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
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COMMENTS OF GOOGLE INC.

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Table of Contents

Introduction and Summary 1

1. The Commission should adopt a definition of "use" that is grounded in sound technical considerations. 2
   a. PAL holders' Citizens Broadband Radio Service Devices (CBSDs) and their affiliated end user devices should be protected against aggregate interference by a SAS. 2
   b. Adopting this proposed approach to protecting PAL operations will maximize use of the band, protect actual operations, and enable rapid deployment of devices. 10
   c. The Commission should require PAL holders to register protection areas based on engineering requirements of actual operations. 12
   d. If the Commission wishes to maximize spectrum utilization, it should also modify or eliminate its rule limiting transmit power at the edge of a PAL boundary. 13
   e. The proposed engineering approach to defining "use" is compatible with SAS support for secondary market operations. 18
   f. An economic definition of "use" predictably would reduce spectrum utilization. 19

2. In-band and out-of-band FSS earth stations should be protected using reasonable interference criteria. 20
   a. In determining FSS protections, the Commission should rely on certain trigonometric equations and key FSS system characteristics set forth in its 2005 coordination methodology. 21
   b. The Commission should tailor FSS protections to actual conditions, rather than establishing a default protection zone for all FSS stations. 24
   c. Protection of FSS stations should take into account aggregate interference effects. 24
   d. The Commission should allow SAS providers to adopt varying propagation models, so long as such models protect incumbent services from harmful interference. 25

3. The Commission should adjust its hardware certification process to allow devices with superior out-of-band emissions performance to access additional spectrum. 28

Conclusion 31

INTRODUCTION AND SUMMARY

The Commission's Report and Order adopting rules for the 3.5 GHz band represents a significant achievement: It establishes an innovative approach to intensive spectrum sharing that will free 150 MHz of currently underused spectrum.[1] In the accompanying Second Further Notice of Proposed Rulemaking (Second FNPRM), the Commission asks for comment on key issues that will determine whether opportunities in the band are maximized to their fullest potential. The following principles should guide the Commission as it elaborates its framework for operations in the 3.5 GHz band.

- The Commission should adopt an engineering-based definition of "use," rather than an economic definition. An engineering definition based on actual deployment conditions will maximize availability for General Authorized Access (GAA) users while protecting Priority Access License (PAL) holders and can accommodate secondary transactions. An economic definition, by contrast, will encourage warehousing and hoarding.
- The Commission should establish rules that protect Fixed-Satellite Service (FSS) sites based on real-world, rather than hypothetical worst-case, scenarios. In order to maximize spectrum use near FSS stations while protecting those operations, moreover, the Commission should recognize the aggregate effects of interference and allow Spectrum Access System (SAS) providers to apply improved propagation models.

[1] *Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band*, GN Docket No. 12-354, Report and Order and Second Further Notice of

- The Commission should adjust its hardware certification process to identify devices with superior out-of-band emissions performance, so that their users can access 3.5 GHz spectrum in additional geographic areas.

Each of these principles fosters an environment where 3.5 GHz spectrum can be used to the maximum extent possible, while fully protecting both incumbent and PAL users.

1. **The Commission should adopt a definition of "use" that is grounded in sound technical considerations.**

In its Second FNPRM, the Commission requests comment on the adoption of an engineering-based definition of "use" of PALs, as opposed to an economic definition or other approach.[2] In order to maximize usage of the band, Google recommends that the Commission adopt an engineering-based approach.

a. **PAL holders' Citizens Broadband Radio Service Devices (CBSDs) and their affiliated end user devices should be protected against aggregate interference by a SAS.**

The Commission should protect registered areas from interference according to the following considerations reflecting an engineering-based approach.

- PAL CBSDs should be allowed to seek protection only within a service area and frequency band assigned for the PAL licensee's use.[3]

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[2] *Id.* ¶¶ 420-24.

[3] This approach would protect interior points as well as the license boundary, provided that actual deployments reach the boundary edge. One approach is to model these protections by using a SAS to sample interior points at 1.5 m above ground level and ensure that the protection limits are not exceeded. *See* 47 C.F.R. § 96.41(d)(1) (2015) (establishing received signal strength threshold at 1.5 m above ground level).

- The claimed protection area is to be defined by the PAL licensee according to engineering considerations, based on the licensee's actual deployments.
- A protection area should be defined as the area within which end users can reasonably expect service from a PAL CBSD, while end users could not reasonably expect service from the PAL CBSD outside the protection area.
- A claimed protection area should be contained completely within the PAL licensee's authorized service area, but may traverse the boundaries of multiple contiguous license areas, provided those licenses are held by the same licensee.
- The Commission should permit licensees to register multiple protection areas within the same license area or service area.
- The Commission should permit affected PAL licensees in adjoining service areas to agree alternative protection limits and communicate those alternative limits to the SAS. This exception could be captured as a waiver of the default interference level or by using an alternate power level as the threshold for aggregate interference. That is, adjacent PAL licensees could reach an agreement regarding operations at their shared service area boundary, and a SAS would implement the terms of the agreement, rather than the Commission's default interference level of -80 dBm/10 MHz. The non-default condition would apply to all nearby CBSDs that use agreed mitigation techniques.

- GAA users should be permitted to use spectrum within or near a PAL license area, provided that such operations do not interfere with operations the licensee has deployed in its protected areas.

The figures below show how these principles would work in practice. The illustrations adopt the service and license area definitions set forth in the Report and Order establishing rules for the band.[4] The protection area is the area from which a PAL licensee would be permitted to exclude GAA use based on actual deployment by the licensee. The colored areas in each figure represent different service areas. (Some service areas encompass multiple license areas.) The solid, colored shapes with black borders represent permissible protection areas. The red-bordered areas would not qualify for protection. The gray circles represent requested GAA deployments, which have black borders if a SAS would permit them and red borders if a SAS would not permit the requested protection.

Implementing this approach would require the Commission to revisit, modify, or eliminate Rule 96.41(d)(1), which limits CBSD transmissions to a received signal strength of -80 dBm at the boundary of a service area. Google understands that one or more petitions for reconsideration will address this issue, which bears directly on defining "use" in a way that maximizes utilization of the band.

[4] 47 C.F.R. § 96.3 (2015) (defining license area and service area).

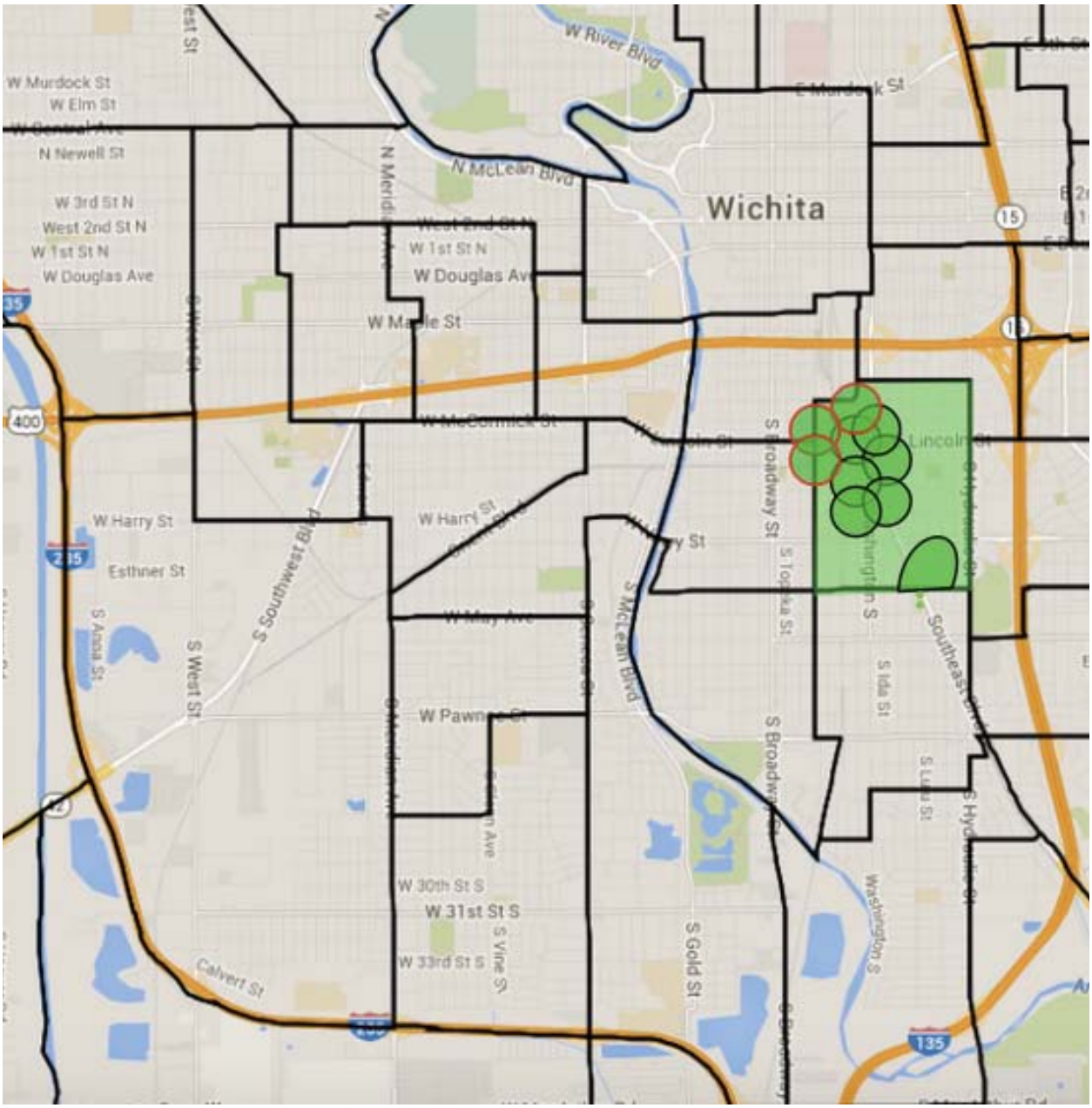

Figure 1: Illustrative PAL protection areas

Figure 1 shows Priority Access (PA) protection in one census tract and the surrounding area. The black-bordered green areas all receive protection, even if they overlap: The same PAL licensee has registered them, and they fall completely within the licensee's authorized service area. The oddly shaped protection area at the bottom of the

census tract has been truncated to lie completely within the service area. While it may be possible for some end-user devices to receive service outside this area from a CBSD located inside the service area (for example, in the green spots shown), service to those end-user devices is not entitled to protection from interference. The red-bordered areas are not afforded protection because they seek protection extending outside the PAL service area. (A SAS should have the option to grant a modified protection area that ends at the service area boundary or simply reject such a request. This figure and the ones below describe the simpler treatment of rejecting the request.)

As discussed further below, modifying or eliminating the rule requiring protection at the service area boundary will maximize use of the spectrum near the edge of a service area, such as in the southernmost protected area in Figure 1. The current rule states that "[f]or both Priority Access and GAA users, CBSD transmissions must be managed such that the aggregate received signal strength, measured at any location on the Service Area boundary of any co-channel PAL, shall not exceed an average (rms) power level of -80 dBm."[5] It is not clear whether this requirement is intended to apply if there is no adjacent co-channel PAL, as is the case in the license tract just south of the green tract in Figure 1. But there is no reason to apply the limitation in such cases: If there is no PAL adjacent to an operator's service area, an operator should receive protection all the way to the edge of that service area and should not be required to limit received signals to -80 dBm at the service area boundary because there are no protected adjacent operations to respect.

[5] 47 C.F.R. § 96.41(d)(1) (2015).

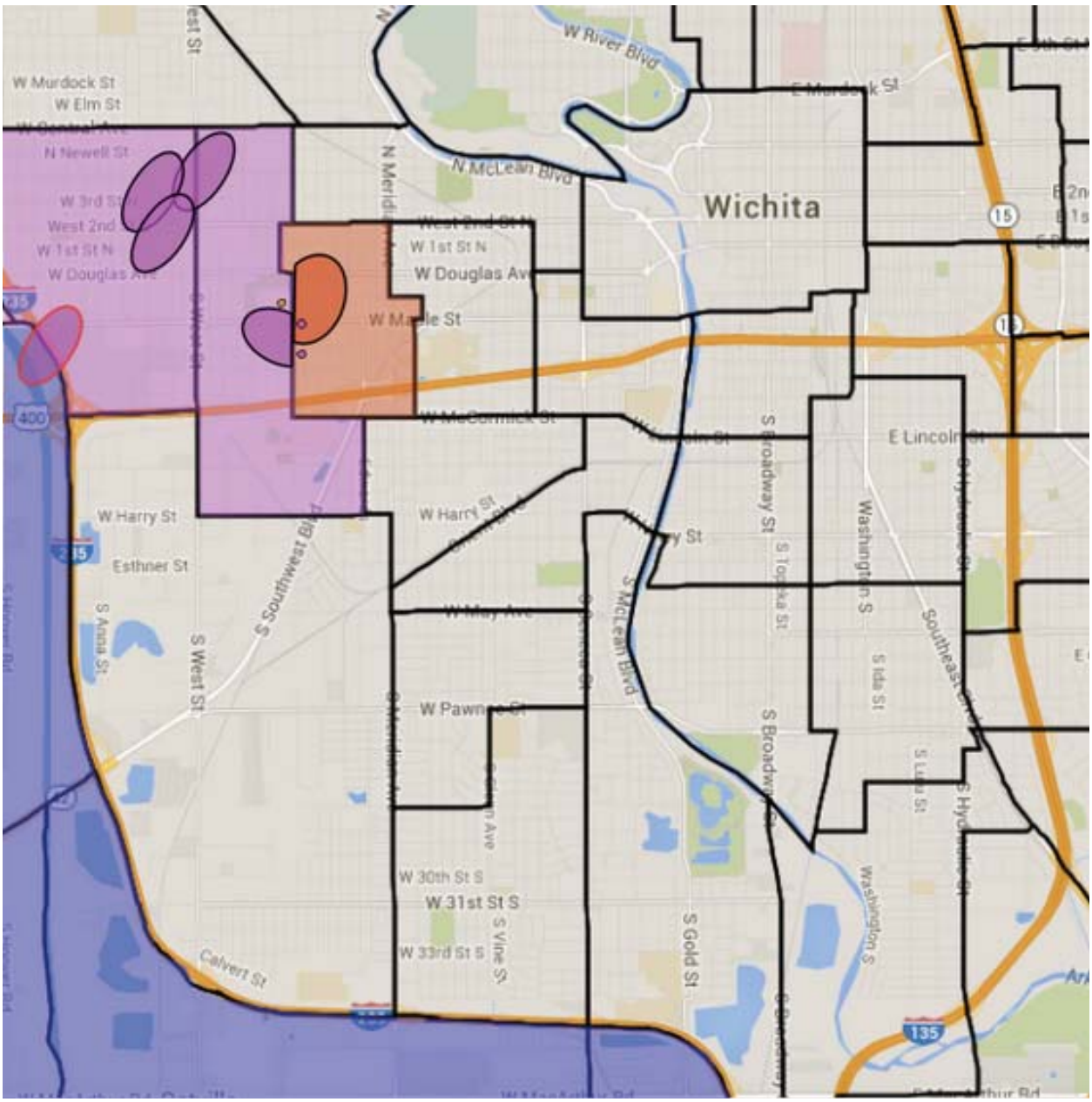

Figure 2: PAL protection for users who have reached an alternative agreement

Figure 2 shows how a SAS may accommodate alternative agreements. The orange and pink licensees have an arrangement to waive interference protections. They are cooperating to avoid interference, so they are not protected from each other via a SAS, even though devices in one protection area would otherwise be modeled by a SAS as

interfering. This approach enables end users in adjacent areas, represented by the pink and orange spots, to receive service across service area boundaries. However, even if the pink licensee has a similar arrangement with the blue licensee, a claimed protection area may not overlap the border of a service area, so the illustrated red-bordered pink PAL protection area on the pink-blue border would not be permitted in its current form.

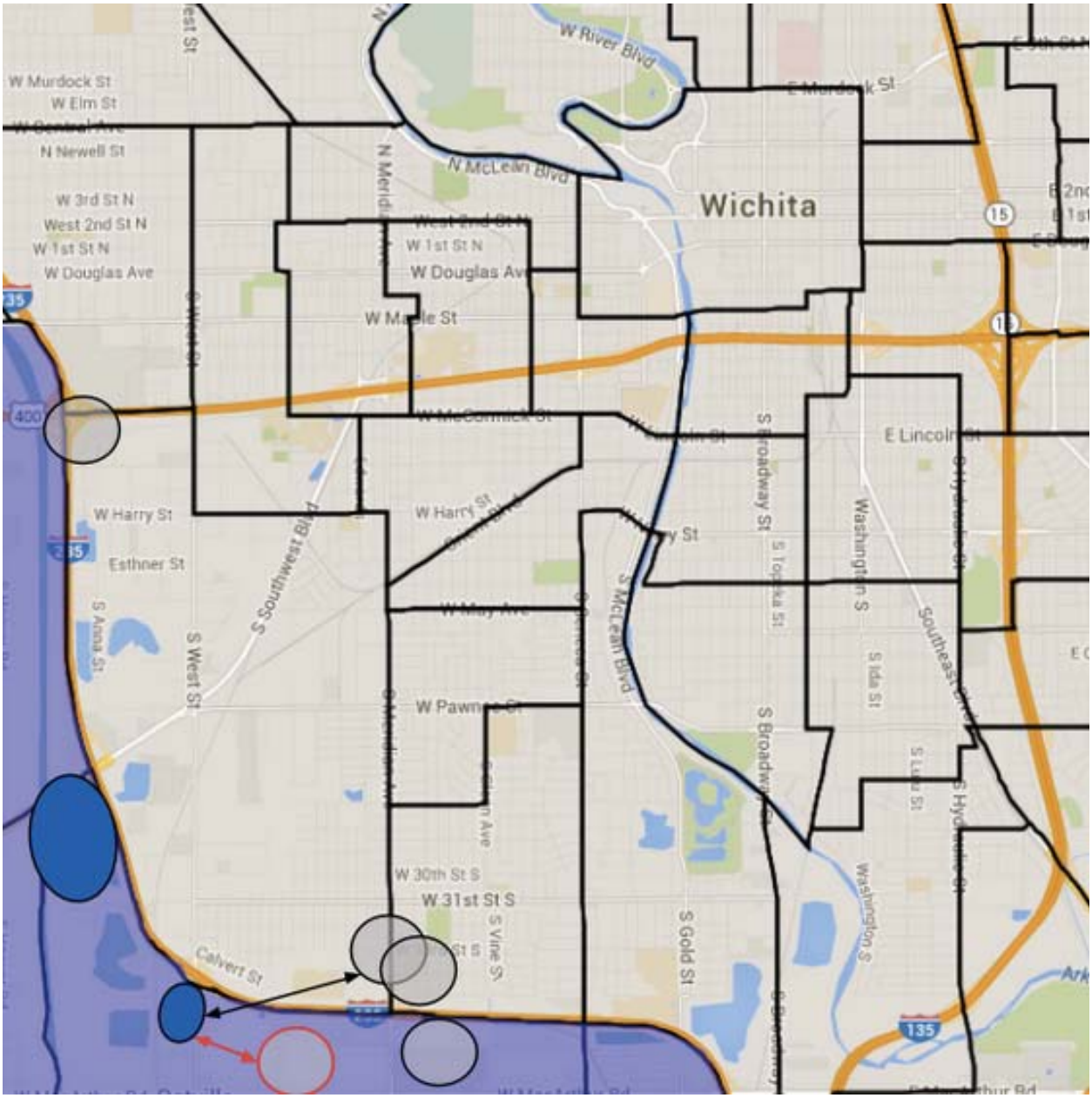

Figure 3: GAA deployments

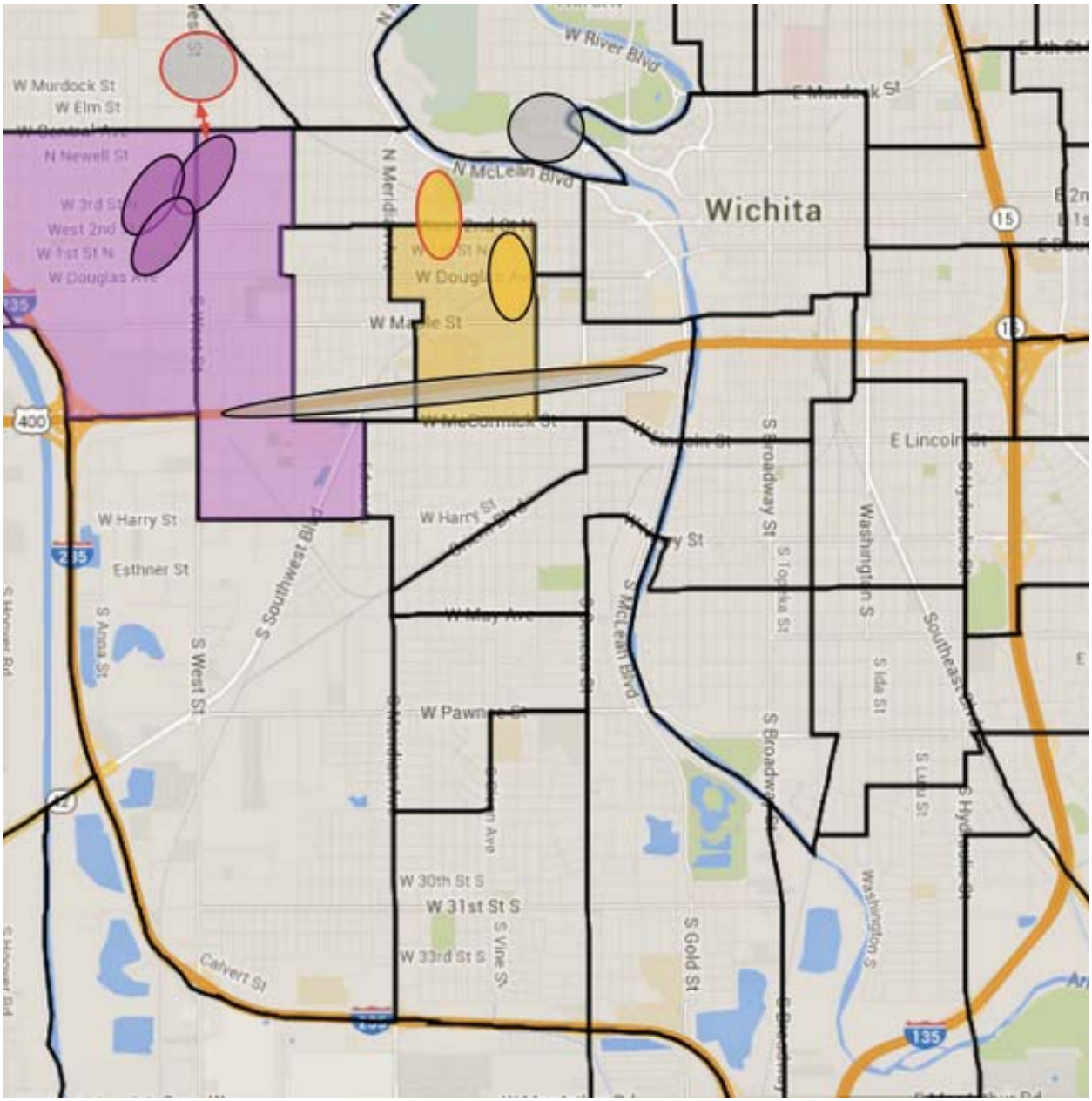

Figure 4: GAA deployments

Figures 3 and 4 show interactions between GAA and PA users. The black-bordered operational areas are all permitted protection areas, provided that the GAA CBSD stand-off distance is sufficient to provide aggregate protection for all claimed protection areas operating on the same channel. In both figures, the gray circles with red outlines are not allowed. They are too close to the indicated PAL protection areas.

In addition, some GAA users operate within or overlapping the service area of a PAL. Adopting Google's proposed engineering definition of "use" allows GAA users to operate co-channel within the service area, provided that they do not in fact interfere with the PAL protection area. Figure 4, in particular, illustrates the use of a point-to-point GAA link that stretches down a freeway close to a number of PAL protection areas, represented by pink and yellow ellipses. Because the beam is highly directional, this GAA use does not interfere with PAL operations within the claimed PAL protection areas (pink and yellow ellipses). While this GAA deployment would not interfere with PAL operations in its vicinity, the Commission's rule limiting signal strength at the boundary of a PAL service area to -80 dBm makes it impracticable: If the GAA user does not seek PA licenses for four census tracts that its beam traverses, it will likely violate the rules limiting signal strength at the boundary of the yellow and pink service areas.

b. Adopting this proposed approach to protecting PAL operations will maximize use of the band, protect actual operations, and enable rapid deployment of devices.

The approach outlined above has several advantages. First, it maximizes opportunities for productive use, especially in large, irregularly shaped census tracts. Where the PAL holder has not extensively deployed facilities, GAA CBSDs in a large census tract can make use of PAL channels if they do not introduce aggregate interference exceeding the PAL protection limits. Large census tracts comprise most of the land area of the United States, so this change will significantly improve utilization of the 3.5 GHz band in rural areas. It particularly enables point-to-point GAA deployments, which may be highly directional and thus generally non-interfering, to operate co-channel with PAL licensees in

the same census tract. Conversely, GAA CBSDs in small census tracts adjoining a PAL license area will not be permitted to use a channel if such use introduces aggregate interference exceeding PAL protection limits into a protection area.

Second, this approach relies on well-studied point-to-area interference models, which are comparatively simple and inexpensive for an SAS to implement. In addition, small cells will be concentrated in areas of higher population density, which tend to be in areas of lower terrain complexity. Making interference calculations and assessments is especially straightforward in areas where the terrain modeling is simple.

These benefits, however, will be realized only if the Commission also revisits its rule regarding received signal strength at the service area boundary. Otherwise, SAS providers will be required to implement point-to-area interference models to accommodate the definition of "use" *and* point-to-line interference models to address boundary edge conditions. Point-to-line models are less well-developed, so SAS providers will be forced to choose between simple point-to-line models, which will likely be overly conservative, and complex models, which will take time develop and delay dense deployments of devices into the band. Similarly, if the Commission adopts the proposed definition of "use" without eliminating the boundary edge condition, SAS providers will be required to model interference effects over complex terrain because census tracts often track terrain formations such as rivers, mountain ridges, or gorges. As such, the benefits of limiting modeling to actual deployment areas will be diminished, and possibly nullified.

c. The Commission should require PAL holders to register protection areas based on engineering requirements of actual operations.

Registering protection areas based on the location and technical specifications of CBSDs actually deployed in the field would result in the most accurate interference protection and would open the greatest amount of spectrum for GAA use. However, recognizing carrier concerns regarding disclosure of their own operational plans, Google recommends a pragmatic approach to defining protection areas that sacrifices some measure of efficiency in the interest of confidentiality: The Commission should permit a PAL holder to define the area of operations for which it seeks protection, provided that its claim is supported by engineering analysis of actual operations. Such engineering analysis should be documented as of the time protection is requested, and that contemporaneous documentation should be preserved so that it can be made available to the Commission upon request.

As illustrated in the figures above, protection areas could be specified using the same series-of-vertex-points descriptions that define census tracts, or in terms of a point and radius, or parameters for an ellipse. Protection areas should be registered directly in a SAS. After receiving protection area information both directly from PAL holders and from other SASs, a SAS will make spectrum not in use by PAL holders available to GAA users, even if such spectrum is within a PAL holder's license area. Of course, PAL holders will be free to update their protection areas as operations change—whether areas are added to active service or deployments are scaled back in a particular region.

d. If the Commission wishes to maximize spectrum utilization, it should also modify or eliminate its rule limiting transmit power at the edge of a PAL boundary.

In its Report and Order, the Commission adopted a rule requiring CBSD transmissions to be managed such that the aggregate received signal strength, measured at any location on the service area boundary of any co-channel PAL, does not exceed an average (rms) power level of -80 dBm in any direction when integrated over a 10 megahertz reference bandwidth, with the measurement antenna placed at a height of 1.5 meters above ground level, unless the affected PAL licensees agree to an alternative limit and communicate that to the SAS.[6] As noted, this rule is inconsistent with the engineering-based approach to "use" described above. Indeed, Google understands that a petition for reconsideration will be filed that asks the Commission to modify this boundary requirement—which will both over- and under-protect PAL operations—to allow use of the protection criteria proposed above. That petition should be granted.

The rule limiting signal strength at the service area boundary creates problems in a number of common situations. First, even if received signal strengths are limiting according to Rule 96.41(d)(1), a CBSD operating within a protected service area may not, in fact, be protected from interference. The topographical variation at many census tract boundaries results in imperfect protection. For instance, a census tract which has borders in deep valleys may have interior points at much higher elevations. Because they are not shielded by terrain, CBSDs sited at the higher elevations may experience higher interference levels than CBSDs at the census tract boundary where the -80 dBm limitation

[6] *Id.*

applies. In this situation, Rule 96.41(d)(1) fails to provide the intended protection to the PAL holder.

Figure 5, below, illustrates this weakness with an example near Pittsburgh, Pennsylvania. The eastern edge of the highlighted census tract is at the bottom of a deep gorge. Points at 1.5 meters above ground level at the census tract edge—i.e., deep within this gorge—will receive very limited signal energy, even from nearby CBSDs. Signals will be weak at the boundary because of the natural shielding present in the environment, so measuring the protection required at that point will not adequately protect operations located above the gorge, particularly if interfering CBSDs are also above the level of the gorge.

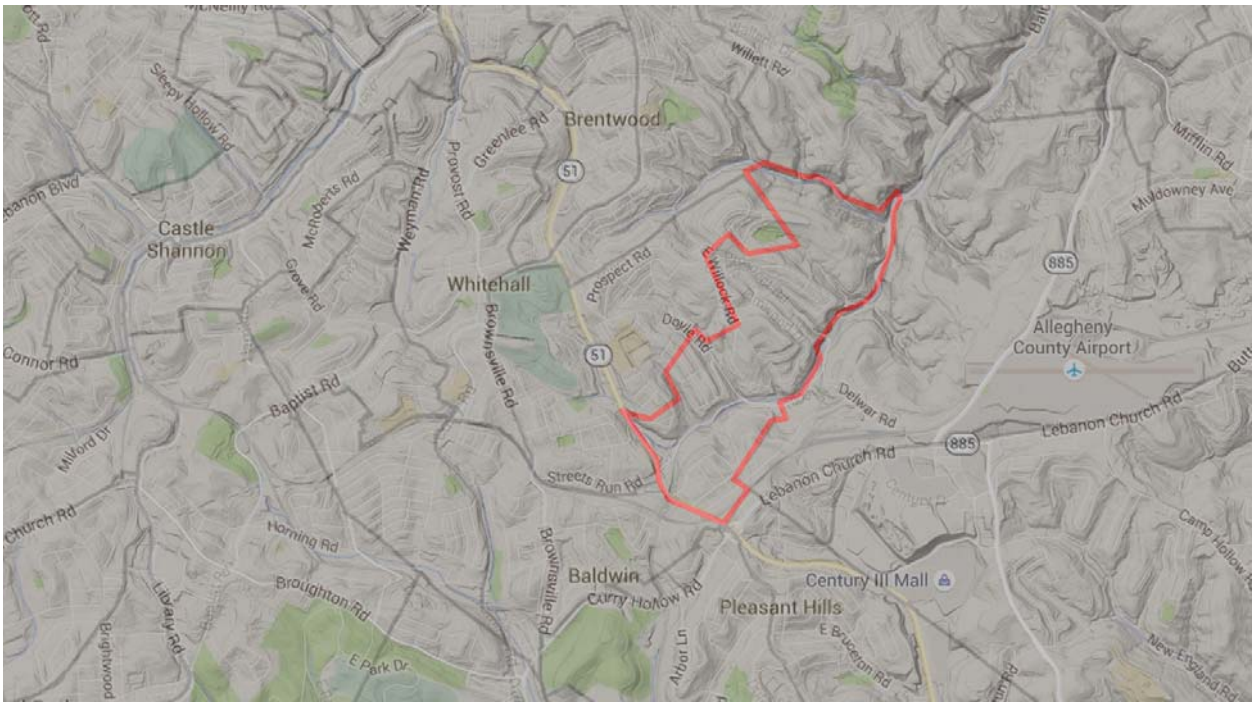

Figure 5: Census tract near Pittsburgh, Pennsylvania

Conversely, if a census tract edge crosses or follows high terrain, CBSD deployments may be pushed back unnecessarily in order to avoid exceeding the maximum signal strength at the tract boundary. When confronted with line-of-sight paths to a high-elevation point, most propagation models apply free-space path loss estimates. The high-elevation point is treated as one that will receive a high level of radio energy, while lower-elevation locations will receive less energy even if they are closer to the transmitter. As a result, the mere existence of high-elevation points along a PAL's license area boundary will require neighboring CBSDs to adopt an extremely conservative stand-off distance. Yet if the high-elevation point does not host any PAL operations, those large stand-off distances serve no practical purpose. This overprotection of elevated tract boundaries will prevent PAL licensees from serving some areas even if the service would create *no* risk of interference to co-channel PAL operations in an adjacent license area.

Figure 6 illustrates this aspect of the problem. The southern edge of the highlighted census tract, located near Los Angeles, is placed high above more populated areas. This southern edge has heights above average terrain (HAAT) around 1000 feet. Because the terrain at the boundary edge is itself so much higher than the surrounding areas, a point merely 1.5 meters above ground level at these high elevations commands a large view over dozens of high-density census tracts to the north of the highlighted tract. But because the current rules require that interference limits be defined at the census tract boundary line, deployments in places like Avocado Heights will be constrained unnecessarily. While signals from the northern tract may reach the far boundary edge of the highlighted adjacent census tract, which sits at a higher elevation, they are still unlikely to reach

deployments *inside* the highlighted tract, which are closer but much lower in elevation. Such interior deployments should not prevent use in Avocado Heights, but Rule 96.41(d)(1) would have that prohibitive effect.

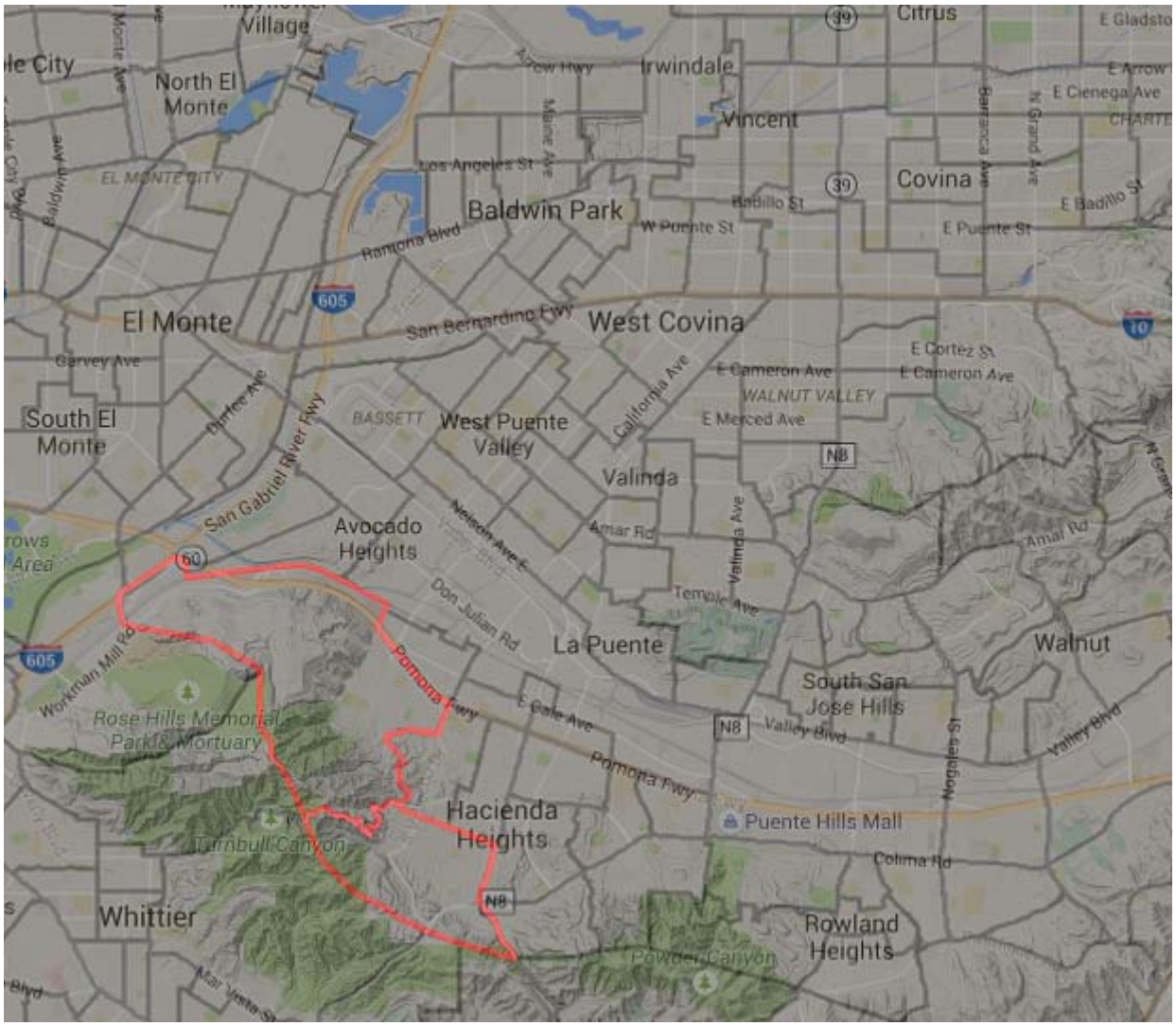

Figure 6: Census tracts near Los Angeles, California

The limit on received power at the boundary edge also unnecessarily limits the registration and use of Category B devices. These devices will often be used to support point-to-point communications using higher-gain directional antennas. These devices will

typically be sited in less dense population areas, and their higher-gain antennas allow them to avoid interfering with co-channel CBSDs located away from the main beam. A useful point-to-point link may traverse one or more census tract boundaries, particularly if the census tracts are irregularly shaped. But if the protection criterion is defined at the census tract edge, operators of such point-to-point links that cross census tract boundaries would almost certainly be required to purchase PAL rights for each tract that a link traverses, even if there is no PAL CBSD to be protected along the line-of-sight path between the endpoints of a link.

By contrast, if the Commission adopts an engineering definition of "use" and eliminates the boundary protection requirement, several advantages will result. This approach will provide effective protection to actual CBSDs offering service, which may be situated in propagation environment very different than the one present at a license area border. It will also provide protection to end-user devices communicating with a PAL CBSD—a critical feature in operating a real-world network. And it does not necessarily require that a PAL CBSD be restricted to a -80dBm/10MHz limit on received power at its own PAL license border. Instead, the PAL is simply prohibited from interfering with other co-channel PAL CBSD operations in their own respective protection areas—which may be quite distant from the closest PAL service area edge, especially if the service area includes a large census tract. Under this approach, SASs apply their propagation models where there is an actual PAL CBSD deployed and a properly claimed area to protect, rather than applying the models to complex PAL license tract boundaries which may be far from any deployed CBSD.

e. The proposed engineering approach to defining "use" is compatible with SAS support for secondary market operations.

In its Second FNPRM, the Commission asks whether a SAS can support the operations of a secondary market, which could potentially partition PAL license areas geographically or in frequency.[7] An engineering definition of "use" is compatible with such a function of a secondary market, and introduces no significant additional complexity to the operation of a SAS.

SASs will be designed and scaled to manage thousands of license areas and many times that number of PAL CBSD deployments, each with their attendant protection area. For these robust systems, supporting transfers of PAL protection rights, in whole or in part, will introduce only the minor additional complexity of verifying that claimed PAL protections reflect transactions in the secondary market. SASs must verify PAL protection rights to implement the Commission's auctions of 3.5 GHz spectrum, and the same capabilities would support transferability of PAL license rights. Therefore, there is no technical obstacle to SAS support of secondary PAL license market operations. Under such an approach, moreover, licensee and transferee could make arrangements to waive interference protection at their borders, which SASs can implement as described above.

In that regard, the Commission has recognized that secondary markets for spectrum can enable efficient use because they "permit spectrum to flow more freely among users and uses in response to economic demand."[8] While secondary markets may

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[7] Report and Order and Second FNPRM, ¶ 435.

[8] *See, e.g.*, *Promoting Efficient Use of Spectrum Through Elimination of Barriers to the Development of Secondary Markets*, WT Docket No. 00-230, Second Report and Order, Order

be less significant in the 3.5 GHz band because the Commission has established relatively short license terms,[9] they nevertheless may play a beneficial role in management of PAL spectrum. For example, partitioning PAL license areas may allow smaller providers to offer quality-of-service offerings in limited geographic areas. For maximum flexibility and efficiency, therefore, PALs should be partitionable by channel and geography. The Commission should remain responsible for qualifying participants for secondary market transactions and establishing secondary market rules for the 3.5 GHz band, but as noted in Part 1.e., above, a SAS can easily support such beneficial sharing. Because SASs can support these arrangements and they have the potential to accelerate beneficial license transfers and improve spectrum utilization, the Commission should allow such flexibility.

f. An economic definition of "use" predictably would reduce spectrum utilization.

The Second FNPRM asks whether adopting an economic definition of "use" would meet the Commission's goals of maximizing spectrum utilization and enabling opportunistic use of PAL spectrum.[10] Because an economic definition places no obligation on the PAL holder actually to use PAL spectrum, it increases the likelihood of spectrum hoarding or warehousing. For example, under the framework proposed by William Lehr, a PA user could purchase an option to exclude GAA users, which could then be exercised at a

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on Reconsideration, and Second Further Notice of Proposed Rulemaking, 19 FCC Rcd. 17503, ¶ 1 (2004).

[9] *See* 47 C.F.R. § 96.25(b)(3) (2015). Google notes that secondary markets should not be considered a substitute for frequent relicensing.

[10] *Id.* ¶¶ 425-29.

later date.[11] Lehr proposes that a PA licensee should be able to exercise its option to exclude GAA users *regardless of whether it has deployed service in the license area.* By decoupling the ability to exclude other users from a requirement to make productive use of spectrum, an economic definition allows and may even encourage licensees to bid on licenses even if they have little or no intention of deploying service.

The Commission has long disfavored private warehousing of public spectrum resources,[12] and there is no reason to depart from this sound policy in devising rules for the 3.5 GHz band. Instead, the Commission should adopt an engineering-based definition of use that takes into account actual deployment conditions.

2. In-band and out-of-band FSS earth stations should be protected using reasonable interference criteria.

The Commission should establish protections for FSS earth stations operating in and adjacent to the 3.5 GHz band that take advantage of SAS capabilities and are based on real-world conditions. Striking a balance that adequately protects FSS stations without unnecessarily constraining CBSD deployments, rather than adopting interference criteria that rely on a cascading series of worst-case assumptions, will enable maximum use of the 3.5 GHz band.

The Wireless Innovation Forum's Spectrum Sharing Committee has established a task group to address the FSS protection issues raised in the Commission's Second FNPRM. The task group has broad participation from representatives across the wireless industry, including potential SAS providers (including Google and Federated Wireless), service

[11] *Id.* ¶ 425.
[12] 47 U.S.C. § 309(j)(4)(B) (2015).

providers, infrastructure vendors, as well as participation from satellite and broadcast representatives. The task group hopes to submit consensus views on FSS protection as soon as practicable. In the meantime, Google offers several observations regarding FSS protection requirements.

a. In determining FSS protections, the Commission should rely on certain trigonometric equations and key FSS system characteristics set forth in its 2005 coordination methodology.

The Commission's 2005 order addressing coordination between FSS stations and fixed wireless stations contains useful elements for determining FSS protection in the context of this proceeding.[13] Three particular aspects of the Wireless Broadband Services Order provide useful starting points.

First, Equations 1-4 of Appendix D provide useful derivations of the complex spherical trigonometry equations that allow the calculation of the discrimination angle between an earth station and a potential source of terrestrial interference. The inputs to these equations include the latitude and longitude of the earth station, the geostationary orbital slot that toward which the earth station is pointed, and the azimuth from the earth station to the interference source. Second, Table 1 of Appendix D provides a useful

[13] Report and Order and Second FNPRM, ¶ 288 (citing *Wireless Operations in the 3650-3700 MHz Band*, ET Docket No. 04-151; *Rules for Wireless Broadband Services in the 3650-3700 MHz Band*, WT Docket No. 05-96; *Additional Spectrum for Unlicensed Devices Below 900 MHz and in the 3 GHz Band*, ET Docket No. 02-380; *Amendment of the Commission's Rules With Regard to the 3650-3700 MHz Government Transfer Band*, ET Docket No. 98-237, Report and Order and Memorandum Opinion and Order, 20 FCC Rcd. 6502, Appendix D (2005) (Wireless Broadband Services Order)). Formulas in Appendix D were subsequently corrected by *Wireless Operations in the 3650-3700 MHz Band*, ET Docket No. 04-151; *Rules for Wireless Broadband Services in the 3650-3700 MHz Band*, WT Docket No. 05-96; *Additional Spectrum for Unlicensed Devices Below 900 MHz and in the 3 GHz Band*, ET Docket No. 02-380, Memorandum Opinion and Order, 22 FCC Rcd. 10421, ¶ 63 n.143 (2007).

summary of typical FSS earth station parameters, including receive bandwidth and system noise temperature.

While these two aspects of the Wireless Broadband Services Order provide starting points for determining FSS protection, the Commission should not adopt wholesale the separation distance methodology set forth in Appendix D. Equations 6 and 7 of the appendix, which establish recommended separation distances between interference sources and FSS earth stations, contain latent assumptions that are not discernible from the information provided. For example, assumptions regarding propagation models, transmitter characteristics, and interference objectives are built into these equations, but those assumptions are not formulated in the appendix in a manner that would allow Equations 6 and 7 to be modified if the assumptions change. As a result, modifying the Appendix D methodology to address different types of interference sources and accommodate improved propagation models is likely to be very difficult. For this reason, Google suggests that the FCC base FSS protection on the FSS system characteristics and the trigonometric equations set forth in Appendix D, as well as the system requirements adopted by the International Telecommunication Union (ITU) and discussed below, without adopting Appendix D's overall approach.

Third, the Wireless Broadband Services Order recognizes that ITU Radiocommunication Sector (ITU-R) Recommendation S.1432-1 sets forth appropriate design objectives for FSS stations.[14] Google recommends that the ITU's design performance criterion for system noise interference serve as a starting point for protection

[14] *Id.* ¶ 63.

of FSS earth stations. The ITU recommendation adopts a design performance criterion for FSS earth stations that allows as much as 6% of overall system noise temperature to come from interfering non-satellite licensed services.[15] This apportionment includes considerations for statistical variations in propagation, including allowances for temporal variations normally included in FSS interference analyses. To avoid ambiguity due to variations in noise temperatures among FSS systems, this value should be applied specifically to the 142.8 K noise temperature assumed in Appendix D, resulting in a baseline interference protection criterion of 6% * 142.8 K, or 8.6 K. The baseline interference noise temperature should serve as a starting point for FSS protection, but the Commission should consider revisiting it in the future, once it has gathered additional data on effective protection of incumbent FSS systems.

This standard—limiting noise increases to less than 8.6 K—should be applied to both in-band and out-of-band systems. Co-channel interference, blocking, and out-of-band emissions all result in the same phenomenon: an increased noise level within the FSS receiver's intended band. Because there is no functional difference between earth stations that operate below 3700 MHz and those that operate above, they should be protected to the same degree. However, protections for FSS earth stations operating above 3700 MHz

[15] ITU-R Recommendation S.1432-1, *Apportionment of the Allowable Error Performance Degradations to Fixed-Satellite Service (FSS) Hypothetical Reference Digital Paths Arising from Time Invariant Interference for Systems Operating below 30 GHz* (2006). The ITU recommends that FSS systems be designed to tolerate 32% of system noise temperature in interference from all sources.

must assume that such stations are using commonly available filters that limit reception of signals below 3700 MHz.[16]

b. The Commission should tailor FSS protections to actual conditions, rather than establishing a default protection zone for all FSS stations.

The Commission should not adopt default or generalized protection zones for FSS earth stations. Instead, protection zones should take into account real-world factors such as propagation, terrain, earth station pointing angles, and transmitter characteristics. Default protection zones typically rely on worst-case or near-worst-case assumptions regarding all of these factors, resulting in over-protection of incumbents, substantial inefficiencies in spectrum use, and diminished investment. SAS technology can be used to calculate individual protections with specificity and accuracy. The Commission's rules regarding FSS protection should take advantage of these technological advances.

c. Protection of FSS stations should take into account aggregate interference effects.

Aggregate interference from multiple sources can have a substantial impact on incumbent operations. Most obviously, multiple transmitters can create more interference than any single transmitter in isolation. For this reason, calculating an aggregate level of interference provides the most realistic estimate of the total impact on an FSS system. By contrast, failure to take into account aggregation effects will require SASs to plan for worst case density assumptions (for example, by using fixed multiple-exposure factors regardless of how many exposures there actually are), even if deployments are not dense.

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[16] *See* Letter from Aparna Sridhar, Telecom Policy Counsel, Google Inc., to Marlene H. Dortch, Secretary, FCC, GN Docket No. 12-354, Sept. 3, 2013, at 2.

There may be equitable concerns about allowing early entrants into the 3.5 GHz band to use up a large share of the interference margin associated with a particular FSS site.[17] This advantage for early entrants could instead be viewed as a beneficial incentive to invest quickly in the band. Furthermore, while other approaches—such as requiring all devices to reduce power if the band becomes saturated near an FSS site—could mitigate some of those concerns, they may have attendant costs, including increased complexity and uncertainty regarding CBRS deployment conditions. But regardless of *how* the Commission chooses to protect for aggregate effects, it is important for the Commission to do so. Otherwise, power levels and other technical parameters will be based on worst-case assumptions and thus limited to what suits the densest deployments, unnecessarily limiting CBRS users' operational flexibility where dense deployments do not in fact exist. Because there are no existing deployments, moreover, spectrum in all areas would be under-utilized at first. In many places, particularly outside urban centers, it would always be underutilized. If the band cannot be used to its fullest potential because the Commission creates a rule that applies only to worst-case scenarios, then investment will be limited.

d. The Commission should allow SAS providers to adopt varying propagation models, so long as such models protect incumbent services from harmful interference.

As the Commission recognizes, "research in propagation path loss models in recent years has advanced considerably and offers an increasing array of practical and realistic tools and methods for predicting path loss and determining practical bounds on prediction

[17] Report and Order and Second FNPRM, ¶ 441.

errors."[18] Yet, even while recognizing these advances, the Commission tentatively concludes that "each SAS must use the same propagation model."[19] This approach is misguided.

Rather than mandating a one-size-fits-all standard for propagation modeling, the Commission should establish a baseline model for computing interference to FSS earth stations. This model could serve as a "safe harbor" for basic or early-stage SASs. For example, the propagation model set forth in ITU-R Recommendation P.452 has been created specifically for satellite coordination work,[20] and could serve as a baseline propagation model for use in calculating FSS protection. At the same time, the Commission should permit and encourage innovation in propagation modeling by allowing SASs to use more sophisticated propagation models if they are capable of doing so.

Establishing a baseline while allowing refinements promotes investment in improved propagation models for use in the 3.5 GHz band. Indeed, a variety of government, industry, and academic teams are conducting extensive research on propagation in the 3.5 GHz band. The National Telecommunications and Information Administration's Institute for Telecommunication Sciences, for instance, is developing new 3.5 GHz suburban clutter loss models based upon measurements in the Boulder, Colorado,

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[18] *Id.* ¶ 438.
[19] *Id.*
[20] ITU-R Recommendation P.452, *Prediction Procedure for the Evaluation of Interference Between Stations on the Surface of the Earth at Frequencies Above About 0.1 GHz* (2013).

area.[21] Google is collecting and analyzing hundreds of thousands of propagation loss data points in California and Virginia, which, when combined with data regarding terrain, buildings, and foliage, can bound clutter losses in the 3.5 GHz band.[22] With support from Google and other sources, Professor Chris Anderson of the U.S. Naval Academy has been conducting measurements and building improved propagation models for the 3.5 GHz band using an incumbent 3.5 GHz Navy radar and sophisticated measurement equipment in and around rural St. Inigoes, Maryland.[23] Google hopes to take advantage of such investments in developing improved propagation models for the band to offer superior spectrum use options to PAL and GAA users who choose to use our SAS. Requiring uniformity in propagation modeling would discourage similarly motivated future investment in more sophisticated and accurate propagation models and limit the opportunities for innovation in the 3.5 GHz band.

Because the Commission requires CBSDs to report interference levels back to a SAS,[24] commercial use of the 3.5 GHz band also will vastly improve knowledge regarding propagation in the band. CBSDs will report potentially millions of data points, all of which could be used to further refine assumptions about propagation in the band. Such "closed-loop" propagation modeling promises to enable significant refinements over time. SAS

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[21] Chriss Hammerschmidt & Bob Johnk, Clutter Measurement Research at 3500 MHz, Presentation at the International Symposium on Advanced Radio Technologies (May 13, 2015), *available at* http://goo.gl/AuoWjF.
[22] These experiments are being conducted under an experimental license obtained by Google. *See* FCC Call Sign WH2XNF.
[23] Chris Anderson, Propagation Measurements & Modeling: A Philosophical Approach, Presentation at the International Symposium on Advanced Radio Technologies (May 13, 2015) (sharing preliminary results), *available at* http://goo.gl/mGvupD.
[24] 47 C.F.R. § 96.39(d) (2015).

providers should be encouraged to use this resource to build better and more accurate models. But the Commission will discourage such efforts if it requires all SAS propagation models to be developed in lock-step based on Commission mandate.

This issue, moreover, is relevant beyond just the 3.5 GHz band. Allowing innovation in propagation modeling in the 3.5 GHz band will likely improve spectrum utilization across all bands. This is because information regarding propagation model improvements in the 3.5 GHz band can be applied to propagation modeling problems in other bands as well.

For all these reasons, the Commission should adopt a baseline, safe-harbor propagation model but permit SAS providers to deploy more advanced or innovative techniques, provided they adequately protect incumbents. To ensure full protection of FSS and other priority users, such models should be vetted by the Commission, NTIA, or an appropriate expert organization such as ITU Study Group 3, under appropriately streamlined processes.

3. The Commission should adjust its hardware certification process to allow devices with superior out-of-band emissions performance to access additional spectrum.

Google agrees with the Commission that "market incentives may . . . encourage industry to deploy radios with improved (lower) adjacent emissions and thereby have greater access to spectrum."[25] Adopting such an approach to out-of-band emissions will require only minor adjustments to the Commission's equipment certification framework. When a device is tested for certification today, its out-of-band emissions are measured only to confirm that they comply with the limits established in the Commission's service rules.

[25] Report and Order and Second FNPRM, ¶ 445.

In fact, with respect to out-of-band emissions, certification test reports often provide only an affirmation that the subject device meets the required levels (for example, by providing a plot of the out-of-band emissions compared to the emission mask), rather than the actual emission levels at all frequencies as measured in the test lab.

In order to enable better-performing devices to take advantage of additional spectrum access as a result of their lower out-of-band emissions into FSS frequencies above 3700 MHz, the Commission should make the following changes to its certification procedures for CBSDs:

- First, certification reports should specify the actual levels of out-of-band-emissions between 3700 MHz and 4200 MHz that were measured during testing.
- Second, certification reports should state the minimum level, in dB, by which the device improves upon (i.e., is lower than) regulatory limits. When determining this level, the test lab should account for statistical variations in the manufacturing process.
- Third, the test lab should categorize the device within a class based on how much it reduces out-of-band emissions beyond what is required by regulation. For example, devices that meet the minimum regulatory requirements might be designated as Class 0 devices, while devices that exceed the regulatory requirement by 5-10 dB in the 3700-4200 MHz band could be designated Class 1 devices. Devices that exceed the regulatory requirement by 10-15 dB could be designated Class 2 devices, and so forth.

A 5 dB step between classes is a minimum meaningful performance differentiation.

- Fourth, the device's class should be included as a field in the FCC's certification database. Because the Commission's Part 96 rules require each CBSD to include its FCC ID number in the registration information provided to the SAS,[26] a SAS could determine a registered device's out-of-band emissions performance class by querying the FCC's certification database.

Adopting these definitions will ensure that SASs can use device class information to calculate spectrum availability based on the device's actual out-of-band emissions performance. Taking device characteristics into account when protecting FSS earth stations in the upper adjacent band (3700-4200 MHz) will maximize spectrum availability while ensuring those stations receive protection from harmful interference.

By contrast, it may not be appropriate to take account of CBSDs' improved out-of-band emissions characteristics in protecting military radar activity below 3550 MHz. SASs generally will have no information regarding the response of military radars to differing levels of out-of-band emissions, and therefore will have no basis upon which to take differing levels of out-of-band emissions into account when computing interference.

Implementing the suggested refinements requires only small changes in test lab procedures. And the Commission's certification database already supports the concept of device classes. Unlicensed devices in the television band, for example, are categorized as

[26] 47 C.F.R. § 96.39(c) (2015).

Mode 1, Mode 2, or fixed.[27] A review of the FCC's Equipment Authorization Search page also reveals multiple certification classes that delineate between characteristics such as "held to ear," "held to face," and "body worn," among other examples.[28] As such, establishing device classes for Part 96 devices will require minimal additional effort and will maximize use of the 3.5 GHz band while protecting incumbent operations.

CONCLUSION

The Commission's Report and Order in this proceeding lays out a framework that should enable intensive use of the 3.5 GHz band. Refinements to the framework should continue to prioritize maximum spectrum utilization, while protecting both incumbent and PAL users.

Respectfully submitted,

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[27] 47 C.F.R. § 15.703(c), (e), (f) (2015).
[28] FCC Office of Engineering and Technology, Equipment Authorization Search, https://apps.fcc.gov/oetcf/eas/reports/GenericSearch.cfm.