**Before the**
**Federal Communications Commission**
**Washington, DC 20554**

| | | |
|---|---|---|
| In the Matter of | ) | |
| | ) | |
| Wireless Telecommunications Bureau Seeks | ) | |
| Comment on Request By Cricket License Company | ) | |
| For Waiver of Section 27.60 | ) | WT Docket No. 14-17 |
| For Lower 700 MHz A Block License | ) | |

**COMMENTS OF FOX TELEVISION STATIONS, INC., LICENSEE OF WPWR-TV**

Joseph M. Di Scipio
Fox Television Stations, Inc.
400 N. Capitol Street, NW
Suite 890
Washington, DC 20001
(202) 824-6522

March 4, 2014

TABLE OF CONTENTS

I. INTRODUCTION AND SUMMARY. . . . . 1

II. CRICKET'S PROPOSED OPERATION WILL RESULT IN INTOLERABLE INTERFERENCE AND ITS STUDIES ARE FATALLY FLAWED. . . . . 2

A. FTS MSW Study Predicts Severe Interference. . . . . 3

B. The Cricket Studies are Fatally Flawed. . . . . 4

III. CRICKET FAILS TO MEET WAIVER STANDARD REQUIREMENTS AND A GRANT OF THE WAIVER WOULD VIOLATE THE PUBLIC INTEREST. . . . . 7

A. The Waiver Petition is Contrary to the Public Interest. . . . . 7

B. Grant of the Waiver Petition Would Eviscerate the Purpose Of the DTV Protection Rule. . . . . 10

IV. COMMERCIALLY VIABLE CRICKET OPERATION IN CHICAGO IS NOT RELEVANT. . . . . 11

V. FTS HAS COOPERATED WITH CRICKET. . . . . 12

VI. CONCLUSION. . . . . .13

**Before the**
**Federal Communications Commission**
**Washington, DC 20554**

| | | |
|---|---|---|
| In the Matter of | ) | |
| | ) | |
| Wireless Telecommunications Bureau Seeks | ) | |
| Comment on Request By Cricket License Company | ) | |
| For Waiver of Section 27.60 | ) | WT Docket No. 14-17 |
| For Lower 700 MHz A Block License | ) | |

**COMMENTS OF FOX TELEVISION STATIONS, INC., LICENSEE OF WPWR-TV**

## I. INTRODUCTION AND SUMMARY

Pursuant to the Public Notice released January 31, 2014 in the above referenced docket,[1] Fox Television Stations, Inc. (FTS), the licensee of WPWR-TV, Channel 51, Gary, Indiana, located in the Chicago Designated Market Area, hereby files these comments in opposition to the request by Cricket License Company, LLC (Cricket) for Waiver of Section 27.60 of the FCC's rules (Waiver Petition). Section 27.60 sets an absolute bar precluding wireless providers from interfering with a DTV broadcast station above a D/U ratio of -23 dB at its noise-limited contour. Cricket acknowledges that Section 27.60 established an exclusion zone to protect the operations of stations operating on Channel 51, even where the risk of interference is *de minimis*.[2] As Cricket readily admits in its Waiver Petition, its proposed operation would violate the interference protection criteria set forth is Section 27.60. More importantly, FTS' own expert

[1] *Wireless Telecommunications Bureau Seeks Comment on Request By Cricket License Company For Waiver of Section 27.60 For Lower 700 MHZ A Block License*, Public Notice, WT Docket 14-17, DA 14-113 (rel. Jan. 31, 2014). These Comments are timely filed, as the federal government was closed on March 3, 2014 (the original comment due date) due to inclement weather.
[2] Cricket Waiver Petition at 2. The interference here is far from *de minimis*.

engineering study predicts that grant of the Waiver Petition would result in more than a 99% population service loss for WPWR-TV. Cricket has not provided any public interest justification for obliterating WPWR-TV's signal. Because grant of the Waiver Petition is not in the public interest and would result in intolerable interference to the operations of WPWR-TV, the Commission must deny the Waiver Petition.

## II. CRICKET'S PROPOSED OPERATION WILL RESULT IN INTOLERABLE INTERFERENCE AND ITS STUDIES ARE FATALLY FLAWED

As demonstrated by the expert engineering analysis conducted by Meintel, Sgrignoli, & Wallace (MSW) at the request of FTS (attached as Exhibit A), Cricket's LTE operation would result in a population service loss of **99.84%** when Cricket operates with a power of +23 dBm using an OET-69 Longley-Rice analysis.[3] As established in detail below, Cricket's claim of interference occurring to only 20 WPWR-TV viewers is grossly inaccurate due to the faulty design of its studies and unwarranted exclusion of almost all of the households that would be susceptible to interference. The OET-69 Longley-Rice analysis as conducted by MSW is the proper engineering analysis to use here and was found acceptable by the FCC in both cases (*Qualcomm* and *New York State)*[4] that Cricket cited for support of its Waiver Petition. Cricket did not properly use or conduct an OET-69 Longley-Rice analysis in either of its engineering

---

[3] MSW at pp 46-50, Section 8.0 - 8.3 and Table 13 and Figure 12. The procedures and models used are discussed in detail in Section 8.2 of the MSW study. Moreover, the methods used by MSW are fundamentally the same as those discussed in the *Office of Engineering and Technology Seeks to Supplement the Incentive Auction Proceeding Record Regarding Potential Interference Between Broadcast Television and Wireless Services*, Public Notice, DA 14-98, rel. Jan. 29, 2014 (*OET PN*).

[4] *Qualcomm Incorporated Petition for Declaratory Ruling*, Order, 21 FCC Rcd 11683, 11695 (2006) (*Qualcomm*); *State of New York, Request for Waiver of Section 90.545 of the Commission's Rules to Implement a 700 MHz Public Safety System in Specified Counties in the Greater New York City Metropolitan Area*, Order, 22 FCC Rcd 22195, 22205 (2007) (*New York State*). *See also* OET PN.

studies.[5] The Commission cannot grant the Waiver Petition when Cricket's proposed operation would destroy the over-the-air (OTA) signal of WPWR-TV within its service contour and Cricket's own studies did not use proper or Commission-approved engineering methodology.

### A. FTS MSW Study Predicts Severe Interference.

Evaluated using proper and acceptable engineering study methodology, Cricket's LTE operation will result in a population service loss of **99.84%** at 23 dBm with the D/U interference ratio at the FCC prescribed limit of – 23 dB.[6] Lowering the Cricket LTE handset power to just +9 dBm, the population service loss still would be an entirely unacceptable 12.35% at the D/U interference ratio of -23 dB.[7] Even relaxing the FCC limit to – 27 dB would result in a 99.72% loss at +23 dBm, a 68% loss at +15 dBm, and a 10% loss at +9 dBm.[8] Each of these likely real-world scenarios would inarguably lead to interference that is unacceptable and well over any definition of *de minimis*. In *Qualcomm* and *New York State*, the Commission granted a waiver of Section 27.60 of the Commission's rule because the predicted interference was no more than 1% as determined by a proper OET-69 Longley-Rice analysis.[9] Here, using the Commission-approved engineering methodology reveals that enormous amounts of interference to WPWR-TV would result even if Cricket's LTE handsets or other end-user equipment operate below maximum allowable transmit power. In the more likely operating scenario, with Cricket's end-user equipment at full power, Cricket's operation would cause a population service loss to more

---

[5] MSW at Sections 6 and 7.
[6] MSW at p. 50 (Table 13 and Figure 12). MSW conducted its study using OET-69 analysis based on the premise that *all* points within a station's noise-limited contour are entitled to protection. The full methodology is explained at Section 8.0 of the MSW analysis.
[7] Id.
[8] Id.
[9] *Qualcomm* at 11692-11695; *New York State* at 2204-05.

than 99% of WPWR-TV's service area. Accordingly, the Commission must deny the Waiver Petition.

**B. The Cricket Studies are Fatally Flawed.**

Without doubt, the engineering studies relied on by Cricket are fatally flawed. In every way, Cricket sought to artificially limit, circumscribe, and narrow the potential interference to WPWR-TV, painting an inaccurate and unreliable picture of the harm that would result. MSW completed a rigorous and detailed review (attached at Exhibit A) of both Cricket studies finding that the Cricket studies are riddled with several substantial flaws. Most importantly, neither Cricket study used proper OET-69 Longley-Rice analysis or procedures.[10] MSW concludes that both the Intertek and Newfield studies fall well short of establishing that DTV reception within the WPWR-TV service area would remain unimpaired with the deployment of the proposed Cricket operation.[11] In fact, as shown throughout the MSW study, the data and analysis provided in these reports indicate that significant debilitating interference impairment will result from the proposed Cricket deployment.[12]

Specifically, looking further at the Cricket Intertek Laboratory Study (Intertek), MSW found that it was flawed for a variety of reasons. Intertek performed a simple conductive laboratory test and a radiated OTA study in an anechoic chamber.[13] Intertek studied only fixed indoor TV reception using passive indoor antennas. It made no attempt to evaluate outdoor, attic or amplified antennas.[14] Intertek also failed to consider the likelihood, given the density of

[10] MSW at Sections 6 and 7.
[11] MSW at p. 8.
[12] Id.
[13] MSW at Section 6.2.
[14] MSW at p. 23.

housing in WPWR-TV's service area, that interference is likely to occur between residences.[15] Inexplicably, Intertek relied on the 1979 FCC rule applicable to Part 15 devices for protecting *analog* stations rather than applying OET-69 to digital operations.[16] This Part 15 analog TV interference rule has no application when evaluating interference to DTV operations. DTV is subject to a cliff effect, so any interference renders the signal unwatchable. In addition, it appears that the Intertek tests were conducted with the LTE source not operating at maximum power and at a theoretical interference distance designed to falsely diminish predicted likely interference.[17] Thus, the Intertek laboratory study is essentially useless for predicting interference to DTV signals.[18]

The laboratory OTA tests conducted by Intertek are similarly flawed and without merit.[19] Intertek provides no raw LTE handheld transmitted power data. The OTA report is also full of incongruities that render its findings unreliable. For example, there are D/U ratios listed as greater than 80 dB (which is impossible) and there are a number of D/U ratios listed with dBm units instead of dB.[20] The tests were conducted with best-case assumptions and without any mention or study of real-world transmission echoes or signal degradation.[21] In short, Intertek did not conduct tests that followed proper Commission-approved engineering methodology and its tests are not sufficient to predict interference that would be caused in real-world scenarios.

---

[15] MSW at pp. 6, 24-25.
[16] MSW at p. 25. (emphasis added).
[17] Id. at p. 25.
[18] The interference distance metric introduced by Intertek is not an FCC approved methodology for determining interference to DTV service. The interference D/U ratios set forth at Section 27.60 of the Commission's rules must be used. MSW at p. 8, 33.
[19] A complete and detailed analysis of the Intertek OTA tests are at Section 6.2 of the MSW report.
[20] MSW at p. 39.
[21] Id. at pp. 8, 40.

As with Intertek, the Cricket Newfield Report is also fatally flawed. The Newfield Report is based on the prediction of interference to OTA reception that would be experienced by a projected number of Cricket subscribers.[22] This is a dubious and extremely inaccurate engineering design. By using only Cricket subscriber estimates, the study dramatically underestimates the number of households that would be subject to interference in the WPWR-TV service area leading to grossly inaccurate conclusions.[23] There is no basis for the assumption used by Newfield, and then trumpeted by Cricket, that LTE interference would impact only a household with an active LTE end-user device. As explained in detail by MSW, proper prediction of interference to DTV uses an interference D/U ratio methodology that is based on a geographic area and includes all households within the predicted contour of a given station – not just the households that may also subscribe to the proposed Cricket offering.[24] Further compounding the flaws, the Newfield Report severely circumscribed the number of households potentially impacted because it only counted the number of households watching WPWR-TV in May of 2012 (based on Nielsen data) instead of studying the impact on all households in the station's service area.[25] Section 27.60 of the Commission's rules specifically requires measurement of interference to the reception of the signal throughout the service area, not just the households watching a given station at a particular time. Any prediction of interference to DTV must be based on the OET-69 Longley-Rice methodology and in accordance with Section 27.60 of the Commission's rules, not the methods used in the Newfield Report. The Cricket studies are not consistent with generally accepted engineering practices for measurement of

[22] MSW at Section 7.0 at p. 45.
[23] Id.
[24] MSW at Section 7.0.
[25] MSW at pp. 45, 51.

interference to broadcast signals.[26] Because these studies are wholly flawed, Cricket's claim of *de minimis* interference to only 20 viewers is not valid.

## III. CRICKET FAILS TO MEET WAIVER STANDARD REQUIREMENTS AND A GRANT OF THE WAIVER WOULD VIOLATE THE PUBLIC INTEREST

A waiver of the DTV over-the-air broadcast protection criteria contained in Section 27.60 of the Commission's rules in the instant case is not in the public interest. Rather, a grant of the Cricket Waiver is contrary to the public interest and would destroy the signal of WPWR-TV. In order to grant a waiver the petitioner must show that (a) the underlying purpose of the rule would not be served or would be frustrated by the application to the instant case, and that a grant of the requested waiver would be in the public interest; or (b) in view of the unique or unusual factual circumstances of the instant case, application of the rule(s) would be inequitable, unduly burdensome, or contrary to the public interest, or the applicant has no reasonable alternative.[27] The Waiver Petition does not meet either of the tests in the waiver standard.

### A. The Waiver Petition is Contrary to the Public Interest.

Section 27.60 of the Commission's rules serves as an absolute bar to interference at a level greater than -23 dB with respect to a given DTV signal at its noise-limited contour.[28] In adopting this protection standard, the Commission noted that no commenters opposed this provision of *full* protection for incumbent broadcast TV licensees.[29] The Commission went on to state that it adopted a more conservative criterion (than that applied to analog stations) to best

---

[26] MSW at p. 46, Cricket's studies are inapposite to the study the Commission found acceptable in *New York State* at 22205.
[27] 47 C.F.R. § 1.925(b)(3).
[28] 47 C.F.R. § 27.60(a)(1)(ii).
[29] *Reallocation of Service Rules for the 698-746 MHz Spectrum Band (Television Channels 52-59)*, Report and Order, 17 FCC Rcd 1022 (2002), ¶ 52 (emphasis added).

protect existing digital broadcast operations.[30] Cricket files the Waiver Petition because its proposed operation *would not* (and cannot) fully protect WPWR-TV's operation. In order for the Commission to grant a waiver, not only must the predicated interference be *de minimis* - which here it most certainly is not - but there must be some public interest benefit to granting the waiver. Cricket has shown none. It makes general claims of wireless spectrum constraints in urban areas, but shows no particular constraint in the Chicago nor a pent-up demand for Cricket's wireless offering.[31] Instead, Cricket is seeking an end run around the Commission's rules solely for its commercial benefit. The Waiver Petition is contrary to the public interest and must be dismissed.

For the avoidance of doubt, the public interest at issue here is protecting the signal of WPWR-TV within its service area and ensuring that the signal remains viewable for anyone within its service area who wishes to view its broadcasts. The public interest is not, as Cricket argues, that it should be allowed to violate the Commission's interference criteria so that it may advance its own business interests using spectrum that it purchased knowing full well that the spectrum was encumbered.

In a futile attempt to support its Waiver Petition, Cricket cites a waiver grant to *Qualcomm* wherein the Commission stated that "it is in the public interest to effect forward-looking policy that drives toward the end-point of the DTV transition."[32] Here however, there is

---

[30] *Id.* at ¶ 56.

[31] Cricket's misguided and only attempt to prove the existence of a wireless spectrum constraint in Chicago is by stating that Verizon paid the highest price/MHz*POP among comparable licenses in Auction 73. Waiver Petition at 19 (citations omitted). The price Verizon paid in auction proves only what Verizon was willing to spend – not whether there is any unique wireless spectrum constraints in Chicago. Perhaps Verizon determined that there was no demand for additional wireless capacity in Chicago which was the reason it unloaded its license on Cricket.

[32] Waiver Petition at 20 citing *Qualcomm*, 21 FCC Rcd 11683 at ¶ 28 (2006).

nothing forward-looking in Cricket's proposed commercial operations; it is merely another commercial wireless provider. What is more, Cricket is seeking to sell itself and its spectrum to AT&T.[33] And, unlike in *Qualcomm*, the DTV transition is long past its end-point. In addition, a critical difference between the Waiver Petition at issue here and in *Qualcomm* is that the interference present in *Qualcomm* was *de minimis*. The interference here would be virtually total. The public interest would not be served by granting the Waiver Petition.

Similarly, Cricket cites to the *Interoperability Order* to prop up the mistaken claim that the order supports causing interference to broadcast stations serving viewers on Channel 51.[34] Instead, the Commission found that continuing to allow broadcast stations to serve viewers on Channel 51 was not an impediment to 700 MHz interoperability.[35] While the *Interoperability Order* did ease the ability of broadcasters to move off of Channel 51 in some circumstances, it did not change the interference protection criteria contained in Section 27.60 of the Commission's rules, nor did it suggest that any waiver of the interference protection criteria would be accommodated.

Cricket has shown no public interest benefits that would accrue and, as is established throughout these comments, a grant of the Waiver Petition would harm the public interest by causing unacceptable interference to the signal of WPWR-TV.

---

[33] Cricket also asks that waiver relief be transferable to any successor owner. In the event the Commission grants Cricket a waiver, the relief should not be transferable. A new licensee with more subscribers will by definition cause additional interference to WPWR-TV beyond Cricket's proposed operation.

[34] Waiver Petition at 20 citing *Promoting Interoperability in the 700 MHz Commercial Spectrum; Requests for Waiver and Extension of Lower 700 MHz Band Interim Construction Benchmark Deadlines*, WT Docket Nos. 12-69, 12-332, Report and Order and Order of Proposed Modification, FCC 13-136 at ¶ 43 (rel. Oct. 29, 2013) (*Interoperability Order*).

[35] *Interoperability Order* at ¶ 43.

### B. Grant of the Waiver Petition Would Eviscerate the Purpose of the DTV Protection Rule

The purpose of Section 27.60 is to protect broadcasters serving viewers on Channel 51 from receiving interference greater than -23 dB from any wireless providers proposing to operate in the wireless Lower A Block. FTS does not disagree with Cricket that Section 27.60 is designed to allow wireless service *while protecting* incumbent DTV broadcast operations.[36] The problem, however, is that Cricket does not propose to operate within the constraints of Section 27.60. Cricket readily admits that its operations would violate Section 27.60, and FTS's own studies show WPWR-TV would suffer overwhelming service loss. Consequently, a grant of the Waiver Petition would make a farce of the interference protection rule.

Cricket argues that Section 27.60 stands for the principle that wireless operators need only to reduce the potential for interference to existing broadcast operations on Channel 51.[37] That claim is false on its face. The rule, in relevant part, states that [wireless] transmitters "*must be operated only in accordance with the rules in this section* to reduce the potential for interference…"[38] Cricket conveniently leaves out the pertinent language, which makes clear that wireless operations can only occur if those operations comply with the rule. Cricket's operation, by its own admission, would not.

Cricket notes several times that the Commission has granted waivers where the petitioner has shown it will cause only *de minimis* interference to broadcasters serving viewers above Channel 51 – on channels no longer in use by any full power broadcast TV station. The waivers granted in *Qualcomm* and *New York State* were under circumstances far different than those found in the instant Waiver Petition. The differences between the instant Waiver Petition and

---

[36] Waiver Petition at 21.
[37] Waiver Petition at 22.
[38] 47 C.F.R. § 27.60 (emphasis added).

*Qualcomm* are discussed above. In *New York State*, the Commission granted a waiver for interference to mostly analog TV operations on channels 62-69.[39] Similar to *Qualcomm*, the Commission reasoned such a grant was acceptable because viewers and stations were in the midst of migrating from viewing TV on channels 63, 64, 65, 68 and 69 to DTV channels at channel 51 and below.[40] As in *Qualcomm*, in *New York State*, the DTV transition was well underway and the Commission had already decided that the affected broadcast stations would soon be required to cease broadcasting on those channels. In contrast, the Commission has made no decision to end broadcasting on Channel 51, let alone established a date certain by which broadcasters transmitting on Channel 51 will have to vacate that spectrum. As Cricket admits, "issues relating to the clearing of Channel 51 are unlikely to be resolved and fully implemented for several years."[41] Because of this, Cricket must protect WPWR-TV's continued operation on Channel 51 for the foreseeable future. To do otherwise would disturb the underlying purpose of Section 27.60, would be inequitable to WPWR-TV, and would unacceptably interfere with the WPWR-TV signal and any potential viewers in its service area that wish to watch WPWR-TV for several years to come.

## IV. COMMERCIALLY VIABLE CRICKET OPERATION IN CHICAGO IS NOT RELEVANT

As Cricket states in the Waiver Petition, it is required to maintain a 60-mile exclusion zone around WPWR-TV's transmitter site.[42] Indeed, as Cricket readily concedes, it knowingly

---

[39] *State of New York, Request for Waiver of Section 90.545 of the Commission's Rules to Implement a 700 MHz Public Safety System in Specified Counties in the Greater New York City Metropolitan Area*, Order, 22 FCC Rcd 22195 ¶ 2 (2007) (*New York State Order*). Moreover, any DTV channels operating on these channels were soon to have to cease operation and move operations to channels 51 and below.
[40] Id at ¶ 29.
[41] Waiver Petition at 20 *citing Interoperability Order* at ¶ 45.
[42] Waiver Petition at 6.

purchased spectrum in Chicago where it was precluded from serving 90% of the licensed population in the market area.[43] Thus, Cricket purchased a wireless license in an area where it knew it likely would be impossible to operate a commercially viable business.[44] Whether or not Cricket is able to operate a commercially viable facility is not relevant to the waiver standard or to the absolute interference limits set in Section 27.60 of the Commission's rules. Cricket cannot be allowed to operate a facility, as demonstrated above and detailed in Exhibit A, where such operation will cause over 99% population service loss to the WPWR-TV signal. Cricket should not be allowed to change the bargain it knowingly entered into when it purchased the encumbered wireless license in the Chicago area. It knew it could not possibly operate such a license without causing debilitating interference to WPWR-TV. The Commission should not allow it to do so via a grant of the Waiver Petition.

## V. FTS HAS COOPERATED WITH CRICKET

From the very beginning of the process, although under no requirement to do so, FTS has cooperated with Cricket in evaluating potential solutions. FTS agreed to review potential alternative channels, but Cricket could not identify any alternative channel that came close to replicating WPWR-TV's current service area. Additionally, all of the replacement channels suggested by Cricket would have required the agreement and assignment of several other broadcast licensees whose operations would have been adversely affected. In short, there was no viable alternative channel. FTS also agreed to review and evaluate the Cricket studies. As is made clear herein, the Cricket studies were not valid, and operation of the Cricket facilities would severely interfere with WPWR-TVs signal. Although Cricket alleges that FTS has not cooperated, FTS has done all, if not more, than it can be reasonably expected to do. Even though

[43] Id. at 7.
[44] Id. at 7-8.

it did so here, FTS was under no obligation to engage with Cricket to explore potential solutions. Cooperation cannot mean being forced to accept massive interference.

## VI. CONCLUSION

Cricket's proposed operation would violate Section 27.60 of the Commission's rules. A waiver is not warranted where the interference caused to the WPWR-TV signal would be nearly total. Cricket's engineering studies are fatally flawed and do not comply with previous Commission precedent. Therefore, FTS respectfully requests that the Cricket Waiver Petition be denied.

Respectfully submitted,

FOX TELEVISION STATIONS, INC.

By:_____

Joseph M. Di Scipio
Vice President, Legal and FCC Compliance
Fox Television Stations, Inc.
400 North Capitol Street, NW, Suite 890
Washington, DC 20001.
(202) 824-6522

March 4, 2014

# Exhibit A

# Meintel, Sgrignoli, & Wallace Analysis

A Report to

FOX Television Stations Inc.

Regarding

# Severe Impairments to WPWR CH 51 Chicago, IL From Proposed Cricket Wireless Block "A" LTE Signals

**June 7, 2013**

**Prepared by:**


**Meintel, Sgrignoli, & Wallace, LLC**
**1282 Smallwood Drive**
**Suite 372**
**Waldorf, Maryland 20603**
**(202) 251-7589**

# EXECUTIVE SUMMARY

## 1.1 BACKGROUND

After the digital transition concluded on **June 12, 2009**, the 700 MHz television band (formerly CH 52 – CH 69) that was previously auctioned to broadband wireless providers became available for use. While some wireless carriers were able to begin using their purchased spectrum immediately, others were limited by the fact that they have A-Block spectrum (former CH 52) which is immediately adjacent to CH 51 of the terrestrial DTV band. There are **26** full-power DTV stations across the country that still use CH 51, including the 1 MW effective radiated power (EPR) station **WPWR** in Chicago (serving the Gary, IN market). Cricket Communications, Inc. (Cricket Wireless), a subsidiary of Leap Wireless, owns A-Block spectrum in Chicago that it plans to use for Long Term Evolution (LTE) fourth generation (4G) broadband wireless service.

On **December 27, 2012**, Cricket informed FOX Television Stations, Inc. (owner of **WPWR**) that it had hired Hammett and Edison (H&E) to oversee a laboratory test project and an interference study project in the **fall of 2012** to determine feasibility of using the A-Block spectrum immediately adjacent to CH 51 without creating significant interference to **WPWR** viewers. This was necessary since the Federal Communications Commission (FCC) has interference limitation rules (**Section 27.60 [a] [2]**) in the form of desired-to-undesired (D/U) ratios that limit the 700 MHz broadband wireless signal field strength levels in order to protect nearby DTV operations. Since FOX had declined to participate in this study project, Cricket shared with FOX both a laboratory test report (from Intertek Testing Services) and an interference probability study (from Newfield Wireless Inc.) to show that there would be minimal interference to **WPWR** viewers across the Chicago market in order to convince the FCC to waive their own interference rules. However, Cricket would prefer to have a pre-arranged waiver agreement with FOX rather than having to go to the FCC without one. FOX then hired Meintel, Sgrignoli, and Wallace (MSW) to evaluate these reports, analyze their data, and create an independent report with comments and recommendations. This document is the MSW report requested by FOX.

This exercise that Cricket has begun brings into play all of the past digital television (DTV) work performed in the broadcast industry over the last 20 years, including Grand Alliance laboratory (Alexandria, VA) and field testing (Charlotte, NC), FCC allocation studies with OET-69 methodology, DTV Model Station (Washington DC) investigations, and FCC laboratory tests (Columbia, MD) involving consumer receivers and converter boxes. A summary of these aspects are included in the beginning of this MSW report.

The LTE system that Cricket desires to employ in Chicago adheres to the 3rd Generation Partnership Project (3GPP) standard, part of which defines use in the newly created 700 MHz band (former television broadcast channels 52 – 69). The FCC has redefined these former television channels into spectrum blocks, most of which are *paired* blocks of spectrum for Frequency Domain Division (FDD) duplexing. In other words, the paired spectrum blocks can be used for two-way communication (downstream from base station to handsets, and upstream from handsets to base station). One such spectrum block is the A-Block (698 – 704 MHz for the handset and 728 – 734 MHz for the base station). The upstream A-Block frequencies utilize former television channel 52 that is immediately adjacent to existing DTV channels in **26** markets across the United States, including **WPWR** in Chicago. Cricket's goal is to show that the two systems can coexist. The current FCC rules (**Section 27.60**) for LTE devices in the 698-763 MHz band regarding interference protection for broadcast DTV CH 51 stations states that the *maximum* (worst case) D/U ratio must be -23 dB with respect to the DTV signal at the station's noise-limited contour.

The LTE system structure, based on OFDM modulation with QPSK subcarrier modulation, is very flexible, allowing dynamic changes in handset transmit power level, multiple signal bandwidths, and various data versus robustness tradeoffs. Cricket has three possible deployment scenarios that call for the LTE User Equipment

(UE), often in the form of handsets, to use either 1.4 MHz bandwidth, 3 MHz bandwidth, or 5 MHz bandwidth. The base station would transmit with 1 kW (+60 dBm) of power on former CH 57 while the LTE UE handsets would have a maximum output power of 0.2 Watts (+23 dBm) on former CH 52. In addition to using various RF bandwidths, within each bandwidth deployment a variety of 200 kHz resource blocks (RB) can be dynamically allocated for upstream data transfers (maximum of 6 for 1.4 MHz bandwidth, 15 for 3 MHz bandwidth, and 25 for 5 MHz bandwidth).

There are two very difficult challenges for Cricket. The first challenge is to be able to coexist immediately adjacent to the 1 MW CH 51 signal without their LTE base station *receivers* overloading. The second challenge, which is the topic of these various reports, is to show that their mobile handsets will not interfere with CH 51 DTV viewing. This MSW report focuses on Cricket's evaluation of LTE interference with CH 51 DTV reception.

## 1.2 INTERTEK LABORATORY REPORT

The primary focus of the Intertek laboratory test was the determination of potential interference into fixed *indoor* DTV reception using relatively inexpensive *passive* indoor DTV antennas. No *outdoor* or *attic* antenna nor any *amplified* antenna interference was evaluated, which is believed to be one limitation of the Intertek report since LTE devices are expected to be used on upper floors of buildings (i.e., close to outdoor or attic antennas) as well as lower floors. Likewise, consumer amplified antennas are on the market for viewers to purchase, which they often do. Even with outdoor ground level use of LTE devices, many homes, like ranch houses, have attic or outdoor antennas at only 10 – 15 feet (about 3 - 4 meters) above the ground. This is easily considered close enough for concern about potential LTE interference into DTV and even ground level LTE devices can interfere with outdoor DTV antenna signals as high as 20'-30' above the ground (i.e., within 10 meters).

Also, Intertek relies on a **1979** FCC rule protecting analog televisions (which have *graceful* interference degradation) from computer interference for justification of using a 10-meter "interference distance" value for indicating that LTE devices within this distance would likely be within the same household. The theory is that this would then allow mitigating tactics to be taken by the DTV viewer like turning off one of the devices or moving the devices farther apart. This does *not* apply to life in the 21$^{st}$ century where multi-member families often are all simultaneously multi-tasking on different wireless devices in every room, including using the almost ubiquitous "2$^{nd}$ screen". An additional serious omission in their study was the effect of LTE devices on ATSC mobile/handheld (M/H) devices both in the home and in public. Therefore, the 10-meter distance "threshold" for same household use is not an important consideration in this case.

The strategy that Intertek used to perform the laboratory test was primarily a simple two-step approach. The ***first*** part was to perform a laboratory *conductive* bench test (i.e., direct connection of LTE source and DTV receiver via cable, with no signal radiation) on a variety of consumer DTV sets. This conductive test on each DTV receiver determined the threshold of sensitivity (TOS) signal level with no impairments, followed by finding the interference threshold of visibility (TOV) for the various proposed LTE signal bandwidths and minimum/maximum number of resource blocks for a given bandwidth. From this, a theoretical link budget equation was used to determine the interference *distance* between an LTE UE device and a DTV indoor antenna within which DTV interference would occur.

The ***second*** part was an over-the-air (OTA) *radiated* test in an anechoic chamber on a subset of the consumer DTV receivers in order to verify the theoretical interference distance calculations based on the conductive tests and determine if other factors were present that could alter the TOV signal levels and interference distances.

The LTE source for ***most*** of the laboratory tests were actual consumer devices that are on the market. Intertek listed 6 UE devices (4 Band Class 12 units, 2 Band Class 17 units), and picked 3 of them for laboratory testing: Samsung Galaxy S Aviator (BC-12), BandRich USB Modem (BC-12), and Samsung Galaxy Note (BC-17). Intertek measured the noise-like out-of-band energy (OOBE) of these three devices at their *maximum* transmitted power to document them (but not at other transmit power levels). Since this OOBE is adjacent to the LTE signals in the A-Block, some of this energy can fall within the CH 51 band and act as co-channel interference with well-known properties. From the Intertek OOBE measurements at maximum transmitter power (+23 dBm), the actual LTE devices allow worst case interference D/U ratios of -47 dB, -37 dB, and -27 dB for the 1.4 MHz, 3 MHz, and 5 MHz bandwidths, respectively. Now these values are ***not*** worst case values based on limits set by FCC rules, but rather just based on the *measured* OOBE values of the actual LTE UE devices used in this Intertek laboratory test. The FCC rules are somewhat vague on the actual worst case splatter allowed from actual real-world units (e.g., in essence, the FCC assumes a *flat* spectral mask for splatter when in reality it will always fall off at frequencies farther from the in-band LTE UE signal). It must be noted that these measured OOBE numbers, while meeting the simple FCC rules, are not necessarily the values that all future LTE UE devices will have. In other words, future LTE devices may have more splatter and still meet the FCC rules. Therefore, using the interference D/U ratios in the FCC rules (i.e., -23 dB) is the safest and best approach for broadcasters.

Intertek obtained 25 consumer DTV receivers (a 26$^{th}$ unit, a converter box, was not operating properly, and therefore MSW did *not* use any data from this faulty unit) for laboratory testing. These DTV receivers were selected from a wide variety of DTV manufacturers, model types, screen sizes, features, price, and consumer reviews. While the most important aspect for interference testing is the specific tuner chip and 8-VSB demodulator chip employed in a DTV receiver, that information is very hard to obtain from consumer DTV manufacturers. Therefore, with the exception of not knowing specific RF chips employed in these receivers, the selection of these 25 units appear to be a reasonable representation of consumer DTV sets currently on the market.

Before *conductive* interference laboratory tests were performed, Intertek made *sensitivity* measurements on the 25 DTV receivers via direct cable connection between source and receiver (i.e., not over the air). A "clean" DTV signal, i.e., with no impairments, was used to determine the minimum signal level for error-free reception, that is, the threshold of sensitivity (TOS). An observer watched the complex high-definition picture with motion in order to determine when the threshold of errors was reached. The "digital cliff effect" is very sharp (within 1 dB), so it was rather straightforward to determine this threshold with an observer. The Intertek TOS results (**-84.7** dBm with a low 1.4 dB standard deviation among the 25 units) were essentially the same as the recent FCC laboratory testing (**-85 dBm**), which is very encouraging since this means that both 5G and 6G receivers are still as sensitive as ever while improvements in multipath cancelation still continues. These results also validate using the 25 receivers for typical LTE interference testing.

The first LTE laboratory interference test performed by Intertek was *conductive* interference evaluation of the 25 DTV test receivers. MSW tabulated D/U ratio results from the Intertek report for both averages and maximum (i.e., worst case) values. The maximum values, derived from the worst case D/U calculations of the 25 receivers, typically are 5 - 6 dB worse than the average values, which is not insignificant when it comes to LTE interference prediction. The test results produced relatively large interference D/U ratios (typically better than -30 dB and sometimes better than -40 dB, indicating less sensitivity to LTE interference) from the group of 25 receivers for each test case (i.e., varying LTE bandwidth and # of resource blocks). However, besides there being a number of typos in the Intertek tables containing the raw conductive data, these measured interference D/U ratios are better (sometimes, as much as 10 – 15 dB better) than the expected "best case" values given the measured OOBE of the LTE UE test device at maximum transmit power. From this data, it *appears* that these

interference tests were performed with the LTE source ***not*** operating at maximum power which is when the greatest amount of OOBE occurs in the RF output amplifier, and would require further investigation to determine if this was in fact the case.

These very "optimistic" interference results match Intertek's own statements in their laboratory report regarding the fact that many of the D/U ratios were better than what could be allowed for the measured OOBE for the LTE test source. Thus better (i.e., less interference) results were obtained at these lower transmit powers than if the LTE source were at maximum transmitting power with increased adjacent channel splatter that would cause more CH 51 interference. The reason for this is that with less than worst case OOBE (co-channel) interference from the LTE UE source, a much larger LTE signal is required to either hit the limit of the existing OOBE or a much larger LTE signal is needed to create additional OOBE inside the DTV tuner itself, thus allowing better interference D/U ratios. This should cause concern for CH 51 broadcasters. Additionally, all of these values are certainly much more optimistic than what the FCC allows for an LTE interference D/U ratio (-23 dB) for protection of CH 51 DTV signals.

The theoretical interference "threat" *distances*, a metric introduced by Intertek but not used by the FCC for DTV reception prediction, was evaluated for each of the conductive LTE test cases described in the last paragraph. These calculated values, which are based on a *theoretical* link budget equation that describes the effects (gains and losses) of the transmitter, propagation path, and receiver, indicate the necessary distance between the DTV antenna and the LTE UE unit in order to not cause interference to DTV reception. Intertek also devised a 98% coverage parameter that accounted for the various azimuth and elevation antenna patterns of *both* the LTE UE and the DTV indoor antenna. This new coverage parameter allows for a distance correction (average value of 52% for all the LTE and DTV antenna combinations) that allows a statistical variation of relative antenna positions to lower the interference coupling into the DTV antenna. However, even sporadic interference due to relative motion between the LTE UE device and the DTV antenna will disrupt CH 51 DTV service, so maximum values of antenna gains should be used in the analysis, which MSW did utilize.

These theoretical threat distance numbers are based on the conductive lab test results, where it is believed that the LTE UE test device was *not* at maximum power and thus did *not* have the worst case OOBE. Nevertheless, these interference distance values still give some "ballpark" idea of what separation distances <u>might</u> required under *ideal* conditions (not real-world conditions). The Intertek report did ***not*** list the theoretical threat distances based on the conductive laboratory test results, but MSW did calculate these values using the Intertek link budget equation as well as their specific parameter values. According to these calculations using the selected parameter values, not much interference is expected at moderate and strong DTV signal levels. But at weak and very weak signal levels, Intertek obtained interference distances (e.g., 17 meters) that are large enough to cause concern from not only LTE UE devices within the same home, but also from neighboring houses, townhomes, condos/apartments, and even people walking down the street with an LTE device. The worst case conditions, as stated before, are for the 5 MHz LTE bandwidth deployment scenario, but it can be seen that even the 3 MHz bandwidth causes some concern as well. Threat distances of only a couple of meters can be problematic to DTV reception, but some of the theoretical threat distances calculated by MSW using *worst* case powers and maximum antenna coupling ranged from 10 to 40 meters which could be devastating under many conditions.

The second LTE laboratory interference test performed by Intertek was *radiated* over-the-air (OTA) interference evaluation of 5 DTV test receivers in an anechoic chamber for the purpose of confirming the theoretical interference threat distances previously calculated from the conductive interference tests. Once the anechoic chambers were calibrated (Intertek used two chambers: a 3-meter and a 10-meter), various distances were selected and interference thresholds measured. Four parameters were recorded during this test: (1) the distance between the LTE UE and the DTV antenna being recorded, (2) the DTV signal adjusted to the same set of 4 desired DTV signal levels, (3) the received LTE interference signal level at interference threshold, and (4)

the LTE UE transmit power that caused the TOV interference. Unfortunately, the last item (LTE UE transmit power) was *not* included in the Intertek report, which prevents MSW from verifying the Intertek OTA interference distance measurements. Additionally, besides there being a number of typos in the Intertek tables containing the raw OTA data, there are D/U ratios within the tables that are greater than the known OOBE limits if the LTE UE were at full power, implying that the LTE UE were likely not at maximum transmit power.

However, even with all of these issues, Intertek reports that their *measured* OTA interference distances were twice the values of their *theoretical* calculations based on their conductive lab tests, which indicates that other factors must be included in determining threat distances. Intertek identified some of these factors that could affect their OTA laboratory test results and explain why they were "off" (i.e., longer and therefore worse) by a factor of two. Many of these real-world radiation/propagation factors can make DTV interference from LTE devices even <u>more</u> likely. Some of these interference-affecting factors are:

1) DTV signal *levels* not only are often weak, but also have location and time variability, which make DTV signals more vulnerable to interference.
2) DTV signal *quality* is often much poorer in real environments, particularly due to multipath, and thus <u>enhances</u> LTE interference.
3) LTE UE maximum power is +23 dBm (±2 dB), with varying amounts of antenna system loss from different manufacturers and varying amounts of OOBE.
4) Even though the LTE UE transmit power is aggressively controlled by the base station, the close proximity to both indoor and outdoor DTV antennas makes interference likely not only from within the same residence but also from nearby residences.
5) The lack of sufficient frequency guard bands, especially for the 5 MHz LTE bandwidth option, is a problem for DTV reception interference.
6) The separation distance between mobile LTE smart devices and fixed indoor and even outdoor DTV antennas is very important and is a primary variable in determining the amount of LTE interference.
7) Relative antenna positions and orientation can easily vary with mobile devices like LTE UE units, easily allowing for bursts of time when the two are optimally aligned for maximum or at least near maximum coupling of the LTE interference signal into the DTV antenna and thus causing momentary television service interruptions and unacceptable DTV viewing.
8) OOBE in the LTE device is a very real problem at larger LTE UE signal levels, even below maximum level, and often are the limiting factor in DTV interference, especially as the LTE system dynamically allocates resource blocks in one of the three bandwidth deployments being proposed.
9) Residential architectural effects affect *both* CH 51 DTV signals and A-Block LTE signals similarly due to their close proximity in frequency, providing attenuation to both signals which can cause the DTV signal and *downstream* LTE signal to be weak and the LTE *upstream* signal to be strong, which is ripe for increased DTV interference.
10) DTV multipath can challenge <u>both</u> outdoor and especially indoor DTV reception significantly, but multipath mitigation by the DTV equalizer also *enhances* both noise and LTE interference.
11) The amount of detail and motion in the DTV picture affects how noticeable sporadic interference will appear to the viewer, but in the last several years more and more HD material, especially in fast-motion sports, has been broadcast, thereby making DTV interference more noticeable and objectionable.
12) Simultaneous phone usage and DTV viewing is required for interference to be objectionable, but recent trends of *simultaneous* usage have risen dramatically, especially with 2$^{nd}$ screen usage, video streaming over the Internet, music listening, texting, e-mail checking, etc.
13) Smart phones are now joined by recently available mobile/handheld (M/H) broadcast devices for "on the go" television watching, making it necessary for *both* systems to coexist in close proximity (perhaps as short as a

foot or two) not only in the home but also in public places, such as in buses and trains, or at other public events (e.g., sporting events, concerts, etc.).

## 1.2 NEWFIELD REPORT

The primary focus of the Newfield Wireless report is the prediction of interference to **WPWR** reception in those locations where a Cricket LTE subscriber and OTA DTV receiver are in close proximity. However, the approach put forward by Newfield has many short-comings. These short-comings led to optimistic interference predictions and results.

Newfield's approach does *not* account for many scenarios in which interference would also likely result in impairments to DTV reception. Using ratings information and the number of likely Cricket LTE subscribers to extrapolate artificially low interference predictions does *not* reflect the likely resultant interference if Cricket deploys the A-Block LTE service within the **WPWR** coverage area. It is clear that DTV interference will not be limited only to those homes that are also Cricket subscribers as LTE interference to nearby residences is very likely to occur in many instances.

Furthermore, the Newfield report does *not* employ the interference D/U ratio methodology contained within the FCC rules regarding the deployment of A-Block services and the protection of DTV services.

## 1.3 MSW ANALYSIS REPORT

In the final analysis, MSW believes that the traditional and FCC-required DTV service analysis should be performed regarding A-Block LTE interference into CH 51 DTV operations. This requires use of OET-69 methodology and planning factors developed specifically for DTV service and interference prediction. MSW performed this analysis for the case of **WPWR** in Chicago. The **WPWR** transmitter characteristics (e.g., location coordinates, ERP, HAAT, etc.) were used in the Longley-Rice modeling (smallest cell size allowed by the FCC, terrain-based propagation data, Chicago area population distributions, etc.) within the noise-limited contour to predict DTV field strength and thus determine service *area* as well as the *service population*, with and without LTE interference. The local upstream LTE field strength that uses the former CH 52 band, on the other hand, was calculated using the free space formula due to the relatively very short propagation paths (modeled as 3 meter and 10 meter for indoor and outdoor reception, respectively).

While OET-69 contains *outdoor* reception planning factors for use in predicting DTV service and interference, there are no *indoor* planning factors. However, there has been industry work on creating reasonable indoor planning factors. Three different receive scenarios (best case, typical case, and worst case) provide *outdoor* field strengths (53.3, 75.5, and 98.8 dBµV/m, respectively) above which it would be expected to have indoor reception (accounting for the usual types of parameters that attenuate signals entering a building). These field strength *thresholds* of the predicted outdoor DTV signal levels were then used to determine if the remaining analysis is performed assuming a 30' AGL outdoor antenna (i.e., if signals are below the threshold) or if analysis is performed assuming an indoor antenna (i.e., if signals are above the threshold). Separation distances between the DTV antenna and the LTE UE were assumed to be 10 meters if an outdoor DTV antenna is used and 3 meters if an indoor DTV antenna is used.

A variety of computer simulations were performed using various interference D/U ratios (the required FCC value of -23 dB plus two relaxed values of -27 dB and -30 dB that are *not* allowed by FCC rules but provide additional engineering analysis). Various LTE UE transmit powers were evaluated, including the maximum allowable power of +23 dBm as well as lower levels of LTE power down to +9 dBm.

The MSW evaluation of the **WPWR** interference from LTE devices that used the FCC-required DTV methodology and procedures as well as the computer simulation software required by OET-69 showed that even with appreciably relaxed interference D/U ratios and LTE UE transmit power far less than the maximum

allowable levels, significant (and unacceptable) levels of DTV reception interference would still occur from LTE systems. This does not even account for degraded interference performance known to occur when the desired DTV signal has experienced even modest multipath impairments with outdoor reception let alone severe multipath impairments that often occur with indoor reception. It should be noted that the amount of new DTV station interference into another DTV station's protected area is limited by the FCC to 0.5% of the population, a value that is easily exceeded by LTE for all the various interference scenarios evaluated in this MSW report.

## 1.4 CONCLUSIONS OF ANALYSIS

In the final analysis, MSW concludes that both the Intertek and Newfield reports fall well short of demonstrating that DTV reception with the CH 51 WPWR protected contour would remain unimpaired with the deployment of LTE services on the adjacent channel. And, in fact, the data and analysis provided in these reports indicate that significant interference impairment will result from the proposed deployment.

The Intertek laboratory report supplied performance information on 25 various DTV sets that (as best as possible without knowing the actual tuner and VSB demodulator chips inside) provides a reasonable idea of TOS and LTE interference performance under controlled conditions. However, while the TOS numbers were precisely as expected (around -85 dBm), some of the interference D/U ratios seemed to indicate that these were *not* worst case interference performance numbers expected in the field since it appears that many of the tests were *not* limited by the measured OOBE from an LTE UE at maximum power. Likewise, similar results occurred for the anechoic chamber OTA tests as well. Also, these interference test results did not account for the expected interference degradation due to significant multipath that occurs with outdoor reception not to mention the often severe multipath that occurs with indoor reception. Even the Intertek report stated that the OTA anechoic chamber interference distance test results were *twice* that of the theoretical distances calculated from the conductive tests, most likely due to the small amount of multipath that existed in the well-controlled anechoic chamber.

The most important aspect of all of this is that the interference distance metric that Intertek introduced, while interesting, is ***not*** how the FCC determines DTV service or interference. Rather The FCC uses only interference D/U ratios, which they set forth in Section 27 of their rules as -23 dB for the adjacent channel LTE signals in the lower 700 MHz block.

Furthermore, the concept put forth by Intertek that wireless services are entitled to a 10-meter interference threat distance, as specified for other types of devices in Part 15 of the FCC's rules is without merit. Clearly, it makes no sense to assume that a new LTE service deployment is entitled to interfere with any device within 10 meters of the UE is completely unworkable, not just for Digital Television services, but for all other RF services as well.

The Newfield report, while creative in its approach, does *not* comply with the previously used regime in the digital television broadcast services regarding interference prediction. Any evaluation of predicted interference should utilize the traditional geo-location based predictions using the appropriate interference D/U ratio within the **WPWR** coverage area ("Exclusion Zone"). Similarly, prediction of interference should *not* be based upon TV ratings information or LTE subscriber statistics, rather it should be assumed that all locations within the **WPWR** coverage area should be evaluated and protected from interference.

Finally, the MSW evaluation of the **WPWR** interference from LTE devices that used the required methodology and procedures as well as the computer simulation software required by OET-69 showed that even with appreciably relaxed interference D/U ratios and LTE UE transmit power significantly less than the maximum allowable levels, significant levels of DTV reception interference would still occur from LTE systems. This evaluation does *not* account for degraded interference performance known to occur when the desired DTV

signal has experienced even modest multipath impairments with outdoor reception let alone severe multipath impairments expected with indoor reception.

# 1.0 INTRODUCTION

The march towards digital television (DTV) began in **September 1987** with the FCC's formation of the Advisory Committee on Advanced Television Services (ACATS) that was made up of multiple industries, including broadcasting, cable, consumer electronics manufacturers, commercial broadcast manufacturers, and others. The eight year process culminated on **November 28, 1995** when the ACATS group *recommended* the Advanced Television Systems Committee (ATSC) digital television system (including the 8-VSB data transmission system) to the FCC for implementation as this country's digital television system. Approximately 13 months later, on **December 24, 1996**, the FCC *selected* the ATSC system, described in the **ATSC A/53** document, as the new standard for *terrestrial* digital television for the United States.

The plan was to slowly transition from the existing analog National Television Systems Committee (NTSC) system to the new digital ATSC system over a period of time that turned out to be 10 years (**1999 – 2009**), simultaneously transmitting both systems together during this transition using the same VHF/UHF RF television spectrum band of CH 2 – CH 69. This was made possible by the ATSC system's spectrum compatibility feature, i.e., being able to transmit relatively lower power signals than NTSC on 6 MHz channels that were previously considered taboo in given markets. Each eligible full-power station was loaned a second 6 MHz RF channel during the DTV transition. The companion RF channel was determined as part of a huge allocation process that the FCC created with help from the broadcast industry. The success of this transition was the selection of not only the new digital ATSC system with robust transmission characteristics, but also prudent spectrum planning by the FCC that minimized interference in a given market by disallowing allocation of co-channels and first adjacent channels in nearby markets that could cause disrupt DTV service.

The DTV transition officially began in **May 1999** with the requirement for the top 4 networks in the top 10 markets to be transmitting a digital ATSC signal on their companion RF channel in addition to their analog NTSC signal on their original RF channel. This was followed by **November 1999** when the top four networks in the top 30 markets were required to be on the air with DTV in a similar fashion. Likewise, the following year, public stations were required to be on the air with DTV on their companion channels.

During the digital transition, the ATSC created related standards such as the **A/110** single-frequency network (SFN) synchronization standard in **2004** (updated last in **2011**) and the **A/153** mobile/handheld (M/H) standard in **2009** (updated last in **2013**).

The transition from analog NTSC to digital ATSC was completed (for full-power stations) on **June 12, 2009** when the analog signals were turned off by FCC requirement and Congressional mandate. Additionally, all *full*-power stations were to move out of the CH 52 – CH 69 band in order to free this spectrum for other wireless services to bid through auction for its use, including broadband wireless and public safety. While *low*-power television (LPTV) and translators were able to remain in this 18-channel band for a while longer, they were required to move out of the CH 52 – CH 69 spectrum by **December 31, 2011** and must cease *all* analog operations in the remaining core spectrum by **September 1, 2015**[1]. This means that the spectrum in former channels 52 – 69 has been free from any broadcast television signals since the end of **2011** and ready for deployment of other services.

Currently, there are broadband wireless signals already on these newly available channels, and there are also companies, large and small, that are looking to deploy their communications signals in the relatively near future. One such company is Cricket Communications, Inc (referred to as Cricket Wireless), a regional wireless operator founded in **1999** and a subsidiary of Leap Wireless. Cricket provides wireless services to over 7

[1] "Low Power Television Service @ FCC.gov/guides/low-power-television-lptv-service; www.BroadcastLawBlog.com/tags/lptv/)

million customers in the U.S.[2]. Besides CDMA (1X) and EV-DO (1X) systems, Cricket also utilizes Long Term Evolution (LTE) systems to provide their services. In **February 2009**, Cricket launched their service in Chicago, making it the biggest market that Cricket ever launched since its creation. On **August 28, 2012**, Verizon Wireless and Leap Wireless announced a successful spectrum *swap*, which was part of a larger deal between Verizon Wireless, SpectrumCo, and Cox. Leap Wireless divested itself of *excess* AWS and PCS spectrum across the US in exchange for $120 million and 12 MHz of A-Block 700 MHz spectrum licenses in Chicago (Verizon paid $152 million for this spectrum during the FCC's 700 MHz auction in **2008**. Verizon currently offers LTE service in Chicago using its 700 MHz upper C Block spectrum). Upon resolution of interference issues related to 700 MHz A-Block licenses, Leap Wireless plans to use the new spectrum to supplement it existing 10 MHz of the A-Block within Chicago, and use the cash to build its LTE infrastructure across the United States[3].

On **December 27, 2012**, Cricket contacted FOX Television Stations, Inc (referred to as **FOX** in this report) regarding its planned LTE development in the Chicago market area using its 700 MHz A-Block license in the former CH 52 spectrum. Having declined initial participation with Cricket in their LTE interference study of the **FOX**-owned **WPWR** CH 51 DTV signal, **FOX** was informed that Cricket did proceed with the study of the aforementioned interference issues, and now wants to share their results. Cricket retained Dane Ericksen of Hammett & Edison, Inc. as their consultant in this project, as well as Intertek Testing Services (for laboratory interference testing) and Newfield Wireless (for a CH 51 interference probability study). Cricket feels the results of both the lab test and interference probability prediction demonstrate minimal harmful interference into **WPWR**'s CH 51 signal, and therefore hopes for a consensual resolution with **WPWR** and **FOX** in order to facilitate their near-term deployment in the 700 MHz A-Block. However, no such resolution is possible given the interference that is predicted to result from the proposed Cricket operations.

**FOX** has since retained the services of Meintel, Sgrignoli, and Wallace (MSW) to review the Intertek and Newfield reports, evaluate the data and analysis within them, and then create an independent report with comments and recommendations.

# 2.0 BACKGROUND

Cricket, under the direction of their consultants Hammett & Edison, hired Intertek Testing Services to perform a series of laboratory tests and data analysis on a number of current consumer DTV sets and LTE consumer devices, referred to as User Equipment (UE). The written report, dated **January 14, 2013** and titled "*Evaluation of the RF Coexistence LTE Operation on 700 MHz A Block and TV Channel 51 Reception*", is a detailed summary of laboratory conductive bench tests and over-the-air (OTA) anechoic chamber tests using commercial LTE and consumer DTV equipment.

Cricket also hired Newfield Wireless Inc. to analyze the statistical interference effect on **WPWR** service in the metropolitan Chicago area from deployment of LTE devices using the A-Block spectrum (formerly CH 52) recently obtained by Cricket. The written report, dated **December 27, 2012** and titled "*Chicago Channel 51 Interference Probability Study*", is a detailed document evaluating the probability of adjacent channel interference from a Cricket LTE subscriber device into **WPWR** (CH 51) terrestrial DTV viewers using results generated in the Intertek laboratory test. The methodology, assumptions, and data from both of these reports will be evaluated and reported in this document.

[2] MyCricket.com
[3] http://www.engadget.com/2012/08/28/verizon-and-leap-wireless-announce-120-million-spectrum-swap/)

Before evaluation of the Cricket test reports, this document will provide a short overview of the ATSC transmission system fundamentals and basic performance as they relate to LTE interference effects. The purpose for this review is to provide a solid technical basis for *comparison* of the Intertek laboratory test results of 25 DTV units with regard to both sensitivity and adjacent channel LTE interference.

# 3.0 DTV FUNDAMENTALS

## 3.1 ATSC TRANSMISSION SYSTEM GENERAL CHARACTERISTICS

Before evaluating the *two* Cricket reports, a brief summary of the ATSC DTV system is in order, particularly related to its characteristics, coverage, service, and interference properties. The place to start is a basic description of the ATSC digital television, and specifically its eight-level VSB (8-VSB) transmission system. The entire ATSC system is specifically described in detail in the ATSC A/53 document[4].

In the ATSC 8-VSB transmission system, eight data levels carry 3-bits per symbol (2 data bits plus 1 trellis-coded FEC bit) at a 10.762 Msymbol/second rate. Video, audio, and ancillary data are formatted into MPEG transport packets. One MPEG data transport packet (188 bytes) is conveyed in one VSB data segment (along with 20 Reed-Solomon parity bytes) at a 19.391 Mbit/second payload data rate. The MPEG transport stream sync (47hex) is replaced by the 4-symbol data segment sync in every data segment, and every 313 data segments, a *binary* data field sync with a special pseudo-random sequence (PRS) code is transmitted in one VSB data segment for the purpose of data frame synchronization and equalization training. In addition to FEC coding, a data randomizer guarantees a flat, noise-like data spectrum regardless of the data sequence being transmitted, and a 52-segment convolutional byte interleaver spreads the data bytes over a 4 msec interval to mitigate burst errors that may occur during transmission. A summary of the ATSC 8-VSB transmission system characteristics, described in A/53, is shown in **Table 1**.

The advantage of the ATSC transmission system is that it was designed to fit within the same 6 MHz channelization system that its analog NTSC predecessor did, which also allowed the two systems to coexist during the 10-year transition period (**1999 – 2009**). This is known as spectrum compatibility. **Figure B-1** illustrates the spectrum of both the ATSC and NTSC signals together as a comparison. Analog NTSC signal power had been described in terms of its peak envelope power (PEP), which is the *average* power of the visual carrier during its peak envelope time (i.e., during horizontal and vertical synchronization pulses). ATSC signal power, on the other hand, is characterized by its *average* power over the entire 6 MHz band, which includes the flat spectrum due to the noise-like randomized data plus the CW-like pilot signal at the lower edge of the band. The robustness of the ATSC data transmission system, which comes from robust synchronization signals, reliable echo cancelation/equalization, and powerful forward error correction (FEC) codes, allows it to be transmitted 7 – 12 dB below that of analog NTSC while providing similar coverage and service areas. These characteristics allow the ATSC signal to stay synchronized even below data error threshold.

[4] See the ATSC website at www.atsc.org

**Table 1** 8-VSB System Characteristics.

| Parameters | 8T-VSB | Units |
|---|---|---|
| Channel BW | 6.0 | MHz |
| Excess BW | 11.5 | % |
| Symbol Rate / Period | 10.762 / 92.9 | MHz / nsec |
| BW Efficiency | 3 | bits/symbol |
| Trellis-Coding Rate | 2/3 | ----- |
| Net data rate | 2 | bits/symbol |
| Reed-Solomon FEC | t=10 (207, 187) | ----- |
| Segment Length (including sync) | 832 | symbols |
| Segment Sync duration | 4 | symbols |
| Frame Sync duty cycle | 1/313 | ----- |
| Payload Data rate | 19.4 | Mbps |
| Spectral Efficiency | ≈ 4 | bits/Hz |
| Power Increase from Pilot | 0.3 | dB |
| Peak/Ave Power Ratio | 6.3 | dB (@ 99.9%) |
| SNR @ Error Threshold | 15.0 | dB |

However, as with all *digital* television systems with significant FEC coding, the ATSC system has a steep "*cliff effect*", i.e., as the signal decreases towards the receiver's noise floor (as determined essentially by the tuner's front end), it will reach the "cliff" where the data error correction has reached it limit. At the "cliff", DTV reception will transition rather quickly (within 1 dB of further signal reduction) from a perfect, error-free picture and sound to an all-error frozen picture (or black screen) and muted sound. The old analog NTSC system had a *graceful* degradation as impairments and interference were introduced, and therefore when the picture and sound gradually dropped below acceptable reception, it still would provide a "watchable" although snowy (and perhaps "ghosted") picture and good sound (from the narrowband FM audio modulation). However, for an acceptable digital viewing experience, the DTV signal must *not* cross that threshold (i.e., it must not "fall off the cliff"), even for relatively short periodic moments of time, otherwise significant service disruption will occur. While *occasional* hits will not deter OTA DTV viewing, certainly even 10% or 20% outages for any reason are unacceptable, and will cause viewer dissatisfaction to the point of changing the channel. The digital cliff effect occurs not only with a drop in the DTV signal level but also occurs with increases of *impairments* (e.g., from phase noise, multipath, etc.) and signal *interference* (e.g., from other DTV signals, non-TV signals, etc.).

## 3.2 ATSC TRANSMISSION SYSTEM WHITE NOISE THRESHOLD

The ATSC system, during the ACATS era and beyond, has been thoroughly tested over the last 20 years since its design and implementation during the Grand Alliance (GA) era and after its standardization by the FCC. Many of the transmission system's performance parameters have been meticulously tested, from the Grand Alliance prototype through the current sixth-generation (6G) chipsets.

The first performance parameter typically discussed is *sensitivity* and its related parameter signal-to-noise ratio (SNR) at threshold of visible (TOV) data errors when additive white Gaussian noise (AWGN) is present with an otherwise perfect DTV signal (i.e., no other impairments or interference are present). Threshold of sensitivity (TOS) is defined as the minimum RF signal level that can be applied to a DTV receiver that just begins to cause uncorrectable errors. This occurs at some signal level above the white noise floor of the receiver's tuner, which depends on the standard resistive white noise in a matched RF system (kTB = -106.2 dBm/6 MHz) plus the

tuner's noise figure (NF). However, sensitivity is affected not only by the level of white noise at the tuner input (kTB+NF), but also by other receiver design parameters such as AGC range and the level of electromagnetic interference (EMI) produced by the receiver itself that inadvertently radiates into the tuner's input (i.e., self-interference). Therefore, TOS is the first and most basic parameter to test on a DTV receiver.

During GA testing in **1995** at the Advanced Television Test Center (ATTC) in Alexandria VA, correlation between *expert* visual observation and bit-error-rate testing using a pseudo-random bit generator was determined. A bit-error rate of $3.0 \times 10^{-6}$, which was equivalent to 2.5 data transport packet errors per second, produced just barely visible errors in the video of an HDTV picture with motion[5]. TOV was reported to have occurred at a **15.19 dB** SNR value during the official white noise threshold test (with a strong -28 dBm signal level, well above the tuner's internal white noise, when using 0.25 dB steps and a broadband power meter measured the 6 MHz in-band power)[6]. However, during other parts of the GA testing where a vector signal analyzer (VSA) with bandpower markers was used and 0.1 dB steps were employed, the threshold was found to be **14.9 dB**. Therefore, a **15 dB** SNR value at TOV is the commonly used value in most terrestrial broadcast analysis, including that required by the FCC. It should be noted, however, that sensitivity was *not* measured on the GA prototype (just the SNR at TOV at strong DTV signal levels) and that the threshold SNR value only refers to a clean (i.e., unimpaired) ATSC signal with added white noise. This threshold SNR value degrades with additional *impairments* and *interference*, sometimes significantly.

Since the GA era ended in **1995**, many other formal tests were conducted, including at the FCC laboratories in Columbia MD. In the **2005** FCC laboratory testing that was required by the Satellite Home Viewer Extension and Reauthorization Act of 2004 (SHVERA)[7], *both* SNR at TOV and RF sensitivity were measured on 28 standard, off-the-shelf consumer DTV receivers. Two ***types*** of receivers were evaluated: both DTV sets and set-top boxes (STB). The 28 receivers were manufactured under 16 different brand names during the **2004** and early **2005** time frame, with each receiver *type* having a varying price range.

It was determined that there were *two* major groups of receivers that showed slight threshold level differences: those introduced into the market during **2004** and earlier, and those introduced after **March 2005**. These DTV receivers were measured in 0.1 dB increments of SNR with TOV threshold determined by 60-second *error-free* video intervals. The average TOV SNR value remained consistent among the various DTV receivers, with a median value of **15.3 dB** (0.2 dB standard deviation) across all units, with no bias based on retail *cost* or *type* of receiver (i.e., DTV set versus STB). It was also determined in this testing that the newer 5G receivers not only had significantly better multipath mitigation capability (as determined by the RF capture test), but also had a lower median SNR at TOV of **15.1 dB**. At that point in time (i.e., in **2005**), it was felt that the previous improvements made in equalizer performance which traded off slight increases in SNR at TOV was over, and that technology had advanced to the point where low noise thresholds could be achieved concurrently with improved multipath mitigation performance.

Similarly, the sensitivity of the units, which describes the minimum "clean" DTV signal (i.e., distortion-free and interference free) that produces error-free reception, was also measured. The median value of TOS was **-83.9 dBm** (with 0.9 dB standard deviation) on UHF CH 30. While both SNR @ TOV and tuner noise figure affect DTV receiver sensitivity, it is believed that the ***effective*** noise figure was the parameter that varied the most in these consumer products causing a sensitivity value variation. As stated earlier, it was determined that the earlier 4G units had equalizers that enhanced its internal noise floor by a slightly greater degree than the newer

[5] Digital HDTV Grand Alliance System: Record of Test Results, October 1995, PI-3-1 to I-3-2.
[6] Digital HDTV Grand Alliance System: Record of Test Results, October 1995, PI-3-10.
[7] Martin, Stephen, "Tests of ATSC 8-VSB Reception Performance of Consumer Digital Television Receivers Available in 2005", Federal Communications Commission Report FCC/OET TR 05-1017, November 2, 2005. This test was performed as part of the requirement for the SHVERA Act of 2004.

5G units with improved equalizers. Most of the UHF noise figures for these 28 receivers in this test were found to be about 7 dB ± 1 dB, which represents the state of the art at that time. Once again, the price of the receiver did *not* prominently play a role in sensitivity variation, i.e., the front-end 8-VSB tuner/demodulator design was most likely similar across the board in various models of DTV receivers, with backend features and screen sizes determining the bulk of the price variation. Remember, however, that this FCC laboratory test included a *mixture* of 4G (2004) and 5G (2005) receiver designs, and the FCC ascertained that the 5G receivers included the latest generation of 8-VSB demodulation chips from at least two of the major DTV chip developers.

In the 2010 FCC laboratory testing of the Coupon Eligible Converter Box (CECB) receivers[8], the FCC tested 115 approved DTV converter box models, presumably with 6G RF tuner and 8-VSB chip sets inside. Part of this testing was to determine sensitivity of the converter boxes in order to see if they passed the CECB sensitivity requirements placed on these receivers. Since these converter boxes were being subsidized by the government (two $50 coupons for 2 CECB units), receiver *performance specifications* were required to be met for eligibility of these CECB receivers in the coupon program. Regular DTV receivers sold on the open market have no such performance specifications requirement.

One of the test channels in this FCC testing program happened to be CH 51, no doubt because it was about to become the known upper band edge of the UHF television spectrum (with CH 52 – CH 69 to be relinquished for spectrum auction for broadband wireless and public safety). The FCC reported (**Table 2-1** of their report) that the median RF sensitivity level (i.e., with no signal impairments) for CH 51 was -85.0 dBm with only 0.90 dB standard deviation. This amazing TOS value indicated that there was incredible consistency with 6G receivers regarding sensitivity. Since the multipath performance of 6G receivers was improved over that of the 5G receivers measured in **2005** (≈1 dB better sensitivity) and the fact that sensitivity not only did not increase but actually decreased provided further evidence that the negative tradeoff trend of slightly degraded sensitivity needed for improved multipath performance had ended.

### 3.3 ATSC TRANSMISSION SYSTEM DTV-into-DTV CO-CHANNEL THRESHOLD

Interference effects are an important part of digital terrestrial transmission. Interference from nearby signals in the same or adjacent spectrum can potentially hinder or even render useless the DTV signal if not limited properly. The effects of interference can be described in *absolute* terms, such as desired signal power and undesired signal power, or it can be described in *relative* terms at a given desired signal level, such as desired-to-undesired (D/U) signal *ratios*. It must be noted, however, that the level of tolerable interference is typically ***not*** constant with desired signal level. Since an interfering DTV signal is noise-like, one would expect the co-channel DTV-into-DTV TOV results to be similar to white noise threshold results, i.e., at a D/U ratio of about 15 dB.

During the GA testing[9], DTV-into-DTV co-channel was carefully tested and described in terms of D/U ratios. It was found that at moderate levels (-53 dBm), far above the noise floor from the GA tuner, TOV from a co-channel DTV signal occurred between 14.78 dB and 14.92 dB. The fact that this occurred at a slightly *lower* D/U ratio than white noise is due to the fact that the interfering DTV signal is only noise-like. One difference between an 8-VSB signal and white noise is the peak-to-average ratio (6.3 dB versus 8.7 dB @ the 99.9% point). It might be expected that an interfering signal with a higher peak-to-average ratio (like COFDM used in LTE systems) might have a co-channel D/U ratio equal to that of white noise (i.e., the 15 dB value).

[8] Martin, Stephen, FCC OET Bulletin 9-TR1003, "DTV Converter Box Test Program – Results and Lessons Learned," October 9, 2009.
[9] Digital HDTV Grand Alliance System: Record of Test Results, October 1995, PI-3-14 to I-3-17.

While the case for LTE spectrum use in the A-Block (i.e., former CH 52) will *not* have a direct co-channel relationship, the adjacent channel emissions from an LTE UE device can fall into CH 51 and act as a co-channel interferer with a *non*-flat spectrum. Therefore, it is expected that the total integrated noise-like LTE interference that falls into the CH 51 band must be at least 15 dB below the DTV signal level (more if the DTV signal level is near the tuner noise floor, has experienced multipath, or been subjected to other types of interference). Details of this situation will be described later in this document.

### 3.4 ATSC TRANSMISSION SYSTEM DTV-into-DTV 1ST-ADJACENT CHANNEL THRESHOLD

First adjacent channel DTV-into-DTV was a very important parameter tested during the GA era and beyond. Since DTV signals would be subject to both analog and digital television signals in the adjacent channels immediately above and below a desired DTV signal (*during* the transition period) and only DTV signals (*after* the transition period), this parameter was important to quantify. Adjacent channel splatter is the result of non-linearities that a DTV signal experiences mostly in active devices such as amplifiers. These non-linearities can manifest themselves in various ways, but they typically cause intermodulation (IM) effects of various orders. Common IM effects are 3rd order ($IM_3$), 5th order ($IM_5$), and 7th order ($IM_7$), with $IM_3$ being the most common and most severe. As each the IM order increases, the non-linear spectral components spread out and the level of adjacent channel splatter energy decreases significantly. Typically, only $IM_3$ is of concern, although sometimes $IM_5$ is noticed. **Figure B-2** illustrates the adjacent channel splatter created by a 6 MHz DTV signal. $IM_3$ spreads out over 3 channels (including the desired in-band channel), therefore spreading to the adjacent channel immediately above and below the in-band interfering channel. $IM_5$ spreads out over 5 channels, and therefore affects adjacent channel spectrum above and below by 2 times the interferer's in-band signal. Later in this document, the same will be shown to be true for the flat-spectrum, noise-like LTE UE signals.

The GA system was tested for *upper* adjacent channel performance[10], and found to be-43.17 dB for weak desired signals (-68 dBm). The problem that arose in the GA testing after completion of the laboratory test was that these D/U ratios were originally obtained by using a DTV interference source with little out-of-band energy (OOBE) in the adjacent channel, which does not reflect real-world practice. Once again, the FCC CECB laboratory testing [11] can be used to see how converter boxes with 6G receivers in them fared. The median D/U ratio for upper first adjacent interference on the 115 approved CECB units was -43.0 dB for weak signals (i.e., at -68 dBm), similar to the GA test results. Just as the first GA test at the ATTC, it must be remembered that the interfering DTV signal had very little adjacent channel energy during this FCC laboratory test. However, since these large interference ratios typically don't exist in the field it shows that adjacent channel interference is often limited by (or at least dominated by) the adjacent channel *splatter* emissions from undesired signals (which act like co-channel signals) rather than the adjacent channel in-band interferer signal.

In the terrestrial DTV system, the FCC created a *rigid* out-of-band emission mask for their rules[12], and further clarified this mask in a public notice[13]. **Figure B-3** illustrates this emission mask. Additionally, the IEEE RF Working Group G2.2 created a document to explain the emission mask testing and verification methodology[14]. To understand the effects of this rigid emission mask on adjacent channel DTV receiver performance, a brief explanation of the mask creation process is in order. **Figure B-4** illustrates two rigid emission masks: the

[10] Digital HDTV Grand Alliance System: Record of Test Results, October 1995, PI-3-17 to I-3-20.
[11] Martin, Stephen, FCC OET Bulletin 9-TR1003, "DTV Converter Box Test Program – Results and Lessons Learned," October 9, 2009, P2-8 to 2-11.
[12] FCC Rules, 47CFR Section 73.622 (h), (1) and (2).
[13] FCC Public Notice, DA 05-1321, May 10, 2005.
[14] IEEE P1631 Recommended Practice for Measurement of 8-VSB Digital Television Mask Compliance for the USA", RF Standards Committee, G-2.2 of the IEEE Broadcast Technology Society, 2007.

original *proposed* mask (that was superseded before it ever made it into the rules) and the actual (current) mask contained within the FCC rules.

The original proposed mask was a *quadratic*-shaped mask that was originally proposed because it mimics the natural shape of 3rd-order intermodulation ($IM_3$) occurring in high power digitally-modulated transmitters. This mask limits worst-case first adjacent channel total 6 MHz *integrated* average splatter power to about 39 dB below the total 6 MHz in-band *integrated* average signal power. This adjacent channel splatter in effect is a noise-like co-channel interference with a non-flat spectrum, and its total average splatter power in 6 MHz should be 15 dB below the desired in-band DTV signal at TOV. Theoretically, this would allow a -24 dB D/U ratio (i.e., 15 - 39) at TOV.

Since the original GA testing did *not* perform first adjacent channel testing with an interfering DTV signal with this amount of out-of-band energy, the ATTC subsequently performed additional laboratory testing in the summer of **1996** (*after* the GA system was recommended to and accepted by the FCC). This amount of quadratic-shaped splatter was simulated by overdriving a low-power RF amplifier with a DTV signal and then used to perform a first upper and lower adjacent channel interference test on the GA prototype system. The DTV-into-DTV D/U levels were found to be -23 dB and -21 dB for lower and upper first adjacent interference, respectively. Theoretically, the two D/U ratios for DTV interference should be the same (i.e., symmetrical interference causing perhaps a D/U ratio of -23 dB), but the lab-created DTV interferer splatter (described in a document[15] for a related DTV-into-NTSC test) was *not* quite symmetrical, i.e., there was slightly more interference splatter energy on one side than the other. The 1 or 2 dB difference between theoretical (15 - 39 = -24 dB) and measured (-21 dB and -23 dB) could partly be due to measurement tolerance and partly due to the interferer's in-band signal energy causing *some* additional splatter creation in the DTV receiver.

However, subsequent evaluation of the preliminary FCC channel allocations showed a need for tighter transmitter splatter requirements, and a new emission mask was proposed (see **Figure B-3**). The new mask, which became part of the FCC rules, had a total 6 MHz integrated splatter about 5 dB better than the original mask (i.e., 44 dB below in-band power instead of 39 dB). Therefore, the FCC took the D/U interference values (-23 dB & -21 dB) from this *worst-case* splatter from the *original* emission mask interference laboratory results and added 5 dB to them to use as the final D/U values (-28 dB and -26 dB) for their lower and upper first adjacent channel planning factors[16]. These new allowable D/U ratios are a large difference from the original -43 dB measurement value with insignificant OOBE. This means that less adjacent channel interference could be tolerated in a real-world environment if the interfering DTV signal had FCC-compliant OOBE that acted as co-channel interference to the desired DTV signal. The same will also be shown to be true for a non-6-MHz LTE interference signal.

Therefore, as stated above, if the adjacent channel splatter from a first upper adjacent channel DTV interferer is the *primary* limiting factor in causing TOV in the desired DTV signal, then this integrated splatter would be about 15 dB below the desired in-band signal at TOV and allow a *theoretical* D/U ratio of -29 dB (i.e., 15 dB – 44 dB), as shown in **Figure B-5**. The FCC is using the adapted laboratory measurement value of -26 dB from the worst-case splatter measurement for upper first adjacent channel DTV protection from another DTV signal. Remember that if the in-band adjacent channel signal power has some effect, even a little, it can degrade the interference D/U ratio limit. In their rules, the FCC used these first adjacent D/U ratios for all values of *desired* DTV signal level, although it must be noted that the level of tolerable adjacent channel interference is typically *not* constant as the desired signal level varies.

---

[15] "Adjacent Channel Interference Revisited", Stanley Salamon, Advanced Television Technology Center, Alexandria, VA, NAB 1997.

[16] OET Bulletin No. 69, "Longley-Rice Methodology for Evaluating TV Coverage and Interference", February 6, 2004.

The first adjacent channel interference limits described above are for noise-like digital interference signals that have a flat-spectrum across the 6 MHz television channel. If *non*-television digital signals (e.g., LTE) reside next to a DTV signal, they will have similar characteristics even if their bandwidth is not 6 MHz. The location of their adjacent channel splatter will depend exactly on where their in-band spectrum resides and the spectral width of their in-band signal. In this MSW document, the effects of a noise-like LTE signal (with various bandwidths) will be the upper first adjacent interferer that is of concern and which must be quantified.

# 4.0 OET BULLETIN 69 PLANNING FACTORS

## 4.1 INTRODUCTION

Prior to the start of DTV transition, the FCC published some guidelines for their TV service coverage and interference analysis methodology used in the allocation of TV station channels. This guideline, created as an FCC bulletin[17], was written at the request of broadcasters to help clarify the FCC rules on this matter[18] that were adopted as part of the Sixth Report and Order[19].

The bulletin, often referred to in its short form as "OET-69", explains the technical details of using the Longley-Rice radio propagation model to predict, using computer analysis, RF field strength at geographic points based on terrain profiles between the transmitter and any given reception point. In particular, evaluation of DTV service area and coverage as well evaluation of interference from other signals is covered in this bulletin. OET-69, which explains the *FCC-required* methodologies and techniques for not only new DTV channel allocations but also DTV station parameter changes, was previously published on **July 2, 1997**, but updated in **2004**.

These guidelines, as they relate to the FCC rules, help engineers understand the criteria on which the FCC relies for determining both DTV *service* and *interference* into DTV using outdoor receive antennas located 30' above ground level (AGL). While no FCC planning factors exist for indoor reception of either analog NTSC or digital ATSC, there has been work done on such factors within the broadcast industry (to be discussed later in this document). These OET guidelines and rules will be used later in this document to determine CH 51 DTV service and interference in the presence of an upper adjacent LTE UE device using the A-Block spectrum.

## 4.2 EVALUATION OF SERVICE

For digital television, service is evaluated inside *contours* determined by DTV planning factors in combination with F(50,90) field strength curves (50% of the locations, 90% of the time). The use of the 90% *time* factor was deemed important in the development of the DTV transition since the inherent "cliff effect" of digital transmission requires, for acceptable DTV viewing, minimal MPEG packet errors occurring due to the signal dropping below TOV, regardless of the cause (e.g., either desired signal fading or signal interference).

OET-69 describes the noise-limited field strength *contour*, determined from the FCC's DTV planning factors, within which the entire area within this contour is to be evaluated for service and interference using Longley-Rice terrain-dependent prediction. These contour-defining field strengths are shown in **Table 2**. Note that UHF channels have an additional factor for calculating the service contour based upon the specific UHF channel that is being analyzed. This factor is called the *dipole factor*, and accounts for the frequency-dependent variability in conversion of field strength into signal power that occurs in antennas.

[17] OET Bulletin No. 69, "Longley-Rice Methodology for Evaluating TV Coverage and Interference", February 6, 2004.
[18] 47 C.F.R. Sections 73.622, 73.623 and 74.704.
[19] Sixth Report and Order, MM Docket No. 87-268, FCC 97-115, adopted April 3, 1997.

**Table 2**: Field strengths defining service contour.

| RF Channels | Field Strength Required for DTV Service (dBµV/m) |
|---|---|
| 2 – 6 | 28 |
| 7 – 13 | 36 |
| 14 – 69 * | 41 – 20*LOG[615 / (CH mid-frequency in MHz)] |

* **Note**: The highest channel of the UHF band is now CH 51.

The planning factors for DTV service are dependent on *assumptions* of the equipment, including antenna systems, used for "typical" home reception with a roof-top antenna at 30' AGL. The FCC planning factors from OET-69 are shown in **Table 3**. The last row of this table is an *additional* entry that results from calculating the required minimum unimpaired signal level (TOS) at the input terminal to a DTV receiver.

**Table 3** Planning Factors for DTV Reception.

| Planning Factor | Symbol | Low VHF | High VHF | UHF [1] |
|---|---|---|---|---|
| *Geometric* Mean Frequency (MHz) | F | 69 | 194 | 615 |
| Dipole Factor (dBm-dBµ) | $K_d$ | -111.8 | -120.8 | -130.8 |
| Dipole Factor Adjustment | $K_a$ | None | None | **Note 2** |
| Thermal Noise (dBm/6 MHz) | $N_t$ | -106.2 | -106.2 | -106.2 |
| Antenna Gain (dBd) | G | 4 | 6 | 10 |
| Downlead Line Loss (dB) | L | 1 | 2 | 4 |
| System Noise Figure (dB) | $N_s$ | 10 | 10 | 7 |
| Required Carrier-to-Noise Ratio (dB) | C/N | 15 | 15 | 15 |
| **TOS Sensitivity Level (dBm/6 MHz)** | **$S_{TOV}$** | **-81** | **-81** | **-84** |

**Note 1**: OET-69, written before the 2009 analog turnoff & before spectrum reclamation, does *not* reflect CH 51as highest channel

**Note 2**: The dipole factor is defined as: 20*LOG[615 / (channel *mid*-frequency in MHz)]

Note that the TOS sensitivity level is 15 dB above the equivalent noise floor of the tuner, which is $N_t + N_s$ (where $N_t = kTB = -106.2$ dBm/6 MHz, k is Boltzman's constant, T is temperature, and B is the 6 MHz bandwidth). The FCC assumes that the noise figures of a typical DTV receiver varies, being 10 dB at low-VHF and high-VHF and 7 dB at UHF. The TOS sensitivity field strength at the outdoor antenna input can be calculated from the following equation:

$$\text{F.S. (dB}\mu\text{V/m)} = N_t + N_s + C/N + L - K_d - K_a - G \qquad [1]$$

The assumptions made by the FCC, as shown in the planning factors as well as the equation above, do *not* account for presence of impairments such as multipath or signal fading nor interference such as other DTV signals or LTE signals. The presence of impairments or interference would require even <u>greater</u> field strengths to remain above TOV reception, thus indicating that these calculated values are *not* conservative and have little (if any) margin.

While this type of analysis is done assuming a 30' AGL receive antenna location (for official FCC applications or request for facility changes), other receive antenna heights above ground can be evaluated as well (e.g., 20' AGL or even 15' AGL) by the predictive field strength software. If attic antennas are considered, then some attenuation should be accounted for in the analysis. Indoor reception is more difficult since it must account for even more parameters, including a much lower antenna height above ground level, more building attenuation, and more multipath effects.

In addition to the receive system transmission patterns described above, the field strength prediction analysis utilizing the Longley-Rice terrain-dependent methodology includes the use the transmitter's maximum effective

radiated power (ERP) in a given direction, the transmit antenna's Height Above Average Terrain (HAAT), and the transmit antenna's azimuth and elevation patterns (*relative* antenna signal gain for a given direction is squared and multiplied by the ERP to provide signal power in the same direction). On the receive side, the outdoor antenna azimuth pattern assumed in OET-69 has a simple mathematical model (cosine raised to $4^{th}$ power, but never greater than the front-to-back ratio stated in OET-69). These parameters and others, in addition to specific values for constants used in the computer programming, can be found described in OET-69.

## 4.3 EVALUATION OF INTEFERENCE

Interference is an important part of the predictive service analysis because it determines how many areas that would have had successful DTV reception are removed from consideration due to an interfering (undesired) signal. Analysis of interference is similar to coverage, except that the interfering transmitter parameters are used, a different propagation path from that of the desired signal typically exists, and the Longley-Rice procedure uses F(50, 10) statistics. That is, the interfering signal is only allowed to be above a certain critical interference value for only 10% of the time in order to maintain acceptable DTV viewing experience. This 10% statistical time value worked well for analog NTSC since it has graceful degradation (i.e., an unacceptable picture is still watchable even though it is poor) but it is certainly pushing the limits on acceptable DTV reception since the digital cliff effect can cause complete loss of picture while below TOV and during resynchronization.

The criteria for determining the limits of signal interference on DTV signals is the ratio of the desired signal to the undesired signal, commonly referred to as D/U ratio. Values were determined during the GA era, as discussed in previous sections of this report. **Table 4** shows the co-channel and adjacent channel D/U ratios used in DTV spectrum allocation:

**Table 4** Interference criteria for DTV co-channel and adjacent channel.

| Channel Offset | D/U Ratio (dB) | | | |
|---|---|---|---|---|
| | Analog into Analog | DTV into Analog | Analog into DTV | DTV into DTV |
| N-1 (lower adjacent channel) | -3 | -14 | -48 | -28 |
| N (co-channel) | +28 | +34 | +2 | +15 |
| N+1 (upper adjacent channel) | -13 | -17 | -49 | -26 |

**Note**: Now that since *full-power* analog stations have turned off, the only column of interest is the last column for DTV-into-DTV

It is important to note that the DTV-into-DTV **co-channel** D/U ratio is only valid at locations where the DTV SNR is 28 dB or higher. For locations where the SNR is less than 28 dB, a formula for the interference threshold D/U is employed that takes into account the summation of the noise-like DTV interferer and the inherent AWGN in the tuner, which add together as *multiple* impairments to the desired DTV signal.

$$D/U = 15 + 10*LOG[1.0 / (1.0 - 10^{-x/10})] \qquad \text{where } x = 15.19 \text{ dB (white noise threshold)} \qquad [2]$$

An interesting fact that is germane to this report is that the FCC's *adjacent* channel D/U ratios in OET-69 do ***not*** have this same type of corrective mechanism for locations where the desired DTV signal is close to the TOS level (i.e., close to the white noise floor of the DTV receiver). The adjacent channel splatter of an interfering DTV signal (or any other noise-like broadband digital signal such as LTE) is also noise-like (albeit not with a flat spectrum), and is *often* the limiting factor in determining the interference threshold. Therefore, it should be understood that the required minimum D/U ratio in **Table 4** is affected by the DTV receiver's white noise near the TOS level. In other words, when the noise-like splatter of an adjacent channel interferer is present along with a very weak DTV signal, the DTV receiver tuner noise should be accounted for even though the FCC does

not require it. Nevertheless, this is a real effect that must be considered in order to accurately predict interference threshold levels from first adjacent channel signals (DTV or LTE).

### 4.4 FCC RULES REGARDING TELEVISION BAND INTERFERENCE PROTECTION

The FCC rules contain a provision which MSW believes to be applicable in the case at hand with Cricket. In 47 CFR Section 27.60 (a) (2) the Rules state the following:

"§ *27.60 TV/DTV interference protection criteria.*

*Base, fixed, control, and mobile transmitters in the 698-763 MHz, 775-793 MHz, and 805-806 MHz frequency bands must be operated only in accordance with the rules in this section to reduce the potential for interference to public reception of the signals of existing TV and DTV broadcast stations transmitting on TV Channels 51 through 68.*

*(a) D/U ratios. Licensees must choose site locations that are a sufficient distance from co-channel and adjacent channel TV and DTV stations, and/or must use reduced transmitting power or transmitting antenna height such that the following minimum desired signal-to-undesired signal ratios (D/U ratios) are met.*

*(2) The minimum D/U ratio for adjacent channel stations is 0 dB at the hypothetical Grade B contour (64 dBμV/m) (88.5 kilometers (55 miles)) of the TV station or* ***−23 dB*** *at the equivalent Grade B contour (41 dBμV/m) (88.5 kilometers (55 miles)) of the DTV station.*

MSW believes this FCC rule to be applicable in this instance. The rule was written originally in the context of protection of UHF stations during the DTV transition, but, as noted in paragraph (2) of the section, the equivalent 41dBμV/m *contour* is to be considered for DTV stations. Hence, one can reasonably assume that *within* the equivalent Grade B contour the interference D/U ratio would at *least* be required to be -23 dB or larger (i.e., less interference). Therefore, any operation proposed by Cricket would need to comply with this FCC rule. Or, as an alternative, Cricket would need to obtain permission from **WPWR** and the FCC to "waive" this rule and permit operation of their system within the Grade B contour of **WPWR**.

# 5.0 LTE OVERVIEW

### 5.1 700 MHz SPECTRUM ALLOCATION

Long Term Evolution (LTE) for broadband wireless is expected to be used in the 700 MHz spectrum block. A significant amount of spectrum (channels 52 – 69 between 698 and 804 MHz) was relinquished by television broadcasters in **June 2009**. This newly available spectrum, whose primary use is for wireless broadband and public safety, was put on the auction block multiple times in the past. Much of the spectrum has been bought and some of it already is in use for fourth generation (4G) LTE systems (e.g., Verizon on the upper C-Block). The FCC has divided this spectrum into an upper and lower 700 MHz block, with *proposed* deployment as shown in **Figure B-6** where the lower 700 MHz spectrum block has channels that are still 6 MHz wide. As this spectrum chart illustrates, there is a 1 MHz guard band (698 MHz – 699 MHz) that separates the lower A-Block channel from DTV CH 51, which is still in use in about **26** television markets. While there has been a freeze put on CH 51 changes and talk about moving CH 51 stations off of this channel even before the spectrum repacking takes place, nothing specific is planned to happen at the moment. Therefore, interference in this lower A-Block will be an issue for at least the immediate future. Note that **Band Class 12** operation overlays Blocks A. B, and C so that wireless carriers who bought all three blocks can use them efficiently. However, at the present, they have to deal with interference from CH 51 transmitters. An interesting development occurred in that AT&T lobbied, and received from, the 3GPP group a **Band Class 17** mode within the standard that <u>only</u> uses the B-

Block and C-Block (i.e., no requirement to transmit or receive A Block signals). Therefore, they plan to have receivers and base stations with front end filters that pass only desired B-Block and C-Block frequencies, but reject DTV splatter present on A-Block frequencies. This reduces the interoperability that the wireless industry (i.e., the smaller operators) had hoped for with the newer 4G LTE technology as they would not be able to have their users roam in cities using the AT&T Band Class 17 (B-Block and C-Block) system in the lower 700 MHz band (or Verizon system on the upper C-Block, for that matter).

In an expanded view, **Figure B-7** illustrates the exact frequencies utilized by A-Block for upstream frequencies (698-704 MHz) by the handheld LTE UE and downstream frequencies (728-734 MHz) utilized by the base station. However, the adjacent channel splatter from CH 51 transmitters typically spreads out over the entire A-Block upstream frequencies, more so at the lower end than at its upper end. Another important spectral characteristic is that there are 3 bandwidth deployment scenarios under consideration for LTE use in this band: 1.4 MHz, 3 MHz, and 5 MHz. Within each of these three bandwidths, a number of 200 kHz resource blocks (RB) exist (6, 15, and 25, respectively). These bandwidths and resource blocks can be dynamically allocated as needed by the LTE system, providing flexible and optimal wireless communication system performance.

## 5.2 LTE SPECIFICATIONS

As shown in **Figure B-7**, the base station transmits the downstream signal at a power of 1 kW (+60 dBm) while the LTE UE transmits the upstream signal at a maximum transmitter power output (TPO) of 0.2 Watts (+23 dBm), and represents the *worst* case interfering signal level that radiates towards a DTV antenna. The amount of power actually radiated is dependent on the efficiency of the antenna system. LTE systems use a closed loop power control from the base station which keeps the units at reasonable power levels commensurate with acceptable communication reliability and data rates. However, when an LTE handset is inside a building with significant signal loss, both the incoming DTV signal and LTE signal will be weak, which will drive the LTE handset power towards its maximum value via feedback with the base station. While there may be some losses associated with the antenna system, the Intertek report (**Section 9.1, P82**) states that there may also be 2-3 dB of antenna gain at some azimuth angles to partially offset the antenna system inefficiency, so large transmit powers are feasible with the LTE device. Also, research for small antennas for handsets and dongles continues with advancements both in materials and design.

The LTE UE device output signal will experience non-linearities as it passes through the final power amplifier stage, thus producing a varying amount of OOBE on *each* side of the LTE in-band spectrum. The LTE signal's lower adjacent channel splatter can fall into the CH 51 band, depending on the LTE bandwidth used. **Figure B-8** illustrates OOBE splatter for the *three* different LTE transmission bandwidths under consideration. Note that the most significant splatter is due to 3$^{rd}$ order intermodulation ($IM_3$), which falls in the adjacent spectrum on each side of the LTE in-band signal by an amount equal to the transmission BW. The 5$^{th}$ order intermodulation ($IM_5$) energy is lower than the $IM_3$, but extends in *each* direction by twice the LTE in-band bandwidth. An important aspect to consider is how much of the $IM_3$ (and possibly $IM_5$) falls within CH 51. Notice that the 5 MHz A-Block bandwidth, with only 1 MHz guard band, will have most of its $IM_3$ fall into CH 51 while the 3 MHz bandwidth only has its $IM_5$ fall within CH 51. In addition to the intermodulation components from non-linearities, there is always some broadband amount of noise beyond these in-band and adjacent channel frequencies that can fall into CH 51 as interference. Finally, there is always the possibility that the LTE's in-band signal can cross-modulate into the desired (CH 51 DTV) signal as well causing additional interference.

**Table 5** summarizes the LTE UE specifications for 700 MHz A-Block use.

**Table 5** LTE A-Block handset parameters.

| PARAMETER | SETTING |
|---|---|
| Center Frequencies | 701.5 MHz (5.0 MHz BW)<br>702.5 MHz (3.0 MHz BW)<br>703.3 MHz (1.4 MHz BW) |
| Release | 3GPP (Release 11.4) |
| Duplexing | Frequency Domain Division (FDD) |
| Modulation | OFDM/OFDMA |
| Allocation | 1 Lower-most RB<br>Frequency = 699 – 704 MHz |
| Resource Block Bandwidth | 180 kHz (within |
| UE Power Maximum TPO | +23 dBm ± 2 dB (0.2 Watts) |
| Total Radiated Power | Dependent on efficiency of handheld antenna system |
| Subcarrier Modulation | QPSK |
| Dummy Data | PN9 |

# 6.0 INTERTEK LABORATORY REPORT

## 6.1 PURPOSE and GOAL OF LABORATORY TEST

The goal of the Intertek laboratory test was to study the potential interference into DTV receivers tuned to CH 51 (692-698 MHz) from an LTE UE device that transmits in the lower 700 MHz A-Block spectrum (698-704 MHz, former broadcast CH 52). Intertek performed the tests in the fall of **2012**. Three bandwidth deployment scenarios in the A-Block spectrum (per the FCC and 3GPP band plans) were studied: 1.4 MHz, 3 MHz, and 5 MHz, with each scenario providing a different *guard band* to CH 51 (4.6 MHz, 3 MHz, and 1 MHz, respectively).

The primary purpose of the Intertek laboratory test was to determine potential interference to CH 51 fixed indoor DTV reception (using relatively inexpensive passive consumer DTV indoor antennas) from a nearby LTE UE device. The presumption made in the Intertek report (**Section 1, P11**) was that DTV receivers with outdoor antennas would unlikely be close to a transmitting LTE device in almost all circumstances.

The effect on **outdoor antenna** reception, however, is important to broadcasters as well as indoor reception. While indoor reception, *typically* useful within 25 or 35 miles from the transmitter depending on transmission parameters, covers a lot of the population in the metropolitan Chicago area, there are many people still residing beyond this distance due to the urban sprawl over the last few decades. Outdoor rooftop antennas at 30’ AGL can be also affected by an LTE device on the ground, even at distances greater than 10 meters away from the antenna, and worthy of evaluation for LTE field strength. This is especially true when DTV viewers are at great distances from the DTV transmitter (e.g., near the noise-limited DTV contour). It is also well-accepted within the industry that many modern day dwellings typically have rooftop antennas that are only 25’ AGL (e.g., raised ranch houses) or 20’ AGL (e.g., ranch houses) which experience lower DTV signal levels and increased LTE device signal levels due to closer proximity. Then there are the homeowners who do not want outdoor (rooftop) antennas due to aesthetic reasons or who *incorrectly* believe that local ordinances prohibit outdoor antennas despite the Telecommunications Act of 1996 rescinding (striking down) these local ordinances. They therefore use attic antennas, and accept some attenuation from a lower height above ground as well as some building attenuation as a tradeoff to mounting the antenna on a mast on the roof. These attic antennas are even closer to

the ground, allowing less DTV signal and more LTE UE signal into the DTV antenna. Of course, use of LTE devices inside the house can often occur on the upper floors of the viewer's residence or upper floors of neighbors' houses or apartments, which also reduce the distance between the LTE device and the outdoor or attic antenna.

Another important aspect of this Intertek study that was omitted was the effect on ATSC **mobile/handheld** (M/H) DTV reception, when both handheld devices are in close proximity to one another, whether in a building or in a car or walking down the street on the sidewalk. Broadcast mobile television is in its earliest stages, and can *not* tolerate interference issues in its startup phase, particularly in Chicago where **WPWR** has plans to begin transmission of an M/H signal.

## 6.2 LABORATORY TEST EVALUATION STRATEGY

The Intertek report (**Section 2.1, P15**) states that the laboratory test was designed to determine three things: **(1)** the *D/U interference ratios* where DTV reception would be lost for each of the three LTE bandwidth scenarios (1.4 MHz, 3 MHz, and 5 MHz), **(2)** the *distance* between the LTE device and the DTV antenna where the maximum LTE transmitted power would reach the interference TOV level, and **(3)** the *change* in TOV distance with reduced LTE transmitted power. These three objectives were fulfilled by first performing a simple *conductive* laboratory test (i.e., transmission system evaluation over coaxial cables with out radiation) on 25 consumer DTV receivers that assumes both the desired DTV and undesired LTE signals enter primarily through the antenna port, followed by a *radiated* over-the-air (OTA) test in an anechoic chamber on a subset of 5 consumer receivers with 3 of them identified with the poorest interference performance and 2 of them identified as mid-range interference performance. The results from the conductive and OTA testing, as well as other known field variables (that were not tested in the laboratory but surmised from past experience) were then used to predict field performance by extrapolation.

The Intertek report (**Section 2.1, P16**) uses the FCC's Part 15 rules for consumer devices as an *example* of interference problem mitigation by users (i.e., consumers, television viewers). The **1979** FCC Rules[20] regarding computer interference into *analog* television receivers describes instances when a nearby computer can create unacceptable interference into an analog television receiver that is within 10 meters (≈ 33') of the computer. An assumption is made that it very well could be in the same household and that the homeowner or apartment dweller can perform some mitigation techniques like decide which device to operate at any one time, move the two units further apart, or reorient the antenna of either of the two pieces of equipment. These days, many DTV viewers are simultaneously watching the "second screen", i.e., the very device that is creating the interference. Many feel that the name "smart phones" is misleading since these relatively new devices do so many more things than just allow phone calls, including surfing the web which can last for long periods of time. Of course, there is also the possibility that the computer <u>is</u> the television receiver (e.g., Hauppauge USB dongle) connected to an OTA indoor <u>or</u> outdoor antenna and the LTE UE device is also a USB dongle (e.g., Bandrich C525), which puts the two devices literally right next to each other.

However, even the FCC recognizes in this rule that the 10 meter distance allows for the distinct possibility that the interfering equipment is in a *different* household. Within the *city limits* of Chicago, with its very dense population of 2.7 million, many homes are located on lots only 35' wide with each home separated by only a 3' walkway, meaning that one neighbor can easily be within 10 meters of another neighbor's television set. This closely-space housing is also true of many of the adjacent *small* Chicago suburbs. Townhomes with multiple households share a common wall as do apartments and condos (neighbors on both sides as well as above and below). In a similar manner, even the much higher Wi-Fi frequencies (with poorer building penetration

[20] First Report & Order in Gen Docket, FCC 79-555, released October 11, 1979, 44 Fed. Reg. 59530 (October 16, 1979), Appendix C.

characteristics) allow many nearby neighbor wireless networks to be seen in any given residence. Therefore, there is a very good chance that an LTE device in the lower 700 MHz band can not only easily be within 10 meters of a digital television set and *not* be within the same household, but strong interference signals may come from *multiple* nearby residences.

Relocating or adjusting television antennas is *not* the same in **2013** as it was in the **1979**. Back then, indoor antennas sat on top of analog television sets that were easily deep enough to place an adjustable indoor antenna base on top of it. Also, many analog sets had a hole in its plastic back cover to insert VHF rabbit ears antenna with a UHF bow tie snapped to it for easy installation and adjustment. Adjusting the antenna was easily accomplished by viewing the analog picture, which directly reflected the proper antenna position in the picture quality.

With DTV signals, antenna adjustment can not be accomplished by looking at the picture quality but rather must be done via an on-screen *signal quality* meter that is not always easy to turn on (rather than a single button on the remote control, it is often buried several menus deep that a viewer must find). In the new digital world, the majority of DTV sets in the market are flat screen with no room for the old style antennas to reside thus providing a common problem for many viewers on antenna placement. Some modern antennas are flat and mounted to the wall, ceiling, or even window, and are therefore unable to be easily adjusted.

Therefore, in this modern era of remote-controlled "couch potatoes", indoor antenna adjustment is often done once, with a position selected that will bring in as many of the desired DTV channels as possible. While the Intertek report (**Section 2.1, P17**) assumes the DTV antenna is reasonably optimized for DTV reception, this is often *not* the case as long as desired signals are above TOV. While the LTE UE device can be of any orientation or polarization with respect to the DTV antenna, the fact that it often moves around with the user due to its mobility, it can often reach close to its optimum orientation for best interference coupling. The idea of a "98% coverage" distance is foreign to broadcasters since it only takes a small percentage of the time for picture or sound loss to frustrate an impatient viewer. As is so often stated in this modern era of communications, the younger generation does not even want to deal with any antennas at all (DTV or otherwise) let alone adjust them. They think antennas look "uncool" and out of date (i.e., retro). This can be seen by the negative comments made about small telescoping antennas on the new M/H DTV receivers that recently went on the market.

Additionally, the **1979** rule pre-dates digital television, meaning that when interference into an analog television with its graceful degradation occurs, the picture may be objectionable, but often still very watchable and the sound is still decent. With DTV and its cliff effect, the pixelization of the picture or outright freeze frames (or blue screens) is considerably more annoying (not to mention irritating audio breakups), and, therefore, much more desirable and important to avoid.

According to the Intertek report (**Section 2.1, P16-17**), the power of each LTE UE device is controlled by the base station in a feedback manner in order to maintain power for acceptable communication performance (required data rate and reliable reception). The transmitted LTE UE power can be varied over quite a dynamic range, if need be, in 1-dB steps. If there is little attenuation between the LTE UE and the base station, the base station requests less transmitted power from the UE. To get an idea of how the LTE UE power varies over a cell, the Intertek report (**Section 2.1, P16**) indicates that data was obtained from a *drive test* in an optimized LTE network. Statistics were obtained indicating that maximum power was required only 16.3% of the time. Additionally, it was found that 83% of the time, the LTE was requested to transmit at a power level at least 2.5 dB below maximum. It is not clear where this drive test was performed (i.e., the city and the type of local terrain), but a drive test does *not* include indoor reception, which has additional signal attenuation and signal distortion. Also, it should be pointed out that even operating at maximum power for at least 16.3% of the time,

if it causes CH 51 DTV reception interference, does not allow acceptable viewing. This time percentage value exceeds even the FCC's 10% interference statistics for analog graceful degradation viewing.

However, if there is quite a bit of LTE signal attenuation at a residence, as may be the case not only from the farthest expected distance to the base station but also due to significant building attenuation, then the base station requests more power from the LTE UE. Since both the CH 51 DTV signal and the LTE signals are in the 700 MHz range and adjacent to each other, they will have the similar antenna dipole factors and attenuation factors.

Therefore, the importance of a 10 meter interference distance is *not* critical but rather the ease with which the LTE signal can interfere with nearby DTV reception is of utmost importance.

## 6.3 TEST DEVICES, SIGNALS, AND SETUPS

Currently (i.e., **2012** time frame, during Intertek laboratory testing), there were only a few LTE UE devices that used the A-Block frequencies as specified by the 3GPP consortium. Intertek *identified* four **Band Class 12** (3 Samsung phones and one BandRich USB dongle) and 2 Band Class 17 (2 Samsung phones) devices, as shown in the Intertek report (**Table 4, Section 4.3, P30**). Three LTE UE devices were *selected* for testing (two Band Class 12 devices and one Band Class 17 device). These devices have an allowed maximum *TPO* specification (according to the 3GPP standard) of +23 dBm (±2 dB), with the amount of radiated signal power dependent on the efficiency of the LTE UE antenna system. Power is measured as the total average power over the entire bandwidth of the system (i.e., either 1.4 MHz, 3 MHz, or 5 MHz). All three units were evaluated for maximum transmit power level, OOBE at maximum transmit power, and occupied bandwidth before testing began. The measured maximum power was compared to the FCC equipment authorization test report for verification. As shown in the Intertek report (**Appendix F, P-F1**), the TRP for each unit was different due to varying losses of the antenna systems employed.

Each of the three units was measured for OOBE at maximum transmit power in each of the three test bandwidths (with the maximum resource blocks used), as compiled in **Table 6**. Spectral plots for two of the three selected LTE UE test devices (3 bandwidths each) at *maximum* transmit power is shown in **Figure A-1** and **Figure A-2** in **Appendix A**. Maximum transmit power is where there will be the worst case IM splatter in adjacent channels due to non-linearities in the LTE UE output amplifier. However, splatter will also exist to some degree at lower transmit power levels, but OOBE for these other power levels was *not* reported by Intertek. Note the overall width of the splatter increases as the bandwidth of the LTE in-band signal increases. Also note the distinct $IM_3$ and $IM_5$ regions in **Figure A-1** and **Figure A-2** as the slope of the splatter changes.

The two **Band Class 12** devices can use up to 5 MHz of the A-Block frequencies, which produces the most OOBE into CH 51. **Band Class 17** devices do not transmit in the A-Block frequencies. Note the 5 MHz bandwidth has most of its $IM_3$ OOBE fall into CH 51 as demonstrated in the drawings in **Figure B-8**. As shown in **Table 6**, the BandRich unit exhibited the most OOBE of the test units, and, according to the Intertek report (**Appendix D, P-D2**), was therefore used as a source in the *conductive* testing while all three units were used in the *OTA* testing (**Section 6.4, P54-61** and **Appendix E**, **P-E2-3**). This adjacent channel splatter appears as co-channel interference to a CH 51 DTV signal. As explained in the Intertek report (**text** and **Figure 12**, **Section 3.1.2, P23**), the *best* possible interference D/U ratio is dependent on the LTE UE OOBE being 15 dB or more below the CH 51 DTV signal. This is because the OOBE non-flat broadband noise acts like co-channel interference to the DTV signal (similar to the DTV example given in Section 3.4 of this document). The interference D/U can be *worse* than this if the *in-band* LTE energy also causes significant interference directly to the DTV receiver's front end (e.g., cross-modulation or desensitization through brute force overload) or the desired DTV signal is near its TOS level (e.g., near its tuner white noise floor). In these cases, there are *multiple* interferers hindering DTV reception in addition to the likely presence of multipath impairments. Using the

OOBE values for the BandRich device at maximum transmit level as an example (since that unit was used in the reported conductive interference testing), the *best* D/U ratios at maximum transmit powers that can be obtained are approximately -27 dB, -37 dB, and -47 dB for the 5 MHz, 3 MHz, and 1.4 MHz LTE signals, respectively (all with maximum number of resource blocks utilized).

**Table 6** Full power LTE UE transmitter out-of-band energy falling into CH 51.

| **LTE UE OOBE**<br>**Energy in DTV Channel 51**<br>**(dB below LTE Fundamental)** | | |
|---|---|---|
| **Band Class 12 Devices** | | **Band Class 17 Device** |
| **BandRich Model C525** | **Samsung R930** | **Samsung Note** |
| **5 MHz Bandwidth 25 Resource Blocks** | | |
| -42.1 dB | -43.3 dB | -56.6 dB |
| **3 MHz Bandwidth 15 Resource Blocks** | | |
| -52.5 dB | -51.5 dB | NOT Tested |
| **1.4 MHz Bandwidth 6 Resource Blocks** | | |
| -61.6 dB | -58.8 dB | NOT Tested |

However, these adjacent channel splatter numbers are just *measured* values of existing consumer test devices, and *not* the maximum allowable CH 51 splatter energy allowed by FCC rules[21]. This FCC rule for LTE emissions is fairly simplistic, with no use of an emission mask like the *rigid* emission mask in the DTV rules. It simply states that any LTE operation in the 700 MHz band (i.e., 698-746 MHz) shall have out-of-band emission power attenuated below the in-band power P, measured in Watts, (e.g., 0.2 W = +23 dBm = -7 dBW) by at least **43 + 10*log(P)** dB using an instrument with a 100 kHz resolution bandwidth (RBW). Filling in the numbers when P is at its maximum allowable +23 dBm transmitter power according to the 3GPP standard, the OOEB in a 100 kHz RBW must be 36 dB (i.e., -7 dBW + 43 dB) *below* its transmitted total average in-band power. This puts the OOBE limit at -13 dBm when the maximum allowable transmit power is used. Note that the mathematics behind this requirement says that any 100 kHz RBW measurement must be below -13 dBm, even if the LTE UE were transmitting at only 1 mW (i.e., at 0 dBm = -30 dBW. which would require OOBE to be 13 dB below in-band transmitted power, again at -13 dBm).

This would require any theoretical flat spectrum splatter (which is not flat in actual circuits, but rather falls off with increasing frequency from the in-band signal) to be at -13 dBm in a 100 kHz RBW. This would mean that the total integrated interference power from an LTE at its maximum transmission power of +23 dBm falling into the CH 51 band would be about +5 dBm (-13 dBm + 10*log[6 MHz/100 KHz]), or only 18 dB below the total in-band power. Of course, flat IM splatter does not occur in the real world, which leaves a dilemma for determining the maximum allowable OOBE into CH 51 from LTE UE devices. However, the OOBE for the 3 test devices measured by Intertek aren't guaranteed to be the worst case device splatter in the future, especially as new 700 MHz LTE devices become available on the market.

The amount of total integrated OOBE that falls within CH 51 is typically the *primary* (but not necessarily the only) limitation in determining the adjacent channel LTE interference D/U ratio at weak (-68 dBm) and moderate (-53 dBm) DTV signals. At strong (-28 dBm) DTV signal levels, there typically was not enough LTE UE signal level in the conductive tests to determine the actual interference D/U ratio. If interference D/U degradation existed due to the in-band LTE UE signal cross-modulating with the DTV signal, it was not found

[21] 47CFR Section 27.53(g).

using a +8 dBm interference signal. In a similar manner, the Intertek report (**Section 1.2, P12**) states that during OTA testing, a maximum *radiated* signal level of only +1 dBm or +2 dBm was possible, even with the LTE device almost touching the DTV antenna. However, all of the DTV antennas measured were passive units typically with over 6 dB of loss, as opposed to some passive antennas with less than 1 dB of loss not to mention amplified antennas. In other words, this does not mean the maximum LTE signal power limit is +1 dBm or +2 dBm for other DTV antennas with lower loss or other LTE UE devices with larger maximum TRP values.

Many DTV receivers are now on the market from a significant number of manufacturers, with most major manufacturers selling numerous different models. Twenty-five DTV receivers and 3 LTE UE devices were selected for testing that represented a good sample from the entire population of their respective devices[22]. The selection of the DTV sets, in order to achieve good representation of the existing population, considered various factors such as type of screen (e.g., LCD, Plasma, LED), screen size (e.g., 7" – 47"), features, price, sales number, and consumer reviews. Additional DTV sets were selected to represent "low end" models. Twenty five units were selected, which included a CECB converter box (a 26$^{th}$ unit was selected, also a converter box, but was deemed non-working and therefore left out of the analysis by MSW). Information on the 25 DTV sets can be found in **Appendix A**.

The front end DTV processing chips that select the RF signal and convert it to IF (tuner), and decodes the 8-VSB signal (8-VSB demodulator) often will be the *same* in various models from a manufacturer regardless of the backend features (screen type and size, features, price, etc.). Therefore, the most important factor is the type of tuner and demodulator chips used in the selected DTV sets. However, this information is often very hard to obtain from consumer manufacturers, which was the case for the Intertek laboratory testing. The important thing is that these DTV sets all use 5G or 6G receiver hardware with advanced processing for better multipath equalization, which is indicative of a vast majority of the DTV sets in the field.

The various conductive test setups (i.e., block diagrams) described in the Intertek report (**Section 5.2, P41**) are shown in **Figure A-3**. The conductive test for determining TOS used a similar setup with just the TV signal generator, isolator, coupler for spectrum analyzer signal monitoring, and 50/75-Ohm impedance converter for driving the DTV receiver under test. In both LTE interference test block diagrams shown in **Figure A-3**, note that *neither* setup (the one using an LTE simulator or the one using an actual LTE device with a base station simulator) has a means to attenuate the LTE UE signal *external* to the LTE source. If the setup described in the Intertek report is accurate, this means that the actual LTE UE device itself was used to vary the LTE signal level in 1-dB steps as controlled by the LTE base station simulator or within the LTE simulator itself. The problem with this methodology is that the adjacent channel splatter is typically different dependent on the LTE signal level required for TOV. If the LTE UE is not a maximum transmit power, the OOBE is lower and will produce more optimistic interference D/U ratios, which was *not* the focus of the worst case testing goal. As stated above, the D/U interference ratios can never be better than what is limited by the amount of OOBE present. The expected D/U limits calculated from the measured OOBE at maximum power will then be "violated" during *presumed* worst case testing if the LTE source is not at maximum power, making the results unreliable for worst case field performance prediction.

The Intertek report (**Appendix H**) examines and clarifies some of the fundamental concepts behind the test methodology. The focus of this laboratory evaluation was to determine how well all of these units coexist in an actual deployment (i.e., real-world environment).

[22] Note that Intertek initially obtained 26 DTV receivers, but one unit (Access HD converter box) clearly was *not* operating according to specification. Therefore, MSW did *not* use data from this faulty unit in any analysis in this report.

## 6.4 CONDUCTIVE TESTS

Conductive testing began with determining TOS for 25 DTV sets by determining the minimum DTV signal level for error-free reception with no signal impairments. Since interference threshold is affected by the inherent noise floor of the tuner, interference testing was planned not only at strong, moderate, and weak levels, but also at TOS+3 dB. Therefore, TOS had to be determined first for ***each*** of the 25 DTV sets under test.

To determine TOS during the conductive test, a simple lab setup was used (see **Figure A-3**) employing an R&S SFE DTV signal generator. The test system was completely 50 Ohms except for the impedance conversion device at the input to the TV receiver. The Intertek report states (**Section 4.6.2, P37**) that "Throughout the project, *both* TOS and TOV are measured with an ascending signal (TOS-A/TOV-A) and a descending signal (TOS-D/TOV-D)". The sensitivity level was found by starting with an unimpaired DTV signal above TOS (i.e., a clean, viewable HDTV picture) and *decreasing* the signal in 0.5-dB steps until TOS-D (descending TOS) was reached and then repeating it again by starting from below TOS and *increasing* the signal in 0.5-dB steps until TOS-A (ascending TOS) was reached, providing TOS values accurate to within 0.25 dB. Note that for TOS-A (but ***not*** for TOS-D), a *channel change* was performed to guarantee proper receiver synchronization and decoding. The value of TOS-D was then used as the interference metric since the TOS-A value was typically very similar (typically within 0.5 dB). As described in the Intertek report (**Section 4.6.1,P37; Section 5.2,P41**), TOS was determined using a "TV signal quality observer", i.e., Intertek personnel to view (for 20 seconds) the complex, moving 1080i HDTV picture and determine the "last passing level", i.e., the last signal level with *error-free* operation.

TOS for these 25 DTV sets were expected to be very similar as to the ones measured in the **2005** FCC testing project (specifically the 5G units that were part of the DTV test receiver inventory) and the FCC converter box testing project (which were all 6G units). That is, a value for sensitivity around -84 dBm or -85 dBm would be expected. **Table 7** lists the TOS values (TOS-D) for each DTV set as well as overall statistical values.

The average TOS value was -84.7 dBm (median value of -85.4 dBm), with a standard deviation of only about 1.4 dB, meaning that there was little relative variation in the measured TOS values.

Note that the *median* TOS value of -85.4 dBm places it in full agreement with the most recent FCC converter box tests. Yet there has been continued improvement in multipath performance and tuner noise figure while keeping the sensitivity SNR value at 15 dB. The remaining issue is whether the DTV tuner overload performance, in the form of interference D/U ratios for adjacent channel interference, is keeping pace with the other improvements.

**Table 7** Sensitivity Threshold (TOS) values for *each* DTV receiver.

| Manufacturer | Model Number | TOS (dBm) |
|---|---|---|
| LG | 42LK450 | -85.7 |
| Panasonic | Viera TC-L32C3 | -84.9 |
| Samsung | LN37D550 | -85.2 |
| Sony | Bravia KDL46NX720 | -84.8 |
| Toshiba | 24SL410U | -83.6 |
| Vizio | E220VA | -85.6 |
| Samsung | UN19D4003 | -82.9 |
| LG | 42CS560 | -85.7 |
| Samsung | UN32EH4000 | -85.8 |
| Panasonic | Viera TC-L32E5 | -85.6 |
| LG | 47LK520 | -85.9 |
| Samsung | PN43E450 | -85.5 |
| Samsung | UN32EH5300 | -85.8 |
| Sony | Bravia KDL32BX330 | -82.9 |
| Toshiba | 24V4210U | -84.0 |
| Visio | E3D320VX | -85.8 |
| Sharp | LC46SV49U | **-86.2** |
| Insignia | NS-19E320A13 | **-81.3** |
| RCA | 26LA33RQ | -85.5 |
| Haier | L32D1120 | -85.4 |
| JVC | LT19E610 | -85.7 |
| Coby | TF-TV1212 | -84.4 |
| Sansonic | FT-300A | -83.0 |
| Jensen | JDTV-1020 | -82.1 |
| Vizio | VMB070 | -83.7 |
| | Minimum Value | **-86.2** |
| | Maximum Value | **-81.3** |
| | Average Value | -84.7 |
| | **Median Value** | **-85.4** |
| | Standard Deviation | 1.36 |

The interference rejection capability of DTV receivers was laboratory tested with a carefully controlled combination of DTV and LTE signals (see **Figure A-3**). Four DTV signal levels (strong @ -28 dBm, moderate @ -53 dBm, weak @ -68 dBm, and TOS+ 3 dB) were tested. Two different methodologies for testing were considered. Using an LTE signal generator (i.e., a commercial piece of test equipment) allows repeatable testing with a simpler setup (no LTE base station simulator is needed) as well as creating a range of parameters to simulate different LTE devices on the market. However, using actual LTE equipment (i.e., consumer equipment actually on the market) allows actual use environment and perhaps real-world variables that are not included in the signal generator (but it requires an LTE base station simulator to control operation of the LTE UE devices). Both approaches have advantages and disadvantages, and were used in the final evaluation of the A-Block interference into CH 51 (**Section 5.2, P40**). In both test setups, except for the final feed to the 75-Ohm DTV receivers via an impedance converter, the test setup was implemented in 50 Ohms. As confirmed by Intertek via an e-mail, the conductive interference data that was presented in the Intertek report (**Appendix D**) initially used the LTE simulator but early on in the testing it was determined that this LTE signal was significantly "cleaner" (less OOBE) than actual LTE UE devices and therefore produced better interference results. Therefore, a switch was made from that point forward so that an *actual* LTE UE device (BandRich Compact LTE USB modem) was utilized for a majority of the testing. However, it is not known exactly how many tests were performed with the superior LTE simulator and how these may have affected the statistics of the test results.

The TOV interference levels were determined by setting the unimpaired ("clean") DTV signal to one of the four test signal levels *above* TOS (i.e., producing an error-free, viewable HDTV picture), and then adding the LTE interference signal forcing the DTV set *below* TOV-A before increasing the attenuation in 1-dB steps to just *above* TOV-A (within 0.5 dB), performing a channel change to verify proper synchronization and decoding. A similar methodology was repeated for determining TOS-D (except *without* a channel change). As with the TOS test, TOV was determined using a "TV signal quality observer", i.e., Intertek personnel to view (for 20 seconds) the complex, moving 1080i HDTV picture and determine the last signal level of error-free operation.

Intertek noted that interference TOV is not only affected by signal *level* but also by signal *quality*, i.e., the DTV SNR in dB (or EVM in %), that describes the amount the sampled data eyes are open. The more distortion in the signal (i.e., lower SNR) due to either linear or non-linear effects, the less interference can be tolerated. If linear distortion is present (e.g., due to multipath), the DTV equalizer will remove it, but with a noise enhancement penalty, which reduces interference tolerance. The Intertek (**Section 4.2, P30**) report states that at weak signal levels, variation in signal quality could "dramatically influence the sensitivity to interference", and once again states (**Section 5.7, P43**) that "independent of signal amplitude, signal quality was found to have a significant influence of the results." The example shown in the Intertek report (**Figure 22, Section 5.7, P46**) indicates a 6 dB change in TOV for only a 2.5 dB change in EVM (i.e., SNR). Note that Intertek converts the traditional EVM value in percent to logarithmic form by using the formula: 10*log[(EVM in %)/(100)]. However, DTV reception in the presence of multipath is exactly the type of reception condition that exists in the field not only with outdoor reception but *especially* with indoor reception, particularly if poor quality consumer indoor antennas are used (which is common). Therefore, conductive laboratory interference testing as well as OTA anechoic chamber laboratory interference testing are only "best case" scenarios, with real-world conditions (both outdoor reception and *especially* indoor reception) possibly significantly worse.

The conductive data is taken from the Intertek report (**Appendix D**, **Table 32 - Table 55, P-D2** to **P-D26**). LTE interference plots (**Figure 23**, **Figure 24**, and **Figure 25** on **P47** and **P48**) illustrate the maximum and minimum LTE interference signal levels at TOV for each of the four desired DTV levels (TOS+3 dB, -68, -53, and -28 dBm) as well as for each of the three LTE test bandwidths (1.4 MHz, 3 MHz, and 5 MHz) with different numbers of RB units (1 RB and maximum number RB). A final plot in the Intertek report (**Figure 26**) shows all 6 sets of test results using *average* LTE signal levels at the different TOV points. It was determined that a number of "typos" in the Intertek report (**Appendix D**) data tables occurred (mostly D/U ratio calculations), and were corrected before any new MSW analysis was performed, as shown in the Intertek Errata Summary in **Appendix C** of this MSW report. Also, a number of the minimum and maximum numbers calculated by Intertek were dependent on the Access HD converter box, which did not have consistent test data and, in some cases, had totally out-of-line results. Therefore, MSW did ***not*** use any data from the Access HD converter box, thus reducing the total set of DTV test units to 25.

The conductive interference threshold (TOV) summary results compiled by MSW from the original Intertek report (**Appendix D**) raw data are shown in **Table 8** and plotted in multiple figures within **Figure B-9**. In these plots, the interference D/U ratios (at TOV) for each LTE BW (1.4 MHz, 3 MHz, 5 MHz) and each LTE RB selection (either 1 RB or maximum number of RB units) are plotted for easy comparison between *averaged* D/U values and *maximum* (worst case) D/U values. Averaging was performed (in each group of tests) by taking the total average of *both* TOV-D and TOV-A for all 25 receivers. The maximum value was performed (in each group) by finding the maximum TOV value regardless of whether the maximum value was due to TOV-D or TOV-A.

**Table 8** Conductive average and maximum (worst case) interference D/U ratios of 25 DTV receivers.

| DTV Signal | | TOS+3 dB | | | -68 dBm | | | -53 dBm | | | +28 dBm | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LTE BW (MHz) | LTE RB (#) | Ave D/U (dB) | Max D/U (dB) | OOBE Limit (dB) | Ave D/U (dB) | Max D/U (dB) | OOBE Limit (dB) | Ave D/U (dB) | Max D/U (dB) | OOBE Limit (dB) | Ave D/U (dB) | Max D/U (dB) | OOBE Limit (dB) |
| 1.4 | RB1 | -38.4 | -30.9 | --- | -48.5 | -43.8 | --- | -48.0 | -43.4 | --- | -34.0 | -27.4 | --- |
| | RB6 | -38.6 | -31.6 | -47 | -48.6 | -43.0 | -47 | -48.5 | -43.4 | -47 | -34.5 | -28.3 | -47 |
| 3.0 | RB1 | -37.6 | -30.0 | --- | -46.6 | -41.4 | --- | -45.7 | -43.1 | --- | -33.4 | -26.3 | --- |
| | RB15 | -38.7 | -32.3 | -37 | -46.6 | -42.8 | -37 | -45.8 | -43.3 | -37 | -33.7 | -27.3 | -37 |
| 5.0 | RB1 | -35.1 | -28.2 | --- | -43.7 | -37.7 | --- | -43.8 | -39.7 | --- | -33.1 | -26.1 | --- |
| | RB25 | -36.7 | -31.1 | -27 | -41.5 | -36.6 | -27 | -36.3 | -32.9 | -27 | -26.5 | -22.8 | -27 |

The *average* value of TOS+3 dB for the 25 DTV sets was -84.7 dBm.

Max D/U indicates *worst* case (conservative) interference D/U, which is the most positive (i.e., less negative) D/U value.

OOBE limit is defined as limit based solely on co-channel LTE UE lab-measured splatter within CH 51 at ***maximum*** transmitted power.

"TOS+3 dB" DTV levels *assumed* to be average value over 25 units, but actually varied (unit-to-unit), slightly affecting worst case value.

As expected, *both* the average and maximum interference gets worse as the LTE bandwidth increases from 1.4 MHz to 3 MHz to 5 MHz. The increase in the *average* D/U ratio between using 1RB unit and the maximum number of RB units was not very significant within each of the three LTE bandwidths at lower DTV levels. However, the *average* D/U ratios did get worse with more RB units at the higher DTV levels where additional non-linearities might occur with the additional LTE energy closer to CH 51. Note the huge interference D/U ratios at the weak and moderate DTV signal levels, where LTE signal power was 30 to $40^{+}$ dB above the DTV signal levels.

While the difference between the average and maximum interference D/U values was often the greatest at the very lowest and very highest DTV signal levels, the overall average of the difference between the averaged D/U values and the maximum D/U values was *about* 5.5 dB. Using the worst case D/U interference ratios from the 25 DTV test sets allow for some real-world environmental realities (e.g., in-band DTV signal multipath impairments or additional interference signals) that can easily occur during actual DTV outdoor and (especially) indoor reception. The *maximum* interference D/U value that is of concern to the broadcasters did have a noticeable degradation with increased LTE bandwidth as well as with use of more RB units, especially at larger LTE bandwidths.

There is one anomaly that causes concern, though, that can *not* be ignored from the Intertek conductive test data. Looking at the test data for LTE signals with maximum resource blocks used, the measured interference data is better (often much better, by as much as 10 – 15 dB) than the expected best case determined by the measured OOBE at maximum signal level (see "OOBE Limit" columns in **Table 6** and surrounding text in **Section 6.3** of this MSW document). This issue is described in the Intertek report (**Section 3.1.2, Figure 12, P23**) where an example plot of the BandRich LTE at maximum power for 5 MHz 25 RB units has its measured OOBE within CH 51 shown as 42 dB below its in-band power. This limits the interference D/U ratio to about -27 dB for this LTE setup. Nevertheless, the Intertek report (**Section 3.1.2, P23**) states: "However, the measurements found that the D/U ratios were significantly better under most DTV signal conditions." The report continues with "Of course the actual D/U ratio could be worse than this if the DTV receiver front end allowed additional energy into the DTV from the adjacent band with the LTE fundamental." In other words, if the LTE device is at maximum power with the measured OOBE, than the best interference D/U ratio for the 5 MHz, 25 RB case is -27 dB due to the co-channel OOBE, but could be worse if additional non-linearities allow the LTE in-band signal to degrade DTV reception (e.g., cross-modulation or brute force overload).

Again, using the OOBE values for the BandRich LTE device at maximum transmit level as an example (since that unit was used for most of the reported conductive interference testing), the best interference D/U ratios that can be obtained are approximately -27 dB, -37 dB, and -47 dB for the 5 MHz, 3 MHz, and 1.4 MHz , respectively (all with maximum number of 25, 15, and 6 resource blocks utilized). Yet the values shown in **Table 8** indicate much better interference D/U ratios than this. The only way this can happen is if the signal level measurements (OOBE or D/U) were made incorrectly, or (most likely) the BandRich LTE UE unit was *not* at maximum power as described in the Intertek report (**Appendix D**). A further indication of this is the block diagrams in the Intertek report (**Figures 19 and 20, Section 5.2, P41**), repeated in **Figure A-3** of this document, show that there was no external variable attenuator in the path from the LTE source to the DTV set, indicating that the LTE UE itself was used to adjust the threshold levels (in 1-dB steps, as declared by Intertek). If this is true, then it is likely that the BandRich LTE source was *not* at maximum power level for all of these tests, creating less OOBE than measured and reported, and would explain why better than expected interference D/U ratios were obtained. Also remember that the conductive testing began by using the much cleaner LTE simulator before switching to an actual LTE UE device, and that it is unknown how many conductive tests were performed before the LTE source switch was made. At the very least, this should be investigated further.

It is clear that broadcasters want to use the *worst case* DTV interference D/U ratios measured on consumer receivers when evaluating if the current **Section 27** FCC field strength rules (i.e., D/U limits) are reasonably sufficient to protect their CH 51 service from LTE interference throughout their market. There are very few performance rules placed on the consumer manufacturers regarding their DTV sets, and therefore it can not be assumed that any one parameter is safe from design tradeoffs. The same is true for consumer LTE UE device manufacturers.

While the field strength D/U ratios are the parameters that the FCC uses to protect one broadcast station from another or one service from another, the Intertek report evaluates another interference parameter: the theoretical interference *distance* between an LTE cell phone using the A-Block frequencies and a DTV antenna before it interferes with DTV reception in CH 51.

## 6.5 THEORETICAL INTERFERENCE DISTANCE CALCULATIONS

Interference "threat" distances are defined in the Intertek report (**Section 8.1, P74**) as "the distance at which an LTE UE is capable of causing interference" to a DTV receiver. These interference threat distances are calculated using a *theoretical* link budget model with parameters that include (1) transmitter gains and losses, (2) propagation path loss with frequency and distance, and (3) receiver gains and losses. This link budget equation can be used to describe laboratory test results for the purpose of verifying theoretical threat distances, but also can be used with the theoretical interference D/U ratios to estimate a real-world threat distance assuming a "typical" viewer's receive system. Either way, a value for the each parameter in the equation is required before the link budget can be used to estimate a threat distance.

The basic line-of-sight, free-space model, while still not perfect due to ground effects (outdoors) and building construction and furniture effects (indoors), is at least a reasonable simple *starting* point for a rough, *first*-order approximation of the required *minimum* distance to avoid interference between an LTE UE device operating at maximum transmit power (+23 dBm) and an antenna receiving a DTV signal. Beyond *near-field* signals that exist close to the antenna, signals generally propagate using free-space propagation that varies inversely with the square of the distance, with the assumption of no significant reflection or diffraction of the propagating signal.

A second order approximation of the required interference distance might attempt the very challenging task of modeling indoor propagation with the presence of walls and other objects found in homes. Nevertheless,

general modeling of required outdoor and indoor field strengths for successful DTV reception has been done[23], with applications in field strength prediction software.

Significant *near-field* DTV antenna affects must be recognized, often defined as in terms of wavelength λ (λ = c/F, where **c** = speed of light ≈ $3x10^8$ m/sec[24], and **F** = frequency in Hz). Near-field effects are defined somewhere between a distance of 1λ and 2λ from the antenna. In addition to wavelength, near-field antenna effects are also dependent approximately on the largest dimension of the antenna (excluding mast mounting hardware). In the case of A-Block frequencies operating around 700 MHz, where λ is about 0.4 meters (i.e., ≈1.3'), this puts near-field antenna effects within a couple of feet of the DTV antenna. The Intertek report states (**Section 8.1, P74**) that it is believed that a line-of-sight model is appropriate for distances up to 3 meters (i.e., ≈10'), while a modified line-of-sight approach (line of sight with some assumption of architectural influence beyond 3 meters) can be used up to 30 meters.

However, in many homes, there are rooms that have dimensions of 3 meters (i.e., 10') or more (e.g., living rooms, family rooms, dens, finished basements, etc.) that have large screen DTV sets for multiple-person television watching. And for nearby rooms within the same house or apartment/condo, there very well may be only one or two "simple" walls between the LTE interference source and the DTV antenna (i.e., walls with 2" x 4" studs having 0.5" plasterboard attached on each side that can be modeled as a simple fixed loss with a value of perhaps 5 or 6 dB). The most difficult problem with indoor modeling is the presence of large objects with multiple surfaces of varying materials that not only present difficulty in determining path loss, but more importantly significantly challenge the modeling of complex multipath which can have a significant effect (i.e., degradation) on both the white noise threshold SNR and interference D/U ratios at TOV.

The line-of-sight model described in the Intertek report (**Section 8.1, P75**) uses the following link budget equation to calculate receiver signal input power when all of the other transmission parameters (transmitter system, propagation path, and receive system) are known:

$$P_{RX} = P_{TX} + G_{TX} - L_{TX} - L_{FS} - L_M + G_{RX} - L_{RX} \quad \textbf{[3a]}$$

$$P_{RX} = P_{TX} + G_{TX} - L_{TX} - [20*\log(D) + 20*\log(F) - 27.55] - L_M + G_{RX} - L_{RX} \quad \textbf{[3b]}$$

where $P_{RX}$ is the receiver input power, *after* feedline cable loss (in dBm)

$P_{TX}$ is the transmitter output power, *before* feedline cable loss (in dBm)

$G_{TX}$ is the transmitter antenna gain (in dBi), where dBi = dBd + 2.15 dB

$L_{TX}$ is the transmitter losses, such as feedline cable loss, VSWR, connectors, etc. (in dB)

$L_{FS}$ is the propagation path loss for distance, frequency, and miscellaneous losses (in dB)

- 20*log(D) is the *inverse distance squared* $(1/D)^2$ logarithmic path *loss* factor (i.e., $10*\log[D^2]=20*\log[D]$)
- 20*log(F) is the *inverse frequency squared* $(1/F)^2$ frequency-dependent path *loss* factor
- 27.55 is a fixed value that relates to various constants in the free space propagation loss calculation

$L_M$ is the miscellaneous losses, such as polarization mismatch, body loss, fading margin (in dB)

$G_{RX}$ is the receiver antenna gain (in dBi), where dBi = dBd + 2.15 dB

$L_{RX}$ is the receiver losses, such as feedline cable loss, VSWR, connectors, etc. (in dB)

D is the distance between the transmit and receive antennas (in meters)

F is the frequency of the signal (in MHz)

---

[23] "A Report to The Metropolitan Television Alliance Regarding Urban DTV Planning Factors for Distributed Transmission Systems", MSW, May 8, 2007.

[24] The speed of light, **c**, is actually $2.99792458 \times 10^8$ meters per second, which is *approximately* $3 \times 10^8$ meters per second.

Note that the free-space propagation *loss* (FSPL) parameter, a fundamental part of this link budget equation and labeled $L_{FX}$, is defined in the *far* field (where spherical spreading is assumed) as:

$$FSPL = [4\pi D / \lambda]^2 = [4\pi DF/c]^2 = [4\pi/c]^2 * [D]^2 * [Fx10^6]^2 \quad \textbf{[4a]}$$

which clearly shows the inverse square law for both distance and frequency[25] and the frequency variable is written to clearly show that it is in MHz (*not* Hz) since the "$10^6$" is expressly written as a separate factor. Upon converting this *linear* equation for FSPL to *logarithmic* format (i.e., 10* log), the following equation results:

$$FSPL(dB) = 10*\log[D]^2 + 10*\log[F]^2 + 10*\log[4\pi 10^6/c]^2 = 20*\log[D] + 20*\log[F] - 27.55 \quad \textbf{[4b]}$$

where D is distance in meters and F is frequency in MHz. The constant "$4\pi 10^6/c$", when made part of a "20*log" logarithmic calculation, results in the -27.55 dB constant value (a negative decibel value since the linear constant is less than one). It is important to note that free space propagation does *not* attenuate the electromagnetic wave according to its frequency as the equation might appear to indicate. Rather, the expression for FSPL actually represents two separate effects: the distance inverse square law (no frequency dependence) and the receiving antenna's aperture, which describes the efficiency of that antenna in collecting the electromagnetic signal, which is, in fact, frequency dependent (similar to the frequency-dependent antenna dipole effect used in OET Bulletin #69). Again, this FSPL equation does **NOT** hold for distances very close to the transmit antenna (i.e., it's not valid in the *near* field of an antenna).

The previous equation allows the receive power to be calculated when all of the other parameters are known. On other occasions, the required *transmitter* power needs to be calculated when a desired or expected receive signal power is known. Simple manipulation of the original link budget equation provides the new equations:

$$P_{TX} = P_{RX} - G_{TX} + L_{TX} + [20*\log(D) + 20*\log(F) - 27.55] + L_M - G_{RX} + L_{RX} \quad \textbf{[5]}$$

One final alteration of the link budget equation allows the *distance* separation between the transmit and receive antennas to be calculated when transmit and receive signal powers are known as well as all the propagation parameters. The equation for this calculation is:

$$\log(D) = -[P_{RX} - P_{TX} - G_{TX} + L_{TX} + L_M - G_{RX} + L_{RX} - 27.55]/20 - \log(F) \quad \textbf{[6a]}$$

$$D = [1/F] * 10\text{^}(-[P_{RX} - P_{TX} - G_TX + L_{TX} + L_M - G_{RX} + L_{RX} - 27.55]/20) \quad \textbf{[6b]}$$

In the case of the Intertek report (**Section 8, P76**), certain parameter assumptions were made based on the test equipment used during the laboratory testing. The assumption was stated that the LTE UE was operating at full power (+23 dBm), although there is doubt as to whether the testing was consistently performed at this maximum power level. The LTE UE transmit antenna and the DTV receive antenna were assumed to be 0 dBi, with each of those antenna "gains" (actually losses in this case) accounted for in the antenna factor that is part of the miscellaneous losses. As a reference point, with a 1 meter separation distance, the path loss is 29.4 dB, the total link loss is 48.5 dB and the expected receive power with a maximum LTE UE transmit power (+23 dBm =0.2 W) is -25.5 dBm. The receive signal power for other separation distances can be easily determined from this reference point, such as for 10 meters where the path loss increases by 20 dB (i.e., 20*log[(10 m)/(1 m)]), and the receive power decreases to -45.5 dBm.

The constants shown in **Table 9** are used in the link equation in the Intertek report (**Section 8.1, Page 76**):

[25] Note that since FSPL is defined as a ***loss***, the distance D and frequency F variables are in the numerator; otherwise, if they were defined as ***gains***, these two variables would be in the denominator, which would translate to negative dB loss values upon conversion to logarithmic variables.

**Table 9** Link budget parameters for predictive path loss

| Symbol | Device Type | Distance | Value | Unit |
|---|---|---|---|---|
| $P_{TX}$ | RF Tx Transmitter Power Output | | 0.2<br>+23 | Watts<br>dBm |
| $L_{TX}$ | TX VSWR Loss | | 0.0 | dB |
| $L_{RX}$ | RX VSWR Loss | | 0.0 | dB |
| $L_{FS}$ | PATH LOSS @ 1 meter | | 29.4 | dB |
| $G_{TX}$ | Tx ANTENNA Gain | | 0 | dBi |
| $G_{RX}$ | RX ANTENNA Gain | | 0 | dBi |
| $L_M$ | Cross Polarization | | 0 | dB |
| | Antenna Misalignment | | 0 | dB |
| | Antenna Factor | | 13.8 | dB |
| | DTV Cable & XFMR Loss | | 5.4 | dB |
| | Unidentified Loss | | 0.0 | dB |
| | **TOTAL** MISCELANEOUS Losses | | 19.2 | dB |
| | TOTAL Link Loss | 1 m<br>3 m<br>6 m<br>10 m | 48.5<br>58.1<br>64.1<br>68.5 | dB<br>dB<br>dB<br>dB |
| | Expected Rx Power at DTV from full +23 dBm Tx power | 1 m<br>3 m<br>6 m<br>10 m | -25.5<br>-35.1<br>-41.1<br>-45.5 | dBm<br>dBm<br>dBm<br>dBm |

It is *not* entirely understood from the Intertek report how the specific *values* for some of their constants were determined (e.g., 13.8 dB antenna factor and 5.4 dB DTV cable & transformer loss). While the antenna factor accounts for the TRP of both the LTE device and the DTV antenna, the determination of the specific value 13.8 dB is not understood. *Perhaps* it is a net effect of all the combinations of LTE devices and DTV antennas gathered for this Intertek laboratory test.

Likewise, the 5.4 dB of loss for DTV Cable and transformer loss is puzzling since the North Hills coaxial impedance converter (Model 0114-JA) only has 0.3 dB of loss at 700 MHz, leaving a surprising 5.1 dB of loss for the DTV cable. While the conductive laboratory tests use an impedance converter and *perhaps* enough cascaded cable to warrant 5.1 dB of loss at 700 MHz, the OTA test does not. In the OTA test where the DTV receiver is shown located inside the anechoic chamber, a 75-Ohm consumer indoor antenna is connected directly to the DTV set by presumably a short 75-Ohm cable, which does not require an impedance conversion (i.e., there is no 50-Ohms circuits at the "receive site"). Therefore, this additional 5.1 dB of loss should not be included in any of the analysis if its purpose is to take the theoretical interference D/U ratios and determine a real-world threat distance that might exist in a real application. Note that due to the 20*log(D) factor in the link budget equation, a 3 dB reduction in loss results in threat distances 41% longer (i.e., 1.414) and a 6 dB reduction of loss results in threat distances twice as long.

The theoretical threat distances calculated from the interference TOV values measured in the conductive laboratory tests could ***not*** be found in the Intertek report (only a relative *comparison* between them and the actual OTA measured values). However, MSW calculated the threat distances using Intertek's link budget equation and specific parameter values. MSW results of the *calculated* theoretical interference distances are shown in **Table 10** and plotted in multiple figures within **Figure B-10**. In these plots, interference distances for

each LTE bandwidth (1.4 MHz, 3 MHz, 5 MHz) and each RB selection (either 1 RB or maximum number of RB units) are plotted for easy comparison when calculations use the *averaged* TOV values (of all 25 DTV set TOV measurements) and when they use the *maximum* (worst case) TOV measurements. Averaging was performed (in each group of tests) by taking the total average of *both* TOV-D and TOV-A for all 25 receivers. The maximum value was performed (in each group) by finding the maximum TOV value regardless of whether the maximum value was due to TOV-D or TOV-A. The theoretical interference distances were then calculated using **Equation [6]** with the Intertek parameter values (including the questionable 5.4 dB loss value).

**Table 10** Conductive average and maximum (worst case) interference distances for 25 DTV receivers.

| DTV Signal | | TOS+3 dB | | | -68 dBm | | | -53 dBm | | | +28 dBm | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LTE BW (MHz) | LTE RB (#) | Ave Dist (m) | Max Dist (m) | OOBE Limit (m) | Ave Dist (m) | Max Dist (m) | OOBE Limit (m) | Ave Dist (m) | Max Dist (m) | OOBE Limit (m) | Ave Dist (m) | Max Dist (m) | OOBE Limit (m) |
| 1.4 | RB1 | 7.7 | 17.1 | --- | 0.5 | 0.9 | --- | 0.1 | 0.2 | --- | 0.0 | 0.1 | --- |
| | RB6 | 7.5 | 16.1 | 4.0 | 0.5 | 0.9 | 0.6 | 0.1 | 0.2 | 0.1 | 0.0 | 0.1 | 0.0 |
| 3.0 | RB1 | 8.4 | 19.1 | --- | 0.6 | 1.1 | --- | 0.1 | 0.2 | --- | 0.0 | 0.1 | --- |
| | RB15 | 7.4 | 14.7 | 12.8 | 0.6 | 1.0 | 1.9 | 0.1 | 0.2 | 0.3 | 0.0 | 0.1 | 0.0 |
| 5.0 | RB1 | 11.3 | 22.5 | --- | 0.9 | 1.7 | --- | 0.2 | 0.2 | --- | 0.0 | 0.1 | --- |
| | RB25 | 9.4 | 18.3 | 40.4 | 1.1 | 2.0 | 5.9 | 0.4 | 0.5 | 1.1 | 0.1 | 0.1 | 0.1 |

**Note**: The *average* value of TOS+3 dB for the 25 DTV sets was -84.7 dBm.

Max D/U indicates *worst* case (conservative) interference D/U, which is the most positive (i.e., less negative) D/U value.

OOBE limit is defined as limit based solely on co-channel LTE UE lab-measured splatter within CH 51 at max transmitted power.

"TOS+3 dB" DTV levels *assumed* to be average value over 25 units, but actually varied (unit-to-unit), affecting worst case value.

Notice that once again the most significant interference occurs with 5 MHz LTE signals, although at weak signal levels (-68 dBm and below) all three LTE bandwidths exhibit increasing interference as signal levels approach TOS of the DTV receivers. At moderate and strong DTV signal levels, the 1.4 MHz and 3 MHz LTE signals are not strong interferors in this theoretical study, but the 5 MHz LTE signals still exhibit noticeable interference for DTV reception. From these threat distance calculations, it can be seen that the average distance values were about *half* the maximum distance values which is not insignificant. However, the biggest factor to consider is the theoretical threat distances for the worst case limiting condition where the LTE UE is at maximum power with the worst case OOBE. It is clear that at the weak level and even moderate level cases the threat distances challenge DTV reception. Also to be considered is the fact that if the additional 5.4 dB of receive system loss is removed from the equation, the threat distances would nearly double, making LTE interference even more problematic. And this does not even count the fact that the worst case antenna gains are not accounted for in the link budget.

The preceding work describes interference distances calculated using *theoretical* equations with assumed antenna and propagation parameters based on laboratory testing and not on real-world conditions. That is, they do *not* account for other impairments (e.g., multipath) or interference (e.g., other DTV signals) which can further worsen LTE interference into DTV reception. Nevertheless, they do provide at least some idea of what occurs during moments of interference and an order of magnitude of the problem.

To further refine the process, Intertek conducted over-the-air tests in an anechoic chamber to see if comparable results could be obtained with the theoretical calculations based on conductive testing.

## 6.6 OTA Tests

The Intertek test plan called for *conductive* testing to be complimented by *radiated* over-the-air (OTA) testing in an anechoic chamber. Their goal was to validate, if possible, the results of the conductive tests, particularly the interference distance calculations, and build confidence in these results. However, a comparison of the threshold D/U ratios between conductive and radiated testing was also possible, noting any degradation to these ratios for the various LTE bandwidths that might be due to the radiated nature of the test (e.g., imperfections of anechoic chamber). Another goal was to reveal any additional factors that affect DTV interference that might not have been observed in the conductive tests but manifested themselves when the signal is radiated (using actual LTE and DTV antennas) over the air in a very well-controlled environment such as an anechoic chamber.

There are two test setups described (in words and block diagrams) in the Intertek report (**Section 6.1, P49-51**); one for using an *actual* LTE UE device (in conjunction with an LTE base station simulator) for realism and connection to real-world equipment use, and one for using an LTE *simulator* with controllable parameters for flexible testing. However, it is also stated in the Intertek report (**Section 6.1, P49**) that "each device was tested using an LTE signal from a commercially available LTE UE in order to insure that the test results simulated the real-world situation." No mention is made in this Intertek statement of using an LTE simulator for OTA testing that has different characteristics (particularly OOBE) and maximum power level capability. Therefore, it is ***assumed*** that the OTA data reported by Intertek is only from these *actual* LTE UE devices, with whatever OOBE exists at the particular transmitted power. Additionally, Intertek does not indicate a specific indoor DTV antenna (of the 6 listed and characterized) used in these OTA tests or if multiple DTV antennas were tested with the results averaged. By looking at the picture in the two block diagrams in the Intertek report (**Figure 27 & 28, Section 6.1, P50-51**), one might make an *educated* guess that the picture used for the DTV antenna appears similar to the Zenith VN1ANTP1 shown in the Intertek report (**Table 59, Appendix G, PG-2**). Therefore, a number of questions exist regarding this particular OTA laboratory test.

All three of the consumer LTE UE devices (2 Band Class 12 units and 1 Band Class 17) were used as signal sources in the OTA test. None of the LTE sources radiated the entire +23 dBm (due to antenna system losses), as stated in the Intertek report (**Section 6.1, P49**): "no LTE UE devices were found that radiated the +23 dBm ERP transmit power allowed by the 3GPP standard. To account for this, the radiated power from the LTE UE, as reported by the base-station simulator, and the LTE UE signal power at the DTV receiver antenna port were recorded. When reporting threat distances, the test results were extrapolated to represent those projected for an LTE UE radiating a full +23 dBm ERP." The Intertek report (**Section 6.4, P52**) states that the Samsung R930 LTE UE has a TRP of +18 dBm, but this does match with the +13 dBm value for TRP listed in their Appendix (**Appendix F, P-F1**) that describes the measured TRP for each test unit. Nevertheless, if LTE UE power levels were less than their maximum value, their OOBE would be lower than worst case, and cause misinterpretation of the interference data.

Only 5 DTV receivers were selected as a subset of the original 25 sets that were evaluated in the conductive test. Three of the units were considered "worst performers" for interference rejection and two were considered "average performers", as determined in the conductive tests. The choice of these units attempted to bring focus on mid-range and lower end consumer-grade receivers. However, after completing all of their measurements (conductive and OTA), it was determined that these 5 units performed close to the average of all 25 DTV sets as revealed in the Intertek report (**Table 28, Section 8.2, P76-77**).

Two different anechoic chambers were utilized, as described in the Intertek report (**Section 8.2, P77**). The primary OTA testing was performed in a 3-meter anechoic chamber. However, when interference distances exceeded 3 meters, additional OTA tests were conducted in a 10-meter semi-anechoic chamber. For interference threat distances greater than 10 meters, (typically for the low-level DTV signal cases at TOS+3 dB, which

require greater threat distances), the results were *extrapolated* from the 10-meter anechoic chamber measurements.

The Band Class 17 device (Samsung Note) was used to provide a comparative reference to an LTE operating in the next adjacent channel (B-Block), i.e., former CH 53. All three LTE UEs were also used in the conductive tests to provide additional comparison points, but the *conductive* results of the two additional Samsung LTE UE units are ***not*** included in the Intertek report.

The Intertek test plan called for *calibrating* the anechoic chamber test setup prior to the start of OTA testing. Since the DTV antenna was connected directly to the DTV set via 75-Ohm coaxial cable (no need for 50-to-75-Ohm impedance matching device) with no splitter or coupler to monitor the received DTV and LTE signal levels, a system calibration was necessary prior to the start of testing. The transmitted LTE UE power was monitored via the LTE base station controller, and the transmitted DTV signal level were measured by a spectrum analyzer at the coupler output. The DTV receiver was temporarily replaced by a spectrum analyzer in order to (1) adjust the DTV antenna for optimum coupling with the LTE source, and (2) measure and record the relationship (i.e., range factor) between both these two fixed signal source monitoring points and the DTV set inputs.

The test procedure used was straightforward. The goal was to determine once again the interference TOV levels at the input to various DTV receivers (although only 5 DTV sets this time instead of the entire population of 25). With the DTV antenna and the LTE UE device both oriented for maximum coupling of the LTE interference signal, various interference tests were performed, including the commonly selected distances of 1.2 meters, 1.8 meters, and 3.0 meters where recorded raw data is included in the Intertek report (**Tables 19-23, Section 6.4, P62-66**). One would expect that for a given preset distance that the LTE UE transmit power (via base station "call" control) would have to be varied (1-dB steps) since the OTA test block diagram does not show any other means of externally attenuating the signal. This means that the LTE UE transmit power needs to be known in order to calculate the extrapolated threat distance predicted for the maximum LTE UE power so that it could be compared to the theoretical threat distance calculated from the conductive tests.

However, there is no raw LTE UE transmitted power data in the Intertek report (**Tables 19-23, Section 6.4, P62-66**) included for each measured interference TOV value as stated in the test procedures described in the Intertek report (**Section 6.3, P52**). In order to independently verify their interference threat results, these LTE UE transmitted powers are required yet nowhere to be found. Therefore, MSW can *not* verify the interference threat distances summarized in the Intertek report (**Tables 11-18, Section 6.4, P54-61**) and plotted (**Figures 29-30, Section 6.4, P53**).

Also, the OTA data collected in the Intertek report (**Tables 19-23, Section 6.4, P62-66**) has apparent typos. For example, a number of D/U ratios are listed with dBm units (instead of dB). There are also D/U ratios listed as greater than 80 dB (which is impossible). Some D/U ratios are greater than the worst case values determined by LTE UE OOBE measurements (at maximum power) in CH 51 despite the claim by Intertek that the LTE UE devices were at maximum power. Some of the LTE signal levels at the DTV input are listed as 0 dBm, which is unlikely since they would easily cause interference for very weak and weak DTV signal levels (yet they are listed as "No TOV"). Again, Intertek apparently used the link budget equation, but it is not known if they used the same parameter values shown in their report (**Section 8.1, P76**), including the 5.4 dB loss for coaxial cable and impedance conversion device (which does not apply). If so, the extrapolated calculations would have been artificially shortened.

Nevertheless, even using the threat distance numbers in the Intertek report (**Tables 11-18, Section 6.4, P54-61**), the worst case distances at DTV signal levels of TOS+3 dB are 17.2 meters, 5.8 meters, and 2.4 meters at 5 MHz, 3 MHz, and 1.4 MHz bandwidth, respectively. Even at weak signal levels (-68 dBm), Intertek's threat

distances are over 2 meters (≈ 7') for the 5 MHz bandwidth. These are not insignificant distances, especially when these distances do *not* take into account the interference degradation due to multipath or the extra loss in the assumed link budget equation that was employed.

Despite the lack of complete measured data in the Intertek report, the following material briefly describes Intertek's conclusions. The results of the OTA testing, as reported in the Intertek report (**Section 8.2, P77-78**), provided interference threat distances that were *higher* than those predicted from the conducted data by a *factor of two*, which is not insignificant. The Intertek report (**Section 8.3, P79**) illustrates the measured results in various threat distance plots, showing that most of the interference occurs at the lower levels of DTV signals (i.e., -68 dBm and lower). Interference threat distances at -68 dBm and lower varied over the 3 different bandwidths, with the expected result of the 1.4 MHz LTE bandwidth causing the least interference, then the 3 MHz LTE bandwidth, followed by the most interference caused by the 5 MHz bandwidth. This confirms that increased frequency guard band reduces interference into DTV, as expected. Intertek measured worst case threat distances that varied from under 1 meter to up to 17 meters, all of which can easily cause interference under the most common of circumstances to either outdoor or (especially) indoor DTV reception. And these results do *not* account for severe multipath signal distortion on the received DTV signal which will make these interference distances significantly worse in real-world environments as well as the fact that the LTE UE source was apparently not at maximum transmit power very often, which would increase the threat distances.

Also included in the Intertek report (**Section 8.3, P78**) is a statement indicating that the 1.4 MHz and 3 MHz bandwidths in A-Block had "roughly comparable" interference results to that of the Band Class 17 LTE UE device using 5 MHz bandwidth only in B-Block. Actual comparable results between the two Band Classes were likely to be only for the 1.4 MHz A-Block signals. However, without the raw LTE UE transmit power data, this can not be verified.

Besides the usual possibility of measurement uncertainty and tolerances, Intertek made a significant effort to understand the differences between the predicted threat differences calculated from the conductive tests and those measured in the OTA tests.

Interestingly, Intertek claimed in their report (**Section 8.3, P77**) that reflections degraded the DTV signal even though testing was performed in an anechoic chamber (there are always *some* reflections in any OTA test due to imperfections in the chamber and the hardware setup used to support the test). Reflections will, in fact, degrade receiver error thresholds (e.g., both white noise TOS and interference TOV values), but usually becoming noticeable at echo levels greater than what one would expect in anechoic chambers. A measure of signal quality used in DTV is either SNR (in dB) or EVM (in %). Nevertheless, the Intertek report (**Section 8.3, P77**) states that if "the DTV receivers were given degraded signal quality, even though the signal amplitude was the same, an increase in sensitivity to interference is to be expected". It is important to note that, with all of the testing under <u>ideal</u> conditions such as existed in the conductive and anechoic chamber OTA laboratory tests, there is ***no*** mention in the Intertek report of how severe <u>real-world</u> terrestrial transmission echoes will be due to multipath (static and dynamic) and what their effect on interference levels and distances will be. This would indicate that any bench and anechoic chamber tests would certainly not be worst case conditions, but rather only a first-order model of what really transpires in the field.

In the OTA testing, the LTE UE sources were *thought* to be operating at maximum transmitter power, which would naturally increase the A-Block signal's adjacent channel splatter that acts as co-channel interference to CH 51 DTV signals. The Intertek report (**Section 8.3, P77**) indicates that increased OOBE existed due to operating at maximum power. However, the interference D/U ratios in the OTA appear to reflect that the LTE UE was not a maximum power. However, there will be times, under weak LTE signal conditions that are determined by the base station, the LTE UE will be at or near maximum power. The Intertek report (**Table 2,**

**Section 3.1.2, P24**) includes spectral measurements and plots for the three LTE UE devices at *maximum* power, but does not indicate the amount of OOBE at transmit power levels below maximum power.

### 6.7 Predicted Field Performance Issues

The entire purpose of this laboratory test was to allow Intertek to develop parameters for a computer model that can be used to predict LTE field interference performance (particularly interference *distance*) based on their test results. Specific conditions were identified in both conductive and OTA testing under which LTE interference is likely to occur, and then interference distances between the LTE UE and the DTV antenna that would cause interference to CH 51 reception were measured and calculated.

One primary factor for determining interference in the field is the limit that OOBE from LTE UE devices places on how strong an adjacent channel LTE signal can be before interference occurs to DTV reception. If the *dominant* interference factor is the LTE adjacent channel splatter energy that falls into DTV channel, then the D/U ratio is limited by integrating this LTE splatter over the 6 MHz band that defines CH 51 and then subtracting the 15 dB interference TOV ratio allowable for the ATSC signal. Since the actual LTE UE Band Class 12 devices (BandRich C525 and Samsung R930) measured in this Intertek lab test had splatter for 5 MHz bandwidth (25RB) LTE signals (see **Table 2, Section 3.1.2, P24**) that integrated to about 42 dB *below* the in-band average power, the D/U ratio limit where interference TOV occurs is about -27 dB (i.e., 15 – 42). This means that, even in the laboratory under very well-controlled conditions, the D/U ratios should always be greater than this value (degraded), i.e., D/U ratios that are more positive than -27 dB. The reason that the measured D/U ratios can be *worse* than this value is because the in-band LTE signal power can also cause adjacent channel interference (e.g., cross-modulation) in *addition* to the co-channel interference from the LTE's OOBE. Likewise, at very weak signal levels, the DTV tuner's noise floor is added to the co-channel LTE OOBE to further limit interference D/U ratios. However, as discussed above, the conductive lab test data in the Intertek report (**Tables 52-55, Appendix D, PD23-26**) often has interference D/U values that are better (i.e., lower, more negative) than the -27 dB OOBE limit. This is *puzzling* since these conductive tests were originally thought to be performed at maximum LTE UE device power where the splatter is greatest (as reported in **Table 2** on **P24** in the Intertek report). This anomaly was also observed in the OTA test results. Additionally, while OOBE will decrease with lower transmit powers, the amount of OOBE is not known at other LTE transmit levels just below the maximum value.

As the Intertek report states (**Section 9, P81-82**), additional variables come into play regarding DTV interference from LTE devices in real-world environments. The following is a list of possible influences on LTE interference into DTV reception.

1) DTV signal *levels* already have location and time variability that make DTV reception challenging, for outdoor and especially indoor reception, even before interference issues are considered.
2) DTV signal *quality* variability, whether due to linear or non-linear propagation effects, also challenge DTV reception, even before interference issue are considered.
3) LTE UE transmit power output (TPO) is limited to +23 dBm ± 2 dB (i.e., 0.2 Watts -75 mW/+115 mW) by the 3GPP standard, and therefore limits the worst case radiated power level. This TPO power level at the input to the LTE UE antenna system is often affected by antenna system loss, although typically there will be some small amount of antenna gain (2-3 dB) to help offset the other losses. While the best device found on the market had a **TRP** of 20.5 dBm, with peak levels at +23.9 dBm, others had 4 - 6 dB less power capability. When setting up DTV coverage and service rules, however, there must be the assumption that other manufacturers can duplicate or even improve upon competitor hardware performance, but they can also lower the cost and degrade the performance to

the limits allowed by the particular standard. Therefore, the state of the market, especially in its infancy (as the 700 MHz market can be currently described), should *not* be used to predict potential interference in the future as the market matures. Also, when referring to radiated power with *integrated* TRP metrics, it must be understood that as the LTE UE device is held by the user, it is in relative motion much of the time as the consumer uses it, and therefore passing through minimums of antenna pattern to maximums as well, thus increasing the chance for sporadic DTV interference. Antenna pattern nulls can effectively disappear in the real world due to signal reflections, both with outdoor reception and especially indoor reception.

4) The LTE UE transmit power is aggressively controlled by a base station, sometimes as often as every millisecond, trying to maintain an optimum power condition to maintain reliable communication (robustness and data rate). Ttransmit power levels in excess of +17 dBm are not insignificant when in reasonably close proximity to DTV antennas that are receiving relatively weak distorted signals from either distant DTV towers or that have been attenuated significantly inside shielded houses (e.g., those with aluminum siding, foil-backed insulation, internal plaster walls with metal mesh, etc.). The traditional contour circles used to describe power levels around the DTV transmitter and the LTE base station are only part of the analysis since urban clutter near the viewer's house as well as building attenuation factors will also play an important role of determining indoor signal levels. Therefore, weak signals for either incoming DTV signal levels or LTE UE signals reaching their base station can result in strong interfering LTE UE transmit signals, even close to their respective towers. While the LTE feedback process tries to maintain the transmit power at the *lowest* possible LTE UE transmit power for reliable communication, the large data rates needed for present day needs (e.g., streaming video to "2$^{nd}$ screens" as well as large Internet data downloads) in limited 4G spectrum can require larger LTE UE transmitter power, which can cause more DTV interference. Even when transmit powers are not at their maximum level, reduced levels of 3 – 6 dB below maximum can still provide strong interfering radiated signals into nearby DTV antennas. When DTV signals are weak, the DTV tuner will operate its front end RF amplifier wide open (i.e., maximum gain) allowing for increased opportunity of overload. If broadband AGC is employed and a large LTE signal is detected within the AGC detection bandwidth, it could reduce the DTV tuner's RF gain, and attenuate the weak DTV signal below TOS. Either way, DTV reception is lost.

5) LTE resource blocks (180 kHz bandwidth) are dynamically assigned into 200 kHz frequency bands to support the needs of the communication session. When larger data rates are needed, or many users are in need of data communication, more resource blocks are used, making the LTE UE signal spectrum broader (i.e., wider). A broader LTE signal, especially with one that uses resource blocks closer to the CH 51 channel, will have more OOBE that can fall into CH 51 and cause DTV reception interference. With more need for higher data rates, and continuing popularity of high-speed 4G services, broader signals with more potential DTV interference will be prevalent.

6) Separation distance between the DTV antenna and the LTE UE is a primary variable in determining the amount of LTE interference picked up by the DTV antenna, whether it is an outdoor, attic, or indoor antenna. Broadcast planning in the past dealt only with *fixed* transmit and receive locations for both the desired and undesired signals, but in this case, the LTE device is *mobile*. This means that the interferer device can easily move near the DTV antenna as the user varies their location, allowing for LTE signal injection into DTV antennas. DTV interference even for relatively small percentages of time can render terrestrial television viewing unacceptable, as demonstrated by the FCC's use of F(50, 10) curves for interference prediction even for the old analog NTSC television

system with graceful degradation. Also, it may not be obvious to the LTE user that this device is the cause of sporadic interference to their DTV reception.

7) *Relative* antenna position and orientation can easily vary as the user moves around with an LTE UE device. Despite somewhat directional patterns of *both* the LTE transmitter and the DTV receive antennas, the fact that there will be multipath in real-world applications reduces the effects of antenna nulls (i.e., signal nulling attenuation becomes minimized) and increases the chance of signal de-polarization (i.e., cross-polarization attenuation becomes minimized). Again, it doesn't take much percentage of time for DTV interference to render terrestrial television viewing unacceptable. Therefore the use of "98% coverage" theory is not desired. Another aspect of this problem is that many viewers have been found to inadvertently place very poor DTV antennas (antenna *loss* > 10 dB and poor matching to DTV tuner) in significantly poor locations (e.g., on the floor or behind DTV sets) with improper adjustment/orientation of the elements. This often converts a DTV receive condition that would have been reasonable (with viewer education) into a very weak, multipath-laden receive condition (with no viewer education) that challenges reception even before LTE interference is introduced.

8) Out-of-band energy is a very real and very primary cause of DTV interference, as the A-Block LTE UE adjacent channel signal splatter can fall directly into CH 51 and act as co-channel interference. Large signals push the linearity limits of consumer product LTE phones causing 3$^{rd}$, 5$^{th}$, and possibly some 7$^{th}$ order intermodulation (IM). The splatter into CH 51 will be worse for larger bandwidth LTE signals (e.g. 3 an 5 MHz versus 1.4 MHz) and for active resource blocks closer to CH 51. However, even narrower bandwidth LTE signals that are transmitted can still have some broadband output amplifier device noise that falls into CH 51 and therefore has some effect on DTV signal reception which must *not* be discounted.

9) Architectural effects of the DTV viewer's residence, both outdoor and indoor structural effects as well as indoor furnishings, can have similar effects on *both* the CH 51 DTV signals and A-Block LTE signals since they are only separated in frequency by 6 MHz or less. Clearly the relative locations and distances with respect to the viewer's residence of the DTV and LTE transmit towers plays a role in how the signal is received by an outdoor or indoor antenna, and thus enters the home.

10) Multipath, as mentioned earlier, plays a significant role in DTV reception. DTV receivers are most challenged by multipath found in indoor reception, especially complex, dynamic multipath, arriving with varying RF phase relationships. While multipath can be challenging even with outdoor antennas in highly-urbanized areas (e.g., with lots of tall buildings and other urban clutter along with moving vehicles), it is much worse with indoor reception where very often there is no line of sight, which allows for Raleigh type of propagation paths (i.e., the various echoes can be greater in amplitude than the main signal). Dynamic multipath can be caused by both moving objects outside the viewer's residence (e.g., planes, trains, trucks, buses, cars, etc.) but also by object inside the viewer's residence (e.g., people walking around, including the ones using the LTE UE devices). Not only can multipath challenge the ability of the receiver's internal signal equalizer (i.e., multipath canceller) to converge on an optimum solution and stay locked, but the DTV equalizer when working properly to eliminate multipath can also enhance the receiver's own internal tuner white noise as well as any noise-like interference (e.g., LTE in-band signal or LTE adjacent channel splatter), thus degrading a receiver's interference protection.

11) TV picture content is another factor in the level of interference. Less complex, static video have a greater chance of effective picture error concealment, although rarely perfect. However, in recent

years, much more HD video content with lots of detail is available for viewers, often with complex motion (especially with the popularity of sports) which makes the effectiveness of video error concealment more challenging and less effective. There is no good error concealment for audio, other than muting the sound, which is often more annoying for viewers than occasional picture pixelization.

12) Phone usage simultaneous with DTV viewing is required for DTV interference to occur. Use of cell phones has increased dramatically in recent years, both in numbers of people using them and the amount and purposes of use. While phone calls may sometimes be relatively short sessions, data transfer sessions are increasing. With the ubiquitous use of smart phones (and recently tablets) to do much more than verbal communication (texting, music listening, Internet searching, video streaming, using various apps, etc.), 4G LTE use is expected to greatly increase what is already a steady trend of increased phone usage. Recently a new paradigm has come upon the television scene, that of the second screen. More people are not only watching mobile television away from home on various platforms including the new ATSC Mobile/Handheld (M/H) system, but also watching their mobile device at home while viewing the main, large high definition screen. Therefore, more simultaneous use of DTV and smart phones is expected.

13) Smart phones that provide many services while users are mobile can interfere with DTV users who are using the ATSC M/H system for mobile viewing away from home. Now, these two devices (LTE and M/H) can be in close proximity to each other, often only a foot or two apart (e.g., on a bus or train, in the workplace, at a sporting even, etc.). LTE interference to DTV viewing can be critical.

While consideration of interference in theoretical terms (including simulation) and in controlled-environment laboratory testing is critical and necessary, it is *not* sufficient to predict all of the potential challenges of deployment in the real world. Using theoretical understanding of systems and interference modeling as well as testing these principles in a laboratory environment is a good starting point for understanding individual DTV interference effects. The lab test results provide a *reference* point in a well-controlled environment to understand required planning factors for real-world applications. It would be a mistake to assume that worst case conditions in the laboratory occur rarely in the field since the simple modeling used in the laboratory tests is insufficient to accurately predict many of the real-world problems that occur from *multiple* impairments in addition to well-intended but unknowledgeable (regarding DTV RF propagation) television viewers. However, field testing and field evaluations are critical in determining the effects of multiple impairments and in creating planning factors (e.g., D/U interference ratios) for performing computer simulations of DTV coverage and service areas.

## 7.0 NEWFIELD INTERFERENCE PREDICTION REPORT

The laboratory data from the Intertek lab test report was utilized along with other data by Newfield Wireless to prepare a report to Cricket entitled “Chicago Channel 51 Interference Probability Study”. This paper study is intended to predict the distance from the DTV receive antenna where CH 51 DTV interference would occur for a *Cricket* LTE subscriber using an LTE UE device.

This Newfield interference study utilized an “Exclusion Zone” that was determined using a propagation model provided by Hammett & Edison as well as Received Signal Level (RSL) predictions at 2.0 meters AGL for the DTV power at the location of interest. Newfield also utilized Neilson ratings data for **WPWR** from **May 2012** to estimate the number of current CH 51 viewers using OTA reception. The number of Cricket subscribers was also utilized to estimate the number of potential LTE subscribers in the Chicago area that may experience DTV interference in their homes.

The premise of the Newfield report is centered on the prediction of interference to OTA reception that would be experienced by a projected number of *Cricket subscribers*. However, there are several flaws with this approach to interference prediction. Traditionally, prediction of interference to DTV and other broadcast services uses an interference D/U ratio methodology that is based upon a geographic area. Therefore, any prediction of interference to DTV service should be based upon the regime employed in broadcast services and *not* the methods described in the Newfield report. Using the techniques that Newfield proposes would likely result in a significantly *under*-estimated impact.

There are many concerns regarding the Newfield report as they relate to **WPWR**. First, the use of the RSL signal at 2.0 meters for only indoor reception ignores other important DTV viewers such as those who use outdoor antennas at various heights as well as viewers of the new M/H services. It is certainly possible for a UE device to be within close proximity to an outdoor antenna and therefore, the outdoor antenna scenario should be considered in the evaluation. Likewise, UE devices can be in very close proximity to an M/H device as well.

Secondly, in our experience, in dense urban locations such as Chicago, homes (and their DTV receivers) are located very close to each other. Housing units such as apartments, condominiums, duplexes, and single family homes on 35' wide lots is very prevalent. Consequently, Cricket subscribers in one dwelling will be in close proximity to neighboring DTV receivers which can lead to impairment of receivers that are not under the control of the Cricket subscriber. The report excludes from its estimates those households that were *not* Cricket subscribers. Therefore, the interference estimates provided by Newfield would be lower than expected.

Third, we disagree with the premise used by Newfield and Intertek that the FCC Part 15 rules should govern the distance from a UE device to a DTV receiver. The prescribed FCC D/U ratio, as noted in the following section, will dictate the prescribed distances to be evaluated.

Furthermore, considerations regarding only the homes that were credited in the **May 2012** Neilson data would exclude those homes that have access to the CH 51 DTV signal but were watching another program during the survey period. **WPWR** should be able to reach <u>all</u> OTA homes within its coverage area – not just those homes watching **WPWR**'s programming in **May 2012**. By only evaluating potential interference on the basis of current viewership trends, the Newfield report excludes all homes that were not tuned to **WPWR** programming in **May 2012**, as well as to viewers who will in the future "cut the cord" from pay services and desire OTA reception. This Neilson data approach will artificially reduce the number of potentially impaired viewers.

Also, by using only the number of Cricket LTE subscriber estimates as the analysis population, the study results seriously understate the number of potential **WPWR** viewers that would have impaired reception of CH 51. The premise that only the population of Cricket subscribers should be included in the study is grossly inaccurate. As stated throughout this document, the assumption that LTE interference only affects the same household with an active LTE UE device is invalid. Not only neighboring houses or apartment/condo units can cause LTE interference, but also LTE users walking down the street.

The full population of the Chicago DMA within the **WPWR** coverage area should be considered in the evaluation whether they are Cricket subscribers or not. According to data from **2012**, approximately 17.8% (national average) of homes are exclusively OTA homes, and for lower income households the number of OTA-only households exceeds 26%. Additionally, these figures do **<u>not</u>** include homes with a 2$^{nd}$ or 3$^{rd}$ OTA only DTV receivers in a bedroom, office, or garage. According to some Nielson reports, approximately 75% of homes have 2$^{nd}$ and 3$^{rd}$ sets that are *not* connected to cable or satellite.

Therefore, for the interference analysis, MSW suggests that it should be assumed that each 0.5 km cell within the exclusion zone has an OTA receiver and co-located Cricket LTE UE device. This provides a more

comprehensive and geo-located based evaluation much more in-line with the Broadcast industry interference prediction regime used to date.

In the Newfield report, evaluation of the various bandwidths of LTE operation was undertaken using the interference data collected in the Intertek lab tests. However, given the dynamic nature of the LTE modulation and operating parameters, in which the LTE operational bandwidth changes frequently, it is believed that a conservative evaluation of potential interference should be based upon the *worst*-case 5 MHz (RB=25) LTE operation. Since the OOBE is the primary interference mechanism, the assumption of the worst-case operational bandwidth is recommended to ensure conservative results.

The UE operational power studied in the Newfield report does *not* address the maximum power that is allowed for the UE device. The UE device is allowed to operate at +23 dBm, but none of the evaluation was conducted at this level. Intertek reported that the maximum power that was able to be achieved from the UE device was +18dBm for a particular unit, some 5 dB lower than the allowed power. Thus, the results provided at the +18dBm power level are considered to be optimistic. An evaluation of the interference at the +23dBm level should be considered in order to ensure a conservative prediction of interference.

One area of concern that is not addressed in either the Newfield or Intertek reports is the possibility of interference from the CH 51 **WPWR** DTV signal into the UE device. This particular mechanism and various scenarios have been explored in work conducted by Mr. Charles Rhodes over the last few years. The concern is the possible intermodulation of multiple DTV signals in the receiver of the UE device.

There is concern that two or more high power DTV signals could mix in the front end receiver (tuner) of the LTE UE device impairing the reception of base stations downstream signals on CH 57. While we have not done an extensive analysis of the various intermodulation scenarios, we believe that significant tuner-induced intermodulation is very likely to result in downtown Chicago where the DTV signal levels are very high (>100 dBμV/m) from multiple stations. This would create a scenario where the signal from the base station to the LTE UE device is significantly impaired and would render the LTE system with significantly impaired coverage.

The following section outlines an evaluation regime which is believed to be more appropriate for the case at hand. It is important that the interference evaluation be based upon the geographic coverage area of the **WPWR** facility and not based upon likelihood of a Cricket LTE subscriber viewing **WPWR** with an indoor antenna.

# 8.0 MSW INTERFERENCE PREEDICTION METHODOLOGY

## 8.1 Rationale for Analyzing Impact of LTE to DTV

FOX-owned station **WPWR** is located in Chicago, IL, and serves the Gary, IN market as well as Chicago. **WPWR** transmits from the top of Willis Tower (formerly Sears Tower) in downtown Chicago (233 S. Wacker Drive, Chicago, IL 60606). **Table 11** shows the **WPWR** DTV transmitter parameters, as found in the FCC database.

The interference protection between two or more DTV stations is based on the premise that all points within a station's noise-limited contour (dipole-adjusted for UHF frequencies) are entitled to protection. In view of this, the same methodology must be applied when determining the impact of LTE to a DTV station. The procedure used by the FCC to determine interference between broadcast stations is described in FCC OET Bulletin 69 (OET-69)[26].

[26] OET Bulletin No. 69, "Longley-Rice Methodology for Evaluating TV Coverage and Interference", February 6, 2004.

**Table 11** **WPWR** DTV transmission characteristics.

| Parameter | Info | Units |
|---|---|---|
| Call Letters | **WPWR**-DT | --- |
| Licensee | FOX Television Stations, Inc. | --- |
| City of License | Gary, IN | --- |
| Region | Zone 1 | --- |
| Nielsen DMA | Chicago, IL | --- |
| Network | My Network | --- |
| Virtual CH # | 50 | --- |
| Physical CH # | 51 | --- |
| DTV TSID | 1113 | --- |
| Facility ID | 48772 | --- |
| Tx Site Location | 41-52-44.0 N, 87-38-10.0 W | deg, min, sec |
| ERP | 1000 | kW |
| Polarization | H-POL | --- |
| TPO | 52.75 | kW |
| HAAT | 523 | meters |
| Radiation Center AGL | 522 | meters |
| Radiation Center AMSL | 703 | meters |
| Site Elevation | 181 | meters |
| Beam Tilt | 1.0 | degree |
| Antenna Manufacturer | Dielectric | --- |
| Antenna Model # | TFU-16DTC-R CT160 | --- |
| Antenna ID | 30328 | --- |
| Antenna pattern | Cardioid (see FCC database for plot) | --- |
| Maximum azimuth pattern direction | 150, 310 | degrees |

## 8.2 Procedure for Analyzing Impact of LTE to DTV

The procedure used to analyze the impact of LTE devices operating in the A-Block frequency space (former TV Channel 52) to DTV broadcast station **WPWR** on physical Channel 51 (Gary, IN) is as follows. The field strength of DTV station **WPWR** is calculated using the methodology described in OET-69. This methodology divides the area within the station's dipole-adjusted noise-limited contour into a grid of essentially square cells. The size of the grid cells in the study of **WPWR** is 0.5 km (smallest size allowed by the FCC). The population of each cell is determined by the census blocks whose geographic coordinates fall within the block. For *each* cell an evaluation point is established with that point being the centroid of the cell's population. After the grid is established, the Longley-Rice terrain dependent propagation model is used in conjunction with the transmission parameters of the DTV station (see **Table 11**) to predict the field strength at *each* evaluation point for a receive antenna height of 30 feet above ground level (AGL).

In order to evaluate the LTE impact, it is assumed that there is the likely possibility at some point in time that an LTE UE device will be in close proximity to each grid cell. Therefore, an evaluation was performed for *each* cell to determine if predicted interference will occur based on the application of an interference ratio of desired DTV signal to undesired LTE signal (i.e., D/U ratio) *field strength* at the input to a DTV receive antenna. Since

the field strength of the DTV signal has been previously determined, it is necessary to determine the field strength of the LTE device using the *free space* formula employed by the FCC.

$$\text{Field Strength (dB}\mu\text{V/m)} = 106.92 + 10*\log(\text{ERP in kW}) - 20*\log(\text{DISTANCE in km}) \quad [7]$$

The area within a station's noise-limited contour will have locations where the DTV signal level is sufficiently high that digital television reception is possible using an *indoor* antenna located near the DTV receiver. Therefore, a series of studies was performed for a mixture of indoor and outdoor receive sites, the mixture dependent on whether there is enough signal strength outside the house at 30' AGL to achieve indoor reception.

The criteria used to determine which locations would likely be suitable for *indoor* DTV reception was based on an extensive study performed by and reported on by MSW[27]. While outdoor service requirements have been determined by the FCC in OET-69, this relatively recent planning factor document from MSW identified three types of indoor sites described as best case, typical case and worst case. For each of these cases, a minimum outside field strength was established that would allow successful indoor DTV reception based on a number of receive site planning factors including antenna height loss, building penetration loss, antenna gain, cable loss, mismatch loss (antenna and receiver), multipath fading level, and multipath receiver noise enhancement. Each of these parameters was determined from research, and the best estimates of the appropriate value were selected. **Table 12** is a summary of the UHF planning factors used in this service prediction study.

The LTE field strength for *indoor* locations is determined at an assumed distance of 3 meters from the indoor DTV antenna whereas the LTE field strength for outdoor sites is determined at an assumed distance of 10 meters from the outdoor DTV antenna. The DTV field strength for the indoor sites was determined by subtracting the estimated building penetration loss and antenna height loss from the predicted field strength value at 30 feet AGL. The other impairments were not subtracted since the evaluation is made at the receive antenna input (i.e., field strength) and these impairments are already taken into consideration when establishing the minimum required outside field strength. However, just as described in the Intertek laboratory section of this report, actual multipath in the field will enhance (i.e., increase) LTE interference from that calculated in these evaluations, sometimes severely if the multipath is significant.

A detailed computer prediction study was performed for each of the *indoor* reception types in **Table 12**, where indoor reception is defined by minimum outdoor DTV levels of 53.3 dBμV/m (best case), 75.5 dBμV/m (typical case), and 98.8 dBμV/m (worst case) and LTE UE transmit power levels were varied using six different values: +23 dBm, +20 dBm, +17.5 dBm, +15 dBm, +12 dBm, and +9 dBm.

The ratio of desired to undesired field strength specified in the FCC Rules Part 27[28] for protection of DTV by LTE is -23 dB at the DTV station's contour (i.e., the undesired LTE total average power in its 1.4 MHz, 3 MHz, or 5 MHz signal bandwidth can be no greater than 23 dB *above* the desired DTV average signal power in 6 MHz). No D/U values are specified for points inside the DTV station's noise-limited contour as it appears that the FCC did ***not*** anticipate LTE device operation *inside* the DTV station's contour. Although -23 dB is the official D/U ratio, MSW also performed computer studies for relaxed D/U ratios of -27 dB and also -30 dB for completeness; however, it would seem highly unlikely that the latter values are realistic and therefore they are likely to not be allowed by the FCC.

Therefore, a total of **54** different computer simulation studies (3 DTV reception scenario types x 6 LTE transmit powers x 3 interference D/U ratios) were performed according to FCC-required digital television service and interference prediction methodology. It should also be noted once again that all of this analysis does NOT

[27] "A Report to The Metropolitan Television Alliance Regarding Urban DTV Planning Factors for Distributed Transmission Systems", MSW, May 8, 2007.
[28] 47CFR Section 27.60(a)(2)

account for the fact that interference D/U ratios and distances are degraded (i.e., worsened) by other propagation impairments in the field, primarily complex dynamic multipath.

**Table 12** Recommended UHF indoor service planning factors.

| Parameter | Variable | Indoor #1 Best Case | Indoor #2 Typical Case | Indoor #3 Worst Case | Units |
|---|---|---|---|---|---|
| Required ***Outdoor*** Field Strength | $FS_{30}$ | **53.3** | **75.5** | **98.8** | dBµV/m |
| Channel Number | CH | 38 | 38 | 38 | ----- |
| Channel Center Frequency | $F_C$ | 615 | 615 | 615 | MHz |
| Antenna Height AGL | $H_{AGL}$ | 15 | 6 | 6 | feet |
| ***Height Differential Attenuation*** | $A_H$ | **5** | **9** | **14** | dB |
| Building Material | M | Glass | Brick | Brick | ----- |
| Room Location | --- | Exterior | Exterior | Interior | ----- |
| ***Building Penetration Loss*** | $A_B$ | **5** | **12** | **20** | dB |
| Required ***Indoor*** Field Strength | $FS_{IN}$ | **+43.3** | **+54.5** | **+64.8** | dBµV/m |
| Antenna Type | A | Amplified Directional (Sharp Shooter) | Passive Directional (Silver Sensor) | Passive Dipole (Bow Tie) | ----- |
| Antenna Gain (maximum) | $G_A$ | +11 | +5 | 0 | dBd |
| Dipole Factor | $K_D$ | -131.0 | -131.0 | -131.0 | dBµV/m-dBm |
| Antenna Output Power (75 Ω) | $P_A$ | -76.7 | -71.5 | -66.2 | dBm/6 MHz |
| Coaxial Cable Length | $X_C$ | 3 | 3 | 3 | feet |
| Coaxial Cable Loss | $L_C$ | 0.5 | 0.5 | 0.5 | dB |
| Minimum Signal Level (Raleigh Channel) | $P_{IN2}$ | -77.2 | -72.0 | -66.7 | dBm/6 MHz |
| Mismatch Loss (Antenna & Receiver) | LM | 1 | 2 | 3 | dB |
| Sky & Man-Made Noise Enhancement | $L_I$ | 0 | 0 | 0 | dB |
| Multipath Fading Level | MFL | 2 | 3 | 4 | dB |
| Multipath Rx Noise Enhancement * | MNE | 4 | 6 | 8 | dB |
| Multipath Rx Diversity Antenna Advantage | MDAA | 0 | 0 | 0 | dB |
| Minimum Signal Level (Gaussian Channel) | $P_{IN1}$ | -84.2 | -83.0 | -81.7 | dBm/6 MHz |
| Rx White Noise Threshold for TOV | $SNR_{TOV}$ | 15.0 | 15.2 | 15.5 | dB |
| Rx Input Noise Floor | $N_{IN}$ | -99.2 | -98.2 | -97.2 | dBm/6 MHz |
| Rx Input Noise Figure | NF | 7 | 8 | 9 | dB |
| Rx kTB Noise Floor (theoretical, matched system) | $N_{kTB}$ | -106.2 | -106.2 | -106.2 | dBm/6 MHz |

**NOTE**: DTV receiver equalizers are *assumed* to have at least ±20 µsecs of cancellation range.

## 8.3 Interference Prediction Results

As a baseline reference to the these studies, computer analysis was performed for **WPWR**'s DTV signal to determine the service area and service population that will be used to ultimately determine *population loss* due to LTE interference. **Figure B-11** illustrates the **WPWR** service area along with the 42 dBµV/m dipole-adjusted noise-limited contour and the 48 dBµV/m city grade contour (which is defined by the FCC as being 6 dB above the non-dipole compensated UHF noise-limited contour of 41 dBµV/m).

To simplify the description of the results, a *subset* of the MSW computer studies were selected and plotted for this report. Nine sample cases that illustrate the types of LTE interference under a variety of different conditions are shown in **Table 13** and illustrated in various figures in **Appendix B**.

**Table 13** Summary of sampled computer simulation runs.

| Figure Reference | LTE Tx Power | D/U Interference Ratio | *Outside* DTV Field Strength THR for *Indoor* Service | Population Service *Loss* Caused by LTE |
|---|---|---|---|---|
| (*) | (dBm) | (dB) | (dBµV/m) | (%) |
| Figure B-12 | +23 | -23 | 75.5 | 99.84 |
| Figure B-13 | +12 | -23 | 75.5 | 76.41 |
| Figure B-14 | +9 | -23 | 53.3 | 12.35 |
| Figure B-15 | +23 | -27 | 75.5 | 99.72 |
| Figure B-16 | +15 | -27 | 75.5 | 68.22 |
| Figure B-17 | +9 | -27 | 53.3 | 10.10 |
| Figure B-18 | +23 | -30 | 75.5 | 99.41 |
| Figure B-19 | +15 | -30 | 75.5 | 41.25 |
| Figure B-20 | +9 | -30 | 53.3 | 8.76 |

The end result is that this FCC methodology, which requires a limited interference D/U ratio of -23 dB, has clearly unacceptable interference not only for +23 dBm LTE UE transmit powers, but even as low as +9 dBm powers. This is because increasing lost DTV viewer population to 0.5% is unacceptable, so even the "best" (lowest) of the lost population numbers in **Table 13** show almost 9%, which results from the scenario of allowing D/U ratios to be -30 dB and the best operating receive systems. While +23 dBm *might* not occur more than 15% or 20% (which is still unacceptable for DTV viewing), lower LTE UE transmit powers of +15 dBm will happen much more often, which will lose over 75% of the **WPWR** potential viewers. While the FCC requirement for allowable interference D/U ratios is -23 dB, even relaxing this limit to -27 dB still provide over 99% loss of viewing population at maximum power and over 68% loss at only +15 dBm.

Therefore, using FCC methodology to follow FCC rules indicates that large amounts of interference into DTV CH 51 would result from this analysis even if the LTE UE powers were below maximum allowable transmit power. Even with relaxed FCC rules (e.g., -30 dB D/U) and lower LTE UE transmit powers (e.g., +15 dBm), the analysis results are such that LTE interference into CH 51 DTV reception would be unacceptable.

## 9.0 SUMMARY and CONCLUSIONS

The actions taken by Cricket and their hired consultants have resulted in two reports that FOX has evaluated. The Intertek laboratory testing sought to provide device interference performance parameters in conductive bench and OTA anechoic chamber laboratory tests that were subsequently used in the Newfield field interference prediction report.

The Intertek laboratory report supplied performance information on 25 various DTV sets that (as best as possible without knowing the actual tuner and VSB demodulator chips inside) provides a reasonable idea of TOS and LTE interference performance under controlled conditions. However, while the TOS numbers were precisely as expected (around -85 dBm), some of the interference D/U ratios seemed to indicate that these were *not* worst case interference performance numbers expected in the field since it appears that many of the tests were *not* limited by the measured OOBE from an LTE UE at maximum power. Likewise, similar results occurred for the anechoic chamber OTA tests as well. Also, these interference test results did not account for the expected interference degradation due to significant multipath that occurs with outdoor reception not to

mention the often severe multipath that occurs with indoor reception. Even the Intertek report stated that the OTA anechoic chamber interference distance test results were *twice* that of the theoretical distances calculated from the conductive tests, most likely due to the small amount of multipath that existed in the well-controlled anechoic chamber.

The most important aspect of all of this is that the interference distance metric that Intertek introduced, while interesting and insightful, is ***not*** how the FCC determines DTV service or interference. Rather The FCC uses only interference D/U ratios, which they set forth in Section 27 of their rules as -23 dB for the adjacent channel LTE signals in the lower 700 MHz block.

The Newfield report, while also interesting in its approach, does *not* comply with the previously used regime in the digital television broadcast services regarding interference prediction. Any evaluation of predicted interference should utilize the traditional geo-location based predictions using the appropriate interference D/U ratio within the **WPWR** coverage area ("Exclusion Zone"). Similarly, prediction of interference should *not* be based upon TV ratings information or LTE subscriber statistics, rather it should be assumed that all locations within the **WPWR** coverage area should be evaluated and protected from interference.

As noted earlier, neither the Intertek nor Newfield reports explore the possibility of interference to the LTE UE device from multiple high-power DTV stations located in downtown Chicago. The possibility of multiple-interferer intermodulation interference is very high. It would seem that even if LTE interference to DTV sets was "magically resolved", the interference issues of DTV signals into the LTE UE devices would still remain rendering the proposed LTE system significantly impaired.

Finally, the MSW evaluation of the **WPWR** interference from LTE devices that used the required methodology and procedures as well as the computer simulation software required by OET-69 showed that even with appreciably relaxed interference D/U ratios and LTE UE transmit power significantly less than the maximum allowable levels, significant levels of DTV reception interference would still occur from LTE systems. This evaluation does *not* account for degraded interference performance known to occur when the desired DTV signal has experienced even modest multipath impairments with outdoor reception let alone severe multipath impairments expected with indoor reception.

# APPENDIX A TEST STRATEGY: EQUIPMENT AND SETUPS

The following data illustrates the characteristics of the equipment tested by Intertek during their laboratory test, and are taken directly from their written lab test report (dated 1/14/13).

The various consumer LTE UE devices listed in the Intertek report (**Section 4.3, P30**) are shown below in **Table A-1**, with identification of the *three* units that were actually tested.

**Table A-1** LTE UE devices listed in Intertek laboratory test report.

| Mfg-er Name | Device Name and Model | Device Type | FCC and ID Grant Date | TPO (dBm) | Tested |
|---|---|---|---|---|---|
| Samsung | Galaxy Tab 10.1 M/N SCH-1905U | Smart Phone | A3LSCHI905U; 2/13/2012 | | NO |
| **Samsung** | **Galaxy S Aviator M/N SCHR930** | **Smart Phone** | **A3LSCHR930; 1/6/2012** | **13.1-14.0** | **YES** |
| Samsung | Presto MiFi | | A3LSSSCHR380; 4/22/2011 | | NO |
| **BandRich** | **Compact LTE USB Modem** | **USB Dongle** | **UZI-MODEL C525; 2/23/2012** | **19.8-20.5** | **YES** |
| Samsung | Galaxy SII (Skyrocket) | Smart Phone | A3LSGHI1727; 9/1/2011 | | NO |
| **Samsung** | **Galaxy Note** | **Smart Phone** | **A3LSGH1717; 1/20/12** | **13.3-14.6** | **YES** |

**Note**: Only three (3) LTE UE (i.e., handsets) were used in the Intertek laboratory test.

The various consumer DTV antennas that were evaluated and listed in the Intertek report (**Appendix G**) are shown below in **Table A-2** with identification of the units that were actually tested..

**Table A-2** DTV antenna gain characteristics.

| Antenna Information | TRP (dB) | Min (dB) | Max (dB) | Ave (dB) | Std Dev (dB) |
|---|---|---|---|---|---|
| Generic DTV Indoor Antenna | -7.6 | -21.9 | -2.1 | -7.5 | -9.1 |
| Zenith: VM1AMTP1 | -4.4 | -27.3 | -1.2 | -8.1 | -8.5 |
| GE Enhance: 34760 | -10.4 | -26.3 | -3.7 | -11.5 | 3.4 |
| RCA Multidirectional Flat Antenna: ANT1600R | -8.4 | -18.6 | -3.2 | -9.0 | 3.2 |
| RCA Indoor Antenna: ANT112R | -7.5 | -20.5 | -2.5 | -8.2 | 3.1 |
| RCA Digital Flat Antenna: ANT1050R | -6.2 | -21.5 | -0.7 | -7.1 | 4.7 |
| Average | **-7.4** | **-22.7** | **-2.2** | **-8.6** | **-0.5** |
| Median | **-7.6** | **-21.7** | **-2.3** | **-8.2** | **3.2** |
| Standard Deviation | **2.0** | **3.4** | **1.1** | **1.6** | **6.4** |

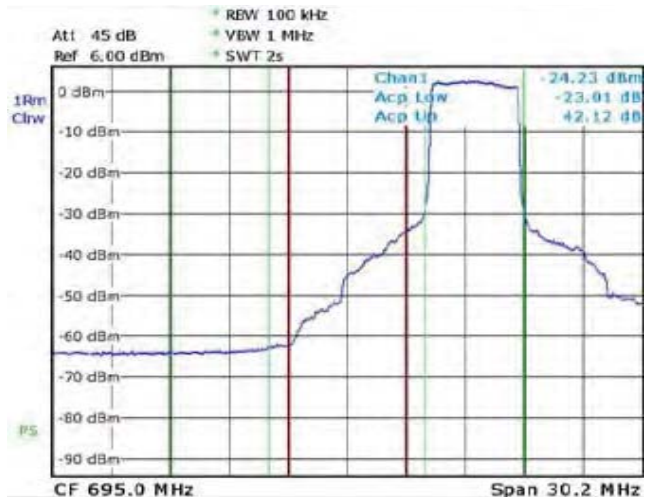



**Figure A-1a** BandRich C525 UTE UE: 5 MHz, 25 RB, max TRP.

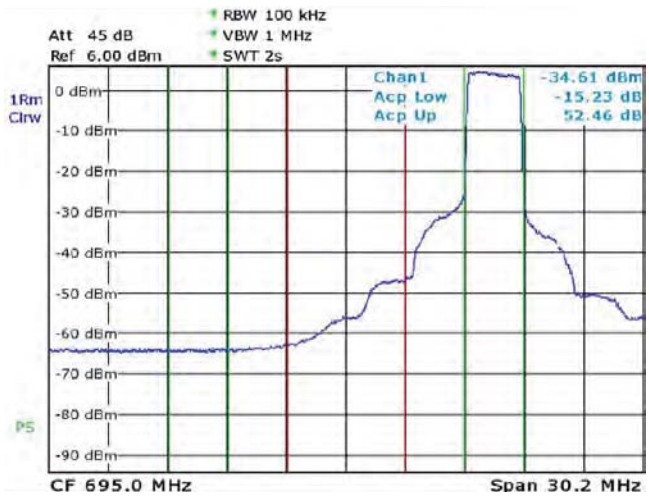



**Figure A-1b** BandRich C525 UTE UE: 3 MHz, 15 RB, max TRP.

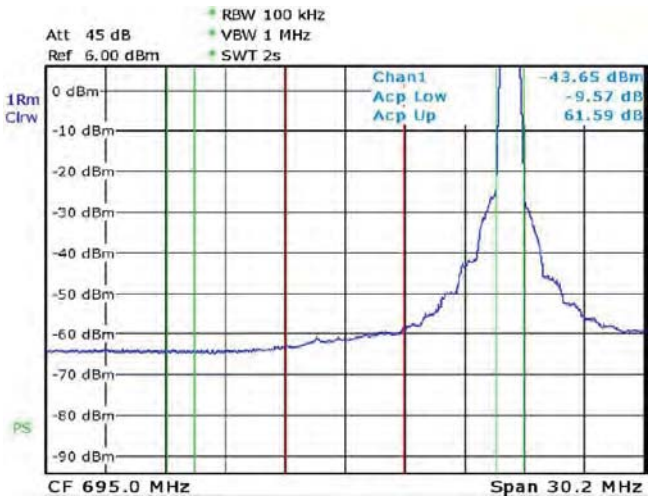



**Figure A-1c** BandRich C525 UTE UE: 1.4 MHz, 6 RB, max TRP.

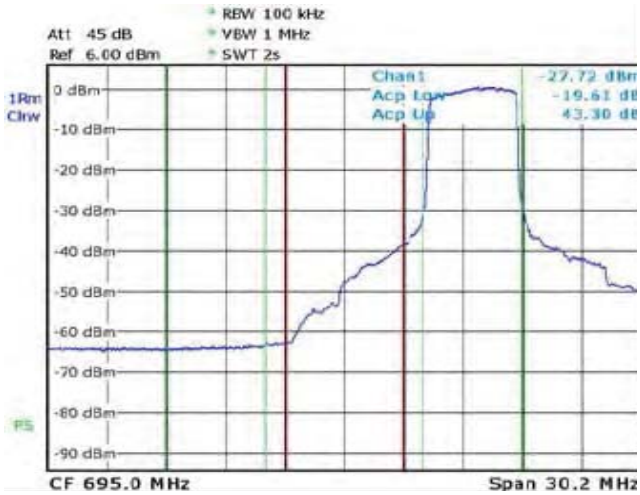



**Figure A-2a** Samsung R930 UTE UE: 5 MHz, 25 RB, max TRP.

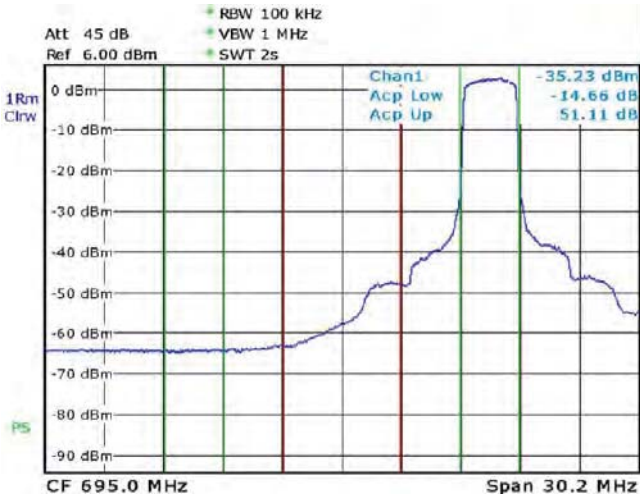



**Figure A-2b** Samsung R930 UTE UE: 3 MHz, 15 RB, max TRP.

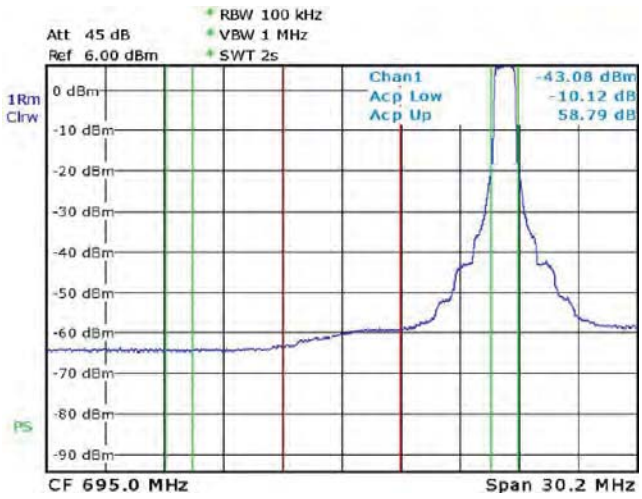



**Figure A-2c** Samsung R930 UTE UE: 1.4 MHz, 6 RB, max TRP.

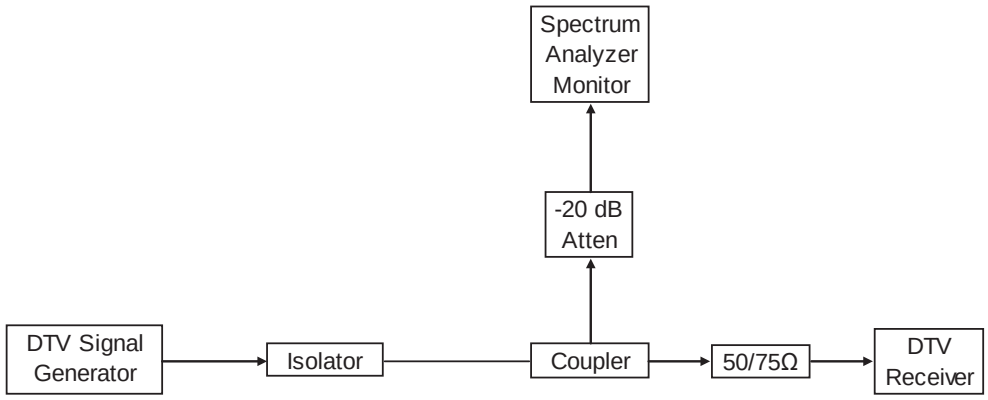



**Figure A-3a** Conductive *sensitivity* laboratory test setup.

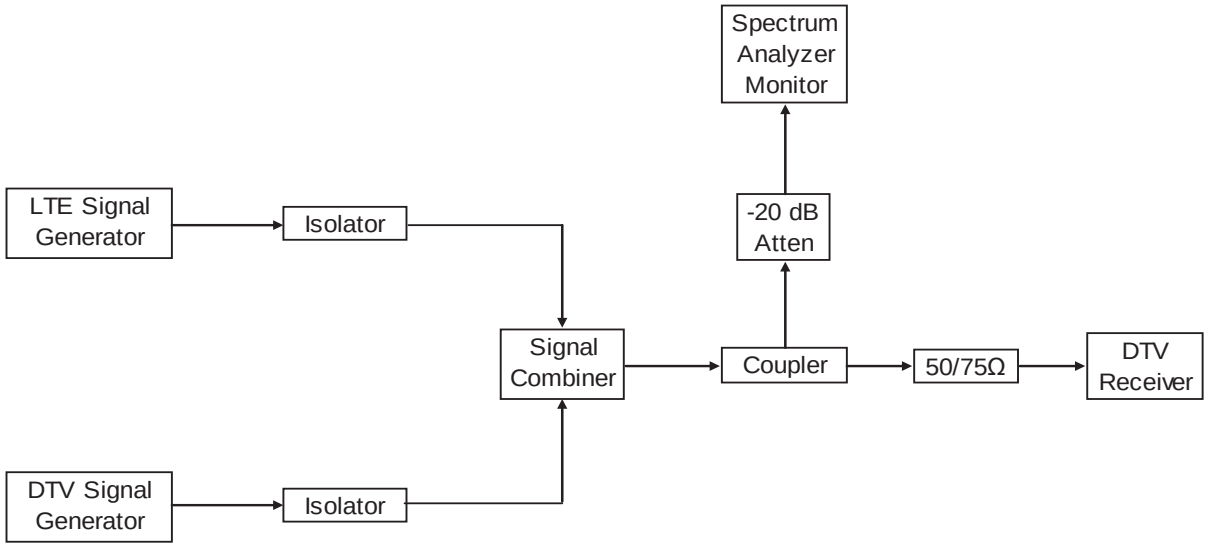



**Figure A-3b** Conductive LTE *interference* laboratory test setup using LTE UE signal generator.

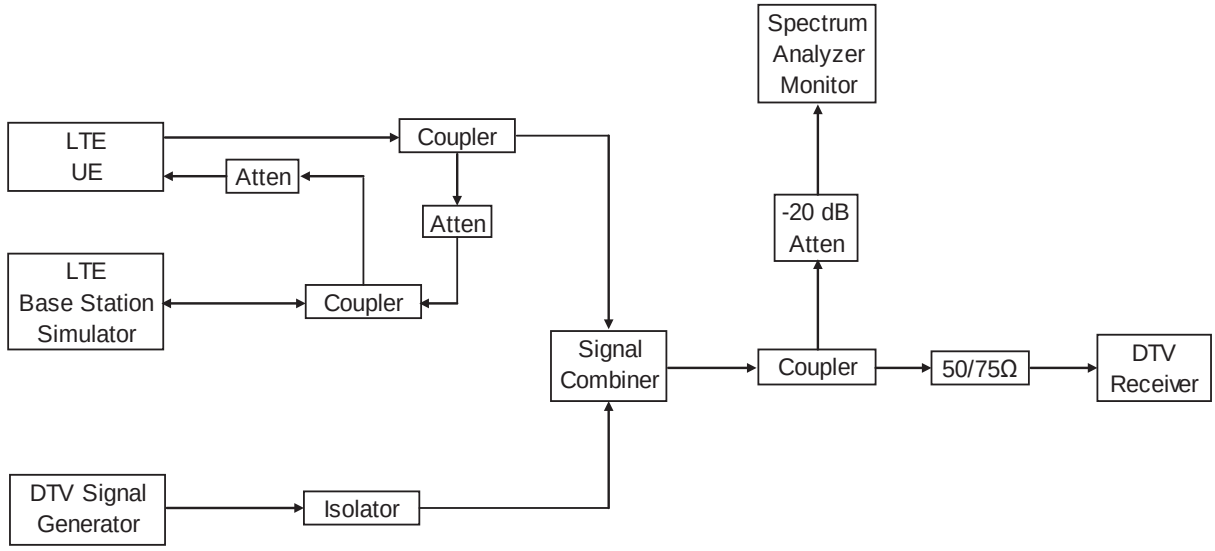



**Figure A-3c** Conductive LTE *interference* test setup using *actual* LTE equipment.

# APPENDIX B FIGURES

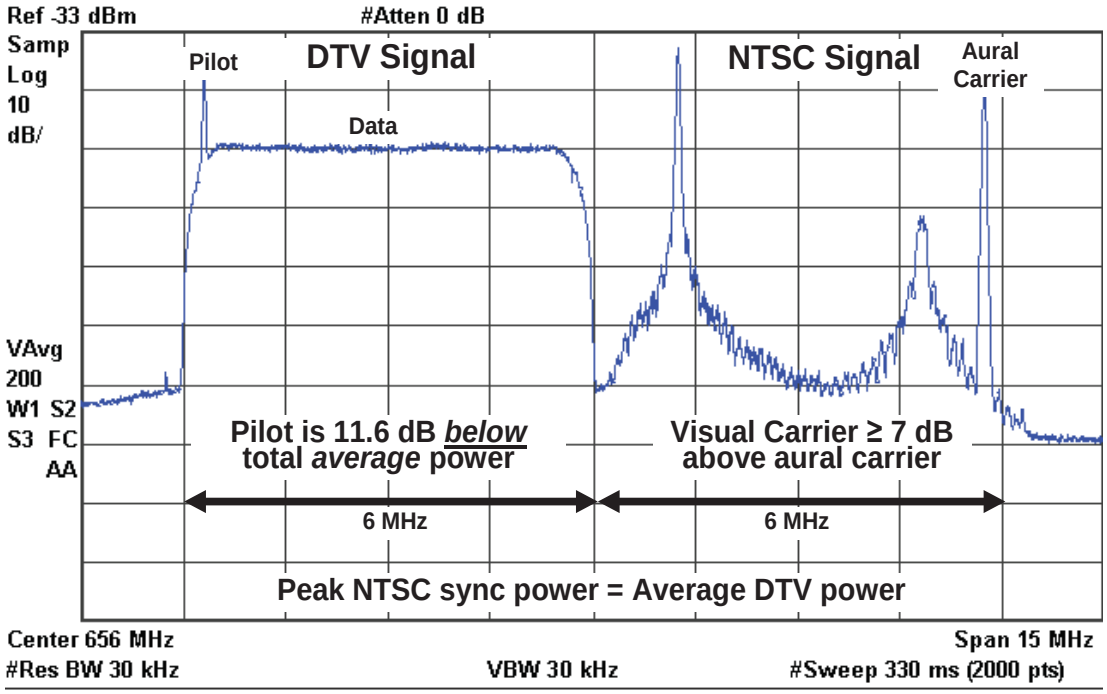



**Figure B-1** Comparison of 6 MHz *analog* NTSC and *digital* ATSC signals.

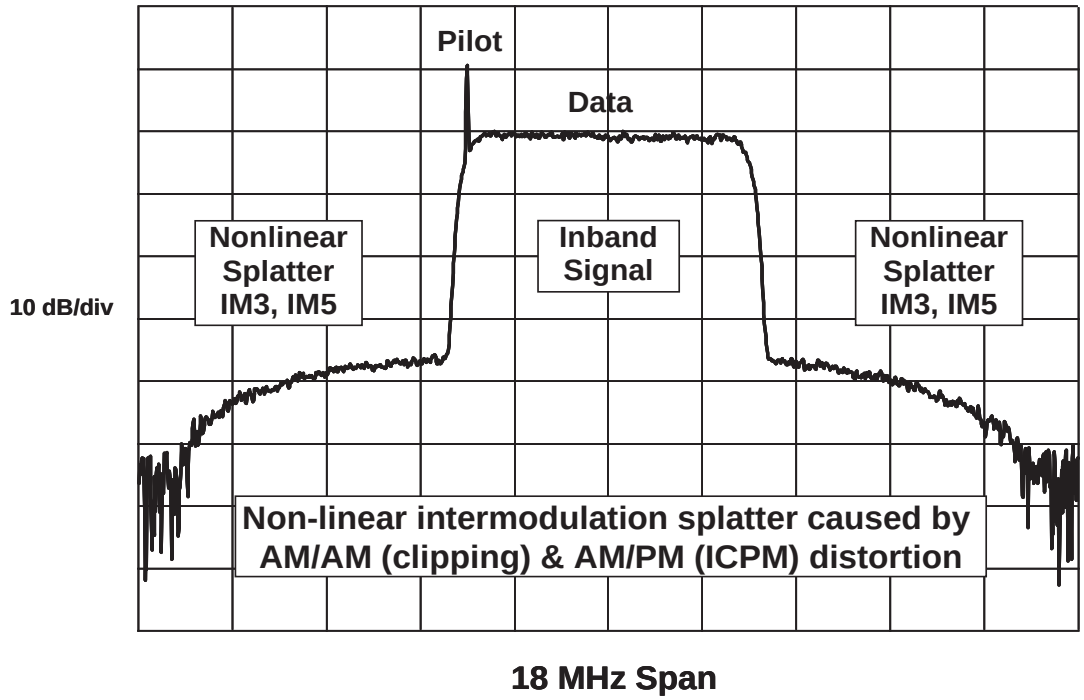



**Figure B-2** Results of intermodulation on the DTV signal due to non-linearities.

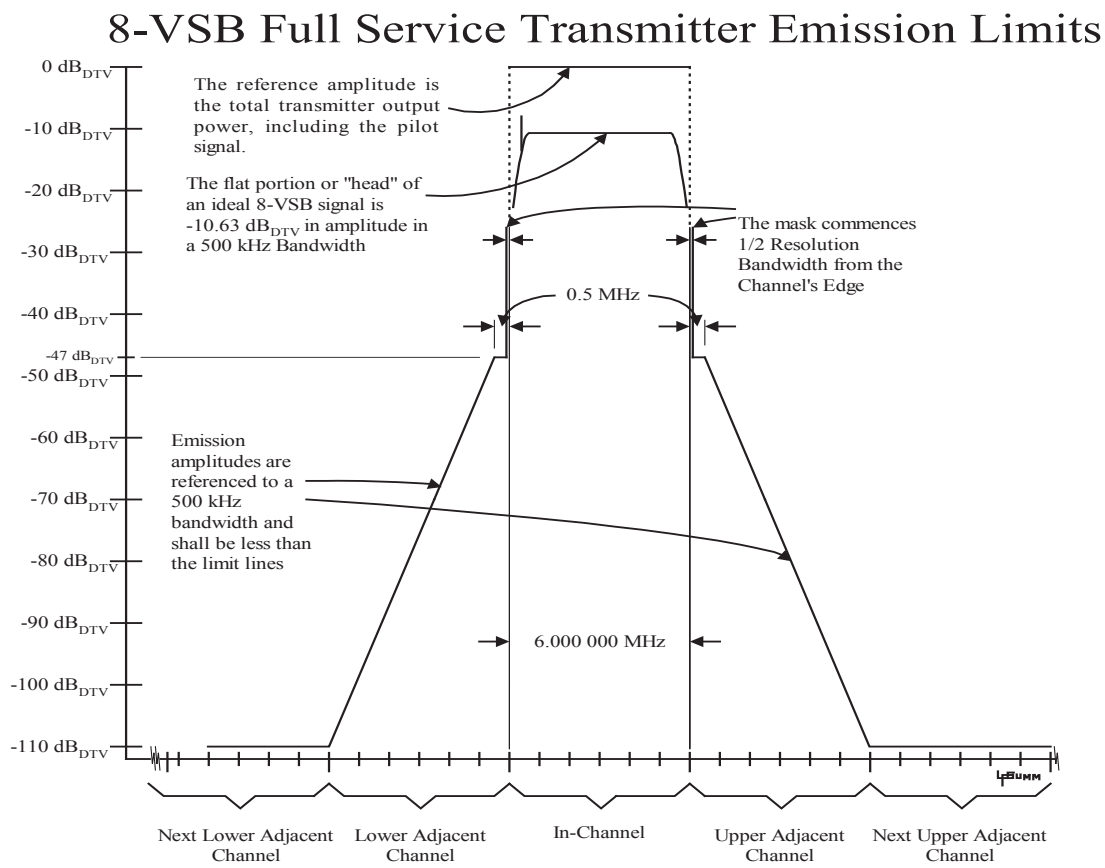



**Figure B-3** FCC rigid emission mask definition from IEEE recommended measurement procedures.

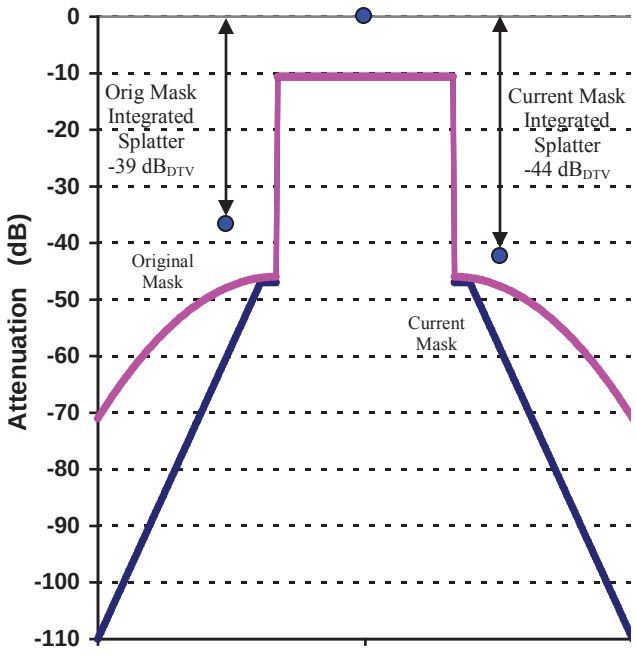



**Figure B-4** *Original* & *current* FCC emission mask.

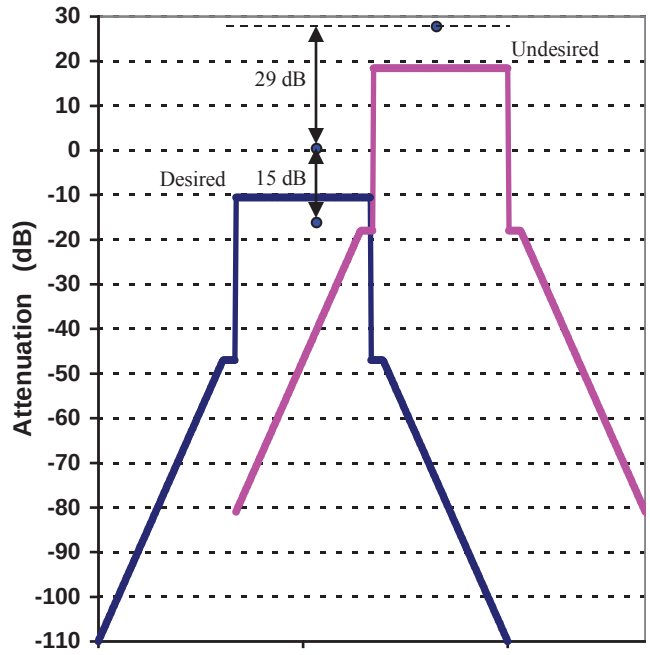



**Figure B-5** Adjacent channel DTV signals.

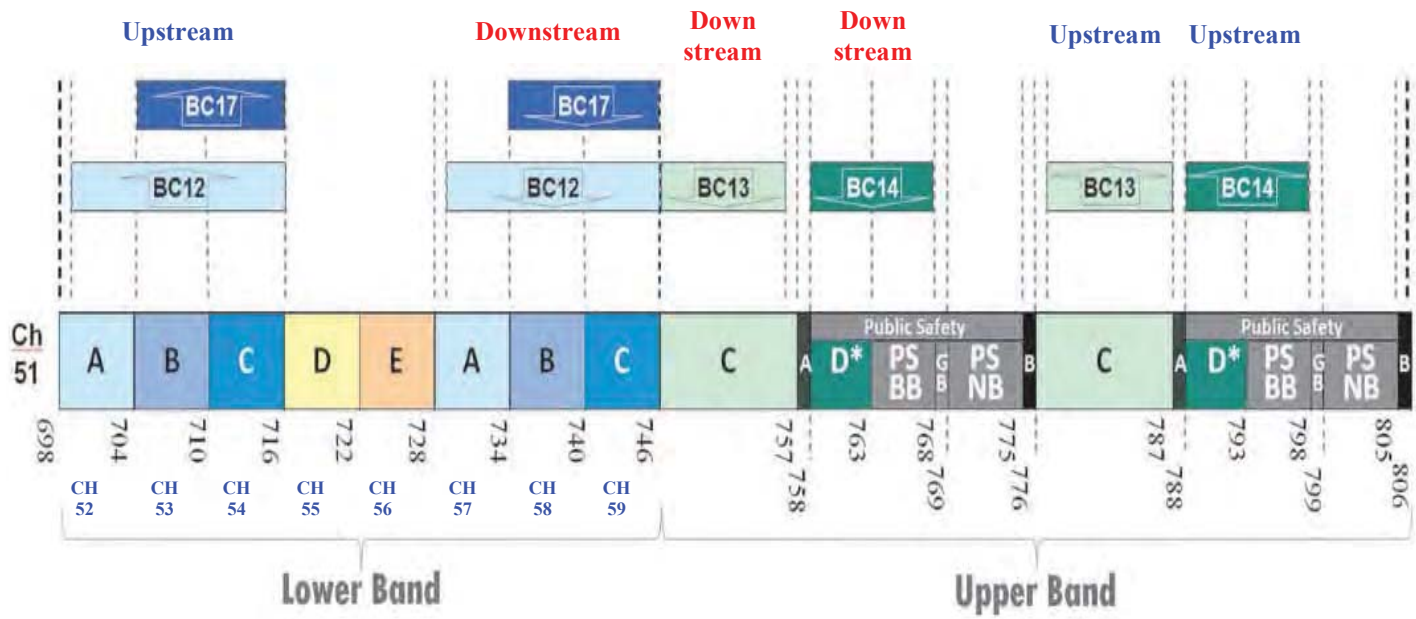



**Figure B-6** FCC 700 MHz band plan with 3GPP band classes.

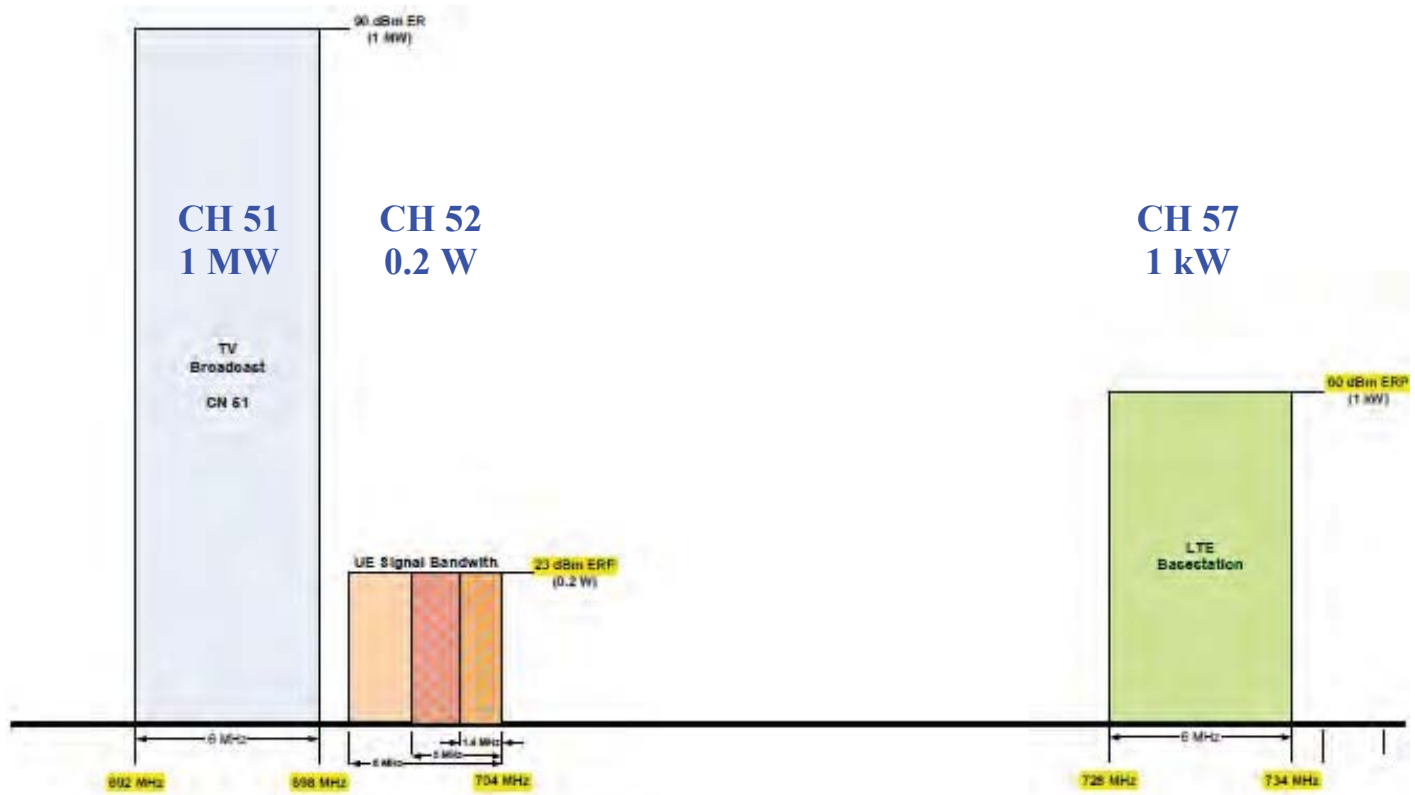



**Figure B-7** *Proposed* Cricket LTE deployment plans (1.4 MHz, 3 MHz, and 5 MHz).

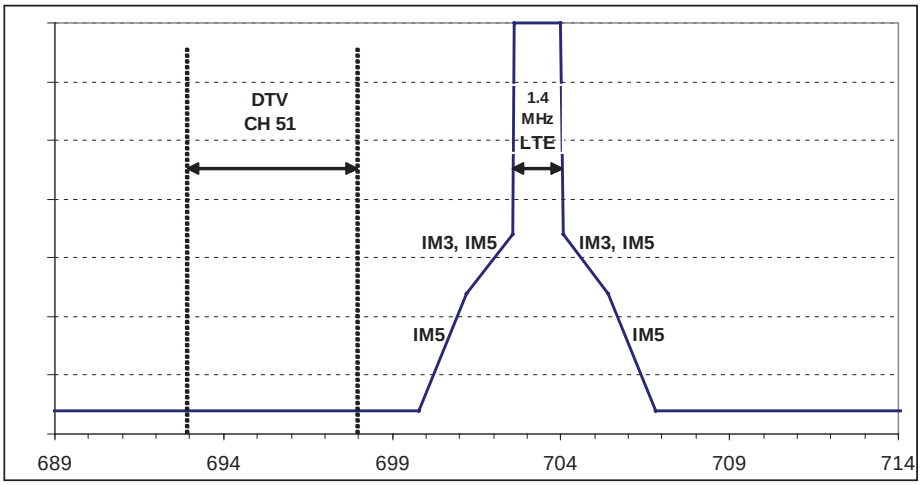



**Figure B-8a** 1.4 MH LTE scenario with OOBE interference.

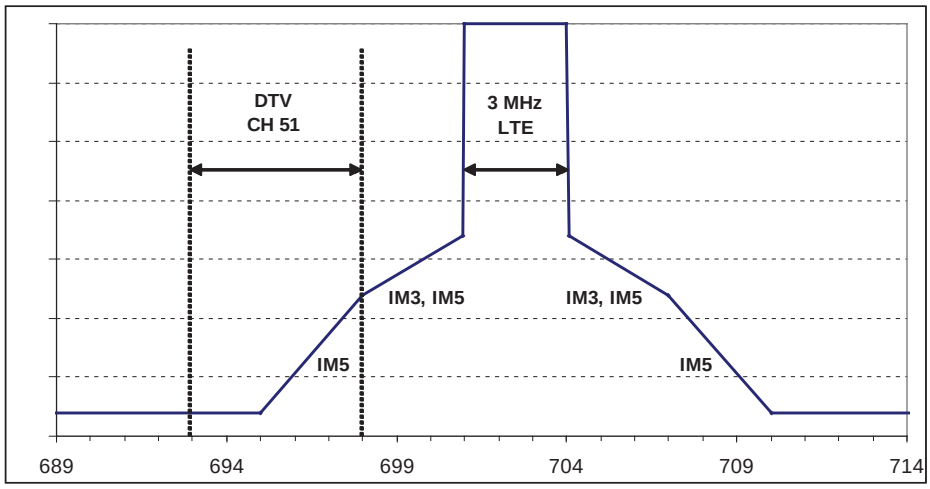



**Figure B-8b** 3 MH LTE scenario with OOBE interference.

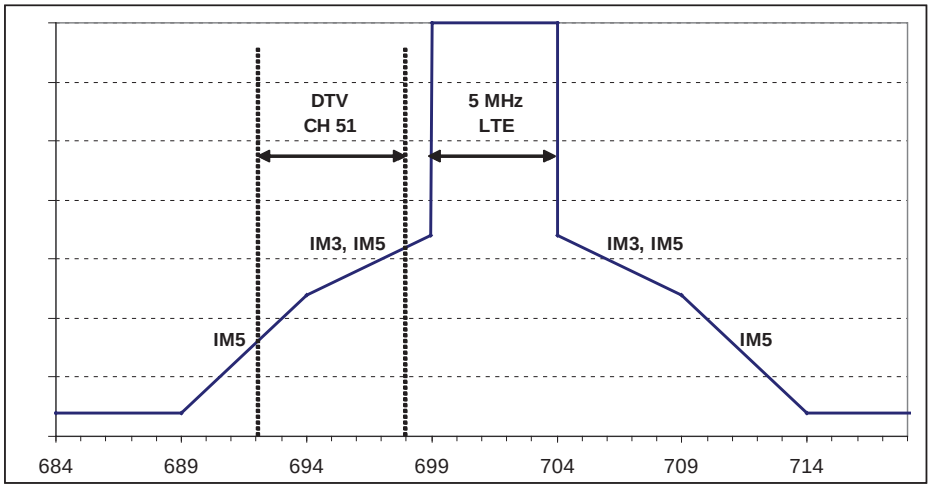



**Figure B-8c** 5 MH LTE scenario with OOBE interference.

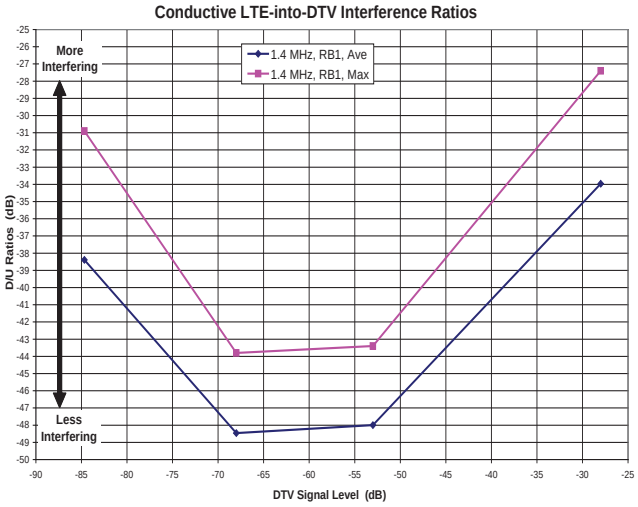



**Figure B-9a** Conductive D/U ratios: 1.4 MHz, RB=1.

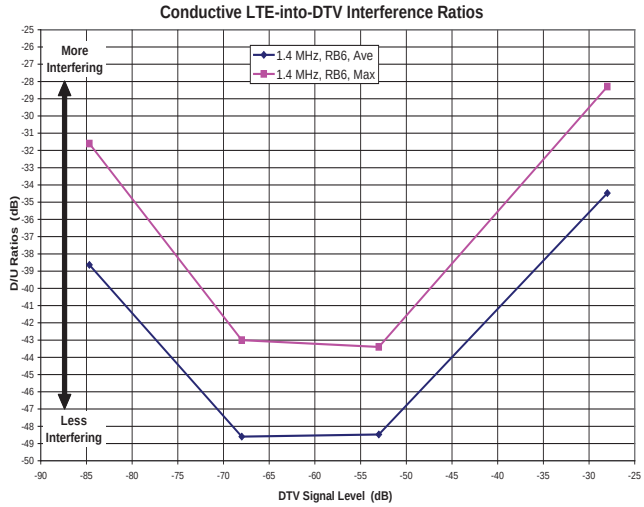



**Figure B-9b** Conductive D/U ratios: 1.4 MHz, RB=6.

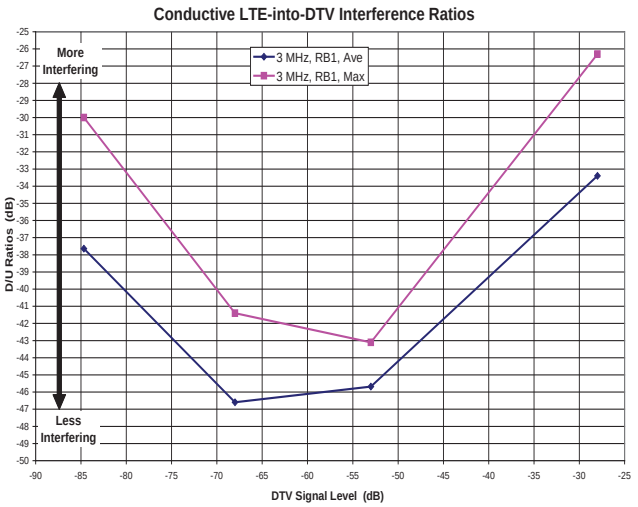



**Figure B-9c** Conductive D/U ratios: 3 MHz, RB=1.

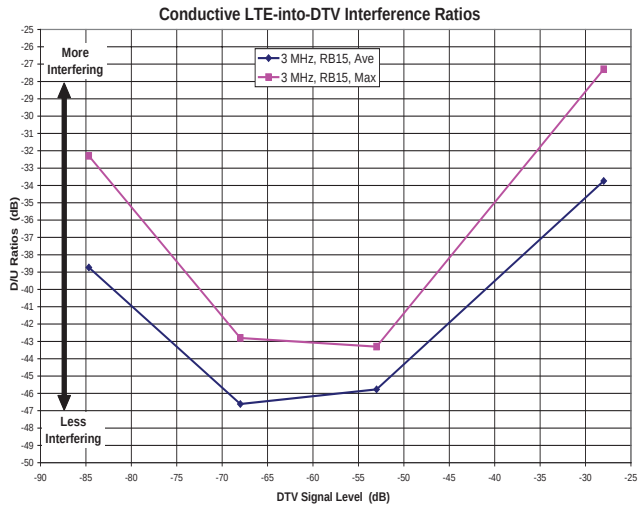



**Figure B-9d** Conductive D/U ratios: 3 MHz, RB=15.

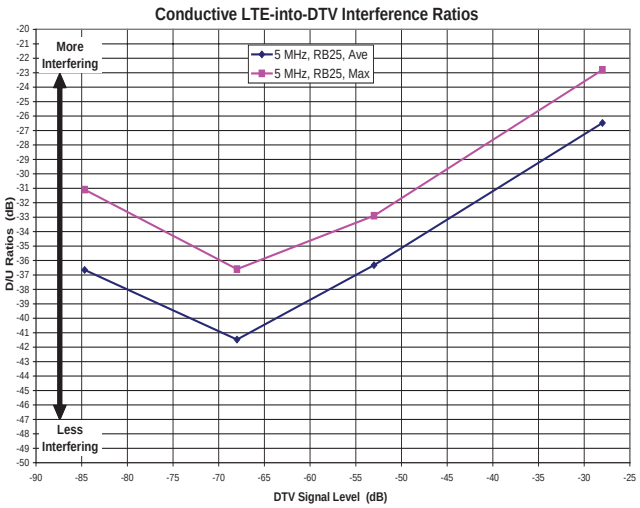



**Figure B-9e** Conductive D/U ratios: 5 MHz, RB=1.

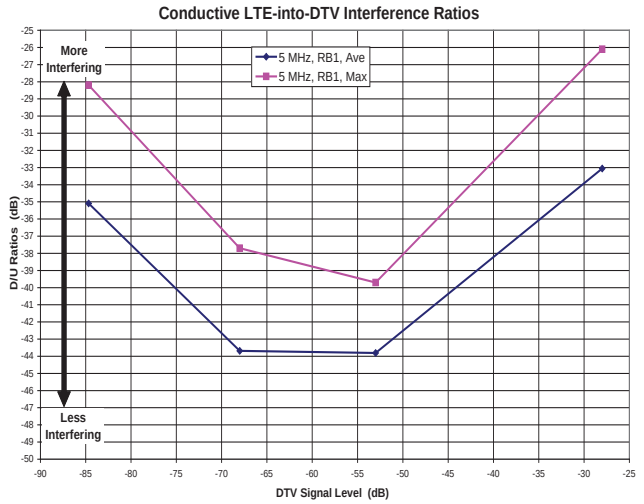



**Figure B-9f** . Conductive D/U ratios: 5 MHz, RB=25.

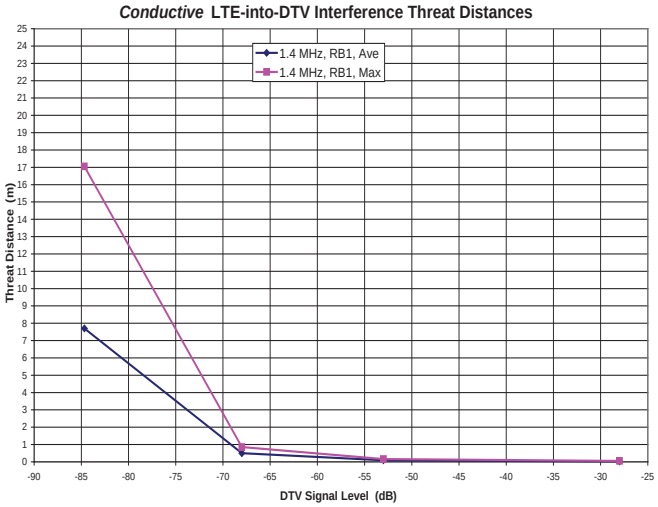



**Figure B-10a** Conductive interference *distances*: 1.4 MHz, RB=1

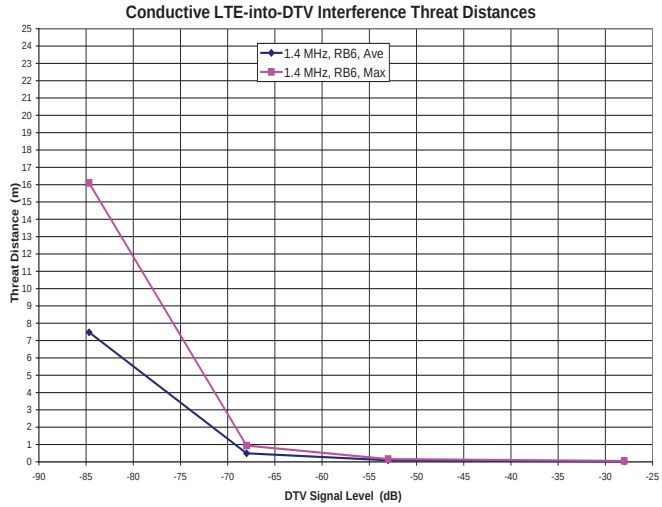



**Figure B-10b** Conductive interference *distances*: 1.4 MHz, RB=6

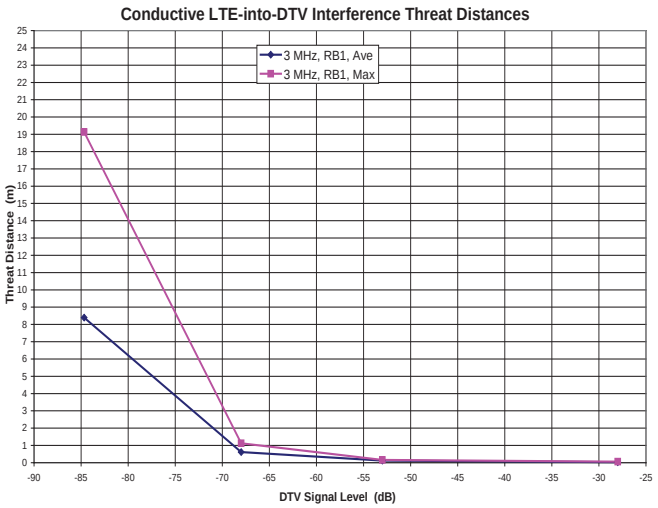



**Figure B-10c** Conductive interference *distances*: 3 MHz, RB=1

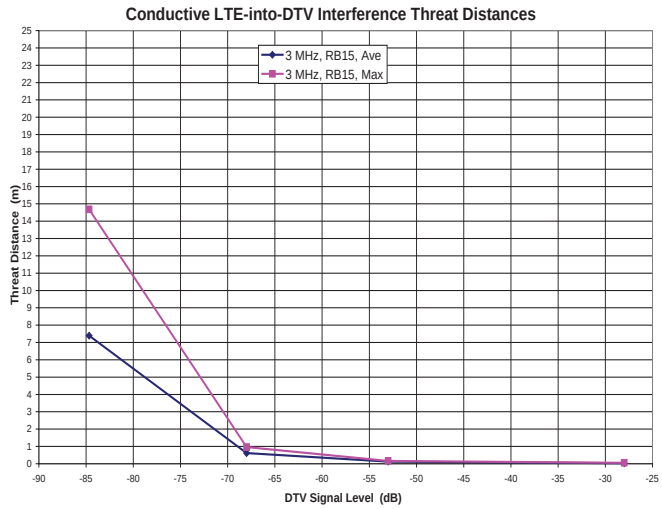



**Figure B-10d** Conductive interference *distances*: 3 MHz, RB=15

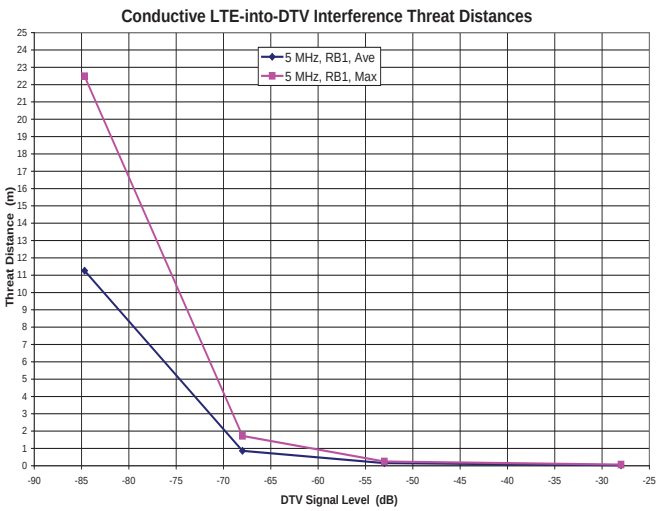



**Figure B-10e** Conductive interference *distances*: 5 MHz, RB=1

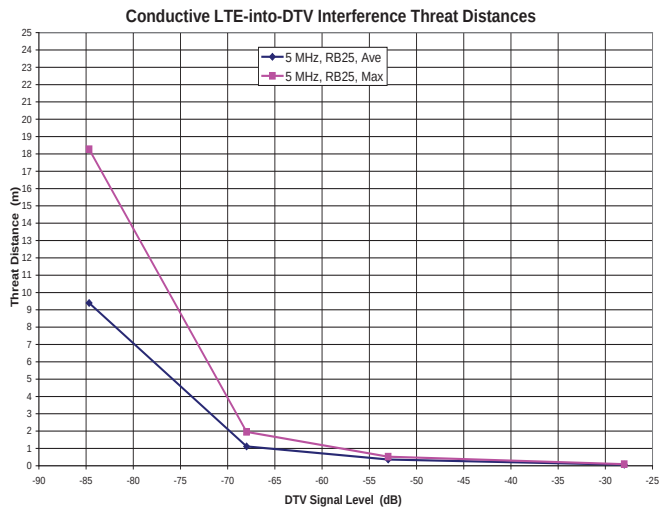
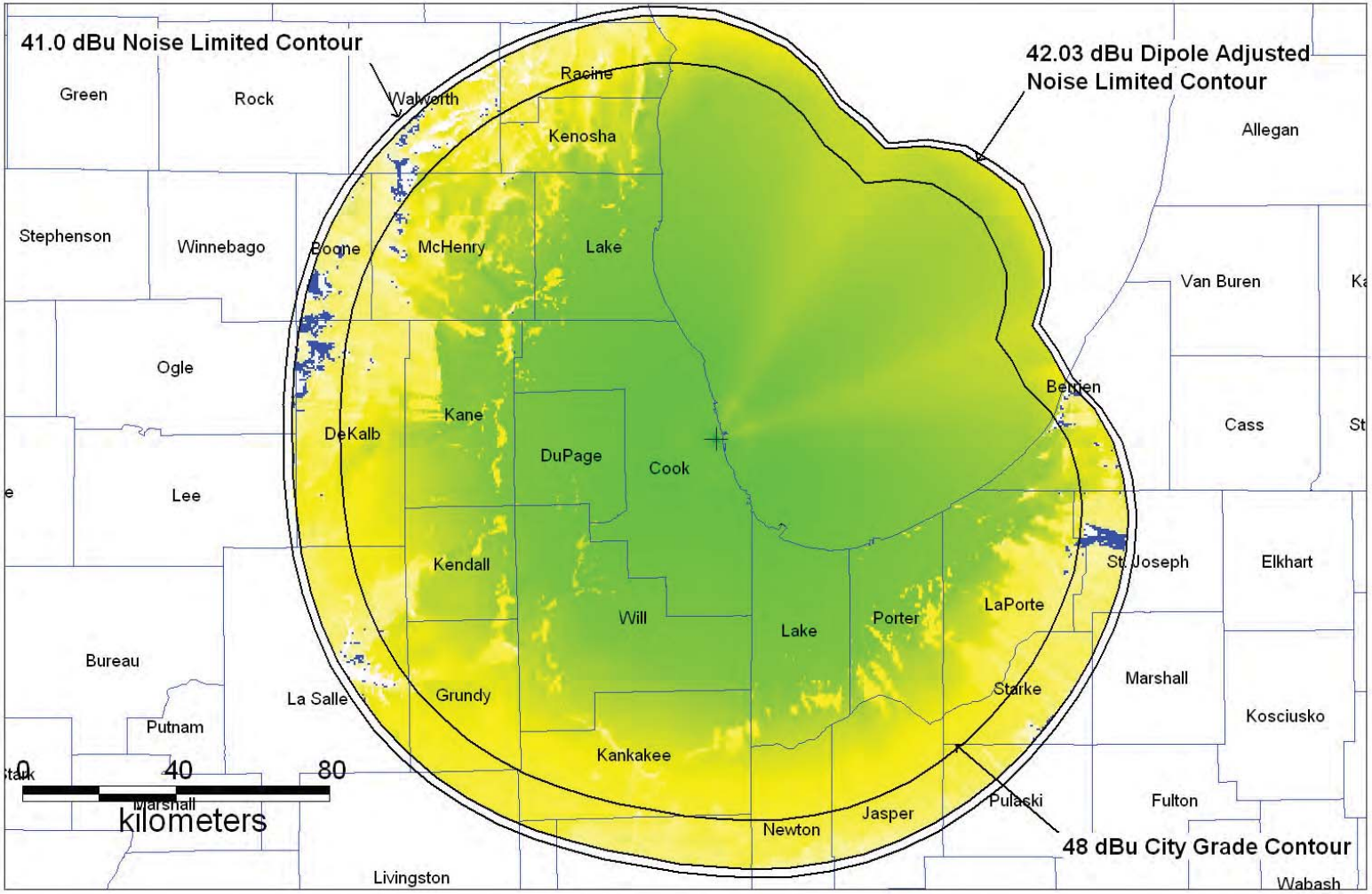



**Figure B-10f** . Conductive interference *distances*: 5 MHz, RB=25

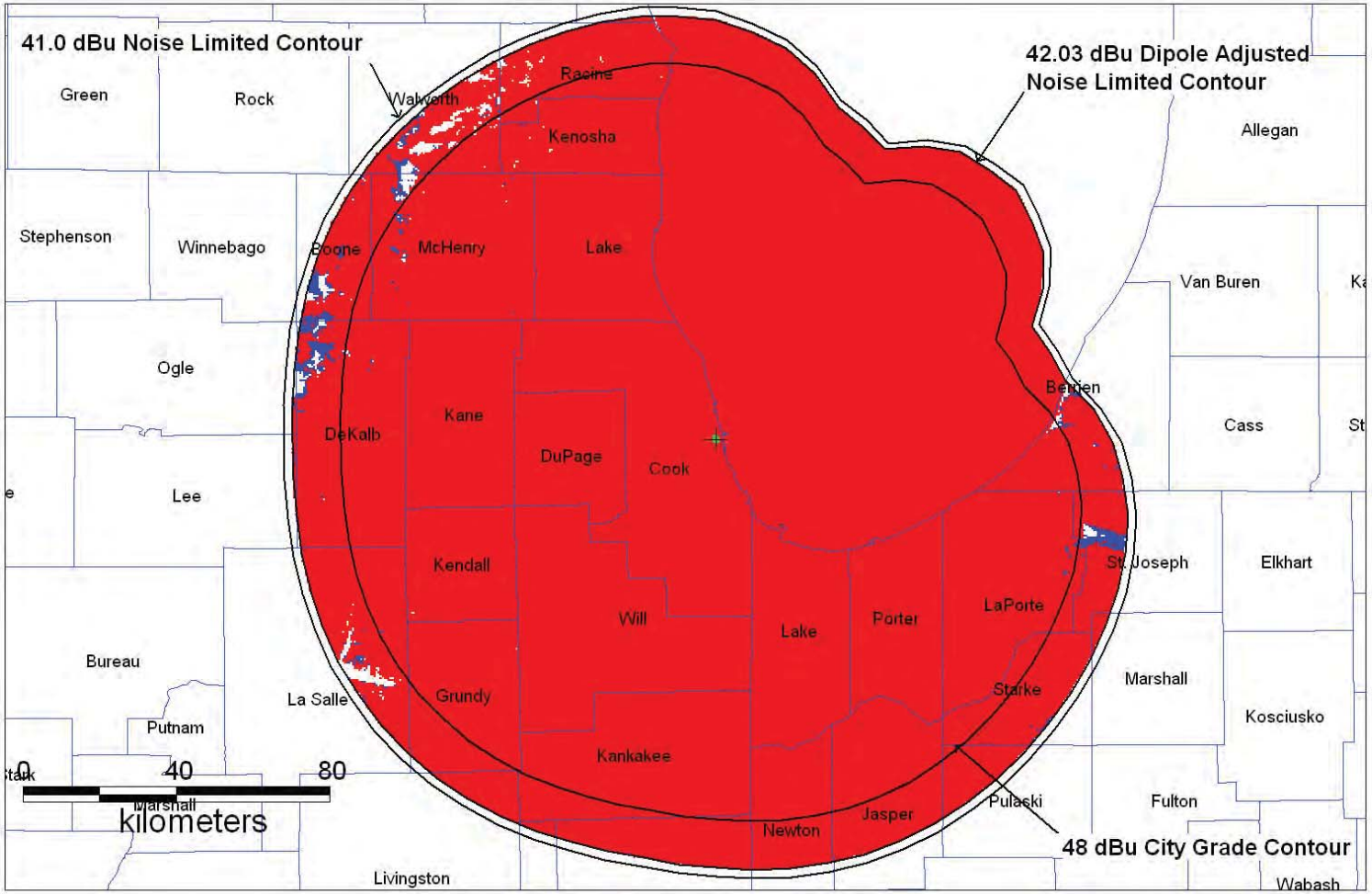



WPWR-TV Channel 51 Gary, IN

Blue - Existing DTV Interference

Green indicates high field strength fading to yellow and then to white at the noise limited threshold

**Figure B-11** WPWR current service *without* LTE interference.

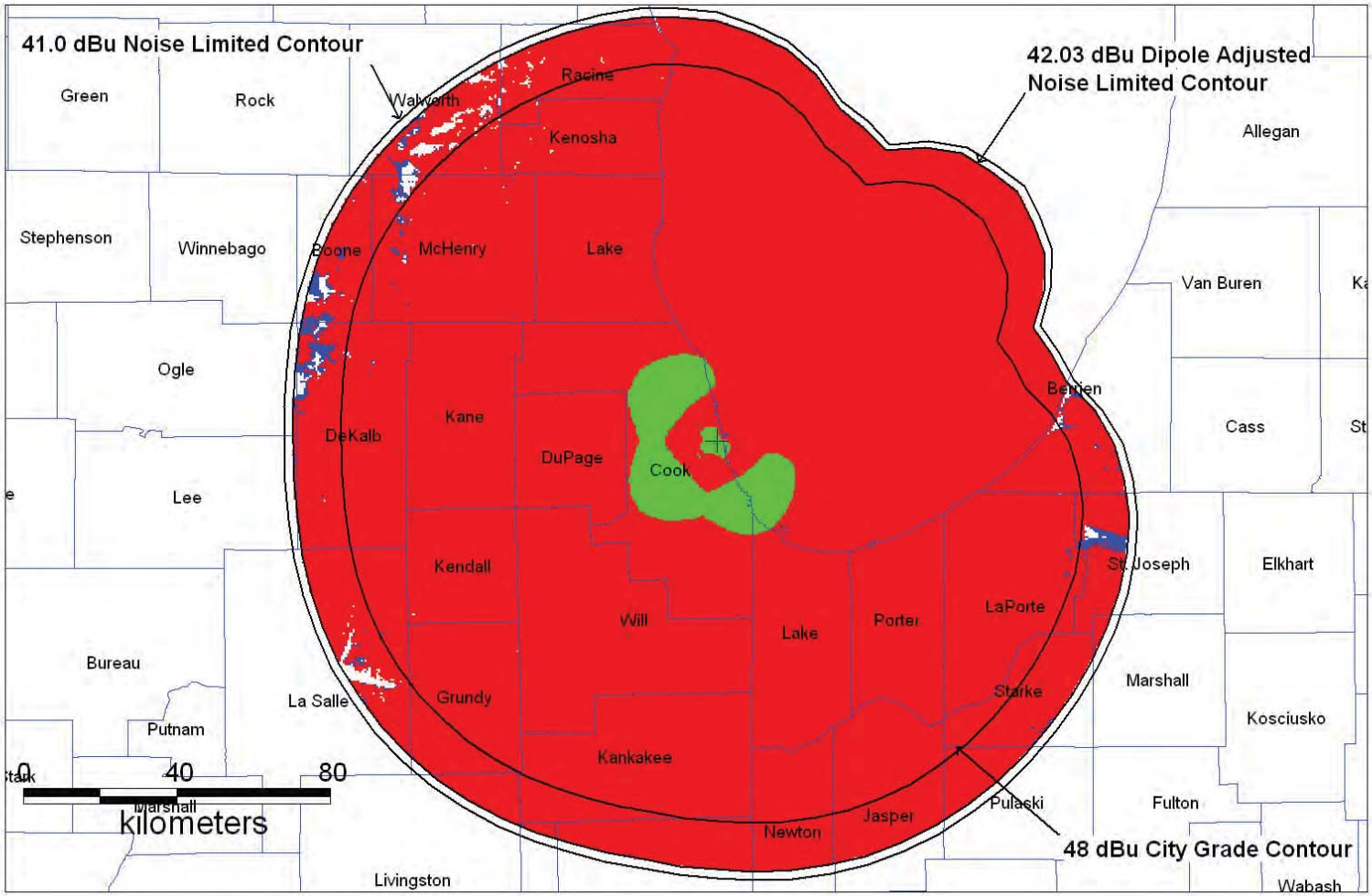



WPWR-TV Channel 51 Gary, IN

Green - Interference free areas
Red - LTE Interference areas
Blue - Existing DTV Interference
Whilte - Areas where field strength is below servcie threshold

Study Parameters
Outside field strength threshold for indoor service: 75.5 dBu
DTV loss for indoor service: 21 dB
LTE ERP 23.0 dBm D/U Ratio -23.0 dB
LTE field strength: 109.92 dBu Outside / 120.38 Inside

**Figure B-12** WPWR service with LTE interference for: LTE UE power = +23 dBm; DTV field strength = 75.5 dBμV/m; D/U = -23 dB.

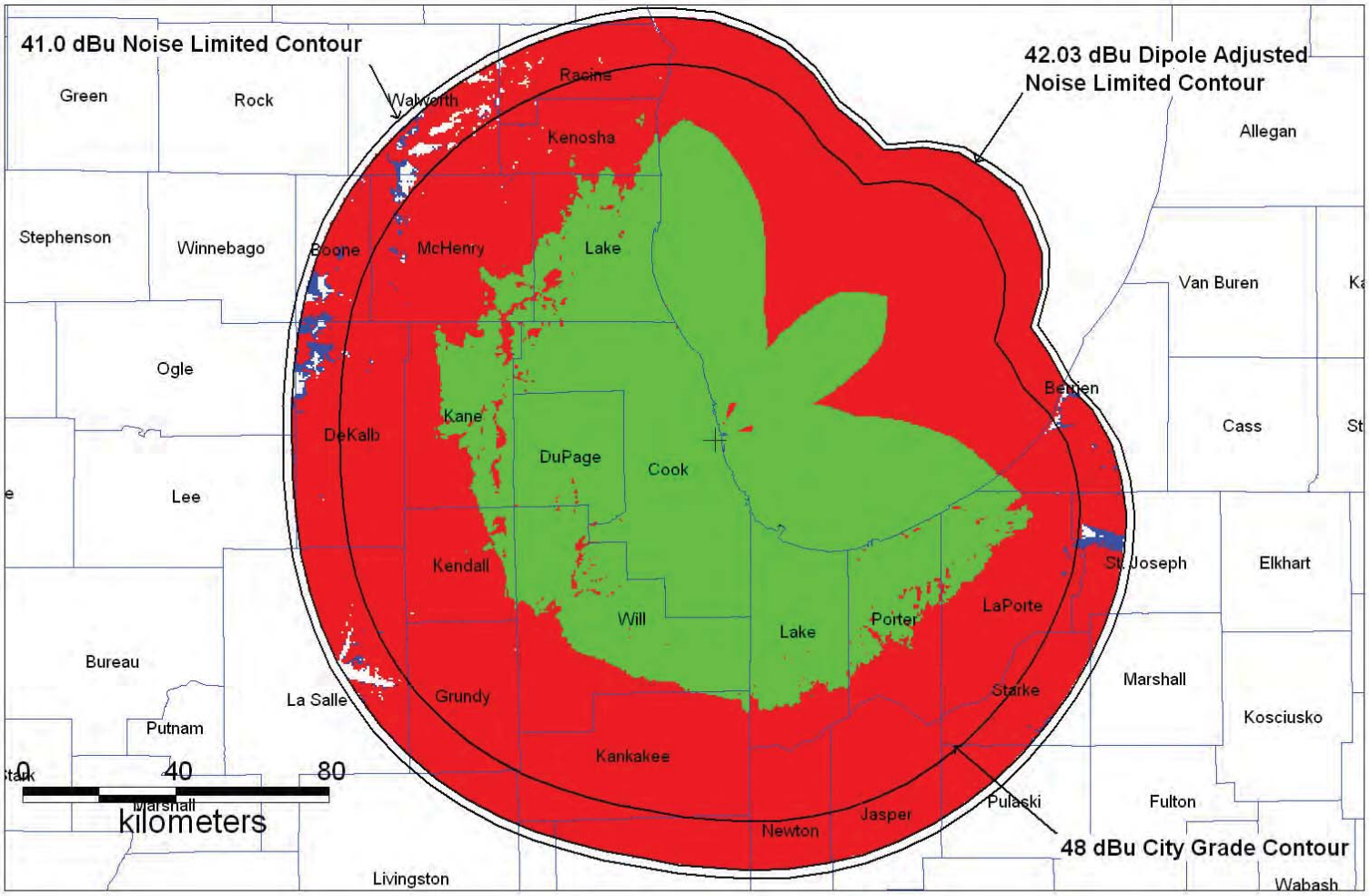



WPWR-TV Channel 51 Gary, IN

Green - Interference free areas
Red - LTE Interference areas
Blue - Existing DTV Interference
Whilte - Areas where field strength is below servcie threshold

Study Parameters
Outside field strength threshold for indoor service: 75.5 dBu
DTV loss for indoor service: 21 dB
LTE ERP 12.0 dBm D/U Ratio -23 dB
LTE field strength: 98.92 dBu Outside / 109.38 Inside

**Figure B-13** **WPWR** service with LTE interference for: LTE UE power = +12 dBm; DTV field strength = 75.5 dBμV/m; D/U = -23 dB.

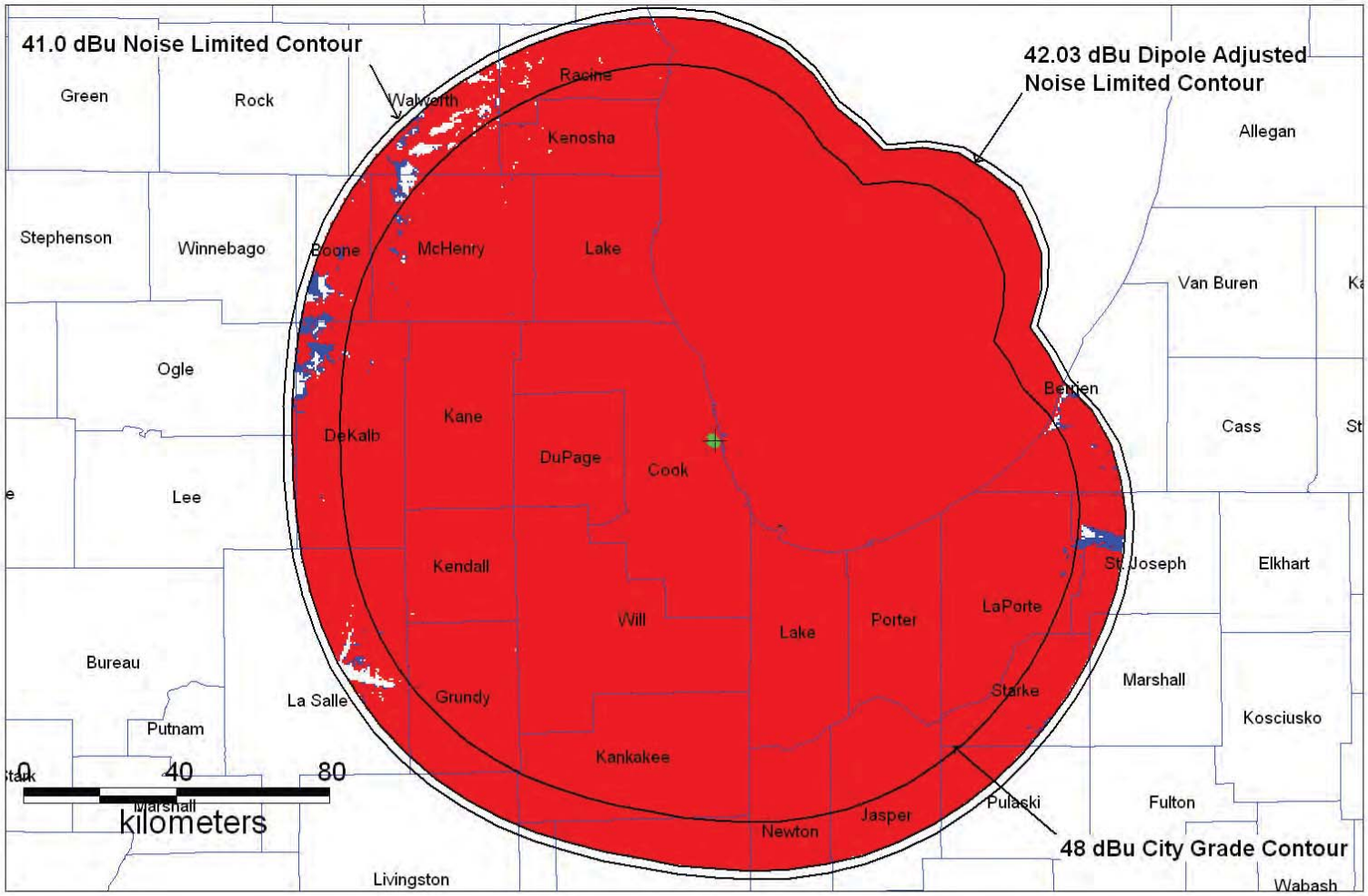



WPWR-TV Channel 51 Gary, IN

Green - Interference free areas
Red - LTE Interference areas
Blue - Existing DTV Interference
Whilte - Areas where field strength is below servcie threshold

Study Parameters
Outside field strength threshold for indoor service: 53.3 dBu
DTV loss for indoor service: 10 dB
LTE ERP 9.0 dBm D/U Ratio -23 dB
LTE field strength: 95.92 dBu Outside / 106.38 Inside

**Figure B-14** WPWR service with LTE interference for: LTE UE power = +9 dBm; DTV field strength = 53.3 dBμV/m; D/U = -23 dB.

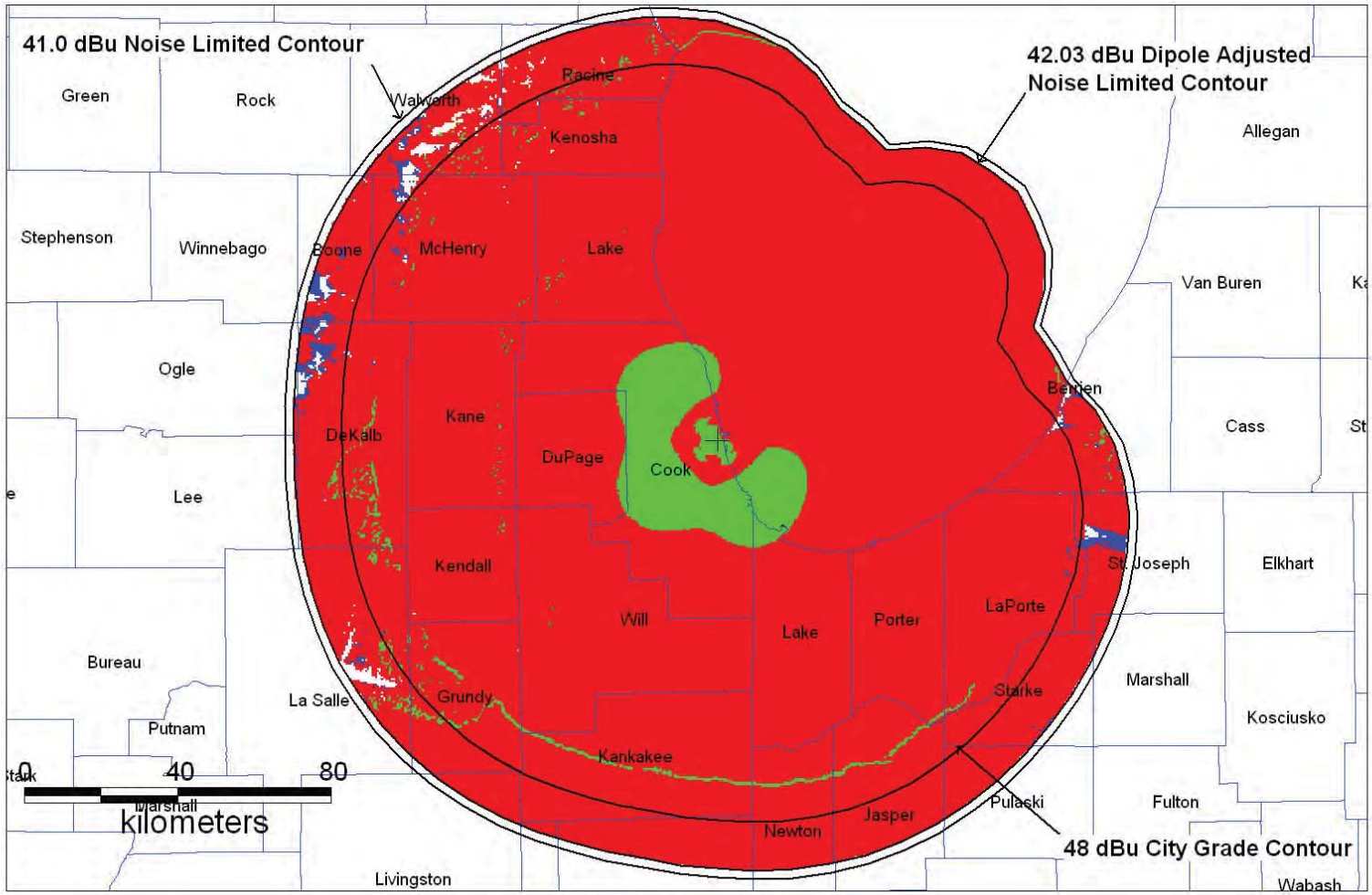



WPWR-TV Channel 51 Gary, IN

Green - Interference free areas
Red - LTE Interference areas
Blue - Existing DTV Interference
Whilte - Areas where field strength is below servcie threshold

Study Parameters
Outside field strength threshold for indoor service: 75.5 dBu
DTV loss for indoor service: 21 dB
LTE ERP 23.0 dBm D/U Ratio -27.0
LTE field strength: 109.92 dBu Outside / 120.38 Inside

**Figure B-15** WPWR service with LTE interference for: LTE UE power = +23 dBm; DTV field strength = 75.5 dBμV/m; D/U = -27 dB.

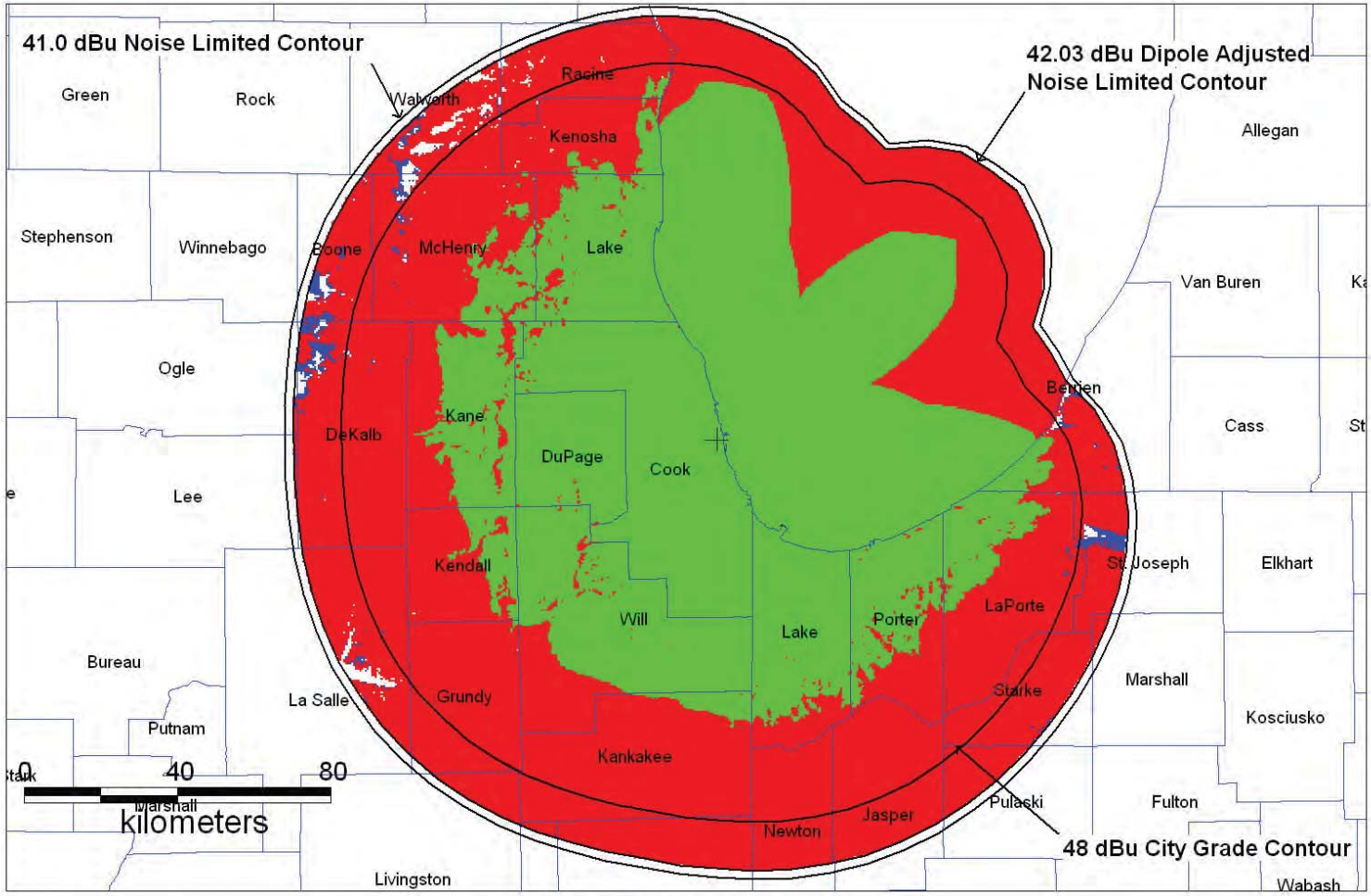



WPWR-TV Channel 51 Gary, IN

Green - Interference free areas
Red - LTE Interference areas
Blue - Existing DTV Interference
Whilte - Areas where field strength is below servcie threshold

Study Parameters
Outside field strength threshold for indoor service: 75.5 dBu
DTV loss for indoor service: 21 dB
LTE ERP 15.0 dBm D/U Ratio -27.0
LTE field strength: 101.92 dBu Outside / 112.38 Inside

**Figure B-16** WPWR service with LTE interference for: LTE UE power = +15 dBm; DTV field strength = 75.5 dBμV/m; D/U = -27 dB.

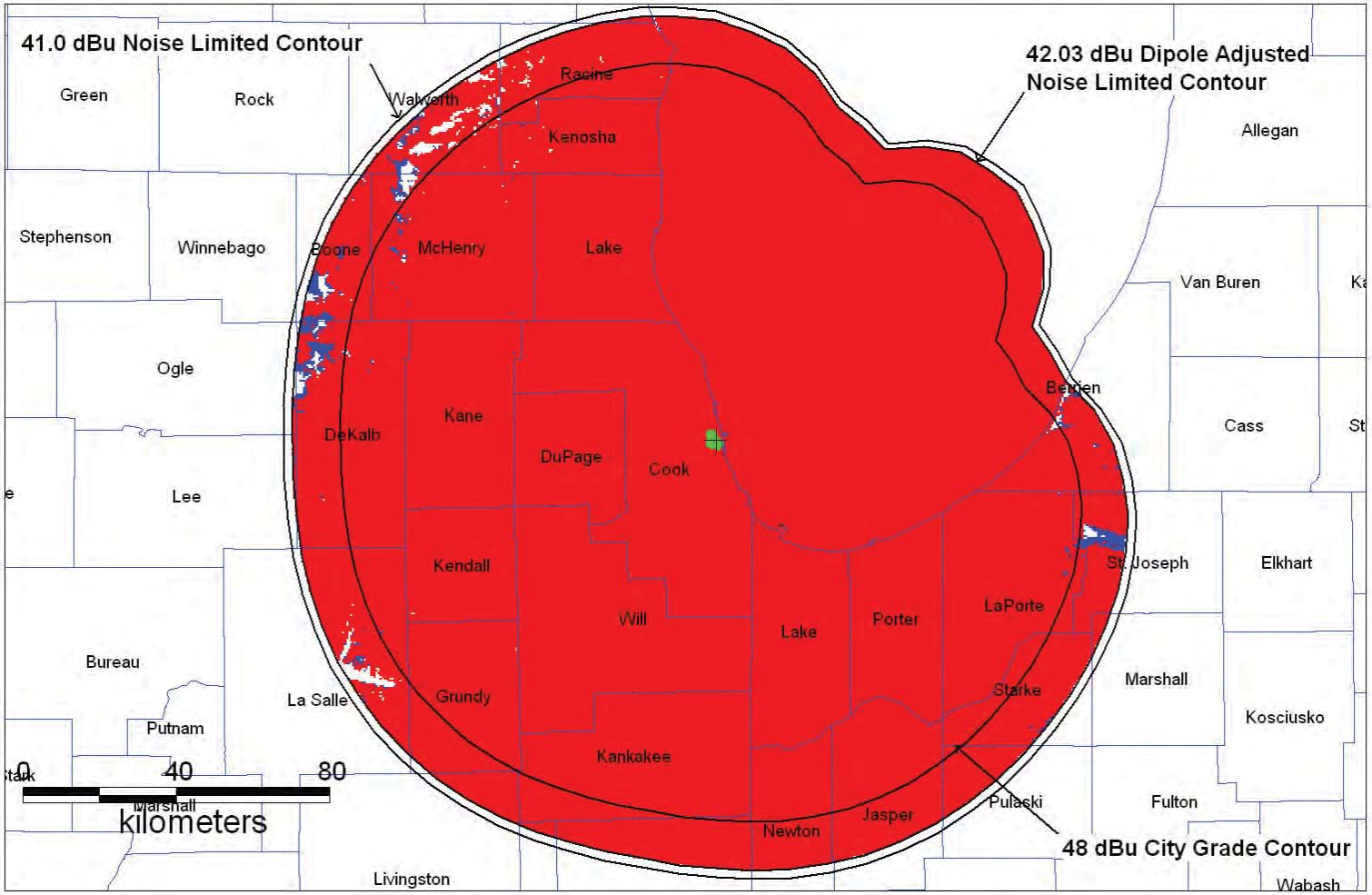



WPWR-TV Channel 51 Gary, IN

Green - Interference free areas
Red - LTE Interference areas
Blue - Existing DTV Interference
Whilte - Areas where field strength is below servcie threshold

Study Parameters
Outside field strength threshold for indoor service: 53.3 dBu
DTV loss for indoor service: 10 dB
LTE ERP 9.0 dBm D/U Ratio -27.0
LTE field strength: 95.92 dBu Outside / 106.38 Inside

**Figure B-17** WPWR service with LTE interference for: LTE UE power = +9 dBm; DTV field strength = 53.3 dBμV/m; D/U = -27 dB.

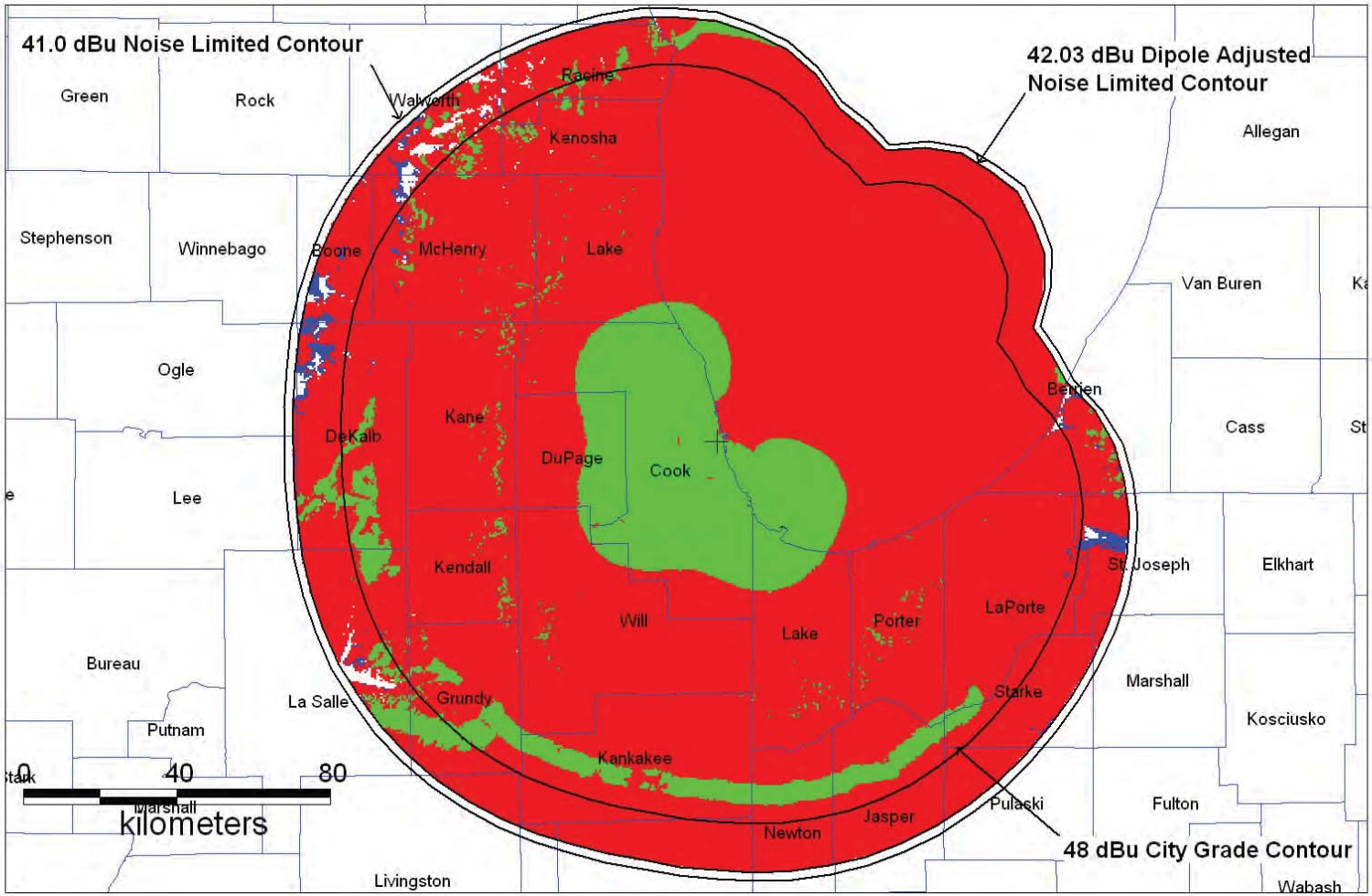



WPWR-TV Channel 51 Gary, IN

Green - Interference free areas
Red - LTE Interference areas
Blue - Existing DTV Interference
Whilte - Areas where field strength is below servcie threshold

Study Parameters
Outside field strength threshold for indoor service: 75.5 dBu
DTV loss for indoor service: 21 dB
LTE ERP 23.0 dBm D/U Ratio -30.0
LTE field strength: 109.92 dBu Outside / 120.38 Inside

**Figure B-18** WPWR service with LTE interference for: LTE UE power = +23 dBm; DTV field strength = 75.5 dBμV/m; D/U = -30 dB.

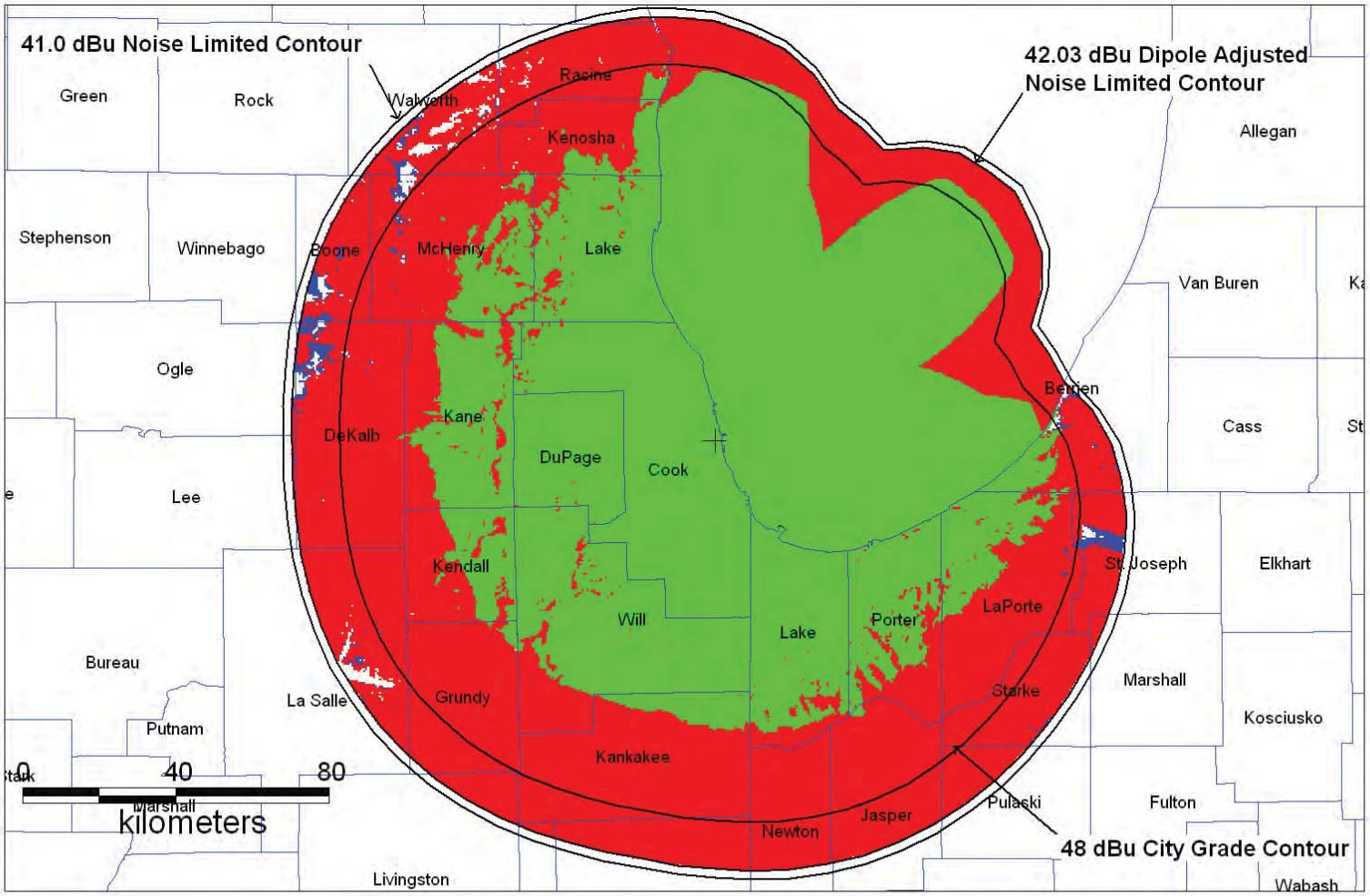



WPWR-TV Channel 51 Gary, IN

Green - Interference free areas
Red - LTE Interference areas
Blue - Existing DTV Interference
Whilte - Areas where field strength is below servcie threshold

Study Parameters
Outside field strength threshold for indoor service: 75.5 dBu
DTV loss for indoor service: 21 dB
LTE ERP 15.0 dBm D/U Ratio -30.0
LTE field strength: 101.92 dBu Outside / 112.38 Inside

**Figure B-19** WPWR service with LTE interference for: LTE UE power = +15 dBm; DTV field strength = 75.5 dBμV/m; D/U = -30 dB.




WPWR-TV Channel 51 Gary, IN

Green - Interference free areas
Red - LTE Interference areas
Blue - Existing DTV Interference
Whilte - Areas where field strength is below servcie threshold

Study Parameters
Outside field strength threshold for indoor service: 53.3 dBu
DTV loss for indoor service: 10 dB
LTE ERP 9.0 dBm D/U Ratio -30.0
LTE field strength: 95.92 dBu Outside / 106.38 Inside

**Figure B-20** WPWR service with LTE interference for: LTE UE power = +9 dBm; DTV field strength = 53.3 dBμV/m; D/U = -30 dB.

# APPENDIX C INTERTEK REPORT ERRATA

## Appendix D Tables 32 – 55, P D2-D26

| | | | | |
|---|---|---|---|---|
| 1 | Table 33: | RCA (26LA33RQ) | TOV-A D/U ratio | -62.0 dB changed to -52.0 dB |
| 2 | Table 34: | Panasonic (Viera TC-L32E5) | TOV-A D/U ratio | -50.9 dB changed to -49.6 dB |
| 3 | Table 34: | Samsung (PN43E450) | TOV-A D/U ratio | -50.1 dB changed to -49.6 dB |
| 4 | Table 34: | RCA (26LA33RQ) | TOV-A D/U ratio | -51.6 dB changed to -46.4 dB |
| 5 | Table 42: | Sony (Bravia KDL46NX720) | TOV-D D/U ratio | -43.5 dB changed to -47.2 dB |
| 6 | Table 42: | Sony (Bravia KDL46NX720) | TOV-A D/U ratio | -47.4 dB changed to -50.2 dB |
| 7 | Table 42: | Samsung (UN32EH4000) | TOV-D D/U ratio | -45.8 dB changed to -47.1 dB |
| 8 | Table 42: | Samsung (UN32EH4000) | TOV-A D/U ratio | -48.9 dB changed to -48.0 dB |
| 9 | Table 42: | Panasonic (Viera TC-L32E5) | TOV-D D/U ratio | -43.3 dB changed to -46.1 dB |
| 10 | Table 42: | Panasonic (Viera TC-L32E5) | TOV-A D/U ratio | -47.3 dB changed to -47.9 dB |
| 11 | Table 42: | Visio (E3D320VX) | TOV-D D/U ratio | -43.4 dB changed to -45.1 dB |
| 12 | Table 42: | Visio (E3D320VX) | TOV-A D/U ratio | -47.4 dB changed to -45.9 dB |
| 13 | Table 42: | Insignia (NS-19E320A13) | TOV-D D/U ratio | -43.4 dB changed to -47.0 dB |
| 14 | Table 42: | Insignia (NS-19E320A13) | TOV-A D/U ratio | -47.4 dB changed to -48.8 dB |
| 15 | Table 42: | RCA (26LA33RQ) | TOV-D D/U ratio | -43.5 dB changed to -43.1 dB |
| 16 | Table 42: | RCA (26LA33RQ) | TOV-A D/U ratio | -47.5 dB changed to -46.0 dB |
| 17 | Table 42: | Haier (L32D1120) | TOV-D D/U ratio | -45.4 dB changed to -46.0 dB |
| 18 | Table 42: | Haier (L32D1120) | TOV-A D/U ratio | -45.5 dB changed to -45.9 dB |
| 19 | Table 42: | Coby (TF-TV1212) | TOV-D D/U ratio | -43.8 dB changed to -49.0 dB |
| 20 | Table 42: | Coby (TF-TV1212) | TOV-A D/U ratio | -55.1 dB changed to -50.2 dB |
| 21 | Table 43: | Sharp (LC46SV49U) | TOV-D D/U ratio | -30.6 dB changed to -27.9 dB |
| 22 | Table 43: | Sharp (LC46SV49U) | TOV-A D/U ratio | -34.1 dB changed to -28.0 dB |
| 23 | Table 44: | Toshiba (24SL410U) | TOV-D D/U ratio | -33.9 dB changed to -42.4 dB |
| 24 | Table 46: | Sony (Bravia KDL32BX330) | TOV-D D/U ratio | -56.3 dB changed to -45.2 dB |
| 25 | Table 46: | Sony (Bravia KDL32BX330) | TOV-A D/U ratio | -56.5 dB changed to -45.3 dB |
| 26 | Table 50: | Samsung (UN32EH5300) | TOV-D D/U ratio | -43.1 dB changed to -46.2 dB |
| 27 | Table 50: | Samsung (UN32EH5300) | TOV-A D/U ratio | -48.3 dB changed to -47.2 dB |
| 28 | Table 50: | Haier (L32D1120) | TOV-D D/U ratio | -43.3 dB changed to -43.6 dB |
| 29 | Table 50: | Haier (L32D1120) | TOV-A D/U ratio | -47.3 dB changed to -43.6 dB |
| 30 | Table 55: | LG (42LK450) | TOV-D D/U ratio | -25.8 dB changed to -25.7 dB |

## Section 6.4, Tables 32 – 55, P 62-66

| | | |
|---|---|---|
| D/U Ratios: | Change dBm to dB | 76 times |
| D/U Ratios: | 82.2 dB is incorrect | 11 times |
| D/U Ratios: | 0 dB is incorrect | 10 times |