Before the
Federal Communications Commission
Washington, D.C. 20554

In the Matter of	)	
	)	
Promoting Interoperability in the 700 MHz Commercial Spectrum	))	WT Docket No. 12-69
	)	
Interoperability of Mobile User Equipment Across Paired Commercial Spectrum Blocks in the 700 MHz Band	)))	RM-11592 (Terminated)

REPLY COMMENTS OF V-COMM, L.L.C.

PREPARED ON BEHALF OF

CAVALIER WIRELESS

CONTINUUM 700

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I. EXECUTIVE SUMMARY

SUMMARY: Pursuant to the Commission's request in their NPRM 12-31, this report includes "measurements and quantitative analysis regarding the magnitude and extent of the interference risk from adjacent Channel 51 and Lower E Block transmissions for band Class 12 devices operating in the Lower B and C Blocks"[1]. Based upon our measurements and quantitative analyses, we conclude there is no meaningful performance differential between Band 12 and Band 17 devices that can reasonably be expected to result in Harmful Interference. The use of Band 12 devices should not impact B, or C, or B + C operators in any practical way. Our analyses are based upon worst-case thresholds of a 1 dB rise in noise floor, and therefore do not take into account typical industry engineering deployment practices which would further eliminate any potential interference concerns associated with interoperability. Therefore there is no reason, based upon empirical data, to select Band 17 operations over Band 12 operations.

1. V-COMM was retained to provide an objective independent engineering assessment regarding whether B, C, or B + C block operators would be subjected to meaningful additional interference if they utilized a Band Class 12 configuration, as opposed to Band Class 17. As set forth below, the results of the V-COMM study confirm that there will be no meaningful additional interference when using a Band 12 as compared to a Band 17 configuration. As such, the V-COMM study corroborates the results of an earlier study conducted by Wireless Strategy and Paul Kolodzy and adds to the earlier results by comparing Band Class 17 operations with actual Band Class 12 devices that were not available at the time that the earlier tests were performed. Further, this study which is based upon laboratory test results from an array of Band 12 and Band 17 devices, serves to allay broad based concerns filed by several organizations in this proceeding.

2. The Study focused on both the Channel 51 Reverse PA Intermodulation and Channel 56 E-Block receiver blocking and Reverse PA Intermodulation concerns identified

[1] NPRM, ¶ 40

in the NPRM and by other commenters. Laboratory tests of several Band 12 and Band 17 devices across various performance scenarios (power, modulation) were developed as a baseline for comparison and subsequent case study. The laboratory testing recorded the performance threshold of 1 dB rise in noise floor; representing bare minimum device performance with no additional design or performance margins, and not typical of a wireless network deployment in close proximity to an undesired interference source; i.e. a worst-case scenario. This scenario was appropriately applied as a baseline to all case studies to assess potential impacts.

3. The Channel 51 case studies revealed the potential for harmful interference due to Band 12 vs. Band 17 operation for B or C-Block operators is effectively non-existent. The Case Studies for every Channel 51 licensed operator in the CONUS were evaluated using the actual station antenna parameters. A conservative line-of-site (LOS) model was applied to establish the potential DTV signal on the ground and field measurements for select Channel 51 facilities were performed to confirm the LOS modeling. Of the 26 Channel 51 facilities studied, only 8 DTV locations had even any potential to create interference conditions on the ground and only when in very close proximity to the DTV tower locations themselves. With the application of reasonable and realistic Radio Frequency design assumptions and real-world conditions (clutter losses, customer usage patterns, and application loading requirements) and the field confirmation of Channel 51 signal strengths, the potential for harmful interference is effectively eliminated altogether.

4. Further, testing on a live commercial network configured in B, C, and B+C channelization schemes was conducted with the cooperation of the United States Cellular Corporation (USCC) and their partner King Street Wireless in the Waterloo, Iowa market using Band 12 devices. This market is nearby the 850 kW transmitter of KGAN with its city of license being Cedar Rapids, Iowa, the worst case potential DTV Channel 51 interferer in our case study. The KGAN antenna is 585 meters above ground level with line of site to the Waterloo market and DTV Channel 51 signals in portions of this market area are within harmful interference thresholds which would be experienced by consumers as claimed by Qualcomm[2]. The testing demonstrates no difference in performance whether configured as a B-Block only, C-Block only, or B+C-Block network. In fact, as a result of the lack of impact on network performance, USCC has elected to continue this market in the B+C final configuration.

5. There are no Channel 56 E-Block high power deployments on air at this time. Regardless, the Channel 56 E-Block laboratory results demonstrate mitigation of any potential interference can be easily achieved and is certainly possible for both B and C Block operators. In fact, a B-Block licensee, whether deploying a Band 12 or Band 17 configuration, will have essentially the same deployment concerns nearby high power Channel 56 E-Block towers, i.e. 400 feet for Band 12 vs. 450 feet for Band 17 configurations and, therefore, need to coordinate placement of its B-Block towers very nearby or co-located on high power E-Block towers, regardless of Band configuration deployed within its network. Licensees operating with a B+C allocation also have the ability to mitigate any differences between a Band 12 and Band 17 configuration through co-location or placement of its towers nearby high power E-Block towers. Previous D-Block deployments in several

[2] Comments of Qualcomm Incorporated, page 45.

markets around the US were analyzed and demonstrate many of the potential tower locations for E-Block deployment are already on or nearby other CMRS towers. Therefore, the potential to impact a device would not exist or would be easily overcome in any realistic deployment targeting the same mobile population base. Additionally, should conditions on the E-Block licenses be put in place that matches the current D-Block rules; the interference potential would also be effectively eliminated.

6. In conclusion, there is no meaningful differential performance between Band 12 and Band 17 devices that can reasonably be expected to result in Harmful Interference for B, C, or B + C Block operators, i.e. the use of Band 12 devices will not impact B, C, or B + C operators in any practical way.

II. INTRODUCTION

7. As the Commission recognized in its NPRM 12-31, WT Docket No. 12-69 ("12-31");

> "…since the completion of the 700 MHz auction and the subsequent clearing of the spectrum, [however,] certain Lower 700 MHz A-Block licensees have asserted that the development of two distinct band classes within the Lower 700 MHz band has hampered their ability to have meaningful access to a wide range of advanced devices. [3] The result, they argue, is that this spectrum is being built out less quickly than anticipated (and in some cases not at all), so that a large number of Lower 700 MHz A-Block licensees are unable to provide the level of service and degree of competition envisioned at the close of the auction and as contemplated by the Communications Act. The 700 MHz band, at 70 megahertz, one of the largest commercial mobile service bands, is the only non-interoperable commercial mobile service band."

8. In addition, the Commission explained in its NPRM;

> "The record to date in response to the underlying Petition for Rulemaking reveals disagreement over the rationale for the distinct band classes, and the wisdom of maintaining both.[4] At its core, the dispute is whether a unified band class would result in harmful interference to Lower 700 MHz licensees in the B and C Blocks and whether, if harmful interference exists, it reasonably can be mitigated."

9. Further, the Commission requested in its NPRM for;

> "… interested parties to submit measurements and quantitative analysis regarding the magnitude and extent of the interference risk from adjacent Channel 51 and Lower E Block transmissions for band Class 12 devices operating in the Lower B and C Blocks".

10. Several Lower A-Block licensees[5] contracted V-COMM, L.L.C.[6], a recognized wireless engineering firm with a history of FCC participation and filings, to develop a test plan and execute tests to address the FCC NPRM inquiries. This operator group made available actual Band Class 12 devices for testing from the United States Cellular Corporation (USCC), a business partner with King Street Wireless. The ability to test actual Band Class 12 device performance and compare to Band Class 17 devices was envisioned as a key component to the group's contribution to 12-31 and the associated inquiries.

III. BAND 12 AND 17 INTEROPERABILITY TESTING

A. Test Focus

11. The interoperability testing focused on three concerns. The first concern is the potential harm to UE receiver performance due to Intermodulation (IM) products created from Channel 51 DTV signals and UE transmissions that "land" in the UE's receive band

[3] *See* 700 MHz Block A Good Faith Purchaser Alliance Petition for Rulemaking Regarding the Need for 700 MHz Mobile Equipment to be Capable of Operating on All Paired Commercial 700 MHz Frequency Blocks, filed Sept. 29, 2009 (Petition).

[4] The Petition was placed on Public Notice for comment in RM-11592. *See infra* note 26. The record in WT Docket No. 11-18 also discussed the distinct band classes and interoperability concerns in the Lower 700 MHz band. *See* Application of AT&T Inc. and Qualcomm Incorporated For Consent To Assign Licenses and Authorizations, WT Docket No. 11-18.

[5] These include Cavalier, King Street Wireless, Continuum 700, MetroPCS Communications, Inc, and Vulcan Wireless LLC.

[6] V-COMM, L.L.C. ("V-COMM") is an engineering consulting firm recognized for its expertise in wireless matters and as having a history of participating in Federal Communications Commission proceedings. Appendix F in Section XIII hereto provides additional information on V-COMM.

within the device itself. This particular type of IM will be referenced as “Reverse PA IM”. The second concern is the potential harm to UE receiver performance that can occur from high-power broadcasts operating in the E-Block (722-728 MHz) whose adjacent channel energy may result in blocking of desired signals in the UE. The third concern is the potential harm to UE receiver performance from Intermodulation (IM) products created from high-power E Block signals and UE transmissions that ”land” in the UE’s receive band within the device itself. The E-Block concerns will be collectively referenced as “E Band Blocking and IM”. For reference, the 700 MHz Band Plan is included in Figure 1.

12. For Reverse PA IM, the focus was on the frequency combination(s) with Channel 51 that would result in IM products landing in the receive band of the device. Mathematical IM calculations demonstrate that IM resulting from Channel 51 can occur only where a wireless licensee operates on a 5 MHz C Block carrier or a 10 MHz B+C Block carrier as part of a single system. Therefore, the testing focused on both a C licensee operating a 5 MHz LTE carrier as well as B+C licensee operating a 10 MHz LTE carrier across both blocks.

13. For E Band Blocking and IM, the focus was twofold; the first focused on how much adjacent channel energy encumbers the receive band of the device, while the second focused on how much adjacent channel energy AND energy from IM products encumber the receive band of the device. The primary concern examined is whether Channel 56 E-Block signal levels would have a greater impact on a Band 12 device than a Band 17 device. When the Band 17 (then Band 15) was originally considered by 3GPP in 2008, the Band 12, A-Block operations were directly adjacent to the E-Block. Subsequently, in 2010, a 1 MHz internal guard band was introduced to provide 1 MHz of internal guard band within the Lower A-Block spectrum (Channel 57 and Channel 52), while still allowing for a 5 MHz wideband carrier. The Band 12 devices tested reflect this internal guard band configuration. Since the identified concern is the impact on B, C, or B+C block operations, testing of all devices again focused on operations in the B, C, and B+C blocks.

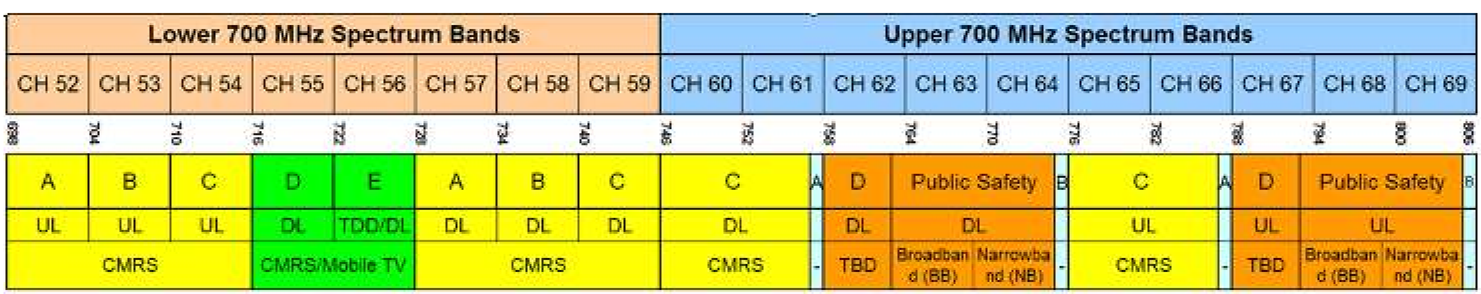

Figure 1 - 700 MHz Band Plan

14. For the purposes of test analysis, e.g. establishment of a baseline performance for the UE, device sensitivity (DEVSENS) tests were completed on each device to be evaluated. The DEVSENS establishes the baseline performance of the device prior to introducing the interfering signals and allows for the analysis and quantification impact on performance.

B. Test Devices

15. Seven (7) devices were available for testing; three Band 12 devices and four Band 17 devices.

16. Table 1 below lists the devices under test, along with their respective band class and device type. All devices were visually inspected, verified 100% operational, and fully charged prior to testing. The breakdown of devices consisted of four smartphones, two dongles and one MIFI. The dongle devices were powered by computer laptop, and were installed with the associated software programs to make them operational. The MIFI device was powered by a power supply.

Devices Under Test		
Name	**Band**	**Device Type**
Device A	17	Smartphone
Device B	17	Smartphone
Device C	17	Smartphone
Device D	12	Smartphone
Device E	12	Dongle
Device F	12	MIFI
Device G	17	Dongle

Table 1 - Devices Under Test

C. Test Laboratory and Equipment

17. The United States Cellular Corporation (USCC) test facility in Chicago, Illinois was made available for the execution of the tests. This facility is a shielded facility and included the necessary equipment to execute the tests envisioned. All test components were confirmed to be within their calibration periods and recorded. There were some test components that had to be acquired specifically for the testing including filters, cabling, and connectors. The test facility and test equipment details are included in the Appendix A in Section VIII below.

IV. DEVICE SENSITIVITY (DEVSENS) TEST

18. The device sensitivity (DEVSENS) test was completed to establish a downlink performance baseline for each device under test (DUT). Each test was done with the equipment configuration of Figure 39 in Section VIII.

19. The results of the test across all devices are documented in Table 2 below. The results were within specification per the 3GPP standards. Each device was tested at minimum power and while transmitting under full power; this confirmed that the devices operated consistently across these conditions. The differential in device sensitivity while transmitting at minimum power and full power is reflected in the "delta" row. In addition, the tests were conducted across the three (3) modulation schemes (QPSK, 16 QAM, and 64 QAM) the devices are capable of receiving as specified within 3GPP.

20. The procedure for each test was to establish the received power threshold at which the device achieves a 5% block error rate (BLER) (e.g. 95% throughput) per the 3GPP standards performance definitions. The LTE Emulator test equipment also established a link communication with the UE as though it was an actual site in the real-world LTE deployment. The LTE Emulator test equipment was set to ensure the modulation scheme was maintained as well as the UE devices transmit power was set to full power (+23 dBm) during

each of the tests. In addition, the LTE Emulator supplied the continuous uplink and downlink data stream to ensure that the UE was constantly transmitting/receiving at the maximum bit rate at each of the set modulation schemes. The LTE Emulator test equipment acted as a monitor and provided BLER performance of the UE device.

21. The results in the +23 dBm row across all devices and all modulation schemes provide the baseline for comparison of the interference testing completed and described below.

Device Sensitivity (DevSENS)	Device A			Device B			Device C			Device D		
	Band 17			Band 17			Band 17			Band 12		
	QPSK	16QAM	64QAM	QPSK	16QAM	64QAM	QPSK	16QAM	64QAM	QPSK	16QAM	64QAM
5 MHz (B Band DevSENS)												
No Power	-100.8	-91.4	-76.0	-99.9	-90.6	-75.9	-100.3	-91.1	-74.6	-101.0	-91.7	-77.0
Full Power (+23 dBm)	-100.8	-91.4	-76.0	-98.1	-88.9	-74.1	-100.2	-90.9	-74.2	-100.1	-90.8	-76.9
Delta	0.0	0.0	0.0	1.8	1.7	1.8	0.1	0.2	0.4	0.9	0.9	0.1
5 MHz (C Band DevSENS)												
No Power	-100.7	-90.6	-76.0	-100.1	-90.8	-76.0	-100.6	-91.2	-74.8	-100.5	-91.2	-77.0
Full Power (+23 dBm)	-100.6	-91.2	-75.7	-97.8	-88.5	-73.7	-100.3	-91.0	-74.4	-100.1	-90.8	-76.5
Delta	0.1	0.6	0.3	2.3	2.3	2.3	0.3	0.2	0.4	0.4	0.4	0.5
10 MHz (B&C Band DevSENS)												
No Power	-98.4	-89.9	-79.6	-97.7	-89.3	-79.0	-98.1	-89.7	-79.4	-98.8	-90.3	-80.3
Full Power (+23 dBm)	-98.1	-89.7	-79.4	-96.0	-87.6	-77.4	-98.1	-89.6	-79.3	-98.3	-90.0	-79.9
Delta	0.3	0.2	0.2	1.7	1.7	1.6	0.0	0.1	0.1	0.5	0.3	0.4

Device Sensitivity (DevSENS)	Device E			Device F			Device G		
	Band 12			Band 12			Band 17		
	QPSK	16QAM	64QAM	QPSK	16QAM	64QAM	QPSK	16QAM	64QAM
5 MHz (B Band DevSENS)									
No Power	-101.9	-92.6	-77.9	-100.4	-91.1	-75.7	-101.5	-92.0	-80.9
Full Power (+23 dBm)	-100.9	-91.5	-76.9	-100.2	-90.9	-75.5	-101.4	-91.9	-80.8
Delta	1.0	1.1	1.0	0.2	0.2	0.2	0.1	0.1	0.1
5 MHz (C Band DevSENS)									
No Power	-101.1	-91.8	-77.2	-99.9	-90.6	-75.9	-101.6	-92.1	-80.9
Full Power (+23 dBm)	-101.0	-91.7	-77.0	-99.3	-90.0	-75.5	-101.4	-92.0	-80.8
Delta	0.1	0.1	0.2	0.6	0.6	0.4	0.2	0.1	0.1
10 MHz (B&C Band DevSENS)									
No Power	-99.0	-90.5	-80.2	-97.5	-89.1	-78.8	-99.1	-90.6	-80.2
Full Power (+23 dBm)	-98.9	-90.4	-80.1	-97.4	-88.9	-78.5	-99.0	-90.6	-80.1
Delta	0.1	0.1	0.1	0.1	0.2	0.3	0.1	0.0	0.1

Table 2 - DEVSENS Test Results for Band 12 and Band 17 Devices

V. CHANNEL 51 REVERSE POWER AMPLIFIER INTERMODULATION ANALYSIS

22. The Channel 51 case studies, using the test results from Band 12 and Band 17 devices, reveal that the potential for harmful interference due to Band 12 vs. Band 17 operation is effectively non-existent. The Case Study evaluated each Channel 51 licensed operator in the CONUS, using the actual station transmission parameters. Of the 26 Channel 51 facilities studied, only 8 can theoretically exceed worst-case signal strength conditions, and these areas are limited to within a very close radius (i.e. 450 m or less)[7] of the tower. With the application of reasonable and realistic Radio Frequency design assumptions and real-world conditions (clutter losses, customer usage patterns, application loading requirements), the potential for harmful interference is effectively eliminated altogether. Moreover, actual Channel 51 DTV signal strengths were measured in the field from select towers with a variety of receive antenna polarizations (horizontal, slant and vertical). The data from the field tests exhibits that the number of points where signals exceed the Band 12 device threshold is statistically insignificant, and consequently establishes that there will be no real-world interference concerns from Reverse PA IM.

A. Test Set-up

23. The Reverse PA IM testing documents the performance of the devices in the presence of a strong Channel 51 transmitter. Each test was done with the equipment configuration of

24. Figure 40 in Section VIII. For each test, data was taken for 1 dB (worst-case), 3 dB, 10dB, and 30 dB rise in noise floor to see how the impact changes as the desired signal is increased. Mathematical IM calculations reveal that Channel 51 combined with C-block can have products which in turn land in the receive band of the device. Therefore, the testing focused on a 10 MHz B+C carrier, as well as a 5 MHz C-Block carrier.

B. Channel 51 Reverse PA IM Test Results

25. The results for the 10 MHz B+C Block for both Band 17 and Band 12 devices are documented in Figure 2. The results for the 5 MHz C-Block for both Band 17 and Band 12 devices are documented in Figure 3. They demonstrate that the potential for harmful interference, when operating with a Band 12 device as opposed to Band 17 configuration, is effectively non-existent for both cases, B+C licensees as well as C-only licensees. Analysis of these two charts shows that the Band 12 devices performed comparably, and sometimes better than, Band 17 devices. For the 10 MHz B+C carrier, the worst-case Band 17 device was impacted at -1 dBm, while the Band 12 device was impacted at -13 dBm. For the 5 MHz C-only carrier, the worst-case Band 17 device was impacted at +6.6 dBm while the worst-case Band 12 device was impacted at -8 dBm. All of these signal levels are very high and would not be levels expected to be found over a large area, if at all. Although a 12 dB differential in absolute terms, the case study detailed in Section V.C below documents no pragmatic performance impacts in real-world scenarios.

[7] It should be noted that this maximum radius is based on a conservative model, and **not** actual field test data. In the field, as noted below, signal strength rarely if ever gets to levels that would exceed Band 12 device thresholds.

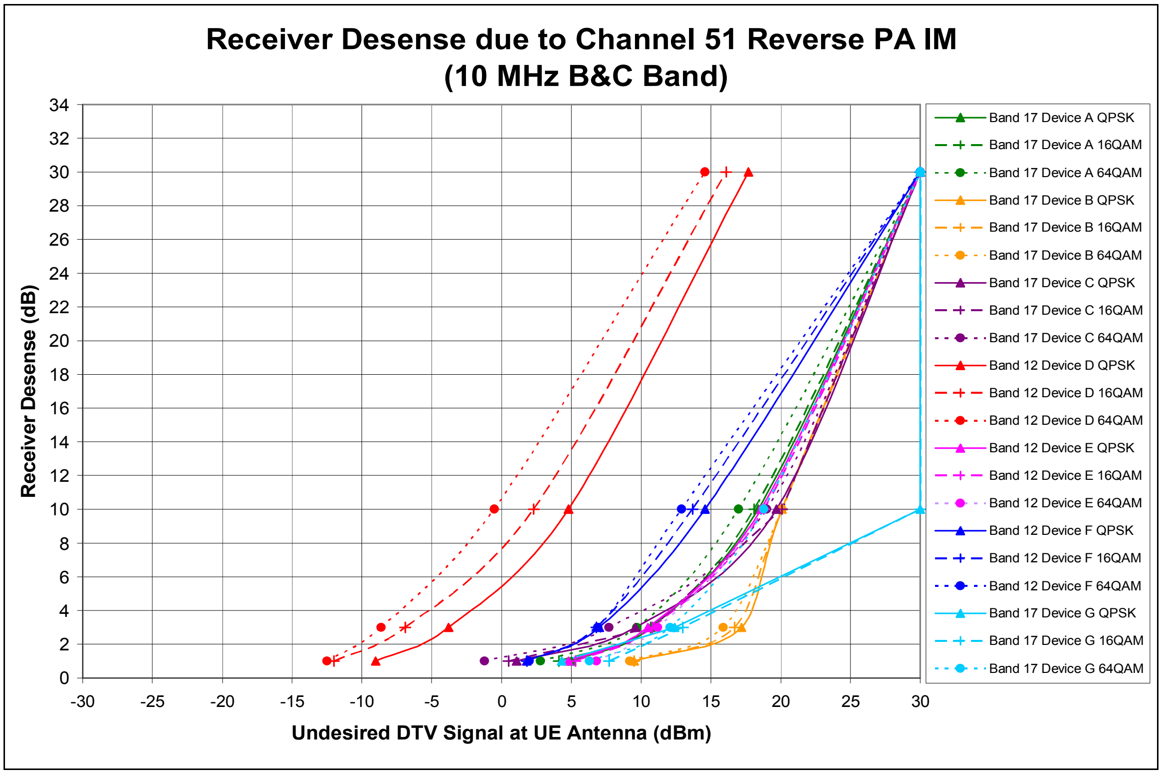

Figure 2 – 10 MHz B+C Block Reverse PA IM Results Chart

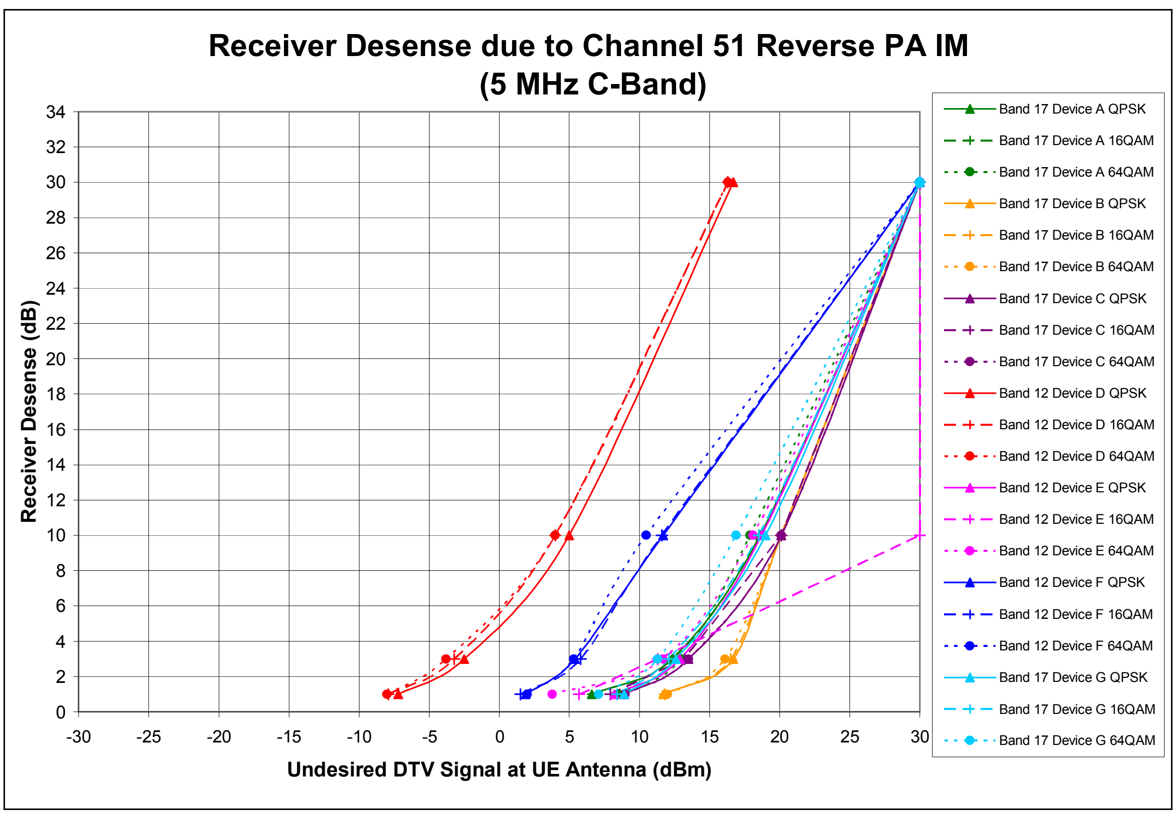

Figure 3 – 5 MHz C-Block Only Reverse PA IM Results Chart

C. Reverse PA IM Case Study

26. Comparison of Band 12 and Band 17 device operation reflects that any difference in performance is either non-existent or negligible, as demonstrated below. The signal strength from the interferer which have to be received (greater than -12.5 dBm) by the devices, at 1 dB desense (worst-case) are extremely high, even for high-power broadcasters. The practical impact of these received signal levels was further analyzed.

27. *The Channel 51 Geography* – Across the entire CONUS, there are 26 Channel 51 licensed stations, as listed in Table 3. Two of these stations have plans to relocate to different channels[8]. In Figure 4, the locations of the remaining 24 licensed stations are mapped, and those stations that are currently licensed for the maximum (1 MW) power are identified with orange dots. These locations would be more likely to produce levels on the ground (greater than -12.5 dBm) that may have the potential to impact performance.

Callsign	City	State	ERP	Latitude	Longitude	Antenna Height
KPPX-TV	TOLLESON	AZ	210. kW	33-20-3 N	112-3-38 W	533 m
KDTV-DT	SAN FRANCISCO	CA	476.3 kW	37-29-57 N	121-52-16 W	701 m
KXLA	RANCHO PALOS VERDES	CA	1000. kW	34-13-35.3 N	118-3-57.7 W	937 m
KCEC	DENVER	CO	900. kW	39-43-58 N	105-14-8 W	232.5 m
WHLV-TV	COCOA	FL	1000. kW	28-35-12 N	81-4-58 W	494 m
WBIF	MARIANNA	FL	50. kW	30-30-42 N	85-29-17 W	254 m
WPXA-TV	ROME	GA	1000. kW	34-18-48 N	84-38-55 W	622 m
WSST-TV	CORDELE	GA	91. kW	31-53-35 N	83-48-18 W	110 m
WPWR-TV	GARY	IN	1000. kW	41-52-44 N	87-38-10 W	523 m
WMYO	SALEM	IN	1000. kW	38-21-0 N	85-50-57 W	390.4 m
KGAN	CEDAR RAPIDS	IA	850. kW	42-18-59 N	91-51-30 W	585 m
WAGV	HARLAN	KY	550. kW	36-48-0 N	83-22-36 W	577 m
WLAJ	LANSING	MI	900. kW	42-25-13 N	84-31-25 W	300 m
KPXE-TV	KANSAS CITY	MO	1000. kW	39-1-20 N	94-30-49 W	339 m
KFXL-TV	LINCOLN	NE	14. kW	40-51-10 N	96-40-36 W	125 m
WNJN	MONTCLAIR	NJ	200. kW	40-51-53 N	74-12-3 W	233 m
WFMY-TV	GREENSBORO	NC	1000. kW	35-52-13 N	79-50-25 W	568.8 m
WEPX-TV	GREENVILLE	NC	114. kW	35-24-9 N	77-25-10 W	140 m
WKEF	DAYTON	OH	515. kW	39-43-28 N	84-15-18 W	351 m
KSBI	OKLAHOMA CITY	OK	1000. kW	35-35-52 N	97-29-22 W	457.9 m
KOHD	BEND	OR	84.1 kW	44-4-40.6 N	121-19-56.9 W	205.7 m
WTAE-TV	PITTSBURGH	PA	1000. kW	40-16-49 N	79-48-11 W	273 m
WJAR	PROVIDENCE	RI	1000. kW	41-51-54 N	71-17-15 W	306 m
WPXX-TV	MEMPHIS	TN	1000. kW	35-12-41 N	89-48-54 W	298 m
KCEB	LONGVIEW	TX	500. kW	32-15-36 N	94-57-2 W	379 m
KTFN	EL PASO	TX	250. kW	31-48-19 N	106-28-59 W	525.3 m

Table 3 - List of Channel 51 Licensed Transmitters

[8] Both the Greenville, NC station (WEPX-TV) and the Lincoln, NE station (KFXL-TV) already have plans to relocate to a different channel.

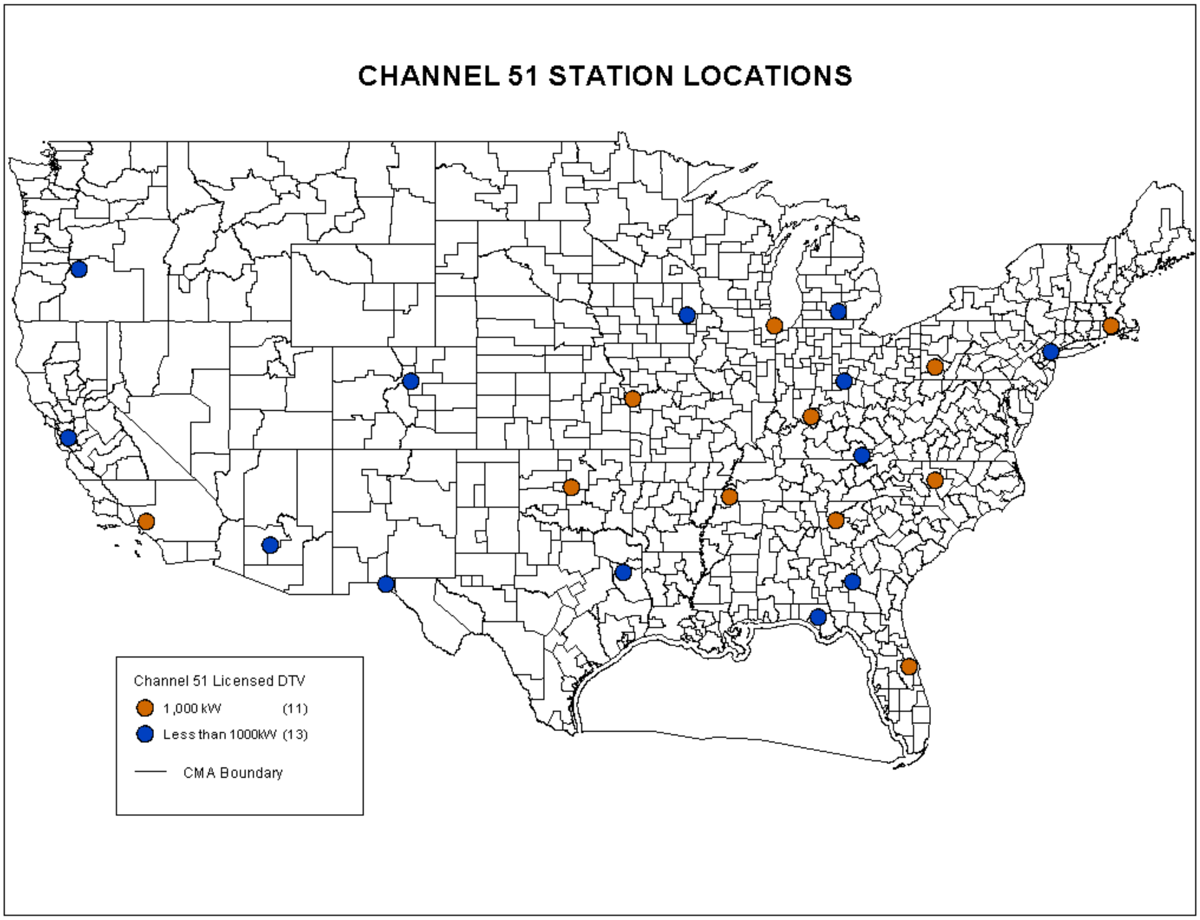

Figure 4 - Channel 51 Licensed Station Locations across the United States

28. *Channel 51 Antenna Analysis* – The transmitter characteristics of every Channel 51 station was identified using the information available via the FCC. The actual DTV antenna patterns (vertical patterns) being used for twenty-one (21) of the sites were obtained and input into the Case Study model. For the remaining five (5) sites for which vertical patterns were not available, a vertical antenna pattern with similar gain and downtilt characteristics was applied. Application of the antenna patterns is critical to the analysis as it is quite reasonable to assume that the high-power broadcaster does NOT direct energy to the ground, but instead to the horizon to realize the protected coverage area (55 miles) around the site. The use of the actual antenna patterns confirms that assumption.

29. *Channel 51 Potential Interference Modeling* - A line-of-sight (LOS) model was applied to calculate the energy from the TV transmitter that could reach the ground using the actual Channel 51 antenna patterns. This analysis was executed across ALL Channel 51 stations. Due to the number of stations, the results were broken down into two charts as shown in Figure 5 and Figure 6 below. In both figures, potential interference impact lines were drawn horizontally across the figure for each of the devices. A vertical line showing where any of the Channel 51 signal levels exceeded the device threshold was additionally applied, and extended the line to the area of impact. In Figure 5 it can be seen that only the Band 12 worst-case device ("device D") performance threshold is exceeded, and only for 5

TV stations. The maximum distance of these 5 stations is at 1476 ft (450m)[9] away from the transmitter for the Cedar Rapids, IA station. In Figure 6, it can be seen that only the Band 12 worst-case device ("device D") performance threshold is exceeded, and only for 3 TV stations. The maximum distance of these 3 stations is at 1230 ft (375m) away from the transmitter for the Cocoa, FL station.

30. Therefore, across all stations, two of the Band 12 devices showed no interference potential. In fact, only eight (8) total stations even posed a "potential" for device performance impact when employing a 10 MHz B+C carrier. Of these eight stations, only two (2) would also affect a 5 MHz C-only market.

31. The use of the LOS model means there are no additional losses and subsequent reduction in received energy by the user equipment (UE), from factors such as morphology and antenna polarization. Therefore, these small areas in the real-world scenario would be effectively eliminated altogether.

[9] It should be noted that this maximum radius is based on a conservative model, and **not** actual field test data. In the field, as noted below, signal strength rarely if ever gets to levels that would exceed Band 12 device thresholds.

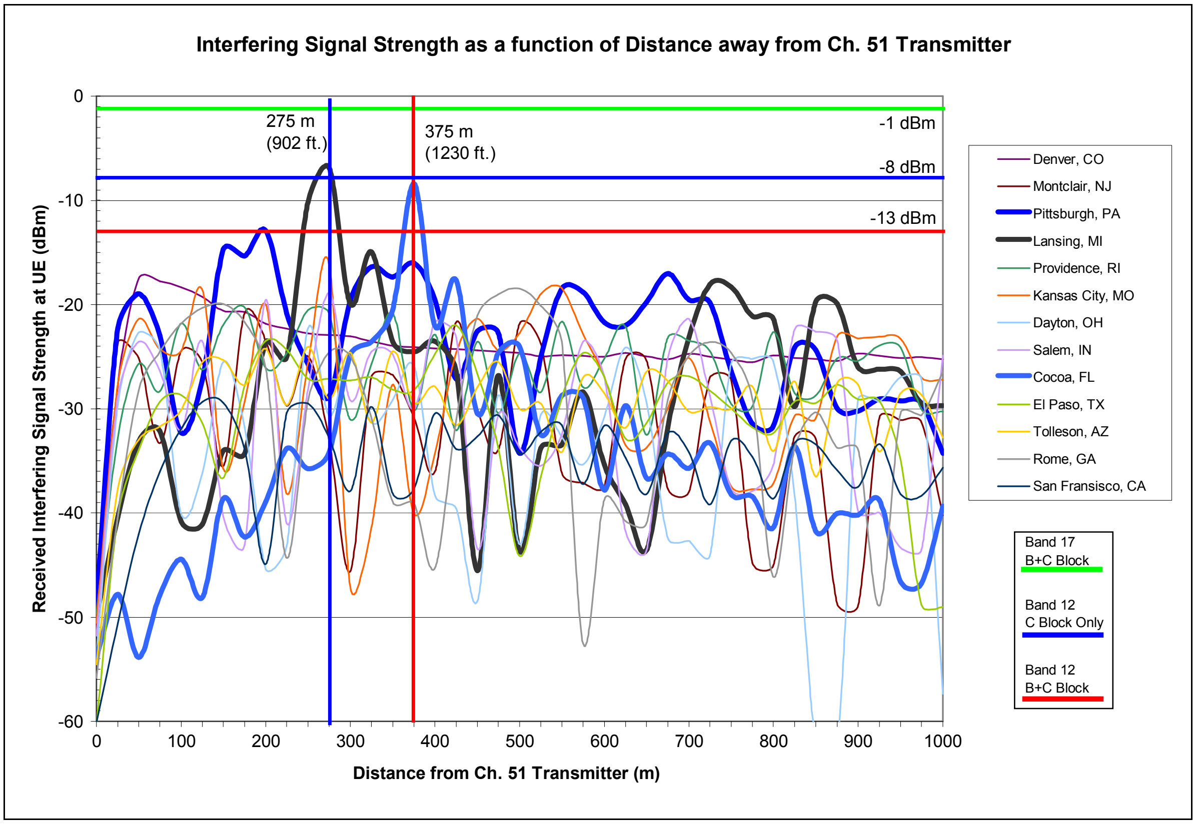

Figure 5 - Channel 51 Impact on Device Performance Area Analysis (Chart 1 of 2)

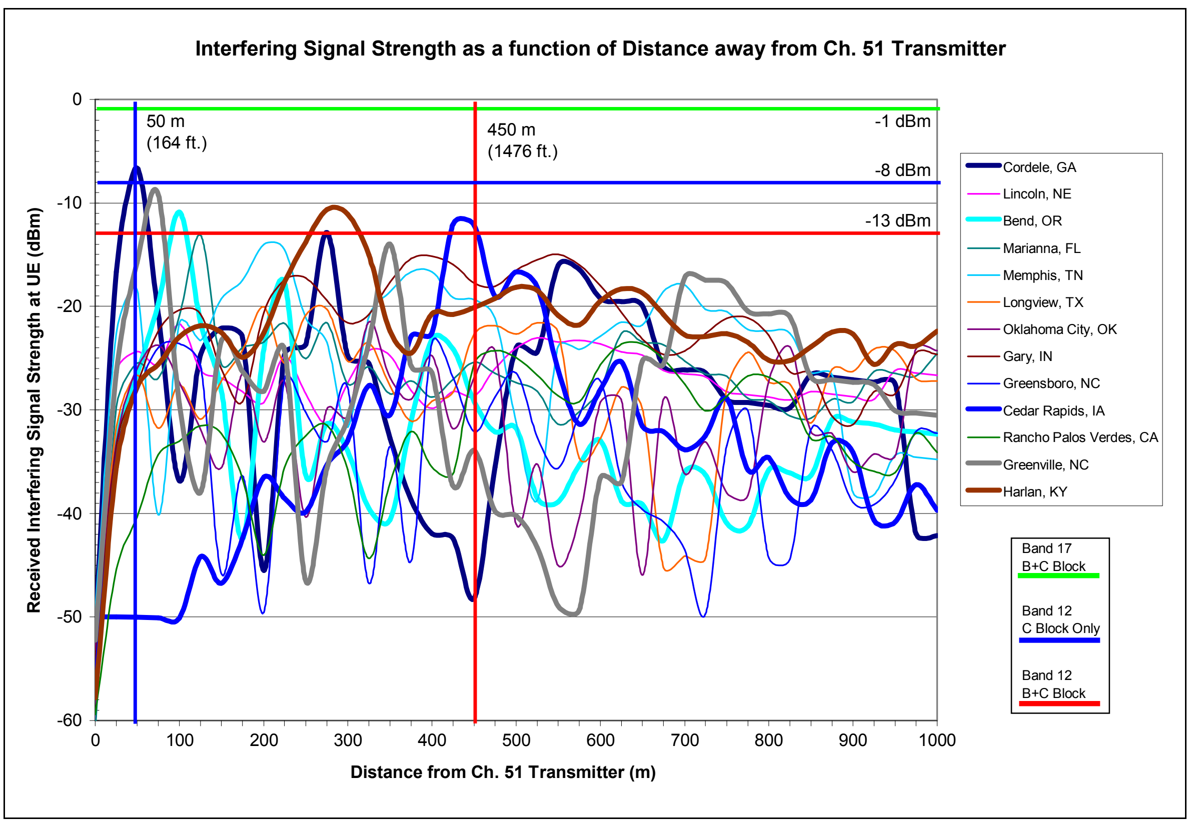

Figure 6 - Channel 51 Impact on Device Performance Area Analysis (Chart 2 of 2)

32. *Channel 51 Site Specific Analysis* – The next step in the case study was to use the results of the graphic analysis, apply across the eight stations identified with a "potential" interference impact, and document the area within a Google Earth map window. Once again, this analysis is based on theoretical, conservative calculations and not on actual real-world test data. Real-world Channel 51 signal levels high enough to exceed Band 12 device thresholds for Reverse PA IM are effectively non-existent. Two of those maps have been included below in Figure 7 and Figure 8. The remaining can be reviewed in Figure 45 through Figure 50 in Appendix C Section X below. It should be noted that, in all of the below map figures, the area of "potential" interference is not perfectly round due to terrain roll-off in the area of some sites.

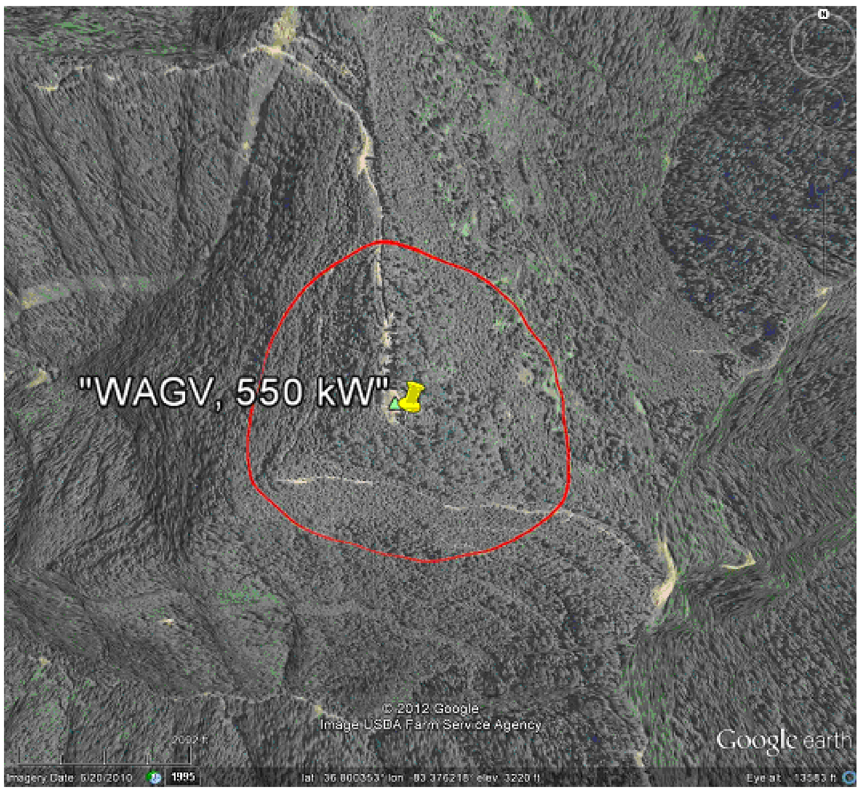

Figure 7 - Harlan, KY (WAGV) Area of Potential Interference

33. The Harlan, KY WAGV station location is located on a remote hilltop away from any development and is more reflective of a classic broadcast location. There is virtually no "potential" of interference. Figure 7 above depicts the Harlan, KY WAGV "potential" interference area.

- Worst-case Reverse PA IM occurs at 300 m (984 ft.)[10]
- Affected Area: 0.283 sq. km (0.109 sq. mi.)
- Percent of DTV Footprint: 0.00115 %

[10] It should be noted that this maximum radius is based on a conservative model, and **not** actual field test data. In the field, as noted below, signal strength rarely if ever gets to levels that would exceed Band 12 device thresholds.

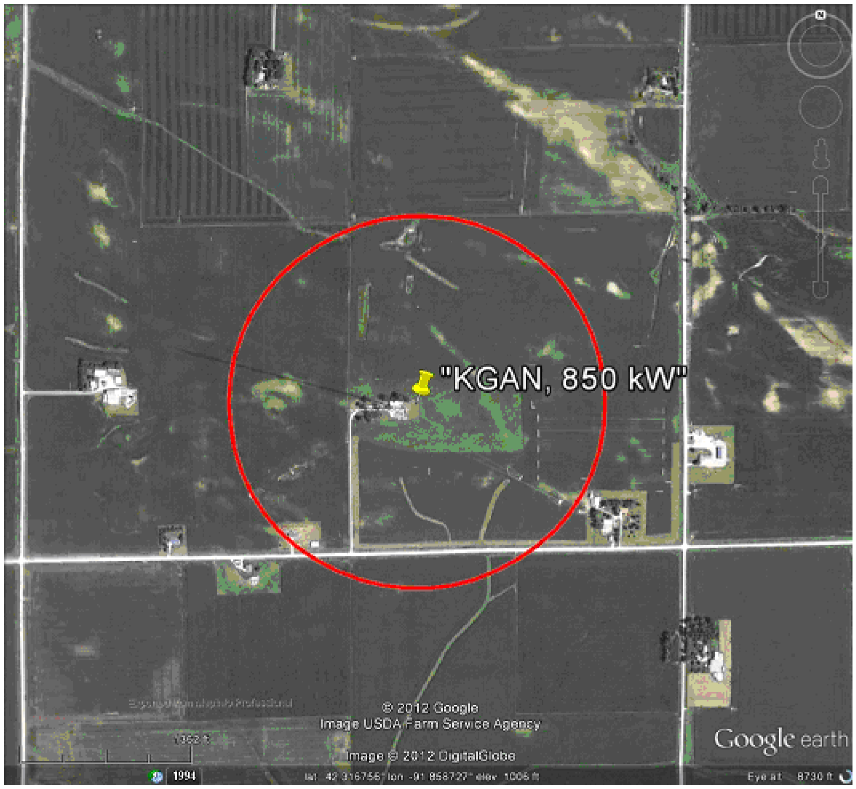

Figure 8 - Cedar Rapids, IA (KGAN) Potential Area of Interference

34. The Cedar Rapids, IA KGAN station location has the largest area of "potential" interference at 1476' in Figure 5. However, the site is in a very low-density, rural setting. Figure 8 depicts the Cedar Rapids, IA KGAN "potential" interference area.

- Worst-case Reverse PA IM occurs at 450 m (1476 ft.)[11]
- Affected Area: 0.636 sq. km (0.246 sq. mi.)
- Percent of DTV Footprint: 0.00258 %

35. In review of the figures above, and the figures of Appendix C, a percentage area in relation to the overall DTV protected area of 55 mile radius has been included. It should be noted that even the areas of "potential" interference are miniscule (less than 0.005%) in comparison to the overall Grade B coverage area.

36. In practice, design engineers will design the network to have "on-street" coverage at levels much higher than DEVSENS to overcome fading and other system margins. Therefore, the area of "potential" performance impact in comparing a Band 12 device to a Band 17 device is limited to the cell edge, or to those areas where desired signal strength is low. Were a typical link budget applied, all 8 of these "potential" interference areas would

[11] It should be noted that this maximum radius is based on a conservative model, and **not** actual field test data. In the real-world, as noted below, signal strength rarely if ever gets to levels that would exceed Band 12 device thresholds.

no longer exist. Additionally, the desense scenario tested happens when all C Block RBs on the Uplink and all 50 RBs on the Downlink are allocated to one user, a scenario that would only occur for an extremely limited set of applications. Furthermore, the “potential” impact of Reverse PA IM interference is limited to only 5.6% of the RBs[12]. In summation, the already miniscule potential interference area has no practical chance of occurring in a real-world situation.

37. *Channel 51 Field Test Analysis* – In order to obtain real-world Channel 51 signal strength data, V-COMM performed drive tests of various Channel 51 transmitters in different environments. Measurements were taken in areas around the Cedar Rapids, IA; Chicago, IL; and Montclair, NJ Channel 51 DTV transmitters. Data was taken through three different antenna polarizations (horizontal, vertical, slant), to characterize the effects that polarization had on received signal strength. The worst-case antenna that produced the highest signal levels are displayed in the maps below. Additionally, the test route was located in publicly accessible locations within 1 km of the transmitter, where the signal strength would be the highest.

38. The first Channel 51 DTV transmitter that was field tested was the Cedar Rapids, IA transmitter. The results of the drive test are shown below in Figure 9. The map is thematically colored to show points where the signal strength exceeded the Band 12 device limitation of -13 dBm. From this test, it can be concluded that the areas where the DTV signal strength exceeds the device threshold are statistically insignificant, and therefore would not cause harmful interference.

[12] Vulcan, et. al. Table 5.1

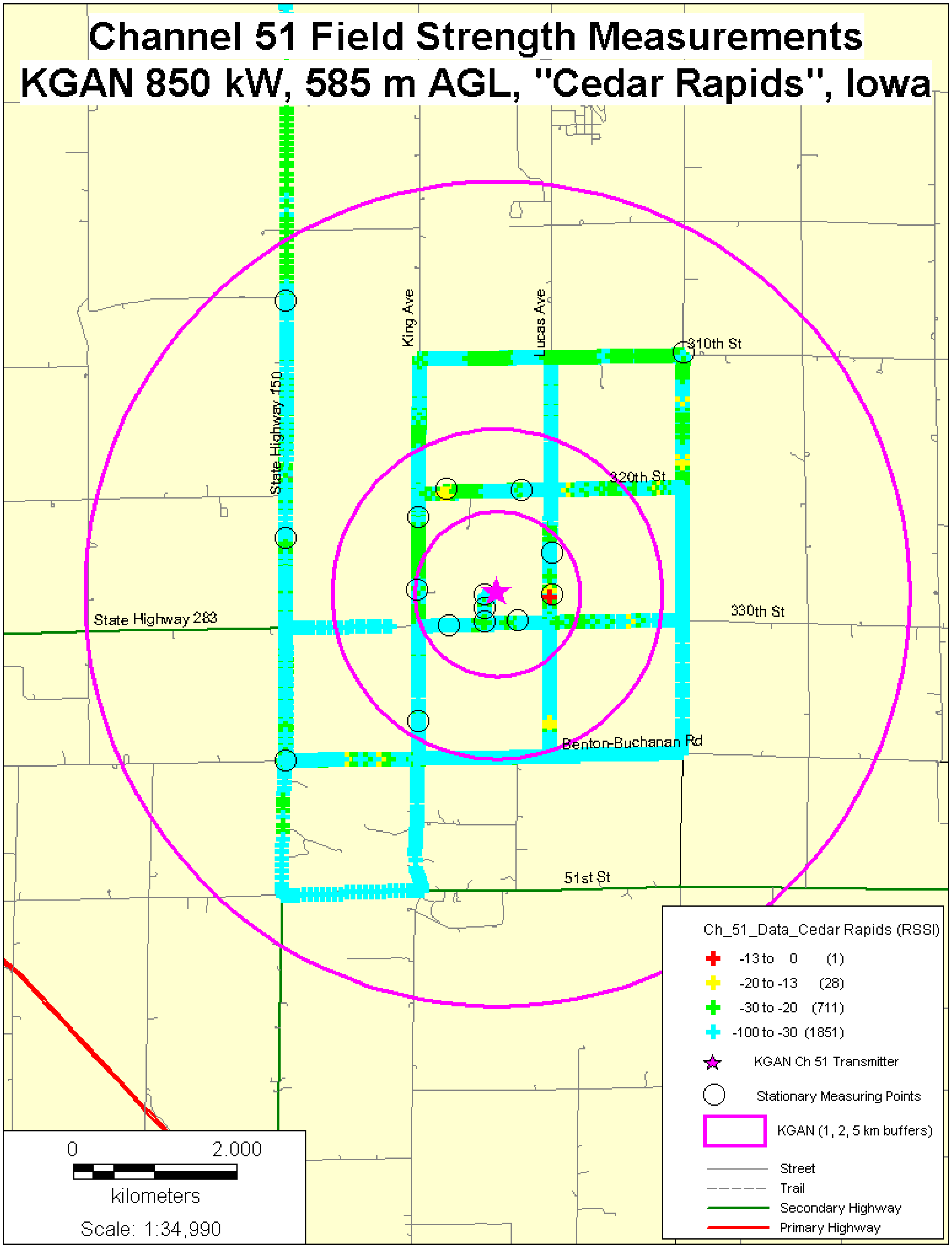

Figure 9 - Cedar Rapids, IA Channel 51 Drive Test Results Map

39. The second Channel 51 DTV transmitter that was field tested was the Montclair, NJ transmitter. The results of the drive test are shown below in Figure 10. The map is thematically colored to show points where the signal strength exceeded the Band 12 device limitation of -13 dBm. From this test, it can be concluded that there are no areas where the DTV signal strength is greater than the device threshold, and therefore would cause harmful interference.

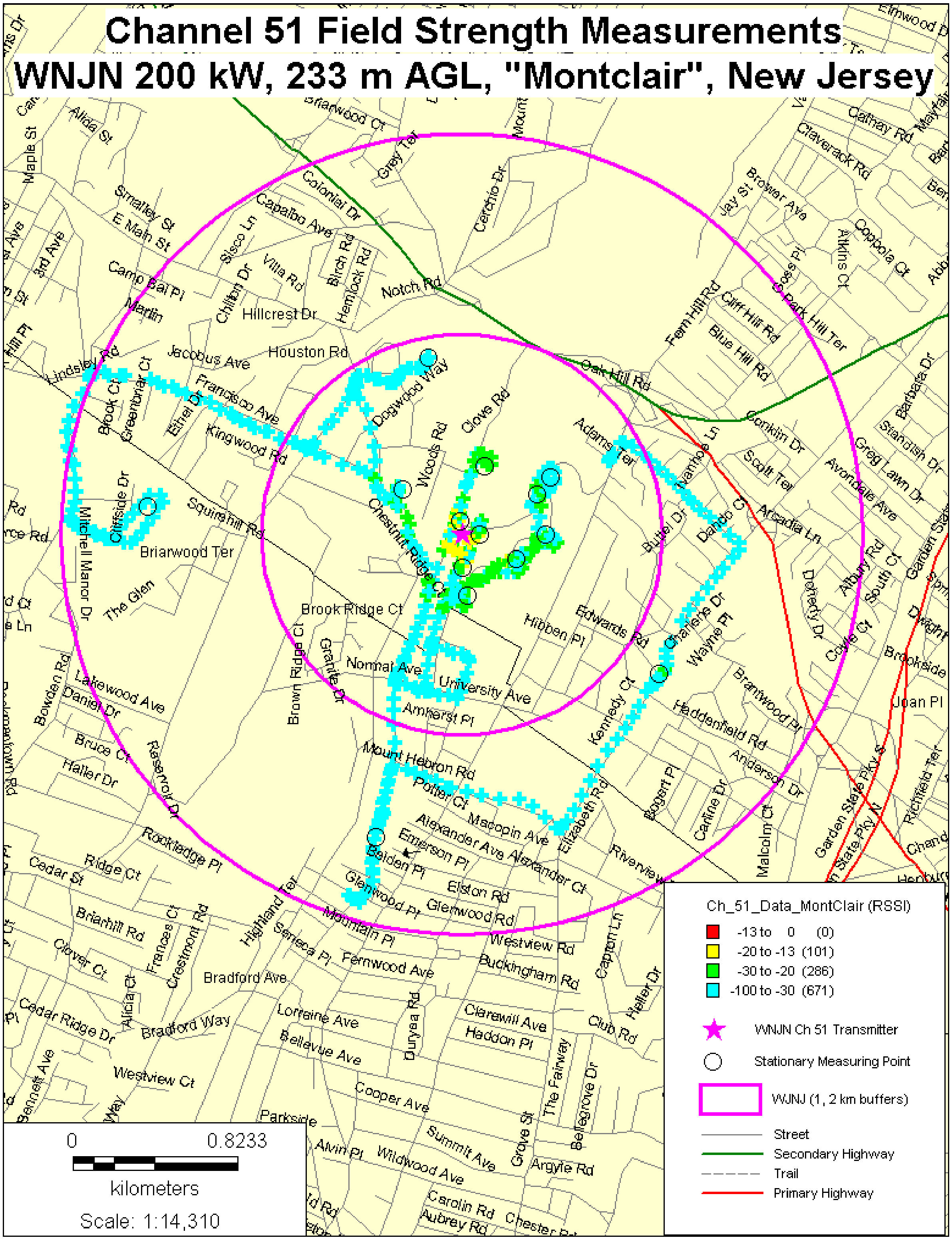

Figure 10 - Montclair, NJ Channel 51 Drive Test Results Map

40. The final Channel 51 DTV transmitter that was field tested was the Chicago, IL transmitter. The results of the drive test are shown below in Figure 11. The map is thematically colored to show points where the signal strength exceeded the Band 12 device limitation of -13 dBm. From this test, it can be concluded that the areas where the DTV signal strength exceeds the device threshold are statistically insignificant, and therefore would not cause harmful interference.

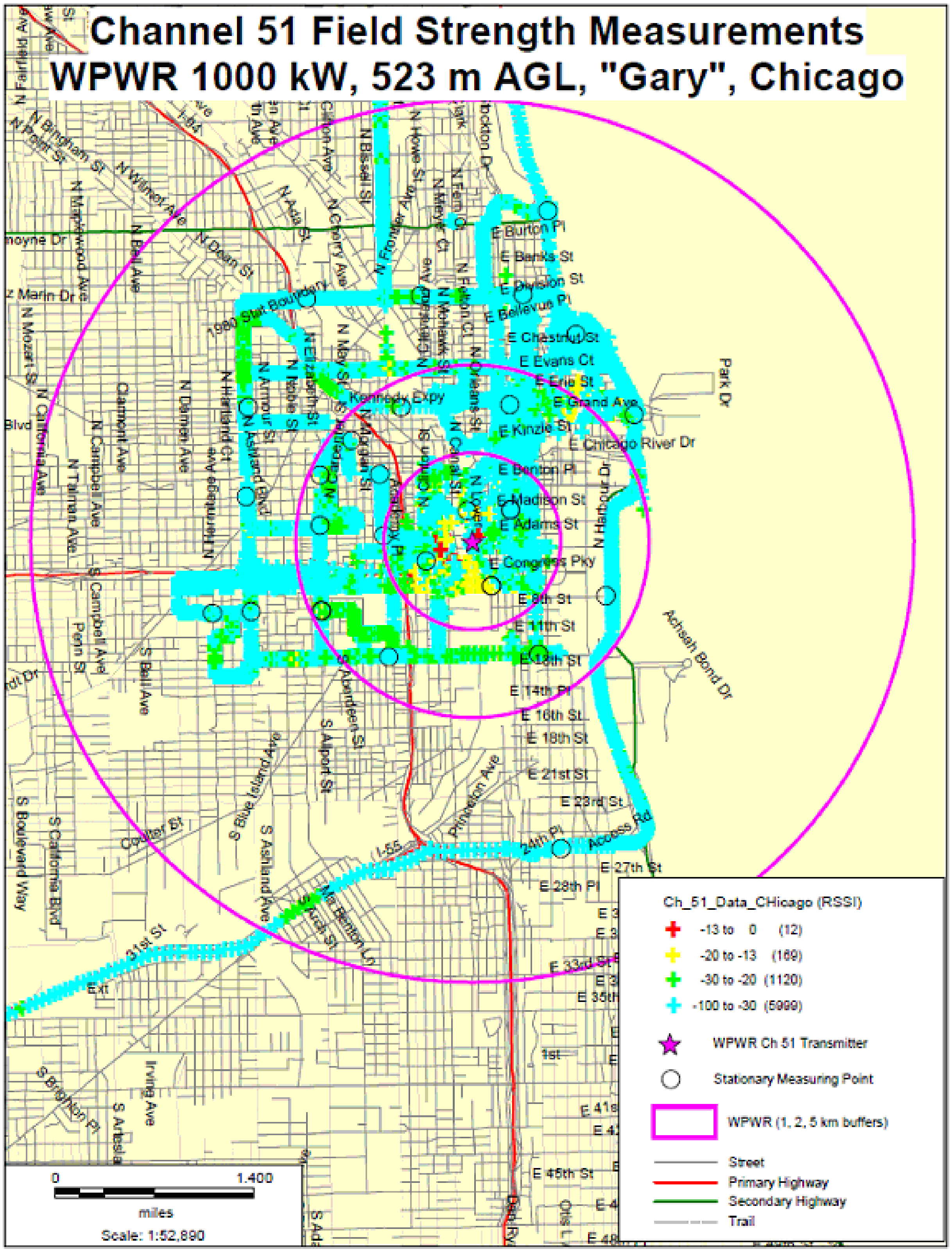

Figure 11 – Chicago, IL Channel 51 Drive Test Results Map

41. In previously filed documents[13], Longley-Rice propagation maps were submitted that showed ranges of strong signal strength (0 to -10 dBm) extending out several km from the DTV transmitter. There are numerous flaws in this analysis, from which one can draw the conclusion that this analysis greatly over-predicts the actual signal strength from the transmitter. The first flaw with this analysis is that the Longley-Rice model is not a reliable propagation model within 1 km of the transmitter. This therefore cannot and should not be used to model short range propagation. The second flaw with this analysis is that the receive height of 1.5 m that is described in the verbiage of the paper[14] does not correspond to the results that are displayed in the maps. V-COMM performed spot checks of DTV signal level from the dtv.gov website, and the signal strengths displayed in the analysis correspond almost perfectly to the dtv.gov website. The problem here is that the dtv.gov website uses a 10 m receive antenna height, which is indicative of a rooftop antenna. This flaw can also be confirmed by the screenshot of the propagation model[15], where it clearly shows a receive antenna height of 10 m. This large discrepancy between receive antenna heights will skew signal strength values, making them appear much greater than what is actually received by a hand-held device at 1.5 m above ground.

42. Because the Longley-Rice propagation model is unreliable at distances within 1 km of the transmitter, and because signal strength within 1 km of the transmitter would intuitively be the strongest, V-COMM has implemented a conservative Line-of-Sight (LOS) model with which to predict the signal strength. The LOS model is a more conservative model than the actual field data because it does not take into account losses due to clutter, terrain, shadowing, or fading. Thus, the LOS model was implemented to provide a "worst-case" analysis.

43. In summation, no practical difference in performance of a Band 17 and a Band 12 device exists. The case study implemented above uses a conservative, worst-case modeling approach to identify only five (5) interference circles of radius less than 450 m around DTV transmitters could even theoretically exist throughout the entire CONUS, with a total affected population of 1-4 households. Moreover, the field data measured within close proximity of the DTV transmitters and across multiple antenna polarizations effectively eliminates all five of these theoretical interference areas, showing only 13 out of tens of thousands of points exceed the Band 12 threshold. Additionally, previously submitted analyses are invalid, insofar as they do not use a reliable method to calculate short-range propagation, nor do they take into account the correct value for receive antenna height.

44. *Waterloo, IA Market Test* – Currently, the United States Cellular Corporation (USCC) is operating an active, on-air LTE network in the Waterloo-Cedar Falls, IA (CMA201) market. This market is in the vicinity of the Cedar Rapids, IA Channel 51 DTV transmitter. The network was originally running on a 5 MHz B-Block carrier, which is owned by their partner, King Street Wireless. However, USCC also owns the rights to the C-Block in the Waterloo-Cedar Falls, IA market. Therefore, this presents an opportunity to test the real-world impact of Channel 51 DTV signal on Band 12 UE's across all deployment

[13] Comments of Qualcomm Incorporated, pages 43-52

[14] Id. Page 45

[15] Id. Page 44

scenarios.

45. V-COMM acted in close coordination with USCC on these activities so as to include the results and analysis in this report. The analysis of the testing data below confirms that their network performance is not impacted by Channel 51 Reverse PA IM, over a wide variety of interfering / desired signal strength conditions. Qualcomm has asserted[16] that signal strengths from -20 to -30 dBm are high enough to significantly affect a Band 12 LTE network, and would result in degraded performance. As can be seen from the below analysis, the signal strength is within or above this range at many points along the drive test route, and yet the performance of the network, in all of the different configurations, was not adversely impacted by Channel 51 Reverse PA IM.

46. The Channel 51 signal strength was first evaluated within the Waterloo-Cedar Falls, IA market. In accordance with OET 69, V-COMM created a Longley-Rice plot of the DTV transmitter using the antenna characteristics as specified in the FCC database. The coverage analysis and drive test route is shown below in Figure 18 As can be seen, the Waterloo-Cedar Falls, IA market is approximately 10 mi. from the Channel 51 transmitter, and signal strengths within the market can exceed Band 12 interference thresholds (-30 dBm) where Qualcomm predicted "…consumers may experience interference…"[17].

47. USCC was willing to take the risk to modify an already commercially deployed network and incur any expenses related to migration of the network from B to C and eventually B+C. They did so, and it is verified in the below analysis, because operation of Band 12 devices is not impacted by Channel 51 Reverse PA IM. The network now is currently running on a 10 MHz B+C carrier, with no adverse effects due to Channel 51 Reverse PA IM.

48. The testing was executed by a third party drive test company, PCTEL, and occurred over 3 separate nights. All testing was done during the maintenance window (4-6 am), to mitigate any throughput degradation due to traffic congestion. All testing occurred while simultaneously transmitting on the downlink and uplink, in order to properly emulate the interference scenario. The drive test data was collected using the same drive test route each time. The expanse of the drive test route ensured data was collected across a large variation of LTE received signal and Channel 51 received signal conditions. Additional details of the testing procedure are given in Appendix XII.

49. The initial network configuration was as a B-Block only and was driven first, in order to provide a baseline for the throughput and BLER levels. This provides the baseline because theoretical calculations show that B-Block uplink transmissions and Channel 51 signals do not create intermodulation products that fall within the UE receive filter. The network was then migrated over to a 5 MHz C-Block carrier, spot-checked to ensure proper performance, then grid-tested. The results show no significant difference in BLER or throughput for this scenario. The network was then migrated over to a 10 MHz B+C carrier, spot-checked to ensure proper performance, then grid-tested. These results also show no significant difference in BLER or throughput when in the presence of strong Channel 51 signals. The performance evaluation of the USCC market in all configurations includes areas

[16] Id. Page 45

[17] Id. Page 45

where the predicted Channel 51 signal strength would include the threshold (-20 to -30 dBm) where Qualcomm predicted "…consumers may experience interference…"[18]. The findings show that the network performance is directly comparable across Channel 51 signals strengths above and below -30 dBm. The performance of the USCC Waterloo establishes that Channel 51 signals above -30 dBm do not have any adverse effects on Band 12 devices.

50. The results in Figure 12 through Figure 17 below show the BLER and downlink throughput for each deployment scenario. These tests used thousands of data points from hundreds of file transfers, in order to obtain an accurate sampling of the network. Additionally, measurements were taken across a broad range of Channel 51 signal strength and USCC RSRP, in order to quantify any potential impact of Channel 51 over various RSRP conditions. Use of Band 12 devices brought about no significant difference in throughput performance or BLER as a result of changing from a 5 MHz B-Block carrier to a 5 MHz C-Block carrier, or to a 10 MHz B+C carrier. Theoretically, one would expect the results of the 5 MHz C-Block carrier and the 10 MHz B+C carrier to have an increased BLER or degrade throughput; however it can be seen from the graphs that the BLER are essentially identical, and that the throughput graphs are shown to provide maximum possible throughput for its bandwidth configuration.

51. In summary, the results of the Iowa market test refute previously submitted analyses of the effect of Channel 51 Reverse PA IM on Band 12 devices. The test results clearly show that, in areas of both low and high Channel 51 signal strength, network performance is not affected across all deployment scenarios. As can be seen from Figure 18, the signal strength is at or above levels that Qualcomm has stated would cause harmful interference for many parts of the drive test. Additionally, USCC is so convinced of non-interference that they are continuing to run their Waterloo-Cedar Falls, IA market as a 10 MHz B+C Band 12 network.

[18] Id. Page 45

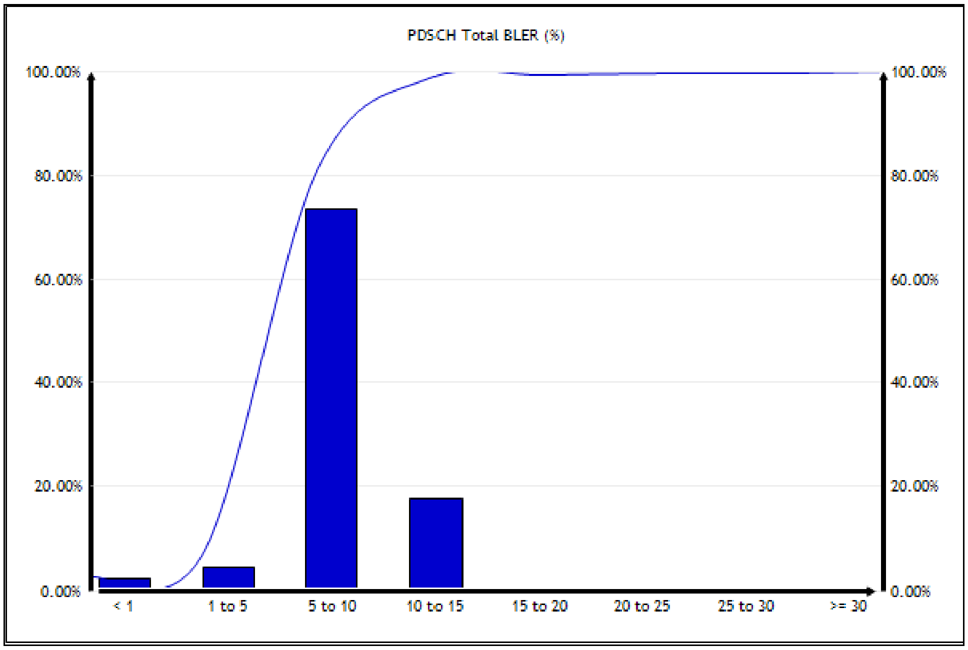

Figure 12 - 5 MHz B-Block UE BLER

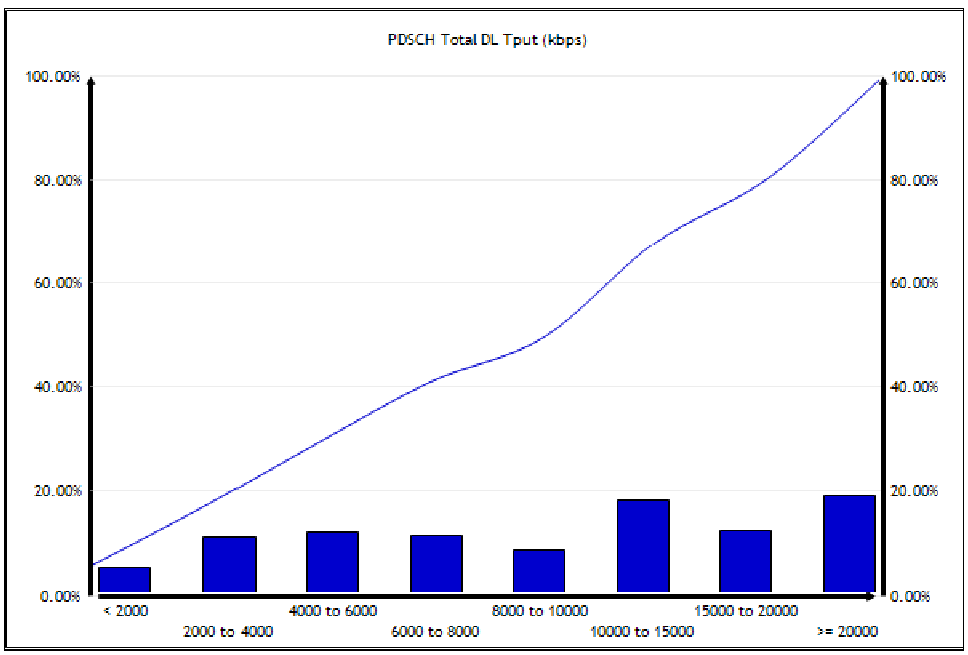

Figure 13 - 5 MHz B Block DL Throughput

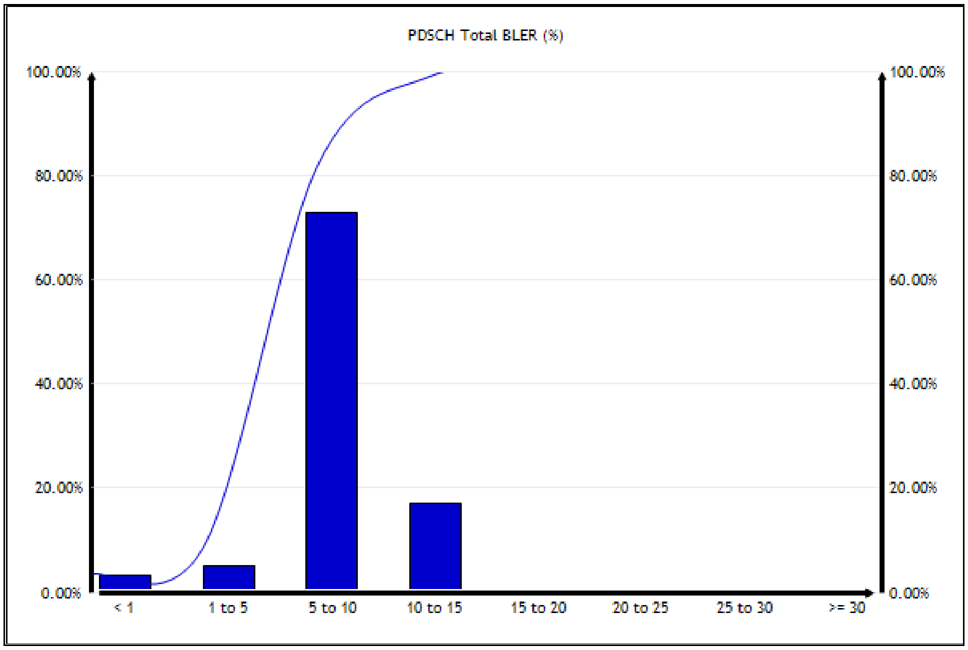

Figure 14 - 5 MHz C-Block UE BLER

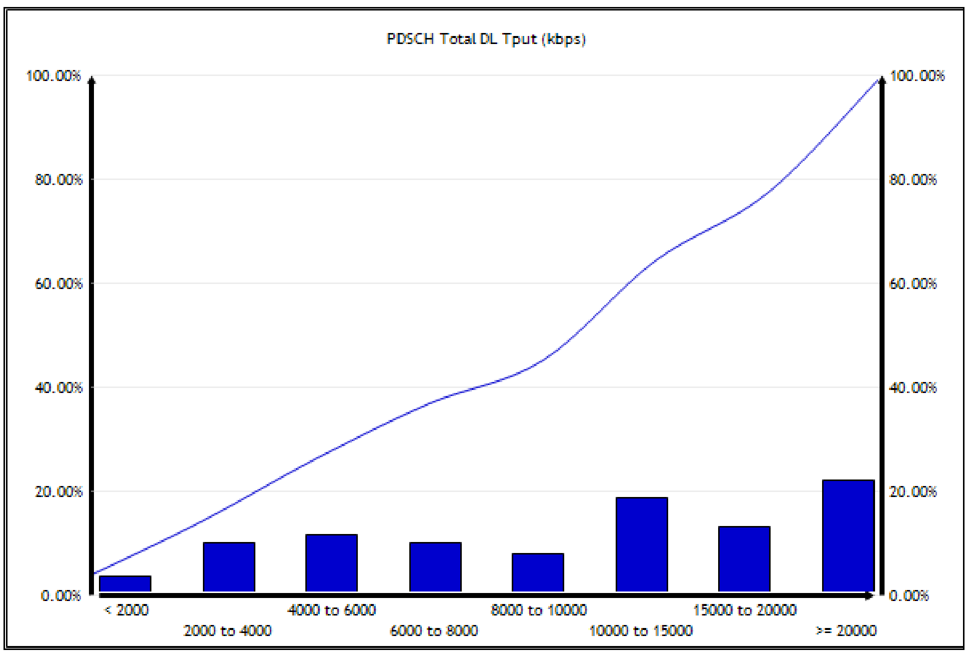

Figure 15 - 5 MHz C-Block DL Throughput

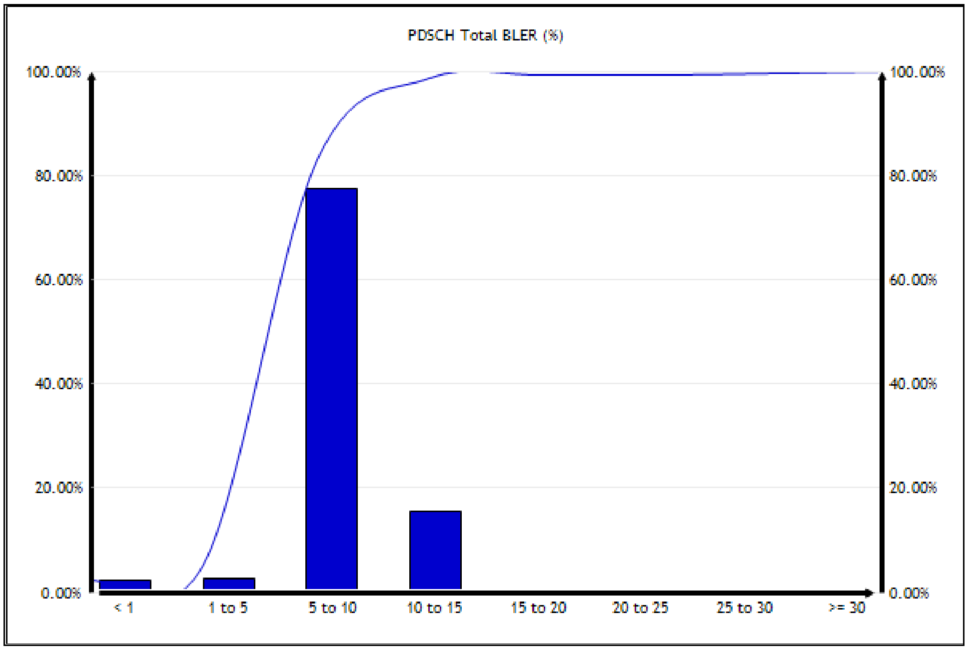

Figure 16 - 10 MHz B+C Block UE BLER

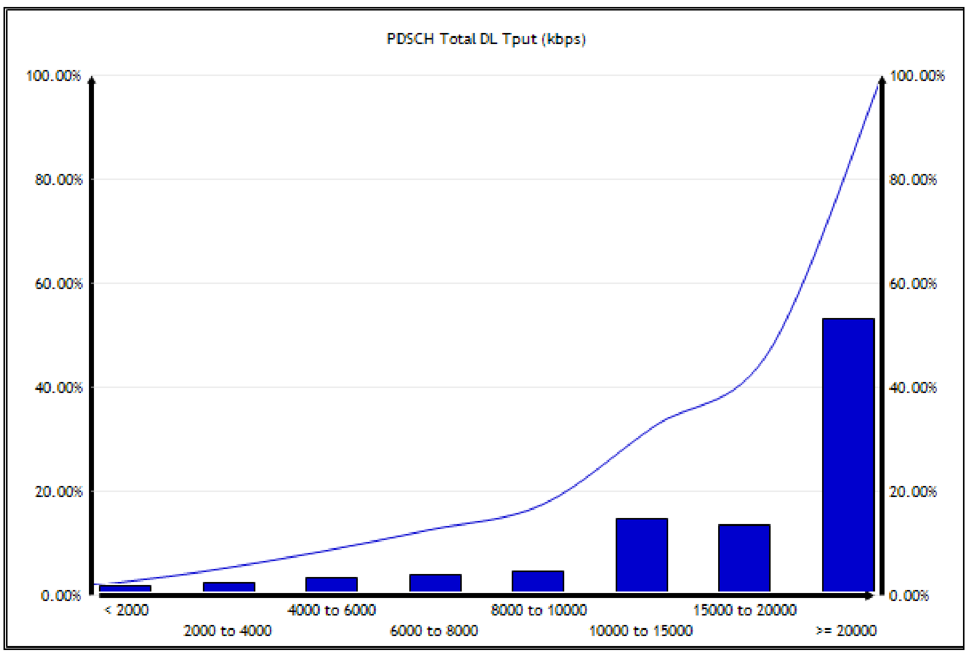

Figure 17 - 10 MHz B+C Block DL Throughput

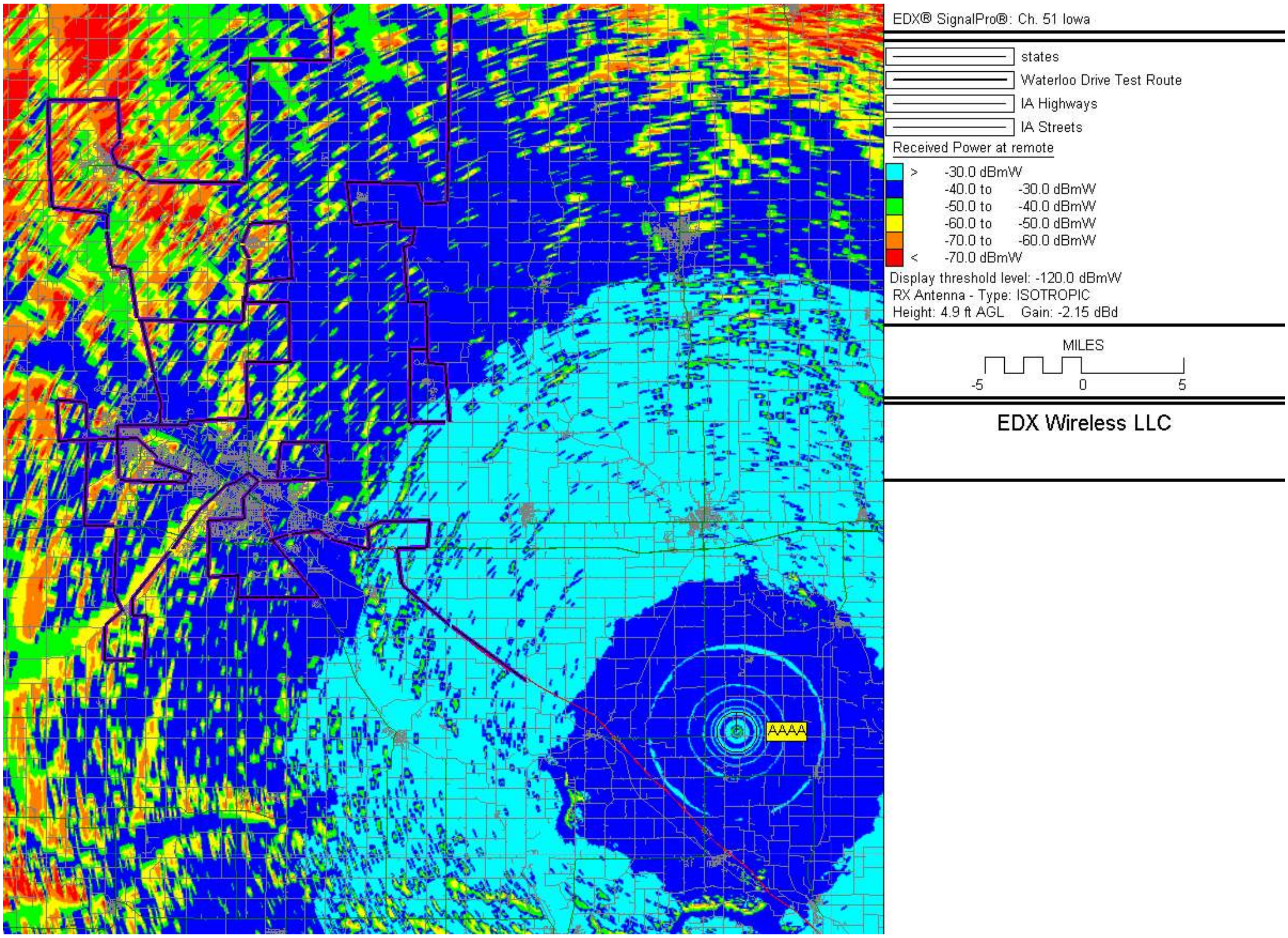

Figure 18 - Longley-Rice Propagation Model of Cedar Rapids, IA Site near Waterloo-Cedar Falls Market

D. Channel 51 Formal Response to NPRM Questions

52. In the "Discussion" section of the NPRM Section III.B, "Potential for Harmful Interference", the FCC requested comment, feedback, data, and analysis regarding interference for both the Channel 51 and the Channel 56 E-Block scenarios. This section focuses on the Channel 51 issues and concerns raised, along with the results and analysis.

53. The test approach used, combined with the ability to measure the performance of actual Band 12 devices (heretofore not available) in comparison to Band 17 devices (NPRM 40), provides the FCC with excellent insight into the performance of the devices and the resulting Potential for Harmful Interference. The latest test instrumentation was leveraged in a professional laboratory set-up to execute the testing on the Band 12 devices, as well as a Band 17 device as a performance comparison baseline. The necessary filters were procured to ensure proper isolation of the equipment and to collect clean signals.

54. As described herein, the test data collected was used to perform a comprehensive quantitative analysis (NPRM 40) on the potential for interference from the Channel 51 transmitters. The actual Channel 51 parameters (location, power, height) and antenna patterns (if available) were used to develop a prediction of "*the level of the DTV Channel 51 wideband signal that would be present at the UE antenna port based on a reasonable deployment scenario*" (NPRM 34). By using a pure LOS model, a worst-case scenario has been presented with regards to the level of Channel 51 signal that would be present at the UE. From this quantitative analysis, it is shown that the potential for harmful interference exists at only 8 of the 26 licensed DTV stations within the CONUS. Further, it is demonstrated in all eight (8) cases that the area of "potential" interference is restricted to very small areas around the DTV transmitter locations; these areas being, generally speaking, locations in which public activity would not be taking place. Still further, this area, when compared to the overall area of the Channel 51, 55-mile, Grade B contour, represents areas of "potential" impact consistently less than 0.005%.

55. The values were calculated and measured for areas in close proximity to the Channel 51 station. This was a concern raised by AT&T regarding the Vulcan field testing that measured signal strength no higher than -21 dBm (NPRM 36). It is again noted that the calculations are for best-case LOS conditions (e.g. where signal levels would be at their highest), which generally will not occur in most environments. The actual Channel 51 powers, locations, and vertical antenna patterns have been used to derive the conditions on the ground in close proximity to the Channel 51 transmitter. In conclusion, the Potential for Harmful Interference is de-minimus at best.

56. It was further observed that a Band 12 device performed comparably to the Band 17 device. Therefore, Band 12 devices have been developed that are comparable in performance to Band 17 devices. Practically, any band device will likely have a performance range across devices. Through the testing it was determined that Band 12 performance can be comparable with a Band 17 device. For the purposes of the case study analysis, a worst-case device was used; however, these devices are shown to have comparable performance at higher desired signal levels.

57. Specific to the interference component of the Channel 51 issue, no "measures" (NPRM 42) are necessary to be taken by the FCC to address the potential interference concerns of B and C Block licensees from Channel 51 broadcasters relating to the Band 12 vs. Band 17 device interoperability question for B and C-Block operations which are

purportedly preventing the voluntary adoption of Band 12. The analysis shows the potential area of impact to be small and in areas that are generally unpopulated for Band 12 devices as compared to Band 17 devices. The Commission should continue to ensure there are no additional Channel 51 operations put into the spectrum due to the Channel 51 protection rules that exist and must be adhered to by A-Block licensees; an independent issue from that of Band 12 interoperability and adoption thereof by B and C Block operators.

58. With respect to NPRM paragraph 44, we believe there are no steps the Commission needs to take to reduce the threat of interference from current Channel 51 operations relating to Band 12 vs. Band 17 operations for B and C-Block operators. The Commission should continue to ensure there are no additional Channel 51 operations put into the spectrum due to the Channel 51 protection rules that exist and must be adhered to by A-Block licensees. Additionally, in footnote 127 of this same paragraph 44, the Commission has indicated it intends to open a separate proceeding to address potential interference issues between Channel 51 television operations and Lower A Block operations.

59. With respect to steps the Commission could take aside from regulatory measures to encourage voluntary industry efforts (NPRM 44), the Commission should continue to attend and participate in 3GPP standards activities with particular focus on these Band issues and their impact on regulatory rules, existing and contemplated, potentially avoiding future inconsistencies in policy and technology.

60. The analysis clearly shows that the "potential harm resulting from interference" is in fact outweighed by "the public interest benefits that would result from interoperability in the Lower 700 MHz band" (NPRM 40) since the analysis shows that interoperability would not cause widespread harmful interference.

VI. CHANNEL 56 E-BLOCK BLOCKING AND REVERSE POWER AMPLIFIER INTERMODULATION ANALYSIS

61. Using the test results from Band 12 and Band 17 devices, the Channel 56 E-Block case studies revealed that the use of a Band 12 device as opposed to a Band 17 device would have no meaningful difference in performance with a realistic deployment aimed at targeting the same population as the E-Block licensee. Furthermore, should conditions on the E-Block licenses be put in place that matches the current D-Block rules; any additional interference potential to B and B+C licensees would be effectively eliminated.

A. Test Set-up

62. To identify the influence of the E-Block potential interference components of both Blocking and IM products, the sources for these components required isolation. Therefore, for E Block blocking tests were performed while the UE device is transmitting at minimum power. The device needs to be transmitting at minimum power to establish a baseline connection with the LTE Emulator, yet not transmitting high enough to produce interference associated with Intermodulation. Then with the same configuration, the UE transmission is included at full power since <u>only</u> the UE transmissions can combine with the E Block to create the IM components of interest.

63. The Channel 56 E-Block testing documents the performance of the device receivers in the presence of a strong Channel 56 E-Block transmitter. Each test was performed with the equipment configuration of Figure 41 in Section VIII. For each test, data was taken for 1 dB (worst-case), 3 dB, 10dB, and 30 dB rise in noise floor to see how the impact changes as desired signal is increased. The interfering signal source was representative of a MediaFlo digital mobile broadcast signal, which was a previously implemented transmission standard for one-way, high-power broadcast operations.

B. Channel 56 E-Block Blocking Test Results

64. The results of the testing for the B-only, C-only, and B+C carriers are shown in Figure 19 through Figure 21, respectively and are found below. The case study documented in D below shows there is no meaningful difference in performance in the use of a Band 12 device and a Band 17 device, with Band 12 devices performing better in certain circumstances.

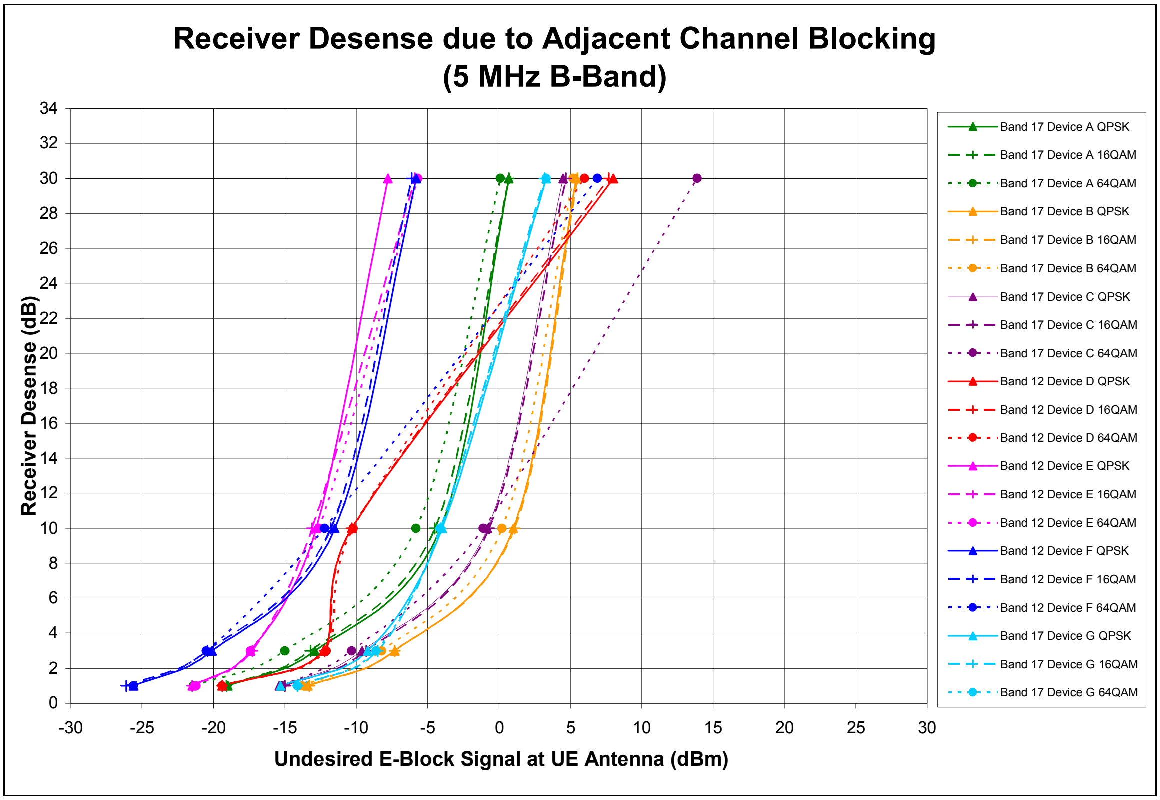

Figure 19 - Adjacent Channel Blocking for B-Only Carriers

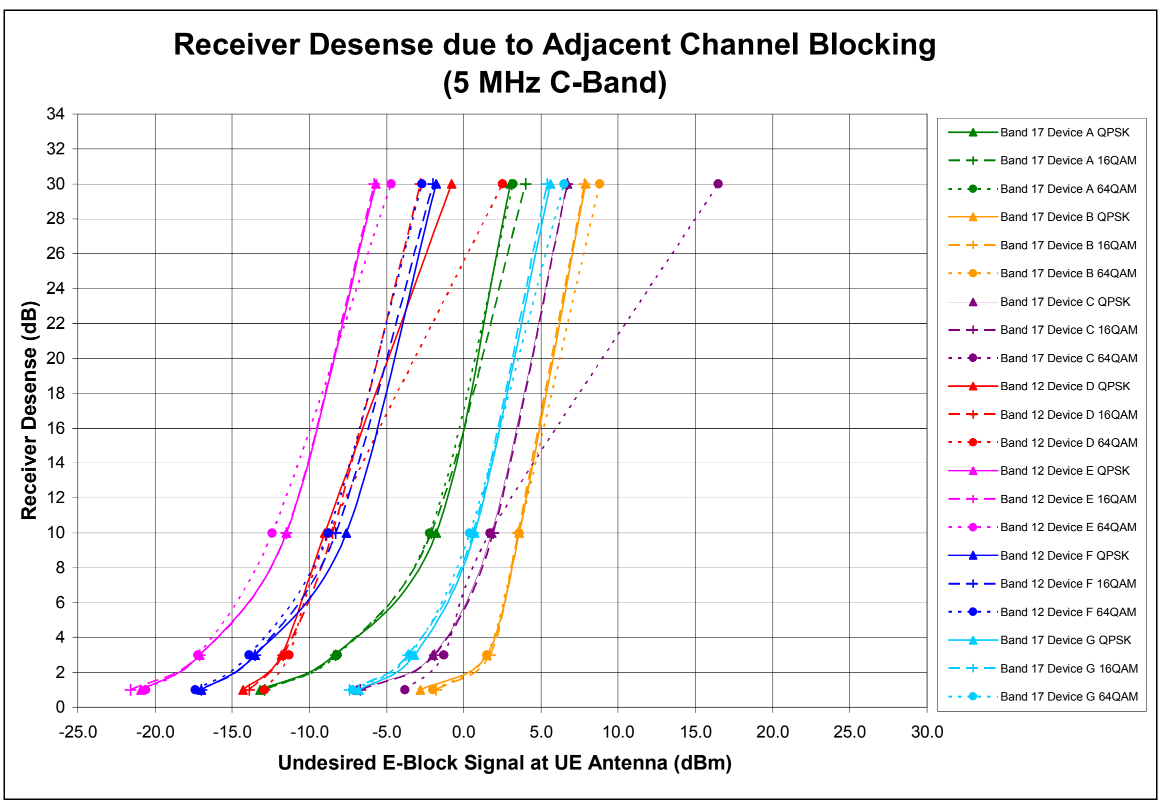

Figure 20 - Adjacent Channel Blocking for C-Only Carriers

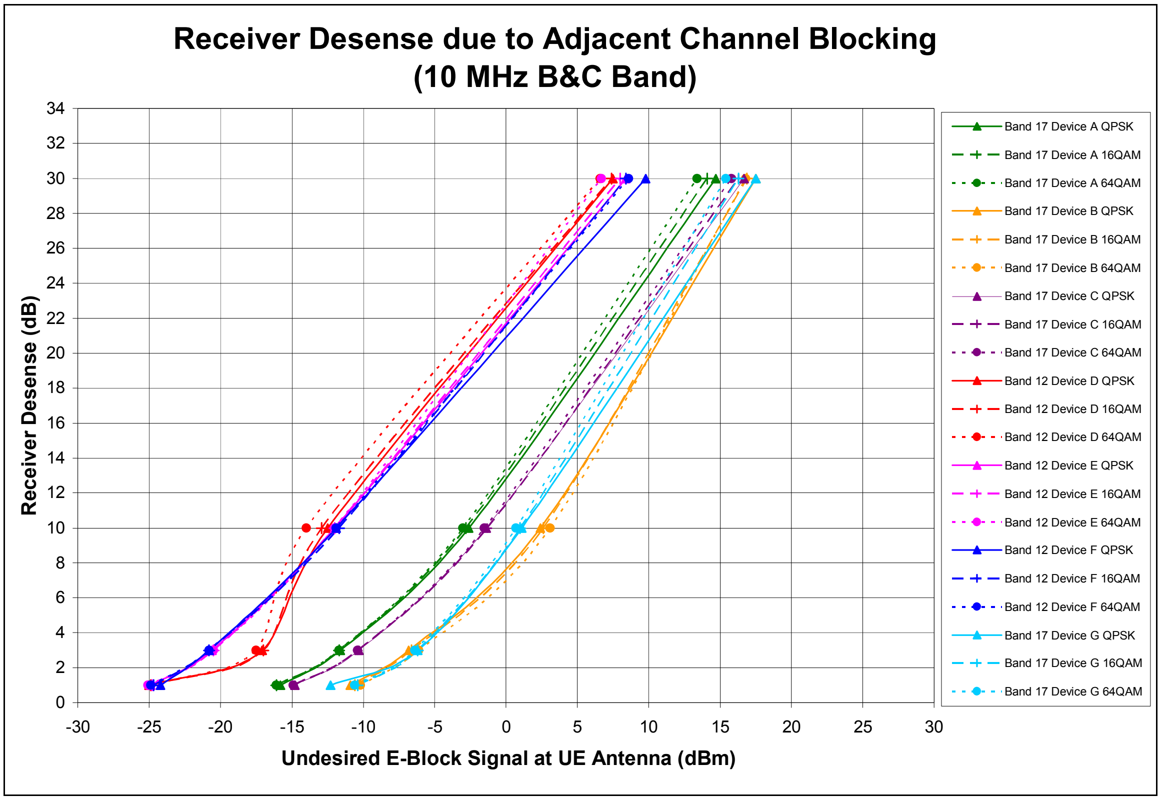

Figure 21 - Adjacent Channel Blocking for B+C Carriers

C. Channel 56 E-Block Blocking and IM Test Results

65. The results of the testing for B-only, C-only and B + C carriers are shown in Figure 22 through Figure 24, respectively. The test results show a worst-case difference of approximately 9 dB throughout all 3 tests; however, the case study documented in D below shows there is no meaningful difference in performance in the use of a Band 12 device and a Band 17 device. In fact, the B-only case shows comparative device performance, with Band 12 devices performing better in certain circumstances. This testing, which includes both adjacent channel receiver blocking as well as reverse PA IM, demonstrates the cumulative effect of these two conditions on the devices.

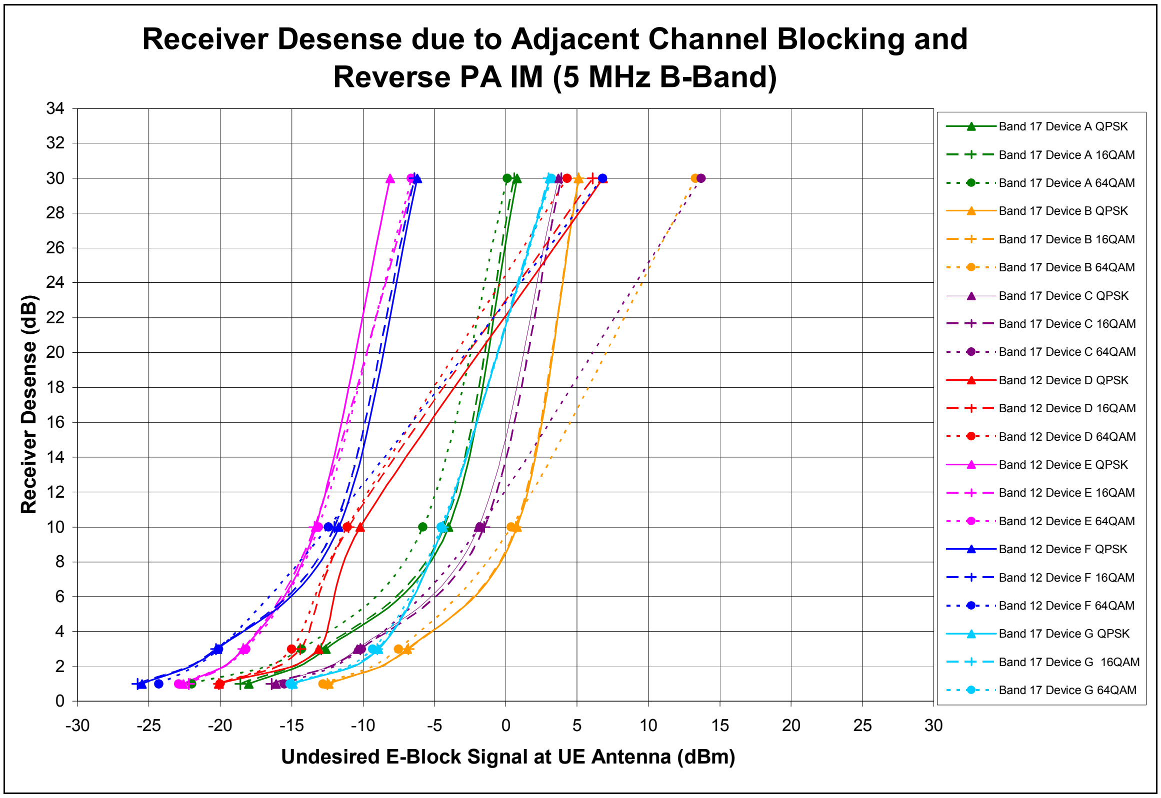

Figure 22 - Adjacent Channel Blocking and Reverse PA IM, 5 MHz B-Only Carrier

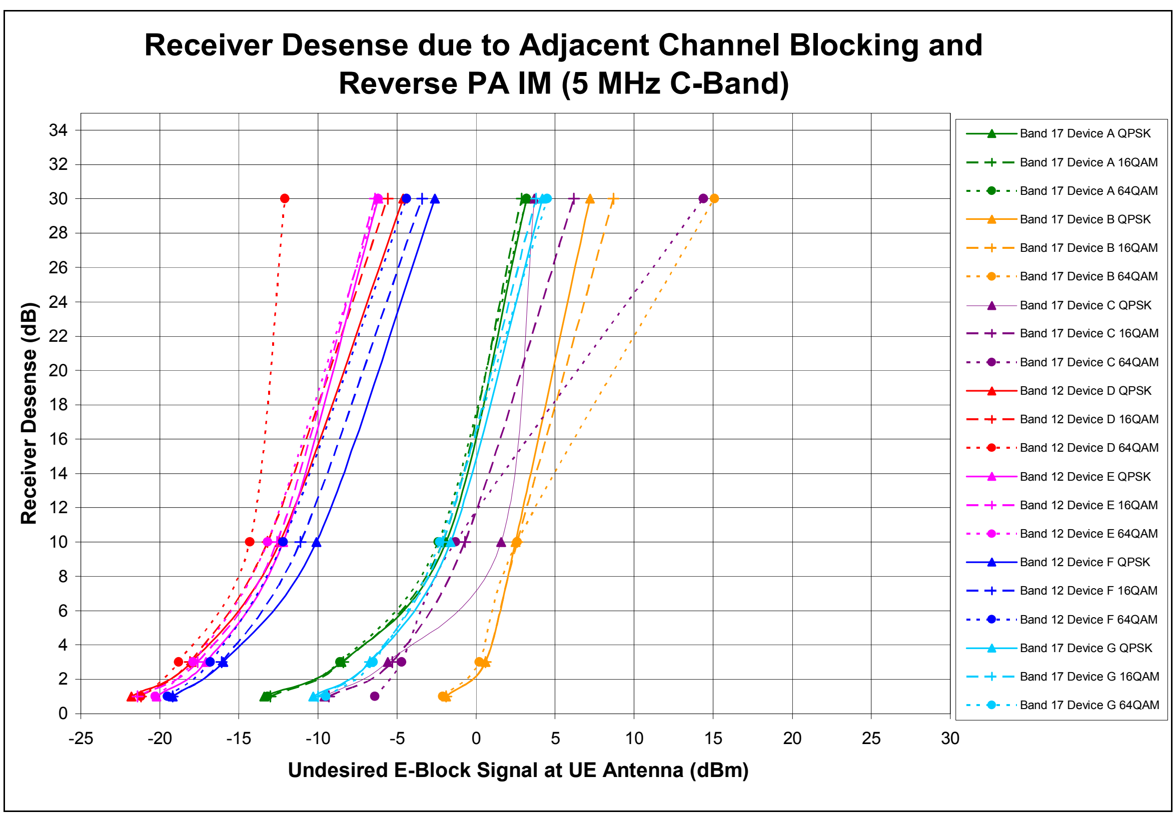

Figure 23 - Adjacent Channel Blocking and Reverse PA IM, 5 MHz C-Only Carrier

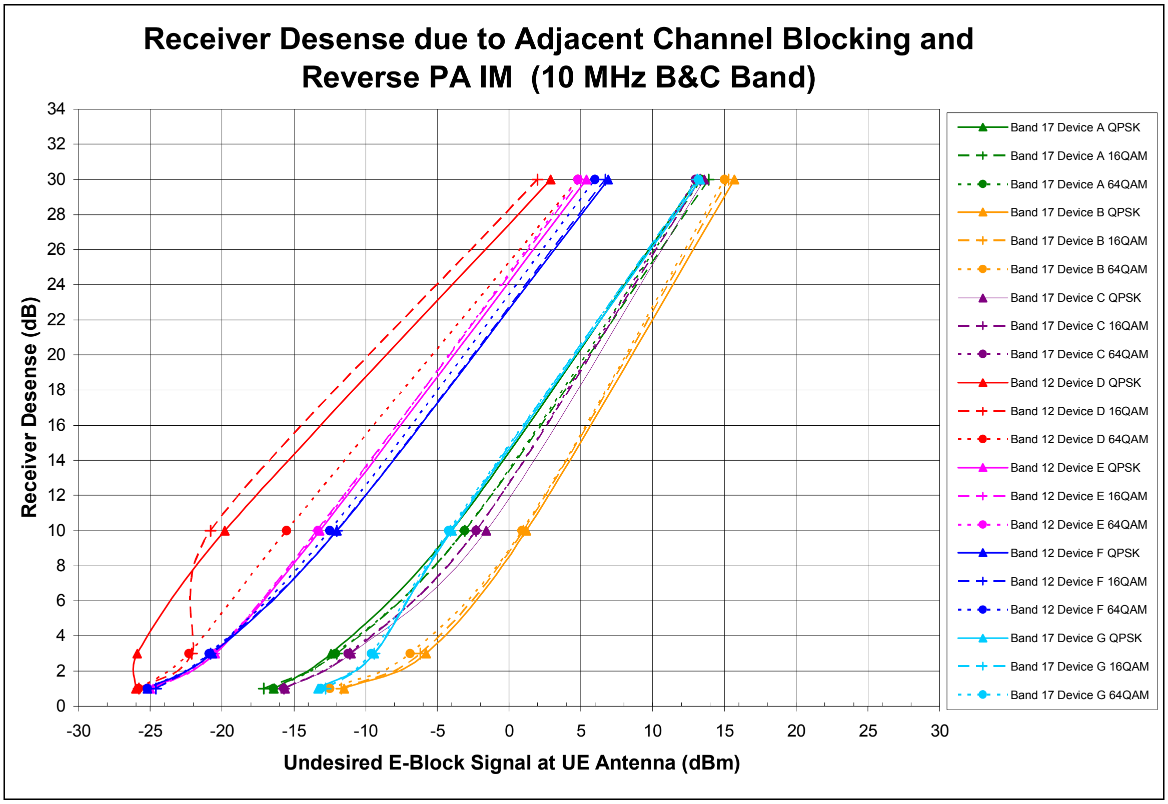

Figure 24 –Adjacent Channel Blocking and Reverse PA IM, 10 MHz B+C Carrier

D. Channel 56 E-Block Blocking Case Study

66. The case study analyzes the practical impact on performance given the differential of the Band 12 and Band 17 device test results. The case study looks at several components from several perspectives. First, an antenna analysis was performed from the perspective of the nature of the one-way broadcast services being deployed and the associated FCC limitations on power and Power Flux Density limits. This analysis shows the energy from these E-Block systems would NOT typically direct energy to the near field on the ground. An interference model analysis was then executed using the antenna vertical pattern across a cross-section of site antenna height (AGL) scenarios to further define the expected field strengths of an E-Block carrier. Applying our device testing results, the analysis shows the potential interference from E-Block systems would be at minimal distances (800' and less)[19] from E-Block towers. Importantly, it also shows that a Lower B block carrier would have nearly identical potential interference concerns whether deploying Band 12 or Band 17 networks. These potential interference distance results were then applied to a site-specific analysis across a sub-set of urban, suburban, and rural transmitter locations. The site-specific analysis reveals that at these potential interference distances, an E-Block transmitter has minimal to no real-world impact in most cases. Lastly, a deployment analysis was performed across several markets. The deployment analysis demonstrates that overcoming any potential E-Block interference through collocation or as part of normal cell planning will take place in the normal course of a network design and implementation. This underscores that an E-Block deployment does not present an unnecessary burden, financial or otherwise, on a deployment of Band 12 devices. In total, the Channel 56 case study analyses demonstrate that a commercial E-Block deployment would have minimal to no effect on a Band 12 deployment in comparison to a Band 17 deployment for a B or C licensee.

67. *Channel 56 E-Block Antenna Analysis* – Using public records of 700 MHz based mobile TV deployments, varying antenna heights and power levels were evaluated for input into the case study model, in order to determine a worst-case scenario of potential interference zones near an E-Block tower site. The signal strength was evaluated from the perspective of the Power Flux Density (PFD) limits associated with these higher power deployments. The limits ultimately take into account the energy from these mobile TV broadcast sites is directed outward rather than downward, and for sites with lower antenna centerlines, the 50 kW power limits of the E-Block transmissions are further reduced to meet PFD rules. The power limitations and PFD limitations are documented in Rule Parts 27.50(c)(7) and 27.55(b) and included below:

- ERP Limit (FCC CFR 47 Part 27.50 (c)(7))
  - A licensee authorized to operate in the 710-716, 716-722, or 740-746 MHz bands, or in any unpaired spectrum blocks within the 698-746 MHz band, may operate a fixed or base station at an ERP up to a total of 50 kW within its authorized, 6 MHz spectrum block if the licensee complies with the provisions of [27.55(b)]. The antenna height for such stations is limited only to the extent required to satisfy the requirements of [27.55(b)].

[19] It should be noted that this maximum radius is based on a propagation model, and **not** actual field test data. There are currently no active E-Block deployments from which to test.

- In accordance with FCC CFR 47 Part 27.55(b):
    - Power flux density limit for stations operating in the 698-746 MHz bands. For base and fixed stations operating in the 698-746 MHz band in accordance with the provisions of [27.50(c)(6)], the power flux density that would be produced by such stations through a combination of antenna height and vertical gain pattern must not exceed 3,000 microwatts per square meter on the ground over the area extending to 1 km from the base of the antenna mounting structure

68. *Channel 56 E-Block Potential Interference Modeling* - The TM 91-1 model was utilized for this analysis, as a predictor for short-range propagation. The TM 91-1 model was specifically developed by the FCC to calculate path loss for distances up to 1 km. Pursuant to the TM 91-1 Report, its Equation 6 is used in combination with the free-space (or LOS) equation to determine short range propagation at the antenna heights envisioned for the E-Block service. The details of the TM 91-1 model and LOS model are included in Appendix B in Section IX herein.

69. The maximum ERP for each antenna height was calculated using the Power Flux Density (PFD) requirement. This PFD limit converts to a received signal strength of -12 dBm referenced to a dipole antenna, and, when user / body losses and UE antenna gain are taken into account, the received signal strength becomes -17 dBm referenced to a UE's antenna port. The results of the analysis are reflected in Figure 25. A Dielectric vertical antenna pattern specifically designed for Lower 700 MHz Mobile Media applications was applied for each site, as this would be reflective of a typical antenna used for commercial deployment. The height of the antennas was varied from 200' to 1000' to be consistent with typical E-Block configurations. Figure 25 through Figure 27 show the results of this model, broken down by frequency block.

70. For each threshold of each device, a color-coded vertical line was placed when the device threshold for both Band 17 (green) and Band 12 (red) devices was exceeded by any of the antenna centerlines.

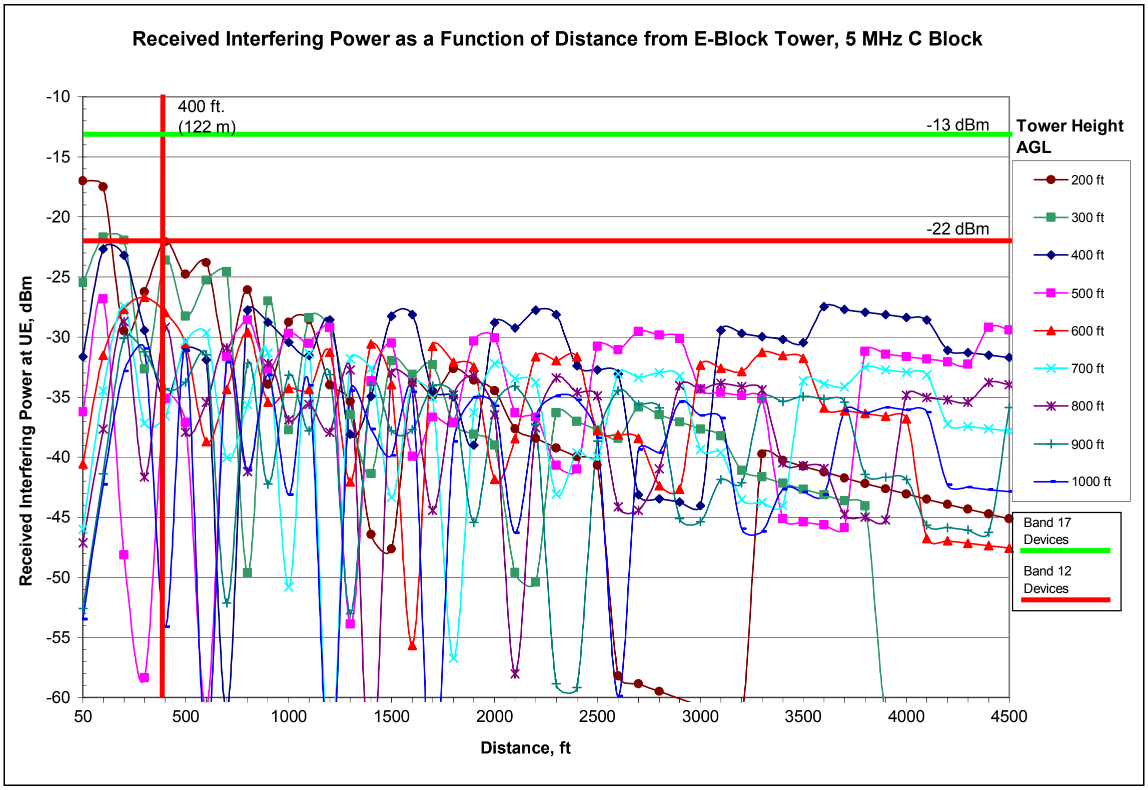

Figure 25 - Analysis of Channel 56 E-Block Deployment Across Various Transmitter Heights, 5 MHz C Block

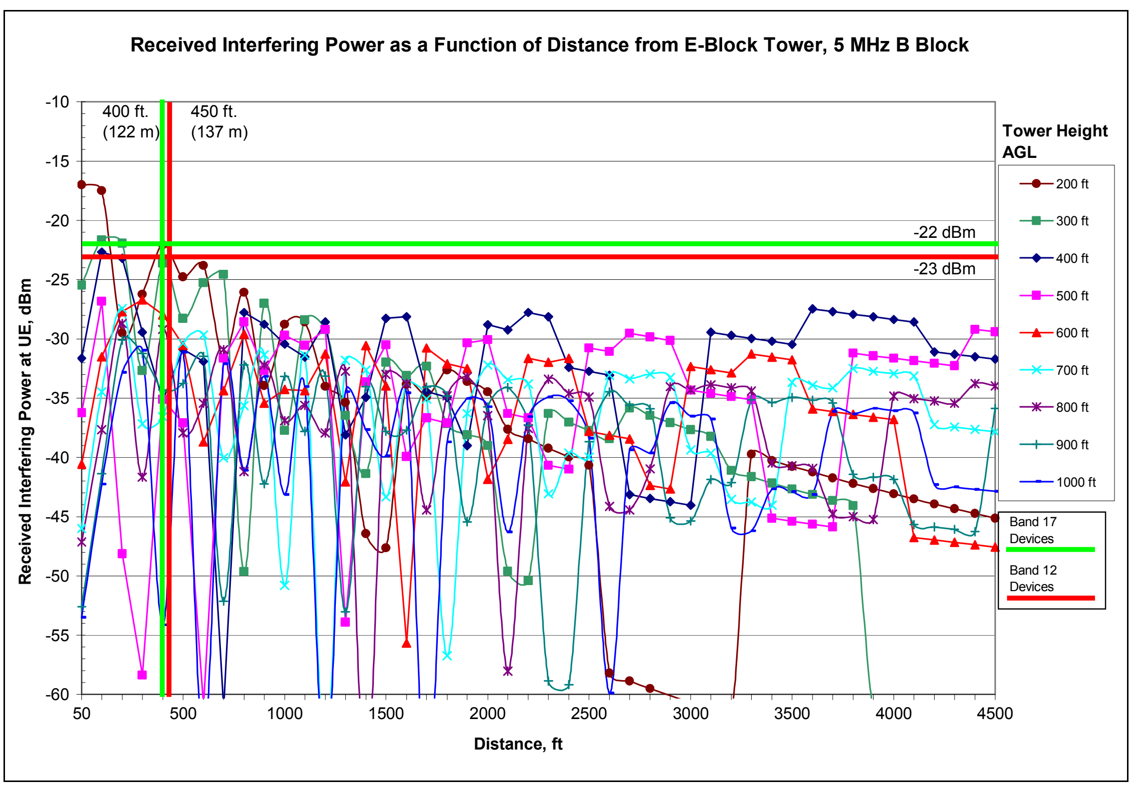

Figure 26 - Analysis of Channel 56 E-Block Deployment Across Various Transmitter Heights, 5 MHz B Block

Figure 27 - Analysis of Channel 56 E-Block Deployment Across Various Transmitter Heights, 10 MHz B+C Block

71. *Channel 56 E-Block Site Specific Analysis* – Using public records of a New Jersey based 700 MHz based mobile TV deployment, sites were selected across several morphologies (rural, suburban, and urban) as a cross section of deployment characteristics. The potential area of interference findings reflected in Figure 25 were applied to Google Earth based maps of the sites and the following were added to each figure:

- **Red Solid Circles – Band 12** "potential" interference area with Channel 56 E-Block Transmit Source at maximum permissible power, 5 MHz B-Block
- **Green Solid Circles - Band 17** "potential" interference area with Channel 56 E-Block Transmit Source at maximum permissible power, 5 MHz B-Block
- **Red Dashed Circles – Band 12** "potential" interference area with Channel 56 E-Block Transmit Source at maximum permissible power, 10 MHz B+C Block

72. The circles represent the "potential" worst-case areas of interference for each band class, as displayed in Figure 28 through Figure 33. As can be seen in Figure 26, there is practically no difference in the area of "potential" interference for a B-Block carrier whether operating with Band 12 or Band 17 devices. Therefore, B-Block carriers would be required to either collocate on or locate nearby E-Block towers to avoid any potential for interference even with Band 17 devices in the normal course of system design and implementation. The maximum distance of "potential" interference from a Channel 56 E-Block transmitter on a 10

MHz B+C carrier, assuming the TM 91-1 model, for a Band 12 device is 800 ft. (244 m)[20]. Similarly, the maximum distance of "potential" interference from a Channel 56 E-Block transmitter, assuming the TM 91-1 model, for a Band 17 device is 100 ft. (30 m).

[20] It should be noted that this maximum radius is based on a propagation model, and **not** actual field test data. There are currently no active E-Block deployments from which to test.

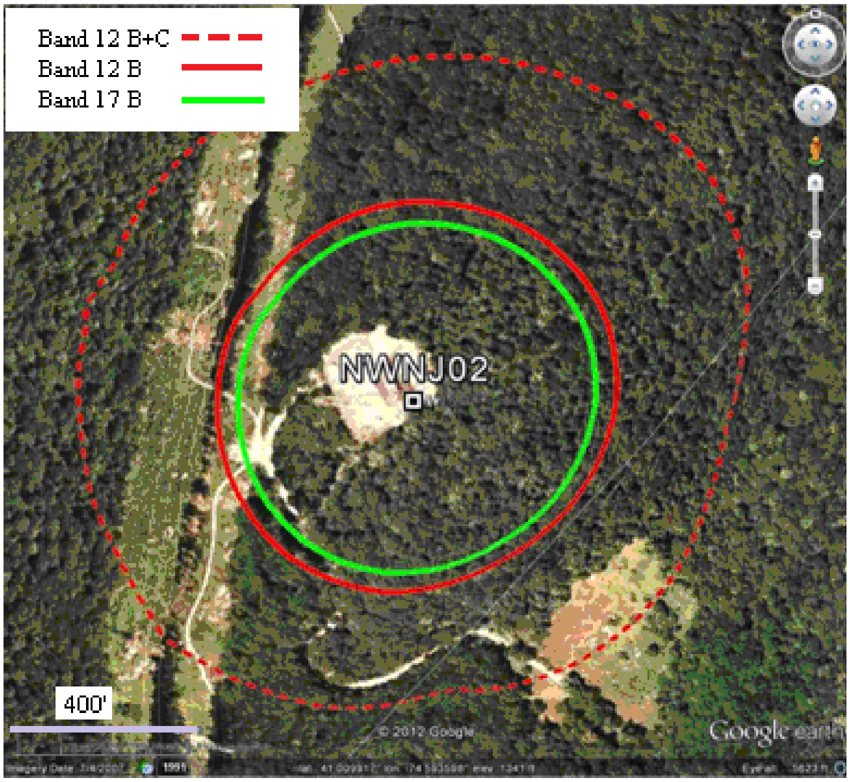

Figure 28 – Sparta, NJ Areas of Potential Interference Band 12 and Band 17

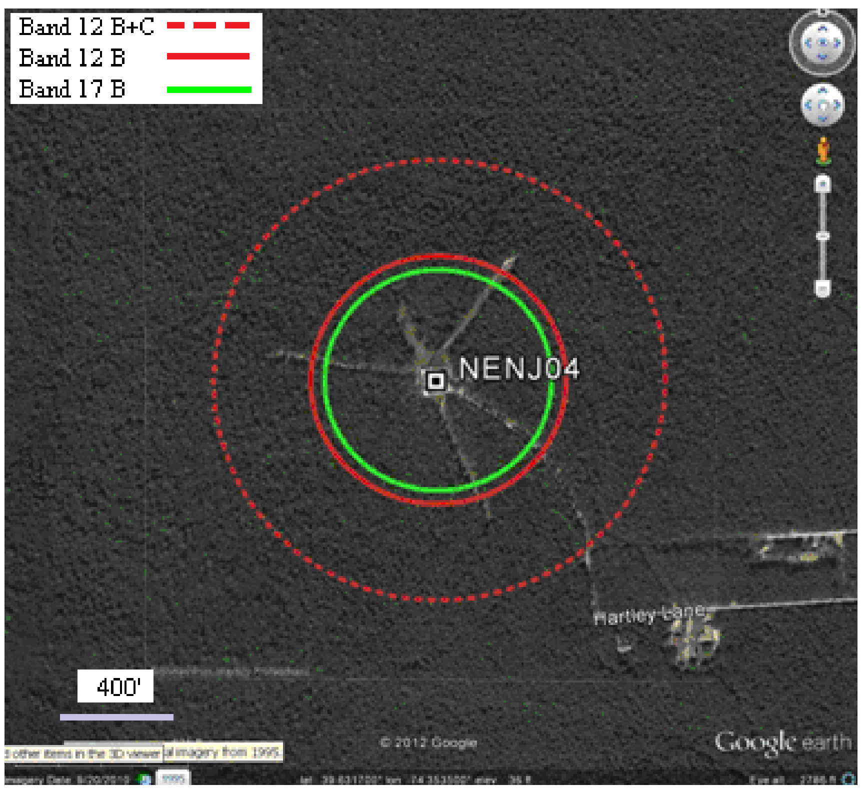

Figure 29 - Little Egg Harbor, NJ Areas of Potential Interference Band 12 and Band 17

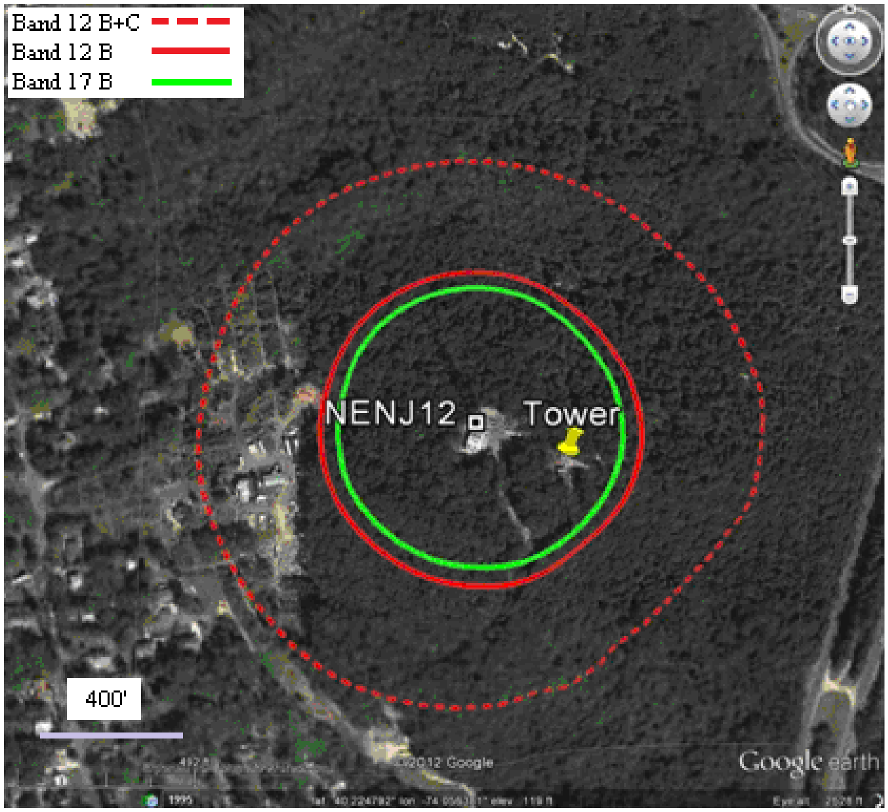

Figure 30 – Neptune, NJ Areas of Potential Interference Band 12 and Band 17

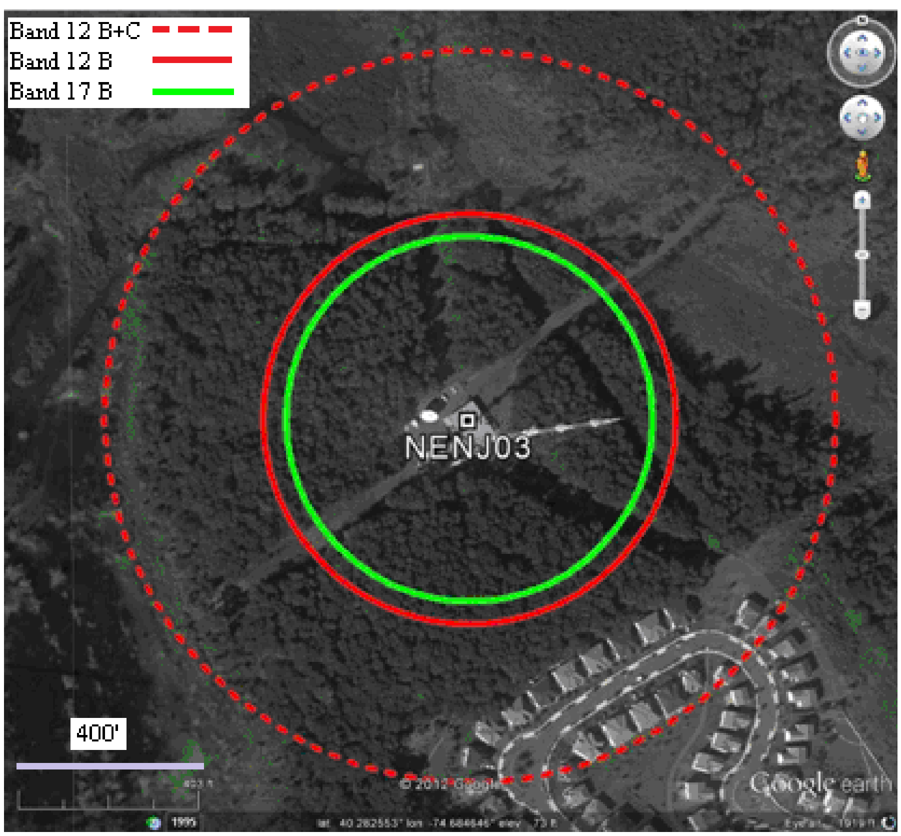

Figure 31 - Trenton/Princeton, NJ Areas of Potential Interference Band 12 and Band 17

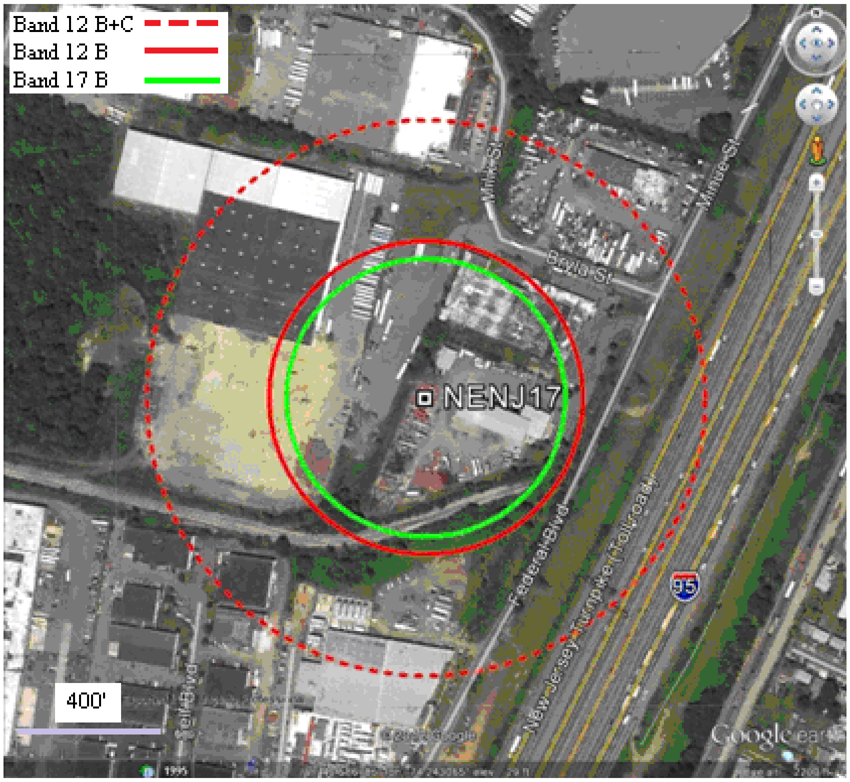

Figure 32 – Carteret, NJ Areas of Potential Interference Band 12 and Band 17

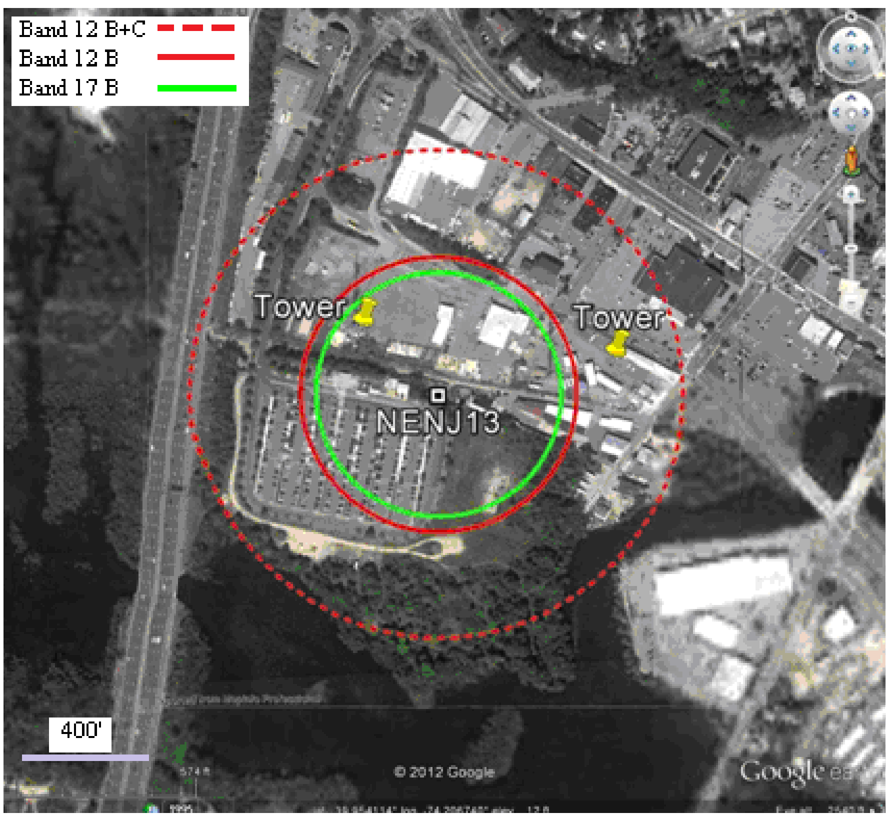

Figure 33 - Toms River, NJ Areas of Potential Interference Band 12 and Band 17

73. *Channel 56 E-Block Deployment Analysis* – If located on a structure close to the E-Block tower, the potential for interference could be eliminated. Previous statements and comments presented to the FCC have indicated that overcoming the E-Block interference potential would be expensive. Currently, there are no active Channel 56 E-Block high-power network operations to evaluate. Since the time of the Atlanta testing Echostar deployment on the Channel 56 E-Block spectrum has been effectively shut down. Similarly, the MediaFlo high-power mobile broadcast network developed by Qualcomm and originally operating on D-Block (Channel 55) is also shut down (with AT&T having acquired the spectrum). Nevertheless, V-COMM is very familiar (a recognized expert) with typical wireless network deployments having designed and optimized thousands of cell sites since its founding in 1996; and an executive team that has been working the commercial wireless industry since the early 1980s. In addition, V-COMM was very familiar with the MediaFlo network deployment. V-COMM supported the zoning of various locations throughout the Philadelphia and New York metro areas, including most of New Jersey. V-COMM was also familiar with these high-power mobile networks through the network engineering, analysis, design and implementation developed in conjunction with Aloha Partners on the Lower 700 MHz C Block spectrum and Crown Castle Modeo DVB-H network in the L-Band spectrum.

74. Our experience with these deployments includes many high-power D-Block sites which are collocated on or very near other wireless towers, therefore increasing the Signal to Interference plus Noise Ratio (SINR). As demonstrated in Figure 19, the device performance improves at higher SINR values and any "potential" area of interference would be reduced accordingly. In V-COMM's experience in the Pennsylvania[21] (PA) and New Jersey (NJ) marketplace, the high power mobile broadcast networks sites were collocated on facilities with other commercial wireless carriers present. This condition was dictated by the availability of tower infrastructure in the area of population these sites were designed to target. Further, another large percentage would be in close proximity to alternative structures where commercial wireless carriers were located. Therefore, the likelihood of a 700 MHz based carrier collocated with, or in close proximity to, an E-Block operator and thus able to overcome any potential interference is very high. Moreover, if the carrier is not nearby, then the area of potential interference is likely not an area being served by the carrier in the first place and no interference would be possible. Additionally, collocation on the E-Block tower would be improving service to the area.

75. In the comments to the NPRM, Qualcomm states[22]:

> "B and C Block operators likely will spread base stations throughout their license areas. E Block operators again will take the opposite approach, locating towers on mountaintops and other areas that allow maximum coverage for each tower, but that are usually inappropriate for cellular base stations."

76. The analysis of the Qualcomm D-Block deployment does not find the E-Block towers sites "usually inappropriate for cellular base stations". In analyzing the MediaFlo

[21] From Harrisburg, PA and east

[22] See Comments of Qualcomm Incorporated at II.C.1

sites in the PA[23] and NJ markets, our analysis finds that 91% of the Qualcomm sites were collocated with commercial wireless carriers. The analysis included: the identification of the Qualcomm location on an FCC registered cellular carrier site per FCC database; or the identification of the Qualcomm location on an AT&T owned tower; or V-COMM local knowledge of this marketplace and subsequent confirmation pictorially or via available aerial photography or Google Street Maps. The results of the analysis are reflected in Table 4.

Quantity of MediaFlo NJ and PA Sites Evaluated	Quantity of MediaFlo NJ and PA Sites with Collocated Commercial Wireless Facilities	Percentage of MediaFlo NJ and PA Sites with Collocated Commercial Wireless Facilities
32	29	91%

Table 4 - Collocation Analysis of MediaFlo NJ and PA Market

77. Qualcomm presented drive test data[24] for two markets (Dallas and Phoenix) in their Comments[25]. Therefore, V-COMM evaluated these markets in similar fashion. The analysis included: the identification of the Qualcomm location on an FCC registered cellular carrier site per FCC database; or the identification of the Qualcomm location on an AT&T owned tower; or publicly available information from photography or Google Street View or tower ownership websites. In analyzing the Dallas market, our analysis finds that 73% of the Qualcomm sites were collocated with commercial wireless carriers (see Table 5).

Quantity of MediaFlo Dallas Sites Evaluated	Quantity of MediaFlo Dallas Sites with Collocated Commercial Wireless Facilities	Percentage of MediaFlo Dallas Sites with Collocated Commercial Wireless Facilities
11	8	73%

Table 5 - Collocation Analysis of MediaFlo Dallas Market

78. The evaluation of the Phoenix market comes closest to Qualcomm's position regarding mountaintop sites unsuitable for cellular. In this market, only 5 sites were utilized and while 3 are on mountains only 2 are not collocated with commercial wireless carriers. However, further analysis of the nature of these two (2) sites and their surroundings, as well as the Qualcomm drive test data, demonstrates that these locations would NOT result in interference. The site identified as PHNX01 is on a mountain south and west of downtown. The closest public buildings are 1 mile south and 1.4 miles north of the site location (see Figure 34). The Qualcomm drive test does not include areas close to the PHNX01 location.

[23] From Harrisburg, PA and east.

[24] The interference levels presented by Qualcomm based (-29.1 dBm et al) on their theoretical analysis and simulations are less than our findings (-25 dBm) from actual Band 12 device testing.

[25] See Comments of Qualcomm Incorporated at II.A and II.B.

Nevertheless, at these distances and in combination with the change in ground elevation (>1000'); the potential for this site to create areas of potential interference are eliminated.

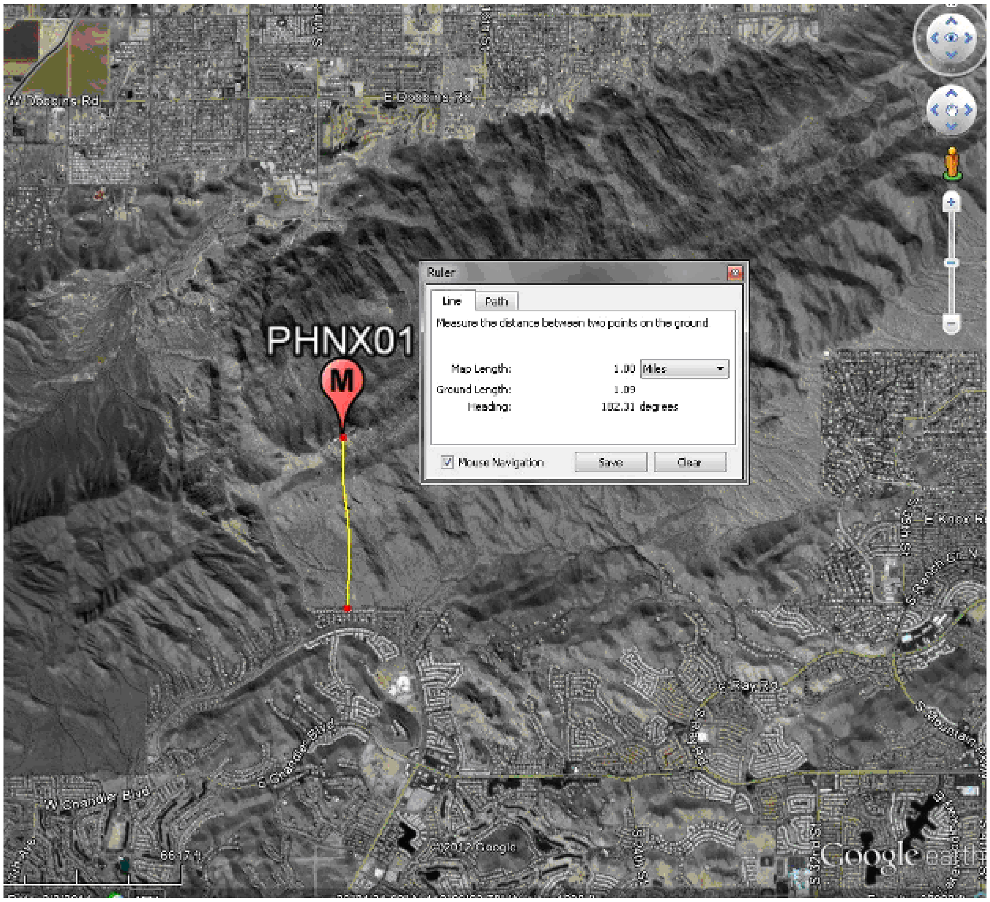

Figure 34 - MediaFlo Site PHNX01 Map

79. The site identified as PHNX02 is more central to population. Per Figure 12[26] of Qualcomm's comments, the highest energy potential is north and east of the PHNX02 location. In evaluating the AT&T owned towers in the area (see Figure 35) it can be seen that there are wireless tower facilities developed to serve the population in the targeted area. However, from the obvious grid pattern of these towers, the AT&T sites alone are not enough infrastructure for a carrier to satisfy their coverage requirements. Nor would it meet the Qualcomm definition of a typical cellular system:

> "average distance between cell sites in a typical cellular system is only 1.7 km or less, which is likely the appropriate distance for B and C Block cell sites."[27]

80. Therefore, other commercial and FCC registered towers were added to Figure 35 to produce Figure 36. Figure 36 represents a more typical cellular system layout and demonstrates that as part of basic cellular planning and system implementation, any potential

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[26] See Comments of Qualcomm Incorporated, page 25.

[27] Id., page 30.

interference resulting from mountaintop E-Block sites can be, and likely would be, overcome with typical cellular design regardless of E-Block transmitter presence. Our findings are in direct contrast to other commenters[28] who have suggested that there is an intensive and excessive burden to overcome E-Block (and Channel 51) interference.

81. This E-Block Deployment Analysis demonstrates that even if an E-Block transmission source exists, multiple tower alternatives also exist to overcome any "potential" interference in close proximity to the E-Block transmitter. As important, V-COMM's experience confirms that the likelihood of wireless carrier presence on, or in close proximity to these mobile broadcast sites is very high. In fact, in order to target the same population as the E-Block transmitter, the B/C-Block 700 MHz carrier would very likely be located on the E-Block tower or a nearby tower. In that case, there would be NO additional burden (cost) to overcome the potential for E-Block interference, as it would be considered in the normal course of system design and implementation. Further, the "potential" for E-Block interference to exist given a higher SINR is greatly reduced or eliminated.

82. In summary, regarding E-Block deployment analysis: E-Block transmitters are more than likely collocated with or very near to other commercial wireless cell site locations; in cases where these transmitter locations are not appropriate for commercial wireless (e.g. mountaintop sites) these locations have very small potential to produce potential interference levels based on V-COMM Band 12 device testing; and, where E-Block sites produce energy that approach the levels to produce potential interference, typical cellular deployment would produce desired levels of SINR and thus eliminate the interference potential.

83. A consideration for the conditions described herein would be to have the E-Block carriers register all their locations with the FCC and/or execute a Prior Coordination Notification (PCN). This would be unnecessary should the E-Block power limitations be changed to match the D-Block and other Lower 700 MHz Block power limits as described herein.

[28] Comments of AT&T Services, Inc. at Exhibit, A Section 3. Comments of Qualcomm Incorporated at II.C

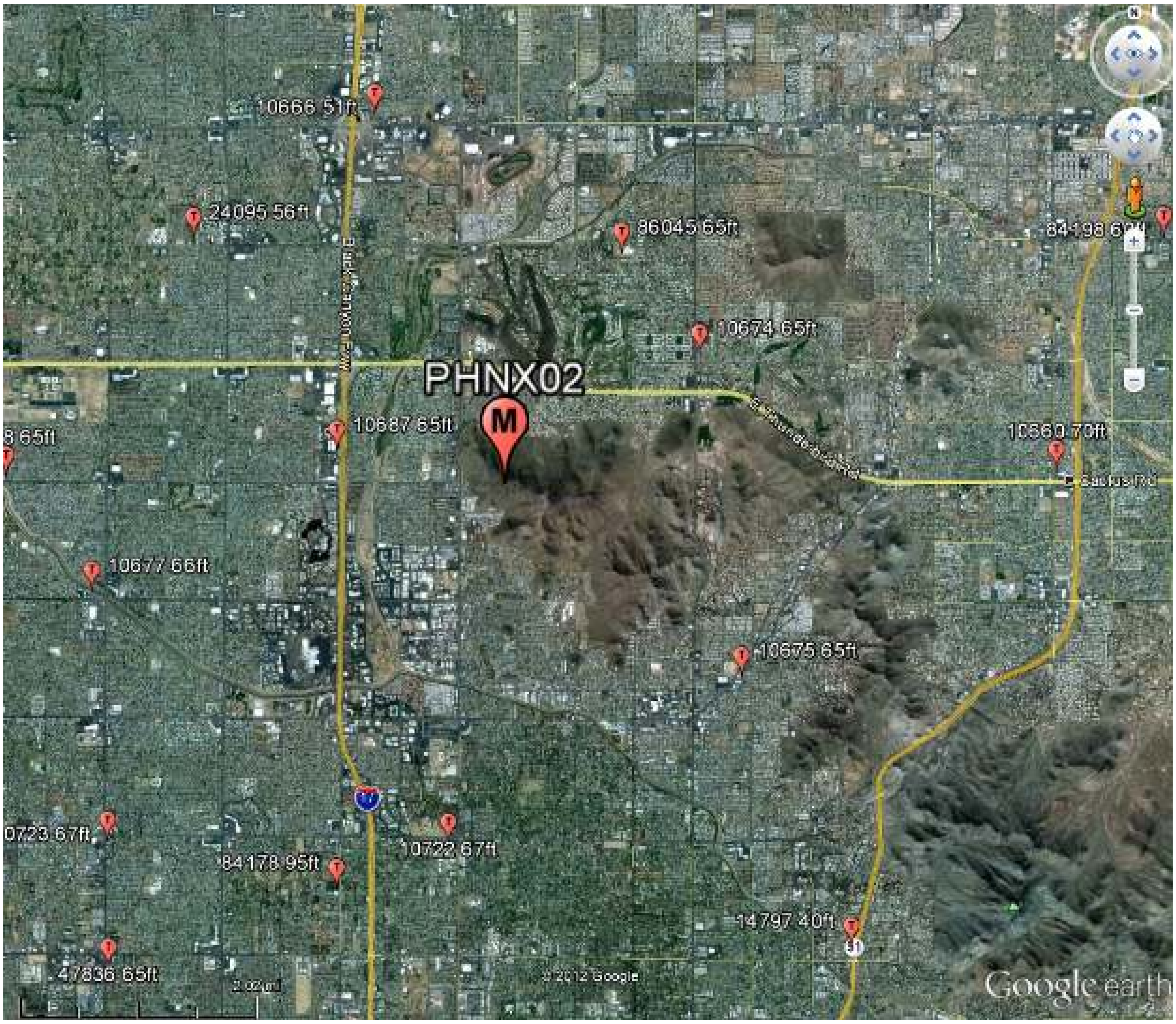

Figure 35 - MediaFlo PHNX02 Site with Surrounding AT&T Owned Towers

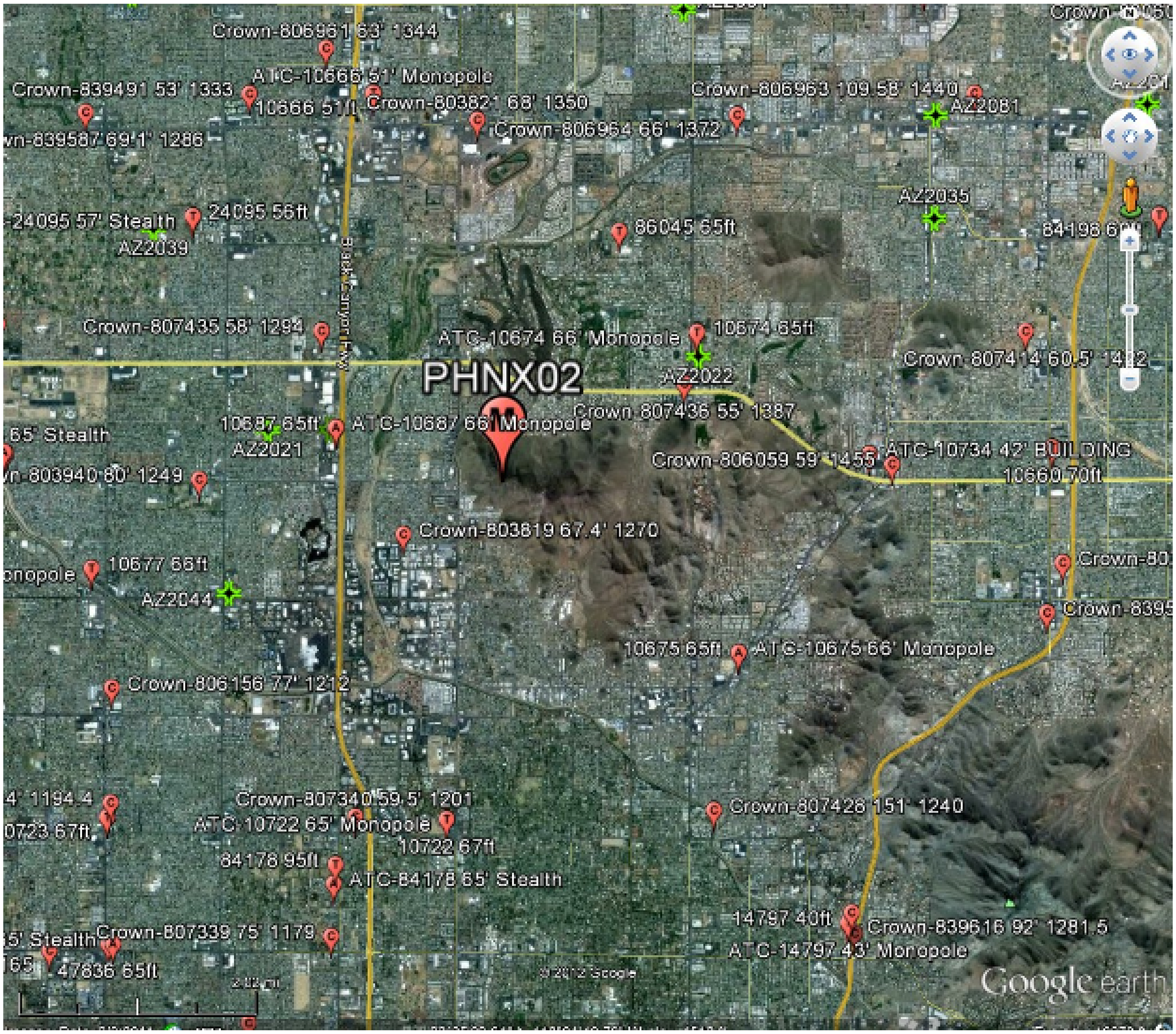

Figure 36 - MediaFlo PHNX02 Site with All Surrounding Towers

84. Another solution to which most parties agree, and to which the NPRM inquired, is the reduction in power for the remaining E-Block licensees to match the condition on the AT&T acquired D-Block and E-Block licenses. This solution effectively eliminates any difference between a Band 12 and Band 17 device as it puts all Lower 700 MHz blocks on identical adjacent channel interference “footing”.

E. Channel 56 E-Block Formal Response to NPRM Questions

85. In the "Discussion" section of the NPRM Section III.B, "Potential for Harmful Interference", the FCC requested comment, feedback, data, and analysis regarding interference for both the Channel 51 and the Channel 56 E-Block scenarios. In this section, the focus is on the Channel 56 E-Block issues and concerns raised, along with the findings and analyses.

86. The test approach used, combined with the ability to measure the performance of actual Band 12 devices (heretofore not available) in comparison to Band 17 devices (NPRM 40), provides the FCC with excellent insight into the performance of the devices and the resulting Potential for Harmful Interference. The latest test instrumentation was leveraged in a professional laboratory set-up to execute the testing on the Band 12 devices, as well as a Band 17 device as a performance comparison baseline. The necessary filters were procured to ensure proper isolation of the equipment and collected signals.

87. As described herein, the test data collected was used to perform a comprehensive quantitative analysis (NPRM 40) on the potential for interference from the Channel 56 E-Block transmitters. Currently, there are no Channel 56 E-Block high-power mobile broadcast systems deployed. Therefore, the Channel 56 E-Block parameters (location, power, height) were based on the former high-power MediaFlo sites deployed across the State of New Jersey. These were used to develop a prediction of the wideband signal strength that would be present at the UE based on a reasonable deployment scenario. The predicted worst-case, ground-level energy was developed by using the TM 91-1 model. A typical antenna pattern was used to derive the level of Channel 56 E-Block signal that would be present at the UE. Applying these worst-case conditions, the findings and analyses suggest the "potential" interference area is shown to be less 800 feet[29] or less from any Channel 56 E-Block site location. For rural areas, the analysis shows the "potential" interference area to be small and generally unpopulated; therefore no practical interference would actually exist. For suburban and urban areas near Channel 56 E-Block transmitters, the "potential" interfering signal strength can be overcome via collocation on the existing E-Block tower or nearby towers and would be in the normal course of system deployment to properly serve these areas. In conclusion, the magnitude and extent of Harmful Interference is virtually non-existent.

88. An evaluation of the likelihood of an operator, utilizing a "typical" LTE deployment, having a site in the area to target the same population as the Channel 56 E-Block licensee, was conducted (NPRM 38, 39, 40). The evaluation analyzed whether an operator would collocate on the Channel 56 E-Block facility or on a nearby structure as part of a basic deployment strategy. The analysis shows that alternative structures in the vicinity are highly likely, as they would be striving to serve the same population as the E-Block tower. It should also be noted that if these nearby structures were not used, than service to the area is unlikely, and the interference would never occur. V-COMM has collected and analyzed tower data from the MediaFlo deployments in multiple markets across the CONUS, and from the above analysis it can be determined that, not only is collocation possible, it was widely-used in the MediaFlo deployment strategy. In cases where nearby cellular

[29] It should be noted that this maximum radius is based on a propagation model, and **not** actual field test data. There are currently no active E-Block deployments from which to test.

infrastructure does not exist, the E-Block sites are sufficiently isolated so that any interference concerns brought about by E-Block Blocking and Reverse PA IM are non-existent.

89. The analysis clearly shows that the "potential harm resulting from interference" is in fact outweighed by "the public interest benefits that would result from interoperability in the Lower 700 MHz band" (NPRM 40) since the analysis shows that interoperability would not cause widespread harmful interference.

90. Although the potential for interference is found to once again be virtually non-existent, if not entirely non-existent, potential measures that the FCC could undertake to further reduce the potential were nonetheless investigated. The NPRM makes an inquiry (NPRM 42, 43) regarding the application of the "technical conditions" set forth in the AT&T acquisition of Qualcomm's D-Block and E-Block, to the remaining E-Block licenses. This modification to the entire E-Block would be appropriate, and would provide consistency across the Lower 700 MHz spectrum and additional relief to A-Block operations. Should high-power E-Block operations be allowed, then requirements for coordination by E-Block operators to the D-Block and A-Block adjacent channel operators should be considered. The coordination would allow for AT&T (D-Block) and A-Block operators to individually determine the level of E-Block impact on their networks and react accordingly.

VII. ROAMING

91. Several comments in this proceeding pertain to the issue of roaming in relation to interoperability. It should be noted that roaming requires commercial agreements, signaling paths between networks and complementary coverage footprints, all of which are more than just interoperable devices which employ a common band class; however with a bifurcated band class, data roaming becomes increasingly more complex and in some cases impossible. Currently, devices which employ a Band 12 configuration will not roam on a Band 17 network and vice-versa because the band class indicator and subsequent channelization scheme is different. For example, even though the actual frequencies which would be used by a Band 12 device on a Band 17 network would be essentially the same, the differences in the Band 12 vs. Band 17 schemes currently prevent the ability to roam.

92. In relation to A-Block operators, AT& T has indicated that CDMA technology would be a "fall-back" for their voice roaming needs[30]. AT&T has also indicated ". . . given their need to fall back to CDMA, AT&T would probably not be their preferred partner for roaming. Band 12 providers also could roam on each other's LTE networks"[31]. Since all A-Block licensees are not specifically affiliated with an existing CDMA operation, this is certainly not the case. In fact, as some of these licensees establish new competitive services in their licensed area(s), they may choose to roam with any operators that give them the most competitive roaming arrangements including AT&T, and then choose devices to match these business plans. These devices could have either a CDMA or GSM/UMTS "fall back", whichever best fits their business plan. Further, many CDMA devices are dual radio devices and the second radio in the device could be chosen by the A-Block licensee to best match their business plans; which if a Band 12 LTE data radio, roaming on any Lower 700 band data network would also be possible. Additionally, LTE-LTE data roaming could exist between A, B and C-Block licensees, if the business plans made sense, and 3G roaming with different carriers could also be possible if necessary.

93. Finally, all Lower 700 band operators would have the same opportunity to provide similar data roaming capabilities to non-700 MHz operators. The results of the laboratory tests described herein indicate that any performance differences between Band 12 and Band 17 devices are limited to very small areas around certain towers or are completely non-existent, thereby making roaming more a policy issue and not a technical Band Class issue.

94. In the end, it is likely different operators will choose different variants of devices to match their service offerings and business plans. This exists today with the various combinations of roaming capabilities in the 2G/3G world. The operation of Band 12 devices would allow the possibility for roaming among any Lower 700 MHz operators.

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[30] See Comments of AT&T Services, Inc., filed June 1, 2012, Declaration of Michael Prise, ¶ 23.

[31] Id. ¶ 27.

VIII. APPENDIX A – LABORATORY TEST FACILITY AND TEST EQUIPMENT

95. The Test Laboratory is a shielded facility located within the United States Cellular Corporation (USCC) building in Chicago, Illinois. Since the facility is within a Channel 51 station footprint, tests were conducted with the facility door open and closed to ensure Channel 51 energy could not corrupt test results. The measurements confirmed no signal energy from Channel 51 or any other source was entering the shielded lab.

A. Test Lab and Equipment Overview

96. The lab facility was built and testing equipment was purchased within the last year. Figure 37 shows the lab facility used for testing.

Figure 37 - Picture of USCC Shielded Test Facility

97. In order to ensure that all of the equipment being used was calibrated correctly and performed at/better than standards, the equipment calibration was verified and tested prior to conducting tests. All cables, connectors and adapters were tested to identify the losses present within the tests. The exact losses of all of these components were noted and factored into the test plan as offsets for the signal generator, so that the test devices were working with "true" power and any extraneous calculations were eliminated. Figure 38 depicts each major component used, with a description of each component used for the testing below.

- SFE-100 Signal Generator – used to generate the CW Ch. 51 signal.
- Spectrum Analyzer – used to view, measure, and record the input and output signals.
- CMW-500 LTE Signal Emulator – used to generate the LTE eNodeB signal and control the UE transmission parameters.
- Channel 51/Channel56 E-Block OOBE Filter – used to reduce the signal generator's noise into the device receive band.
- Isolators - used to minimize the reflections off the filter.

- UE Receive Filter – reduces the amplitude of the device transmission and interfering signal into the Spectrum Analyzer, allowing for a larger dynamic range.
- Power Splitter – needed to combine all test equipment together.
- For safety purposes a "20 dB pad" was used on the output of the CMW500 BTS Emulator to avoid any overload.
- Variable Attenuator – needed to control E-Block transmitter low power output levels
- DC Power Supply – provided power to the devices.

98. A visual inspection of equipment used was completed to ensure that there were no visible faults, marks, bends, or breaks in each cable, connector, and adapter.

99. The filters/isolators were tested to verify they met design specifications. The filters/isolator response was confirmed by sweeping across the desired frequencies.

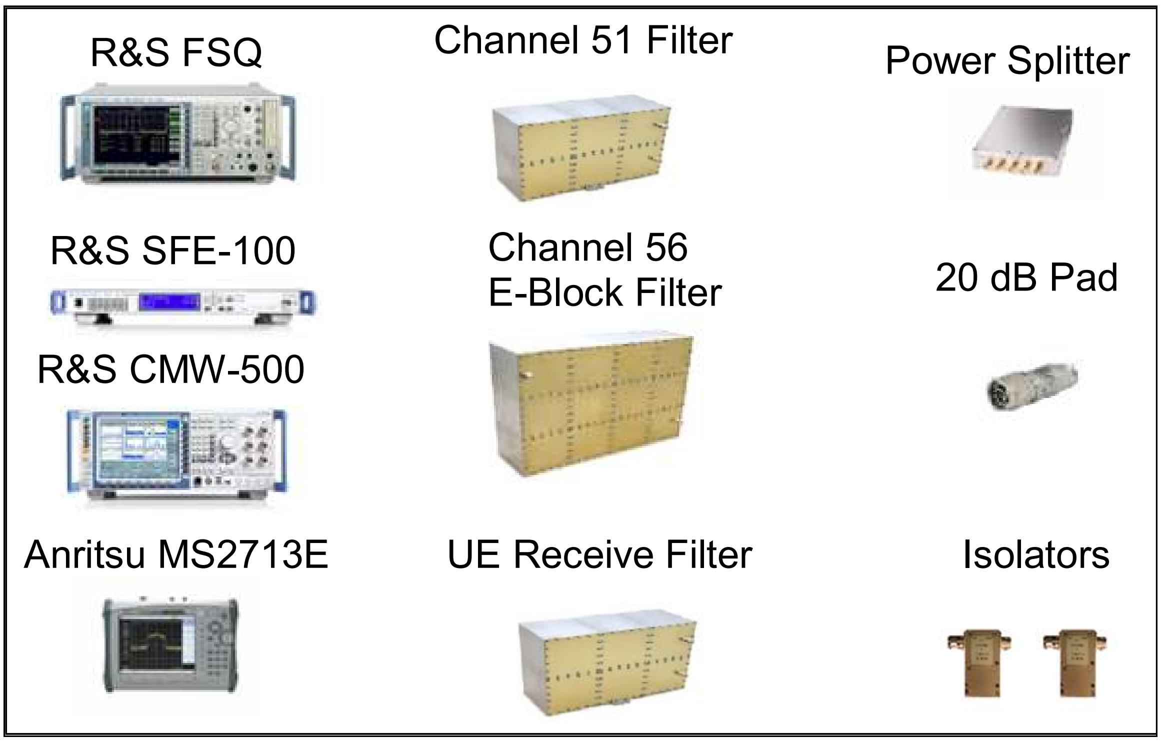

Figure 38 - Test Equipment Components

B. DEVSENS Test Configuration

100. A device sensitivity test was conducted on all Band 12 & Band 17 devices to establish a baseline for each Device Under Test (DUT). The device sensitivity tests were completed for B+C-Block(10 MHz), B-Block (5 MHz), and C-Block (5 MHz). In order to baseline the UE and to mitigate any variations due to self-desensitization, the sensitivity of the device was tested, both when the UE was not transmitting and when the UE was transmitting at Full Power (+23 dBm). The difference can affect the baseline performance of the UE during the Reverse PA IM tests, as the devices were transmitting during these tests. Additionally, multiple modulation and coding schemes were tested in order to measure any increase in sensitivity required for these cases, as compared to the base QPSK modulation scheme.

101. The CMW-500 LTE Emulator was connected with test cables to a power splitter/combiner. From the power splitter, two additional cables connected the DUT and the spectrum analyzer. The spectrum analyzer was used to validate the Uplink (UL) and Downlink (DL) signals.

102. Once all equipment was properly connected, the LTE emulator signal was decreased down to a level where the UE receiver would decode a minimum of 5% Block Error Rate (BLER). A Rhode & Schwarz (R&S) BLER program was used to establish the measurement for each of the DUTs. The BLER program sends UL and DL data on a continuous basis.

103. Measurements were taken using multiple modulation schemes which included QPSK, 16 QAM, and 64 QAM. For each test, measurements were repeated several times to ensure values were consistent among the tests. The procedures were repeated for B+C block, B-block, and C-block on all devices (Band 12 and Band 17 devices).

104. Figure 39 reflects the test equipment used for the device sensitivity (DEVSENS) tests. For the DEVSENS test configuration for both Band 12 and Band 17 devices, the following equipment was used:

- R&S FSQ Spectrum Analyzer – allowed the input and output signals to be viewed, measured, and recorded.
- CMW-500 LTE eNodeB Generator – generated the LTE eNodeB signal, and controlled the UE transmission parameters.
- Band 17 Devices – Band 17 front-end devices used for testing.
- Band 12 Devices – Band 12 front-end devices used for testing.
- UE Receive Filter – used to reduce the amplitude of the device transmission and interfering signal into the Spectrum Analyzer, allowing for a larger dynamic range.
- Power Splitter – combined LTE eNodeB signals with input from the Band 12/Band 17 UE devices.
- DC Power Supply – provided power to the devices.

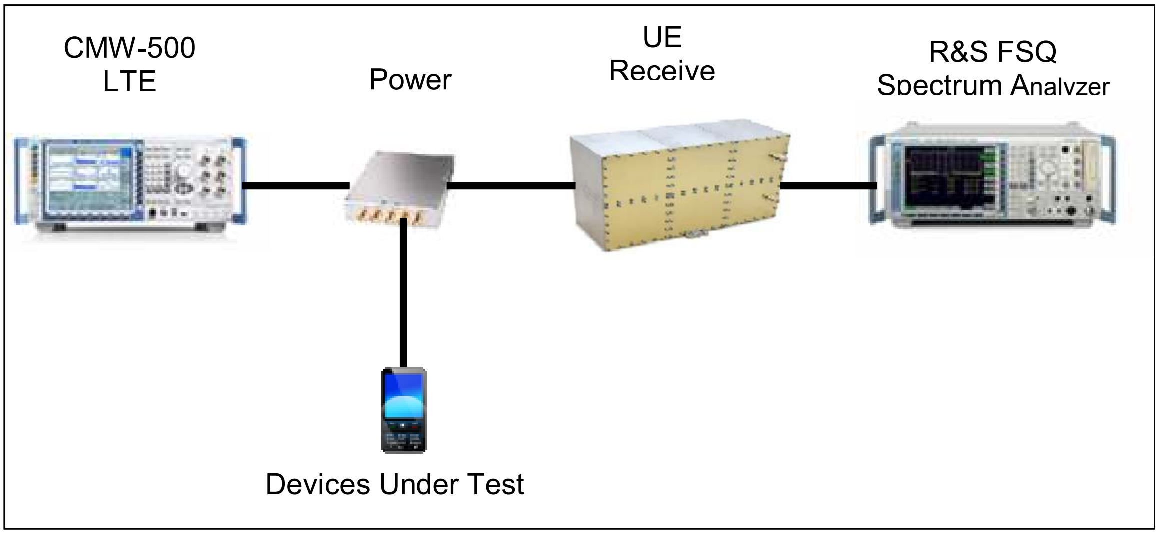

Figure 39 - DEVSENS Test Equipment Configuration

C. Channel 51 Reverse PA IM Test Configuration

105. A Channel 51 Reverse PA IM Test was conducted on B+C-Block and C-Block for all Band 12 & Band 17 devices to establish levels of "potential" interference when injected with a Channel 51 DTV signal. A 5.8 MHz ATSC DTV signal centered at 695 MHz was used to simulate a wideband, high-power broadcast transmission. The interfering signal was combined with an LTE 10 MHz desired source and input to the DUT. As the DUT received the desired LTE signal, the interfering signal was increased until the device BLER reached a level at or over 5%.

106. The Reverse PA IM test configuration is shown in

107. Figure 40 below. For the Channel 51 Reverse PA IM Test configuration for each of the blocks on both Band 12 and Band 17 devices, the following equipment was used:

- SFE-100 DTV Signal Generator – generated the DTV Ch. 51 signal.
- R&S FSQ Spectrum Analyzer – allowed the input and output signals to be viewed, measured, and recorded.
- CMW-500 LTE eNodeB Generator – generated the LTE eNodeB signal, and controlled the UE transmission parameters.
- Band 17 Devices – Band 17 front-end devices used for testing.
- Band 12 Devices – Band 12 front-end devices used for testing.
- Channel 51 Filter – used to reduce the signal generator's noise into the devices' receive band.
- UE Receive Filter – used to reduce the amplitude of the device transmission and interfering signal into the Spectrum Analyzer, allowing for a larger dynamic range.
- Power Splitter – combined DTV Channel 51 and LTE eNodeB signals to input to the Band 12 Band 17 UE device.
- Isolators – reduced reflections from sharp filters.

- For safety purposes a "20 dB pad" was used on the output of the CMW500 BTS Emulator to avoid any overload.
- DC Power Supply – provided power to the devices.

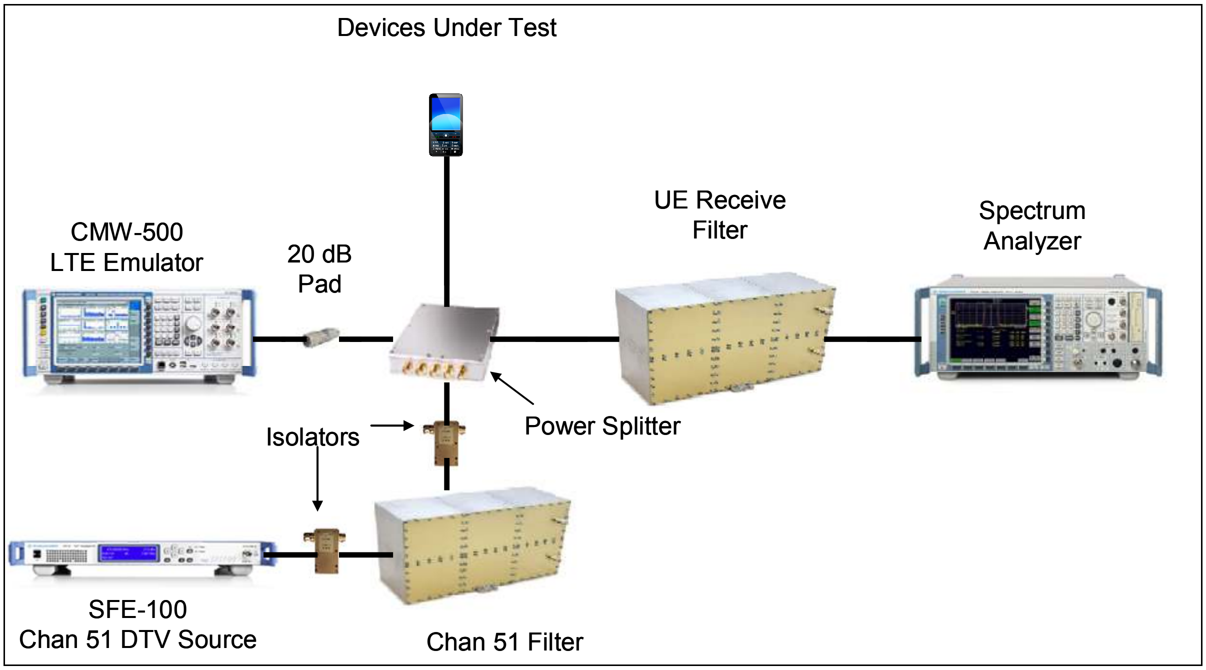

Figure 40 - Reverse PA IM Test Configuration

108. The CMW-500 LTE Emulator was connected with test cables to a power splitter. From the power splitter, three additional cables connected the DUT, Channel 51 interfering source (SFE-100), and the spectrum analyzer. The spectrum analyzer was used to validate the Uplink (UL) and Downlink (DL) signals.

109. The signal generators were properly tuned in order to display the results. The connector/cable losses from the LTE Emulator to the UE RF Port were measured, including the UE adapter cable loss (typically 0.4 dB at 700 MHz).

110. For the 10 MHz channel bandwidth, The UEs were set to full-power transmission on 24 Resource Blocks (RB) with an offset of 26. For both 5 MHz channel bandwidth tests, the UE's were set to full-power transmission on all 25 RBs. The R&S BLER program was used to verify that the device provided the same measured results as when testing DEVSENS. The 10 MHz carrier was centered at 710 / 730 MHz, while the 5 MHz B-Block carrier was centered at 707 / 737 MHz and the 5 MHz C-Block carrier was centered at 713 / 743 MHz.

111. The DTV signal generator was setup to transmit a 5.8 MHz signal centered at 695 MHz to emulate Ch. 51 Digital Television. ATSC standards were used throughout the testing as the transmission standards for DTV source. The power of DTV signal generator was varied to obtain the interfering levels at for each of the blocks testing on all of the Band 12 and Band 17 devices for different raised noise floor levels across multiple modulation schemes (QPSK, 16 QAM and 64 QAM).

D. Channel 56 E-Block Blocking and Reverse PA IM Test Configuration

112. A Channel 56 E-Block Blocking and Reverse PA IM test was conducted for B+C-Block (10 MHz), B-Block (5 MHz), and C-Block (5 MHz) on all Band 12 & Band 17 devices to establish levels of "potential" interference when injected with an E-Block signal. A 5 MHz E-Block signal centered at 725 MHz was used to simulate a wideband, high-power broadcast transmission. The E-Block signal was combined with several combinations of LTE signals as the desired source (10 MHz B+C, B-Block Only, C-Block Only) and input to the DUT. As the DUT received the desired LTE signal, the interfering signal was increased until the device BLER reached a level at or over 5%.

113. The Channel 56 E-Block blocking and Reverse PA IM test configuration is shown in Figure 41 below. For the Channel 56 E-Block Blocking and Reverse PA IM test configuration for both Band 12 and Band 17 devices, the following equipment was used:

- SFE-100 MediaFlo Signal Generator – generated a Ch. 56 E-Block signal.
- R&S FSQ Spectrum Analyzer – allowed the input and output signals to be viewed, measured, and recorded.
- CMW-500 LTE eNodeB Generator – generated the LTE eNodeB signal, and controlled the UE transmission parameters.
- Band 17 Devices – Band 17 front-end devices used for testing.
- Band 12 Devices – Band 12 front-end devices used for testing.
- E-Block Filter – used to reduce the signal generator's noise into the devices' receive band.
- UE Receive Filter – used to reduce the amplitude of the device transmission and interfering signal into the Spectrum Analyzer, allowing for a larger dynamic range.
- Power Splitter – combined Channel 56 E-Block signal and LTE eNodeB signals to input to the Band 12 Band 17 UE device.
- Isolators – reduced reflections from sharp filters.
- For safety purposes a "20 dB pad" was used on the output of the CMW500 BTS Emulator to avoid any overload.
- Variable Attenuator – needed to control E-Block transmitter low power output levels.
- DC Power Supply – provided power to the devices.

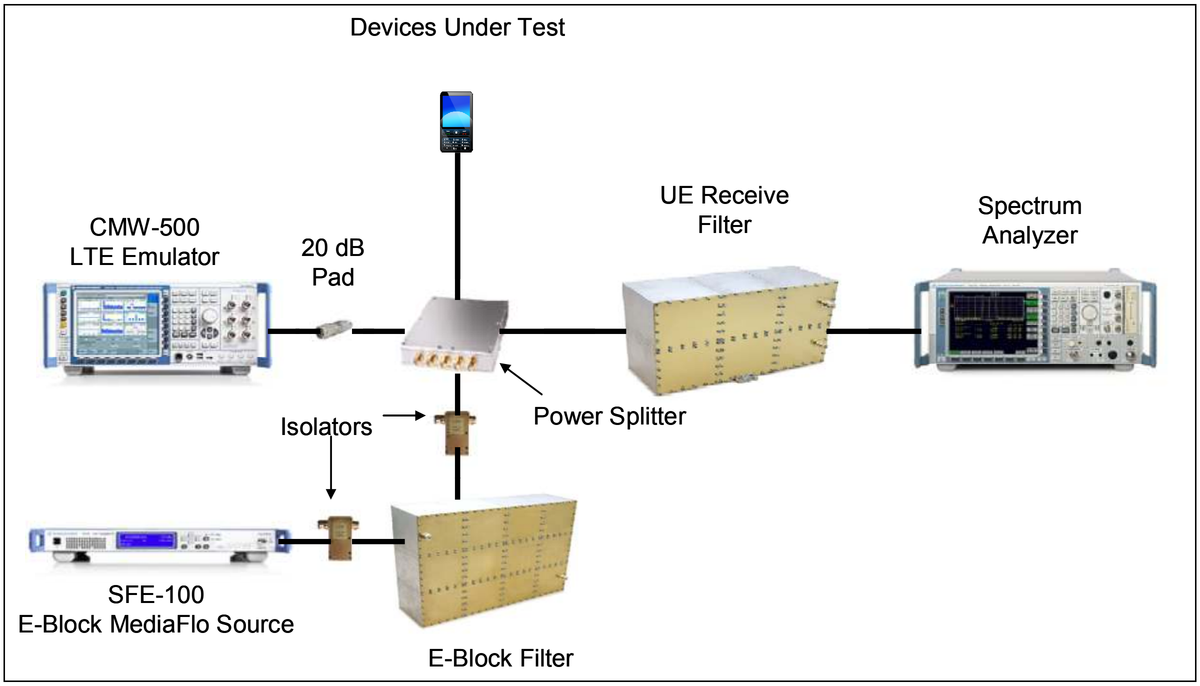

Figure 41 - Channel 56 E-Block Blocking and Reverse PA IM Test Configuration

114. The CMW-500 LTE Emulator was connected with test cables to a power splitter. From the power splitter, three additional cables connected the DUT, Channel 56 E-Block interfering source (SFE-100) and the spectrum analyzer. The spectrum analyzer was used to validate the Uplink (UL) and Downlink (DL) signals.

115. The signal generators were properly tuned in order to display the results. The connector/cable losses from the LTE Emulator to the UE RF Port were measured, including the UE adapter cable loss (typically 0.4 dB at 700 MHz).

116. For the 10 MHz channel bandwidth, The UEs were set to full-power transmission on 24 Resource Blocks (RB) with an offset of 26. For both 5 MHz channel bandwidth tests, the UE's were set to full-power transmission on all 25 RBs. The R&S BLER program was used to verify that the device provided the same measured results as when testing DEVSENS. The 10 MHz carrier was centered at 710 / 730 MHz, while the 5 MHz B-Block carrier was centered at 707 / 737 MHz, and the 5 MHz C-Block carrier was centered at 713 / 743 MHz.

117. The Channel 56 E-Block signal generator was setup to transmit a 5 MHz signal centered at 725 MHz to emulate a MediaFlo DTV high-power broadcast signal on the Channel 56 E-Block. The power of the Channel 56 E-Block signal generator was varied to obtain the interfering levels at each B+C, B and C-blocks on all of the Band 12 and Band 17 devices for different raised noise floor levels and multiple modulation schemes (QPSK, 16 QAM and 64 QAM).

118. Once completed, the Channel 56 E-Block tests were repeated with the UEs set to minimum power transmission on the Uplink. Again, the power of the Channel 56 E-Block signal generator was varied to obtain the interfering levels for each B+C-Block, B-Block, and C-Block on all of the Band 12 and Band 17 devices for different receiver desense levels

which raise the UE's noise floor levels and multiple modulation schemes (QPSK, 16 QAM and 64 QAM). Measurements were taken and documented in a separate table for later comparison to determine the level of IM contribution to the E-Block blocking interference.

IX. APPENDIX B – PROPAGATION MODEL DETAILS

A. Line of Site Model Details

119. The Line of Sight model is the most basic and conservative of RF propagation models. It assumes the signal is propagating in a free-space environment and that there is no attenuation due to shadowing (i.e. the receiver can "see" the transmitter). The model takes into account frequency, distance, transmitting and receiving antenna height, body loss, receive antenna gain, and transmit antenna elevation pattern. Additionally, the model is referenced to a dipole antenna. Shown in Figure 42 is the equation to calculate Received Signal Strength, RSSIUE (in dBm). Shown in Figure 43 is a diagram depicting Line-of-Sight propagation from transmitter to receiver. The model assumes a receive antenna height of 2 m (~6 ft).

Free Space LOS Calculation

$$RSSI_{UE} = ERP + 31.85 - 20\log_{10}(f_c) - 20\log_{10}\left(\sqrt{(h-2)^2 + d^2}\right) + L_{Antenna} + G_{UEAntenna} + L_{Body}$$

Where:

$RSSI_{UE}$ = Received Signal Strength Indicator at dipole, dBm

ERP = Effective Radiated Power, dBm

F_c = Center frequency, in MHz (695 MHz)

h = Antenna height, meters

d = Distance from antenna, meters

$L_{Antenna}$ = Loss associated with Antenna elevation pattern, dB

$G_{UEAntenna}$ = Gain associated with UE antenna with respect to dipole, dB (-2 dBd)

L_{Body} = Losses associated with body, dB (-3 dB)

Figure 42 – Line-of-Sight (LOS) Model Parameters

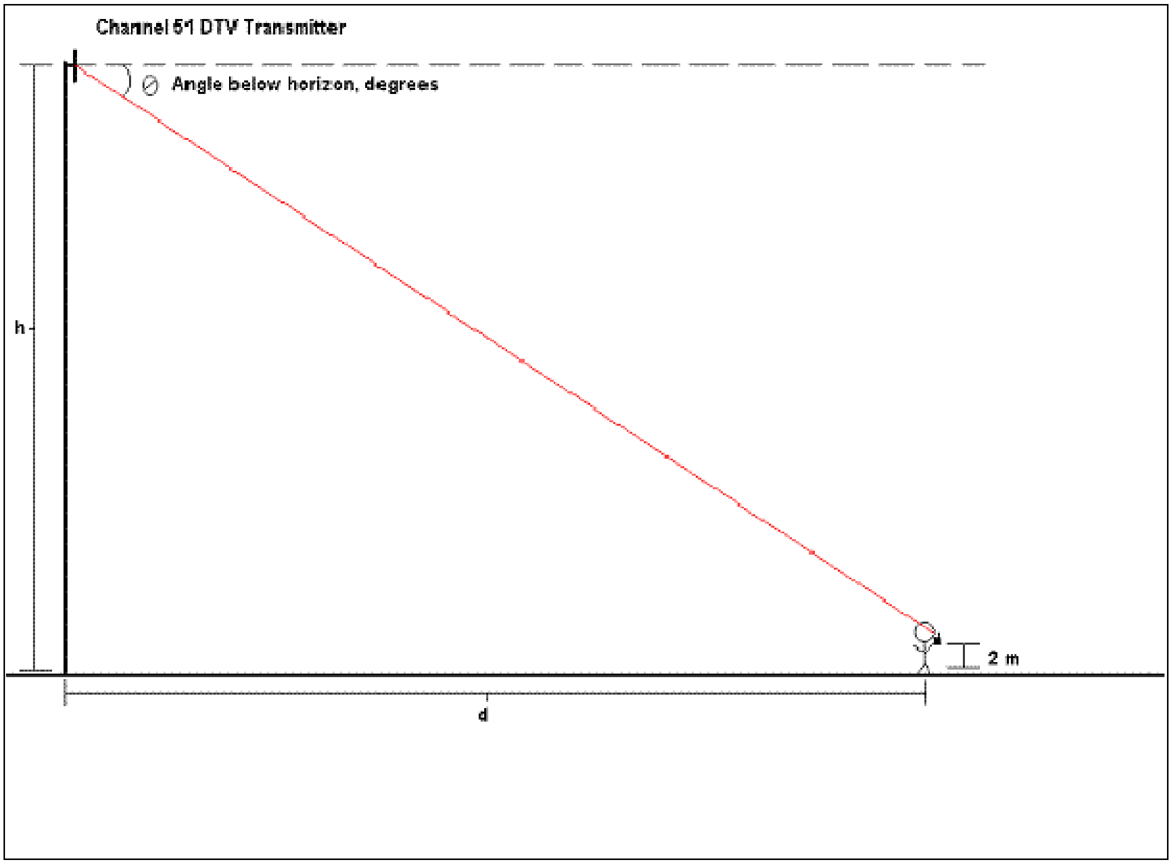

Figure 43 – Line-of-Sight (LOS) Model Diagram

B. TM 91-1 Model Details

120. The TM 91-1 model was developed as a more realistic, short-range propagation model for typical United States suburban areas. The formula takes into account frequency, distance, transmitting and receiving antenna heights, building penetration losses, body loss, receive antenna gain, and transmit antenna elevation pattern. According to OET TM 91-1, the model "is intended as a general planning and allocation tool for frequencies between 40 and 1000 MHz." Shown in Figure 44 are the equations used to calculate Field Strength, F (in dBuV/m), and subsequently Received Signal Strength at Remote, RSSIUE (in dBm). For specifics on the TM 91-1 propagation model, consult OET TM 91-1, entitled "Propagation in Suburban Areas at Distances less than Ten Miles."

$$F = 141.4 + 20\log_{10}(h_1 h_2) - 40\log_{10}(d) + 10\log_{10}(P) + B$$

$$RSSI_{UE} = F - 77.2 - 20\log_{10}(f_c) + 2.15 + L_{Antenna} + G_{UEAntenna} + L_{Body}$$

Where:

F = Field strength, dBuV/m

h_1, h_2 = Transmit / Receive antenna height, feet

d = Distance from antenna, feet

P = Effective radiated power, W

B = Building loss, dB (0 dB)

F_c = Center frequency, in MHz (725 MHz)

$RSSI_{UE}$ = Received signal strength indicator at dipole, dBm

$L_{Antenna}$ = Loss associated with antenna elevation pattern, dB

$G_{UEAntenna}$ = Gain associated with UE antenna with respect to dipole, dB (-2 dBd)

L_{Body} = Losses associated with body, dB (-3 dB)

Figure 44 –TM 91-1 Model Details

X. APPENDIX C – CHANNEL 51 GEOGRAPHIC AREA STUDIES (LAST 6 OF 8)

121. Per section V.C above, this appendix contains the additional 6 DTV stations whose power and antenna patterns could produce energy on the ground with the “potential” to create Reverse PA IM interference. Generally the sites continue to result in virtually no areas that would be frequented by the public and therefore the interference potential would not be realized. Even for sites that do have some housing or other structures in their vicinity, the numbers are very small. Each figure includes a short description and the calculation of the interference area relative to the 55-Mile Grade B service Area.

Figure 45 – Cordele, GA (WSST) Potential Area of Interference

122. The Cordele, GA WSST station location is located in a farmland area away from any development and is reflective of a classic broadcast location. There is virtually no possibility of “potential” interference. Figure 45 above depicts the Cordele, GA WSST “potential” interference area.

- Worst-case Reverse PA IM occurs at 50 m (164 ft.)
- Affected Area: 0.00785 sq. km (0.00303 sq. mi.)
- Percent of DTV Footprint: 0.0000319 %

Figure 46 - Greenville, NC (WEPX-TV) Potential Area of Interference

123. The Greenville, NC WEPX-TV station location is located in a remote field away from any development. There is virtually no possibility of "potential" interference. Figure 46 above depicts the Greenville, NC WEPX "potential" interference area. Additionally and as noted herein, this station will be relocating to another channel.

- Worst-case Reverse PA IM occurs at 75 m (264 ft.)
- Affected Area: 0.0177 sq. km (0.00682 sq. mi.)
- Percent of DTV Footprint: 0.0000718 %

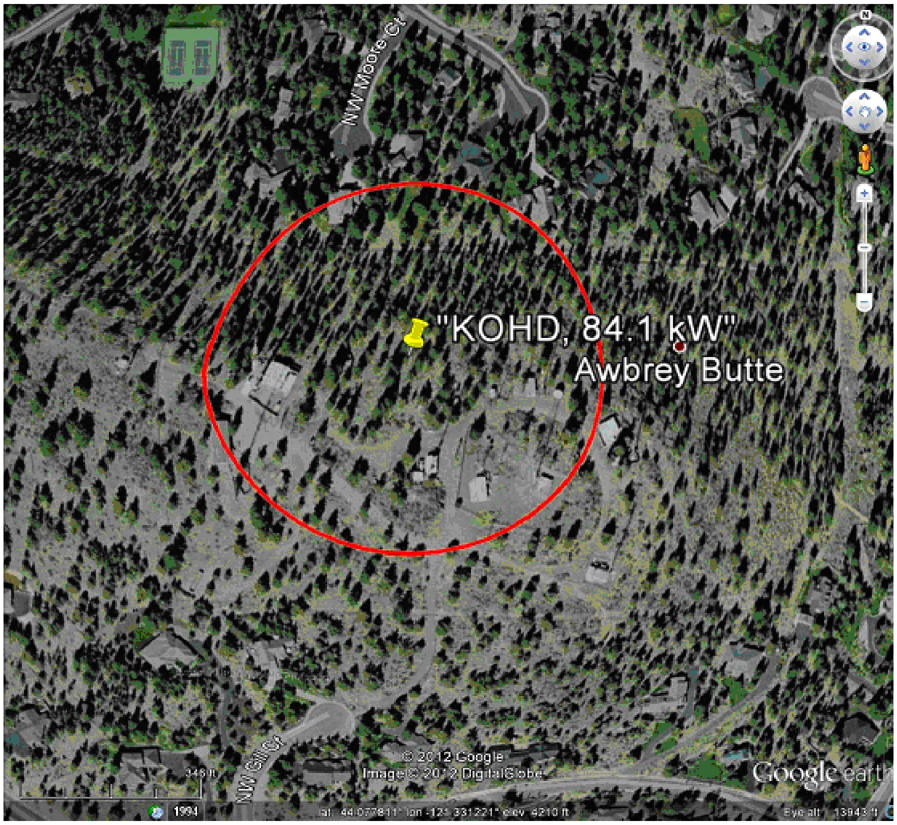

Figure 47 - Bend, OR (KOHD) Potential Area of Interference

124. The Bend, OR WSST station location is located on a hilltop near a small residential development, however the area is heavily wooded and LOS propagation would be very hard to attain. Therefore, the "potential" interference area, which is shown to impact less than 10 households, would shrink even further and there would be no practical interference concern. Figure 47 above depicts the Bend, OR KOHD "potential" interference area.

- Worst-case Reverse PA IM occurs at 100 m (328 ft.)
- Affected Area: 0.00785 sq. km (0.0121 sq. mi.)
- Percent of DTV Footprint: 0.000128 %

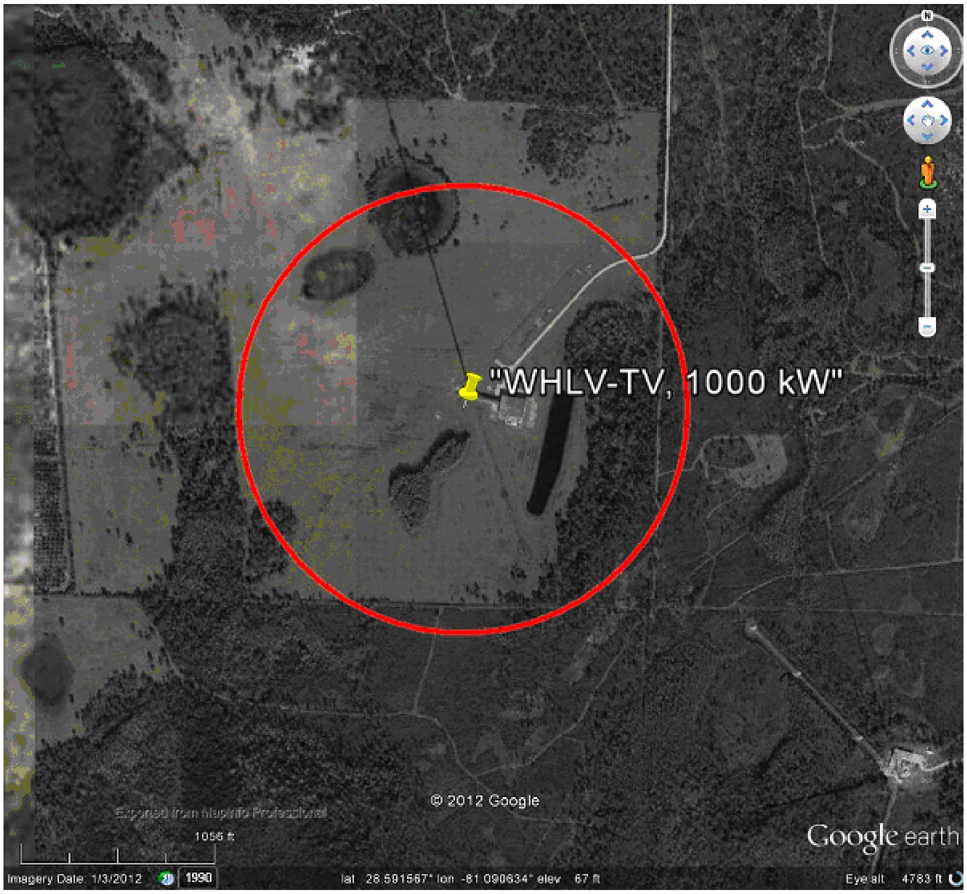

Figure 48 - Cocoa Beach, FL (WHLV) Potential Area of Interference

125. For the Cocoa Beach Florida site, WHLV, there are no populated areas or buildings near the site. Therefore, despite having the largest area in Figure 6 (Chart 2 of 2), the site has virtually no "potential" for interference. Figure 48 above depicts the Cocoa Beach, FL WHLV "potential" interference area.

- Worst-case Reverse PA IM at 375 m (1230 ft.)
- Affected Area: 0.442 sq. km (0.170 sq. mi.)
- Percent of DTV Footprint: 0.00179%

Figure 49 – Lansing, MI (WLAJ) Area of Potential Interference

126. The Lansing, MI WLAJ station location is located in a remote field in a rural area. There is virtually no possibility of "potential" interference. Figure 49 above depicts the Lansing, MI WLAJ "potential" interference area.

- Worst-case Reverse PA IM occurs at 300 m (984 ft.)
- Affected Area: 0.283 sq. km (0.109 sq. mi.)
- Percent of DTV Footprint: 0.00115 %

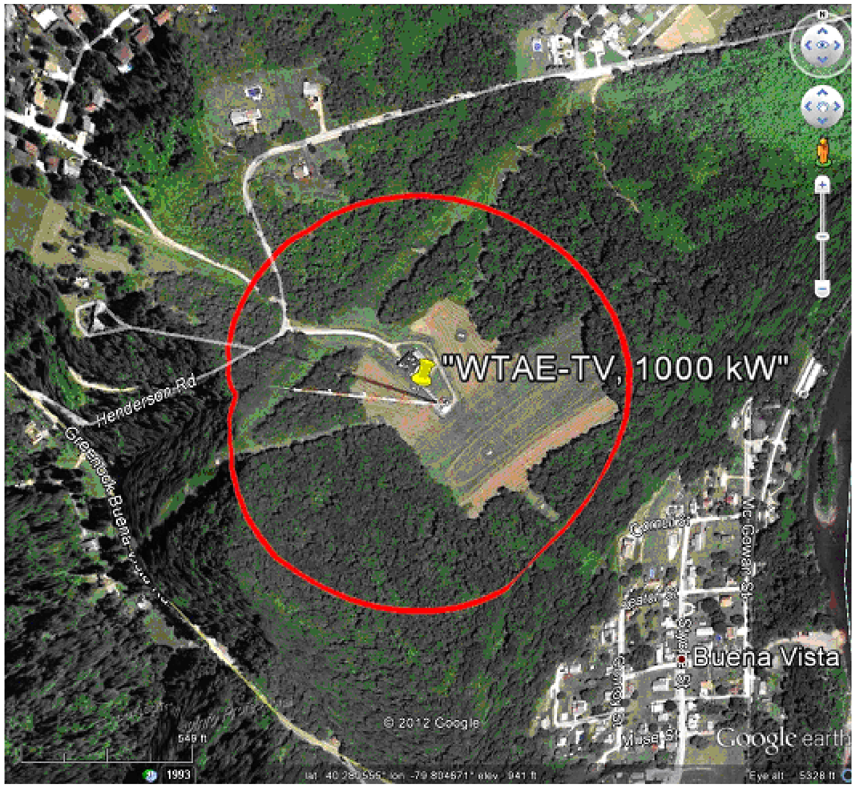

Figure 50 - Pittsburgh, PA (WTAE-TV) Area of Potential Interference

127. The Pittsburgh PA WTAE station is located on a hilltop away from the Pittsburgh metro area. There is a neighborhood southeast of the site, but down the hill, and it would have no "potential" interference impacts. Figure 50 above depicts the Pittsburgh, PA WTAE-TV "potential" interference area.

- Worst-case Reverse PA IM at 200 m (656 ft.)
- Affected Area: 0.126 sq. km (0.048 sq. mi.)
- Percent of DTV Footprint: 0.00051 %

XI. APPENDIX D - CHANNEL 51 "LIVE" BROADCAST TESTING

128. A Channel 51 Drive Test was conducted to establish maximum signal strengths levels versus distances from sites of “live” Channel 51 broadcast. Three locations were selected for testing. These locations include the Montclair, NJ; Cedar Rapids, IA; and Chicago, IL Channel 51 stations. The testing involved the following pieces of equipment:

- 3 antennas in different polarizations: horizontal, vertical, and slant
- GPS to track location
- 1x4 RF switch
- R&S Spectrum Analyzer
- PC laptop
- Vehicle equipped with roof rack

A. Test Setup

129. The drive test configuration is shown below in Figure 51. The antennas were roof mounted with the centerlines being between 5 and 6 feet. They were then connected to the 1x4 RF switch, which would connect to each individual antenna. The 1x4 RF switch was controlled by a script on the computer. The information was then fed to the R&S spectrum analyzer. A script was developed to control the R&S spectrum Analyzer to change parameters settings and take measurements for a set period of time. The script was loaded onto a laptop computer and measurements were recorded for every sample. Post-processing the involved merging data from the GPS with sample readings taken during the drive test combined into one file for mapping.

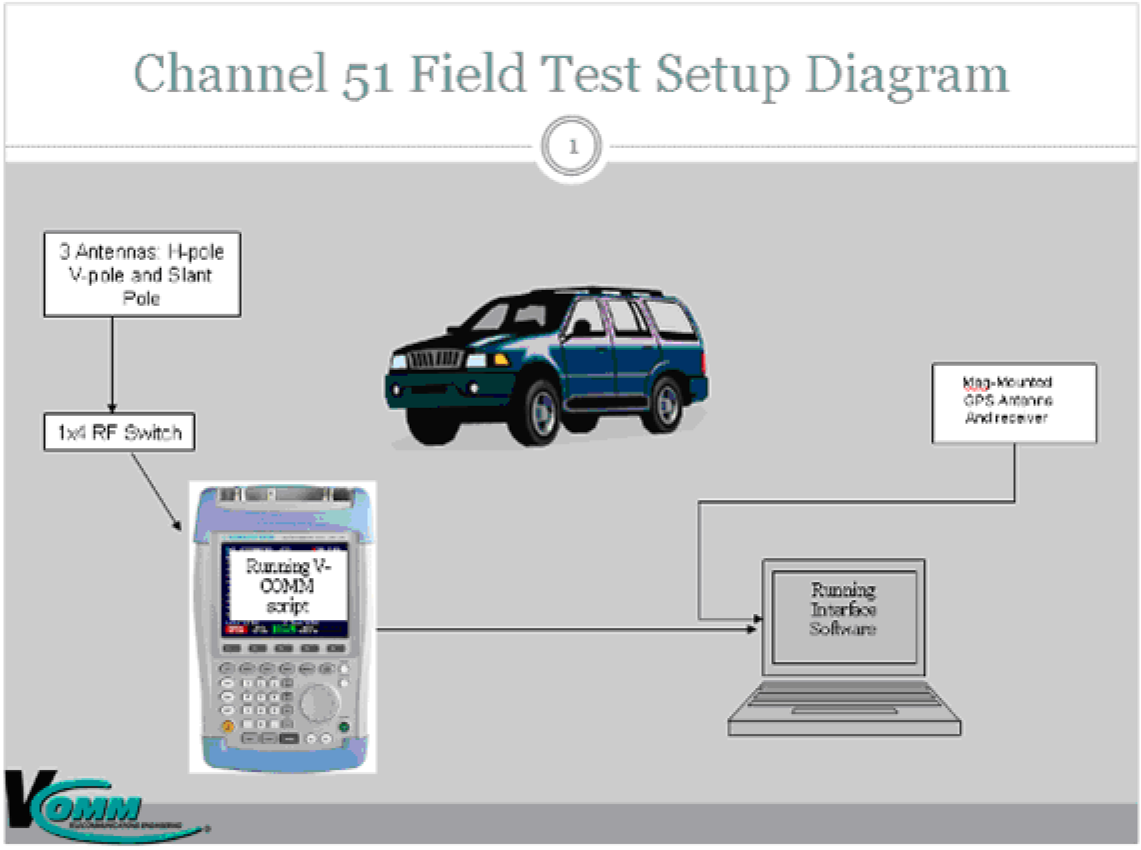

Figure 51 - Channel 51 Drive Test Configuration

B. Testing Procedure

130. Using propagations plots, V-COMM determine a predefined route to drive and collect data for each transmitter. Following the drive test routes, the majority of the testing was done within 1 kilometer of the site. We extended the drive testing to include distances that reach up to 3 kilometers away from the site. In addition, each of the predefined drive test route had individual "stationary points" where data was collected between 3-5 minutes in a stationary position. This was mainly done to collect additional samples to ensure accuracy readings of Channel 51 at each specific location.

C. Site Specific Testing

131. **Montclair, NJ:** This site had 15 individual stopping points and was in a suburban setting which had limited clutter, but still significant, to interfere with the testing signal.

132. **Cedar Rapids, IA:** This site also had 15 individual stopping points, and was the least complex of the locations due to its rural nature. Clutter was reduced to terrain, foliage, and farm buildings.

133. **Chicago, IL:** This site had 30 individual stopping points and was the most complex due to building shadowing, clutter, and other variables due to its urban nature.

XII. APPENDIX E – WATERLOO, IA FIELD TESTING

A. Testing Overview

134. In close coordination between V-COMM and USCC for the purposes of inclusion in this report, USCC implemented a migration of bands of their current 700MHz LTE Waterloo, Iowa network from B-Block (5MHz) to C-Block (5MHz) to B+C-Block (10MHz) band. U.S. Cellular implemented a migration of bands of their current 700 MHz LTE Waterloo, Iowa network from B-Block (5MHz) to C-Block (5MHz) to B+C-Block (10MHz) band. In between switching of the bands, U.S. Cellular drove test the network each time to confirm there was no degradation or change in performance prior to continuing operations on the new band. The migration of bands took place between June 21st and June 29th, 2012.

135. U.S. Cellular contracted PCTEL to conduct the drive test of their LTE network and report the results of the drive test survey measurements for each of the bands. V-COMM acted in close coordination with USCC on these activities so as to include the results and analysis in this report. The equipment involved includes the following:

- LTE UE Band 12 – Samsung Presto MIFI
- LTE Scanner – JDSU W1314A E09

B. Test Setup

136. The JDSU E6474A measurement system (Figure 52) was utilized to collected data of the drive test survey. The testing included measurements from an LTE UE and an LTE Scanner.

137. The antennas for the LTE scanner and equipment built-in GPS was mounted on the rooftop of the vehicle. The MIFI device was mounted on the dash inside the vehicle. The devices were kept in the same locations for all three drive test surveys. All connections and collection of the data were tied to one computer laptop.

Figure 52 - Generic JDSU Drive Test Equipment

C. Testing Procedure

138. U.S Cellular developed a predefined extensive route to drive and collect data for the LTE Network in Waterloo, Iowa. The drive test data was collected using the same drive test route. The majority of the testing consisted within the core of the network and extended to include parts of the exterior of the Network as well. The extent of the drive test route ensured data was collected across a wide variety of LTE received signal and Channel 51 received signal conditions and to determine any difference in the network performance across the network configurations.

139. All testing was done during the maintenance window (4-6 am), to mitigate any throughput degradation due to traffic congestion. Immediately after the rebanding, spot checks were completed throughout the network prior to the drive test to ensure the changes took place and the network was fully operational in the new band.

140. All testing occurred while simultaneously transmitting on the downlink and uplink, in order to properly emulate the interference scenario.

D. LTE Network Specific Testing

141. Three drive test surveys were conducted on the LTE network in Waterloo, Iowa. LTE carrier set to the following bands:

- B-Block (5MHz)
- C-Block (5MHz)
- B+C-Block (10MHz)

142. The first drive test was collected on the existing LTE network on the B-Block band. This drive test collection was used to baseline the existing LTE network and compare with the other drive test data collected on the other bands to determine any degradation or performance issues with the network.

143. The second drive test survey was conducted once U.S. Cellular switched the network to the C-Block band. As the drive test survey was completed, the data was post processed and compare to the baseline results. After further analysis between the baseline and C-Block band data collection, U.S. Cellular engineers determine there were no degradations to the network in switching bands and left the network operating on the C-Block band for a couple of days to monitor performance. No evidence of degradation to the performance of the network was observed during this time.

144. The third drive test survey was conducted when U.S. Cellular tuned the network to the B+C-Block band. Using the identical drive route, data was collected and processed. U.S. Cellular engineers again determined there were no degradation to the network in switching bands and left the network operating on the B+C-Block band. To this day the network continues to operate in the B+C-Block band. U.S. Cellular has not observed any significant difference in performance in their network in the B+C-Block band.

XIII. APPENDIX F – COMPANY INFORMATION & BIOGRAPHIES

145. V-COMM is a leading provider of quality engineering and engineering related services to the worldwide wireless telecommunications industry. V-COMM's staff of engineers is experienced in Cellular, Personal Communications Services (PCS), Enhanced Specialized Mobile Radio (ESMR), Paging, Wireless Data, Microwave, Signaling System 7, and Local Exchange Switching Networks. We have provided our expertise to wireless operators in engineering, system design, implementation, performance, optimization, and evaluation of new wireless technologies. Further, V-COMM was selected by the FCC & Department of Justice to provide expert analysis and testimony in the Nextwave and Pocket Communications Bankruptcy cases. V-COMM has offices in Blue Bell, PA and Cranbury, NJ and provides services to both domestic and international markets. For additional information, please visit V-COMM's web site at www.vcomm-eng.com.

146. BIOGRAPHIES OF KEY INDIVIDUALS

147. **Dominic C. Villecco** - President and Founder- V-COMM, L.L.C. - Dominic Villecco, President and founder of V-COMM, is a pioneer in wireless telecommunications engineering, with 31 years of executive-level experience and various engineering management positions. Under his leadership, V-COMM has grown from a start-up venture in 1996 to a highly respected full-service consulting telecommunications engineering firm.

148. In managing V-COMM's growth, Mr. Villecco has overseen expansion of the company's portfolio of consulting services, which today include a full range of RF & Network design, engineering & support; network design tools; measurement hardware; and software services; as well as time-critical engineering-related services such as business planning, zoning hearing expert witness testimony, regulatory advisory assistance, and project management. Before forming V-COMM, Mr. Villecco spent 10 years with Comcast Corporation, where he held management positions of increasing responsibility, his last being Vice President of Wireless Engineering for Comcast International Holdings, Inc. Focusing on the international marketplace, Mr. Villecco helped develop various technical and business requirements for directing Comcast's worldwide wireless venture utilizing current and emerging technologies (GSM, PCN, ESMR, paging, etc.).

149. Previously he was Vice President of Engineering and Operations for Comcast Cellular Communications, Inc. His responsibilities included overall system design, construction and operation, capital budget preparation and execution, interconnection negotiations, vendor contract negotiations, major account interface, new product implementation, and cellular market acquisition. Following Comcast's acquisition of Metrophone, Mr. Villecco successfully merged the two technical departments and managed the combined department of 140 engineers and support personnel. Mr. Villecco served as Director of Engineering for American Cellular Network Corporation (AMCELL), where he managed all system implementation and engineering design issues. He was responsible for activating the first cellular system in the world utilizing proprietary automatic call delivery software between independent carriers in Wilmington, Delaware. He also had responsibility for filing all FCC and FAA applications for AMCELL before it was acquired by Comcast. Prior to joining AMCELL, Mr. Villecco worked as a staff engineer at Sherman and Beverage (S&B), a broadcast consulting firm. He designed FM radio station broadcasting systems and studio-transmitter link systems, performed AM field studies and interference analysis and TV interference analysis, and helped build a sophisticated six-tower arrangement for a AM antenna phasing system. He also designed and wrote software to perform FM radio station

allocations pursuant to FCC Rules Part 73. Mr. Villecco started his career in telecommunications engineering as a wireless engineering consultant at Jubon Engineering, where he was responsible for the design of cellular systems, both domestic and international, radio paging systems, microwave radio systems, two-way radio systems, microwave multipoint distribution systems, and simulcast radio link systems, including the drafting of all FCC and FAA applications for these systems.

150. Mr. Villecco has a BSEE from Drexel University, in Philadelphia, and is an active member of IEEE. Mr. Villecco is a recognized zoning RF expert in the states of NJ, NY, PA, DE, and MI; as well as a precedent case in New Jersey Superior Court. In addition, Mr. Villecco was retained by the FCC and the Department of Justice and was qualified in federal court as a technical expert on their behalf, pertaining to matters of wireless network design, optimization, and operation in the Nextwave and Pocket cases. Mr. Villecco also served as the Vice-Chairman of the Advisory Council to the Drexel University Electrical and Computer Engineering (ECE) Department. Further, Mr. Villecco was awarded the "Distinguished Alumnus Award" from the Drexel University Electrical and Computer Engineering Department. Mr. Villecco also serves on the Board of Trustees of the New Jersey Wireless Association.

151. **James Shelton** - Director of RF Engineering - V-COMM, L.L.C.

152. Mr. Shelton has 22 years of experience in wireless engineering. He has extensive experience in wireless system design, implementation, testing, and optimization for wireless systems utilizing CDMA, EVDO, TDMA, GSM, LTE, OFDM, APCO 16, APCO 25, EDACS™, SMARTNET™, and AMPS wireless technologies. In his career, he has been responsible for the specification, design, test, implementation, and optimization of numerous wireless data and voice systems. His career began in the specification, design, and testing of secure advanced military digital wireless communications systems and continued with commercial wireless communications systems.

153. While at V-COMM, Mr. Shelton has been responsible for the performance of a RF engineering team supplying a variety of RF and business development services to a diverse client group. Projects include: technology evaluation; managing a team of RF Engineers in the design, test, implementation, optimization, and maintenance of new and existing Public Safety, cellular, PCS, MMDS, SMR, and other wireless voice and/or data throughout the United States and the Caribbean. In addition, Mr. Shelton has been involved in special technology evaluations and the development and procurement of hardware and software engineering tools to enhance both V-COMM and its client's capabilities. Mr. Shelton led the development of tools and procedures to assist clients and carriers in meeting compliance with FCC Rules & Regulations for RF Safety, emission standards and other FCC regulatory issues. His activities have included the development and submission to the FCC of multiple engineering studies on behalf of V-COMM's clients for consideration as part of the FCC's ongoing technology evaluations. Through these efforts, Mr. Shelton has demonstrated an ability to work with multiple team members often with conflicting agendas in the execution of a successful project. In addition, Mr. Shelton is qualified as an industry expert and provided expert witness testimony in the subject matter of RF engineering and the operation of wireless network systems for many municipalities in the state of New Jersey and Pennsylvania and is a member of the Institute of Electronics and Electrical Engineers (IEEE).

154. Prior to joining V-COMM, Mr. Shelton held various management and engineering positions at multiple government defense contract companies. In those duties,

Mr. Shelton participated in a variety of classified engineering and project development activities on behalf of the Department of Defense (DoD). Mr. Shelton was involved in the software testing of a TDMA based command, control, communications, and Intelligence (C3I) system. In addition, he participated in a program to upgrade the C3I system to be able to integrate into additional aircraft and ground level equipment. Mr. Shelton was involved in the development of the System Specification and host platform Interface Control Document which required the participation in, and presentation to, several International Working Groups involving multiple allies. At Lockheed Martin, Mr. Shelton was responsible for the specification and development for the upgrade of the C3I system for the incorporation of a Theatre Ballistic Missile Defense (TBMD) capability.

155. Mr. Shelton earned a Bachelor of Science degree in Electrical Engineering from Villanova University. Mr. Shelton is a recognized zoning RF expert in the states of PA, NJ, MD, KY, and NE. Mr. Shelton attended Masters of Business Administration courses at Villanova University. He has held a NATO Secret security clearance.