In our laboratory tests, the signal power from the radar was fixed, while a variable attenuator was inserted between the eNB and the UE to allow us to vary the interference-to-signal (I/S) ratio seen by the UE. An Agilent N9030A PXA spectrum analyzer was connected in parallel with the UE so that we could view and measure what the UE was experiencing in terms of LTE and radar signals. The radar signal strength as observed by the UE was typically around -49 dBm; this is the average, not peak, radar strength, measured in a 10 MHz channel and averaged over approximately 30 seconds. Based on previous field measurements of an actual SPN-43 radar, this received power level corresponds to a distance of as much as 20.7 km, and as little as 0.6 km, from the radar to the LTE receiver. The 20.7-km distance assumes free space loss with direct line-of-sight to the radar, and is scaled from actual line-of-sight signal strength measurements obtained in the vicinity of the radar. The 0.6-km distance assumes an indoor LTE deployment with 20 dB of attenuation to the outdoors, and free space loss plus additional ground clutter loss of 17 dB/km. The value of clutter loss is the amount measured in the

vicinity of the field test site; this loss was caused by groves of trees that filled approximately 50% of the path between radar and receiver.

16. We varied the power from the eNB as received by the UE from a maximum of approximately -24 dBm down to approximately -100 dBm. Assuming free space loss and an eNB operating at the maximum proposed Citizens Broadband Radio Service Device (CBSD) EIRP of +30 dBm, the power in the tests correspond to a separation between a CBSD and an End-User Device of between approximately 3 m and 21 km. (In reality, a small-cell network will not serve an area anywhere near 21 km in size, but a signal strength of -100 dBm could apply in some circumstances when additional losses, such as trees and/or interior walls and floors, are taken into account.) This LTE signal strength measurement effectively corresponds to the Received Signal Strength Indicator (RSSI), as opposed to the Reference Signal Received Power (RSRP) metric often used in LTE measurements. The RSRP is roughly the average power per 15 kHz Orthogonal Frequency Division Multiplex (OFDM) subcarrier in the LTE signal. For consistency, in this report we will use the 10 MHz channel power of the LTE signal (not the RSRP), and the average power of the radar signal as measured in a 10 MHz bandwidth, as the reference signal strengths (S and I, respectively) for specifying interference-to-signal (I/S) ratios.

17. The following table summarizes the conditions being simulated in the laboratory tests, particularly in regard to the relevant separation distances between the UE and the wireless base station, and between the UE and radar:

Table 3: Range of LTE/Radar Conditions Tested

Parameter	Value(s)	Equivalent Separation Distance
Wireless Network Signal Strength (eNB as received by UE)	-24 dBm to -100 dBm	3 m – 21 km (eNB to UE) Free Space Loss
Radar Signal Strength (radar as received by UE)	-49 dBm	0.6 – 20.7 km (radar to UE) Propagation-dependent
I/S Ratio	+51 to -25 dB	N/A

ii) Test Procedures

18. The principal parameter we measured was downlink data throughput as a function of I/S ratio and frequency offset between the radar and LTE. The measurements were made using the following procedures:

a. Prior to each series of measurements, the 10 MHz channel power of the LTE downlink signal (during data download) was measured with the spectrum analyzer, with eNB attenuation set to 0 dB. The eNB signal strength ("S") as received by the UE was varied during the tests by adjusting the attenuator setting.

b. Prior to each series of measurements, the average power of the radar signal was measured in a 10 MHz channel using the spectrum analyzer. The radar power ("I") was held nearly constant during the tests. It was approximately -49 dBm, but varied by 1-2 dB due to variations in waveform generator output and the inherent accuracy of radar power measurements.

c. The center frequency of the radar signal was set to a specified offset from the center frequency of the LTE signal. We used offsets of 0, 1.25, 2.5,

3.75, 5, 6.25, and 7.5 MHz, where the offset is defined as (radar center frequency) – (LTE center frequency).

d. At each frequency offset, we set a range of attenuations between the eNB and the UE to simulate a range of I/S (radar/LTE) ratios.

e. At each frequency offset and I/S ratio, we tested the downlink and uplink throughput speeds between the eNB and UE by running a standard Internet-based speed test utility on the UE.[12] We also had the ability to push data to the UE through the LTE network, and measure throughput using a proprietary software interface to the test UE. The two methods returned the same results, but we found the Web-based speed test more convenient. Each speed test measurement was an average over approximately 30 seconds. At least three measurements were conducted at each combination of frequency offset and I/S ratio.

iii) Results

19. Figure A-2 is a baseline throughput test with no radar interference. The measured baseline average downlink throughput of our LTE system in the absence of radar interference can be parameterized by the function:

$$\text{Throughput (Mbps)} = \begin{cases} 23.42 & \text{for } S \geq -73.5 \text{ dBm} \\ A \times 10^{(4 + B \times S)} & \text{for } S < -73.5 \text{ dBm,} \end{cases} \quad (1)$$

where S is the LTE downlink signal strength in dBm during downlink data transfer, and the constants are A = 4.4558; B=0.044522. Equation (1) is simply an empirically-derived

[12] We used the mobile-optimized Web site http://m.speedof.me and utilized a server a few km from the lab where the tests were conducted.

curve fit to the baseline data that is used to characterize the impact of interference in subsequent tests. No physical meaning is implied. This curve fit is shown as a dotted line in Figure A-2. In the following analysis, the impact of radar interference will be quantified by how much the downlink throughput in the presence of interference deviates from equation (1).

20. We measured the impact of radar on the downlink data throughput for seven different values of frequency offset. The occupied bandwidth of the radar (less than approximately 1.9 MHz) was contained entirely within the 10 MHz LTE channel for four of the offsets (0, 1.25, 2.5, and 3.75 MHz), was centered exactly on the edge of the 10 MHz LTE channel for one offset (5 MHz), and was entirely outside the 10 MHz LTE channel for two offsets (6.25 and 7.5 MHz).

21. The downlink data throughput as a fraction of the baseline throughput set forth in equation 1 and figure A-2, for each of the seven frequency offsets, as a function of LTE signal strength and I/S ratio, is plotted in figures A-3 – A-9. In actual deployments, LTE signal strength will generally decrease as distance between the eNB and UE increases, and the I/S ratio will typically decrease as the distance between the radar and the UE increases.

22. In the co-channel case (Fig. A-3), the LTE system performs well when I/S is less than approximately -20 dB, but performance is noticeably degraded at larger I/S. But the -20 dB figure is achievable in a wide variety of deployment scenarios. We use the following parameters to calculate required separation distances to meet the necessary -20 dB I/S objective:

a. The radar EIRP toward the horizon is taken as 82 dBm, which is based on field measurements of an actual incumbent radar.

b. The radar signal strength at the UE is -47.8 dBm.

c. For indoor deployments, the radar will be attenuated by building losses. We use 10 dB as a typical loss for residential buildings made of wood, and 20 dB for commercial buildings made of metal and masonry. We assume no attenuation of the radar signal for outdoor small cell installations.

d. We assume the signal from the base station needs to be 20 dB stronger than the radar signal (I/S = -20 dB) at the UE, or -27.8 dBm. Given a 30 dBm base station EIRP, this signal strength is reached at a separation of 5.1 m between eNB and UE, assuming free space loss.

e. Propagation loss from the radar to the small-cell deployment site is free space loss (worst case), or free space loss + 17 dB/km of clutter loss as derived from our field measurements of the radar signal strength.

23. Using these parameters, the following table summarizes the required distance between the LTE small cell and the radar to meet the signal strength limits and I/S objectives for outdoor, indoor residential, and indoor commercial co-channel deployments. It is important to emphasize that the conclusions in this table are based entirely on lab and field measurements instead of theoretical predictions:

Table 4: Co-Channel LTE/Radar Coexistence Scenarios

Co-channel LTE Deployment (5.1 m separation between eNB and UE):	Outdoor (129.8 dB loss)	Indoor Residential (119.8 dB loss)	Indoor Commercial (109.8 dB loss)
Required Separation Distance from LTE to Radar (Free Space Loss)	20.7 km	6.6 km	2.1 km
Required Separation Distance from LTE to Radar (Free Space + Clutter)	1.4 km	1.0 km	0.6 km

24. These conclusions are confirmed by our field tests of an outdoor small cell LTE network in the vicinity of an incumbent SPN-43 radar, *where we were able to operate co-channel with the radar with no discernible impact on LTE performance at a separation distance of only 4 km in a rural environment.* This would result in exclusion zones about 90 times smaller in distance and over 8,000 times smaller in area than those calculated in the Fast Track Report.

25. Figure A-9 shows a non-co-channel example. The radar center frequency is 7.5 MHz above the LTE center frequency and the entire occupied bandwidth of the radar is outside the LTE channel.[13] In this case, there is no discernible effect from the radar interference until I/S is greater than about 25 dB (i.e., the received radar signal is more than roughly 300 times stronger than the received LTE signal), which represents a roughly 45 dB improvement in interference tolerance over the co-channel case.

[13] Note that the measured power from the simulated radar is 1.9 dB less than the co-channel case. In fact, this discrepancy is probably caused by a lack of accuracy in the radar received power measurement rather than an actual difference in radar power injected into the handset. Due to the nature of the pulsed radar emissions, combined with the characteristics of hybrid swept frequency/FFT spectrum analyzers, measuring average radar power with better than 2 dB of accuracy and repeatability is challenging.

26. Following the same analysis as the co-channel case, the separation distance to the radar is assumed to be the same as in the co-channel case, but the separation distance between the LTE eNB and UE can be larger. Noting that the LTE system continues to operate virtually unaffected down to -75 dBm downlink signal strength, and assuming a 30 dBm EIRP (net propagation loss of 105 dB), the base station and UE would continue operating at nearly 100% effectiveness when separated from each other by over 1.1 km so long as there is direct line of sight between the UE and eNB. To achieve this level of effectiveness at 1.1 km the radar must also be greater than 21 km away from the UE in the case of outdoor line-of-sight propagation or more than 0.6 km away from the UE in the case of operation in a commercial indoor environment (20 dB of building loss), assuming additional 17 dB/km clutter losses toward the radar. In other words, given optimal circumstances (non-co-channel operation, direct line-of-sight between UE and eNB, and shielding of the radar by building and clutter losses), *an LTE UE could communicate with its eNB with essentially 100% effectiveness when it is physically closer to the radar than to the eNB.* Again we note that this conclusion is based on laboratory and field measurements, including real LTE systems, simulated radar signals, and an actual incumbent radar, rather than theoretical predictions.

27. Despite the encouraging results described above, there are some negative impacts of operating a small-cell LTE network in the presence of radar interference, especially when the radar signal is within the LTE channel. For example, in the case of 0 MHz offset, operating with line-of-sight separation distances between the UE and eNB of more than 5.1 m, or when there are additional losses to contend with such as an interior wall or floor between UE and eNB, the radar will likely have a noticeable negative

impact on LTE performance. If we increase the line-of-sight separation between UE and eNB to 30 m or, equivalently, add approximately 15 dB of wall/floor loss between UE and eNB at 5.1 m separation, the required separation distance to the radar to meet the -20 dB I/S criterion becomes substantially larger. Formally, under worst-case, line-of-sight free space loss conditions, the radar would need to be some 121 km distant. In reality, line of sight virtually never applies for terrestrial paths over this distance; instead, clutter losses and smooth Earth diffraction dominate. Taking into account only clutter losses, as measured in the field, the required separation distance drops to only approximately 2.1 km.

28. In the lab, we noted additional effects with co-channel radar interference. First, there is a resonance of the 1 kHz Pulse Repetition Rate (PRR) of the SPN-43 radar with the 1 millisecond subframe period of the LTE standard. What we noted in the lab is that depending on where, exactly, in the subframe the radar pulse occurred, different amounts of interference impact could be observed. Because the radar pulse and the LTE signal are not time-locked, the radar pulse slowly drifts through the LTE frame. We believe this is the predominant reason that we could see a wide range of impact on downlink data throughput during multiple tests at the same frequency offset and I/S ratio. We documented this phenomenon in a video that is available online.[14] The impact of the resonance is taken into account in our overall conclusions reached above, but we note that this effect could potentially be exploited by an LTE cell to lessen radar interference, by intentionally locking phase with the radar and keeping the radar pulse in a more interference-tolerant portion of the LTE subframe.

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[14] https://www.youtube.com/watch?v=nDVdwSRDEnM.

29. During the lab tests, we also noted that the impact of the radar interference had considerably more variance when the center frequency of the radar was offset by ±3.75 MHz from the center frequency of the 10 MHz LTE carrier. We believe the reason is that some of the OFDM subcarriers that are used to transport important signaling and control information are pushed off toward the edge of the LTE carrier, and therefore this region of the LTE spectrum is particularly vulnerable to interference. The impact of this effect is clear from figure A-6.

c) Laboratory Tests of Radar Interference into Wi-Fi

i) Setup

30. Similar tests to those presented in section (b) were conducted to determine the impact of simulated radar interference into Wi-Fi. In this case, we used a common consumer-grade Wi-Fi router and an inexpensive USB Wi-Fi adapter connected to a computer (Laptop A). A second computer (Laptop B) was wired directly to the router using a wired Ethernet connection. Iperf[15] was used to push User Datagram Protocol (UDP) streams from Laptop B, through the Ethernet connection to the router, then over the wireless connection to Laptop A. Real-time and time-averaged data connection speeds were provided by Iperf. We measured three 30-second averages at each I/S and frequency offset.

31. The router and USB adapter were communicating over a 20 MHz bandwidth 802.11n channel centered at 5825 MHz (Wi-Fi channel 165). The wireless connection from the router to the USB adapter was through coaxial cables, so that the

[15] Iperf is a program that allows the analysis of data throughput speed between network nodes. *See* https://iperf.fr/.

signal strength and interference could be controlled and measured. As in the LTE tests, we measured SISO performance by terminating two of the three antenna ports on the router and one of the two antenna ports on the USB adapter with 50 ohm loads. Because the Wi-Fi signal was twice the bandwidth of the LTE signal used in section (b), we stepped the frequency offset of the radar by twice as much (2.5 MHz instead of 1.25 MHz). The Wi-Fi power was varied between approximately -25 dBm down to approximately -89 dBm. These power levels are channel power during full download activity over a 20 MHz bandwidth, averaged over 30 seconds, and are consistent with typical power levels encountered in real-world Wi-Fi deployments. The corresponding free space distance between router and USB adapter (assuming free space loss at 3600 MHz and 30 dBm EIRP of the router) is 4 m to 5.9 km. The radar power, measured with the same parameters, was fixed at approximately -48.5 dBm (approximately the same as for our LTE measurements),[16] which corresponds (at 3600 MHz) to a distance of approximately 24 km from the radar assuming free space loss, or about 1.4 km assuming free space loss plus 17 dB/km of clutter loss.

ii) Results

32. The results of the radar/Wi-Fi co-existence tests are shown in Figures A-10 - A-18 of Appendix A, presented in a similar fashion to the LTE results. Generally speaking, co-channel radar interference noticeably impacts Wi-Fi downlink throughput, while as soon as the radar interference is at the channel edge or beyond, performance

[16] *See* n.13, *supra*, discussing the slight discrepancy between measured radar power in the LTE tests and measured radar power in the Wi-Fi tests.

improves at I/S levels of less than about -10 dB.[17] However, throughput at higher I/S levels does not recover as quickly outside the channel edge as it does in the LTE case. We conducted tests out to very large frequency separation, keeping the I/S level fixed at -11.5 dB, and noticed that the Wi-Fi downlink performance was noticeably impacted more than 800 MHz outside of the Wi-Fi band and more than 1.75 GHz outside of the Wi-Fi channel (Fig. A-18). We believe that this is the result of poor front-end filtering in the inexpensive Wi-Fi USB adapter that was used in these tests. While this result is likely not representative of all Wi-Fi devices, it does underscore the desirability of improved receiver design to deal with out-of-band interference.

33. Based on our laboratory measurements, we conclude that an inexpensive Wi-Fi adapter can operate non-co-channel with a radar if the radar signal strength is about 10 dB or more below the Wi-Fi signal strength. As with the LTE tests, we calculate specific scenarios using the following assumptions:

a. The radar EIRP toward the horizon is taken as 82 dBm, which is based on field measurements of an actual incumbent radar.

b. The radar signal strength at the Wi-Fi adapter is -48.5 dBm.

c. For indoor deployments, the radar will be attenuated by building losses. We use 10 dB as a typical loss for residential buildings made of wood, and 20 dB for commercial buildings made of metal and masonry. We assume no attenuation of the radar signal for outdoor small cell installations.

[17] The figures imply that downlink performance improved somewhat at very high levels of I/S. We believe this is likely due to an underestimate of downlink throughput at very low signal levels in the initial baseline measurements, to which the downlink throughput performance figures are normalized.

d. We assume the signal from the Wi-Fi router needs to be at least 10 dB stronger than the radar signal (I/S = -10 dB) at the adapter, or -38.5 dBm. Given a 30 dBm base station EIRP, this signal strength is reached at a separation of 18 m, assuming free space loss.

e. Propagation loss from the radar to the small-cell deployment site is free space loss (worst case), or free space loss + 17 dB/km of clutter loss as derived from our field measurements of the radar signal strength.

The following table summarizes the results for non-co-channel Wi-Fi operations:

Table 5: Non-co-channel Wi-Fi/Radar Coexistence Scenarios

Non Co-channel Wi-Fi Deployment (18 m separation between router and adapter):	Outdoor (130.5 dB loss)	Indoor Residential (120.5 dB loss)	Indoor Commercial (110.5 dB loss)
Required Separation Distance from Wi-Fi to Radar (Free Space Loss)	22.2 km	7.0 km	2.2 km
Required Separation Distance from Wi-Fi to Radar (Free Space + Clutter)	1.4 km	1.0 km	0.6 km

III) Summary of Laboratory Test Results

34. Laboratory and field measurements have been conducted to determine the required separation distances between small cell networks (specifically LTE and Wi-Fi) and the principal incumbent radar system in the 3.6 GHz band.

35. Laboratory and field measurements demonstrated that an outdoor LTE network can operate with 5.1 m separation from eNB to UE, *co-channel with a radar,* when as close as 20.7 km assuming direct line-of-sight between the radar and the LTE cell, and as close as 1.4 km if a more realistic path that includes clutter loss is taken into account. Separation distances are even smaller if indoor residential or commercial small

cell deployments are assumed. Table 4 summarizes all of the co-channel scenarios. In the non-co-channel case, the separation distances to the radar remain the same, but the LTE network is able to support UE-to-eNB separation distances as great as 1.1 km. These conclusions are based upon actual measurements, not theoretical predictions.

36. Laboratory measurements demonstrated that an outdoor 802.11n Wi-Fi cell can operate non-co-channel with a radar when as close as 22.2 km to that radar if the radar is in direct line of sight. If there is clutter between the radar and the Wi-Fi cell, the cell can operate as close to the radar as 1.4 km. Both of these conclusions assume separation distance between the Wi-Fi router and adapter of no more than 18 m. Table 5 summarizes all of the non-co-channel Wi-Fi deployment scenarios, including indoor residential and commercial deployments. Under the same separation distances and propagation scenarios listed above, co-channel operation of a Wi-Fi cell would be possible with approximately 50% loss of downlink capacity. This is likely to be a tolerable degradation in quality for many Wi-Fi operations for the following reasons:

a. At any given time, the majority of Wi-Fi operations will not be co-channel with the radar. Even directly within a Navy operating area near the coast, a single radar can be co-channel with only one of ten available 10-MHz channels in the 3550-3650 MHz band, and cannot operate at all within the 3650-3700 MHz portion within approximately 81 km of the coast, as noted above.

b. Wi-Fi users of this band are likely to use it as one of several options for transmitting and receiving wireless data. In particular, it is likely to be complementary to current unlicensed use at 2.4 GHz and 5 GHz.

c. Wi-Fi users do not expect or rely upon a guaranteed quality of service. The hallmark of operation in the 2.4 GHz and 5 GHz bands is that users do not receive interference protection. As a result, we expect that Wi-Fi manufacturers will be able to design devices that can operate successfully in the interference environment presented by this band.

36. None of the tests resulted in any physical damage to the devices used in testing. This includes devices used in our field tests, which operated as close as 1.2 km to an actual incumbent radar system.

IV) Interference from Wireless Networks into the Principal Radar

37. As stated in my July 14, 2014 Declaration in this proceeding, Google's preliminary results suggest that it is straightforward to detect the presence of a shipborne SPN-43 radar even when the radar is beyond the visual horizon, more than 50 km offshore. For example, in our testing, we detected the return of a carrier strike group to the Naval Station in Norfolk, Virginia, using a DLD installed at the oceanfront in the adjacent Virginia Beach area, prior to the ships appearing within the visual horizon. During the carrier strike group return, the DLD also detected other radiofrequency activity apparently associated with carrier flight operations, which could be used as secondary indicators of likely operations of the SPN-43 radar. Information about federal incumbent radar activity can be used by a SAS to command secondary devices to change frequencies, reduce power, or shut down altogether to avoid creating interference with Navy operations.

38. The received signal strength of the SPN-43 radar when first detected over the horizon can be used, in turn, to derive the signal strength received by the radar from a

wireless network operating at the same location as the DLD. We know the power of the radar, the proposed maximum power of a small-cell transmitter, and the signal strength of the radar received by the DLD, so we can calculate the signal strength of a hypothetical small-cell transmitter received by the radar, taking into account the actual measured net propagation loss and antenna gains. Assuming that the wireless network is operated at 30 dBm EIRP in a 10 MHz channel, we have come to the preliminary conclusion that even 100 full-power, outdoor, co-channel access points located directly on the beachfront and pointing directly at the ship would not harmfully interfere with Navy radar operations more than 50 km offshore, above an interference-to-noise ratio of -10 dB. Because a DLD can detect Navy radar systems at distances of greater than 50 km offshore where scores of CBRS devices will not interfere, a SAS can implement any necessary mitigation measures before devices could cause harmful interference to approaching radar systems.

39. Closer radar operations can be detected and interference can be avoided through mitigation measures after detection. Moreover, Google understands that the principal operations supported by the incumbent radar—flight operations on large-deck amphibious ships—generally are not conducted close to shore, and therefore near-shore operations are likely to be related to tests and maintenance of the incumbent radar.

I, Andrew W. Clegg, declare under penalty of perjury that the foregoing declaration is true and correct. Executed on August 14th, 2014.

Andrew W. Clegg

Appendix A to Declaration by Andrew W. Clegg, PhD

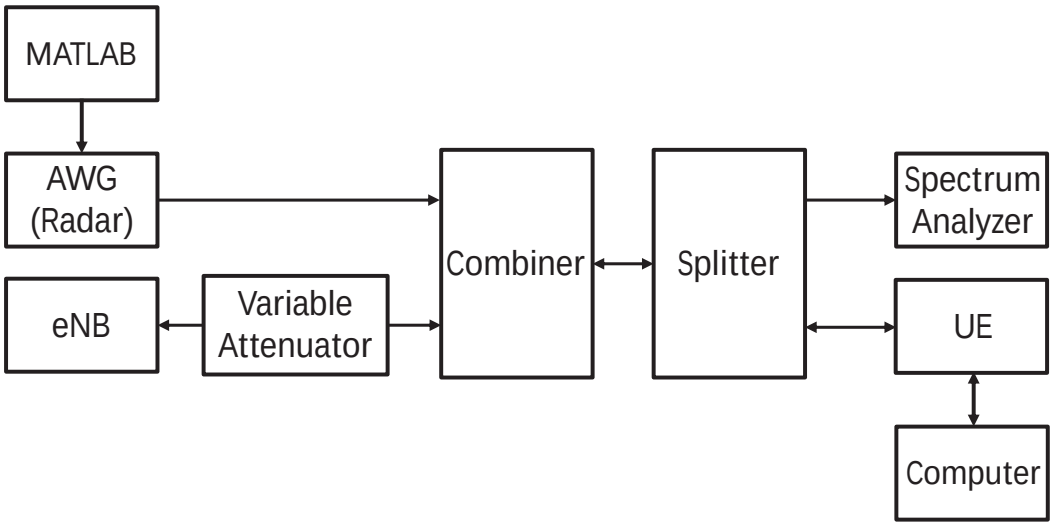
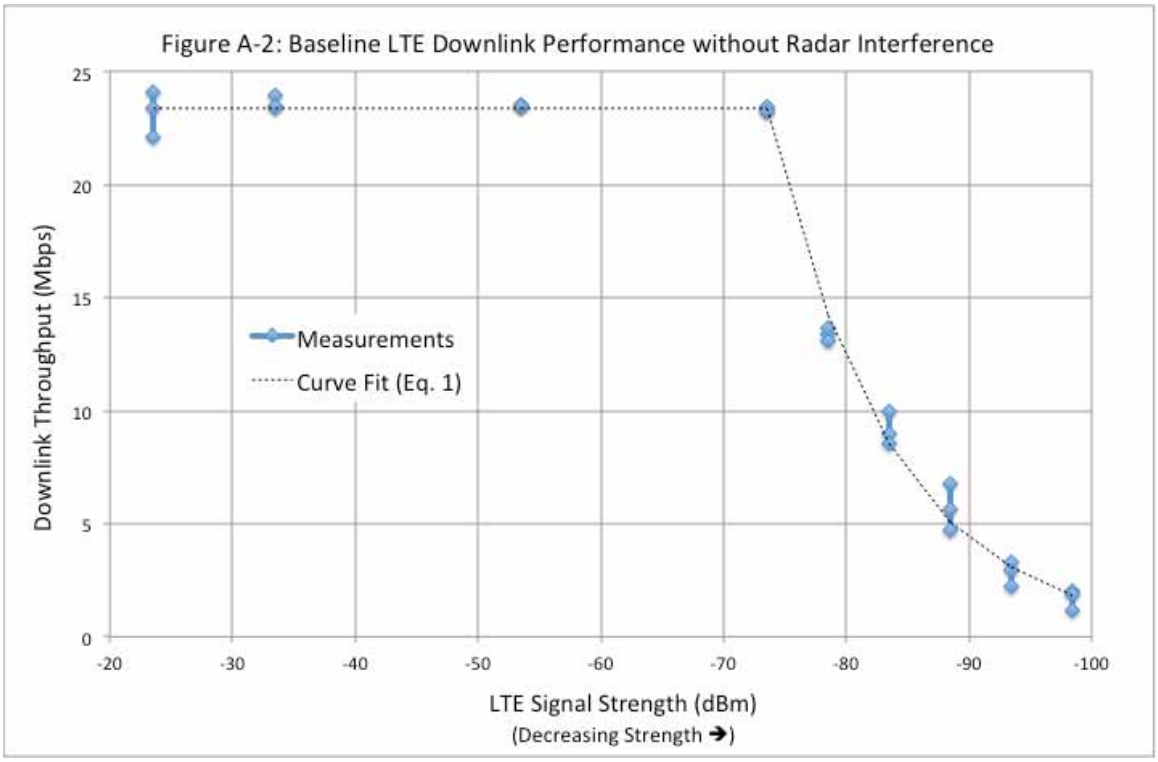


Figure A-1: Simplified Laboratory Test Setup



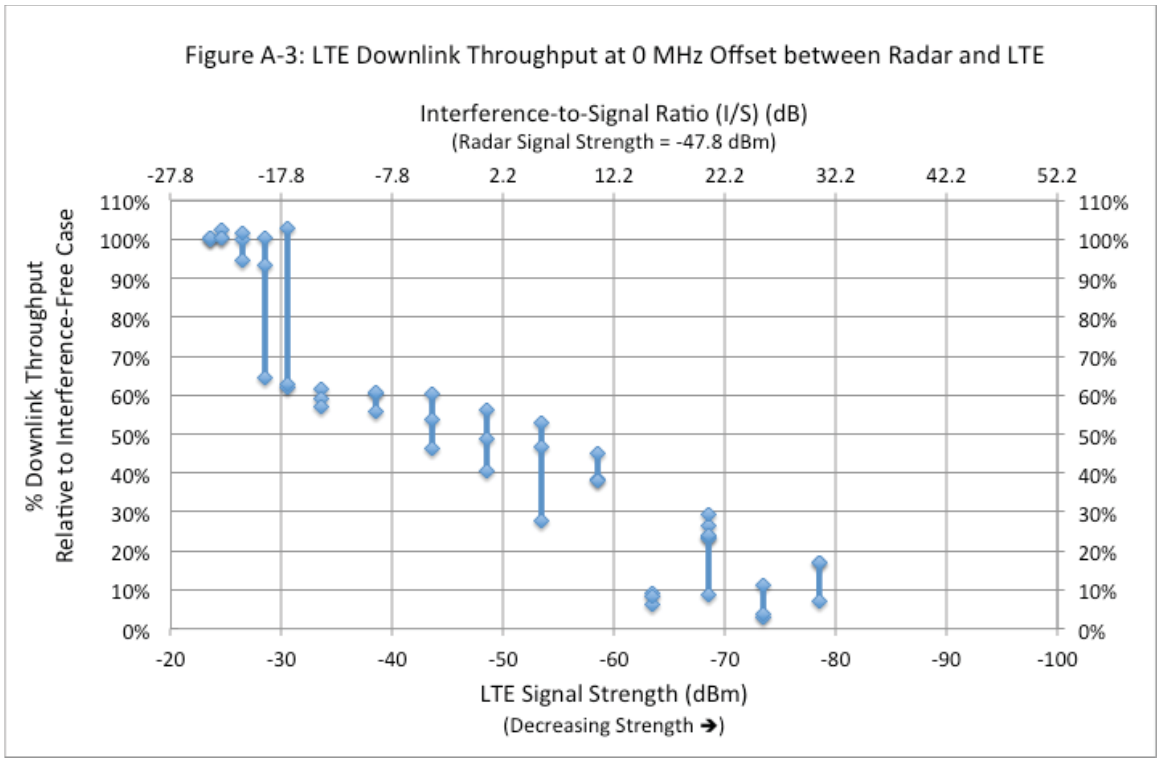


Figure A-3: LTE Downlink Throughput at 0 MHz Offset between Radar and LTE
Interference-to-Signal Ratio (I/S) (dB)
(Radar Signal Strength = -47.8 dBm)
-27.8
-17.8
-7.8
2.2
12.2
22.2
32.2
42.2
52.2
% Downlink Throughput
Relative to Interference-Free Case
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
-20
-30
-40
-50
-60
-70
-80
-90
-100
LTE Signal Strength (dBm)
(Decreasing Strength ➔)

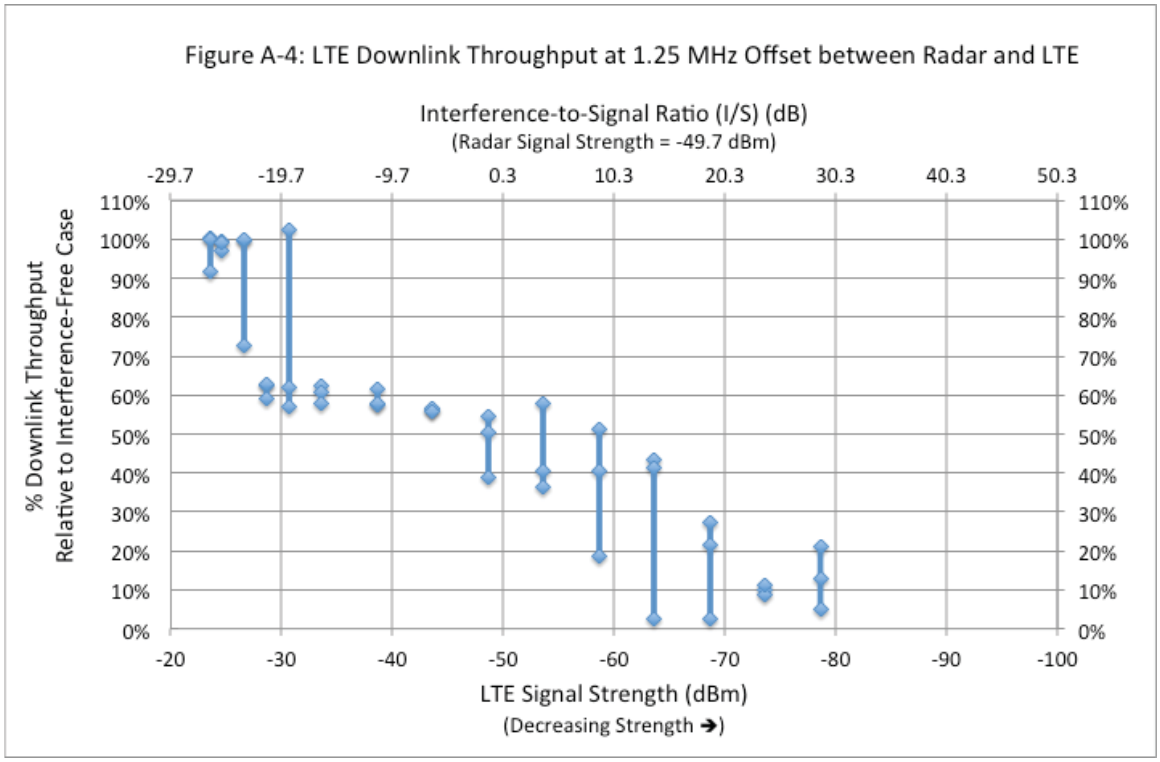


Figure A-4: LTE Downlink Throughput at 1.25 MHz Offset between Radar and LTE
Interference-to-Signal Ratio (I/S) (dB)
(Radar Signal Strength = -49.7 dBm)
-29.7
-19.7
-9.7
0.3
10.3
20.3
30.3
40.3
50.3
% Downlink Throughput
Relative to Interference-Free Case
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
-20
-30
-40
-50
-60
-70
-80
-90
-100
LTE Signal Strength (dBm)
(Decreasing Strength ➔)

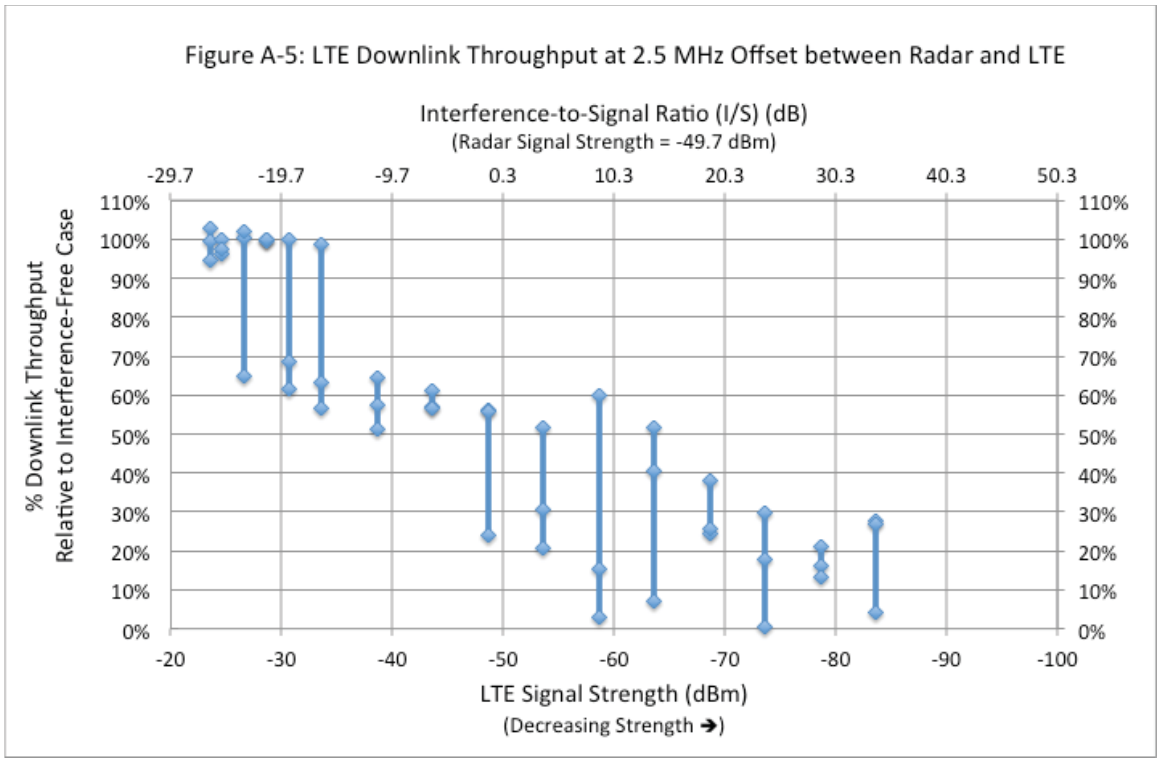


Figure A-5: LTE Downlink Throughput at 2.5 MHz Offset between Radar and LTE
Interference-to-Signal Ratio (I/S) (dB)
(Radar Signal Strength = -49.7 dBm)
-29.7
-19.7
-9.7
0.3
10.3
20.3
30.3
40.3
50.3
% Downlink Throughput
Relative to Interference-Free Case
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
-20
-30
-40
-50
-60
-70
-80
-90
-100
LTE Signal Strength (dBm)
(Decreasing Strength ➔)

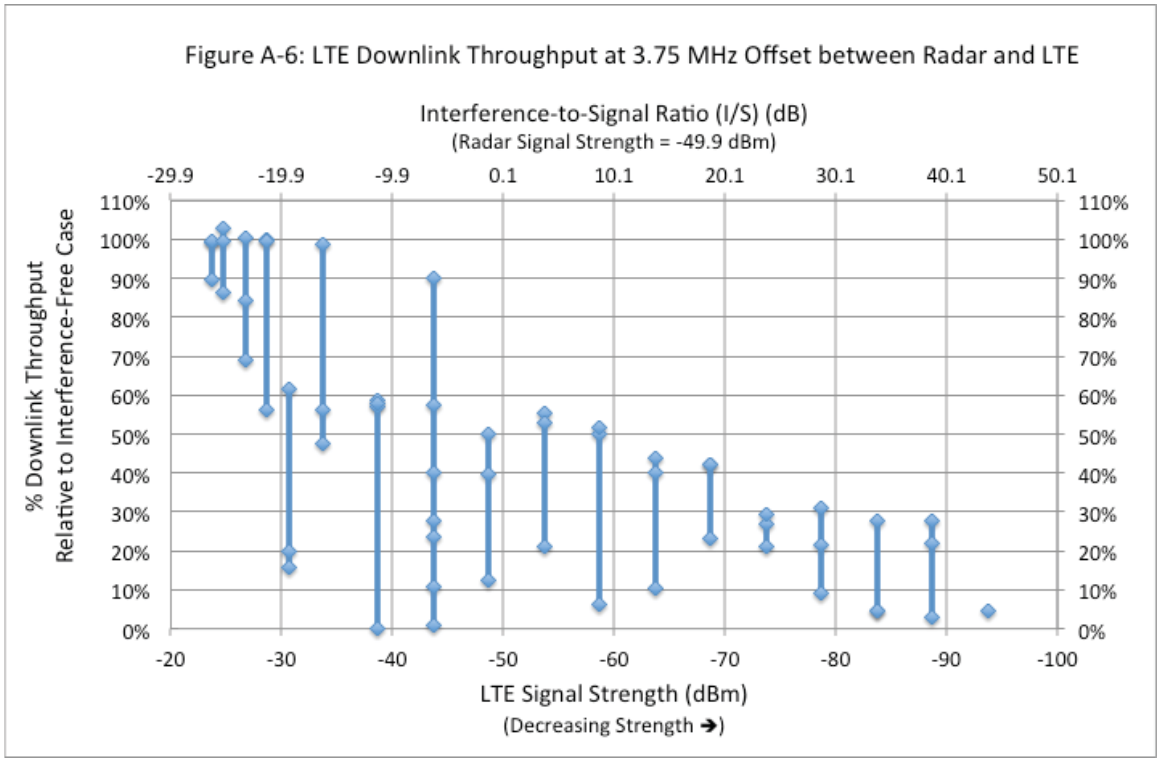


Figure A-6: LTE Downlink Throughput at 3.75 MHz Offset between Radar and LTE
Interference-to-Signal Ratio (I/S) (dB)
(Radar Signal Strength = -49.9 dBm)
-29.9
-19.9
-9.9
0.1
10.1
20.1
30.1
40.1
50.1
% Downlink Throughput
Relative to Interference-Free Case
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
-20
-30
-40
-50
-60
-70
-80
-90
-100
LTE Signal Strength (dBm)
(Decreasing Strength ➔)

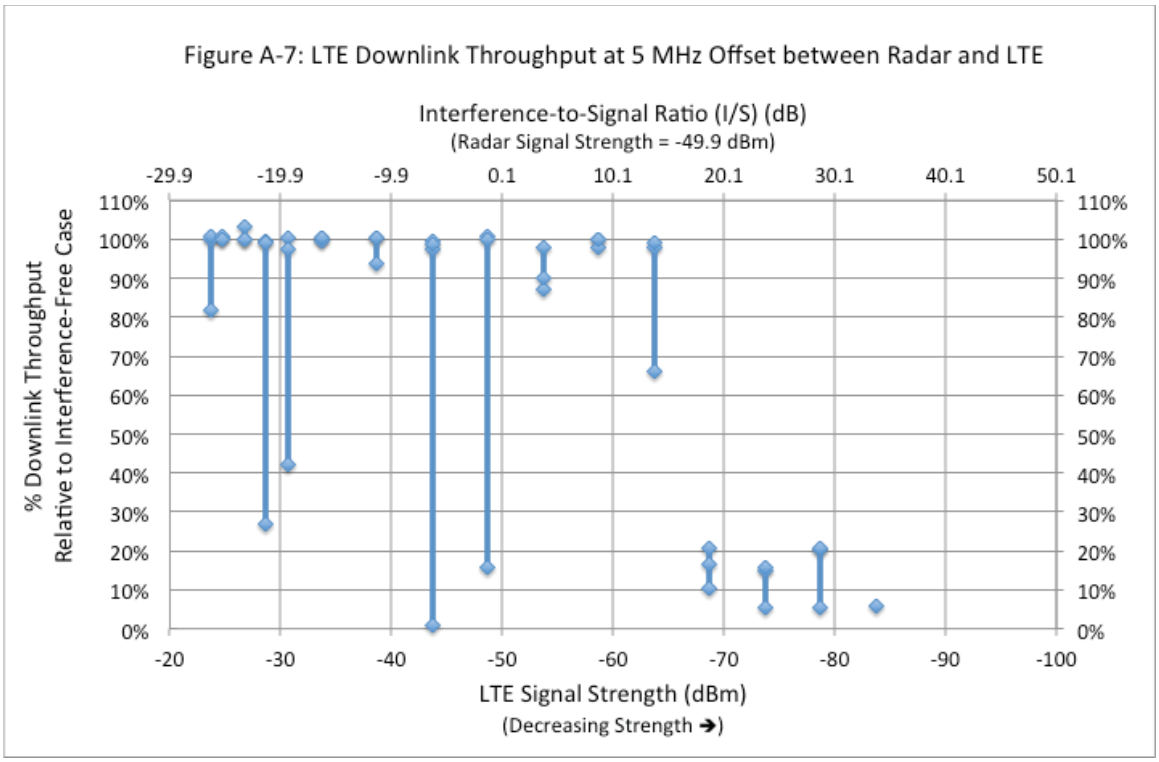


Figure A-7: LTE Downlink Throughput at 5 MHz Offset between Radar and LTE
Interference-to-Signal Ratio (I/S) (dB)
(Radar Signal Strength = -49.9 dBm)
-29.9
-19.9
-9.9
0.1
10.1
20.1
30.1
40.1
50.1
% Downlink Throughput
Relative to Interference-Free Case
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
-20
-30
-40
-50
-60
-70
-80
-90
-100
LTE Signal Strength (dBm)
(Decreasing Strength ➔)

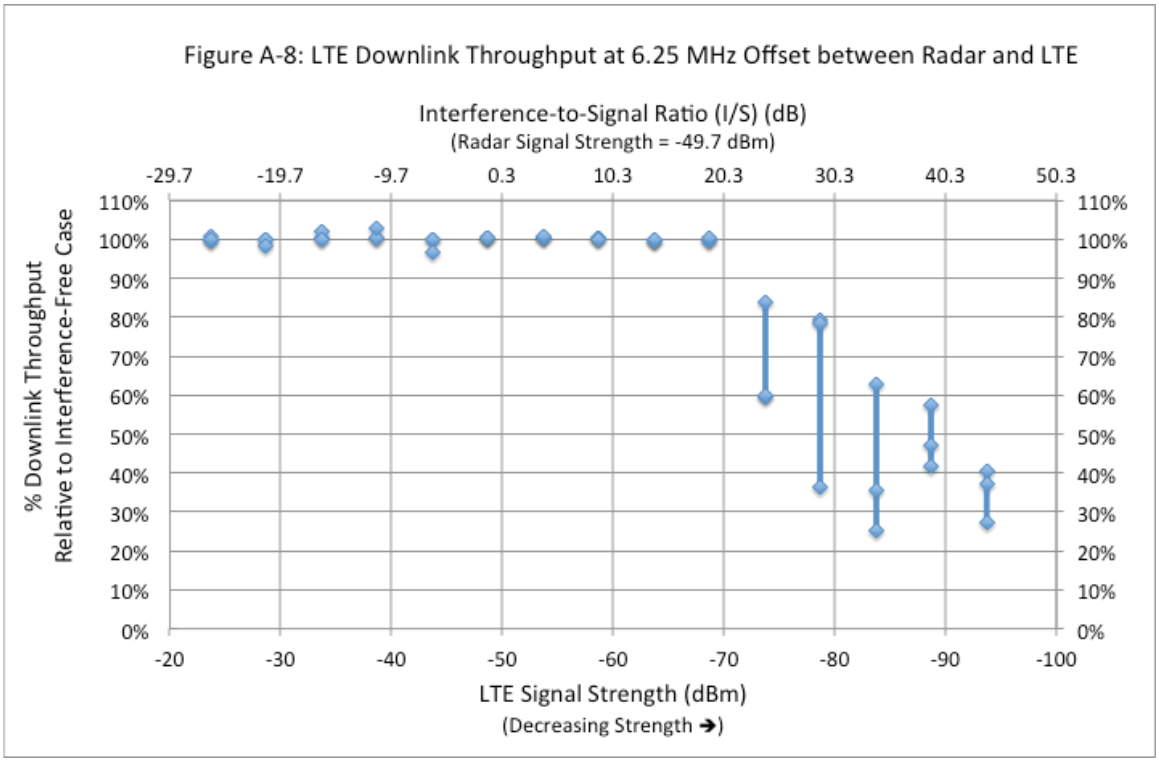


Figure A-8: LTE Downlink Throughput at 6.25 MHz Offset between Radar and LTE
Interference-to-Signal Ratio (I/S) (dB)
(Radar Signal Strength = -49.7 dBm)
-29.7
-19.7
-9.7
0.3
10.3
20.3
30.3
40.3
50.3
% Downlink Throughput
Relative to Interference-Free Case
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
-20
-30
-40
-50
-60
-70
-80
-90
-100
LTE Signal Strength (dBm)
(Decreasing Strength ➔)

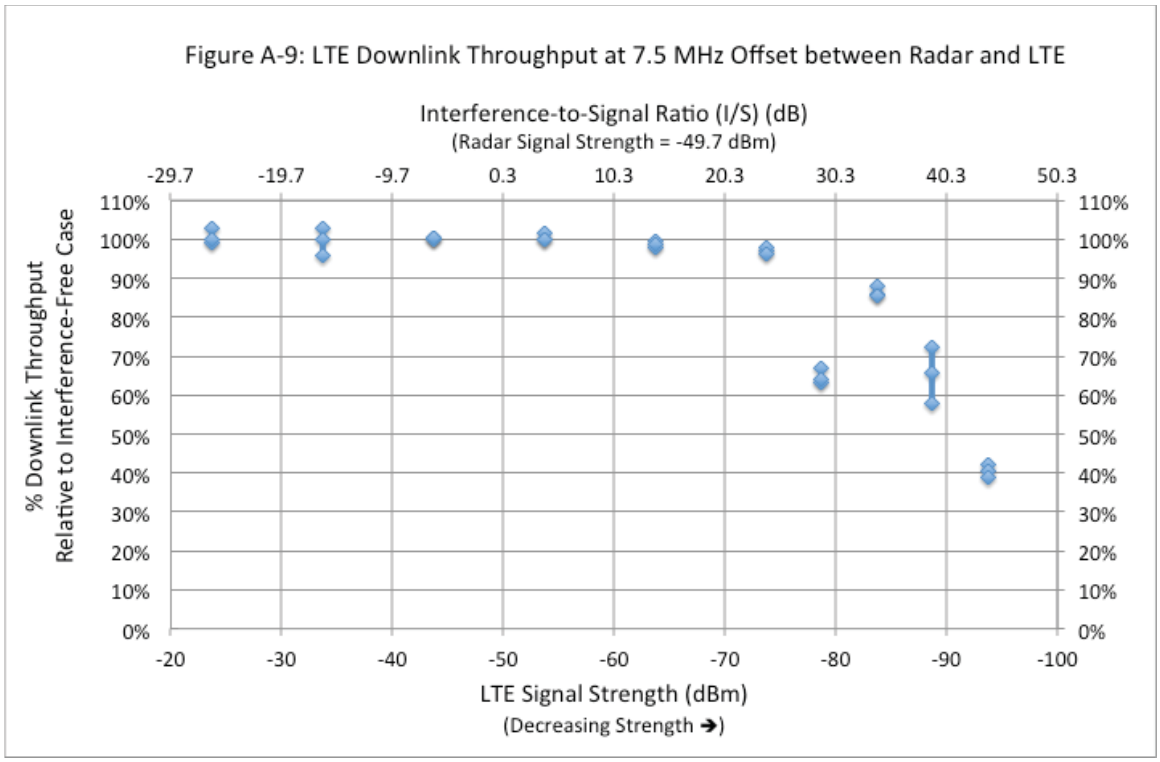


Figure A-9: LTE Downlink Throughput at 7.5 MHz Offset between Radar and LTE
Interference-to-Signal Ratio (I/S) (dB)
(Radar Signal Strength = -49.7 dBm)
-29.7
-19.7
-9.7
0.3
10.3
20.3
30.3
40.3
50.3
% Downlink Throughput
Relative to Interference-Free Case
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
-20
-30
-40
-50
-60
-70
-80
-90
-100
LTE Signal Strength (dBm)
(Decreasing Strength ➔)

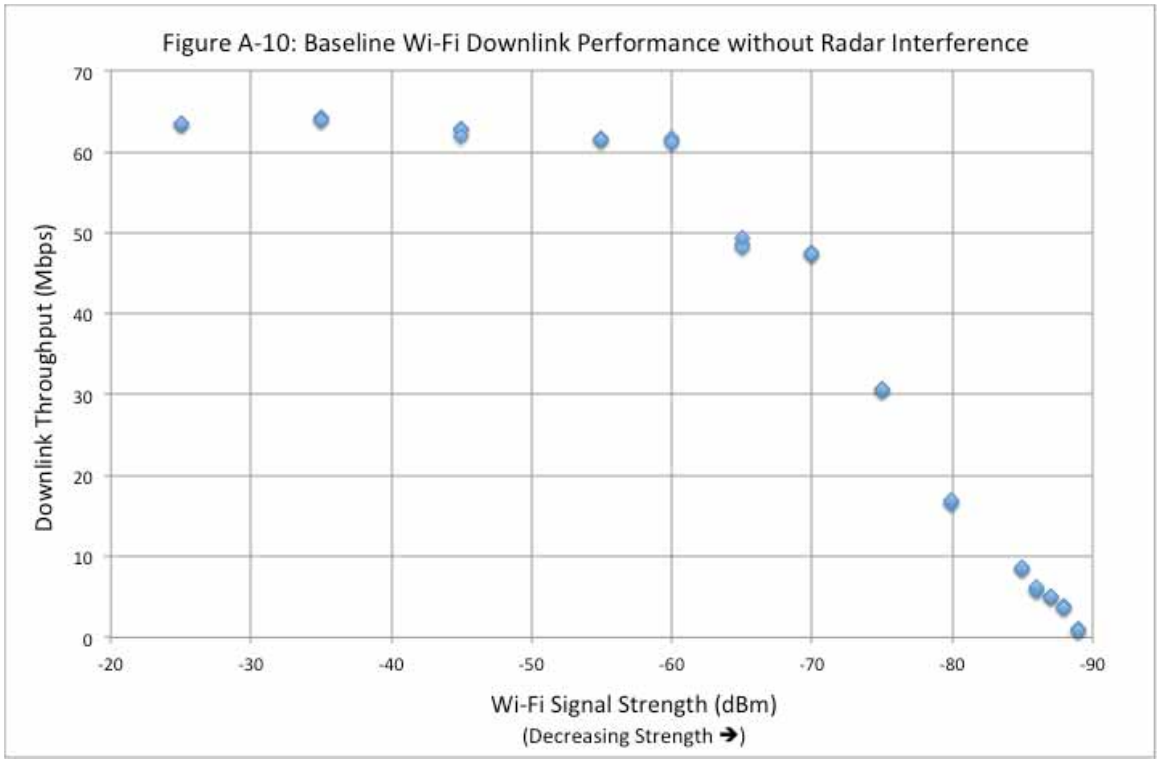


Figure A-10: Baseline Wi-Fi Downlink Performance without Radar Interference
Downlink Throughput (Mbps)
70
60
50
40
30
20
10
0
-20
-30
-40
-50
-60
-70
-80
-90
Wi-Fi Signal Strength (dBm)
(Decreasing Strength ➔)

Figure A-11: Wi-Fi Downlink Throughput at 0 MHz Offset between Radar and Wi-Fi

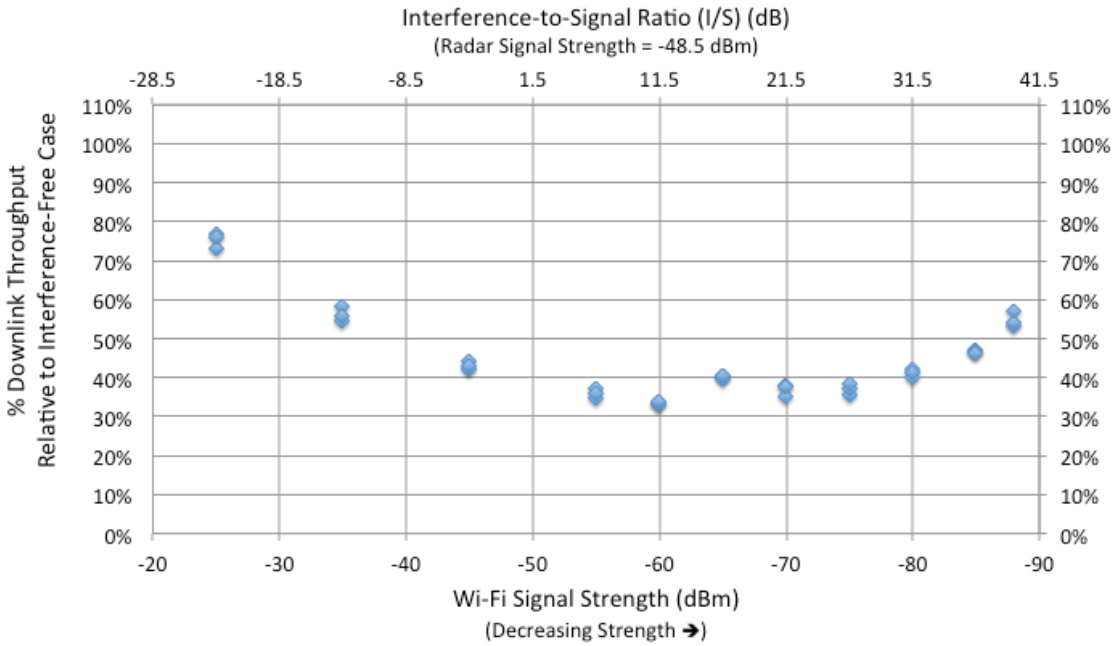


Figure A-12: Wi-Fi Downlink Throughput at 2.5 MHz Offset between Radar and Wi-Fi

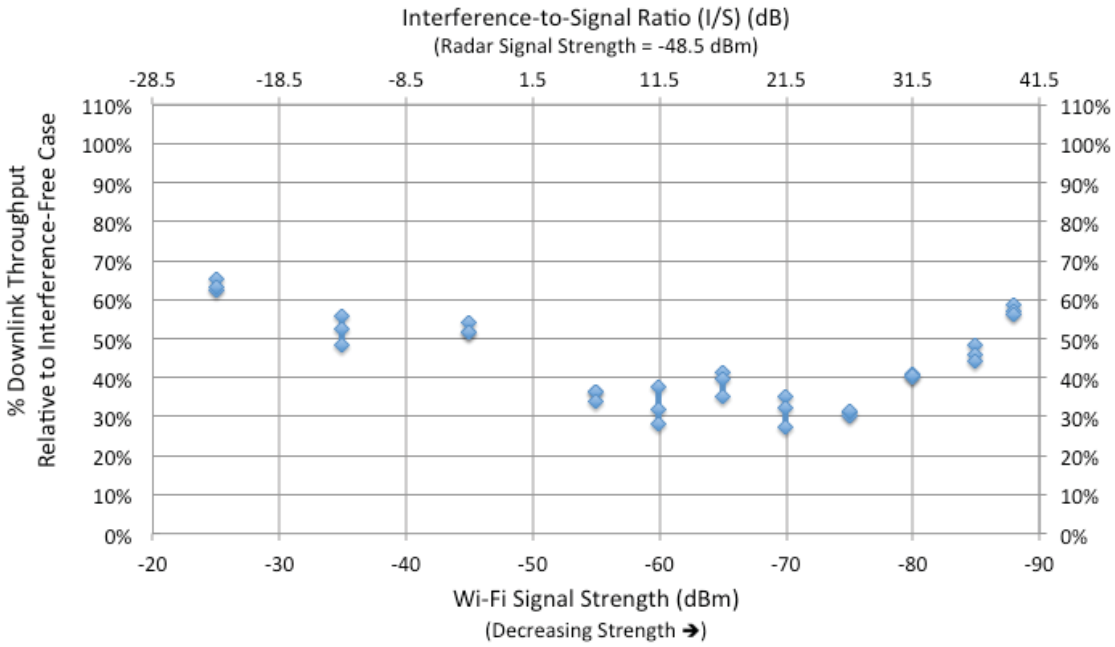


Figure A-13: Wi-Fi Downlink Throughput at 5 MHz Offset between Radar and Wi-Fi

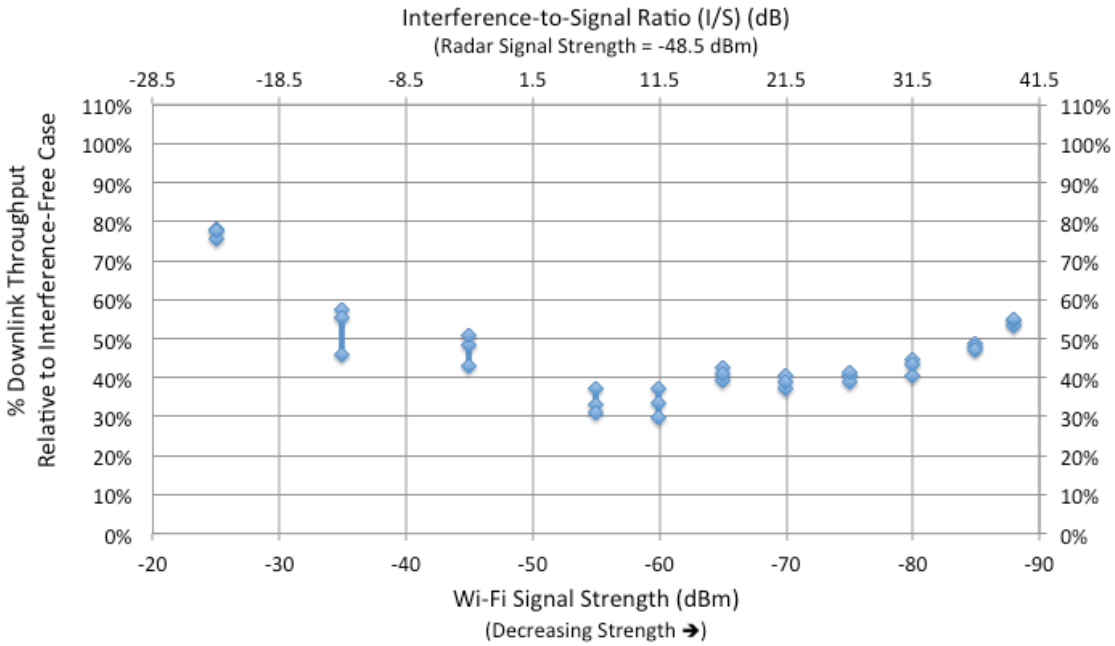


Figure A-14: Wi-Fi Downlink Throughput at 7.5 MHz Offset between Radar and Wi-Fi

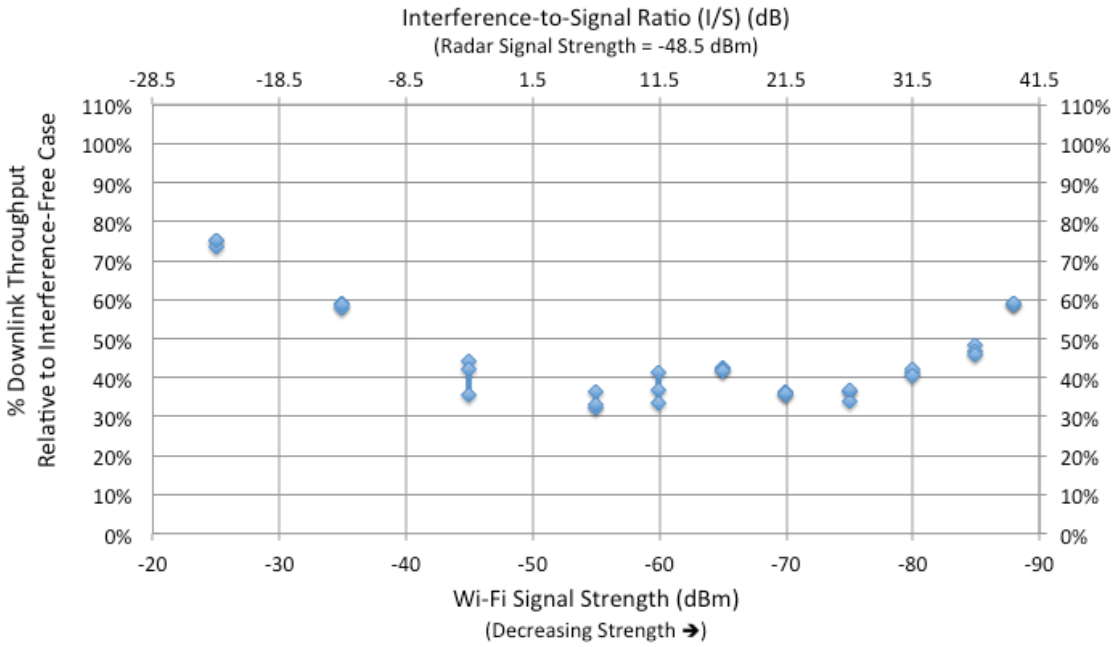


Figure A-15: Wi-Fi Downlink Throughput at 10 MHz Offset between Radar and Wi-Fi

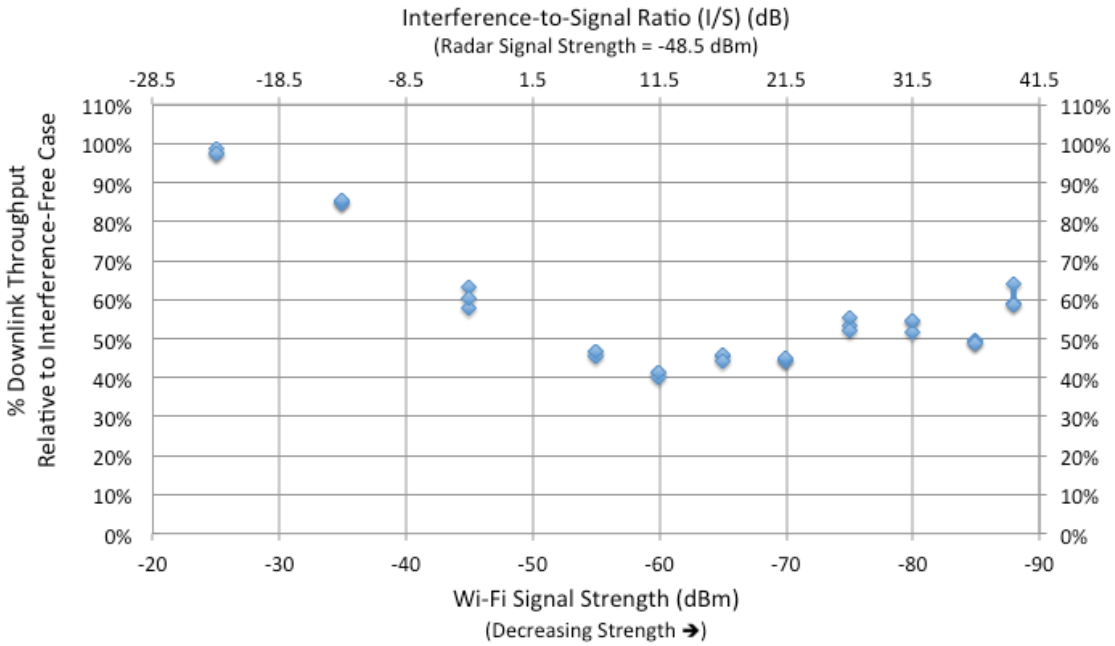
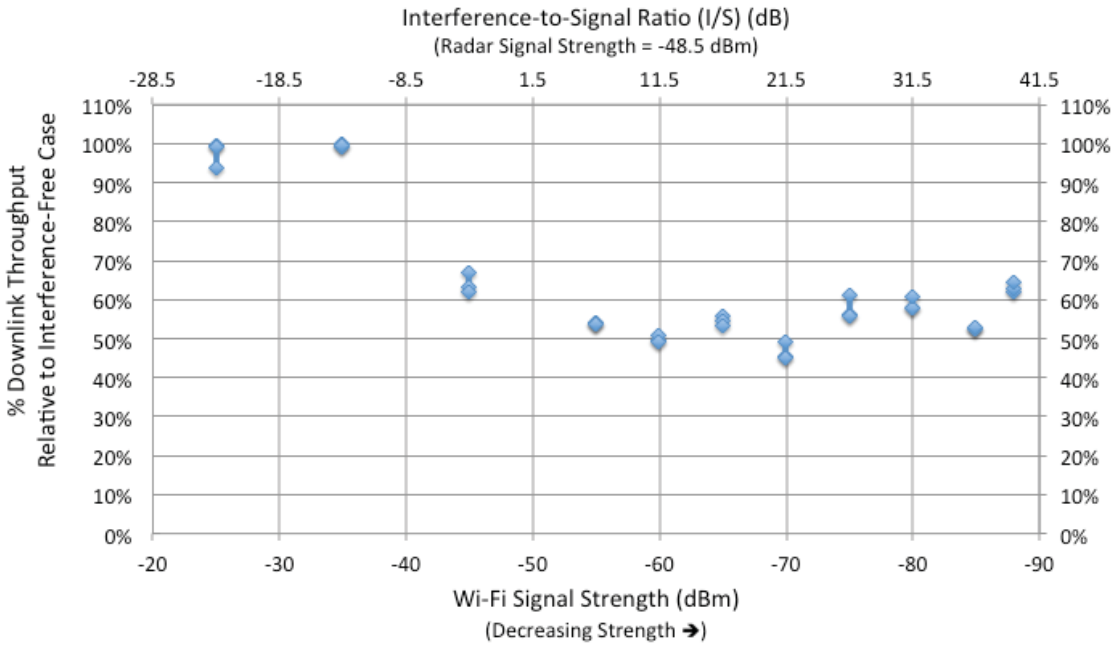


Figure A-16: Wi-Fi Downlink Throughput at 12.5 MHz Offset between Radar and Wi-Fi



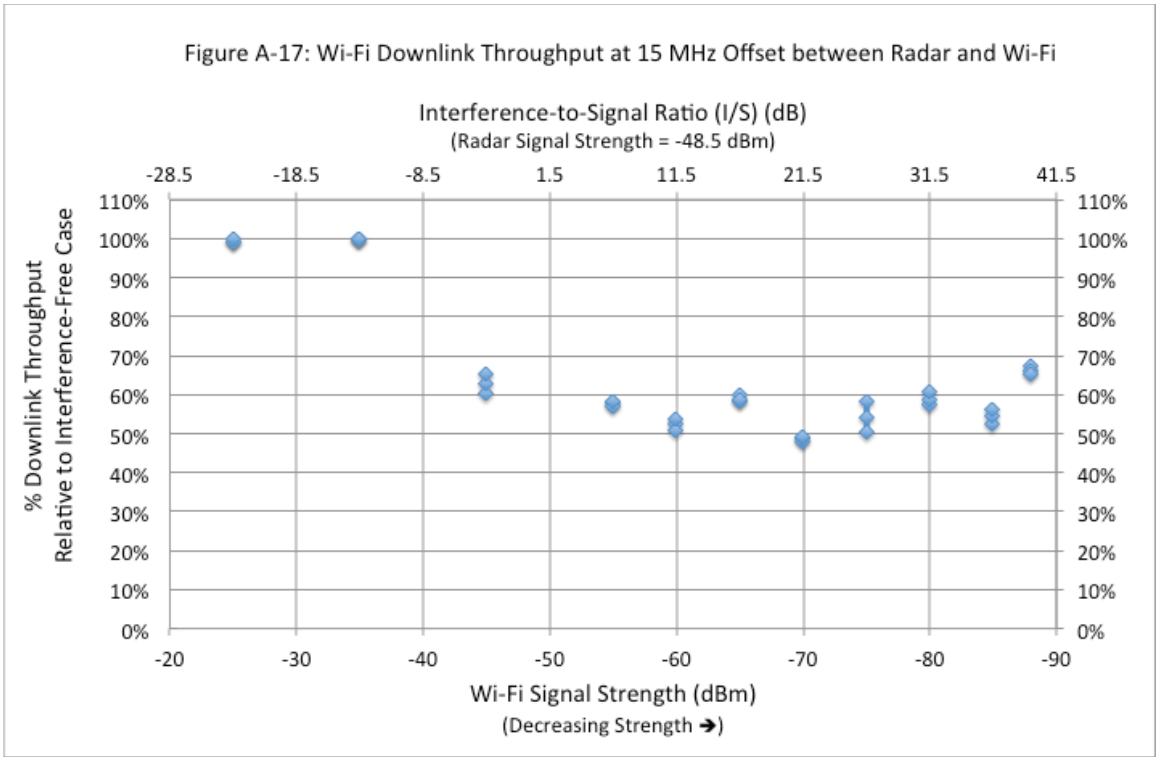


Figure A-17: Wi-Fi Downlink Throughput at 15 MHz Offset between Radar and Wi-Fi
Interference-to-Signal Ratio (I/S) (dB)
(Radar Signal Strength = -48.5 dBm)
-28.5
-18.5
-8.5
1.5
11.5
21.5
31.5
41.5
% Downlink Throughput
Relative to Interference-Free Case
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
-20
-30
-40
-50
-60
-70
-80
-90
Wi-Fi Signal Strength (dBm)
(Decreasing Strength ➔)

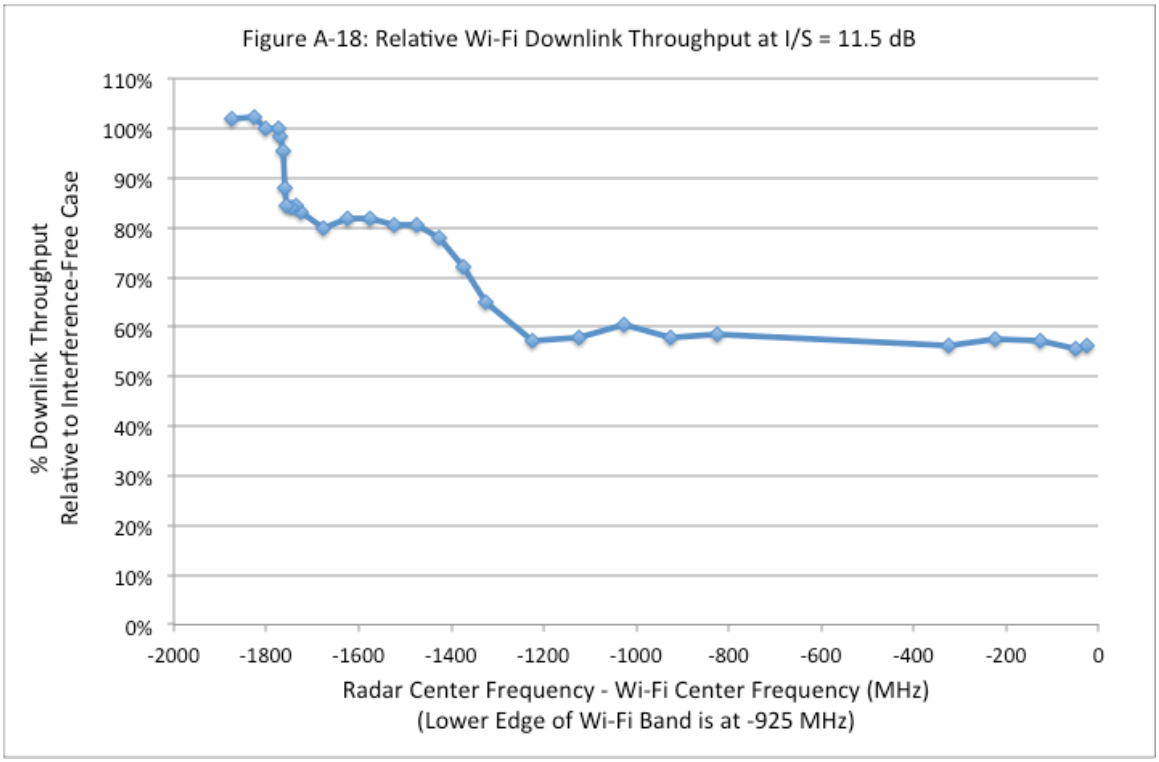


Figure A-18: Relative Wi-Fi Downlink Throughput at I/S = 11.5 dB
% Downlink Throughput
Relative to Interference-Free Case
110%
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
-2000
-1800
-1600
-1400
-1200
-1000
-800
-600
-400
-200
0
Radar Center Frequency - Wi-Fi Center Frequency (MHz)
(Lower Edge of Wi-Fi Band is at -925 MHz)

Appendix B

Declaration of Preston Marshall, Ph.D.

Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, D.C. 20554

In the Matter of Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band	GN Docket No. 12-354

DECLARATION OF PRESTON MARSHALL, Ph.D.

1. My name is Preston Marshall. I am the Principal Systems Architect for Google Access Services. Before joining Google, I served as a Professor of Electrical Engineering and the Deputy Director of the Information Sciences Institute at the University of Southern California in Los Angeles, California. I also worked for many years at the Defense Advanced Research Projects Agency. I served as an invited expert to the President's Council of Advisors on Science and Technology (PCAST) and contributed to PCAST's 2012 report titled "Realizing the Full Potential of Government-Held Spectrum to Spur Economic Growth."[1] I received a Ph.D. from Trinity College in Dublin. I also received an M.S. in Information Science and a B.S. in Electrical Engineering from Lehigh University.

2. I have worked extensively on matters regarding systems design and architecture, wireless technologies, interference, network design, and spectrum management. I also have specific expertise in designing databases to enable spectrum sharing among various types of users.

3. I have reviewed the FCC's Notice of Proposed Rulemaking (NPRM) and Further

[1] PCAST, *Report to the President: Realizing the Full Potential of Government-Held Spectrum to Spur Economic Growth* (rel. July 20, 2012).

Notice of Proposed Rulemaking (FNPRM) in the above-captioned proceeding.[2] I have also reviewed documents filed in response to the FNPRM, including: Comments of AT&T, Comments of Mobile Future, Comments of Nokia Solutions and Networks US LLC, Comments of Pierre de Vries, Comments of T-Mobile USA, Inc., and Comments of Verizon.[3]

Google's SAS Design: Interaction between a SAS and Priority Access Users

4. Various commenters have discussed the relationship between Spectrum Access Systems (SASs) and Priority Access network operators. In particular, a number of commenters addressed the issue of allocating device management responsibilities between a SAS and the Priority Access network operator. Below, I summarize Google's view of a SAS's functions as they relate to Priority Access operations, and to the division of responsibilities for these operations. At its Mountain View headquarters, Google has prototyped an implementation of these principles to ensure the feasibility of their implementation.

5. Our SAS design incorporates the following principles:

a. Priority Access Licensee (PAL) frequency assignments should be as static as possible, given the constraints of interference protection to primary users and other PAL users.

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[2] *Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band*, Notice of Proposed Rulemaking and Order, GN Docket No. 12-354, 27 FCC Rcd. 15,594 (2012); *Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band*, Further Notice of Proposed Rulemaking and Order, GN Docket No. 12-354, 29 FCC Rcd. 4273 (2014) ("FNPRM").

[3] *See* Comments of AT&T, GN Docket No. 12-354 (filed July 14, 2014) ("AT&T Comments"); Comments of Mobile Future, GN Docket No. 12-354 (filed July 14, 2014) ("Mobile Future Comments"); Comments of Nokia Solutions and Networks US LLC, GN Docket No. 12-354 (filed July 14, 2014); Comments of Pierre de Vries, GN Docket No. 12-354 (filed July 14, 2014); Comments of T-Mobile USA, Inc., GN Docket No. 12-354 (filed July 14, 2014) ("T-Mobile Comments"); Comments of Verizon, GN Docket No. 12-354 (filed July 14, 2014) ("Verizon Comments").

Creating initially static assignments will in some ways mimic traditional, exclusive licensing arrangements. For example, in the simplest case, if one operator reserved a PAL for every census tract nationwide, then it could be assigned one channel for the entire nation, subject to constraints from C-Band users and potential use of the spectrum by federal users.[4] The FNPRM suggests SAS providers adopt this approach (i.e., assigning one operator the same frequencies across multiple PAL tracts),[5] and we believe the process for assigning these channels should be developed jointly by potential Priority Access licensees and SAS providers, within the high-level rules established by the Commission, to best meet the needs of the PAL community.

b. Google's SAS process envisions assigning default frequency assignments to PAL holders at the completion of each reservation cycle. Initially, these channels might not be occupied by Priority Access users and, in that situation, could be used by GAA users. As PAL holders deployed devices, however, any GAA users would be displaced to assure non-interference with PAL operations. As a Priority Access user deploys more devices in more areas, the regions of operation would all be assigned to the same channel (consistent with the interference protection to primary users and efficient allocation of the band), so a network operator's "islands" of deployment eventually would merge.

c. The choice of spectrum treatment (as one large block, or multiple islands) should be made by individual PAL licensees. To the extent that licensees reserve large, contiguous

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[4] Google's filing accompanying this declaration sets forth reasons why the Commission should not assign PALs based on census tracts. I use census tracts in this example solely for discussion purposes.

[5] *See* FNPRM ¶ 48 ("To the extent a licensee has PALs in adjacent census tracts, we propose that the SAS should endeavor to assign contiguous frequencies across geographic boundaries.").

blocks of spatial licenses, they can manage them very similarly to current metropolitan area licenses. To the extent that the licensees reserve PAL rights only in localized "hot spots," each of the islands can be managed individually, while the SAS assures that the interference from adjacent Priority Access and GAA users is no more than the FCC-mandated threshold for PAL protection.

d. A SAS has no role in managing the use of spectrum that has been made available to Priority Access users, aside from ensuring that PAL usage (including both in-channel and out-of-band-emissions effects) is consistent with the protection requirements established by the FCC in this proceeding. In particular, aggregate emission limits are necessary to protect Fixed Satellite Service (FSS) and Federal users that would not be interfered with by single devices, or even a single PAL user, but would have their interference limits exceeded by the aggregate emissions from users across all 150 MHz of Citizens Broadband Radio Service (CBRS) usage. Google's SAS design provides operators the ability to manage their own devices, including interference management among their own Priority Access deployed devices. The choice of power, location, modulation bandwidth, and directionality is completely under the control of the operator. In a similar vein, if two operators that end up with spatial adjacencies make arrangements to address conditions at the boundary between their operations, our SAS would defer to any constraints imposed by those agreements.

e. A SAS does need to be aware of the specific deployments of any user of the band. For example, in the case of Priority Access usage, a dense, full power deployment under a C-Band dish antenna footprint might reach interference thresholds for either out-of-band emissions or adjacent band emissions. Therefore, the SAS does require knowledge of placement and operation as it impacts interference (but not those aspects that do not impact interference) in

order to ensure compliance with the interference protection criteria in this band. Individual PAL or GAA operators are not aware of the other user operations in the band, and therefore cannot provide this protection through internal mechanisms. This approach avoids the necessity to arbitrarily limit usage based on modeling of a hypothetical, worst-case density deployment.

f. There may be occasions where a SAS may have to move Priority Access spectrum assignments on a very local level. FSS deployments are relatively static, so we see naval operation as the primary source of dynamic changes to the assignments. The SPN-43 radar has an emission bandwidth that is less than 2 MHz, so when it is present, its protection will require vacating the GAA or PAL channel occupied by the radar, and relocating Priority Access assignments in the vicinity of its operation.[6] (This assumes PAL licensees would prefer to minimize the disruption associated with these events, and therefore would prefer that only the channels in the affected locality be relocated.) Google anticipates that a Google SAS would record the original contiguous PAL channel reservation, so the PAL licensee can resume contiguous operation as soon as the incumbent use ceases. However, as PAL users' network strategies evolve and mature, we would work with PAL holders to accommodate those strategies within the Commission's rules.

Specific Points Raised in Response to the FNPRM

[6] Note that this approach assumes that tailored protection rules are established to protect incumbents from harmful interference, and rigid exclusion zones (such as proposed in the NTIA's report assessing coexistence between federal operations and non-federal wireless services in this band) are not in place. *See* NTIA, An Assessment of the Near-Term Viability of Accommodating Wireless Broadband Systems in the 1675-1710 MHz, 1755-1780 MHz, 3500-3650 MHz, 4200-4220 MHz, and 4380-4400 MHz Bands (rel. October 2010). My colleague Andrew W. Clegg's declaration shows such exclusion zones are, at a minimum, vastly overstated, and most likely not necessary.

6. Below, we apply these principles to specific concerns raised in response to the FCC's FNPRM.

7. A number of commenters made arguments based on the purported complexity of SASs. For example, Mobile Future stated generally that "[t]he SAS architectures, concepts, and implementation details must address a multitude of requirements, including: coordination among multiple, competing commercial SAS managing entities; interface definitions, database and protocol security; speed of channel allocation/reallocation; and effectively managing large numbers of GAA users."[7] Although the concerns raised have been more general than specific, they can be broken down into two categories: (1) calculating appropriate interference protection and (2) scaling the SAS to handle information regarding millions of devices.

8. **Calculating Interference Protection:** Google has prototyped the operation of a SAS and implemented the protection functions at small scale. The analytic technologies used in the prototype SAS are generally the same ones employed in technical submissions filed in this and other proceedings to document potential interference to different classes of service. These methods, in particular the subject of managing front end interference and receiver protection, have been developed in the technical community over several decades. Both the methodologies and technologies are mature, though the SAS approach has the benefit of allowing prompt incorporation of further progress in these areas.

a. The specific interference protections provided by Google's prototype SAS are based on application of extremely conservative interference protections. To assure complete interference protection, we analyze the entire 150 MHz of the proposed 3.5 GHz band, plus 40

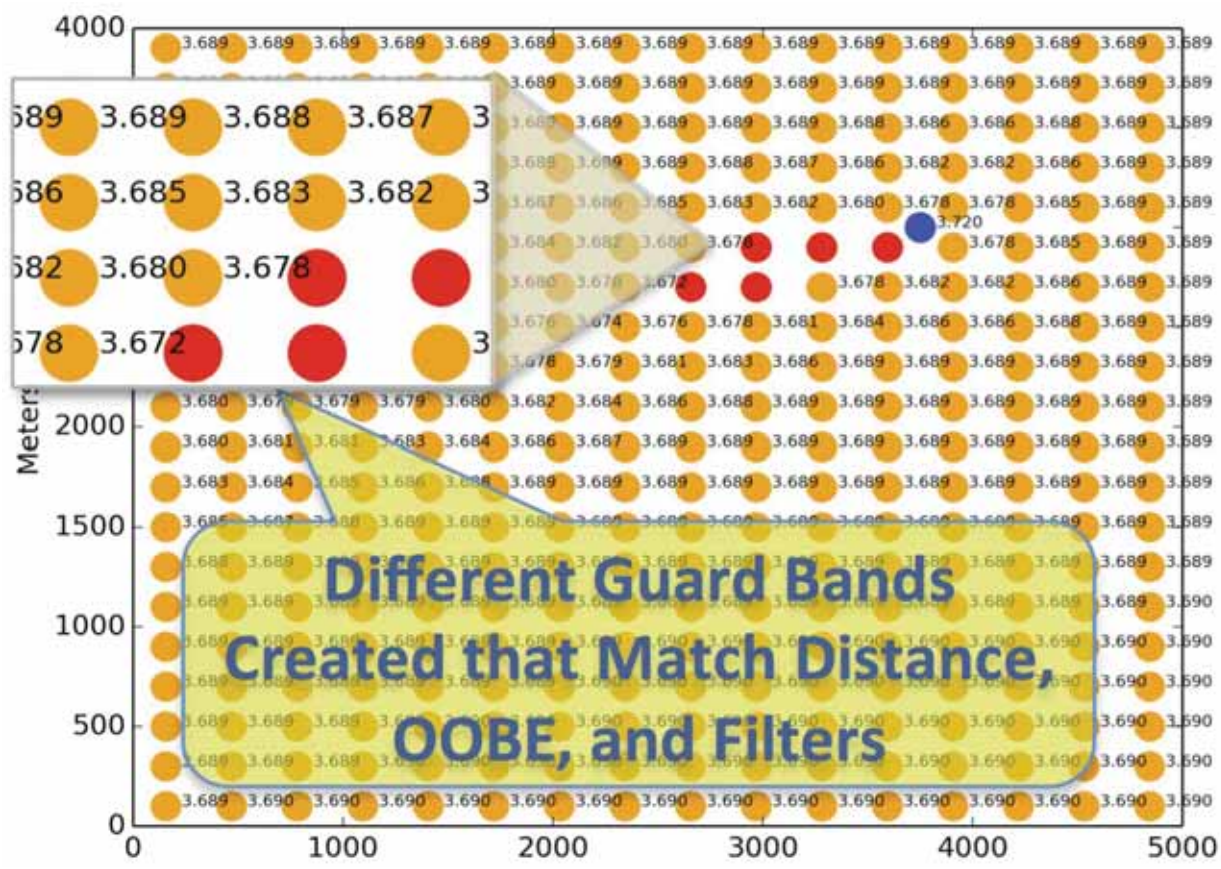
[7] Mobile Future Comments at 4.

MHz above and below the band to test for OOBE. We compute the worst-case power spectral density across this entire band based on either certified device characteristics or the regulatory minimum thresholds. We then account for any additional antenna or fixed-filter spectral impacts. Spatial patterns are then applied based on any directionality in the Citizens Band device. For distances within 2 kilometers of FSS sites, we conservatively assume free space propagation because of the general placement of these devices. For other paths, we use the same terrain model that is employed in Google's FCC-certified TV White Space database. On the receive side, we compute the possible antenna spatial impacts for each possible positioning of the antennas. In the case of FSS above 3.7 GHz, for each registered ground station, we compute the actual azimuth and elevation to each occupied domestic orbital slot, and compute the impact of the emitters on the receiver in each of these possible positions. Our process is similar to the one outlined in the FCC's 2005 Report and Order and Memorandum Opinion and Order addressing wireless operations in the 3650-3700 MHz band, with the added consideration of the entirety of the emitter population.[8] In the case of radars, we consider each position of the rotating antenna individually. Co-channel energy is computed by integrating the power spectral density in the occupied channel frequency and bandwidth (which in the case of FSS is Channel 1 of the FSS transponder, with no cross polarization loss assumed). Adjacent channel energy for FSS units is computed by processing the power spectral density through a model of a commodity bandpass filter response curve, and then computing the total energy that is passed to the Low Noise Block Converter (LNB) or Amplifier (LNA). Both co-channel and adjacent channel energy are compared to system or service-specific criteria for protection. There are no technical

[8] *See generally Wireless Operations in the 3650-3700 MHz Band*, Report and Order and Memorandum Opinion and Order, FCC 05-56, 20 FCC Rcd. 6502, 6554 (2005).

obstacles to any of these processes, and available information is sufficient to implement them, although the additional information – in particular information regarding grandfathered FSS sites – would greatly reduce the loss of spectrum access that is necessitated by our conservative assumptions.

b. As an example of this full band power spectral density processing, the chart below shows the maximum assignable frequency in the presence of a particular FSS ground station. The red dots are locations where a single full power device could not be placed. In the vicinity of this "exclusion zone", the SAS created dynamic guard bands of up to 28 MHz to protect the FSS site from interference based on the actual OOBE mask from the device, and/or the bandpass filter's roll off characteristics below 3.7 GHz.



This framework is flexible enough to accommodate additional protections should the need arise.

9. **Scaling a SAS:** SASs must be scaleable to accommodate the likely population of devices in the 3.5 GHz band. Modern computing technology has shown that well-structured problems are highly amenable to scaling, even at levels well beyond the scope required by a SAS. For instance, if ten million SAS-registered devices were deployed within the 3.5 GHz band within the first 3 years of service – which certainly would make the Commission's rules a success – the registration rate of new devices across all SASs would be just one every ten seconds over the 3 year period. Handling one transaction every ten seconds is trivial in today's computing.

10. **Dynamic Frequency Assignments:** Some commenters raised specific concerns about SASs making dynamic frequency assignments, noting that PAL holders may prefer to operate on the same channels in geographically adjacent PALs and that such harmonization can minimize the potential for interference between PAL holders.[9] As explained above, Google agrees that it can be both efficient and desirable for a SAS to allocate the same channels to a Priority Access operator that holds multiple licenses across contiguous geographies. More important, the FNPRM explicitly states that a SAS should assign contiguous spectrum to the extent possible.[10] If this proposed requirement is adopted, then to the extent possible our SAS (and surely other SASs as well) will provide consistent channels across PALs managed by the same network operator, so long as federal incumbent operations do not preclude such assignments and so long as these assignments would not impede use of the band by other

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[9] T-Mobile Comments at 10; AT&T Comments at 18.

[10] FNPRM ¶ 48 & Appendix A (Proposed Rules) at § 96.23(c)(1)(i).

licensees.

11. **Network Control:** Finally, a number of commenters noted the importance of allowing network operators to control their own networks. For example, these commenters noted that operators want to be able to control frequency reuse, power levels, resource management, and inter-cell coordination, configuration of a network, and overall traffic optimization within a network.[11] Consistent with that, Google's concept of a SAS limits the SAS's management to functions that ensure that the operations by a PAL holder do not create any interference to higher or parallel tier users. While a SAS may need to be *aware* of the deployment location, power, and other characteristics of the Priority Access usage, the SAS does not *control* these characteristics. When new devices are added to a PAL, a SAS will validate that that additional usage does not violate individual or aggregate emission constraints imposed under the Commission's rules. As an example, Google's presentations at the FCC SAS workshop showed how constraints on aggregate emissions into FSS receivers may limit density of all classes of user in their vicinity.[12] Within the constraints set forth by the rules, the choice of power levels will be made by the operator, not the SAS.

I, Preston Marshall, declare under penalty of perjury that the foregoing declaration is true and correct. Executed on August 14th, 2014.

Preston Marshall

Preston Marshall

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[11] *See, e.g.*, AT&T Comments at 15; Verizon Comments at 9-10; T-Mobile Comments at 14.

[12] *See* Preston Marshall, Principal Wireless Architect, Google, Inc., *Spectrum Access System: Managing Three Tiers of Users in the 3550-3700 GHz Band* at 4-5 (Jan. 14, 2014), *available at* http://wireless.fcc.gov/workshops/sas_01-14-2014/panel-1/Marshall-Google.pdf.