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

In the Matter of	
Amendment of Part 15 of the Commission's Rules for Unlicensed Operations in the Television Bands, Repurposed 600 MHz Band, 600 MHz Guard Bands and Duplex Gap, and Channel 37, and	ET Docket No. 14-165
Amendment of Part 74 of the Commission's Rules for Low Power Auxiliary Stations in the Repurposed 600 MHz Band and 600 MHz Duplex Gap	
Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions	GN Docket No. 12-268

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I. INTRODUCTION AND SUMMARY.

The central goals of the Commission's incentive auction proceeding are improving access to wireless broadband and using scarce spectrum more efficiently. As the Commission already has held, permitting unlicensed devices to operate in the duplex gap, guard bands, and vacant channels within the repacked television broadcast band, without causing harmful interference, best advances these goals.

Now, the Commission must adopt technical rules for unlicensed operations that implement this sound policy. To achieve the Commission's goals, these rules must both permit economically and technically feasible use of 600 MHz spectrum by unlicensed devices, and protect licensed services. If the rules substantially *over*protect adjacent or co-channel licensed operations, then they will undo the Commission's work to enable unlicensed services in these frequencies.

To achieve the right balance, the proposed rules in the Notice of Proposed Rulemaking rely heavily on modeling and assumptions about relevant operating conditions.[1] That theoretical approach is necessary where actual conditions cannot be known. But it can produce a systematic bias against unlicensed operations, out of a desire to protect licensed operations from worst-case scenarios. Unlicensed operations must not be limited on the basis that they theoretically *could* cause harmful interference under certain conditions, when those worst-case conditions demonstrably *will not* exist at a given place and time.

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[1] *See In the Matter of Amendment of Part 15 of the Commission's Rules for Unlicensed Operations in the Television Bands, Repurposed 600 MHz Band, 600 MHz Guard Bands and Duplex Gap, and Channel 37*, Notice of Proposed Rulemaking, 29 FCC Rcd. 12,248 (2014) (NPRM).

The Commission has recognized this and taken a generally reasonable approach to unlicensed use of the duplex gap and guard bands. As demonstrated below, the Commission's proposals will comfortably protect licensed operations from harmful interference while permitting reasonable unlicensed operations. Google suggests only modest adjustments to the Commission's proposals to enhance the value of these bands.

The Commission's proposals related to channel 37 and wireless microphones, however, are unnecessarily overprotective. They rely on unrealistic interference scenarios when the real-world data needed to support more reasonable technical rules are available. For instance, the Commission knows that medical telemetry equipment using television channel 37 is deployed inside hospitals, so it can count on hospital walls reducing potential interference from unlicensed devices outside those buildings—a fact not reflected in the NPRM's proposed rules. Similarly, most radio astronomy service (RAS) locations are sited so that mountains shield them from urban radio signals; today's white space databases can take account of this natural shielding, on a site-by-site basis, when establishing protection zones. So too, wireless microphones can be assigned specified channels for breaking news events, making it unnecessary to impose costly and battery-draining "fast-polling" requirements on other channels. In short, by substituting real-world information for worst-case assumptions, and implementing the resulting rules through the existing television white space databases as appropriate, the Commission can free large amounts of additional spectrum for unlicensed use—especially in the metropolitan areas where it is most needed.

Specifically, technical rules for unlicensed devices can protect licensed operations from harmful interference while promoting investment and innovation by:

1. Permitting consumers to use 40 mW unlicensed devices in 6 MHz channels in both the duplex gap and guard bands that are 9 MHz or larger, and lower-power unlicensed devices in 6 MHz channels in sub-9 MHz guard bands;

2. Establishing a "4/6/1" organization for the duplex gap, with a 4 MHz wireless microphone channel at the bottom of the band, followed by a 6 MHz unlicensed channel, followed by a 1 MHz separation between unlicensed operations and the LTE uplink band;

3. Permitting consumers to use Mode I and Mode II 40 mW unlicensed devices in channel 37, while employing white space databases to protect wireless medical telemetry service (WMTS) using realistic propagation assumptions that take into account building loss and shadowing effects in urban areas;

4. Efficiently protecting RAS facilities by restricting unlicensed device operation in the National Radio Quiet Zone and Puerto Rico Coordination Zone, establishing protection zones for Very Long Baseline Array (VLBA) facilities that take terrain blockage into account, and using time coordination to ensure maximum use of spectrum in areas near VLBA sites;

5. Removing outdated prohibitions on unlicensed operations in the closest vacant television channels above and below channel 37, and on personal-portable unlicensed operations in channels 14-20; and

6. Adopting operational rules in the post-repack broadcast band that permit more efficient unlicensed operations consistent with years of white space experience, by:

    - Basing device location accuracy requirements on location confidence rather than a rigid 50-meter accuracy mandate;
    - Permitting fixed operations on frequencies adjacent to television channels;
    - Accounting for intermediate white space device powers;
    - Eliminating the single-channel out-of-band emissions (OOBE) limits in bonded-channel situations;
    - Adjusting white space rules in rural areas; and
    - Accommodating wireless microphones used in breaking news situations with two designated "fast-polling" channels

These rules protect licensed services while permitting commercially viable unlicensed operations, based on a factually grounded approach that maximizes the use of the 600 MHz spectrum.

II. THE COMMISSION'S RULES SHOULD PERMIT 40 MW UNLICENSED BROADBAND OPERATIONS IN A 6 MHZ CHANNEL, BOTH IN THE DUPLEX GAP AND IN LARGER GUARD BANDS.

The Commission has properly decided to permit unlicensed devices to operate in the 600 MHz duplex gap and guard bands, subject to technical rules protecting adjacent-band licensees from harmful interference.[2] As a next step, the NPRM in this proceeding proposes to adopt rules that allow fixed and portable white space devices to operate (1) in a 6 MHz channel at 40 mW within the duplex gap[3] and (2) within a guard band separating LTE downlink operations from the remaining television broadcast band, so long as the guard band is at least 9 MHz wide.[4] The Commission also seeks comment on whether unlicensed devices operating in guard bands smaller than 9 MHz could operate in a 6 MHz unlicensed channel at less than 40 mW or, alternatively, in a smaller unlicensed channel.[5]

The technical studies submitted in this proceeding support the Commission's proposals to permit 40 mW unlicensed operations in 6 MHz channels, in both the duplex gap and guard bands of 9 MHz or more. In fact, these proposed technical rules are conservative: The Commission could permit higher power in some situations. The record also supports technical rules that permit unlicensed operations in a 6 MHz channel operating at less than 40 mW in smaller guard bands.

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[2] *In the Matter of Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions*, Report and Order, 29 FCC Rcd. 6567, ¶ 273 (2014) (Incentive Auction Order).

[3] NPRM ¶¶ 86, 93.

[4] *Id.* ¶¶ 86-88.

[5] *Id.* ¶¶ 89-90.

With respect to the duplex gap, the Commission should establish a "4/6/1" band plan—placing a 4 MHz channel for wireless microphone operations at the bottom of the duplex gap, followed by a 6 MHz unlicensed channel, followed by 1 MHz separation between unlicensed operations and LTE uplink channels. The record demonstrates that 40 mW unlicensed operations will not cause harmful interference to LTE downlink licensees if there is as little as 3 MHz of separation between them. The "4/6/1" band plan provides 4 MHz of separation, so it offers even more protection than the Commission proposes elsewhere. Placing 1 MHz separation at the top of the duplex gap, rather than the bottom, will substantially increase the utility of the unlicensed channel without adversely affecting wireless microphone operations.

A. The Commission Should Permit White Space Devices to Operate in the Duplex Gap and 9 MHz Guard Bands Using Transmit Powers of at Least 40 mW.

Google agrees that the touchstone of interference analysis should be how devices perform under reasonably foreseeable conditions.[6] The interference analyses submitted by Broadcom Corporation (Broadcom) reflect this standard, while those submitted by Qualcomm do not. Broadcom's OOBE analysis considered the interference potential of energy emitted by a white space device into the LTE downlink channel.[7] Its blocking analysis evaluated the potential desensitization of an LTE downlink receiver caused by the energy emitted by a white space device within the unlicensed channel.[8] Finally, Broadcom's intermodulation analysis studied the

[6] *See id*. ¶ 82 ("[W]e believe that under reasonable conditions white space devices can operate in the duplex gap and guard bands without causing harmful interference to LTE receivers.").

[7] *See* Letter from Paul Margie, Counsel to Broadcom Corp., to Marlene H. Dortch, Secretary, Fed. Commc'ns Comm'n, at slide 8, GN Docket No. 12-268 (filed Jul. 22, 2014) (July Letter).

[8] *Id*. at slide 6.

interference potential for an intermodulation product of a white space device signal in the duplex gap and an LTE uplink signal falling into the LTE downlink channel.[9]

Broadcom concluded that the dominant form of interference varied depending on the spectral separation between the two channels.[10] At a separation of 3 MHz, Broadcom's analysis demonstrates that a white space device could operate at a power level as high as 49.0 mW before causing blocking interference,[11] and as high as 75.9 mW before its OOBE would cause harmful interference.[12] At a spectral separation of greater than 3 MHz, unlicensed devices could operate at even higher powers without causing harmful interference.

Broadcom's analysis is vastly more realistic than Qualcomm's. As we explain below, however, even Broadcom's analysis relies on several overly conservative assumptions. Under more reasonable assumptions, highlighted in the following chart, the Commission's proposed 40 mW power limit is not only adequate to protect LTE, but greatly overprotective.

	Broadcom's Conservative Assumptions (dB)	Appropriate Real-World Assumptions (dB)
LTE Body Loss	3	6
Unlicensed Body Loss	3	3
Shadowing	3	3
Polarization Mismatch	3	3
LTE Antenna Gain	-6	-6

[9] *See* Letter from Jennifer K. Bush, Assoc. Gen. Counsel, Broadcom Corp., to Marlene H. Dortch, Secretary, Fed. Commc'ns Comm'n, at slide 8, GN Docket No. 12-268 (filed Mar. 4, 2014) (March Letter).

[10] Broadcom concluded, however, that intermodulation interference would not be the dominant form of interference under any combination of spectral separation and power proposed in the NPRM or discussed herein. *Id*.

[11] *See* July Letter at slide 9.

[12] *Id*. at slide 8.

Free-Space Propagation Loss	35	35
TOTAL PROPAGATION LOSS	**53**	**56**
Unlicensed Transmit Filter Performance	64.3	64.3
LTE In-Band Interference Level	-98.5	-95.5
MAX. UNLICENSED POWER (OOBE)	**18.8 (79.5 MW)**	**24.8 (302.0 MW)**
LTE Receive Filter Performance	11.9	16.0
LTE Blocking Threshold	-48	-38
MAX. UNLICENSED POWER (BLOCKING)	**16.9 (49.0 MW)**	**34.0 (2511.9 MW)**

1. Propagation Assumptions.

Broadcom's assumptions about the white space device propagation environment are uniformly reasonable, and, in most cases, very conservative. First, Broadcom considered the different ways consumers use white space client devices and access points to determine which hold greater potential for interference. Specifically, because white space access points are not typically positioned on or near the user's body, Broadcom's analysis assumed that the signals of access points will not be affected by body loss. But for this same reason, white space access points typically will be used relatively far from LTE client devices, which generally will be located nearer to the user.[13]

Broadcom conservatively assumed that a white space access point would be only one meter further away from the LTE receiver than a white space client device. While users often carry client devices (such as tablets), access points (such as a Wi-Fi access point installed in an

[13] *Id*. at slide 5.

office) are typically stationary and tend to be sited in unobtrusive, out-of-the-way locations. Given this slightly increased separation—and even without taking into account the likely presence of additional obstructions or clutter between the access point and LTE device that would attenuate the white space signal—Broadcom determined that access point signals are subject to greater propagation loss than client devices, and therefore pose less potential for interference to LTE operations than do client devices. That is because the attenuation caused by an additional meter's propagation distance is greater than the 3 dB of body loss to which client devices, but not white space access points, are subject.[14] Consequently, Broadcom's analysis correctly focused on client devices.

Broadcom relied on only a minimal set of propagation assumptions for its client-device analysis. First, Broadcom assumed free space propagation.[15] Because this model contemplates that the unlicensed signal is completely unobstructed, it is the most conservative model possible.[16] Consistent with the Commission's prior practice, Broadcom also assumed at least two meters[17] of separation between different users' white space devices and LTE receivers, resulting in total free space propagation loss of 35 dB. Broadcom then factored in 3 dB of body loss at the white space device transmitter and at the LTE receiver; 3 dB of loss attributable to likely polarization mismatch between the white space device and LTE antennas; 3 dB of shadowing

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[14] *Id*.

[15] *Id*.

[16] *See The FCC's Office of Engineering and Technology Releases Analysis of AWS-3 Interference Tests*, Advanced Wireless Service Interference Tests Results and Analysis, Public Notice, 23 FCC Rcd. 14,669, 14,682 n.16 (2008).

[17] *See, e.g.*, *In the Matter of Service Rules for Advanced Wireless Services H Block—Implementing Section 6401 of the Middle Class Tax Relief and Job Creation Act of 2012 Related to the 1915-1920 MHz and 1995-2000 MHz Bands*, Report and Order, 28 FCC Rcd. 9483, ¶ 142 (2013) (reviewing precedent).

loss; and -6 dBi probable LTE antenna gain.[18] Adding these sources of attenuation, Broadcom concluded that the typical minimum propagation loss between a white space client device and LTE handset would total 53 dB.[19]

As with Broadcom's analysis overall, some of these attenuation assumptions are highly conservative. For example, Broadcom's analysis did not take into account studies indicating that LTE body loss may be significantly higher than the 3 dB Broadcom assumes, typically exceeding 6 dB.[20] Including just this one factor could reasonably add an additional 3 dB of transmit power. This is mathematically equivalent, in absolute terms, to doubling the output power of a device.

2. OOBE Interference.

The NPRM notes that as a general matter, "there is a lack of real world testing between white space transmitters and LTE receivers."[21] Broadcom's OOBE analysis, however, incorporated empirical testing of a representative white space radio.[22] Because Broadcom measured the actual emissions of a white space device transmitter across a range of frequencies, Broadcom was able to model the likely OOBE performance of a white space device and characterize the performance of a white space device transmit filter.

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[18] *See* July Letter at slide 5.

[19] Broadcom determined that propagation losses between a white space access point and an LTE handset would total 53.5 dB. *Id*.

[20] *See* Letter from S. Roberts Carter, Counsel to Broadcom Corp., to Marlene H. Dortch, Secretary, Fed. Commc'ns Comm'n, at slide 6, GN Docket No. 12-268 (filed Apr. 23, 2014) (April Letter).

[21] NPRM ¶ 82.

[22] Letter from Paul Margie, Counsel to Google Inc., to Marlene H. Dortch, Secretary, Fed. Commc'ns Comm'n, Broadcom Attach. at slide 2, GN Docket No. 12-268 (filed Jan. 30, 2014).

With these filter results, Broadcom determined the maximum possible transmit power of a white space device at a given spectral separation from the LTE downlink band by 1) integrating the measured filter performance across the width of a 4.5 MHz-wide LTE receive band with the desired spectral separation from the white space transmit band, 2) subtracting this integrated filter performance from the in-band interference limit of an LTE device, and 3) adding the worst-case 53 dB propagation loss. That is, Broadcom determined the maximum permissible power of a white space device by finding the highest level that keeps the power received by the LTE handset below the LTE handset's interference level, after accounting for both the power filtered out by the white space device's transmit filter, and the power that would dissipate as the signal propagates from the white space device to the LTE handset. As noted above, this analysis focused only on emissions from white space devices into the LTE band itself.[23]

In performing its analysis, Broadcom relied on -98.5 dBm as the maximum level of noise that could be transmitted into the LTE band by a white space device without causing harmful interference. [24] This is same LTE interference level used by Qualcomm. Significantly, however, the Commission's technical studies indicate that it would be reasonable to assume an LTE interference limit that is 3 dB higher.[25] In other words, an LTE device can receive a signal,

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[23] July Letter at slide 8.

[24] *See* July Letter at slide 8; Reply Comments of Qualcomm Inc. at 4, GN Docket No. 12-268 (filed Mar. 12, 2013).

[25] *See* Incentive Auction Order, Appendix C, ¶ 57 ("When considering the power spectral density that may cause interference in the UE receiver, we will use a device noise figure of 12 dB and a criterion of a 3 dB noise rise. Using these figures, we determine that: (1) the thermal noise in 1 MHz is -114 dBm/MHz; and (2) the noise in the device considering the noise figure is -102 dBm/MHz. In order to create at most a 3 dB noise rise, the PSD must be -102 dBm/MHz or less."). A device noise level of -102 dB/MHz, integrated across a 4.5 MHz LTE channel, is equal to -102 dB + 10log10(4.5) = -95.5 dB.

without harmful interference, in the presence of an in-band interfering signal 3 dB stronger than the level assumed in Broadcom's analysis. Had Broadcom's study used this LTE interference level instead of Qualcomm's far more pessimistic number, the analysis would, once again, indicate that white space devices 3 MHz away from LTE downlink could nearly double their transmit power.[26]

Specifically, using the results of its empirical testing of a white space device reference transmitter, Broadcom determined the integrated attenuation attributable to the transmit filter over the 4.5 MHz LTE receive band, at 3 MHz spectral separation from the white space device transmit channel. Under these circumstances, it determined that transmit filter attenuation would be -64.3 dBr. Broadcom then used these values to arrive at a maximum transmit power. Starting with -98.5 dBm, adding 53 dB of propagation loss, and subtracting -64.3 dBr filter attenuation, the analysis yielded a white space device transmit power of 18.8 dBm,[27] or 75.9 mW.[28]

$$-98.5\ dBm + 53\ dBm - -64.3\ dBr = 18.8\ dBm \approx \mathbf{75.9\ mW}$$

This value is well above the Commission's proposed power level of 40 mW.

Had Broadcom's analysis used (1) the more realistic LTE body loss assumptions identified above, and (2) the Commission's LTE interference threshold, the power level would have been much higher still:

$$-95.5\ dBm + 56\ dBm - -64.3\ dBr = 24.8\ dBm \approx \mathbf{302.0\ mW}$$

[26] Because the decibel scale is logarithmic, a change in power of *n* dB is equivalent to multiplying the power by $10^{(n/10)}$. A 3 dB increase, therefore, is equivalent to multiplying the absolute power by $10^{(3/10)}$, or 1.995.

[27] July Letter at slide 8.

[28] $10^{(18.8/10)} \approx 75.9$. *See supra* n.26.

Thus, the Commission's 40 mW power limit is far lower than necessary to protect LTE from white space device OOBE when the two operations are separated by as little at 3 MHz.

3. Interference from Blocking.

Broadcom's analysis similarly demonstrates that white space devices can operate at reasonable power levels without causing blocking interference to LTE receivers. The Commission rightly has cautioned that "analyses that are based on the onset of blocking may not rise to the threshold of harmful interference if one considers transmission protocols and modulation schemes which are designed to facilitate operations when conditions are less than ideal by incorporating coding, bit interleaving, and retransmission events when necessary."[29] Nevertheless, Broadcom's analysis shows that a white space device could operate at a power of 40 mW without causing harmful interference to LTE, even without taking the additional considerations cited by the Commission into account, when separated by only 3 MHz.

While its OOBE analysis relies upon characterization of a typical white space device transmit filter, Broadcom's blocking analysis focuses on the ability of an LTE receive filter to isolate the receiver from power in adjacent bands. Specifically, Broadcom analyzed three different LTE filter curves: It studied both the worst case and the typical performance of a B20 filter, which is used in Europe to isolate LTE downlink from DTV in an adjacent band, as well as the hypothetical filter characterized by the Commission in its Incentive Auction Order, based on submissions from filter manufacturers.[30]

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[29] NPRM ¶ 85.

[30] *See* July Letter at slide 3; Incentive Auction Order, Appendix C, ¶¶ 10-21.

Just as Broadcom determined the performance of the white space device transmit filter across the LTE band for its OOBE analysis, its blocking analysis calculates the average performance of an LTE receive filter across the white space device channel, at various spectral separations. Of the three filter curves Broadcom analyzed, the Commission's hypothetical filter exhibited the worst performance when the unlicensed channel is separated from LTE by 3 MHz.[31] Under these circumstances, the Commission's hypothetical filter would achieve an average attenuation of 11.9 dB.[32]

Broadcom then determined the likely blocking threshold for an LTE device, *i.e.*, the maximum power an LTE device can tolerate in an adjacent band before that power overwhelms the receiver's ability to receive signals in its intended band of operation. To arrive at this value, Broadcom tested the performance of LTE handsets marketed in the United States. These devices were able to receive data over LTE with power levels in an adjacent channel as high as -25 dBm, when the desired signal is 6 dBm stronger than the minimum sensitivity of the handset.[33] This performance is more than 20 dB better than the minimal performance specifications imposed by the 3GPP standard.[34]

These results come as no surprise. As the Commission is aware, mass-market wireless equipment often significantly exceeds the 3GPP standards.[35] Indeed, carriers' performance

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[31] *See* July Letter at slide 3. A white space device would transmit in an approximately 5 MHz wide band centered within the 6 MHz unlicensed channel described by the Commission. Thus, the 3 MHz separation between LTE and the designated 6 MHz unlicensed channel corresponds to an actual 3.5 MHz separation between LTE and the white space transmission.

[32] *Id.* at slide 4.

[33] *Id*. at slide 7.

[34] *Id*.

[35] *See* NPRM ¶ 83.

requirements for LTE handsets, which establish the real-world floor for devices, typically are much stricter than 3GPP.[36] Although Broadcom's empirical results indicated that the receive filters actually used in LTE handsets exhibit filtering performance 20 dB better than the 3GPP specifications, Broadcom nevertheless assumed that filters will exceed the 3GPP standard by only 10 dB—a value that the Commission has already characterized as a "reasonable assumption."[37] Using these assumptions, the worst-case LTE blocking threshold would be -48 dBm at a spectral separation of 3 MHz between the LTE downlink and TVWS channels.[38]

Having determined the worst-case LTE blocking threshold and the average LTE receive filter performance with 3 MHz separation between LTE downlink and the unlicensed channel (3.5 MHz between LTE and the lowest frequency at which a white space device will actually transmit), determining the maximum white space device power is, again, a matter of arithmetic. Maximum power equals the blocking threshold, plus 53 dB propagation loss, minus average receive filter performance. Thus, under Broadcom's assumptions:

$$-48\ dBm + 53\ dBm - -11.9\ dB = 16.9\ dBm \approx \mathbf{49.0\ mW}$$ [39]

This is easily greater than the Commission's proposed 40 mW power limit.

Here again, though, Broadcom's highly conservative assumptions came into play. Most significantly, in Google's view, Broadcom's interpretation of the Commission's hypothetical filter was extremely conservative. Because the Commission defined the performance of this filter at only two points—spectral separations of 7 MHz and 11 MHz from the edge of the LTE

[36] *See* March Letter at slide 3.

[37] *See* NPRM ¶ 84 n.127.

[38] *See* July Letter at slide 7.

[39] $10^{(16.9/10)} \approx 49.0$. *See supra* n.26.

receive channel—Broadcom had to make assumptions about performance at less than 7 MHz separation from the LTE channel edge. Instead of asymptotically approaching zero, as real-world filters do, Broadcom filled this gap with the assumption that the performance of this filter would decrease linearly with each MHz of spectral separation, until the attenuation reached zero. This assumption resulted in a filter attenuation of 0 for the first 3 MHz of separation from the LTE channel edge,[40] while any real-world filter would achieve significantly greater attenuation. Had Broadcom considered a filter similar to even its already highly conservative characterization of a B20 filter, adhered to its empirical results regarding the LTE blocking threshold, and/or incorporated the results of real-world LTE body-loss studies, the results of its analysis would have been even more favorable for white space devices.

For example, according to Broadcom's charts, at a spectral separation of 3.5 MHz, the B20 filter would have achieved an average attenuation of approximately -16 dB over the 5 MHz white space device band, instead of the -11.9 dB Broadcom assumed for the Commission's hypothetical LTE filter.[41] In addition, Broadcom's empirical results suggest a blocking threshold of -38 dBm, 20 dB better than 3GPP. And, again, LTE body loss is likely to be at least 3 dB higher than Broadcom's worst-case estimate.[42] Taking into account the cumulative impact of using reasonable rather than very conservative assumptions, LTE receivers could tolerate dramatically higher transmit powers from white space devices before encountering blocking interference.

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[40] July Letter at slides 3-4.

[41] *Id*. at slide 3.

[42] *See* April Letter at slide 6.

$$-38 \text{ dBm} + 56 \text{ dBm} - - 16 \text{ dB} = 34 \text{ dBm} \approx \boldsymbol{2511.9\ mW}$$[43]

The Commission's 40 mW power limit therefore substantially overprotects LTE downlink operations even when only 3 MHz separates white space operations from downlink operations.

In sum, Broadcom's analysis provides an exceedingly strong foundation for permitting white space operation at 40 mW in both the duplex gap and the guard bands, when the guard bands are at least 9 MHz wide and can therefore accommodate a 3 MHz spectral separation from the downlink operations.[44] In fact, the Commission could permit unlicensed devices to transmit at higher power, without an excessive risk of interference to LTE.

B. The Commission Should Adopt a "4/6/1" Duplex Gap Band Plan.

The Commission also seeks comment on how it should organize the 600 MHz spectrum's duplex gap.[45] The NPRM suggested a "1/4/6" band plan—with 1 MHz between LTE downlink and wireless microphone operations, then a 4 MHz wireless microphone channel, followed by the 6 MHz unlicensed channel. The Commission asks whether this organization is preferable to a "4/6/1" band plan because it would provide an additional 1 MHz of spectral separation between the unlicensed channel and LTE downlink.[46]

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[43] $10^{(34/10)} \approx 2511.9$. *See supra* n.26.

[44] For smaller guard bands, Broadcom's analysis supports reduced operating powers such as 8 mW when the guard band is only 7 MHz wide (i.e., with a spectral separation between unlicensed and LTE downlink of 1 MHz). *See* July Letter at slide 10. In contrast to Broadcom's well-constructed analysis, the Commission cannot rely on submissions, including the 2013 report of the Consumer Electronics Association, that ignore body loss and other significant sources of propagation loss, and fail to take into account spectral separation between the unlicensed channel and LTE downlink. *See* Letter from Julie M. Kearney, Vice President, Regulatory Affairs, Consumer Electronics Ass'n, to Marlene H. Dortch, Secretary, Fed. Commc'ns Comm'n, Attach. at 10, 19, 33-34, GN Docket No. 12-268 (filed Dec. 16, 2013).

[45] NPRM ¶ 95.

[46] *Id*. ¶¶ 94-95.

The "1/4/6" plan is not preferable. As described above, Broadcom's analysis demonstrates that there is no need for 5 MHz of separation between unlicensed and LTE downlink; 3 MHz of separation is more than adequate. Indeed, the Commission's own proposal to allow, in 9 MHz guard bands, 40 mW unlicensed operations with 6 MHz channels, recognizes that 3 MHz of separation is enough to protect LTE downlink channels.[47]

The "4/6/1" band plan not only is technically workable, but also would maximize the utility of the unlicensed band. Separating consumer white space devices by even 1 MHz from LTE uplink will substantially improve white space device performance for consumers, since LTE uplink signals originate from handsets themselves and, therefore, pose the greatest interference risk indoors, where white space devices are likely to also operate.

Finally, a "4/6/1" band plan will not restrict wireless microphone operations. Because wireless microphones can operate very near each other in narrow bandwidths, they necessarily have good receiver selectivity.[48] As the Commission has recognized, the nature of wireless microphone operations results in "a low risk of unlicensed white space devices causing interference to licensed wireless microphones in the adjacent band."[49]

A recent technical report published by Ofcom in the UK supports this conclusion.[50] Based on operations at live events and controlled field tests, Ofcom concluded that "no reduction in audio quality [over wireless microphones] could be detected" as a result of white space

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[47] *Id*. ¶ 88.

[48] *Id*. ¶ 94.

[49] *Id*.

[50] *See generally* Ofcom Technical Report, TV White Spaces: PMSE Coexistence Tests (Nov. 12, 2014), *available at* http://stakeholders.ofcom.org.uk/binaries/research/technology-research/2014/TVWS-PMSE_Coexistence_Technical_Report.pdf.

devices operating on adjacent channels at power levels far greater than the Commission has proposed for duplex gap operations.[51] For example, during a live performance of *Les Miserables* at the Queen's Theatre in London, white space devices placed two meters from the stage operated on first adjacent channels at power levels of up to 29 dBm (approximately 800 mW) without causing harmful interference to any of the microphones on the stage.[52]

LTE downlink operations are similarly unlikely to interfere with microphones under the "4/6/1" plan. LTE downlink signals will originate in base stations remote from wireless microphone receivers, and often separated from the receivers by building walls and other obstructions. Indeed, while microphone manufacturer Shure has argued that the duplex gap may not provide "clean" spectrum for professional wireless microphones due to LTE uplink, it has not raised similar concerns about wireless microphone operations in guard bands adjacent to LTE downlink bands.[53]

III. TECHNICAL RULES SHOULD PROTECT CHANNEL 37 INCUMBENTS WHILE PERMITTING UNLICENSED CONSUMER BROADBAND IN THE VAST MAJORITY OF THE COUNTRY WHERE INCUMBENTS DO NOT OPERATE.

As the Commission has recognized, WMTS and RAS incumbents operate in a relatively small number of known geographic areas. Across most of the United States today, channel 37 is completely unused. This situation is unacceptable in a spectrum-constrained environment.

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[51] *Id.* at 1, 4.

[52] *Id.* at 1.

[53] *See* Reply Comments of Shure Incorporated at 9-10, GN Docket No. 12-268 (filed Mar. 12, 2013) (arguing that the duplex gap "will not provide a suitable spectrum environment for professional wireless microphones that require reliable clean spectrum due to the out-of-band emissions ('OOBE') from the immediately adjacent 600 MHz uplink band," but stating that "[t]he guard band immediately below the downlink band, however, should present a significantly cleaner environment").

Google therefore agrees with the Commission's goal of enabling unlicensed operations in channel 37 as long as white space databases and devices protect incumbents from harmful interference.[54] The NPRM's proposed implementation of that commonsense principle, however, is unnecessarily restrictive and will prevent consumers from accessing spectrum where doing so would present no significant risk of harmful interference to WMTS or RAS incumbents.

With respect to WMTS, the Commission's proposed approach—while fundamentally sound—relies on certain overly conservative assumptions that should be corrected if this general methodology is used. Most important, the Commission's calculations omit building loss between WMTS systems and white space devices. Taking walls into account leads to greatly reduced separation distances. The Commission's assumption of a relatively open, suburban environment also overstates the required separation distances around medical facilities in most real-world situations, where closely spaced structures, dense vegetation, or terrain will reduce signal propagation.

More fundamentally, however, there is a better way to approach the issue. Rather than relying purely on assumptions and modeling, the Commission should align its separation distances with real-world conditions. Specifically, the Commission should authorize WMTS users to collaborate with white space database providers to take account of line-of-sight and non-line-of-sight propagation effects from the *actual* boundaries of each WMTS site.[55]

With respect to RAS, the Commission's proposed exclusion zones for VLBA sites are vastly larger than necessary to protect these facilities from harmful interference. The

[54] NPRM ¶ 99.

[55] *See id.* ¶ 112.

Commission should adopt RAS protection rules that take real-world factors such as terrain and time of use into account.

Finally, there is no reason to prohibit or delay personal/portable white space devices, including Mode I devices, from operating in channel 37. Both fixed and personal/portable white space devices rely on the same database technology to protect incumbents from harmful interference, and separation distances can be adjusted to account for the fact that Mode I devices do not incorporate geolocation capability.

A. The Commission's Proposed Separation Distances from WMTS Are Too Large.

The Commission relies on the TM 91-1 model to calculate propagation of white space device signals and corresponding separation distances from WMTS.[56] Google agrees that this model provides a reasonable starting point for analyzing separation distances, but the Commission's implementation fails to account for a number of factors affecting propagation. When these factors are considered, the separation distances suggested by the Commission are too great.

First, and most critically, the Commission assumes no building loss between the white space transmitter and the WMTS receiver.[57] Essentially all WMTS receivers, however, are located indoors or in an interior space.[58] The Commission, moreover, is proposing to exclude

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[56] *Id.* ¶ 110.

[57] Declaration of Donald Breslin, *infra* Appendix A, ¶ 3 (Feb. 4, 2015) (Breslin Declaration).

[58] 47 C.F.R. § 95.1107 (limiting WMTS operations to within health care facilities and excluding operation in moving vehicles like ambulances); *see also* Comments of Philips Healthcare at 7, GN Docket No. 12-268 (filed Jan. 25, 2013) (taking into account for interference modeling purposes "that WMTS receivers are deployed indoors with some protection provided by the hospital building structure"); WIRELESS MEDICAL TELEMETRY SERVICE (WMTS), FCC, http://www.fcc.gov/encyclopedia/wireless-medical-telemetry-service-wmts (last visited Feb. 3,

white space devices from WMTS sites. It thus is virtually certain that there will be an exterior wall between a white space device and a WMTS receiver. Indeed, there may be multiple walls separating the white space device from the WMTS device.

The TM 91-1 model predicts approximately 7 dB building penetration loss in the television band for suburban homes.[59] Hospitals and other industrial-grade buildings are made of denser material, which results in greater signal attenuation.[60] Merely adjusting the Commission's propagation model to incorporate a conservative building loss of 10 dB for industrial-grade buildings dramatically decreases separation distances. For example, recognizing building loss reduces the Commission's proposed separation distance for a 4 W device operating at a height of 3 meters from 1.0 kilometer, as proposed in the NPRM, to 600 meters.[61]

Moreover, the TM 91-1 model's path loss formula relies heavily on measurements in suburban conditions, which do not account for built and natural environments that limit propagation.[62] In particular, the failure of this model to account for building obstructions in urban deployments—where user density is highest and architectural obstructions are the norm—unnecessarily limits spectrum available for use by white space devices. The example of a typical Manhattan city block illustrates why such shadowing can be very significant: The shortest separation distance proposed by the Commission is 300 meters,[63] but the average Manhattan city

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2015) (stating that "WMTS devices may be used only *within* a health care facility") (emphasis added).

[59] Breslin Declaration, ¶ 4.

[60] *Id.* ¶¶ 5-6.

[61] *Id.* ¶¶ 7-8.

[62] *Id.* ¶ 9.

[63] NPRM ¶ 112.

block is 229 meters by 80 meters.[64] Consequently, in Manhattan, a signal traveling 300 meters would likely have to pass through more than one full city block of obstructions.

B. To Ensure More Effective Protection *and* Reduce Separation Distances, White Space Databases Should Measure Separation Distances from Perimeters That Account for Actual Line-of-Sight Information in the Vicinity of the WMTS Site.

For the reasons given above, the Commission should reduce its proposed white space/WMTS separation distances if it retains the modeled-interference approach suggested in the NPRM. The Commission should also, however, consider a more accurate approach to WMTS protection that makes use of familiar mapping and imagery tools and takes into account the actual conditions surrounding each WMTS site. Because this approach relies on more than modeling alone, it will simultaneously improve protection of WMTS receivers and free additional white space for use by unlicensed devices. To determine more effective protection, Google proposes the following steps, which are further described in the accompanying Declaration of Andy Lee:

First, in order to protect devices throughout the footprint of a site, WMTS providers would register the perimeter of their site with either the American Society for Health Care Engineering (ASHE) or one of the Commission's approved database providers. Replacing existing point registrations in ASHE's WMTS database with site perimeters should take less than 1,000 person-hours, spread across the entire hospital industry.[65]

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[64] *See* Michael Pollak, *Knowing the Distance*, N.Y. TIMES, Sept. 17, 2006, *available at* http://www.nytimes.com/2006/09/17/nyregion/thecity/17fyi.html.

[65] Declaration of Andy Lee, *infra* Appendix B, ¶ 5 (Feb. 4, 2015) (Lee Declaration).

Second, WMTS providers and database operators would collaborate in determining protection contours for each venue that reflect the line-of-sight characteristics in the surrounding area. Where satellite imagery or other line-of-sight information is available, Google is willing and able to collaboratively populate adjusted perimeters for all WMTS sites using tools such as Google Earth Pro,[66] and anticipates that this work easily could be accomplished for all sites registered in the current WMTS database[67] before the end of the 39-month implementation period for 600 MHz band wireless operations.[68] For example, the actual perimeter of a WMTS site would be adjusted outward if a hospital faced an open field, but would track the building closely if there were obstructions—such as tall buildings—in the immediate vicinity of the site. Of course, other database administrators would be free to undertake this process as well.

Third, white space databases would apply separation distances to these revised perimeters. Because the expanded perimeters will already take into account the line-of-sight information that has a substantial effect on propagation, and because representing WMTS sites as larger shapes is inherently more protective than representing them as individual points, the separation distances proposed in the NPRM should be reduced markedly. As explained in the accompanying Declaration of Donald Breslin, under this approach, separation distances should shrink to two kilometers or less for the vast majority of height and power configurations.[69]

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[66] *See Google Earth Pro*, GOOGLE INC., https://www.google.com/work/mapsearth/products/earthpro.html (last visited Feb. 3, 2015).

[67] According to data provided by AHSE, there were 2,739 unique locations using channel 37 devices as of March 2012. *See In the Matter of Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions*, Notice of Proposed Rulemaking, 27 FCC Rcd. 12,357, ¶ 210 (2012).

[68] *See* Lee Declaration, ¶ 6; Incentive Auction Order ¶ 11.

[69] Breslin Declaration, ¶ 10.

Separation distances for personal/portable devices, in particular, could be reduced to roughly 100 meters.[70]

This is a workable approach. As noted, the effort required to establish the initial and adjusted contours of a WMTS site is minimal.[71] White space databases can easily store the adjusted WMTS site perimeters that this rule would employ, and enforce the revised separation distances from these perimeters. Indeed, white space databases already calculate separation distances from geometric shapes that represent the facilities of television broadcasters and many wireless microphone users.[72] Adding similar data regarding WMTS sites will have little, if any impact on the operating costs of white space databases.[73]

This approach also is grounded in Commission precedent. The Commission adopted a similar approach, at GE Healthcare's request, in its recent Medical Body Area Networks (MBAN) proceeding.[74] As GE Healthcare explained there, taking line-of-sight information into account allows maximum use of spectrum "without fear of interference."[75] In the MBAN proceeding, the Commission concluded that it could eliminate the risk of harmful interference between MBAN networks and aeronautical mobile telemetry (AMT) receive stations by

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[70] *Id*.

[71] Lee Declaration, ¶ 9.

[72] *Id.*

[73] *See id.* ¶ 7.

[74] *See, e.g.*, Letter from Ari Q. Fitzgerald, Counsel to GE Healthcare, William K. Keane, Counsel to AFTRCC, and David R. Siddall, Counsel to Philips Healthcare, to Marlene H. Dortch, Secretary, Fed. Commc'n Comm'n, at 1-2, ET Docket No. 08-59 (filed Jan. 14, 2011) (GE Proposal); *see also In the Matter of Amendment of the Commission's Rules to Provide Spectrum for the Operation of Medical Body Area Networks*, Order on Reconsideration and Second Report and Order, 29 FCC Rcd. 10,662, ¶ 41 (2014) (MBAN Order); 47 C.F.R. § 95.1223.

[75] *See* GE Proposal, Attach. B at 1.

assigning a frequency coordinator to determine whether a potential MBAN site would be within line of sight of such a station.[76] The MBAN frequency coordinator's duties include "determin[ing] if an MBAN is within the line of sight of an AMT receive facility in the 2360–2390 MHz band."[77] If so, "the MBAN frequency coordinator shall achieve a mutually satisfactory coordination agreement with the AMT frequency coordinator prior to the MBAN beginning operations in the band."[78] Thus, under GE's proposal, which the Commission adopted, the operation of a given MBAN is conditioned on the frequency operator's line-of-sight determination. The approach we propose is similar.

The benefits of more intensive spectrum use and more accurate protection for WMTS amply justify the slight administrative burden of the line-of-sight approach described here. Should the Commission decline to mandate the more accurate approach in all cases, however, it should—at a minimum—allow use of this method as an optional alternative to relying upon the point-and-radius approach proposed in the NPRM. By the same token, to the extent that it continues to rely on the point-and-radius approach for protection of any WMTS sites, the Commission should adjust the default separation distances set forth in the NPRM to account for hospital walls as well as path loss from other structures and obstructions in a typical WMTS setting.

[76] MBAN Order ¶ 41; *see also* 47 C.F.R. § 95.1223.

[77] 47 C.F.R. § 95.1223(c).

[78] 47 C.F.R. § 95.1223(c)(2).

C. The Commission's Proposed RAS Separation Distances Waste Valuable Spectrum.

The NPRM reflects the Commission's wholly appropriate commitment to protecting RAS sites from interference.[79] But the Commission's proposed separation distances for white space operations—especially its 314-kilometer separation distance for operations at 4 W EIRP—are in most instances larger than necessary to protect radio telescopes from harmful interference, particularly because they fail to take terrain blockage into account. To address this defect, the Commission should adopt an approach to protecting RAS that takes terrain and time of operation into account.

1. Protection of the National Radio Quiet Zone and Puerto Rico Coordination Zone.

Google concurs with the Commission's proposal to exempt white space devices' use of channel 37 within the National Radio Quiet Zone and the Puerto Rico Coordination Zone.[80] Such exclusions will protect single-dish RAS operations through the use of successful and long-standing geographic protections for the RAS.

2. Protection of VLBA Sites That Accounts for Terrain Blockages.

By contrast, the blanket exclusion zones proposed around the VLBA sites are generally too large and will restrict unnecessarily white space operations in some major market areas. The principal shortcoming is that simple circular exclusion zones do not take into account real-world mitigating factors including terrain blockage. Indeed, the Commission specifically recognizes that the separation distances proposed in the NPRM do not include "factors that would act to

[79] NPRM ¶¶ 116-24.

[80] *See id.* ¶¶ 122-24.

shorten the protection distance such as buildings, mountains, trees, or other ground clutter."[81] This failure is especially problematic inasmuch as many RAS sites are situated so that they are surrounded by mountainous terrain, precisely to block the sites from external sources of radio frequency interference.[82] In addition, as the NPRM acknowledges, many of the proposed separation distances prohibit white space operations well beyond the radio horizon from the RAS sites they protect.[83]

Unless they are revised to take such factors into account, the proposed exclusion zones will prohibit consumer use of channel 37 in major markets where, due to heavy incumbent television broadcast activity, the number of available white space channels is already greatly reduced. Indeed, using the Commission's proposed fixed separation distances instead of a terrain-aware model would unnecessarily foreclose white space operations at 4 W in several major population centers in the United States, including New York City. The table below shows just a few of the population centers that would be affected:

[81] *Id.* ¶ 119.

[82] *Id.*

[83] *Id.*

Metropolitan Area	Population
New York, NY	19,949,502
Boston, MA	4,684,299
Phoenix, AZ	4,398,762
Seattle, WA	3,610,105
Las Vegas, NV	2,027,868
Tucson, AZ	996,544
Fresno, CA	955,272
El Paso, TX	831,036[84]

As shown below, by taking terrain blockage into account, the channel 37 exclusion zones will allow tens of millions of potential white space users to access channel 37, while still providing at least the ITU-recommended level of interference protection to RAS.

For the areas surrounding all ten VLBA sites, Google conducted propagation analyses using the Longley-Rice model.[85] The results of these analyses show that when terrain is taken into account, the exclusion distance in directions in which substantial blockage exists is much smaller than the uniform radius proposed in the NPRM.[86] For example, Figure 1 compares the NPRM's proposed exclusion zone for 4 W white space devices around the VLBA site in Hancock, New Hampshire, to the exclusion areas based upon the Longley-Rice predictions.

[84] *Annual Estimates of the Resident Population: April 1, 2010 to July 1, 2013*, Metropolitan Statistical Area; and for Puerto Rico, U.S. CENSUS BUREAU (rel. Mar. 2014), *available at* https://www.census.gov/popest/data/metro/totals/2013/; *see also* Declaration of Andrew W. Clegg, Ph.D., *infra* Appendix C, ¶ 9 and Annex (Feb. 4, 2015) (showing affected areas) (Clegg Declaration).

[85] Clegg Declaration, ¶ 9 and Annex.

[86] *Id*.

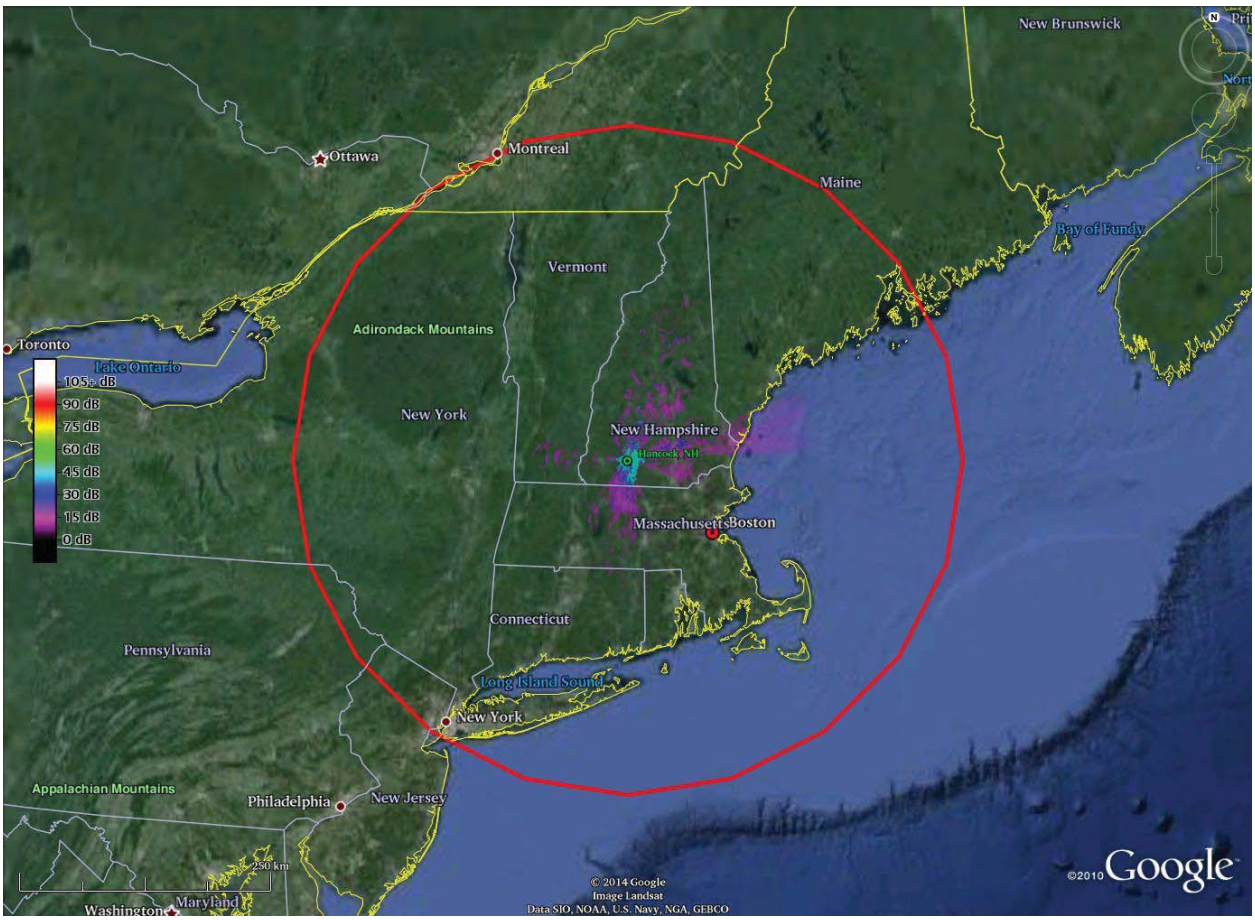

Figure 1: Comparison of exclusion zone for 4 W television band devices surrounding the Hancock VLBA site as proposed in the NPRM (red circle) with exclusion zones calculated with the terrain-aware Longley-Rice prediction model (various shades of blue and purple near the center).

At the Hancock site, the NPRM's proposed exclusion distance of 314 kilometers is up to *63 times* greater than the distance needed to protect RAS observations.[87]

The accompanying Clegg Declaration shows that the Commission's proposed exclusion zones unnecessarily restrict white space operation in many areas where it would not cause harmful interference. Consequently, channel 37 exclusion zones to protect VLBA operations should take into account real-world effects, especially propagation losses due to terrain. The

[87] *Id.* ¶ 8.

Commission can easily implement such exclusion zones through the white space databases.[88] Bearing-dependent exclusion distances may look complex when illustrated on a map, but they are simple to implement in computer code.[89] Indeed, they are no more complicated than basic functions that all white space databases perform today.[90]

Such simple-to-implement, terrain-aware exclusion zones will resolve many of the unnecessary restrictions that are a consequence of the blanket zones proposed in the NPRM. For example, because substantial terrain blockage exists to the southeast of the Hancock VLBA site, and to the west of the Owens Valley, California, site, the use of accurate terrain-based exclusion zones will no longer constrain white space devices' use of channel 37 in Boston, New York, and the eastern portions of Los Angeles, while still protecting RAS from interference.

3. Time Coordination Is an Effective Strategy To Maximize Use of Channel 37 While Protecting RAS.

Even with terrain-based exclusion zones, RAS-related restrictions could still unnecessarily limit consumer wireless uses in metropolitan areas including Phoenix, Arizona, and Albuquerque, New Mexico.[91] To solve this problem, the Commission should permit time-based coordination for the use of channel 37. RAS observatories utilize channel 37 less than 1% of the time.[92] Absent time coordination, some significant regions of the country will remain

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[88] Lee Declaration, ¶ 11.

[89] *Id*.

[90] *Id.*

[91] Clegg Declaration, ¶ 13.

[92] Andrew Clegg, *Spectrum Management and Radio Astronomy: The Future*, presentation at the Scientific Committee on Frequency Allocations for Radio Astronomy and Space Science (IUCAF), Fourth School on Spectrum Management for Radio Astronomy, Santiago, Chile, at 10, (Apr. 2014), http://goo.gl/8dFc4H.

excluded from using white space devices in channel 37, even during the >99.5% of the time that the channel is not being used for RAS.[93] A straightforward entry in a database, notifying the white space databases of RAS use with as little as two hours advance notice (in a similar manner to the way wireless microphones register now), is a simple and effective method to allow efficient access to channel 37 for white space devices while ensuring protection of RAS observations.[94]

D. Both Mode I and Mode II Personal/Portable Devices Can Operate Safely in Channel 37.

The approaches described above provide a framework for protecting WMTS and RAS that can be applied to all types of white space devices. Within this framework, the Commission should permit fixed devices, Mode I personal/portable devices, and Mode II personal/portable devices to operate in channel 37, subject to exclusion zones enforced by a white space database. Fixed devices are important for backhauling wireless broadband services between set locations. But unless the Commission permits the use of personal/portable devices, consumers would not be able to use channel 37 for smart phones, tablets, laptops, or many Internet-of-Things applications. Increased use of these devices is the prime reason that consumers need additional unlicensed spectrum, and excluding such devices from channel 37 would place the channel out of reach for most Americans, greatly compromising a benefit the Commission is working to achieve.

Furthermore, prohibiting Mode I personal/portable devices from channel 37 would exclude all consumer tablets, laptops, and Internet-of-Things devices that do not incorporate

[93] Clegg Declaration, ¶ 14.

[94] *Id.* ¶ 15.

geolocation and database access capabilities. Many of the most popular tablets would be excluded, as well as nearly every consumer laptop. Prohibiting use of these products in channel 37 would severely reduce the utility of these frequencies.

Fortunately, the white space database system can ensure that Mode I and II personal/portable devices fully protect incumbents from harmful interference. Mode II devices are required to report their location.[95] Consequently, white space databases can protect channel 37 incumbents' facilities by prohibiting Mode II devices from operating in areas where they could cause harmful interference.

For this purpose, Google proposes that Mode II devices that rely on external power be treated differently than battery-powered Mode II devices. The former must be plugged into an AC outlet to operate and are, therefore, not truly mobile. Although these devices are fixed in practice, they may not meet the Commission's definition of "fixed" white space devices because they are not professionally installed. An example would be a consumer Wi-Fi access point with a white space radio. Such Mode II devices must re-check a white space database for permission to operate whenever they are activated from a power-off condition.[96] As a result, for devices that rely on external power, the database would establish an exclusion zone that consists of the appropriate protection radius surrounding the WMTS or RAS facility, plus the maximum possible uncertainty in the device's position under the Commission's location accuracy rules. Thus, under current regulations, if the Mode II device is more the 50 meters[97] from the edge of

[95] 47 C.F.R. § 15.711(b)(3)(ii).

[96] *Id.* Such devices must also recheck with the database every 60 seconds to confirm that they have not moved in position, but because the devices rely on external power, they will not be able to move significantly without powering down and powering up again.

[97] The Commission's current rules require a device's reported location to be accurate to within 50 meters. *See* 47 C.F.R. § 15.713(g). Under our proposal below, the database would incorporate

the protection zone, the Commission can be confident that it can transmit without causing harmful interference, because the device cannot move to a location where it would violate the geofence without having to power down, re-connect, and re-check with the database, at which point the database would prohibit transmission.

The Commission can use a similar mechanism to ensure that Mode I devices do not transmit within exclusion zones. The Commission's rules do not require Mode I devices to incorporate an internal geolocation capability or to communicate directly with a white space database. But these devices must always be tethered to a fixed or Mode II device, and must obtain their list of available channels from that device and then communicate with the master device every 60 seconds. If the Mode I device cannot communicate with a fixed or Mode II device, then it may not transmit. The Commission's rules therefore can ensure that Mode I devices do not cause interference to WMTS or RAS in channel 37 by mandating that white space databases establish an exclusion zone calculated as follows: the protection radius surrounding the incumbent's facility, plus the location uncertainty associated with the Mode II master device (as set forth above), plus the operating range of the Mode I client device.

To account for possible variation in operating ranges of Mode I devices, the Commission should establish classes for different types of Mode I devices. This is important because different devices using white spaces could have dramatically different operating ranges: For example, a laptop or tablet has a very short range compared to a low-data-rate sensor. Determining reasonable protection criteria for stationary Mode II devices used in combination with Mode I

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a device's actual reported location accuracy, instead of the blanket 50-meter requirement. *See infra* Section IV.B.

devices will cover some of the most important use cases for this spectrum, such as the use of access points in combination with end-user equipment.

Currently, Mode II devices that do not rely on AC power may move up to 100 meters before re-checking the database for a list of authorized channels.[98] However, a more flexible approach would allow devices to inform the database of a potential range of operation. The database would then provide the available channels within that range. This would allow users to make trade-offs: They could limit database queries even if they had moved significantly, but could be granted access to fewer channels as a result. The Commission should require separation distances for mobile Mode II devices that take into account (1) the separation distances established by the Commission, (2) the Mode II device's location uncertainty, and (3) the Mode II device's reported operating range. Therefore, under the Commission's current rules, the separation distance for this type of Mode II device would be the keep-out distance + 50 meters (to account for the device's uncertainty in determining geolocation) + 100 meters (to account for device portability).

Finally, the Commission should adopt different exclusion zone calculations for different classes of white space devices, rather than expanding exclusion zones for all classes of white space devices to account for the larger distances required for Mode I personal/portable devices. Permitting smaller exclusion zones for fixed and Mode II devices with no paired Mode I devices, especially Mode II devices that rely on external power, will improve access to spectrum for consumers without risking harmful interference for incumbents. In contrast, adopting large, one-size-fits-all exclusion zones would unnecessarily waste spectrum resources.

[98] 47 C.F.R. § 15.711(b)(3)(ii).

It bears remembering that while these calculations are somewhat complicated to describe, they are easy for white space databases to implement. Once a white space database is coded to implement the Commission's rules, Commission staff have reviewed and approved that functionality as required by the rules,[99] and WMTS and RAS registrations have been entered, basic device characteristics and location information are the only additional information required to implement channel 37 protections through simple calculations.

IV. THE COMMISSION SHOULD UPDATE ITS WHITE SPACE RULES TO ENABLE GREATER INVESTMENT AND MORE EFFICIENT SPECTRUM USE.

As the Commission has recognized, reallocating the 600 MHz band and repacking television broadcasters will result in fewer white spaces in the remaining television broadcast band—particularly in urban areas where consumer demand for unlicensed services is heaviest.[100] Accordingly, Google supports the Commission's efforts to update its white space rules to enable more efficient and intensive spectrum use while still protecting incumbents (as well as future wireless licensees) from harmful interference. These steps should be taken quickly, regardless of the timing of the incentive auction.

Specifically, the Commission should promptly (1) open additional vacant television channels for white space devices, both during the transitional period prior to reconfiguration of the broadcast bands and thereafter; (2) adjust its location accuracy rules to enable alternative geolocation solutions; (3) reduce television contour separation distances that have proven to be unnecessarily large; and (4) implement several of its proposed technical rule changes to provide additional flexibility for white space device operations.

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[99] 47 C.F.R. § 15.715.

[100] *See* NPRM ¶ 34.

A. The Commission Should Make Additional Vacant Television Band Channels Available for Unlicensed Operations.

Because of the acute need for additional frequencies for wireless broadband today, as well as the expected loss of white space channels after the incentive auction and repacking, the Commission should immediately remove prohibitions on unlicensed service on vacant television channels wherever possible. In particular, the Commission should remove the prohibitions on (1) unlicensed operations on the two vacant channels above and below channel 37 and (2) personal/portable unlicensed operations in channels 14-20.

1. Freeing Two Vacant Channels Above and Below Channel 37.

Google supports the Commission's proposal to permit white space operations on the nearest vacant television channels above and below channel 37.[101] The existing rules reserve these two channels exclusively for wireless microphones.[102] Because wireless microphone use is periodic and highly localized, this restriction results in two 6 MHz television channels—a full 12 MHz of spectrum—being completely unused in the vast majority of the country the vast majority of the time.

Wireless microphone proponents previously have insisted that this inefficient rule is necessary in order to accommodate "breaking news" scenarios.[103] The Commission, however, proposes to protect electronic newsgathering on each side of channel 37 after it allows white space use.[104] Decreasing white space database re-check and synchronization times will

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[101] *Id.* ¶ 25.

[102] *See* 47 C.F.R. § 15.707.

[103] *See, e.g.*, Comments of the National Association of Broadcasters at 6-7, GN Docket No. 12-268 (filed Jan. 25, 2013).

[104] NPRM ¶ 25.

accommodate electronic newsgathering needs. (As discussed below, however, the Commission should not impose a blanket requirement that white space devices re-check *all* channels, and databases re-sync *all* information about the television band, within 30 minutes. Rather, this requirement should be limited to the two channels surrounding channel 37 that have been designated for newsgathering.[105])

Indeed, broadcasters have ample spectrum for breaking news uses. In addition to the shared channels above and below channel 37 and their proposed new duplex gap operations, licensed wireless microphones can operate on several other broadcast auxiliary service and Part 90 frequencies where there are no white space devices.[106] The Commission's rules further permit microphones to operate co-channel with broadcast television stations in many circumstances, subject to broadcaster coordination.[107] The Commission also has initiated a comprehensive assessment of other potential bands for wireless microphone operations.[108] These existing and proposed allowances generously accommodate breaking news needs.

2. Allowing Personal/Portable Operations in Channels 14-20.

The Commission also should adopt its proposal to permit personal/portable white space device operations in television channels 14-20, which are used by public safety or other land mobile operations in eleven cities.[109] The Commission's existing rules prohibit any

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[105] *See infra* Section IV.D.

[106] *See In the Matter of Promoting Spectrum Access for Wireless Microphone Operations*, Notice of Proposed Rulemaking, 29 FCC Rcd. 12,343, ¶¶ 121-156 (2014) (Wireless Microphone NPRM).

[107] *See* Incentive Auction Order ¶¶ 304-307.

[108] *See generally* Wireless Microphone NPRM.

[109] NPRM ¶ 30.

personal/portable white space operations below channel 21. The Commission allows fixed devices to use these frequencies, reasoning that fixed devices are able to avoid land mobile operations more reliably.[110] The Commission now has sufficient experience with the five certified white space geolocation databases to find that these databases will enable personal/portable devices to avoid areas where there are registered land mobile operations on these channels—just as fixed devices do today. There is therefore no reason to restrict database-managed access to this spectrum.

Indeed, as the Commission explained in its initial order permitting white space operations, it conservatively implemented this restriction even though incumbent mobile operations on these frequencies are intermittent. The Commission did so because white space proponents at the time "anticipate[d] that channels 21-51 will provide adequate spectrum resources" for personal/portable devices.[111] The explosive growth of Wi-Fi and other unlicensed technologies, as well as the impending reallocation of the 600 MHz band and broadcaster repacking, make that anticipation obsolete. At the same time, though, the Spectrum Act requires the Commission to reallocate channels 14-20 and auction this spectrum for other use by 2021, so opening these channels for use by personal/portable devices is not a long-term solution for white space operations.[112]

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[110] *See id.*

[111] *See In the Matter of Unlicensed Operation in the TV Broadcast Bands*, Second Report and Order and Memorandum Opinion and Order, 23 FCC Rcd. 16,807, ¶¶ 142, 152 (2008).

[112] *See generally* 47 U.S.C. § 1413.

3. Allowing Personal/Portable Operations in Channels 7-13.

The NPRM seeks comment on whether to amend the white space rules to permit personal/portable devices to use high band VHF channels 7-13.[113] Fixed white space devices already can access this spectrum, and there is no reason to prohibit personal/portable operations. As the Commission has noted, these channels, which use frequencies between 174-216 MHz, could potentially make an additional 42 MHz of spectrum available for personal/portable operations.[114] The radio wavelengths in high band VHF spectrum generally require larger antennas than for 600 MHz operations, making these frequencies less desirable for many personal/portable applications. Nonetheless, opening this spectrum for additional unlicensed uses could spur development of technologies to make more effective use of these channels.

B. Location Requirements Should Be Based on Device Capability Rather Than an Inflexible 50-Meter Mandate.

White space databases determine the frequencies that are available for unlicensed operations based on the location that fixed and Mode II personal/portable devices report to the database. Under the Commission's existing rules, these devices may obtain a list of available frequencies only if they are able to determine their location to within ±50 meters.[115] This rule is inconsistent with the Commission's general understanding of device-accuracy capabilities. And a rigid mandate for particular location accuracy is not necessary to ensure that white space devices

[113] *See* NPRM ¶ 32.

[114] *Id*.

[115] *See* 47 C.F.R. § 15.711(b).

are excluded from geographic areas where they might cause harmful interference. The Commission's rules should, therefore, accommodate a range of geolocation methods.[116]

Today, white space devices (other than stationary devices that are professionally installed) use GPS to comply with the ±50 meter requirement.[117] As the Commission has recognized, however, GPS technologies do not work reliably in all environments, since there are "circumstances where it is not possible to receive a GPS signal, such as indoors or at outdoor locations where there are obstacles such as buildings and trees."[118] Because of the 50-meter-accuracy rule, the lack of GPS signal availability means that white space devices sometimes cannot comply with the Commission's location requirements, and therefore cannot operate under the existing rules, even when they are in locations where using white space frequencies would pose no interference threat to incumbents.

In the E911 proceeding, the Commission charged the Communications Security, Reliability and Interoperability Council (CSRIC) with assessing additional technologies that could improve indoor location accuracy for wireless E911 purposes.[119] CSRIC has recognized that several technologies other than GPS can play a role in providing location information.[120] For example, in addition to cellular network-based technologies, devices could rely on Wi-Fi and/or

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[116] NPRM ¶ 76.

[117] *See id*.

[118] *Id*.; *see In the Matter of Wireless E911 Location Accuracy Requirements*, Third Further Notice of Proposed Rulemaking, 29 FCC Rcd. 2374, ¶ 9 (2014) (noting that indoor locations are a "difficult environment[]" for obtaining location information because GPS signals do not propagate reliably) (Wireless E911 Third NPRM).

[119] *See* Wireless E911 Third NPRM ¶ 11.

[120] *See generally* CISRIC WORKING GROUP 1, Final Report: Specification for Indoor Location Accuracy Test Bed (June 2014), *available at* http://transition.fcc.gov/pshs/advisory/csric4/CSRIC_IV_WG-1_Subgroup3_061814.pdf.

Bluetooth-based positioning, RF pattern matching (which uses a database to correlate location with unique RF patterns), or the use of beacons deployed at known locations.[121]

Non-GPS geolocation technologies may not always meet the ±50 meter requirement, but still can accomplish the interference-protection goal effectively. For example, while Wi-Fi-based positioning—which relies on a map of access points at known locations to derive a device's location—is likely to be extremely accurate in urban environments, even if it may not be able to meet the 50-meter rule where population density is lower.

The answer to these technical issues is not to expand separation distances to account for technologies with lesser location confidence.[122] This would be highly inefficient. The answer, instead, lies in the role device location plays in the white space context. Unlike the E911 context, where the goal is to determine where a device *is*, the purpose of a location requirement in the white space rules is to determine that the device *is not* in a restricted location. To protect incumbent operations from harmful interference, the device may not operate on certain frequencies in certain areas. To reflect this fundamental difference, the Commission's rules should accommodate a range of geolocation approaches, provided that the approach can ensure that white space devices stay out of exclusion zones and thereby protect incumbents.[123]

Specifically, the Commission should allow white space databases to determine the appropriate protection distance for a device based on the relative certainty with which the device reports its location. If a device reports its location within ±50 meters, the database would calculate available frequencies just as it does under the existing rules. But if a device is able to

[121] *Id.* at 6-7.

[122] *See id.*

[123] *See* NPRM ¶ 77.

achieve location accuracy of only ±250 meters, the database could, for that device, add 200 meters to the edge of incumbents' protected contours to account for the additional uncertainty.[124] Conversely, if a device's location can be determined within ±25 meters, then it should be able to operate closer to a protected entity. Users would have to stay farther away from the incumbent if they use a device with less precise geolocation capability, but the incumbent would nonetheless receive exactly the same level of protection.

This framework will provide manufacturers with an incentive to improve geolocation technologies: As location technologies improve, devices will be able to take advantage of additional spectrum, and superior location accuracy will make a device more capable and desirable in the marketplace. Geolocation innovations in the white space market thus could complement location-accuracy efforts in other fields such as emergency response.

Many portable devices already have the ability to determine and report location accuracy. For example, an API used in the Android operating system includes a function that returns in meters the estimated accuracy of the device's location.[125] Once the device reports the location-accuracy level to a white space database, accommodating accuracy values different than the default 50-meter value is simply a matter of arithmetic, as described above.

Finally, the Commission should make a simple, but important, change to its location re-check requirement for Mode II personal/portable devices, which mandate that every Mode II device "*use its geo-location capability* to check its location at least once every 60 seconds while

[124] *See id.* ¶ 77 n.110 (describing the required increase in separation distance if the Commission changed the allowable location accuracy to ±250 meters).

[125] *See* Public Class Location, Android Developers, http://developer.android.com/reference/android/location/Location.html#getAccuracy() (last visited Feb. 3, 2015).

in operation" in order to determine whether it has moved more than 100 meters and, therefore, must contact a white space database.[126] Many smartphones, tablets, and other devices include accelerometers, gyroscopes, and other motion-sensing technologies that can enable the device to determine with a great deal of precision whether it has moved at all. If a Mode II device can verify that it has not moved, there is no need for it to activate its GPS radio—or other location determination technology—every 60 seconds, particularly since doing so can substantially impact device performance, including battery life. Thus, the Commission should clarify that Mode II devices can meet their obligation to determine that they have not moved more than 100 meters every 60 seconds by using technologies other than those that rely on absolute location determination.

C. The Commission Should Enable More Efficient White Space Use by Adopting Several Proposed Technical Rule Changes.

The Commission has proposed several other sensible adjustments to its technical rules for white space devices.[127] The Commission should adopt these proposals, which, entirely aside from the general reconfiguration of 600 MHz spectrum, will increase access to vacant television spectrum and provide additional flexibility for white space operations while providing sufficient protection to incumbents.

1. Fixed White Space Device Operations on Adjacent Channels.

Google agrees that, in light of experience, the Commission should remove the restriction on fixed device operations using spectrum in channels that are adjacent to occupied television

[126] *See* 47 C.F.R. §§ 15.711(b)(2) & (3)(ii) (emphasis added).

[127] *See* NPRM ¶¶ 33-43.

stations.[128] The existing rules permit personal/portable devices to operate on adjacent channels at 40 mW, and there is no technical reason for excluding fixed devices from operating using at least the same—if not higher—power levels.

As the Commission has recognized, "[s]everal studies have tested the use of white space devices operating adjacent to television channels, and report no instances of interference to broadcast reception."[129] These studies have involved transmit powers at far higher than 40 mW.[130] For example, a trial in Cape Town, South Africa, involved deployments of white space access points at 4 W EIRP where the broadcasters occupied the immediately adjacent channel on each side, without causing harmful interference.[131] Thus, Google agrees with the Commission's assessment that enabling 4 W fixed operations that straddle two contiguous vacant channels—thereby creating 3 MHz of spectral separation from the adjacent broadcasters that was not present in the adjacent-channel studies—"will not increase the potential of interference to television reception."[132] The Commission should adopt these proposed rules for fixed operations, and also use them as a starting point for creating rules that will enable fixed access points to use transmit powers above 40 mW even when directly adjacent to occupied television stations, as was the case in the Cape Town deployments.

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[128] *Id.* ¶ 35.

[129] *Id.* ¶ 37 n.59.

[130] *See id.*

[131] *See* James Carlson, Ntsibane Ntlatlapa, et al., *Studies on the Use of Television White Spaces in South Africa: Recommendations and Learnings from the Cape Town Television White Spaces Trial*, at 38-39, *available at* http://www.tenet.ac.za/tvws/recommendations-and-learnings-from-the-cape-town-tv-white-spaces-trial.

[132] NPRM ¶ 37 (internal citation omitted).

2. White Space Device Operations at Intermediate Power Levels.

Google supports the Commission's proposal to update the table of separation distances in section 15.712(a)(2) to take into account a fixed device's ability to transmit at power levels between 100 mW and 4 W EIRP,[133] and to adjust the adjacent channel emissions limits for fixed devices to reflect when devices transmit at less than 4 W EIRP.[134] White space databases can easily determine the required separation distances for each intermediate power level and provide fixed devices with the maximum transmit power for vacant channels that is available at their location.[135] Alternatively, as the Commission has recognized, a fixed white space device could provide its location and desired transmit power to the database, which would then provide a list of available channels meeting those criteria.[136] The Commission's rules should be flexible enough to accommodate either approach.

3. OOBE Limits and Channel Bonding.

The Commission also should adopt the NPRM's proposal to enable more efficient operations when white space devices use more than one contiguous vacant channel simultaneously.[137] As the Commission has recognized, both the existing rules and the IEEE 802.11af standard enable white space devices to access more than one channel at the same time.[138] When those channels are contiguous, there is no need for the white space device to

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[133] *See id.* ¶¶ 40-43.

[134] *Id.* ¶ 58.

[135] Lee Declaration, ¶ 9.

[136] *Id.* ¶ 43.

[137] *Id.* ¶¶ 54-57.

[138] *Id.* ¶ 55.

comply with the single channel OOBE limits within the bonded channel, since there is no incumbent licensee present in that spectrum. Rather, as the Commission has proposed, its OOBE limits should apply only at the top and bottom of the bonded channel.[139] Similarly, the white space OOBE limits should not apply in cases where a fixed device would straddle two contiguous vacant television channels.[140] No significant database changes would be required to accommodate these changes, since white space databases already support the specification of contiguous adjacent channels.[141]

4. Operation in Rural Areas.

Finally, Google supports enabling more flexible device operations in rural areas and other parts of the country where there are numerous vacant television channels.[142] These changes could include raising the maximum permissible antenna height, which would enable fixed white space devices to transmit above trees, hills, and other obstacles that otherwise would attenuate the signal transmitted by the white space device.[143] Similarly, the Commission should increase the transmit power limit for both fixed and personal/portable devices in rural areas.[144] As the Commission recognizes, doing so would enable rural operators to provide services more efficiently and with less infrastructure, and could also enable additional applications—such as vehicle tracking—that are not currently feasible under the existing rules.[145]

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[139] *Id.* ¶ 56.

[140] *Id*.

[141] Lee Declaration, ¶ 17.

[142] *See id*. ¶¶ 44-53.

[143] *Id.* ¶ 46.

[144] *See id.* ¶¶ 48-53.

[145] *See id.* ¶¶ 48, 52.

D. Breaking News Situations Can Be Accommodated by Creating Two "Fast-Polling" Channels for Wireless Microphones.

The NPRM seeks comment on whether rules requiring more frequent database checks are necessary to support wireless microphone use during breaking news events.[146] Google supports such a change in principle, but the Commission's specific proposal to require white space devices to re-check a database every 20 minutes, regardless of what channels they are using,[147] goes farther than necessary to protect microphone use in breaking news situations, and unnecessarily would impede consumer use of wireless broadband services. The Commission can provide room for time-sensitive microphone uses with less harm to consumers by identifying two "fast-polling" channels on which white space devices must query a database every 20 minutes, but permit white space devices operating on other channels to continue querying a database once per day.

Requiring white space devices always to check a database every 20 minutes, instead of once per day, represents a 72-fold increase in the number of queries executed.[148] Increasing the volume of white space database queries increases the costs of operating a database, because each individual query consumes network capacity, server memory, processing capacity, and other resources.[149] White space database operational costs increase nearly linearly with additional increases in query volume.[150] Thus, the Commission's proposed 72-fold increase in the white

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[146] *Id.* ¶ 190.

[147] *Id.*

[148] Lee Declaration, ¶ 12.

[149] *See id.* ¶ 13.

[150] *Id.*

space database recheck frequency would increase the cost of administering an established a database by approximately the same 72 times.[151]

Google and other white space database administrators recapture their expenses through fees charged to device manufacturers and fixed device registrants.[152] Most white space database administrators strive to minimize this fee in order to stimulate development of the white space device ecosystem. But, in the long run, a 72-fold increase in database administration expenses will necessarily drive a corresponding fee increase. This increased fee would be passed along to consumers in the form of higher prices for buying or using their devices.

The Commission's proposal would also shorten the battery life of portable white space devices.[153] Polling a white space database every 20 minutes would require a device to activate its radio frequently to query the database when it would otherwise be deactivated to save power.[154] Impaired battery life would further diminish the value of white space devices to consumers and, accordingly, the utility of the white spaces as a whole.

The Commission should avoid these outcomes by identifying specific white space channels for fast-polling, electronic newsgathering.[155] Broadcasters and others using licensed wireless microphones for breaking news events in situations where it is infeasible to register a location in the database 24 hours in advance would be able to register on a fast-polling channel, and white space devices would clear that channel within 30 minutes, as the Commission has

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[151] *See id.*

[152] *See* 47 C.F.R. § 15.714.

[153] Lee Declaration, ¶ 14.

[154] *Id*.

[155] *Id*. ¶ 15.

proposed.[156] Those with more typical needs, for whom there is no inherent need to clear a channel on 30 minutes' notice, could continue to use any channel where the rules permit wireless microphones.[157]

Under this approach, a white space device would need to accelerate its database queries only when it operates on a fast-polling channel. A white space device could intelligently choose whether to operate on one of those known channels based upon spectrum availability, bandwidth demands, and other factors. In areas where white space spectrum is plentiful, a device could save power by operating on only "daily polling" channels, subject to the Commission's existing daily polling requirement.[158] In areas where spectrum is especially scarce, the device could operate on a fast-polling channel as necessary to maintain its desired level of performance. In this sense, devices would approach use of fast-polling and non-fast-polling channels in the same way that unlicensed devices access the 5 GHz U-NII sub-bands today.[159] Unlicensed broadband devices use sub-bands for which the Commission's rules do not require dynamic frequency selection (DFS) radar detection much more intensively, but channels subject to DFS requirements are still useful in cases where non-DFS spectrum is unavailable or insufficient.

Google proposes that the Commission designate at most two channels for fast-polling. Currently, these should be the first vacant channels above and below channel 37, which are

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[156] In addition to the 20-minute device check time, the Commission has proposed that database operators share registration information within 10 minutes. *See* NPRM ¶ 190. Thus, the maximum white space device clearing time for a "fast polling" channel would be 30 minutes.

[157] Lee Declaration, ¶ 15.

[158] 47 C.F.R. § 15.711(b)(3)(i)-(ii).

[159] *See generally* 47 C.F.R. Pt. 15 Subpt. E.

reserved for microphone uses.[160] After reconfiguration of the 600 MHz band, the two designations, plus the 4 MHz reservation in the 600 MHz duplex gap, would together provide more spectrum for breaking news coverage than is available under the Commission's existing rules.

To the extent possible, the Commission should make its identification of fast-polling electronic newsgathering channels uniform nationally. Failing that, however, the Commission should adopt a rule that ensures that devices can identify the fast-polling channels through a deterministic algorithm—that is, white space devices and wireless microphones should be able to identify the fast-polling channels on the basis of data already provided by the white space database.

Specifically, the first available white space channel below channel 37 and the first available white space channel above channel 37 could be the fast-polling channels both immediately and after the incentive auction process is complete. Such a rule would benefit wireless microphone users as well as unlicensed operations. First, it would minimize costs and complexity for both white space devices and wireless microphone users in identifying their desired channels of operation. Even if it is not possible for the fast-polling channels to be the same in every market, electronic newsgathering applications would benefit from the ability to secure a vacant channel, on very short notice, in order to respond to fast-breaking events. In addition, because white space devices would tend to avoid the fast-polling channels, unlicensed wireless microphone users would benefit from the availability of two channels with reduced spectral competition from white space devices. The white space ecosystem, meanwhile, would

[160] *See* 47 C.F.R. § 15.707.

benefit from the improved battery life and lower costs that will flow from eliminating unnecessary querying of white space databases.

V. CONCLUSION.

The Commission's success in enabling Wi-Fi, Bluetooth, and other unlicensed technologies is putting tremendous pressure on existing unlicensed spectrum. The Commission is working to permit unlicensed operations in higher-frequency bands, such as the 3.55 GHz and 5 GHz bands. But apart from the 600 MHz band, no other low-frequency spectrum is on the table, even though the Commission has recognized in this very proceeding that access to low-frequency spectrum is critical to the successful provision of wireless broadband services. If the incentive auction proceeding does not permit commercially and technically feasible unlicensed operations in the post-repack broadcast band and the post-auction 600 MHz band, then consumers, businesses, schools, and governments will not have access to adequate low-frequency spectrum resources for the foreseeable future.

Google therefore commends the Commission for deciding to permit unlicensed operations in the duplex gap, guard bands, channel 37, and television white spaces. While this is likely to provide fewer channels for unlicensed devices than was expected when the Commission first allowed unlicensed devices to operate in the television broadcast bands, it will allow industry to plan on having access to at least three unlicensed channels in every market in the country—a bare minimum for supporting development of a 600 MHz unlicensed ecosystem.

An equally important step, which should not wait for completion of the incentive auction proceeding, is modernizing the technical rules for the devices that will use these frequencies. These rules must protect licensees from harmful interference in real-world conditions, rather than hypothetical conditions that will never arise in practice. As the Commission knows well,

technical rules that overprotect licensees will make unlicensed operations impractical. Years of work to permit and develop white space devices will have been wasted, and valuable spectrum will lay fallow. Google therefore supports the majority of the well-reasoned technical-rule proposals in this NPRM, with the further improvements detailed in these comments.

Respectfully submitted,

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February 4, 2015

APPENDIX A

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

In the Matter of	
Amendment of Part 15 of the Commission's Rules for Unlicensed Operations in the Television Bands, Repurposed 600 MHz Band, 600 MHz Guard Bands and Duplex Gap, and Channel 37, and	ET Docket No. 14-165
Amendment of Part 74 of the Commission's Rules for Low Power Auxiliary Stations in the Repurposed 600 MHz Band and 600 MHz Duplex Gap	
Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions	GN Docket No. 12-268

DECLARATION OF DONALD BRESLIN

1. My name is Donald Breslin. I am a wireless systems engineer at Google Inc. (Google). Before joining Google, I was a principal systems engineer at Qualcomm Atheros. At Qualcomm Atheros, I spent 10 years managing systems integration teams within the Wi-Fi hardware development group covering both mobile and access point platforms, and developed deep experience with Wi-Fi technologies. Before joining Qualcomm Atheros, I worked at Arraycomm managing wireless systems teams for macro-cellular data products. I also gained experience in propagation measurements and modeling at Bell Communications Research and in

the Mobile and Portable Radio Research group at the Virginia Polytechnic Institute and State University. I hold four patents, and my work has been published in the IEEE International Solid-State Circuits Conference proceedings, as well as in Bell Communications Research Reports. I received an M.S. and a B.A. in electrical engineering from Virginia Polytechnic Institute and State University.

2. I have reviewed the Notice of Proposed Rulemaking (NPRM) in the above-captioned proceedings, including the Commission's proposals to permit white space devices to operate in channel 37 while protecting incumbent wireless medical telemetry services (WMTS). I have also reviewed the declaration of my colleague Andy Lee, which appears as Appendix B to Google's Comments.

3. The Commission's methodology establishing separation distances between white space devices and WMTS sites relies on the FCC/OET TM 91-1 propagation model.[1] While this model represents a reasonable starting point for determining separation distances, the Commission's implementation of the model does not account for the building loss of the exterior wall of the hospital with the WMTS system.

4. The FCC/OET TM 91-1 study provides a model for building penetration for typical suburban homes given as

$$B = -5.75 + 4.5 \log(F)$$

[1] *See In the Matter of Amendment of Part 15 of the Commission's Rules for Unlicensed Operations in the Television Bands, Repurposed 600 MHz Band, 600 MHz Guard Bands and Duplex Gap, and Channel 37*, Notice of Proposed Rulemaking, 29 FCC Rcd. 12,248, ¶ 64 (2014) (citing William Daniel and Harry Wong, *Propagation in Suburban Areas at Distances Less than Ten Miles*, FCC/OET TM 91-1 (Jan. 25, 1991), *available at* transition.fcc.gov/oet/info/documents/technical/tm91-1.pdf (FCC/OET TM 91-1)).

where B is the building penetration loss in dB for a given frequency F in MHz.[2] The equation above from FCC/OET TM 91-1 indicates building penetration loss of approximately 7 dB for a typical suburban home for the TV band.[3] However, in calculating separation distances for WMTS protection, the Commission omitted building loss.

5. A broader literature survey of wireless propagation measurement study shows generally higher building penetration losses for commercial buildings as compared to suburban homes. In a 1983 study, Don Cox, who is cited with authority in the FCC/OET TM 91-1 analysis, sets forth building penetration losses for a wooden home and more metallic structures, such as commercial buildings and hospitals.[4] Cox reported wooden home penetration loss of 7 dB.[5] By contrast, he found penetration losses of 12 dB to 27 dB for buildings with aluminum siding and metal sheeting respectively.[6] In a similar configuration of transmit and receive antenna heights as referenced in the Cox study mentioned in FCC/OET TM 91-1, the building penetration of commercial buildings in Liverpool, England, was measured to be 16 dB at 440 MHz and 12 dB at 900 MHz.[7] Finally, representative building penetration measured across 3

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[2] FCC/OET TM 91-1 at 6.

[3] *See id.*

[4] D. C. Cox, R. R. Murray, et al., *Measurements of 800-MHz Radio Transmission Into Buildings With Metallic Walls*, 62 BELL SYS. TECH. J. 2695, 2704 (1983), *available at* http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6770712&tag=1.

[5] *Id.*

[6] *Id.*

[7] A. M. D. Turkmani, J. D. Parsons, et al., *Measurement of Building Penetration Loss on Radio Signals at 441, 900 and 1400 MHz*, 58 J. OF THE INST. OF ELEC. AND RADIO ENGINEERS S169, S172 (1988), *available at* http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=5261594.

downtown Chicago commercial buildings was found to range between 18 dB and 13 dB across 10 commercial buildings in the suburbs surrounding Chicago.[8]

6. On our campus in Mountain View, California, Google conducted tests of exterior wall loss for commercial office buildings that are representative of hospital construction materials. At a similar frequency band, our measurements of exterior wall building penetration loss ranged from 13 dB to 20 dB as shown in the table below.

Typical Commercial/Industrial Building Materials	**Wall Loss (dB)**
Concrete Wall with Standard Windows	~ 13
Tinted Glass Wall	~ 15
Full Concrete Wall	~ 20

7. Given that the Commission's analysis did not account for any building penetration loss associated with the external walls of hospitals, the separation distances proposed in the NPRM are overly conservative. To address this issue, Google proposes that the Commission adjust its model to recognize 10 dB of loss associated with building penetration. This is a conservative assumption of additional isolation for a white space device operating in the vicinity of a hospital.

8. Adjusting the Commission's propagation model to account for 10 dB of loss from the exterior wall of the hospital reduces the Commission's proposed separation distance for a 4 W device operating at a height of 3 meters from 1 kilometer, as proposed in the NPRM, to 600

[8] E. H. Walker, *Penetration of Radio Signals into Buildings in the Cellular Radio Environment*, 62 BELL SYS. TECH. J. 2719, 2728 (1983), *available at* http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6770713.

meters. At lower power, a 40 mW device operating at a height of 3 meters could operate 200 meters away from a hospital, as opposed to 300 meters. A revised separation distance table that takes into account 10 dB building penetration loss is provided below.

Antenna height of unlicensed device	**Co-channel separation distances: NPRM values with 10 dB additional loss (km)**					
	16 dBm (40 mW)	**20 dBm (100 mW)**	**24 dBm (250 mW)**	**28 dBm (625 mW)**	**32 dBm (1600 mW)**	**36 dBm (4 W)**
Less than 3 m	0.2	0.2	0.3	0.4	0.5	0.6
3 m to 10 m	0.4	0.4	0.6	0.7	0.9	1.1
10 m to 30 m	0.6	0.8	1.0	1.2	1.5	1.9
30 m to 50 m	0.8	1.0	1.2	1.6	2.0	2.5
50 m to 75 m	1.0	1.2	1.5	1.9	2.4	3.0
75 m to 100 m	1.1	1.4	1.8	2.2	2.8	3.5
100 m to 150 m	1.4	1.7	2.2	2.7	3.4	4.3
150 m to 200 m	1.6	2.0	2.5	3.1	3.9	5.0
200 m to 250 m	1.8	2.2	2.8	3.5	4.4	5.6

9. In addition, FCC/OET TM 91-1 relies heavily on path loss measurements in suburban conditions to calculate the path loss formula.[9] It singles out the findings in a propagation study by Don Cox published in the AT&T Bell Laboratories Technical Journal titled "*800-MHz Attenuation Measured In and Around Suburban Houses*," as a hallmark around which to build the FCC/OET TM 91-1 model.[10] This Cox propagation study, however, is based on empirical measurements in a number of single-family home neighborhoods and, as a result, fails

[9] *See generally* FCC/OET TM 91-1.

[10] *Id.* at 5.

to account for the more substantial commercial building shadowing from nearby buildings that is representative of suburban commercial districts and urban city centers, where the greatest density of white space users is expected.

10. To properly account for additional building shadowing in the environment between a white space device and a WMTS system, an additional shadowing loss factor should be used. The shortest co-channel separation distances proposed by the Commission are hundreds of meters. As this distance translates to at least one city block in suburban commercial districts and urban city centers, it is safe to assume that at least one additional commercial building wall will be intervening between the hospital and the nearest white space device. Because the effects of building shadowing can be significant, Google proposes that the Commission allow parties to develop polygon-shaped protection contours that take into account line-of-sight information.[11] Under this approach, WMTS sites and database operators would collaborate to draw perimeters around WMTS sites and adjust those perimeters to account for line-of-sight condition in the vicinity of the sites. If the Commission pursues this approach, it should further reduce the separation distances required to reflect an additional 10 dB loss factor. This additional 10 dB of loss represents the effects of building shadowing immediately outside the adjusted perimeter. The resulting table of separation distances, which assumes 10 dB loss for the hospital exterior wall and an additional 10 dB loss for at least one wall of building shadowing from neighboring buildings, is provided below.

[11] *See* Declaration of Andy Lee, Appendix B, ¶¶ 4-9.

Antenna height of unlicensed device	**Co-channel separation distances: NPRM values with 20 dB additional loss (km)**					
	16 dBm (40 mW)	**20 dBm (100 mW)**	**24 dBm (250 mW)**	**28 dBm (625 mW)**	**32 dBm (1600 mW)**	**36 dBm (4 W)**
Less than 3 m	0.1	0.1	0.2	0.2	0.3	0.3
3m to 10 m	0.2	0.2	0.3	0.4	0.5	0.6
10 m to 30 m	0.3	0.4	0.5	0.7	0.9	1.1
30 m to 50 m	0.4	0.6	0.7	0.9	1.1	1.4
50 m to 75 m	0.5	0.7	0.9	1.1	1.4	1.7
75 m to 100 m	0.6	0.8	1.0	1.2	1.6	2.0
100 m to 150 m	0.8	1.0	1.2	1.5	1.9	2.4
150 m to 200 m	0.9	1.1	1.4	1.8	2.2	2.8
200 m to 250 m	1.0	1.2	1.6	2.0	2.5	3.1

I, Donald Breslin, declare under penalty of perjury under the laws of the United States that the foregoing declaration is true and correct. Executed on February 4, 2015.

Donald Breslin

APPENDIX B

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

In the Matter of	
Amendment of Part 15 of the Commission's Rules for Unlicensed Operations in the Television Bands, Repurposed 600 MHz Band, 600 MHz Guard Bands and Duplex Gap, and Channel 37, and	ET Docket No. 14-165
Amendment of Part 74 of the Commission's Rules for Low Power Auxiliary Stations in the Repurposed 600 MHz Band and 600 MHz Duplex Gap	
Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions	GN Docket No. 12-268

DECLARATION OF ANDY LEE

1. My name is Andy Lee. I am the technical lead for the Spectrum Database program at Google Inc. (Google). Before joining Google, I founded TV Fool LLC (TV Fool), an industry-leading website providing spectrum analysis tools and other resources for analyzing the strength and availability of over-the-air broadcast transmissions. Prior to TV Fool, I worked for several years on wireless issues for the digital television, cellular, GPS, consumer electronics, and aerospace industries. I have a B.S. degree in electrical engineering from the University of California, Los Angeles, and a M.S. degree in Computer Engineering from the University of Southern California.

2. I have reviewed the Notice of Proposed Rulemaking (NPRM) in the above-captioned proceedings, including the Commission's proposals to (1) permit white space devices to operate in channel 37 while protecting incumbent wireless medical telemetry services (WMTS) and radio astronomy services (RAS) from harmful interference, and (2) increase the frequency with which white space devices must communicate with a database.[1] I have also reviewed the declarations of my colleagues Donald Breslin and Andrew W. Clegg, which appear as Appendices A and C to Google's Comments.

Protection Zones for WMTS Facilities

3. Section III.B.4 of the NPRM proposes to permit white space devices to operate on channel 37. It also proposes to avoid harmful interference to WMTS—which also uses channel 37—by requiring a minimum separation distance between white space devices and WMTS systems.

4. The Commission's goal, as I understand it, is to free channel 37 for commercial use to the greatest extent possible, consistent with protection of incumbents. This goal can be achieved more effectively and efficiently by obtaining perimeter information for each WMTS site, adjusting those perimeters to take into account line-of-sight information, and then calculating appropriate separation distances from those perimeters (which would be much smaller than the ones proposed by the Commission in its NPRM). I outline our proposed approach and explain its feasibility in further detail below.

[1] *See In the Matter of Amendment of Part 15 of the Commission's Rules for Unlicensed Operations in the Television Bands, Repurposed 600 MHz Band, 600 MHz Guard Bands and Duplex Gap, and Channel 37*, Notice of Proposed Rulemaking, 29 FCC Rcd. 12,248 (2014) (NPRM).

5. First, in order to protect devices throughout the footprint of a site, WMTS providers could register the perimeters of their sites either with the American Society for Health Care Engineering (ASHE) database (www.ashe.org/resources/WMTS/registeredhospitals.html) or with one of the Commission's approved database providers. Submitting WMTS site perimeters will require a small amount of work on the part of WMTS site operators. Ready availability of tools, such as Google Earth (www.google.com/earth/), however, will minimize this burden. To test the time required for this action, I used Google Earth to perform the steps that a WMTS site operator would undertake to add site information to a database. Each perimeter was represented by a polygonal shape that tracks the outline of the WMTS site's overall footprint. Based on this experience, I estimate that once a user is familiar with the process, entering a single WMTS site perimeter should take no more than approximately 10-20 minutes. The database maintained by the ASHE contains location information on approximately 2,740 WMTS sites.[2] Accordingly, the total amount of time needed to implement the perimeter approach for all existing facilities in the United States would be less than 1,000 person-hours for the entire hospital industry.

6. Second, parties could collaborate to adjust those perimeters based on line-of-sight information where that information is available. For example, the actual perimeter of a WMTS site would be adjusted outward if a hospital faced an open field, but would track the building closely if there were obstructions—such as tall buildings—in the immediate vicinity of the site. Tools such as Google Earth can assist in determining a shape that reflects both obstructions and open areas. Google is willing and able to work with WMTS operators to establish these adjusted

[2] According to ASHE, there were 2,739 unique locations using channel 37 devices as of March 2012. *See In the Matter of Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions*, Notice of Proposed Rulemaking, 27 FCC Rcd. 12,357, 12,430 ¶ 210 (2012).

perimeters, and this work could easily be accomplished for all relevant WMTS sites registered in the current WMTS database before the end of the 39-month implementation period for 600 MHz band wireless operations.[3]

7. Parties could add WMTS site information—stored as polygons as discussed above—to a white space database directly, for instance by using the Google Spectrum Database site (www.google.com/get/spectrumdatabase/). Alternatively, the WMTS database currently operated by ASHE could be upgraded to contain both the perimeter and adjusted perimeter information, and automatically synchronize with white space databases. Under either approach, including information about the polygonal representations of WMTS system perimeters in white space databases would have little, if any, impact on the operating costs of the databases.

8. Third, white space databases would apply separation distances to these revised perimeters. Because the expanded perimeters will already take into account the line-of-sight information that has a substantial effect on propagation and because representing WMTS sites as shapes will be larger and therefore inherently more protective than representing them as individual points, the separation distances proposed in the NPRM can and should be reduced markedly. A detailed analysis of these revised separation distances is set forth in the Declaration of Donald Breslin.[4]

9. This approach is easily supported by white space database operators. Databases already synchronize information regarding protected entities such as wireless microphones. Databases also routinely use polygons when calculating the necessary separation distances from television broadcasters and wireless microphone venues. Broadcasters' footprints are stored as

[3] See *In the Matter of Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions*, Report and Order, 29 FCC Rcd 6567, ¶ 11 (2014).

[4] Declaration of Donald Breslin, Appendix A, ¶ 10.

360-sided polygons around each transmitter. On Google's protected entity registration site, wireless microphone operators can register for protection by entering a polygon based on points identified by longitude and latitude.[5] White space databases can similarly store adjusted WMTS site perimeters as polygons and enforce the necessary separation distances from these polygons.

Protection Zones for RAS Facilities

10. With respect to RAS, the Declaration of Andrew W. Clegg, Ph.D., demonstrates that protection zones for the ten Very Long Baseline Array (VLBA) sites that operate in channel 37 should take into account terrain effects.[6]

11. The bearing-dependent exclusion distances that Mr. Clegg proposes are simple to calculate and implement. There are well-established modeling algorithms[7] and readily available implementations of those algorithms[8] that can be used to compute the polygonal exclusion zones for protecting RAS facilities. These exclusion zones only need to be computed once for each RAS facility, and then used by the white space database where and when appropriate. Indeed, implementing these polygonal exclusion zones will be no more complicated than the myriad functions that all white space databases perform today, such as calculating interference protection for polygonally shaped broadcaster footprints and microphone venues.

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[5] *See, e.g.*, Spectrum Database, https://www.google.com/get/spectrumdatabase/registrations/lpal (last visited Feb. 3, 2015).

[6] Declaration of Andrew W. Clegg, Ph.D., Appendix C.

[7] *See* P. L. Rice, A. G. Longley, et. al., TRANSMISSION LOSS PREDICTIONS FOR TROPOSPHERIC COMMUNICATIONS CIRCUITS (1965), *available at* https://ia902600.us.archive.org/22/items/transmissionloss1011rice/transmissionloss1011rice.pdf.

[8] *See, e.g.*, TV Fool, http://www.tvfool.com/, SPLAT! Because the World Isn't Flat, http://www.qsl.net/kd2bd/splat.html, and Radio Mobile Freeware by VE2DBE, http://www.cplus.org/rmw/english1.html.

White Space Device Database Re-Check Interval

12. Paragraph 190 of the NPRM proposes amending Section 15.711(b)(3) of the Commission's rules to mandate that white space devices re-check a database every 20 minutes, rather than at the current interval of 24 hours as provided in 47 C.F.R. § 15.711(b)(3)(i)-(ii). Requiring white space devices always to check a database at this interval, rather than once every 24 hours, represents a 72-fold increase in the number of queries executed against a white space database.

13. Increasing the volume of queries received by a white space database increases the costs of operating the database. This is because each individual query consumes network capacity, server memory, processing capacity, and other resources. As a result, the increase in white space database operational costs will be directly proportional to an increase in query volume. Therefore, I estimate that the Commission's proposed 72-fold increase in the database recheck frequency would increase the cost of administering an established white space database, such as Google's, by approximately the same 72 times.

14. The Commission's proposal would also shorten the battery life of portable white space devices. Polling a white space database every 20 minutes would require a device to activate its radio frequently to query the database and receive a response, when the device otherwise could be inactive to save power. Impaired battery life would further diminish the value of white space devices to consumers and, accordingly, the utility of the white spaces as a whole.

15. The Commission should avoid these outcomes by identifying specific white space channels for fast-polling, electronic newsgathering. Broadcasters and others using licensed wireless microphones for breaking news events in situations where it is infeasible to register a location in the database 24 hours in advance, would be able to register a location on a fast-

polling channel, and, as the Commission has proposed, white space devices would clear that channel within 30 minutes.[9] Those microphones with more typical needs, for whom there is no inherent need to clear a channel on 30 minutes' notice, could continue to use any channel where the rules permit microphone operation. As a result, the default polling interval would be 24 hours, as under the current rules, with an exception for the two fast-polling channels.

Modifications to Existing White Space Rules

16. Google supports the Commission's proposal to update the table of separation distances in section 15.712(a)(2) to take into account a fixed device's ability to transmit at intermediate power levels between 100 mW and 4 W EIRP.[10] White space databases can easily determine the required separation distances for each intermediate power level and provide fixed devices with the maximum transmit power for vacant channels available at their location. The establishment of intermediate power levels merely adds one or more extra sets of separation distances to the database; it does not add significant computational complexity.

17. Google also supports the Commission's proposal to enable more efficient operations when white space devices use more than one contiguous vacant channel simultaneously.[11] Both the existing rules and the IEEE 802.11af standard enable white space devices to access more than one channel at the same time.[12] When those channels are contiguous, there is no need for the white space device to comply with the single channel out-of-band

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[9] In addition to the 20-minute device check time, the Commission has proposed that database operators share registration information within 10 minutes. *See* NPRM ¶ 190. Thus, the maximum white space device clearing time for a "fast polling" channel would be 30 minutes.

[10] *See id.* ¶¶ 40-43.

[11] *Id.* ¶¶ 54-57.

[12] *Id.* ¶ 55.

emissions (OOBE) limits within the bonded channel, since there is no incumbent licensee present in that spectrum. Rather, as the Commission has proposed, its OOBE limits should apply only at the top and bottom of the bonded channel.[13] Similarly, the white space OOBE limits should not apply at the center of the white spaces channel in cases where a fixed device would straddle two contiguous vacant television channels.[14] No significant database changes would be required to accommodate these changes, because white spaces databases already support the specification of contiguous adjacent channels.

I, Andy Lee, declare under penalty of perjury that the foregoing declaration is true and correct. Executed on February 4, 2015.

Andy Lee

[13] *Id.* ¶ 56.

[14] *Id*.

APPENDIX C

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

In the Matter of	
Amendment of Part 15 of the Commission's Rules for Unlicensed Operations in the Television Bands, Repurposed 600 MHz Band, 600 MHz Guard Bands and Duplex Gap, and Channel 37, and	ET Docket No. 14-165
Amendment of Part 74 of the Commission's Rules for Low Power Auxiliary Stations in the Repurposed 600 MHz Band and 600 MHz Duplex Gap	
Expanding the Economic and Innovation Opportunities of Spectrum Through Incentive Auctions	GN Docket No. 12-268

DECLARATION OF ANDREW W. CLEGG, Ph.D.

1. My name is Andrew W. Clegg. I am a spectrum engineering lead for Google Inc. (Google). Before joining Google, I served as electromagnetic spectrum manager at the National Science Foundation. At the National Science Foundation, one of my principal duties was to ensure that radio astronomy observatories did not experience harmful radio frequency interference. In addition, I worked for several years in senior engineering positions at companies that are today part of AT&T Mobility, and at Comsearch, a spectrum management and wireless engineering company. 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 Notice of Proposed Rulemaking (NPRM) in the above-captioned proceedings, including the Commission's proposal to permit white space devices to operate on channel 37.[1] Single-dish radio astronomy telescopes located in Green Bank, West Virginia, and Arecibo, Puerto Rico, also use channel 37, as does the Very Long Baseline Array (VLBA)—ten interferometric telescope sites across the United States ranging from St. Croix, U.S. Virgin Islands, in the east, to Mauna Kea, Hawaii, in the west.

3. I have concluded that the NPRM's proposal substantially overprotects VLBA sites, and therefore unnecessarily restricts white space device operations in areas where they would not cause harmful interference to radio astronomy operations. The NPRM's approach is overprotective because the proposed rigidly uniform, circular protection zones fail to take into account the impact of terrain to mitigate the potential for harmful interference to actual VLBA sites. Further, the proposed protection zones were derived from restrictions that protect radio astronomy operations from harmful interference by Wireless Medical Telemetry Service (WMTS) systems. The NPRM uses the field strength limitations and coordination requirements on WMTS in channel 37 as a baseline, and then calculates protection distances for white space devices by applying seemingly analogous restrictions to white space devices.

4. Rather than rely on a methodology that reverse-engineers protection requirements based on rules established for an unrelated service, the better approach, as discussed below, would be to utilize the established interference-protection criteria for the radio astronomy service

[1] *See In the Matter of Amendment of Part 15 of the Commission's Rules for Unlicensed Operations in the Television Bands, Repurposed 600 MHz Band, 600 MHz Guard Bands and Duplex Gap, and Channel, et al.*, Notice of Proposed Rulemaking, 29 FCC Rcd. 12,248 (2014) (NPRM).

combined with a physics-based and terrain-aware propagation model. This model derives interference separation distances based on sound engineering principles.

5. Finally, time coordination can help maximize use of channel 37 by white space devices while effectively protecting radio astronomy operations.

Protection of VLBA Sites that Accounts for Terrain Blockages

6. I have conducted detailed propagation predictions using the Longley-Rice model[2] in the areas surrounding the ten VLBA sites discussed in the NPRM. The predictions utilize high-quality terrain data so that terrain blockage is taken into account. Using the predictions, I calculated the areas in which emissions from a 4W EIRP white space device, located 30 m above ground level, would exceed the radio astronomy protection criteria and values set forth in ITU-R Recommendation RA.769-2[3] (Rec. 769-2). To comply with Rec. 769-2, a radio astronomy operation must not experience received power above the specified level more than 2% of the time.

7. Each of the calculations assumes that all white space devices are transmitting at full power 100% of the time, and that all devices are located 30 m above ground level with no clutter shielding or building losses. The predictions represent a conservative analysis (*i.e.*, an overestimate) of potential interference to radio astronomy because: (1) the FCC rules require

[2] *See generally* National Telecommunications & Information Administration, Institute for Telecommunication Sciences, Irregular Terrain Model (ITM) (Longley-Rice) (20 MHz-20 GHz) *available at* http://goo.gl/o34t19 (last visited Feb. 3, 2015).

[3] *See generally* ITU-R Recommendation RA.769-2 "Protection Criteria Used for Radio Astronomical Measurements," (May 2003), available at http://www.itu.int/rec/R-REC-RA.769-2-200305-I/en (last visited Feb. 3, 2015).

white space devices to utilize power control[4]; (2) not all devices will be located at such high elevations above ground; (3) many (if not most) white space devices will be located indoors, with additional losses to the outside due to building materials; and (4) clutter, including foliage and other buildings located anywhere along the path from white space devices to the radio astronomy observatories, will further attenuate signals received at the radio astronomy sites.

8. Even with unrealistically high predictions of white space emissions, my analyses demonstrate that the exclusion distance in directions in which substantial terrain blockage exists is much smaller than the blanket radius proposed in the NPRM. For example, Figure 1 below compares the FCC's proposed blanket exclusion zone for 4 W white space devices around the Hancock, New Hampshire, VLBA site to the exclusion areas that would be justified based upon the Longley-Rice predictions. While in some cases the exclusion areas calculated by Longley-Rice along radials where little or no terrain blockage occurs can be quite large (as large as approximately 180 km in Figure 1), along other radials, the necessary exclusion zone is as small as 5 km, due to heavy terrain shielding from mountains and other features. Thus, the FCC's proposed exclusion distance of 314 km is as much as *63 times* greater than the distance needed to protect the radio astronomy site.

[4] 47 C.F.R. §15.709(a)(3).

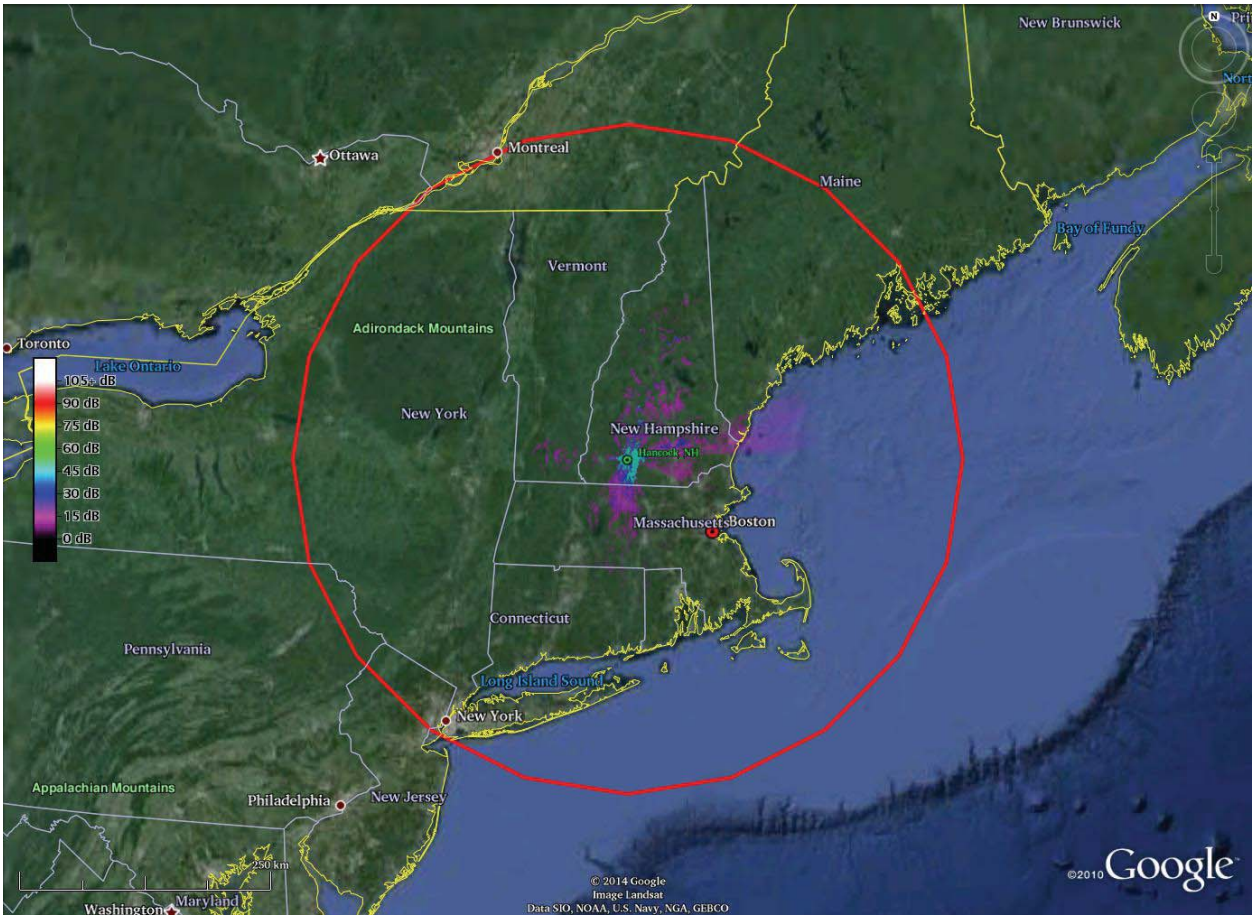

Figure 1: Comparison of 314 km exclusion zone for 4 W white space devices surrounding the Hancock, New Hampshire, VLBA site as proposed in the NPRM (red circle) with exclusion zones calculated with the terrain-aware Longley-Rice prediction model (various shades of blue and purple near the center). The key on the left side of the plot corresponds to the extent to which the colored areas in the Longley-Rice simulation exceed the Rec. 769-2 radio astronomy protection criteria (in dB). Only shaded areas in the Longley-Rice prediction exceed the Rec. 769-2 level; the vast majority of the plot where there is no shading indicates that operation of a 4 W device in those areas would not exceed the Rec. 769-2 criteria. The exclusion area computed with the Longley-Rice model is substantially smaller than the blanket radius proposed in the NPRM, and, due to terrain shielding, major markets such as Boston and New York City are not impacted.

9. Similar plots for all VLBA sites are included in the annex to this declaration. Each plot is reproduced to the same scale; on several, it is difficult even to see the small Longley-Rice-based exclusion zones caused by extreme terrain blockage, emphasizing the substantial overprotection and resulting inefficiency of the FCC's proposed blanket 314 km exclusion radius. These results are no surprise since, as pointed out in the NPRM[5], VLBA sites

[5] NPRM at ¶ 119.

have been chosen precisely because terrain and other factors provide radio astronomy operations at those locations protection from unwanted radio signals.

10. Channel 37 exclusion zones established to protect VLBA radio astronomy operations thus should take into account real-world effects, especially propagation losses due to terrain. Any other approach prevents commercial use of huge amounts of spectrum, with no practical benefit to radio astronomy.

11. White space databases can easily implement such exclusion zones by specifying the exclusion distance around a particular VLBA site as a set of 360 radials, each one degree in angular width. For example, the exclusion distance for white space devices would be established for each bearing, 0-1 degree, 1-2 degrees, 2-3 degrees, etc. All exclusion distances would be based upon the maximum distance over which Rec. 769-2 criteria would be exceeded, based upon the Longley-Rice predictions. The detailed specification of the Longley-Rice radial-based exclusion areas could be subject to discussion and agreement among relevant stakeholders, including the National Academy of Sciences' Committee on Radio Frequencies (CORF), the National Science Foundation, and white space database providers. Such bearing-dependent exclusion distances are simple to implement in computer code.

12. Terrain-aware exclusion zones will resolve many of the potentially crippling restrictions on television white spaces operations in channel 37 that are a consequence of the blanket zones proposed in the NPRM. For example, because substantial terrain blockage exists to the southeast of the VLBA Hancock, New Hampshire, site, and to the west of the VLBA Owens Valley, California, site, the use of accurate terrain-based exclusion zones would no longer constrain white space devices' use of channel 37 in Boston, New York, and the eastern portions of Los Angeles, while still protecting radio astronomy operations from harmful interference.

Time Coordination to Maximize Use of Channel 37

13. Even with terrain-based exclusion zones, radio astronomy-related restrictions could still unnecessarily limit consumer wireless uses in some metropolitan areas at times when there is no possibility that such operations could cause harmful interference to radio astronomy operations. These areas include major markets such as Albuquerque, New Mexico, and Phoenix, Arizona. The Commission can address this issue by directing time-based coordination for the use of channel 37.

14. The NPRM would provide radio astronomy sites the same (grossly excessive) interference protection at all time. But the reality is that radio astronomy observatories utilize channel 37 less than 1% of the time.[6] Absent time coordination, significant regions of the country will be excluded from using white space devices in channel 37 during the 99.5+% of the time that the channel is not being used for radio astronomy.

15. A straightforward entry in one television white space database, notifying all the interconnected databases of radio astronomy use, with as little as two hours advance notice (in the same manner that wireless microphones register now), provides a simple and effective method to allow efficient access to channel 37 for white space devices while insuring protection of radio astronomy observations.

[6] Andrew Clegg, *Spectrum Management and Radio Astronomy: The Future*, presentation at the Scientific Committee on Frequency Allocations for Radio Astronomy and Space Science (IUCAF), Fourth School on Spectrum Management for Radio Astronomy, Santiago, Chile, at 10, (Apr. 2014), *available at* http://goo.gl/8dFc4H (last visited Jan. 14, 2015).

I, Andrew W. Clegg, declare under penalty of perjury that the foregoing declaration is true and correct. Executed on February 4, 2015.

Andrew W. Clegg, Ph.D.

ANNEX

The following plots compare the rudimentary circular 314-km exclusion zones surrounding the Very Long Baseline Array (VLBA) radio astronomy sites (red circles) to exclusion zones calculated from the application of radio astronomy protection criteria (ITU-R Recommendation RA.769-2) and the terrain-based Longley-Rice propagation prediction model. The latter are represented by shaded areas that show the number of dB above which a white space device at that point would exceed the Rec. 769-2 level at the radio astronomy site (color key is on left side of plot) for more than 2% of the time. No shading means the device would be below the Rec. 769-2 level for more than 98% of the time. The white space device in the Longley-Rice simulation is assumed to be located 30 m above ground level and operating at full power 100% of the time, with maximum EIRP in the direction of the radio astronomy site.

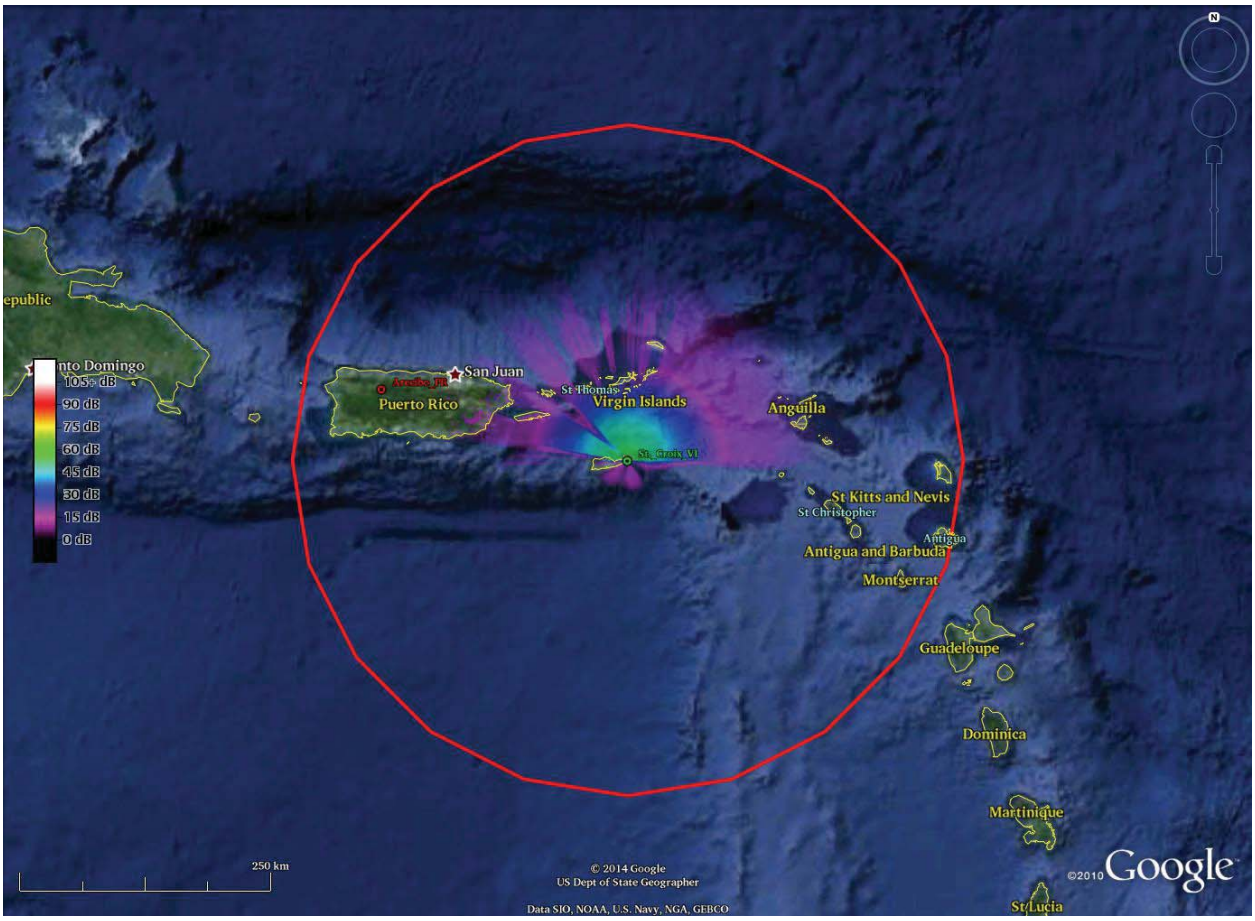

Figure A-1: VLBA St. Croix, U.S. Virgin Islands

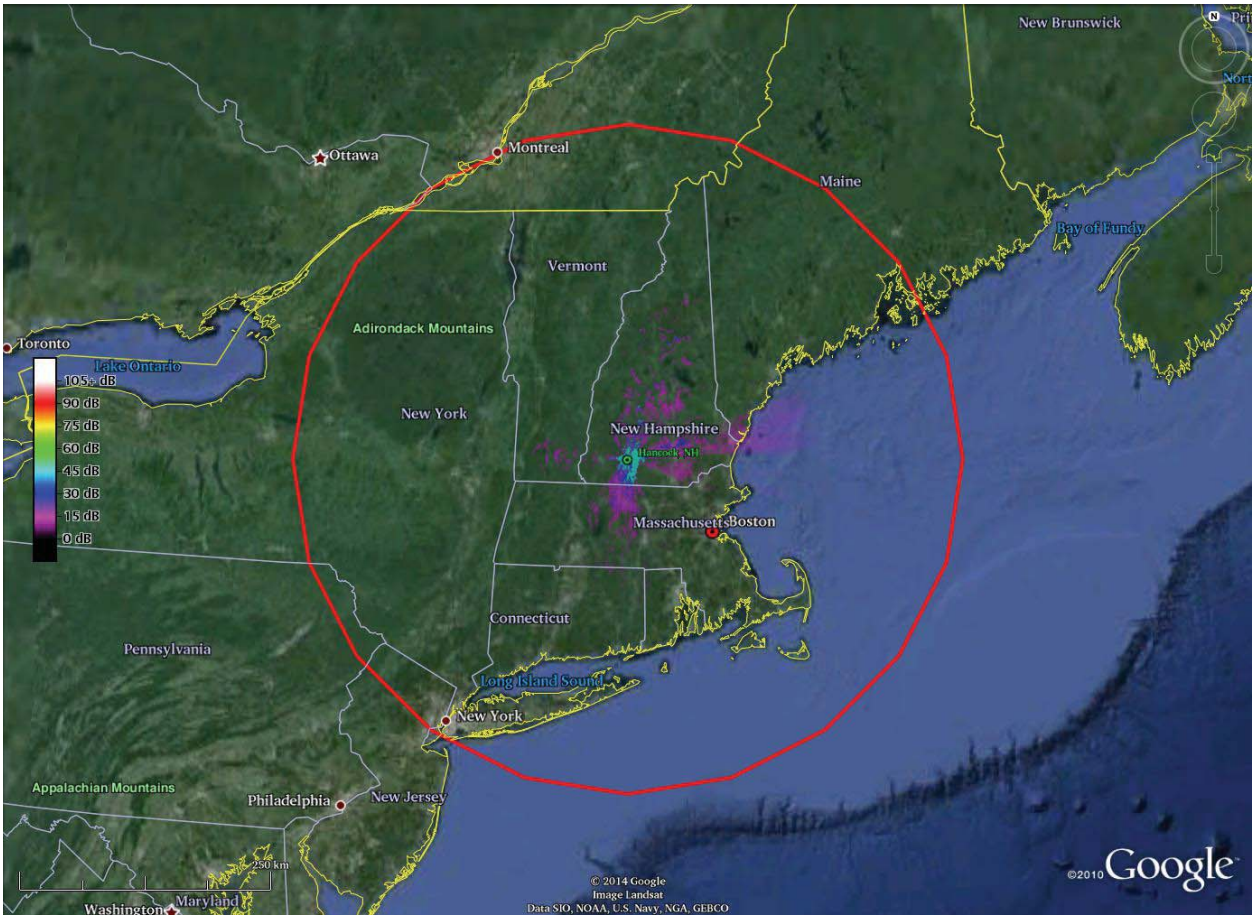

Figure A-2: VLBA Hancock, New Hampshire

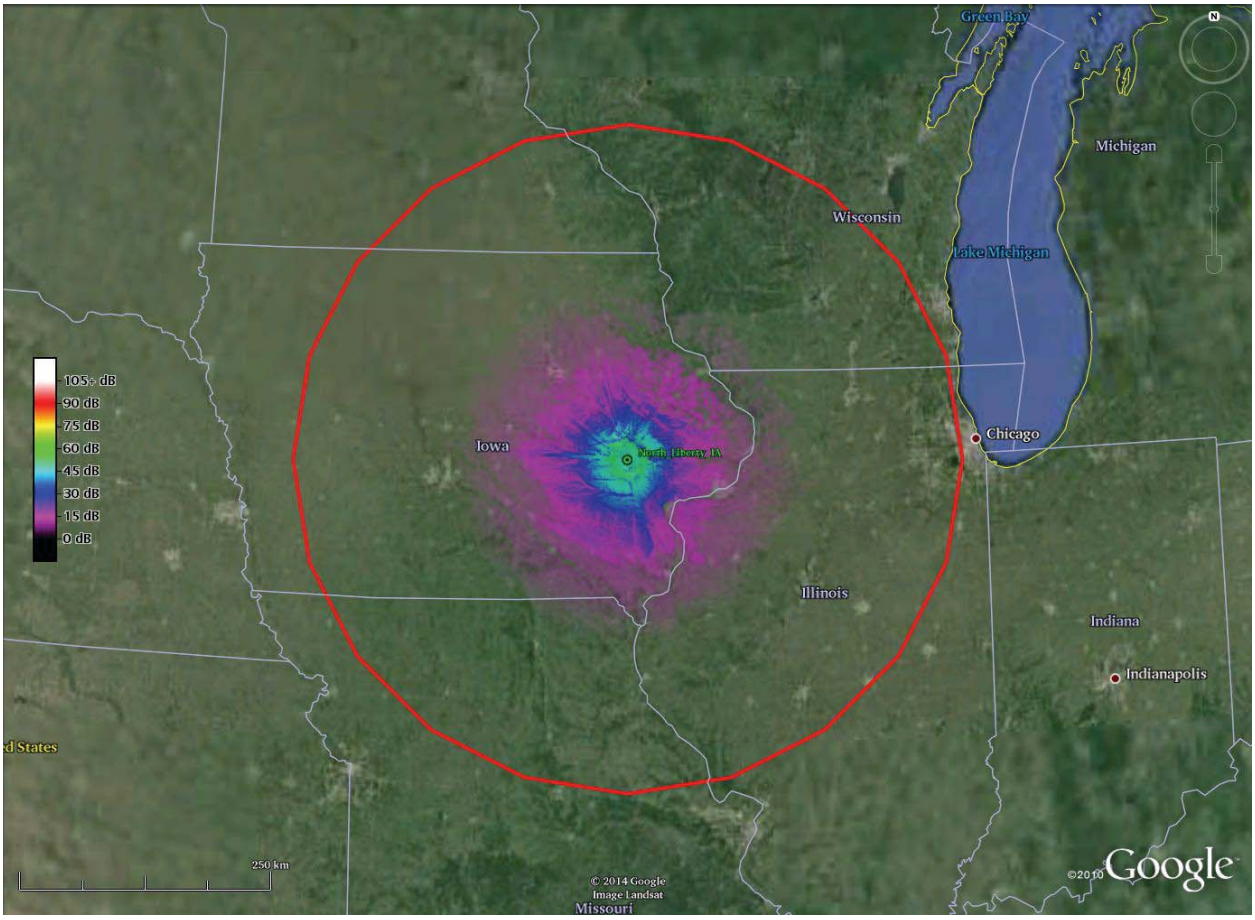

Figure A-3: VLBA North Liberty, Iowa

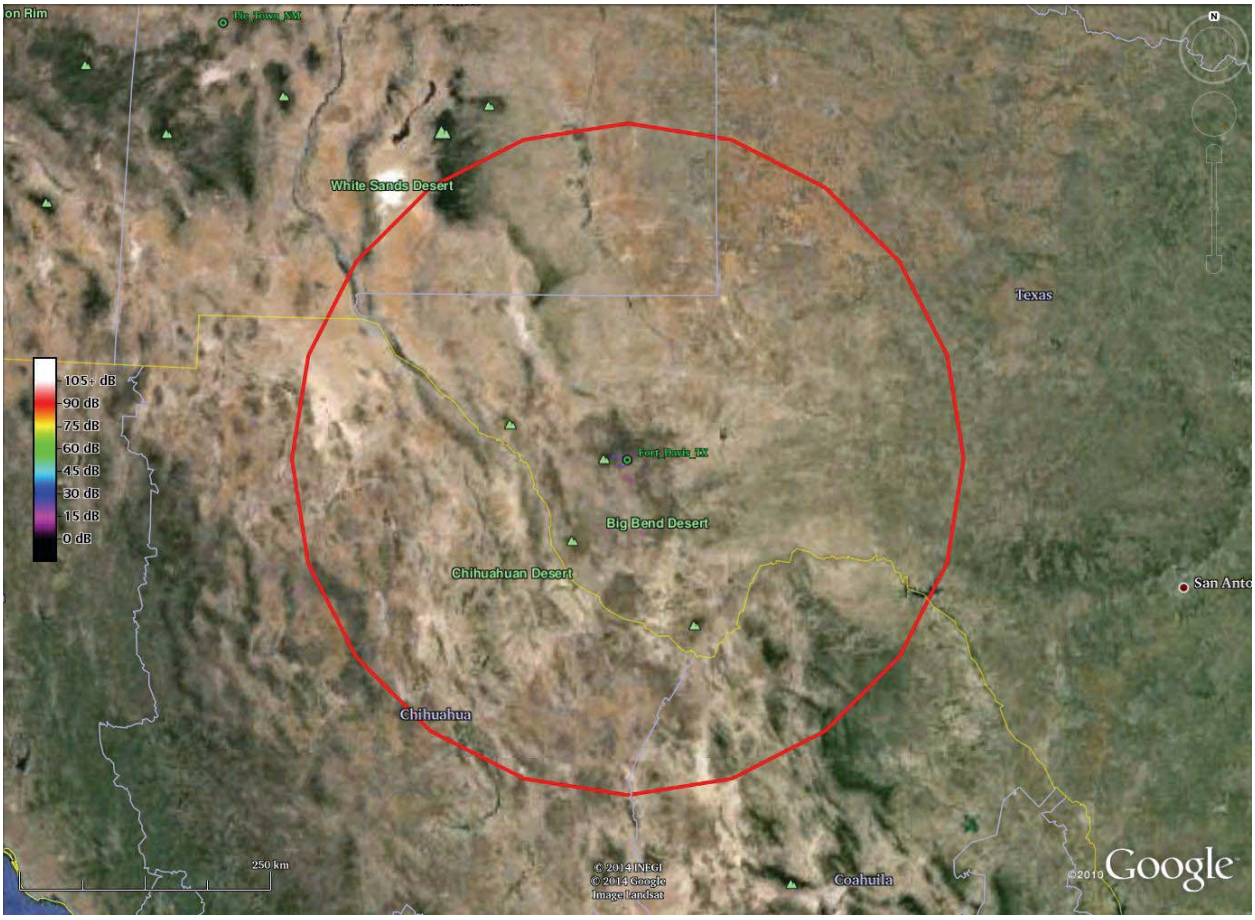

Figure A-4: VLBA Fort Davis, Texas

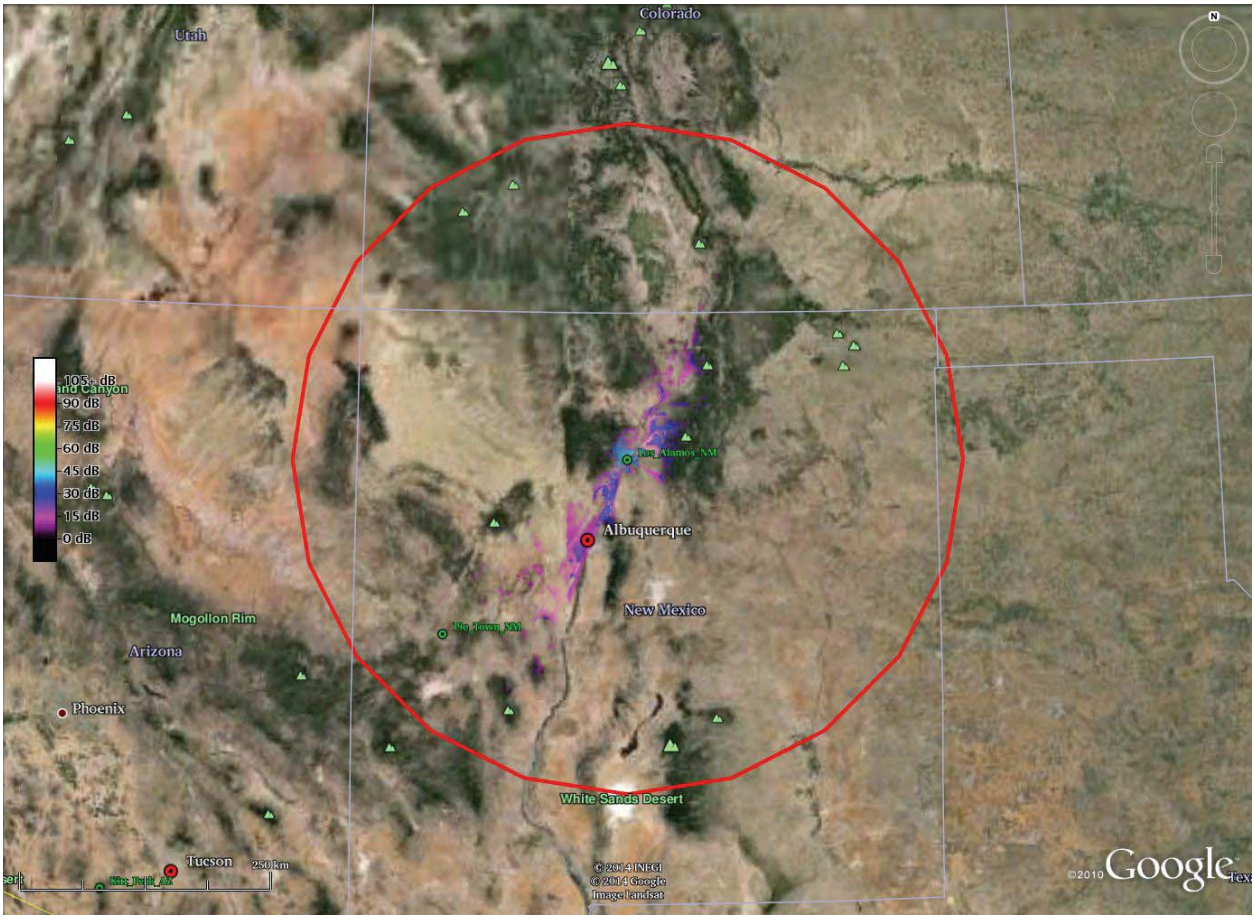

Figure A-5: VLBA Los Alamos, New Mexico

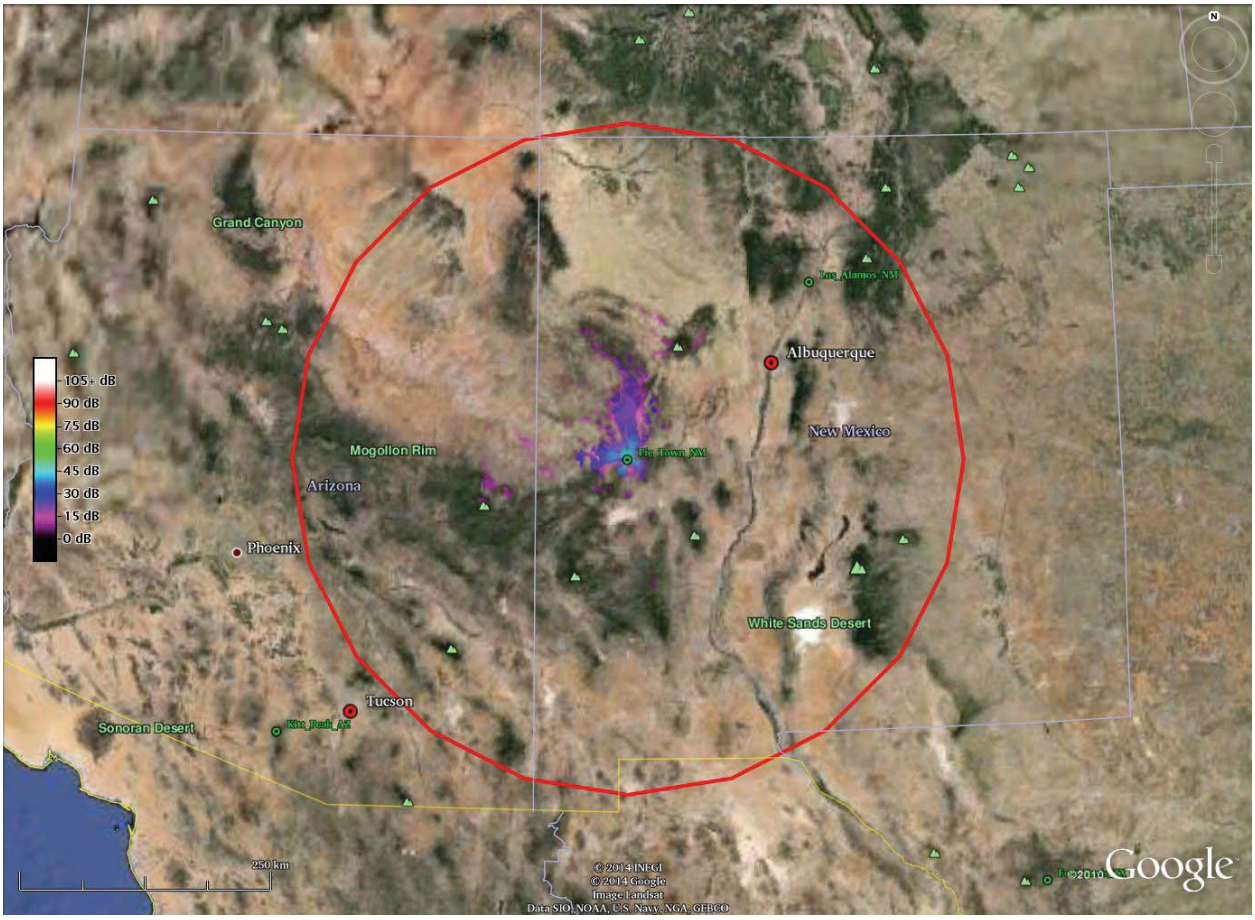

Figure A-6: VLBA Pie Town, New Mexico

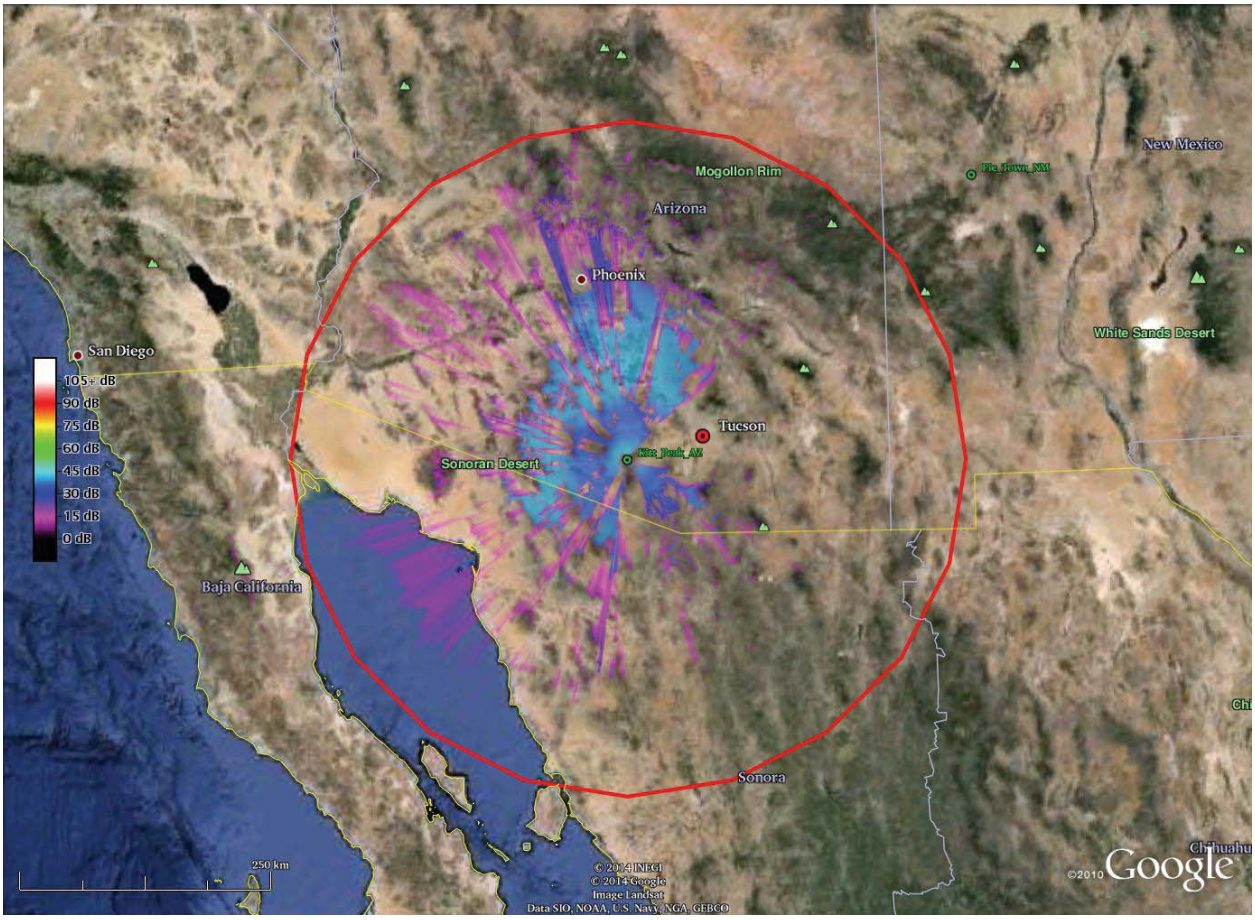

Figure A-7: VLBA Kitt Peak, Arizona

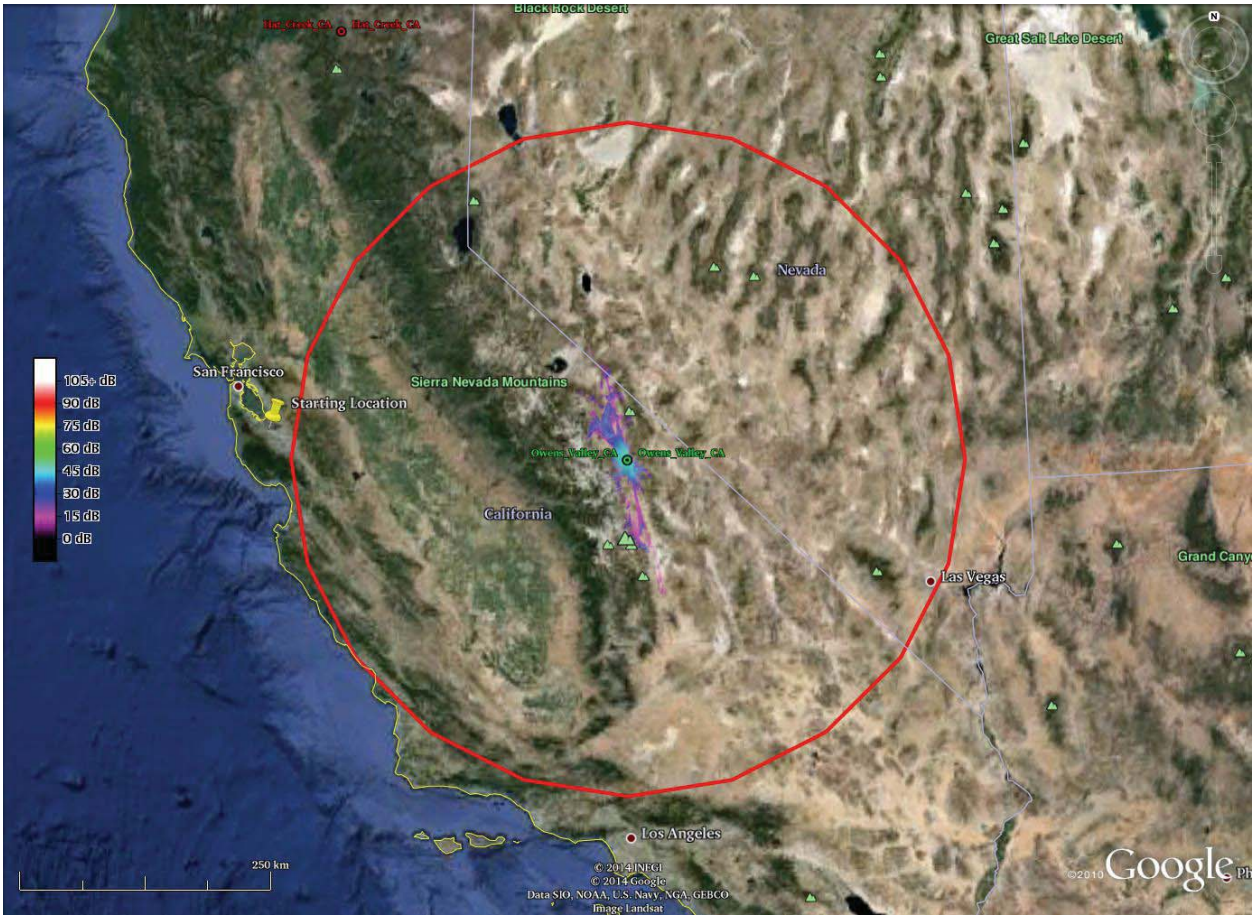

Figure A-8: VLBA Owens Valley, California

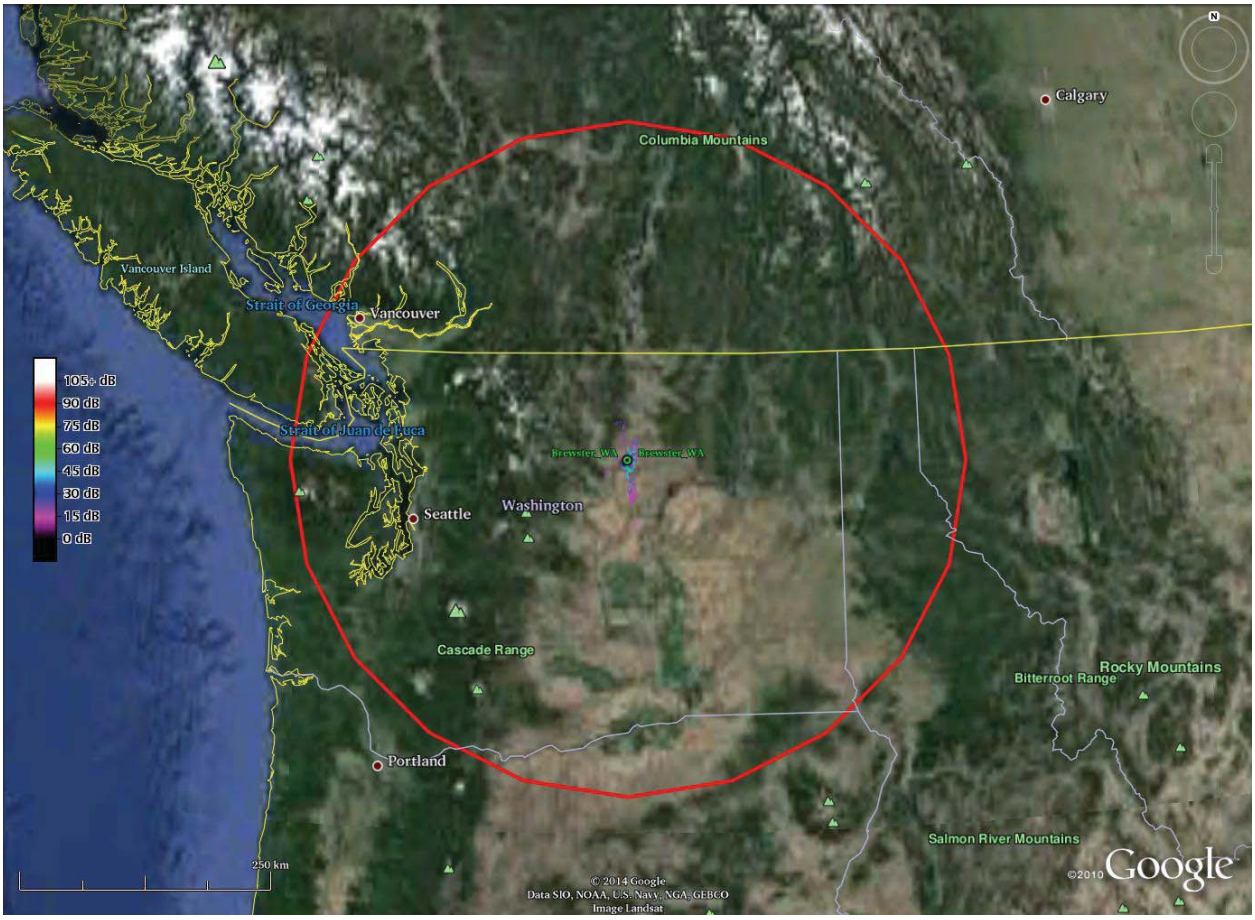

Figure A-9: VLBA Brewster, Washington

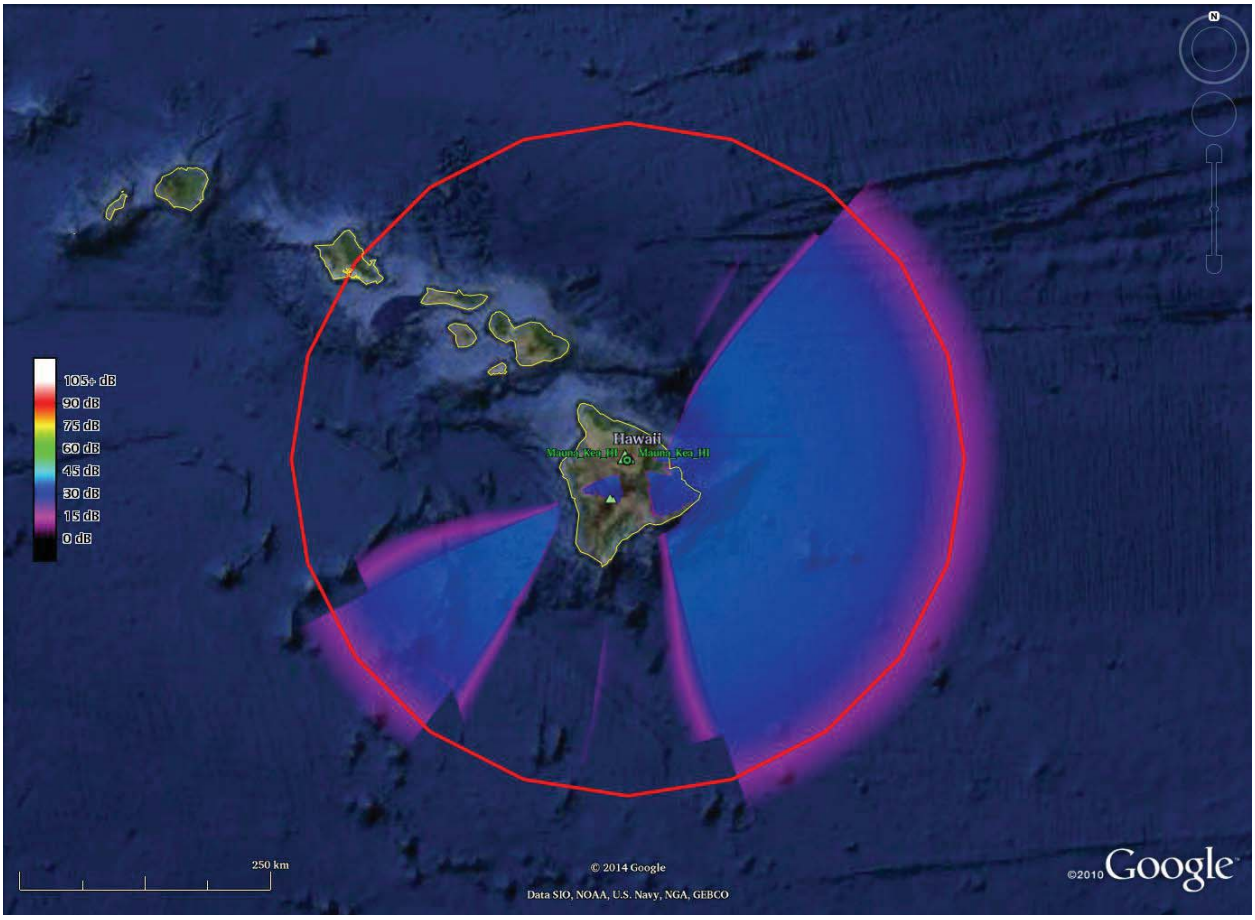

Figure A-10: VLBA Mauna Kea, Hawaii