Before the
FEDERAL COMMUNICATIONS COMMISSION
Washington, DC 20554

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

REPLY COMMENTS OF CBS CORPORATION, 21ST CENTURY FOX, INC., TIME WARNER INC., VIACOM INC., AND THE WALT DISNEY COMPANY ("JOINT CONTENT INTERESTS")

The Joint Content Interests hereby submit these comments in response to the Commission's April 21, 2015, Further Notice of Proposed Rulemaking in the above-captioned proceeding ("*Second FNPRM*")[1] to reiterate the importance of protecting incumbent C-Band satellite operations from any harmful interference that may be generated by Citizens Broadband Radio Service Devices ("CBSDs"). As the Joint Content Interests have explained in prior filings in this docket,[2] these incumbent C-Band operations play a critical role in delivering television content to our affiliates, and ultimately to hundreds of millions of viewers nationwide. Other comments submitted in response to the *Second FNPRM* also have explained the necessity of fully and effectively protecting C-Band licensees.[3]

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[1] *Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band*, R&O and Second FNPRM, 30 FCC Rcd 3959 (2015).

[2] *See* Joint Content Comments, GN Docket No. 12-354 (filed Feb. 20, 2013); Joint Content Interests Reply Comments, GN Docket No. 12-354 (filed April 5, 2013); Joint Content Ex Parte Letter, GN Docket No. 12-354 (filed May 8, 2013); Second Joint Content Ex Parte Letter, GN Docket No. 12-354 (filed June 4, 2013); Joint Content Reply Comments, GN Docket No. 12-354 (filed Dec. 20, 2013); Joint Content Interests Reply Comments, GN Docket No. 12-354 (filed August 15, 2014); Joint Content Ex Parte Letter, GN Docket No. 12-354 (filed October 4, 2014); Joint Content Ex Parte Letter, GN Docket No. 12-354 (filed April 13, 2015).

[3] *See* Comments of the Satellite Industry Association, GN Docket No. 12-354, at 2 (filed July 15, 2015) ("Any impairment to the operations of FSS earth stations would not only harm customers, but also place satellite safety at risk.")

Accordingly, any proposed parameters governing the operation of CBSDs in spectrum adjacent to the C-Band must be carefully analyzed to ensure that CBSDs will not interfere with C-Band operations. The Joint Content Interests previously submitted two studies by Alion in this proceeding explaining the out-of-band interference concerns CBSDs pose to incumbent C-Band receive sites, with each study based on the CBSD technical parameters then under consideration.[4]

In the Report and Order accompanying the *Second FNPRM*, the Commission decided to permit CBSDs to operate directly adjacent to 3.7 GHz,[5] to adopt a less restrictive emission mask for CBSDs operating directly adjacent to 3.7 GHz,[6] and to allow higher-power Category B CBSDs to operate in non-rural areas.[7] The Joint Content Interests asked Alion to update its study to account for these changes. Alion's updated study is attached hereto as Attachment A.

The new Alion study makes two key findings regarding the steps necessary to protect C-Band operations from CBSDs operating under the Commission's revised parameters. First, Alion found that protecting a C-Band satellite earth station from a single CBSD base station would require a protection distance of up to 9.63 km for Category A devices and up to 16.4 km for Category B devices (rural or non-rural).[8] Thus, Alion concludes that "[s]pectrum

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[4] *See* Joint Content Interests Reply Comments, GN Docket No. 12-354, at Attachment A (filed April 5, 2013); Joint Content Interests Reply Comments, GN Docket No. 12-354 at Attachment A (filed August 15, 2014).

[5] *Second FNPRM*, 30 FCC Rcd at 4073.

[6] *Id*. at 4017.

[7] *Id*. at 4025

[8] *See* Attachment A at Tables 4-6. One scenario each for the Category B rural and non-rural devices indicated the required protection distance could be more than 125 km to account for potential anomalous propagation effects. *See* Attachment A at 1.

sharing in these bands would require coordination with incumbent, adjacent band, earth station users" to avoid harmful interference to C-Band operations.[9] Second, Alion found that "the protection distances due to multiple CBSDs could be significantly larger than for single-entry cases," and that the addition of a few dozen CBSDs could double or even triple the required protection distance.[10] The Spectrum Access System (SAS) therefore "must be sophisticated enough to know how many CBSDs are deployed in an area and appropriately extend the protection zone such that the aggregated emissions do not violate the interference threshold."[11]

Alion's updated findings underscore the importance of adopting robust, enforceable rules — based on reliable technical analyses — to protect C-Band operations, and to ensure that any SAS is sufficiently tested and proven to protect incumbent operations before CBSDs are deployed.

Respectfully submitted,

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[9] *Id*. at 1.

[10] *Id*. at 2.

[11] *Id*. at 21-22.

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August 14, 2015

ATTACHMENT A

Alion Report of August 5, 2015

Consulting Report

SHARING STUDY ON THE EFFECTS OF THE PROPOSED CITIZENS BROADBAND RADIO SERVICE TO C-BAND SATELLITE EARTH STATIONS

Prepared for:

Content Companies

RESE-15-010
August 5, 2015

Use and Disclosure of Data

Approved for public release

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EXECUTIVE SUMMARY

The Federal Communications Commission FCC 15-47 Report and Order and Second Further Notice of Proposed Rulemaking (FNPRM) released April 21, 2015 proposes to amend the commission's rules with regard to commercial operations in the 3550-3700 MHz band. The FNPRM proposes specific rules for a new Citizens Broadband Radio Service in the 3.5 GHz Band. Specifically, the proposed rules would implement a framework to authorize a variety of small cell and other broadband uses of the 3.5 GHz Band on a shared basis with incumbent federal and non-federal users of the band, with oversight and enforcement through a Spectrum Access System (SAS). It also proposes baseline technical standards for the operation of Citizens Broadband Radio Service Devices (CBSDs) and End User Devices in the 3.5 GHz Band as well as general rules for the operation of the SAS and approval of SAS Administrators.

The FNPRM seeks further comment regarding the protection of Fixed Satellite Service (FSS) earth stations in the 3700-4200 MHz band. The incumbent commercial users of C-Band (Content Companies) currently utilize the adjacent frequency band (3700-4200 MHz) for satellite downlink of video and television broadcasts of programming materials in the United States. This study updates and expands on previous sharing studies Alion performed for the Content Companies. The Content Companies requested that Alion perform another sharing study to investigate the effects of the FCC 15-47 FNPRM updated technical parameters and new device type on C-Band satellite earth stations.

In this study, protection distances to mitigate Radio Frequency Interference (RFI) to C-Band satellite earth stations were determined for several parametric single-entry and aggregate cases. The earth station interference thresholds, antenna elevation angles, CBSD antenna heights, and propagation percentages were varied. Category A, Category B Non-Rural, and Category B Rural device types were analyzed.

A comparison of the results in this study to the 2014 Alion analysis shows that the single-entry protection distances increased, on average, by more than a factor of 3, with a maximum of a factor of 8. This increase was due to the new less restrictive emission mask as applied to CBSD operations directly adjacent to 3700 MHz and C-Band satellite earth station operations.

The newly proposed Category B Non-Rural device required the largest single-entry protection distance of 125.7 km. This was based on an I/N of -20 dB, propagation percentage of 1%, earth station antenna elevation angle of 5 degrees, and a base station antenna height of 35 meters. This large protection distance is due to anomalous propagation effects.

For cases not exhibiting anomalous propagation effects, the Category B devices required the largest single-entry protection distance of 16.40 km. This was based on an I/N of -20 dB, propagation

percentage of 20%, earth station antenna elevation angle of 5 degrees, and a base station antenna height of 35 meters.

The aggregate analysis showed that the SAS would need to take into account the effects of aggregated CBSDs. If the SAS enforces separation distances based on only a single device, multiple devices operating in the area will violate the interference threshold and cause interference. It was shown that the addition of a few dozen CBSDs could double, or even triple the required protection distance. The SAS must be sophisticated enough to know how many CBSDs are deployed in an area and appropriately extend the protection zone such that the aggregated emissions do not violate the interference threshold.

Since the study showed that protection distances were significant, it is concluded that the CBSD device types proposed in FNPRM FCC 15-47 have the potential to cause harmful interference to C-Band earth station operations. Spectrum sharing in these bands would require coordination with incumbent, adjacent band, earth station users. The aggregate analysis showed that the protection distances due to multiple CBSDs could be significantly larger than for single-entry cases. The aggregate analysis also illustrated the additional complexity of preventing interference from multiple CBSDs, which the SAS would need to accommodate.

BACKGROUND

The Federal Communications Commission FCC 15-47[1] Report and Order and Second Further Notice of Proposed Rulemaking (FNPRM) released April 21, 2015 proposes to amend the commission's rules with regard to commercial operations in the 3550-3700 MHz band. The FNPRM proposes specific rules for a new Citizens Broadband Radio Service in the 3.5 GHz Band. Specifically, the proposed rules would implement a framework to authorize a variety of small cell and other broadband uses of the 3.5 GHz Band on a shared basis with incumbent federal and non-federal users of the band, with oversight and enforcement through a Spectrum Access System (SAS). The FNPRM also proposes baseline technical standards for the operation of Citizens Broadband Radio Service Devices (CBSDs) and End User Devices in the 3.5 GHz Band as well as general rules for the operation of the SAS and approval of SAS Administrators.

The FNPRM seeks further comment regarding the protection of Fixed Satellite Service (FSS) earth stations in the 3700-4200 MHz band. The incumbent commercial users of C-Band (Content Companies[2]) currently utilize the adjacent frequency band (3700-4200 MHz) for satellite downlink of video and television broadcasts of programming materials in the United States. This study updates and expands on previous sharing studies Alion performed for the Content Companies in 2013 and 2014.[3,4] In 2013, the FCC had not yet established technical parameters for the Citizens Broadband Radio Service. The 2013 sharing study was based on assumptions about the technical characteristics of CBSDs. In 2014, the FCC established technical parameters for CBSDs. The 2014 sharing study analyzed these characteristics. In 2015, the FCC updated the FNPRM with new operational characteristics. These included: CBSDs would operate directly adjacent to 3700 GHz, the emission mask was made less restrictive, and a new device type was introduced. The Content Companies requested that Alion perform another sharing study to investigate the effects of the updated technical parameters and new device type on C-Band satellite earth stations.

[1] *In the Matter of Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band*, Report and Order and Second Further Notice of Proposed Rulemaking, Federal Communications Commission, FCC-15-47, GN Docket No. 12-354, April 21, 2015.
[2] These include CBS Corporation, National Association of Broadcasters, 21st Century Fox, Inc., Time Warner, Inc., Viacom, Inc., and The Walt Disney Company.
[3] Lloyd Apirian, Mark Gowans, Jason Greene, *Effects of the Proposed Citizens Broadband Service to C-Band DOMSAT Earth Stations*, Alion Science and Technology Corporation, Consulting Report ESO-13-011-v3, April 2013.
[4] M. Gowans, L. Apirian, *Sharing Study on the Effects of the Proposed Citizens Broadband Radio Service to C-Band Satellite Earth Stations*, Alion Science and Technology Corporation, Consulting Report RESED-14-006, August 2014.

APPROACH

Single-Entry Analysis

The single-entry analysis consisted of calculating C-Band satellite earth station protection distances for CBSDs based on the technical standards described in the FNPRM. Large-signal interactions such as Low-noise Block Downconverter (LNB) gain compression or receiver intermodulation effects were not investigated. Required protection distances due to large-signal effects were determined and provided in a previous Alion analysis [Reference 3]. This analysis was filed with the FCC as Attachment A.[5]

To determine protection distances, a single CBSD base station was placed along a radial path relative to an earth station location, with both antenna azimuths aligned. Emory, TX, was chosen as the earth station location. This location was used for the previous Alion analyses (References 3 and 4), and was chosen as a representative location because of the surrounding moderate terrain characteristics. A location with moderate terrain characteristics was desired rather than a location with either predominantly mountainous or predominantly flat terrain.

The FNPRM describes CBSD operation in the 3550-3700 MHz band. It was assumed that the base station was tuned to the closest adjacent-band channel (3695 MHz) to the lowest C-Band earth station receiver channel for the 3550-3700 MHz band. The CBSD base station was moved along a radial path relative to the earth station, and protection distances were calculated based on the separation distance necessary to reduce the interference level below an interference threshold. Three interference thresholds were investigated; I/N = -10, -20, and -1.3 dB, using the International Telecommunication Union (ITU) P.452 propagation model. Propagation percentages of 20%, 1%, and 0.001667% were investigated.

The FNPRM included CBSD and End User Device general radio requirements. In this study, three CBSD device types were analyzed as categorized in the FNPRM: 1) Category A, 2) Category B Non-Rural, and 3) Category B Rural. Category A represents a lower-power use (small cells being the paradigmatic example). Category A CBSDs will be limited to a maximum conducted transmit power of 24 dBm and a maximum EIRP of 30 dBm in 10 MHz. Category B CBSDs will be authorized to operate at higher power than Category A. In non-rural areas, the conducted power limit is the same as Category A (24 dBm), but the EIRP limit is 40 dBm. In rural areas, the conducted power limit is increased to 30dBm per 10 MHz and EIRP to 47 dBm per 10 MHz. As implied by the difference between low conducted and higher radiated power limits, Category B CBSDs can make use of more directional, higher-gain antennas to achieve increased range.

[5] http://apps fcc.gov/ecfs/document/view?id=7022138155

Some values used in this analysis were parameterized to allow flexibility in applying the results, and to allow for varying situations.

Aggregate Analysis

In addition to the single-entry analysis, an aggregate analysis was also performed. Spectrum sharing in this band will rely on a SAS to mitigate interference. The purpose of the aggregate analysis was to investigate the additional complexity of preventing interference from multiple CBSDs, which the SAS would need to accommodate.

The aggregate analysis consisted of determining protection zones as a function of the number of aggregate CBSDs. It was assumed that the CBSDs were tuned to the closest adjacent-band channel (3695 MHz) to the lowest C-Band earth station receiver channel (3720 MHz). It is noted that CBSDs tuned to lower adjacent-band frequencies would require less separation distance. Protection distances were calculated based on the separation distance necessary to reduce the aggregate interference level below an interference threshold. Two interference thresholds were investigated; I/N = -10 and -20 dB, using the ITU P.452 propagation model with a propagation percentage of 20%.

System Characteristics

Table 1 shows the C-Band earth station technical characteristics that were used in this analysis.

Table 1. C-Band earth station technical characteristics

Parameter	Value
Bandwidth	36 MHz/channel
Channel frequency	3720 MHz (lowest channel in 3700-4200 MHz band)
Antenna gain	43.7 dBi mainbeam
Antenna model	ITU-R Recommendation S.465-6
Antenna elevation angle	5, 15, 25, and 35 degrees
Antenna azimuth	249 degrees
Antenna height above terrain	4 m
System noise temperature	78 K
System noise power	-104 dBm (calculated)
Cable/feed loss	0 dB

Table 2 shows the CBSD base station technical characteristics that were used in this analysis.

Table 2. CBSD base station technical characteristics

Parameter	Category A	Category B Non-Rural	Category B Rural
Number of antenna sectors	1	3	3
Maximum conducted output power	24 dBm (per 10 MHz)	24 dBm (per 10 MHz)	30 dBm (per 10 MHz)
Maximum Effective isotropic radiated power (EIRP)	30 dBm (per 10 MHz)	40 dBm (per 10 MHz)	47 dBm (per 10 MHz)
Maximum EIRP per base station sector	30 dBm	40 dBm	47 dBm
Antenna Gain	6 dBi	16 dBi	17 dBi
Antenna azimuth beamwidth	360 degrees	65 degrees	65 degrees
Elevation angle	0 degrees	-6 degrees	-6 degrees
Antenna height	5, 15, 25 meters	15, 25, and 35 meters	15, 25, and 35 meters
Channel frequency	3695 MHz	3695 MHz	3695 MHz
Bandwidth	10 MHz	10 MHz	10 MHz

Table 3 shows the general analysis parameters and assumptions used in this analysis.

Table 3. Analysis parameters and assumptions

Parameter	Value
Earth station antenna model	ITU-R Recommendation S.465-6
Base station antenna model	ITU-R Recommendation 1336-4
I/N	-10 and -20 dB
Propagation Model	ITU-R Recommendation P.452
Propagation Percentage	20%, 1%, and 0.001667%

I/N Thresholds

For this study, three interference thresholds were investigated; I/N = -10, -20 dB, and -1.3 dB. The commonly used ITU-R S.1432 recommends an interference threshold of I/N = -20 dB for long-term adjacent-band interference effects. ITU-R S.1432 also recommends an interference threshold of -1.3 dB for short-term adjacent-band interference effects, coupled with a propagation percentage of 0.001667%.

Apportionment of Interference

Apportionment is a term used to describe the division of allowable interference among different allocated services. It is important in a sharing study to apportion the interference attributed to the specific service being analyzed. As apportionment for the service under study becomes a smaller fraction of the total allowable interference, protection distances for that service will increase. For example, assuming 50% of the allowable interference to the C-Band earth station receiver is allocated to CBSD systems, for a total interference threshold, I_{total}, the interference threshold allowed for the CBSD

system would be I_{total} – 3 dB. This results in a larger protection distance for CBSD systems. ITU recommendations such as ITU-R SA.1160 provide some representative examples of apportionment, including calculations. However, no apportionment was assumed for this study.

RF Filtering

For the analysis, protection distances were calculated with receiver front-end, radio-frequency (RF) filtering. The filter model MFC 13961W is taken as a representative RF filter.[6] Measured spectral response characteristics are shown in Figure 1.

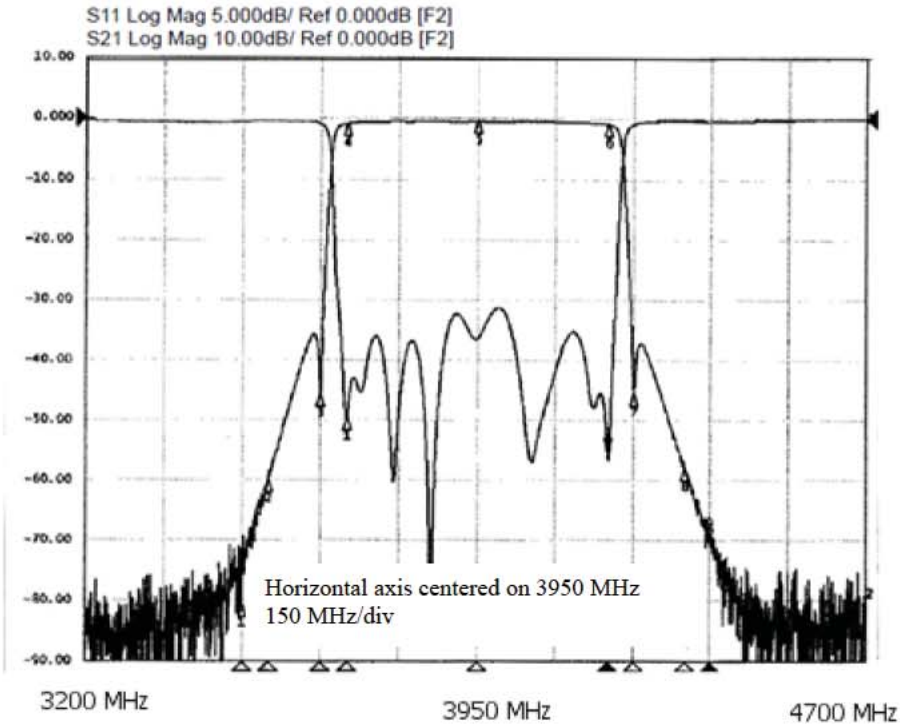

Figure 1. C-Band front-end filter characteristics

CBSD Out-of-band Emissions

The FNPRM specifies limits on Out-of-band Emissions (OOBE). For CBSDs operating in the 3550 - 3700 MHz band, the power of any emission outside the fundamental emission shall not exceed -13 dBm/MHz within 0-10 MHz above the upper channel edge, and within 0-10 MHz below the lower channel edge. At all frequencies greater than 10 MHz above the upper channel edge and less than 10

[6] From Microwave Filter Co., Inc. web site: http://www.microwavefilter.com/pdffiles/13961W.pdf. Last visited August 14, 2014.

MHz below the lower channel edge, the power of any emission shall not exceed -25 dBm/MHz. The power of any emissions below 3530 MHz or above 3720 MHz shall not exceed -40dBm/MHz.

The CBSD fundamental emission was modeled assuming a 9 MHz, 0-dB bandwidth, dropping to the OOBE limit at the edge of the channel bandwidth of 10 MHz. Figures 2 and 3 show the emission masks for the Category A, Category B Non-Rural, and Category B Rural CBSD base stations.

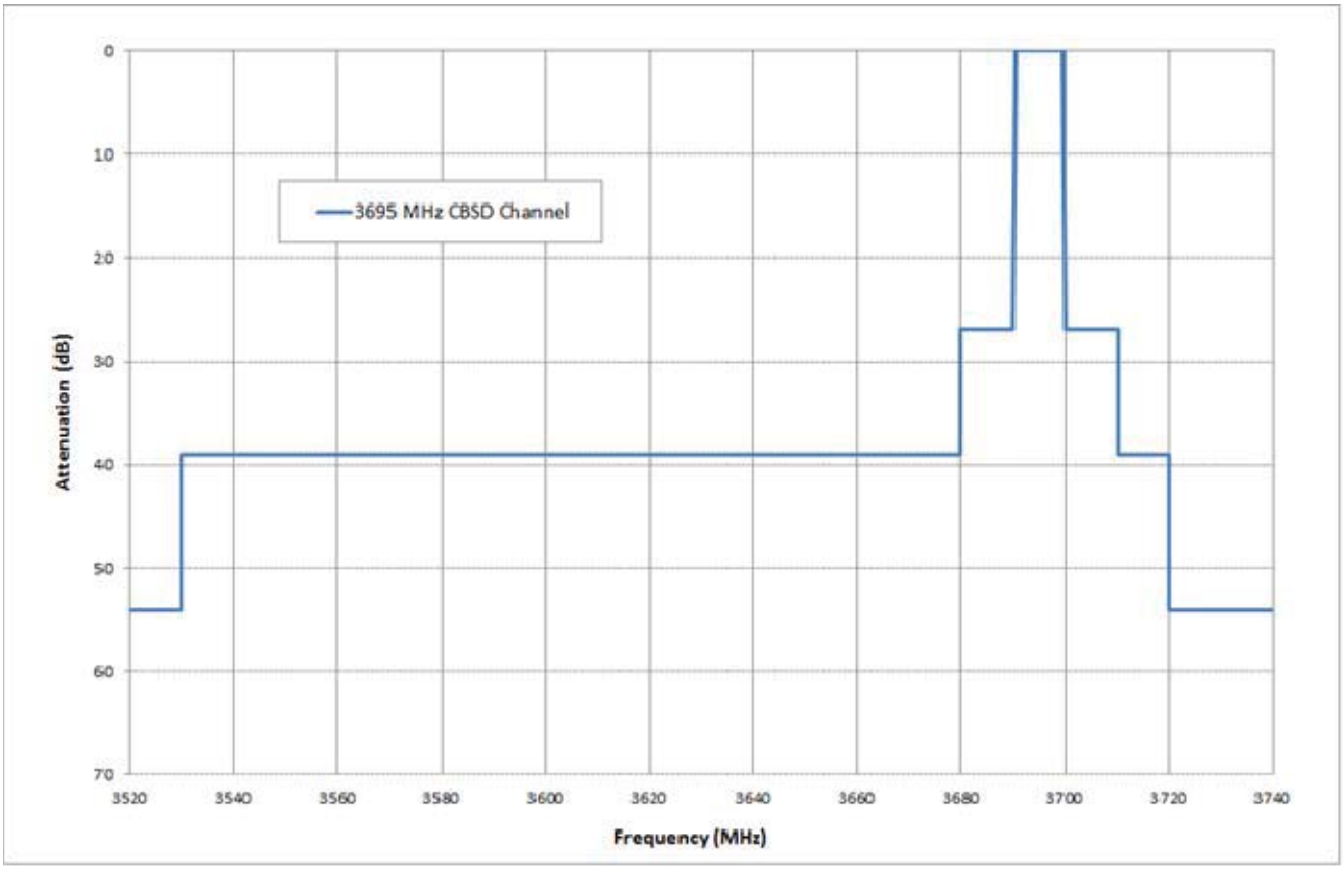

Figure 2. FNPRM Category A and Category B Non-Rural CBSD base station emission mask

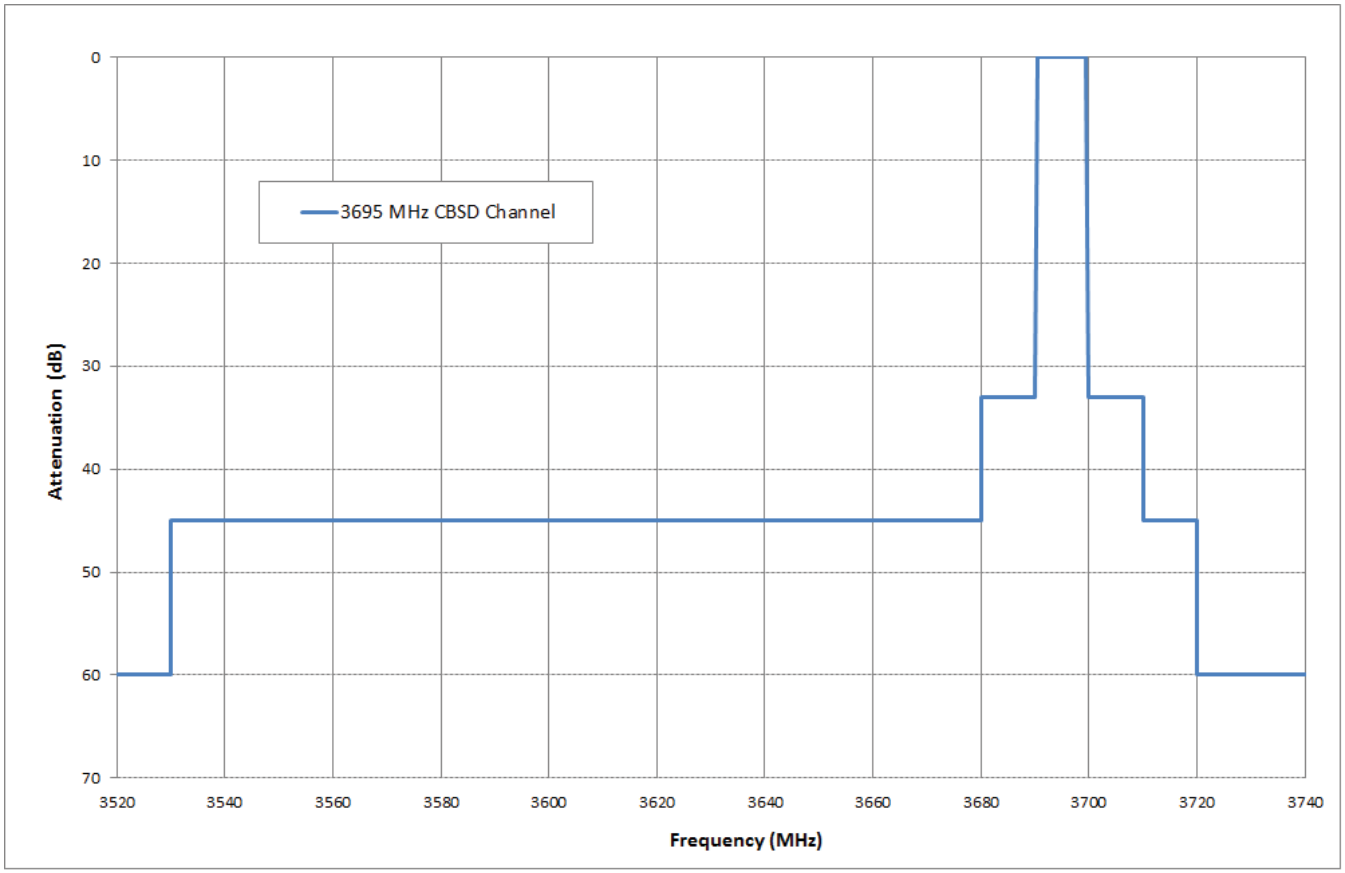

Figure 3. FNPRM Category B Rural CBSD base station emission mask

Frequency-Dependent Rejection

Frequency-dependent rejection (FDR) is the mutual coupling between the interferer (source) and receiver (victim). In other words, FDR is a measure of the rejection produced by the receiver selectivity to unwanted transmitter emission spectra. FDR was used in the computation of received interference levels. More information on FDR can be obtained from ITU-R Recommendation SM.337-6. FDR computations were performed using numerical integration techniques and software.

The CBSD base station emission spectrum was modeled as previously described, based on the FNPRM OOBE limits. For the C-Band earth station receiver, RF filtering was modeled based on the measured characteristics of a representative RF filter (Figure 1). The IF selectivity was modeled based on the C-Band earth station receiver 3-dB channel bandwidth of 36 MHz, and channel width of 40 MHz. It was assumed that at the edges of the channel, the IF selectivity would be 60 dB. Outside the channel a 20 dB per decade roll-off was assumed for the filtering.

Figure 4 shows the FDR curve based on the CBSD system emissions for the 3695 MHz channel. Since the earth station is tuned to 3720 MHz, the difference between center frequencies is 25 MHz. This difference frequency was used to determine the FDR used in the analysis.

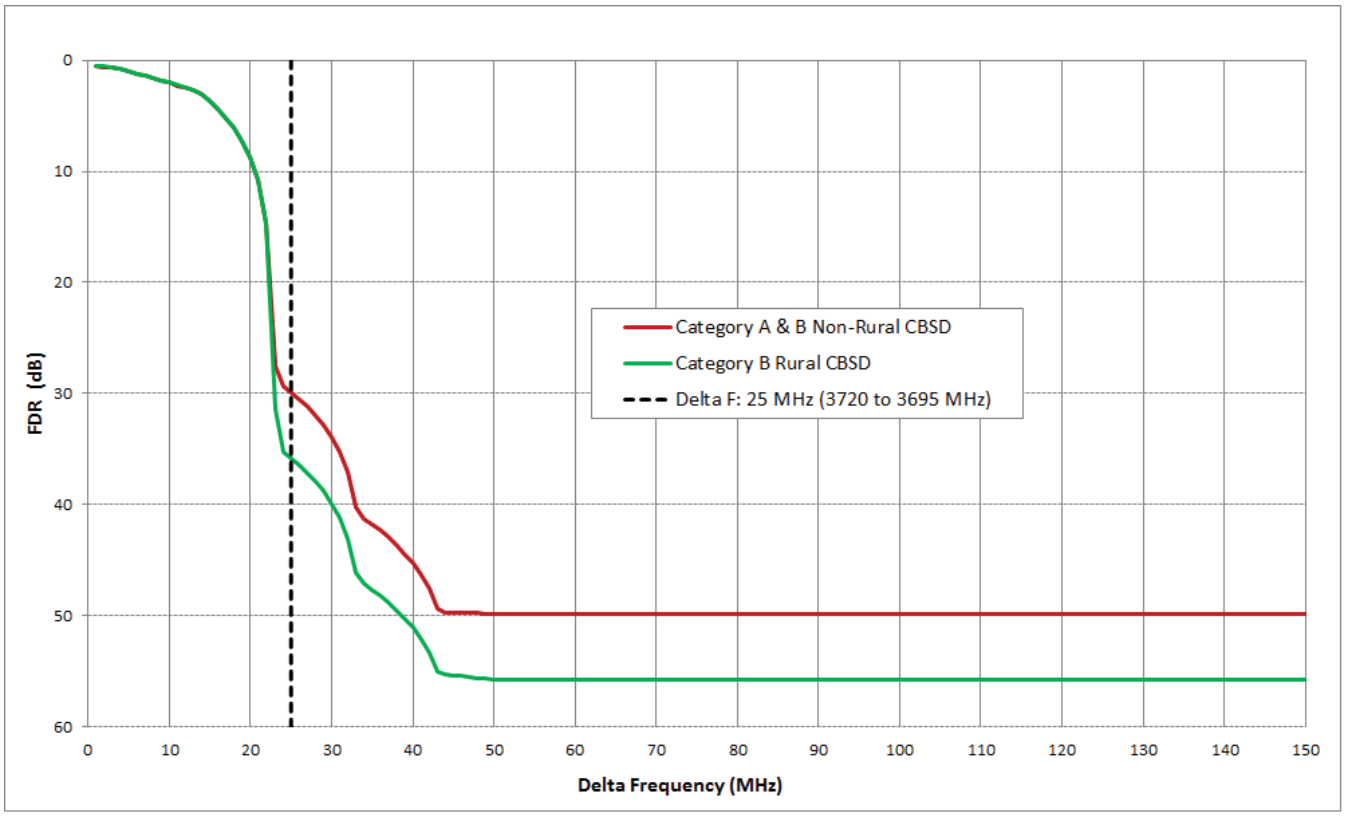

Figure 4. CBSD FDR

ANALYSIS

Single-Entry Analysis

For the single-entry analysis, a single CBSD base station was placed along a radial path relative to the earth station location, aligned with the antenna azimuth. The CBSD was assumed to be tuned to 3695 MHz, which is the worst-case adjacent-band tuning for interference to the earth station. The CBSD base station was moved along the path and a protection distance was determined based on the separation distance necessary to reduce the interference level below the interference threshold. Figure 5 shows the terrain profile for the single-entry path of the base station relative to the C-Band earth station.

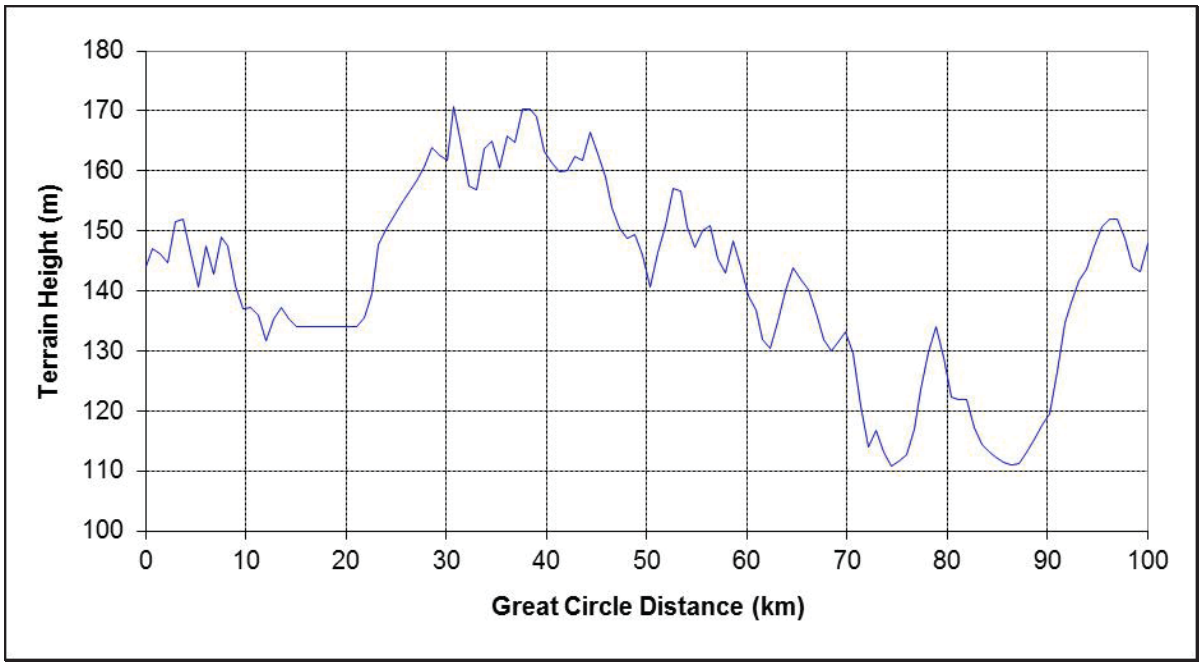

Figure 5. Terrain profile for single-entry analysis

The analysis was performed using a modified version of a model developed by the United States National Telecommunications and Information Administration (NTIA) for the fast-track analysis.[7]

The single-entry analysis results are presented in Tables 4 through 6 for the following cases:

- Earth station elevation angles of 5, 15, 25, and 35 degrees
- ITU P.452 propagation model with propagation percentages of 20%, 1%, and 0.001667%
- Interference thresholds of I/N = -10 dB, -20 dB, and -1.3 dB
- Base station antenna heights for the Category A device of 5, 15, and 25 meters, and for the Category B devices 15, 25, and 35 meters

[7] E.F. Drocella, L. Brunson, C.T. Glass, *Description of a Model to Compute the Aggregate Interference From Radio Local Area Networks Employing Dynamic Frequency Selection to Radars Operating in the 5 GHz Frequency Range*, NTIA Technical Memorandum 09-461, May 2009.

Table 4. Protection distances for Category A single-entry CBSD base station at 3695 MHz to C-Band earth station

Receiver Antenna Elevation Angle, deg	Propagation Percentage, %	Threshold I/N, dB	Category A Single-Entry Base Station Protection Distance, on Azimuth, km, for Base Station Height of:		
			5 m	15 m	25 m
5	20	-20	4.50	8.63	9.63
15	20	-20	4.01	6.07	8.25
25	20	-20	3.75	4.73	7.76
35	20	-20	3.69	4.39	5.09
5	20	-10	4.05	6.16	8.41
15	20	-10	3.65	4.34	4.71
25	20	-10	1.50	2.42	2.45
35	20	-10	1.48	1.57	1.59
5	1	-20	8.25	9.10	13.43
15	1	-20	4.04	6.15	8.45
25	1	-20	3.83	4.78	8.00
35	1	-20	3.75	4.50	6.36
5	1	-10	4.08	6.27	8.73
15	1	-10	3.73	4.45	5.83
25	1	-10	1.51	2.72	2.75
35	1	-10	1.49	1.69	1.71
5	0.001667	-1.3	3.95	4.86	8.30
15	0.001667	-1.3	1.50	2.30	2.37
25	0.001667	-1.3	1.01	1.04	1.08
35	0.001667	-1.3	0.62	0.64	0.66

Table 5. Protection distances for Category B non-rural single-entry CBSD base station at 3695 MHz to C-Band earth station

Receiver Antenna Elevation Angle, deg	Propagation Percentage, %	Threshold I/N, dB	Category B Non-Rural Single-Entry Base Station Protection Distance, on Azimuth, km, for Base Station Height of:		
			15 m	25 m	35 m
5	20	-20	9.73	13.84	16.40
15	20	-20	8.08	8.93	10.26
25	20	-20	6.15	8.39	9.11
35	20	-20	4.85	8.13	8.89
5	20	-10	8.30	9.10	11.13
15	20	-10	4.83	8.06	8.83
25	20	-10	4.49	5.94	6.03
35	20	-10	3.84	3.91	3.98
5	1	-20	124.6	125.3	125.7
15	1	-20	8.53	9.16	11.25
25	1	-20	6.26	8.71	9.49
35	1	-20	6.08	8.29	9.04
5	1	-10	8.92	11.15	13.61
15	1	-10	4.88	8.25	9.00
25	1	-10	4.50	7.75	7.84
35	1	-10	4.32	4.61	4.70
5	0.001667	-1.3	8.14	9.03	11.18
15	0.001667	-1.3	4.50	7.94	8.76
25	0.001667	-1.3	3.29	3.42	3.55
35	0.001667	-1.3	1.77	1.85	1.93

Table 6. Protection distances for Category B rural single-entry CBSD base station at 3695 MHz to C-Band earth station

Receiver Antenna Elevation Angle, deg	Propagation Percentage, %	Threshold I/N, dB	Category B Rural Single-Entry Base Station Protection Distance, on Azimuth, km, for Base Station Height of:		
			15 m	25 m	35 m
5	20	-20	9.66	13.43	16.40
15	20	-20	8.08	8.88	9.89
25	20	-20	6.13	8.35	9.08
35	20	-20	4.84	8.08	8.85
5	20	-10	8.25	9.05	11.08
15	20	-10	4.81	8.02	8.80
25	20	-10	4.45	5.63	5.76
35	20	-10	3.68	3.78	3.87
5	1	-20	124.0	124.9	125.5
15	1	-20	8.30	9.11	11.22
25	1	-20	6.23	8.62	9.30
35	1	-20	4.89	8.26	9.01
5	1	-10	8.83	10.32	11.46
15	1	-10	4.87	8.25	9.00
25	1	-10	4.50	6.44	7.39
35	1	-10	4.28	4.39	4.51
5	0.001667	-1.3	8.08	9.00	11.12
15	0.001667	-1.3	4.50	7.90	8.73
25	0.001667	-1.3	3.08	3.25	3.41
35	0.001667	-1.3	1.69	1.80	1.90

Aggregate Analysis

The aggregate analysis consisted of determining protection zones as a function of the number of aggregate CBSDs. It was assumed that the aggregate CBSDs were tuned to the closest adjacent-band channel (3695 MHz) to the lowest C-Band earth station receiver channel (3720 MHz). Protection distances were calculated based on the separation distance necessary to reduce the aggregate interference level below an interference threshold. These protection distances were calculated along radials from the earth station at 1 degree increments to form a protection zone contour.

The aggregate analysis results are presented in Figures 6 through 17 for the following cases:

- Earth station elevation angle of 5 degrees
- ITU P.452 propagation model with a 20% propagation percentage
- Interference thresholds of I/N = -10 dB and -20 dB
- Base station antenna heights for the Category A device of 25 meters, and for the Category B devices 35 meters

The first figure in each set shows several protection zones as a function of aggregate CBSDs. The contour lines show the locations where N CBSDs placed anywhere on the contour line will result in an earth station received interference power equal to the interference threshold. The N aggregate CBSDs must be deployed outside of these protection zones to prevent exceeding the interference threshold. The second figure in each set shows the maximum protection zone distance as a function of the number of aggregate CBSDs.

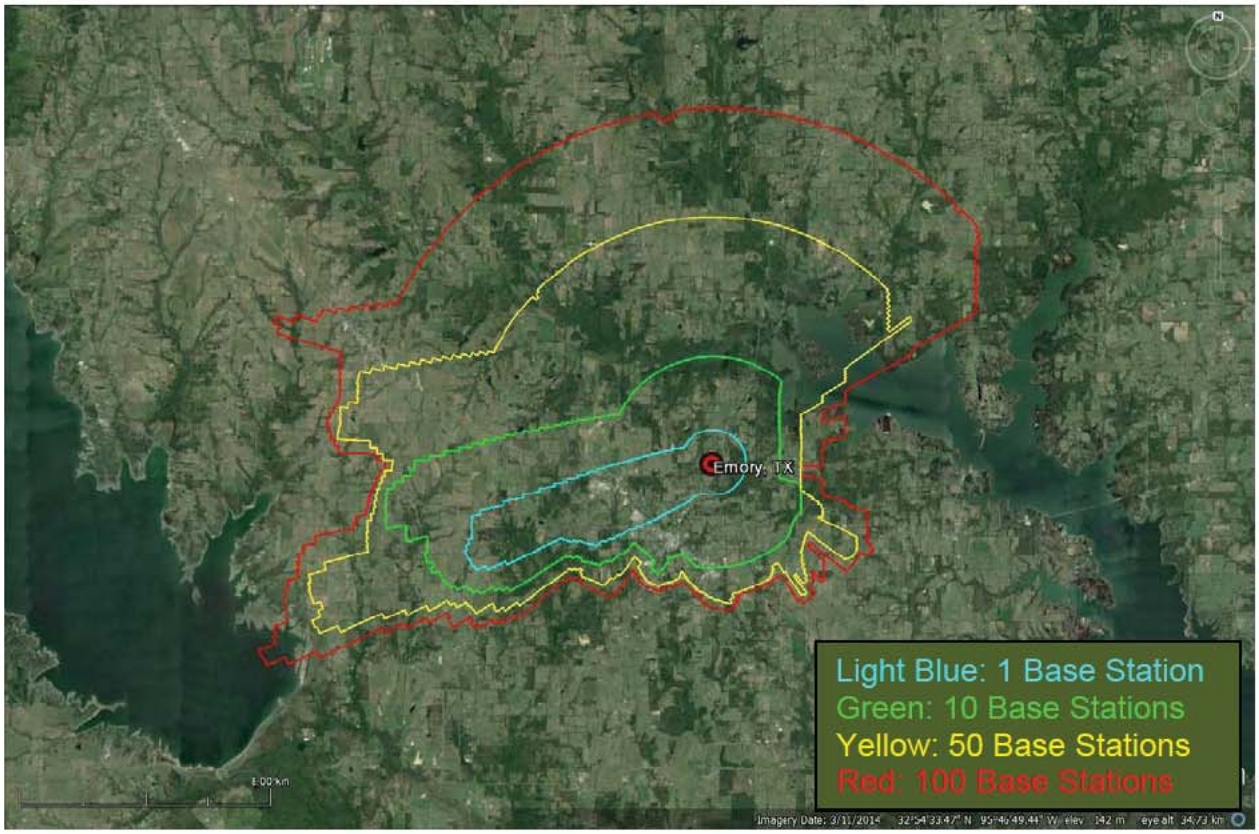

Figure 6. Protection zones as a function of aggregate Category A CBSDs, I/N = -10 dB

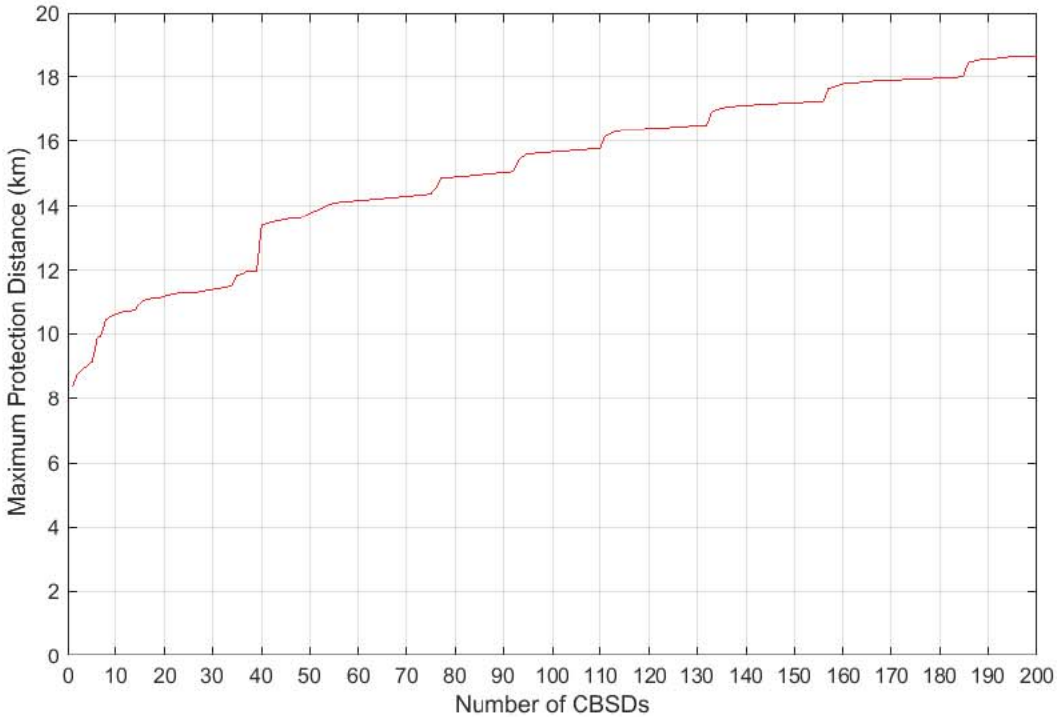

Figure 7. Maximum protection distance as a function of aggregate Category A CBSDs, I/N = -10 dB

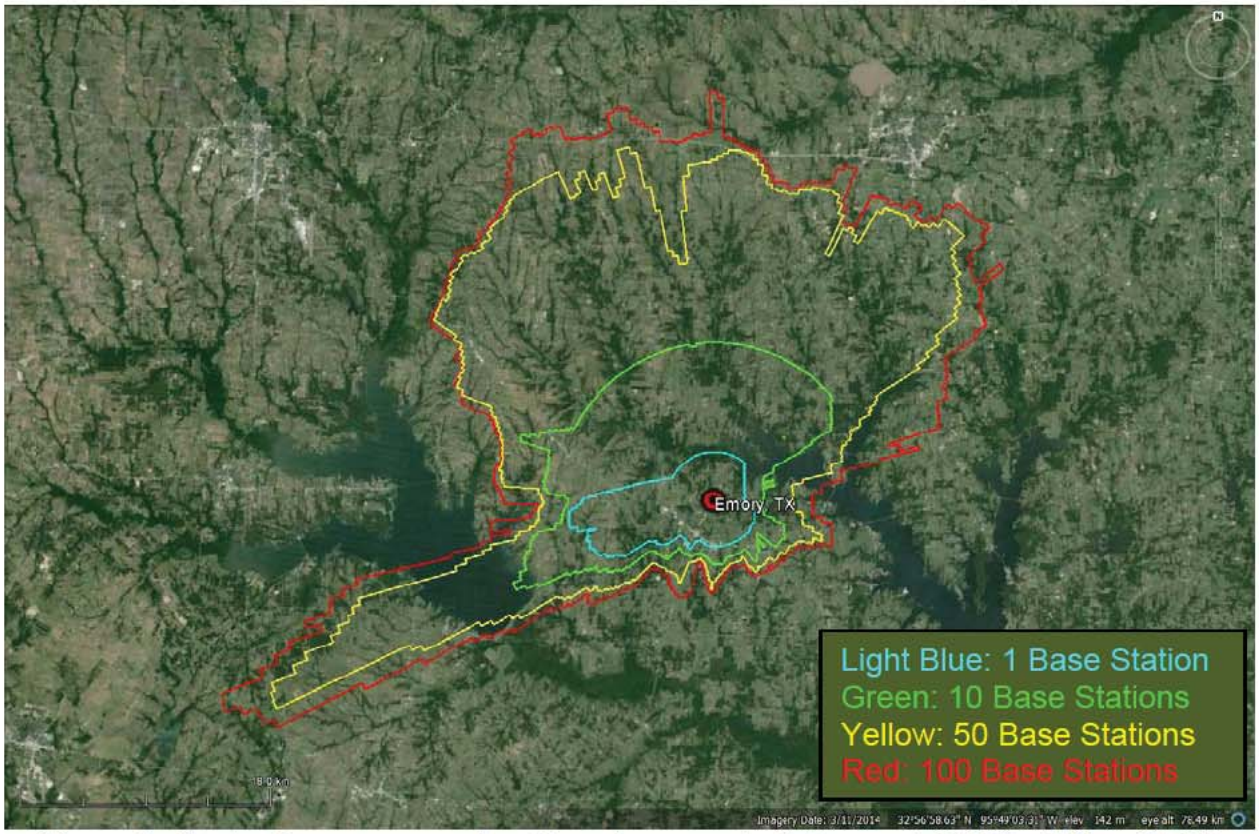

Figure 8. Protection zones as a function of aggregate Category A CBSDs, I/N = -20 dB

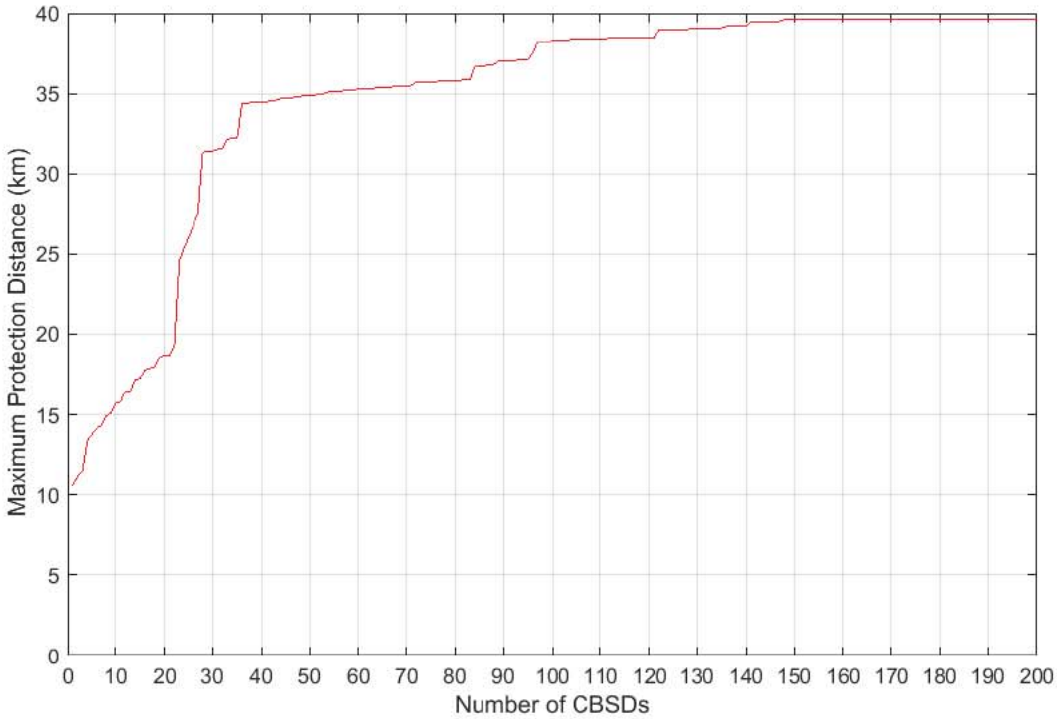

Figure 9. Maximum protection distance as a function of aggregate Category A CBSDs, I/N = -20 dB

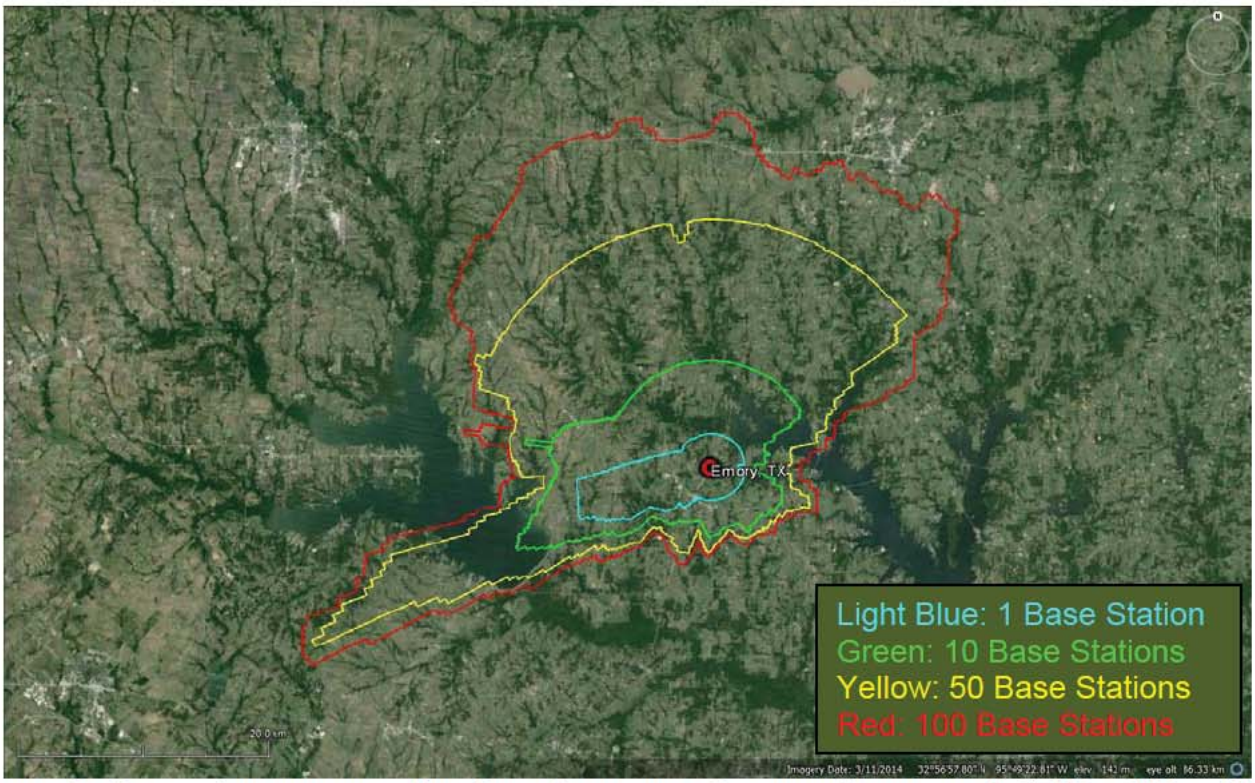

Figure 10. Protection zones as a function of aggregate Category B non-rural CBSDs, I/N = -10 dB

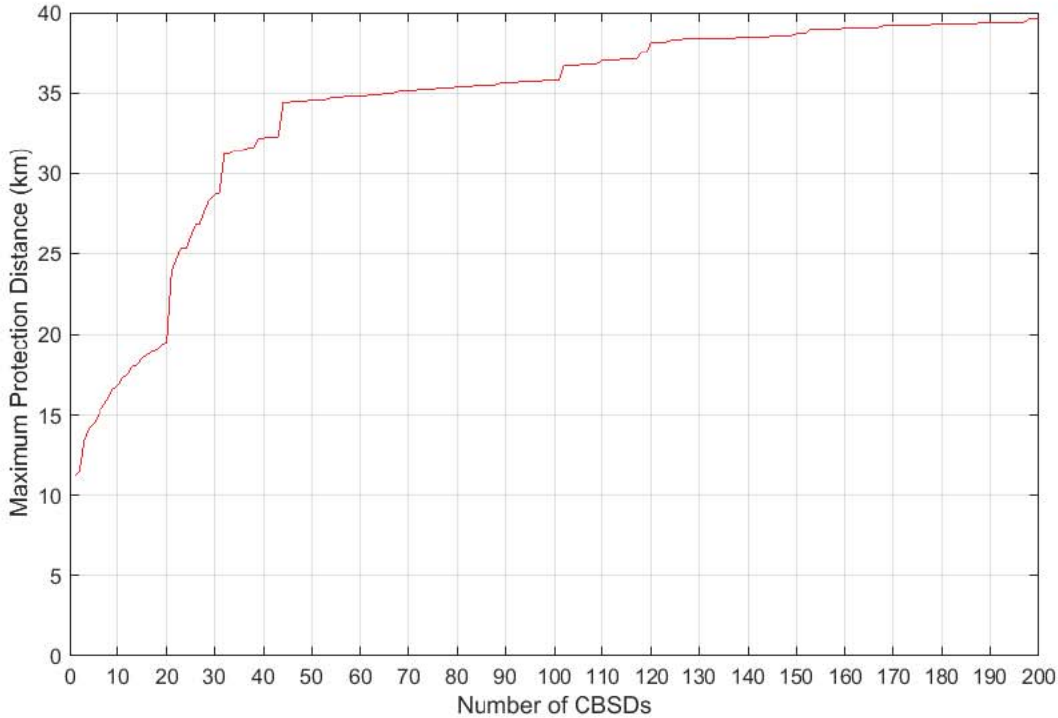

Figure 11. Maximum protection distance as a function of aggregate Category B non-rural CBSDs, I/N = -10 dB

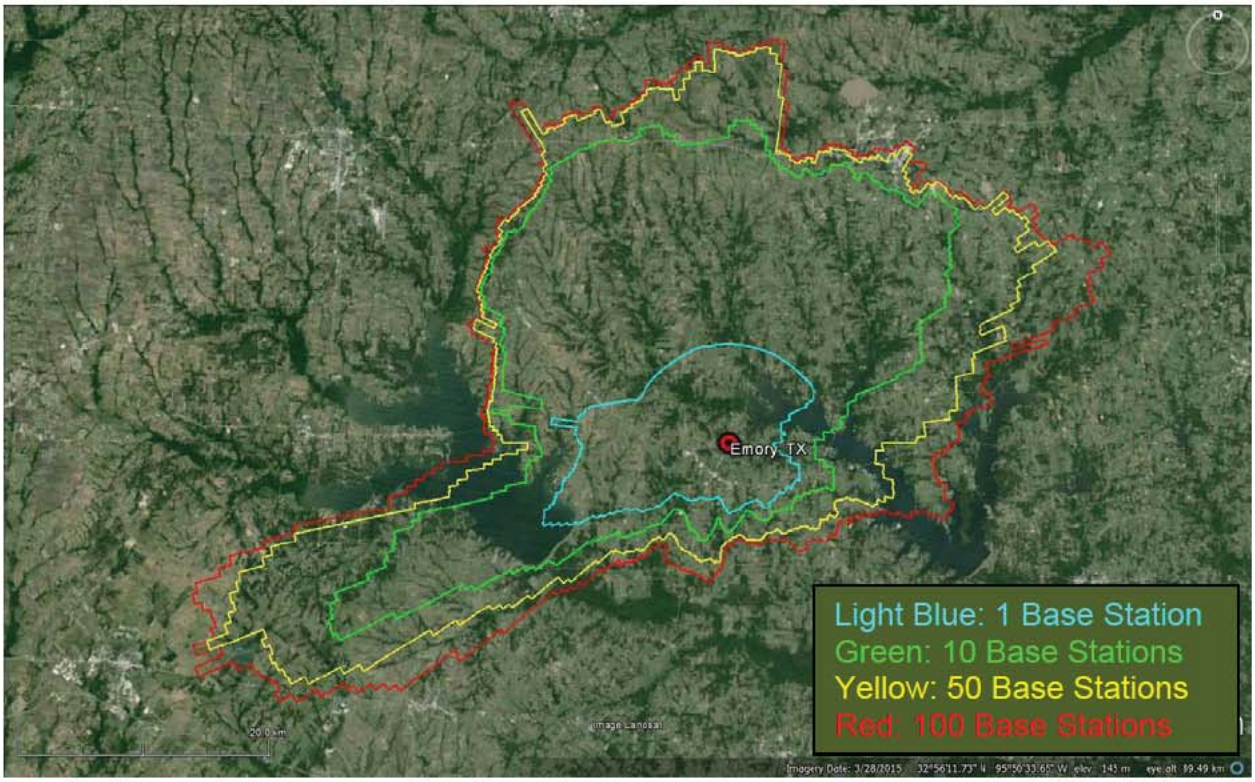

Figure 12. Protection zones as a function of aggregate Category B non-rural CBSDs, I/N = -20 dB

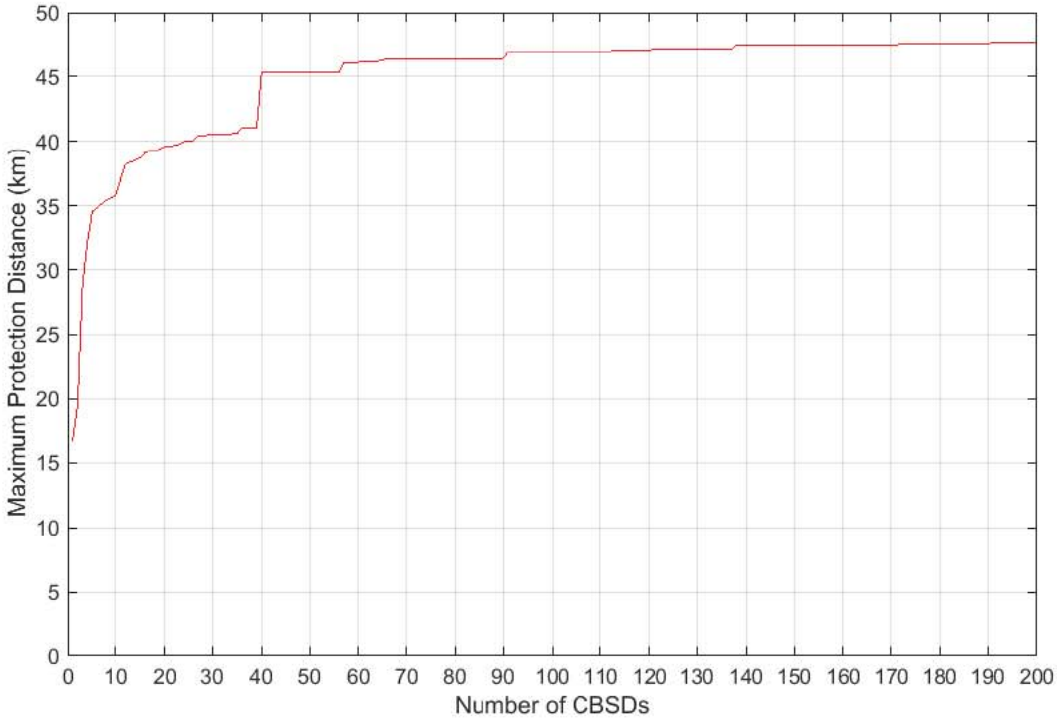

Figure 13. Maximum protection distance as a function of aggregate Category B non-rural CBSDs, I/N = -20 dB

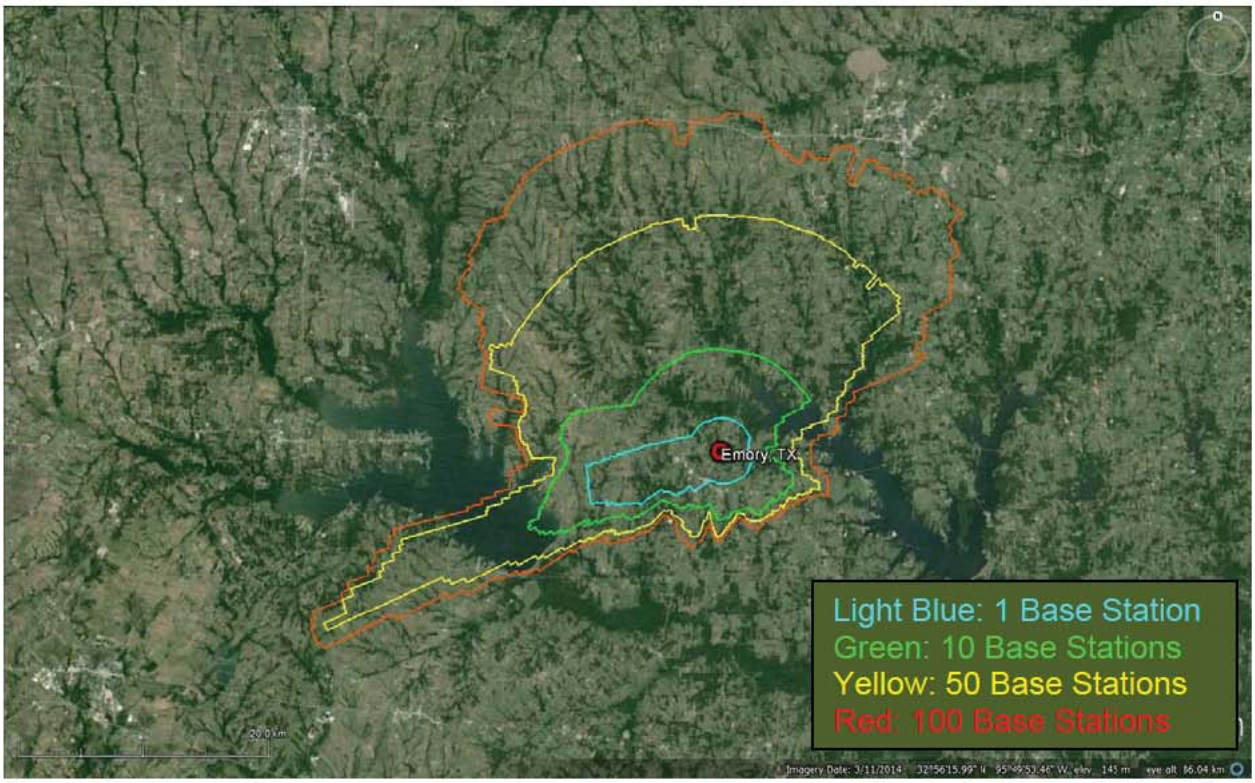

Figure 14. Protection zones as a function of aggregate Category B rural CBSDs, I/N = -10 dB

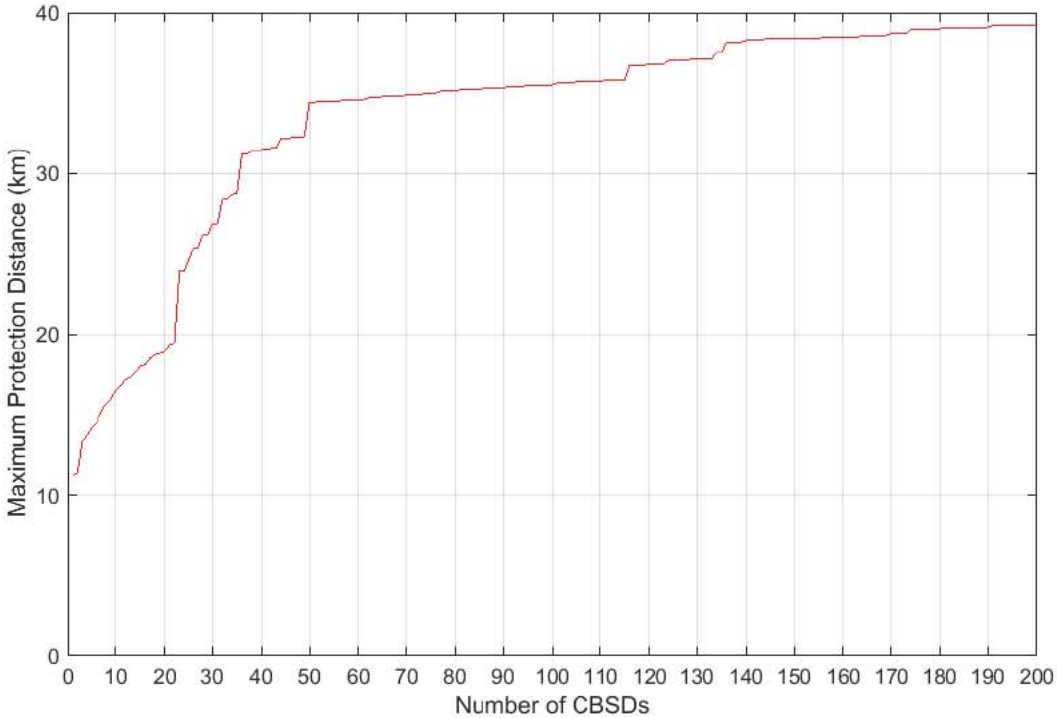

Figure 15. Maximum protection distance as a function of aggregate Category B rural CBSDs, I/N = -10 dB

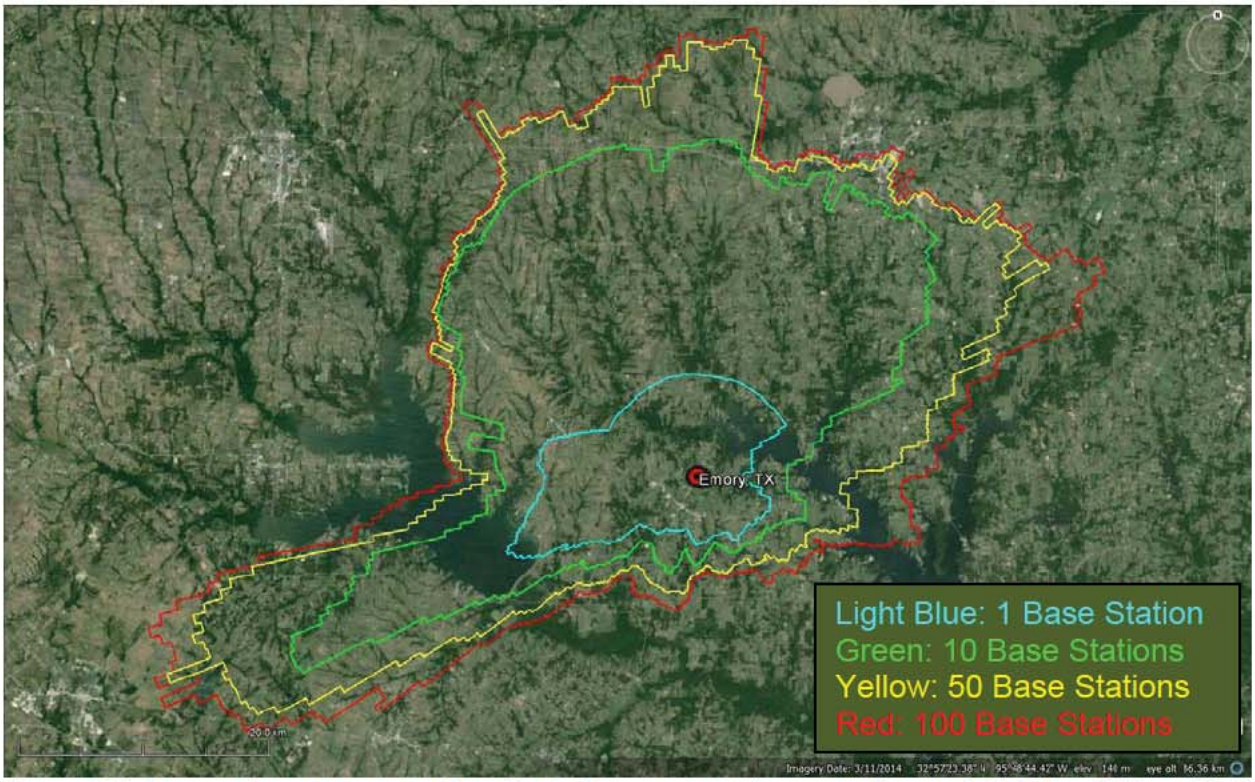

Figure 16. Protection zones as a function of aggregate Category B rural CBSDs, I/N = -20 dB

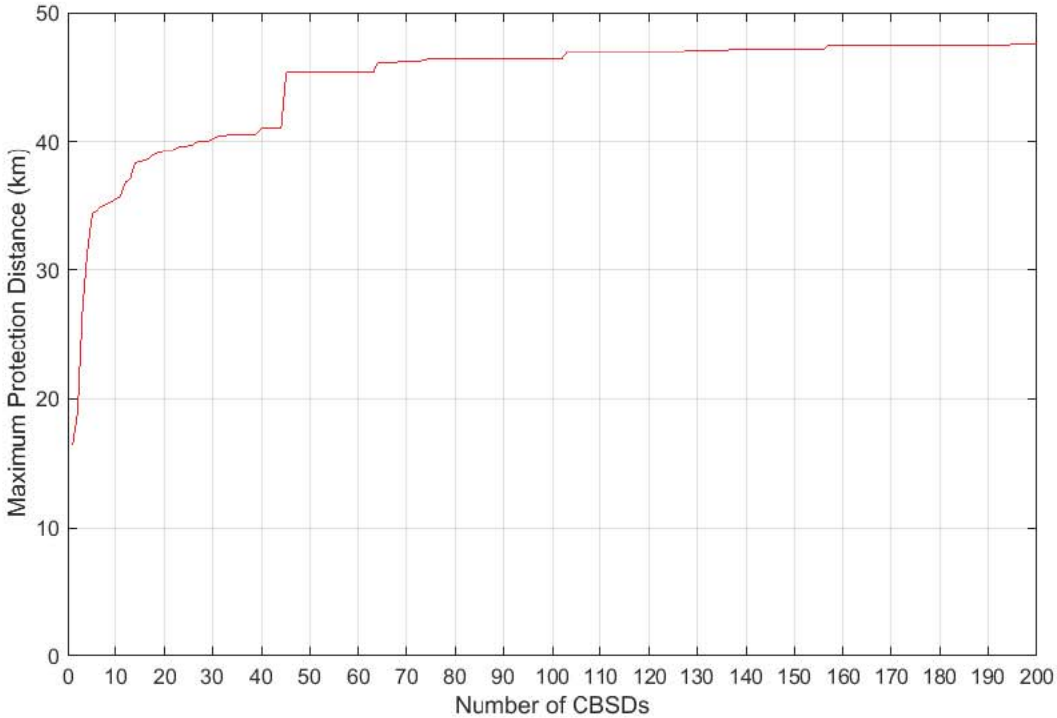

Figure 17. Maximum protection distance as a function of aggregate Category B rural CBSDs, I/N = -20 dB

RESULTS SUMMARY AND CONCLUSION

In this study, protection distances to mitigate Radio Frequency Interference (RFI) to C-Band satellite earth stations were determined for several parametric single-entry and aggregate cases. The earth station interference thresholds, antenna elevation angles, CBSD antenna heights, and propagation percentages were varied. Category A, Category B Non-Rural, and Category B Rural device types were analyzed.

A comparison of the results in this study to the 2014 Alion analysis [Reference 4] shows that the single-entry protection distances increased, on average, by more than a factor of 3, with a maximum of a factor of 8. This increase was due to the new less restrictive emission mask as applied to CBSD operations directly adjacent to 3700 MHz and C-Band satellite earth station operations.

The newly proposed Category B Non-Rural device required the largest single-entry protection distance of 125.7 km. This was based on an I/N of -20 dB, propagation percentage of 1%, earth station antenna elevation angle of 5 degrees, and a base station antenna height of 35 meters. This large protection distance is due to anomalous propagation effects.

For cases not exhibiting anomalous propagation effects, the Category B devices required the largest single-entry protection distance of 16.40 km. This was based on an I/N of -20 dB, propagation percentage of 20%, earth station antenna elevation angle of 5 degrees, and a base station antenna height of 35 meters.

The protection distances for the Category B Non-Rural and Category B Rural device types were comparable, with the Category B Non-Rural distances being slightly larger. This requires some explanation since the Category B Rural device has a 6 dB higher maximum conducted power. The Rural CBSD has 6 dB higher FDR than the Non-Rural CBSD. This is due to the specification of emissions outside the fundamental at absolute levels (-13 dBM/MHz, -25 dBm/MHz, etc.). The 6 dB FDR difference offsets the transmit power difference. The slight difference in protection distances results from a difference in off-axis antenna gains. The Non-Rural CBSD antenna has a peak gain of 16 dBi, and the Rural CBSD, 17 dBi. This causes a slightly narrower elevation beamwidth for the Rural CBSD and approximately 0.5 dB less antenna gain off-axis than the Non-Rural CBSD. This combination of FDR and antenna gain results in the Category B Non-Rural protection distances being slightly larger.

The aggregate analysis showed that the SAS would need to take into account the effects of aggregated CBSDs. If the SAS enforces separation distances based on only a single device, multiple devices operating in the area will violate the interference threshold and cause interference. It was shown that the addition of a few dozen CBSDs could double, or even triple the required protection distance. The SAS

must be sophisticated enough to know how many CBSDs are deployed in an area and appropriately extend the protection zone such that the aggregated emissions do not violate the interference threshold.

Since the study showed that protection distances were significant, it is concluded that the CBSD device types proposed in FNPRM FCC 15-47 have the potential to cause harmful interference to C-Band earth station operations. Spectrum sharing in these bands would require coordination with incumbent, adjacent band, earth station users. The aggregate analysis showed that the protection distances due to multiple CBSDs could be significantly larger than for single-entry cases. The aggregate analysis also illustrated the additional complexity of preventing interference from multiple CBSDs, which the SAS would need to accommodate.