MSTV
MAXIMUM SERVICE TELEVISION

Harming the DTV Transition

WHY UNLICENSED USE OF VACANT TV SPECTRUM WILL CAUSE INTERFERENCE TO DTV VIEWERS

By Victor Tawil and Bruce Franca

Executive Summary

This paper responds to New America Foundation's (NAF's) July 2006 Issue Brief, entitled, *Why Unlicensed Use of Vacant TV Spectrum Will Not Cause Interference to DTV Viewers*.

Over the next few years, consumers will spend billions of dollars in new digital equipment. Broadcasters have spent billions of dollars converting their operations from analog to more efficient digital operations. The benefits of a successful transition to digital television should not be jeopardized over speculative and unproven unlicensed operation and devices.

The issue is about interference to TV sets and the risk to TV consumers and viewers. The selection of the correct regulatory regime, licensed or unlicensed, is essential to ensure adequate safeguards for protecting TV consumers. The current unlicensed proposal fails to provide this level of safeguard.

The "burden of proof," that the so-called vacant TV spectrum can be used without causing interference to TV viewers, should be on those that want to make use of that spectrum. This approach has been a long-standing cornerstone of spectrum policy. However, to date, the proponents of unlicensed operations have provided little or no technical studies and conducted no laboratory testing. No field studies have been carried out of any unlicensed device designs to show that this technology will protect TV viewers. Moreover, proponents of an unlicensed regime have not demonstrated any effective mechanism for preventing or policing interference. Advocates, such as NAF, merely cite to potential theoretical solutions, with no hard evidence that any of these solutions will work in the real world.

This paper shows that interference to consumers' TV reception from unlicensed devices is a serious concern. Specifically, the paper addresses three types of interference, *out-of band, adjacent and co-channel*, from unlicensed devices:

A. *Out-of-band interference* is interference from energy that is generated by an unlicensed device on channels or frequencies outside the channel actually being used for communications purposes.* This energy can appear as interference or additional noise in a TV receiver on the TV channel being received by the viewer.

This paper shows that the proposed requirements for out-of-band emissions are inadequate and that unlicensed devices complying with these requirements would cause interference to DTV sets at distances up to 78 feet. Out-of-band interference can occur on any channel. Even when the unlicensed device is correctly operating on a so-called unused channel, this out-of-band energy can interfere with other channels that are being used by TV viewers. This interference can go through walls and can have an adverse impact on TV reception to surrounding neighbors.

MSTV has conducted laboratory testing and field studies showing that unlicensed operation at the FCC's proposed *out-of-band* limits will cause interference to TV viewers. NAF asserts *inter alia* that MSTV has not provided sufficient details of its testing. As pointed out in this paper, MSTV has made three detailed technical reports publicly available, including *"step-by-step" instructions* on how to replicate the MSTV video. MSTV's laboratory testing was conducted by the Communications Research Center (CRC) of Canada, a preeminent government communications laboratory, and testing and model validity were confirmed using two different signals to simulate out-of-band emissions. These test results and studies show that the proposed out-of-band limits

* For the purpose of this paper, out-of-band interference includes both out-of-band and spurious emissions from an unlicensed device that results from the modulation process; harmonic and parasitic emissions; and, intermodulation and frequency conversion products.

for unlicensed devices need to be revised to avoid interference to TV reception.

B. *Adjacent channel interference* is interference that occurs when the unlicensed device is operating on a channel next to or adjacent to a channel that is being used for TV reception and the unlicensed device is in proximity to the TV receiver. For example, a viewer watching TV channel 20 could receive adjacent channel interference from an unlicensed device operating on either TV channel 19 or 21.

MSTV provides a technical analysis demonstrating that unlicensed devices operating on adjacent channels could cause harmful interference at distances up to 2500 feet in weak signal reception conditions. Interference areas of 300 to 600 feet around an unlicensed device are very likely. The analysis concludes that adjacent channel use within the TV service area must be avoided.

C. *Co-channel interference* is interference that occurs when unlicensed devices transmit either inadvertently or deliberately on the same channels that are being used for TV reception. This type of unlicensed operation can cause interference to TV viewers over an area of more than 75 square miles.[†]

NAF and others assert that listen-before-talk (LBT) or spectrum-sensing technology that is used for protection of 5 GHz radar systems can be used to avoid co-channel interference. This technology is not sufficient to prevent co-channel interference to consumers' TV receivers. The paper explains that the ability of unlicensed devices to detect 5 GHz radar systems does not translate into the ability of unlicensed devices to protect DTV reception. They are completely different problems.

NAF and others confuse the problem of transmitter detection with the real issue of protecting TV reception from interference. Protecting a 5 GHz radar receiver is far easier technically than protecting DTV reception using LBT and sensing technologies. Some of the factors that make the 5 GHz protection scenarios technically easier and less critical than protecting DTV reception are:

- The radar receiver to be protected is co-located with the radar transmitter whose emissions can be "sensed," making protection of the radar receiver relatively easy and straightforward technically. In contrast, TV receivers are not co-located with the TV transmitter, but rather are located throughout the TV station's service area. For protection of TV viewers, there is no signal that can be sensed to tell an unlicensed device how close it is to a TV receiver or viewer.

- Because the path between the radar receiver/transmitter and the unlicensed device, including any losses, is the same and reciprocal, the selection of an appropriate detection signal level will provide adequate protection to the radar receiver. In other words, protection of the radar under clear or unobstructed path conditions will provide protection for all situations. In contrast, the paths (and losses) from the TV transmitter to TV receivers and the unlicensed device are not the same and are not reciprocal. In addition, the paths (and losses) from the unlicensed device to the TV receivers are also not the same or reciprocal. The detection signal level needed in one situation will not provide adequate protection in other situations. The detection signal level must account for all potential interference conditions and all paths (and all losses) between the TV receivers and the unlicensed device both inside and outside the TV service area.[‡]

- While the radar signal is bursty and non-continuous, the signal level itself is strong, which simplifies detection. In contrast, the signal level required for DTV detection is very weak. For example, NAF suggests a level of -129 dBm which is a level about *four million times weaker* than the -64 dBm level a 5 GHz unlicensed device must detect.

[†] This interference area is based on an Intel analysis for a 100 milliwatt unlicensed device that suggests that the required separation distance is 5 miles outside the service area. See, comments of Intel Corp, in ET-Docket No. 04-186, dated November 30, 2004, at p. 17 and Appendix A.

[‡] The detection signal level must ensure that the unlicensed device is located a sufficient distance outside the TV service area to prevent interference. To do that, all paths both inside and outside the service area must be investigated to make certain that this signal level never occurs at a closer distance.

- Radar systems are robust and can effectively deal with interference. Radars must deal with unwanted reflections from non-targets and active jamming by the enemy. Errors in detection and inadvertent unlicensed operation do not result in significant degradation of the radar system. In fact, for equipment approval purposes, 5 GHz unlicensed devices need only to accurately detect the radar signal 80% of the time. In addition, if one assumes that the detection threshold is directly related to the maximum potential interference distance, the potential interference from an unlicensed device operating at 5 GHz to a radar is only 100 meters. In contrast, TV receivers cannot reject interference from unlicensed devices. Any co-channel unlicensed operation in the TV band caused by errors in detection will result in widespread interference to viewers that can extend for 5 miles or more from the unlicensed device. Detection by the TV band unlicensed device must be correct 100% of the time to avoid harmful interference.

- Antennas for unlicensed devices at 5 GHz are small, efficient and have a uniform performance across the 5 GHz band. In contrast, building a small, efficient and practical antenna to detect "occupied channels" that operates with a uniform performance across the VHF and UHF TV channels is extremely difficult and complex.

The paper also points out several fundamental flaws made by the unlicensed proponents concerning the use of this detection technology as a co-channel protection mechanism. For example, Intel presumes that reception of a weak signal will mean that the unlicensed device is far enough outside the TV station's service area not to cause interference and that weak signals never occur within the service area. However, signal level detection alone cannot accurately predict location. A weak signal level may mean that you are far from the transmitter or it may mean that you are behind an obstruction such as a building or a hill. Under Intel and NAF's detection approach, these localized dead spots[§] become locations where an unlicensed device can transmit and potentially cause interference over a 75 square mile area or more. Finally, in developing its detection threshold, Intel fails to properly take into account building losses, multipath degradation and propagation variability, resulting in a margin that is woefully inadequate and would result in significant harmful interference to DTV viewers.

This paper also makes clear that contrary to NAF's assertions, tremendous progress has been made in IEEE 802.22 towards the development of a standard for fixed access wireless broadband operations in the TV bands that will appropriately protect TV viewers. Primarily designed to meet the important need for broadband services for rural America, this standard is in its final evaluation and testing phase and is expected to be completed by the end of the year.

The paper shows that the FCC's Equipment Authorization Program does not provide sufficient interference and enforcement protections. For example, a recent NAB study of Part 15 devices operating in the FM broadcast band shows widespread non-compliance of Part 15 devices with the FCC rules.[**] Other examples of the lack of compliance and enforcement are also noted.

While NAF's latest document acknowledges the validity of a number of MSTV's interference concerns, NAF continues to cling to the argument that these concerns can be solved by FCC rules and then chastises the Commission for taking time for appropriate technical solutions to be developed. NAF disparagingly states the "FCC's proposed rulemaking is pending but currently inactive." This is clearly not the case. The FCC has recently announced a projected schedule for proceeding on unlicensed operation in the TV broadcast bands that includes important and necessary field and laboratory testing.[††] Good spectrum management like good medical care is premised on "first, do no harm." Developing technical solutions to unlicensed devices using the TV spectrum without

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[§] Areas of weak signal strength or " dead spots" commonly occur with the use of radio. For example, many people have experienced this phenomenon from time to time with the use of mobile phones.

[**] See, *A Report to National Association of Broadcasters Regarding Study and Measurements of Part 15 Devices Operating in the FM Broadcast Band*, prepared by Dennis Wallace of Meintel, Sgrignoli, & Wallace, dated June 2, 2006.

[††] See FCC Public Notice, *Office of Engineering and Technology Announces Projected Schedule for proceeding on Unlicensed Operation in the TV Broadcast Bands*, ET Docket No. 04-186, DA 06-1813, released September 11, 2006.

causing interference is a complex problem that needs to be addressed by solid technical analysis, backed by field tests, studies and data. NAF and the unlicensed device proponents have supplied none.

The broadcast industry believes that the expert technical organizations, the FCC and IEEE, should be allowed to do their job in a deliberate and timely fashion. Unfortunately, the legislative proposal now before the Senate authorizes unlicensed devices to be placed into the broadcast band within 270 days, irrespective of whether these problems are resolved. Through legislative fiat, it jumps over the basic scientific and engineering testing necessary to determine which types of devices and services can occupy the TV band without causing interference. Instead, the legislation substitutes "certification" as the primary engineering mechanism to avoid interference. However, without such basic testing, the statutory language that certified unlicensed devices should not interfere with TV reception has very little meaning. As this paper will demonstrate, the interference concerns of the broadcast industry are well founded and need to be adequately addressed to prevent interference to millions of viewers.

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By Victor Tawil and Bruce Franca*

This paper responds to New America Foundation's (NAF's) July 2006 Issue Brief, entitled, *Why Unlicensed Use of Vacant TV Spectrum Will Not Cause Interference to DTV Viewers*.[1] NAF asserts that its new brief addresses technical arguments raised by opponents of pending legislation in the Senate to include a provision directing the Federal Communications Commission (FCC) to adopt rules permitting unlicensed use of "unused" TV spectrum. As made evident in this paper, the NAF paper is devoid of any new technical studies and analysis.

The "burden of proof" that the so-called vacant TV spectrum can be used without causing interference to TV viewers should be on those that want to make use of that spectrum. This approach has been a long-standing cornerstone of spectrum policy. However, to date, the proponents of unlicensed operations have provided little or no technical studies and conducted no laboratory testing. No field studies have been carried out of any unlicensed device designs to show that this technology will protect TV viewers. Moreover, proponents of an unlicensed regime have not demonstrated any effective mechanism for preventing or policing interference. Advocates, such as NAF, merely cite to potential theoretical solutions, with no hard evidence that any of these solutions will work in the real world.

In fact, the latest NAF paper does not dispute or disagree with the interference concerns and issues raised by MSTV and others concerned about interference to their licensed operations.[2] Instead, like its predecessor, this new paper merely infers that there *may* be possible technical solutions to these interference problems and issues raised by MSTV and others that oppose unlicensed use on interference grounds. Whether these solutions are practical or proven does not appear to matter to NAF. More importantly, NAF completely ignores the fact that the proponents of unlicensed use, such as Intel, Dell and Microsoft, have strongly objected in the FCC proceeding to the adoption of the very solutions and safeguards that NAF suggests are necessary to avoid interference.

In this paper, MSTV shows that interference to consumers' TV reception from unlicensed devices is a serious concern. Specifically, the paper addresses three types of interference, out-of-band, adjacent and co-channel, from unlicensed devices.

In Section I, the paper shows that the proposed requirements for out-of-band emissions are inadequate and that unlicensed devices complying with these requirements would cause interference to DTV sets at distances up to 78 feet. Section II provides a technical analysis demonstrating that unlicensed devices operating on adjacent channels could cause harmful interference at distances up to 2500 feet in weak signal reception conditions and that interference areas of 300 to 600 feet around an unlicensed device are very likely. The analysis concludes that adjacent channel use by unlicensed devices within the TV service area must be avoided. Section III provides an analysis of co-channel interference from unlicensed devices and shows that this type of interference can adversely impact TV viewers over an area of more than 75 square miles. The use of spectrum sensing

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technology is also addressed. The paper shows that the ability of unlicensed devices to detect 5 GHz radar systems does not translate into the ability of unlicensed devices to protect DTV reception and viewers. The paper points out several fundamental flaws made by the unlicensed proponents concerning the use of spectrum sensing or detection as a co-channel protection mechanism for use in the TV bands.

In Section IV of the paper, MSTV sets forth the significant progress that has been made in IEEE 802.22 to develop a standard for fixed access wireless broadband operations that can provide important broadband services to rural areas and will appropriately protect TV viewers. In Section V, the paper explains, contrary to NAF's assertions, that the FCC's Equipment Authorization Program does not provide sufficient interference and enforcement protections for TV viewers.

Over the next few years, consumers will spend billions of dollars in new digital equipment. Broadcasters also will have spent billions of dollars converting their operations from analog to more efficient digital operations. The benefits of a successful transition to digital television should not be jeopardized over speculative and unproven unlicensed operation and devices.

I. Out-of-Band Interference

Out-of-band interference is interference from energy that is generated by an unlicensed device on channels or frequencies outside the channel actually being used for communications purposes.[3] This energy can appear as interference or additional noise in a TV receiver on the TV channel being received by the viewer.

Out-of-band interference can occur on any channel. Even when the unlicensed device is correctly operating on a so-called unused channel, this out-of-band energy can interfere with other channels that are being used by TV viewers. This interference can go through walls and can have an adverse impact on TV reception to surrounding neighbors.

MSTV has conducted laboratory testing and field studies showing that unlicensed operation at the FCC's proposed *out-of-band* limits will cause interference to TV viewers. These studies show that the proposed requirements for out-of-band emissions are inadequate and that unlicensed devices complying with these requirements would cause interference to DTV sets at distances up to 78 feet.

MSTV also created a video, entitled "Your Neighbor's Static," to show the impact of this type of interference on TV viewers. NAF's latest paper attempts to impugn this video. As shown below, NAF's criticisms are unfounded and are without technical merit.

a. MSTV has fully documented its testing and experiments

NAF claims that MSTV has not provided enough information so that an independent observer could verify its results. This criticism is totally unfounded. A total of three reports on this matter have been publicly made available by MSTV, including "step-by-step" instructions on the MSTV video.[4] These reports fully describe all of the elements necessary to independently reproduce the results of MSTV's video demonstration or laboratory studies.

The Communications Research Center of Canada ("CRC"), one of the most respected laboratories in North America, conducted MSTV's laboratory tests. The CRC tests showed that unlicensed devices, complying with the FCC's proposed out-of-band emission limits, could cause interference to DTV sets at distances up to 78 feet and interference to analog TV sets up to 452 feet. This first CRC report, filed as part of MSTV's initial comments in the FCC's White Space proceeding in November 2004, fully describes the rationale, methodology and the make and model of the hardware used to conduct these interference tests.

A second study and subsequent report by CRC was completed in February 2005. This study confirms MSTV's and CRC's original findings that the proposed FCC limits for out-of-band emissions are not adequate and harmful interference would be caused to TV reception.[5]

The third report was prepared in February 2006 by the consulting firm of Meintel, Sgrignolli & Wallace to further detail the methodology and the hardware used in the MSTV video, and to furnish "step-by-step" instruction of how the video was produced.

Good science is supported by experimentation and data, not unsubstantiated claims. NAF's criticism of the MSTV video and experimental work ignores the fact that neither NAF nor its "experts" have done any testing or experimental work to support any of their claims.

NAF posits that a "series of tests that would determine the impact of various bandwidths would provide more relevant engineering information to determine appropriate regulations to prevent harmful interference." As shown below, MSTV conducted tests using two different bandwidths and both tests produced similar results that are consistent with the MSTV video. While NAF has criticized MSTV's efforts, NAF has not funded or conducted any tests to provide the information it states is needed for the development of appropriate rules and regulations to prevent harmful interference. Nor have any such tests been conducted by any of the unlicensed proponents.

b. MSTV's video accurately shows out-of-band interference to TV viewers

The MSTV video was created in August 2005 to demonstrate and verify in the field, the previously conducted laboratory tests of harmful interference to TV reception. NAF claims that the MSTV video exaggerates the desensitization problem. The NAF authors, however, do not offer any technical or scientific evidence to substantiate this claim. In fact, NAF acknowledges that desensitization interference is a well-known phenomenon and that consumer-grade TV receivers are more susceptible to this interference than other types of receivers because they are designed to receive signals over a large tuning range and operate with weak signals.

The only laboratory testing to quantify the impact of out-of-band interference and receiver desensitization has been done by CRC. The results of this testing have been confirmed in subsequent laboratory testing and verified in the "real world" demonstration of this interference shown in the MSTV video. Moreover, others have also confirmed that desensitization interference to TV receivers by unlicensed devices is a real problem that needs to be addressed.[6]

c. Signals used in MSTV's tests are appropriate for simulating out-of-band emissions

The NAF authors question the signals used in MSTV's test. They assert that the FCC has not specified a maximum bandwidth for unlicensed devices emitting in the TV band. Also, they claim in all but the most remote areas it is not possible to find contiguous blocks of free spectrum. Accordingly, they argue that the broadband transmission used by CRC is unlikely. Such a claim suggests a lack of understanding of the fundamental mechanism under investigation, i.e., the interference caused to TV reception from out-of-band emissions generated from an unlicensed device.

The availability of contiguous channels has no relevance or significance to the interference mechanism being investigated. An unlicensed device is allowed under the FCC's proposal to generate out-of-band emissions on any frequency or frequencies outside its operating channel at a level of 200 uV/m at 3 meters as measured in any 120 kHz wide band.[7] Therefore, out-of-band emissions can be appropriately simulated as a wide bandwidth or broadband signal that spreads across one or more television channels. In fact, the FCC rules require that such emissions be measured up to the tenth harmonic of the highest frequency of the device or 40 GHz, whichever is higher.[8]

In its first study, CRC simulated out-of-band emissions by use of a 6 MHz OFDM signal. In its second study, out-of-band emissions were simulated using a White Gaussian noise generator with a bandwidth of 30 MHz. The second study reaffirmed the results of the first study and both tests show that signals at the "out-of-band" limit proposed by the FCC will cause interference to TV receivers.

The NAF claims "by assuming unlicensed devices will transmit at maximum allowed power levels over an unrealistically wide range of continuous channels, the interference demonstrated in the video exploited a longstanding loophole in the FCC rules that has never caused a problem using real emitters in the field." What NAF authors fail to mention is that these unlicensed devices have yet to be built and their assertions on how these devices will operate is mere conjecture. The MSTV study was based on and evaluated the "concrete proposal" made by the FCC with regard to out-of-band emission limits. Many of the proposed uses of these devices include broadband operations that include the use of wide bandwidth (6 MHz or more) transmissions. To reduce the out-of-band emissions of such devices requires expensive filtering and additional cost that unlicensed device manufacturers may not want to incur. Therefore, it is not unreasonable to assume that such devices will operate at out-of-band levels that comply with the FCC rules rather than limit the out-of-band emissions to levels far below what is permitted. While NAF suggests that out-of-band emissions have never been a problem in the past, recently this same situation did occur with regard to licensed services and resulted in interference to public safety users from commercial land mobile operations. Motorola's IDEN system has out-of-band emissions at or close to the FCC limit over a wide range of frequencies -- the very situation that NAF claims does not occur in the field.

d. MSTV's tests clearly show that proposed out-of-band limits need to be revised

NAF attempts to further confuse the out-of-band issue by inferring that the findings in the two CRC reports are inconsistent and confusing to a non-technical audience thus rendering the analysis/or demonstration meaningless.

Contrary to NAF's assertions, the two CRC studies come to exactly the same conclusion. The proposed FCC out-of-band emission limits are inadequate to protect TV receivers from interference. There is nothing confusing or inconsistent with this finding. MSTV and others have shown that the proposed FCC out-of-band emission limits are inadequate and that unlicensed devices operating at this level would cause unacceptable and harmful interference to TV receivers. Moreover, the out-of-band emission problem highlighted by MSTV was independently studied by a working group of the 802 IEEE Wireless Society, (IEEE-802.22). This working group tentatively determined that the FCC out-of-band limits are insufficient to protect DTV receivers by some 33 dB.[9] NAF and its experts have done no testing that contradicts these conclusions and nothing in NAF's new updated paper refutes these facts.

II. Adjacent Channel Interference

<u>*Adjacent channel interference*</u> is interference that occurs when the unlicensed device is operating on a channel next to or adjacent to a channel that is being used for TV reception and the unlicensed device is in proximity to the TV receiver. For example, a viewer watching TV channel 20 could receive adjacent channel interference from an unlicensed device operating on either TV channel 19 or 21.

In its paper, NAF states that MSTV has recently raised the issue of adjacent channel protection and calculated that a "100 mW unlicensed device can cause interference to adjacent channel DTVs up to 950 meters away**."** NAF does not dispute MSTV's analysis or calculations.[10] In fact, NAF states that "*we agree that interference from devices operating in adjacent channel can exist*" and that the *"FCC needs to establish some rules for adjacent channel protection as it has in many other radio services."*[11]

NAF does not offer or provide any technical solutions other than to argue that this adjacent channel problem is not new and can be remedied with appropriate rules and technology. NAF notes that TV-land mobile sharing has resulted in codified protection criteria (47 CFR 90.307) and states that these criteria can be used to "compute the extra protection which is needed to decrease unlicensed power in channels adjacent to TV channels."

MSTV is pleased that NAF now agrees with MSTV that the FCC needs to establish adequate adjacent channel protection criteria.[12] These protection criteria, however, need to apply to even low power unlicensed devices. As MSTV's analysis shows, unlicensed personal/portable devices operating even at 100 milliwatts can cause interference to DTV viewers hundreds of meters away.

a. First adjacent channels cannot be used by unlicensed devices

MSTV's adjacent channel interference analysis is straightforward. The FCC has established certain DTV co- and adjacent channel protections in its rules.[13] The required adjacent channel protection for DTV operations is specified in Section 73.623 of the FCC rules and has been proposed by the FCC for fixed/access unlicensed devices.[14]

The MSTV analysis uses the same adjacent channel protection proposed by the FCC and looks at the impact of personal/portable devices operating at 100 mW and at 400 mW. Four hundred milliwatts is the proposed maximum output power including antenna gain for personal/portable unlicensed devices. Three signal levels (from moderately strong to weak signal conditions) were considered for DTV reception. A free space propagation model is assumed for the interfering unlicensed device consistent with the FCC's recommendation to use free space for distances of less than 1 kilometer (km). The results of this analysis are shown below:

Unlicensed Device Power	DTV Signal Strength	Interference to DTV Reception
100 mW	41 dBu	780 meters
	59 dBu	100 meters
	69 dBu	30 meters
400 mW	41 dBu	> 1 km
	59 dBu	200 meters
	69 dBu	60 meters

The analysis clearly shows that the operation of personal/portable devices on the first adjacent channel of a television station must be avoided. Since received signal strength will vary throughout the TV station's service area and will depend on the type of antenna a viewer is using for reception, there is no practical way to predict or avoid this type of interference. Other experts and studies have independently confirmed MSTV's analysis and conclusion that first adjacent channel operations must be avoided.[15]

While NAF did not contradict MSTV's adjacent channel analysis, NAF did seem to imply that MSTV's assumptions that the unlicensed device is transmitting a noise- or DTV-like signal or that the signal would be filling the whole adjacent channel are suspect. NAF is wrong. The entire FCC unlicensed proposal is based on the fact that the unlicensed device will be transmitting a noise-like digital signal similar to a DTV signal so that the DTV signal protections apply. The FCC clearly stated "*(g)iven the expected noise-like character of signals from unlicensed devices, we are proposing to use the same protection criteria that are currently specified in the rules for digital television*" and "*the signals from unlicensed devices can be expected to appear 'noise-like.'*"[16]

MSTV's calculations assume that the DTV-like signal would fill the adjacent channel because that is what is permitted under the FCC's proposed unlicensed rules. In fact, the proposed rules would allow larger than 6 MHz bandwidths to be used. Moreover, the unlicensed proponents have also suggested "filling" the entire 6 MHz channel. For example, Microsoft, in its comments, provides an entire table of data rates that can be supported by an unlicensed device using a 6 MHz channel bandwidth.[17]

The assertions by NAF and others pointing to the fact that land mobile stations now operate at higher power and therefore there will be no interference from lower power unlicensed devices are misleading and technically wrong. There are fundamental technical differences between *licensed* land mobile operations that are licensed and assigned to a specific frequency within a given geographic area, and an *unlicensed* regime that has no control over where or how the unlicensed device operates.

While raising the specter of TV and land mobile sharing, NAF also conveniently does not mention the fact that the FCC rules do not permit any land mobile operation on adjacent channels within the protected contour of a TV station. Section 90.307 of the FCC rules clearly states that a land mobile base station may not be located closer than 90 miles or 145 kilometers from an adjacent channel TV station.[18] This ensures that all land mobile operations are well outside the protected contour of the TV station. Similarly, operation of unlicensed devices on adjacent channels would have to be restricted to areas beyond the protected contour of the TV station in order to avoid interference, as shown in MSTV's analysis above.

b. NAF's previous spectrum availability studies are wrong

As discussed above, NAF now acknowledges that adjacent channel protections are needed.[19] However, the NAF and Freepress spectrum availability assessment, entitled, *Measuring the TV "White Space" Available for Unlicensed Wireless Broadband*, dated November 15, 2005, was premised on full use of the 6 MHz in the adjacent channels.[20] NAF's "experts" now concede that this adjacent channel assumption was wrong. In fact, they even concede that "if the FCC supports MSTV's position that access to channels immediately adjacent to a licensed TV channel in an area will not be permitted", that any use of adjacent channel operation would not be possible.

This means that NAF's previous assertions with regard to spectrum availability are significantly in error and substantially overestimate the amount of spectrum that would be available for unlicensed use. Rather than correct and rectify this egregious mistake in their new paper, NAF and its experts instead continue to mislead the public by citing to this study and by repeating their previous and now admitted erroneous spectrum availability findings. NAF further compounds this error by again citing to this misleading and incorrect spectrum availability information in another subsequent August 2006 working paper by Pierre de Vries.[21]

III. Co-channel Interference

Co-channel interference is interference that occurs when unlicensed devices transmit either inadvertently or deliberately on the same channels that are being used for TV reception. This type of unlicensed operation can cause interference to TV viewers over an area of more than 75 square miles.

NAF and others assert that listen-before-talk (LBT) or spectrum sensing technology that is used for protection of 5 GHz radar systems can be used to avoid co-channel interference. This paper shows that this technology is not sufficient to prevent co-channel interference to consumers' TV receivers. The paper explains that the ability of unlicensed devices to detect 5 GHz radar systems does not translate into the ability of unlicensed devices to protect DTV reception.

a. Spectrum sensing for 5 GHz radar does not translate to protection of TV viewers

NAF asserts that detecting television signals is much easier technically than detecting a radar signal. It points to the fact that radar signals transmit in bursts and rotate while DTV signals transmit continuously in a well-defined format and on known frequencies.[22] NAF has performed the classic misdirection on the public and policy makers. The issue is not detection of either the radar signal or the TV signal. The issue is **protection** of receivers used by licensed services from interference by unlicensed devices.

The ability to detect radar at 5 GHz does not translate to protection of DTV reception. MSTV has not disputed that radar signals at 5 GHz are hard to detect. MSTV's position is that detection of a radar signal and the protection of TV reception are technically different problems. In this section, we will first address NAF's criticisms of MSTV's statements. We will then explain, from a technical perspective, why using sensing technology for protection of 5 GHz military radar is different (and easier) and why this approach will not adequately protect DTV reception.

b. MSTV's statements with regard to 5 GHz detection are valid

MSTV's statement that 5 GHz unlicensed devices are "only required to detect a strong radar signal" is valid**.** NAF provides no technical information to dispute MSTV's statement. The only statement NAF makes is to claim that "compared to a military radar, TV is a bullhorn on a stick" and therefore easy to detect and avoid. MSTV has not found any measurement information relating to "bullhorns on sticks" in any scientific literature. We rely on the more common engineering practice of analyzing received power and signal strength. Both of which strongly support MSTV's statement that the levels required for 5 GHz detection correspond to strong radar signal levels.

The FCC measurement procedures for 5 GHz unlicensed devices stipulate a signal detection threshold of -62 to -64 dBm, depending on the output power of the unlicensed device.[23] This signal detection threshold is equivalent to receiving a very strong signal level, especially when compared to the detection level required for protection of DTV reception.[24] In fact, NAF alludes to a detection threshold of -129 dBm for DTV reception.[25] The difference in detection threshold for 5 GHz radar and DTV is 66 dB![26] This means that the radar signal detection level is ***four million times stronger*** than the TV signal detection level! MSTV believes that this simple technical fact supports our statement that 5 GHz unlicensed devices are "only required to detect a strong radar signal" and why NAF provides no technical information to dispute this fact.

MSTV's statement that 5 GHz unlicensed devices are only required to detect the radar signal 80% of the time is also valid. NAF admits that the 5 GHz unlicensed measurement procedures require only 80% of the radar test signals to be detected but suggests because these devices are tested over a few seconds this translates to "near certain detection."[27] NAF provides no measurements or technical analysis to validate this statement. On the contrary, we see nothing in the extensive analysis and testing that was undertaken by NTIA, DoD and the FCC with regard to sharing at 5 GHz to indicate that the final adopted measurement procedures were not intended to fully and accurately measure the actual performance of the unlicensed device. There is no evidence presented to suggest that an unlicensed device that is tested and found to successfully detect a certain signal 80% of the time will suddenly perform at a much higher level when presented with those same signal conditions in the field.

Conversely, MSTV does not dispute that 80% detection is adequate to *fully protect* 5 GHz radar systems. MSTV notes that military radar systems employ robust and sophisticated technology to reject interference and active jamming by the enemy. Unlike military radar, however, TV receivers are not made to reject interference. Detection by unlicensed devices operating in the TV band must be accurate 100% of the time to avoid interference and protect TV viewers.

MSTV's statement that no studies have been conducted showing that sensing technology can protect DTV reception is also true. In response to MSTV's comment that "(a)fter over two years, no 'sensing' technology studies or proof have been submitted to the FCC showing that 'feature detector' or other technology can reliably detect TV signals even at these levels," NAF's only cite is a single reply comment from the Shared Spectrum Company ("Shared Spectrum"), a developer of "sensing technology."[28] Further, NAF fails to note that even in this document Shared Spectrum stated that measurements in "high RF noise locations" ,such as a typical office environment, presented problems. Shared Spectrum stated that to operate in this environment further testing needed to be done.[29]

c. Protection of 5 GHz radar and DTV reception are very different technical problems

To begin, it is important to remember that interference is caused to the receiver, either the radar receiver or a consumer's DTV set, and it is the receiver for which protection is required. In this section, we will show that protection of 5 GHz radar is a technically easier problem than protecting DTV reception; that harmful interference to radar operation from unlicensed devices is unlikely; and, that very small sensitive receiving antennas are practical at 5 GHz but not across the TV band.

1) Radar Transmitter and Receiver are Co-located and the Path Losses between Radar Receiver/Transmitter and Unlicensed Device are Reciprocal

Let's examine the 5 GHz radar situation. The 5 GHz radar system operates at very much higher power levels than the potentially interfering unlicensed device and, even more importantly, **the radar receiver is co-located with the radar transmitter.** This means that the propagation path between radar and the unlicensed device and the radar receiver is the same as the propagation path between the unlicensed device and the radar receiver. See Figure 1:

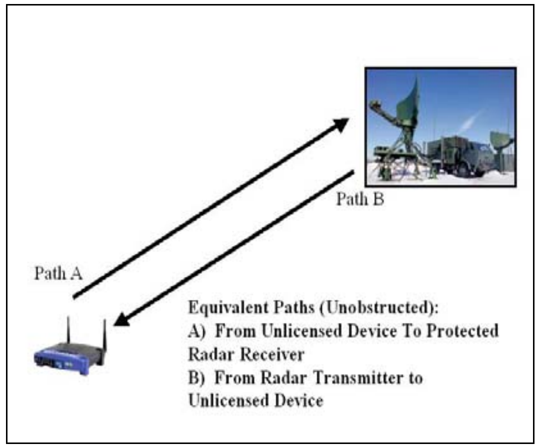


Figure 1. 5 GHz Unobstructed Path

This also means that any obstructions between the unlicensed device and the radar system will effect both the radar transmitter and the unlicensed device equally. So, if the unlicensed device cannot "hear" the radar because there is a hill or terrain blockage or even a person's body in the way, then the radar receiver cannot receive interference from the unlicensed device, because the unlicensed device's signal will also be blocked by the same obstruction. Figure 2 illustrates this point.

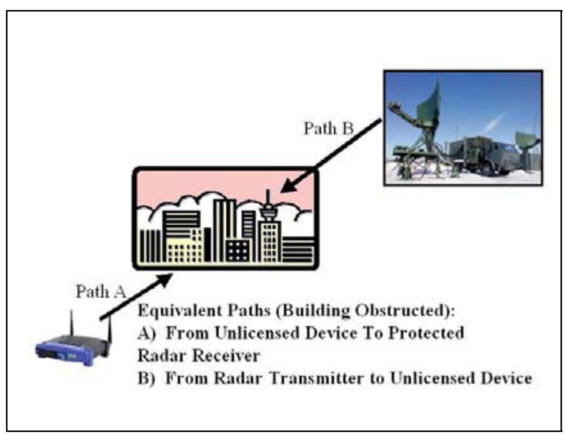


Figure 2. 5 GHz Obstructed Path

In other words, the losses from the radar transmitter to the unlicensed device and from the unlicensed device to the radar receiver are the same. Any obstruction that effects one side of the path will effect the other path to the same extent.

NAF's assertions to the contrary, this is a much easier interference problem to solve than the non-equivalent and unknown path situation involved in protection of DTV reception.

2) For TV Reception Case, Paths are Non-reciprocal and Unknown - A Different and Harder Protection Problem

In the case of TV reception, the TV transmitter and TV receivers are not co-located. There is no signal available to "sense" the location of the TV receiver. TV sets and unlicensed devices can be located anywhere in the service area. There is also no way of knowing what is the actual signal level being received at any TV receiver.

For example, in Figure 3, TV viewer 1 may be 30 miles away from the transmitter and using an outdoor antenna, while TV viewer 2 may also be 30 miles away but using an indoor antenna so that the signal level received by TV viewer 2 is less than received by TV viewer 1 even though they are at the same distance. Moreover, there are different propagation paths between the TV transmitter and each of the TV receivers, as well as between the unlicensed transmitter and the same TV receivers.

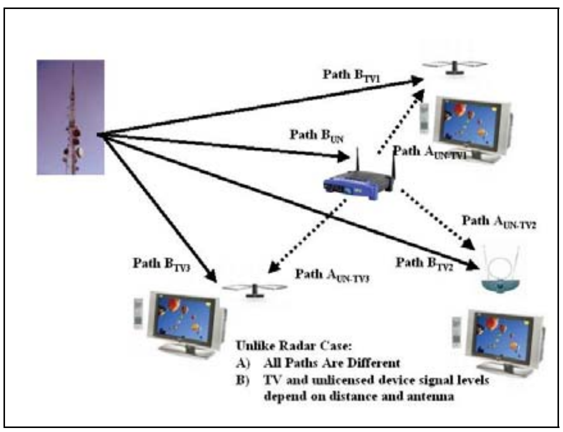


Figure 3. Unobstructed TV and Unlicensed Device Paths

Taking into account path obstructions further complicates protection of TV reception and viewers. Figure 4 provides a simple illustration, where the signal path from the TV transmitter to the unlicensed device and TV viewer 2 is obstructed and all other paths are unaffected. In this case, the signal level received by the unlicensed device and TV viewer 2 is reduced due to signal losses from buildings or other obstructions. The unlicensed device therefore "senses" it is much further away from the TV transmitter and, therefore, the channel is vacant or available and it can transmit. However, because the unlicensed device is actually within or close to the TV service area, the unlicensed device will cause interference to TV reception. In addition, the obstruction also reduces the strength of the TV signal received by TV viewer 2 making the TV signal much more vulnerable to harmful interference.

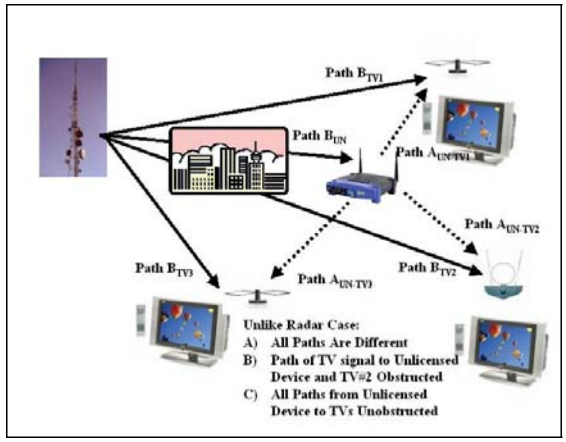


Figure 4. TV Signal Obstructed Paths

This simple case illustrates why protecting TV reception is much more difficult than the 5 GHz radar situation. In the 5 GHz radar case, the radar receiver and transmitter are co-located. "Sensing" the radar transmitter signal identifies the location of the radar receiver. In addition, there is a single path between the radar and the unlicensed device that is the same in either direction.[30] In the case of DTV protection, there is no signal to "sense" the location of the TV receiver. In addition, there are multiple paths from the TV transmitter to TV receivers; there are multiple and different paths from the unlicensed device to the TV receivers; and path obstructions can affect any path differently.

Finally, in the event that the unlicensed device initially "fails to detect" the radar signal and moves closer to the radar system becoming more of an interference threat, the radar signal level received by the unlicensed device will become stronger thereby increasing the probability of detection and the likelihood for the unlicensed device to automatically shut off. In contrast, this safeguard is not present in the protection of DTV reception. Because the DTV receiver is not co-located with the TV transmitter, moving the unlicensed device closer to the DTV receiver does not increase the probability of detection but rather makes it merely more likely that interference will occur!

3) *Harmful Interference to 5 GHz Radar Operations is Unlikely*

In contrast to TV receivers, radar systems are designed to reject interfering and unwanted signals. Radar systems must deal with unwanted reflections of radar transmissions from non-targets. Military systems must also deal with active jamming by the enemy. The impact on 5 GHz military radar systems by a few unlicensed transmitters operating unintentionally is negligible. In fact, Wi-Fi systems are already operating and co-existing on a portion of the spectrum used by 5 GHz military radar systems.[31] The new FCC requirements also permit these devices to continue to operate indefinitely and allow manufacturers to continue to market previously approved devices without spectrum sensing or DFS capability until July of 2007.

The FCC measurement procedures specify a detection threshold value of either -64 or -62 dBm depending on the device's transmitter power. If one views the detection threshold as defining the radar "service area," then one can conversely use this value to determine how far away the unlicensed device should be from the edge of this service area. Let's assume a 5 GHz unlicensed device operating at 200 milliwatts or 23 dBm, and determine the maximum received power at a distance of 100 meters. To determine the received power, one needs to compute the free space path loss value at a distance of 100 meters and subtract that value from the transmitted power of 23 dBm. The equation for free space path loss is:

$$L_{dB} = 32.44 + 20 \log D + 20 \log f,$$

where

D is in kilometers and f is in megahertz.

For a distance D of 100 meters and a frequency of 5.5 GHz, the resulting path loss is 87 dB. Therefore, the signal strength received at 100 meters would be 23 dBm minus 87 dB or -64 dBm -- the same threshold level required for "sensitive" radar detection.[32] This means that the unlicensed device must be located at least 100 meters beyond the radar's "service area" to avoid interference. If the 5 GHz unlicensed device inadvertently operates at or slightly inside the service area, the radar interference area is at most a 100 meter radius around the unlicensed device.

On the other hand, the impact on TV reception of an unlicensed device inadvertently operating on an occupied TV channel is significant. Intel in its comments to the FCC suggests that the interference range of a 100 mW unlicensed device is approximately 8 kilometers or 5 miles and therefore the device must be at least this distance outside the TV contour.[33] While the potential interference would actually be greater, using Intel's interference calculation shows that the interference area to TV viewers from a single unlicensed device would be over 75 square miles.[34]

4) *Operation at 5 GHz Allows for Physically Small, Efficient and Uniform Sensing Antennas*

Sensing or LBT begins with receiving the signal at the antenna. In simplest terms, the ability or effectiveness of an antenna to receive a transmitted signal is related to its physical size, which in turn is related to the wavelength of the signal to be received.[35] At 5 GHz, the wavelength of the signal is less than about 2.5 inches. Therefore, a very effective sensing antenna can be made in a small physical space. For example, some computer manufacturers place multiple antennas in the screen area of a laptop computer. In addition, since the 5 GHz unlicensed band extends from 5150 to 5825 MHz, the frequency range is only about ±6% of the median frequency. This means that the antenna effectiveness can be made fairly uniform across the entire frequency band.

In contrast, the TV broadcast allocation is actually on three separate frequency bands (54-72 MHz, 174-216 MHz and 470-806 MHz) that extend across both the VHF and UHF region of the spectrum.[36] The wavelength at 54 MHz is over 18 feet and the wavelength at 806 MHz is about 14 inches. In addition, the total frequency range is over ±87% from the median frequency. Even if one limits unlicensed operation to only the UHF band, the wavelength varies from almost 25 to 14 inches and the deviation from the median frequency is ±25%. This makes building an antenna with uniform performance across the band difficult and complex. In addition, the physical size of even a poorly performing antenna for an unlicensed device in the TV band must be significantly larger than an antenna at 5 GHz.[37] Furthermore, physical size of the antenna is an important consideration for portable/mobile unlicensed devices. Unfortunately, a "small" TV band antenna in an unlicensed device is not likely to be effective in sensing the very low signal levels needed for detection.

d. Use of signal detection will not protect DTV viewers

The NAF paper correctly identifies the hidden node problem as one of the major concerns that needs to be addressed to avoid harmful interference. NAF states that *"studies have shown that in both urban and rural areas, where buildings and terrain serve as obstacles to TV signal penetration, there may exist many 'shadow' spots in which TV signals may be weakened or totally diminished."* In other words, where sensing or LBT will likely fail!

NAF posits that the use of very sensitive receivers could solve the hidden node problem. It states that the *"FCC could simply set a sensitivity value for detectors that would give a high confidence that usable TV signals would not be missed"* and then verify through its Equipment Authorization Program that each unlicensed device meets this specified sensitivity level.

NAF's hypothesis that a predetermined threshold level can solve the hidden node problem is incorrect. Even if the premise that a very sensitive threshold detector can be built is accepted, the ability of that detector to accurately predict its location relative to a television receiver or a television service area is nil. Signal detection alone cannot accurately predict location. Further, if the detection level is set low enough to actually provide protection to DTV viewers, the detection level will be so far below the ambient "noise floor" that all spectrum will appear occupied and the detector will never find unused or unoccupied spectrum.

Let's examine what sensitivity level is needed to address the hidden node problem and protect DTV reception. In fact, let's look at the detection level Intel suggests is needed for low power unlicensed devices.[38]

Tables 1 & 2 show the DTV receiver and unlicensed device parameters used by Intel in its analysis.

Table 1: DTV Receiver Parameters

Receiver	Parameters
Minimum usable signal at DTV receiver	-83 dBm
The required signal to co-channel interference ratio of the TV signal to be protected	23 dB
DTV Receiver co-channel interference threshold protection	-106 dBm
The gain of the DTV receiver antenna with respect to the antenna of the unlicensed device	+10 dB
Receive frequency (MHz)	600

Table 2: Unlicensed Device Parameters

Unlicensed Device	Parameters
Maximum transmit EIRP when receiving signal at detection threshold (100 mW)	+20 dBm
Detection receiver bandwidth	1 kHz
Antenna Gain (dBi)	0 dB

Listed below is the step-by-step analysis used by Intel to develop link budgets to determine what it believes is "safe threshold values for detecting unused channels for use by low power unlicensed devices."[39]

Step 1: Determine the separation distance needed between a 100 mW unlicensed device and a potential victim DTV receiver as shown in Table 3.

Table 3: Link Budget for Computing the Required Separation Distance between an Unlicensed Device and a Victim DTV Receiver

Link Budget	Values
Unlicensed device transmit power (100 mW)	20 dBm
Receiver interference protection threshold	-106 dBm
Loss needed between unlicensed device and each victim receiver (20dBm - (-106 dBm))	126 dB
Average building losses	6 dB
Off axis DTV antenna gain	-14 dB
Loss needed to be attributed to path loss at 600 MHz (126 dB - 6 dB - 14 dB)	106 dB[40]
Free space interference range outside of the Grade B service contour	8 km

Step 2: Determine the detection threshold to protect potential victim DTV receiver from a 100 mW unlicensed device as shown in Table 4.

Table 4: Detection Threshold Link Budget for Protecting a DTV Victim Receiver

Link Budget	Values
DTV signal at Grade B service contour	-83 dBm
Excess path loss at 8 km beyond DTV service contour[41]	2 dB
Antenna gain differential	-10 dB
Building loss due to walls, antenna height, and multipath	-23 dB
Power level of feature detector relative to DTV signal	-11 dB
Required pilot tone detection threshold to protect DTV Receiver	-129 dBm

Let us now discuss some of the fundamental flaws in Intel's analysis.

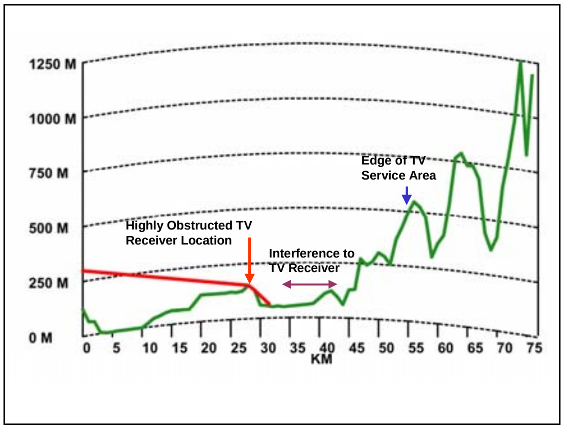
e. Signal detection alone cannot accurately predict location

Intel's analysis is fundamentally flawed. The basic assumption that signal detection and sensing is sufficient to prevent unlicensed devices from operating inside a television station service area is incorrect. The analysis takes for granted that a predetermined detection threshold level will guarantee that the unlicensed device will be located 8 kilometers or 5 miles beyond the TV station's service area and therefore the unlicensed device will not cause interference.[42] This assumption is erroneous and the premise that a "detection threshold" level can guarantee that an unlicensed device is at a location some distance from the television's service area is wrong. Signal detection and sensing alone cannot accurately predict location

The -129 dBm detection value, suggested by Intel, is based on a received DTV level of -85 dBm (includes 2 dB of additional path loss to account for the 8 km distance beyond DTV service contour of -83 dBm). The -129 dBm value takes into account the physical and technical differences between the TV receive system and the unlicensed device, such as the antenna gain and the power level of the detector.[43] Intel also includes 23 dB for other factors that degrade the signal detected by the unlicensed device such as building losses, multipath and antenna height.[44] If one assumes that building losses and mulitpath can occur at the same levels both within the TV service area as well as 5 miles outside the service area and that the unlicensed device can be at the same antenna height both outside and within the TV service area, then these factors can be ignored. The real issue then becomes whether a -85 dBm or lower DTV signal can occur at a location closer than 5 miles from the edge of the television service area contour or even within the service contour.

The correct answer is, of course, there may be locations within the service area where the signal level may be below this value. While apparently unknown to NAF and its authors, the fact that locations within a TV stations service area may not receive an adequate television signal or are "unserved" is well known.[45] Under Intel's approach, each "unserved" location would translate into a *carte blanche* approval for an unlicensed device to transmit even though it is located well inside the service area of a television station and will cause interference to surrounding TV viewers.

Let's look at a real consumer reception situation. MSTV was asked to provide assistance to a television viewer in the Seattle area who could not receive the Seattle DTV stations although he was located less than 25 miles from the stations.[46] MSTV ran terrain profiles from the viewer's home to the TV station. The following is a terrain profile from one of the Seattle television stations to the viewer's residence.



The terrain profile shows that the viewer's location is blocked by terrain from although locations beyond the viewer are not blocked and have clear line of sight to the television station. This location clearly receives a signal much weaker than -85 dBm. An unlicensed device at this location would therefore "sense" that it is located at least 5 miles beyond the service contour when it is in fact well within the service area. In addition, because the unlicensed device is located within the service area, Intel's assumption of a 6 dB building loss "over the 5 miles beyond the Grade B and a 14 dB loss due to the unlicensed signals being transmitted into the "back" of the TV antenna would not apply.[47] In this instance, the interference distance would be much larger than the 5 miles assumed by Intel from an unlicensed device operating beyond the television contour.

f. Intel's suggested detection level is inadequate to protect TV viewers

Next, let's examine the "margin" in Intel's detection threshold. In its analysis, Intel assumes a value of 23 dB for "(b)uilding loss due to walls, antenna height, and multipath."

Antenna Height. Intel does not specifically address the loss attributed to differences in antenna height between the unlicensed device and an outdoor TV antenna. This factor is merely included in its 23 dB of loss "margin." However, as part of its analysis for transmit power control, Intel does calculates the "slant range" and path loss between the unlicensed device and an outdoor antenna. This calculation assumes that the outdoor antenna is at a "height of 8 meters above the unlicensed device antenna."[48] This is consistent with an outdoor TV antenna of 30 feet and an unlicensed device antenna height of 6 feet or a difference of 7 dB.[49] While this is certainly not a "worst case" situation, for the purposes of this paper, we will use this 7 dB value.[50]

Therefore, the margin for the remaining factors of building loss and multipath is 23 dB minus 7 dB or 16 dB. Intel's analysis also includes a 2 dB propagation loss since it assumes that the unlicensed device is 5 miles beyond the TV station's Grade B contour. Although we have shown previously that this may not be the case, for simplicity, let's include and add this additional 2 dB to the margin for a total "margin" of 18 dB for building loss and multipath.

This 18 dB of margin is used to account for <u>all</u> degradation that might occur to the DTV signal received or "detected" by the unlicensed device. The principal question is whether the 18 dB margin is sufficient to protect TV receivers? The answer is NO, even considering Intel's own analysis and data.

Building Loss and Multipath. In an *ex parte* presentation to the FCC, Intel stated that building losses average 5.7 dB with a standard deviation of 8.6 dB.[51] If one assumes that building losses follow a normal distribution, this means that about two-thirds of the values for building losses will fall between the average or mean value and one standard deviation. Therefore to provide enough protection for building losses for two-thirds of the situations where building losses occur the needed margin would be 14.3 dB; to protect for 95% of cases, the building loss margin would have to be 22.9 dB (the average and two standard deviations); and, to account for almost all or about 99% of the situations, the building loss margin value would have to be 31.5 dB (the average and three standard deviations).

In addition to building losses, Intel notes that the signal can experience multipath degradation on the order of 4 to 19 dB.[52] In its comments, Intel argues that this degradation can be reduced to 6 dB through the use of diversity antennas, although there is no proposal by the FCC to require diversity antennas nor does Intel in its comments argue for such a requirement. Intel also fails to explain how such diversity performance could be maintained or how antenna performance would be affected if the antennas were rotated or moved, such as in the case of a game controller or toy.

Nevertheless, assuming *arguendo* that all unlicensed devices are required to use diversity antennas that always reduce multipath to 6 dB, the 18 dB margin used by Intel in its analysis would only provide protection to TV viewers for less than 2/3 of all building loss or attenuation situations.[53] The following chart computes the "margin" required to take into account losses due to building blockage and correct for multipath degradation:

Percentage of Building Attenuation Situations Covered	Margin Required with Diversity Antennas	Margin Required with No Diversity Antenna
68% (1 sigma)	20.3 dB	33.3 dB
95% (2 sigma)	28.9 dB	41.9 dB
99% (3 sigma)	37.5 dB	50.5 dB

Accordingly, NAF's and Intel's suggested 18 dB of "margin" for its unlicensed device detection threshold is woefully inadequate and would result in significant harmful interference to DTV viewers.

g. Intel's analysis fails to adequately take propagation variability into account

NAF and Intel also fail to recognize the fact that radio propagation is probabilistic and that its assumed DTV signal level of -85 dBm is a "predicted" value. The predicted TV service contour is based on the signal level that occurs at 50% of the locations and 90% of the time. In practice, the actual signal levels will vary significantly over both time and location.[54] The detection level suggested by Intel does not take into account this signal variability and therefore will not prevent interference to DTV reception. In order to improve the reliability of detection, DTV signal level variation needs to be taken into account and a more appropriate predictive model that takes into account a higher percentage of location variability needs to be used. For example, at UHF frequencies, the difference in location variability between the 50th percentile and the 90th percentile for UHF is on the order of 15 dB.[55] Reducing the detection level by such a factor would help to ensure, but not necessarily guarantee, that unlicensed devices would not cause harmful interference to TV reception as required by the FCC rules.

In summary, the use of a signal detection threshold alone can not guarantee that a device is located a specific distance beyond the television station's service area. This error is particularly problematic since Intel's interference analysis is predicated on the assumption that a –85 dBm signal level will always be at least 8 kilometers beyond the Grade B contour and therefore one can reduce the interfering signal of the unlicensed device by a factor of 20 dB or 100 times.[56] When in fact, as shown above, DTV signals at levels at or below –85 dBm can and do occur within the DTV service area where this reduction is not appropriate and the unlicensed device would cause additional significant interference to DTV viewers.

Further, not withstanding this fatal flaw, assuming *arguendo* signal detection is used, to reduce the likelihood of harmful interference to DTV reception, the detection threshold proposed by Intel and NAF would have to be reduced substantially to properly account for building attenuation and multipath losses, and to account for location variability. The authors of this paper would argue that, at the very least, sensing at these reduced levels is significantly more complicated than the sensing used for protection of 5 GHz radar systems and is well beyond the current state of the art for practical circuit designs and software for low-cost unlicensed devices.

IV. Significant Progress Has Been Made on the IEEE 802.22 Standard

NAF and its authors attempt to discredit the IEEE 802 standards organization and its processes. NAF states that the IEEE 802 rules make it very unlikely that this group will reach consensus because it has members who are proponents of unlicensed use as well as broadcast interests that NAF assert are firmly opposed to it. NAF also states that because membership and voting is based on individuals and membership is open-ended, it therefore possible to "stack" the committee to achieve a particular outcome.[57] NAF's clear intent is to insinuate that broadcast interests have "stacked" this group to prevent an unlicensed standard from being developed.

Nothing could be further from the truth. All of NAF's claims show a complete lack of understanding of the IEEE organization and its processes. In its desperate attempt at discrediting the world's leading wireless standards setting organization, NAF ignores the fact that the eligibility requirement for voting on an IEEE standard in a Working Group such as the 802.22 Group is not a trivial process.[58] NAF"s position is curious given the high level of participation in other IEEE working groups by the major proponents of unlicensed devices.

Far from being opposed, as suggested by NAF and its authors, MSTV and other broadcast industry participants have strongly supported the work of IEEE 802.22, which is committed to the development of a wireless standard that is based on sound scientific study needed to protect TV reception rather than mere political rhetoric. Further, broadcast participation is far lower than would be required to influence and "*stack*" the committee as suggested by NAF. Only 5 individuals from the broadcast community have participated in 802.22 while voting membership within the Working Group has ranged from 50 to 95 individuals.[59] NAF's suggestion that consensus is hard to achieve is also contradicted by the facts. If a standard is based on sound engineering, a 75% minimum voting requirement of the Working

Group is not difficult to achieve. This is evident by the fact that all the standards adopted in IEEE 802 have always exceeded the minimum requirement by having an approval rating greater than 90%.

Since its inception in early 2005, the IEEE 802.22 Working Group has made tremendous progress toward the development of a standard for a broadband Wireless Regional Area Networks (WRAN) in the TV bands. The Working Group has received and studied 16 different technical proposals and is currently working on a **single merged proposal** for standardization. Final evaluation and testing is on-going and is expected to be completed by the end of his year.[60]

V. FCC Equipment Authorization Program Does Not Provide Effective Interference Protection

The new NAF paper includes an insert on the FCC's Equipment Authorization Program asserting that it can be used to assure that equipment authorized under this program does not cause interference to TV broadcast reception. The insert is intended to respond to MSTV's very valid concerns that "well-intentioned rules … with respect to compliance of new unlicensed equipment" may not be sufficient to prevent interference and the fact that it is generally "impossible to recall equipment" once it is in the field and being used by consumers.

While not completely clear from NAF's language, NAF appears to recommend that only the FCC, rather than privately operated testing bodies, would be able to approve unlicensed devices that operate in the TV bands. NAF also appears to recommend that "(s)ince the radios under question here are expected to be used, in most cases, in conjunction with Internet access, it would not be a significant burden for them to connect to the equipment manufacturer or distributor periodically to update their software" and that if this were not done the devices could be shut down though expiration date features, such as Macrovision's Flex*net* technology used by the computer software industry. NAF also suggests that other "very low-power devices that are not connected to the Internet" such as those used to "track herds of cattle, or to monitor industrial machinery" would not be subject to this requirement. NAF does not, however, define the terms "periodically" or "very low-power."

MSTV commends NAF for its recognition that MSTV's concerns with interference from unlicensed operations are valid. MSTV supports a requirement that unlicensed devices be connected to the Internet to ensure that the unlicensed device can be reprogrammed or modified in case of interference. The periodic solution proposed by NAF, however, is inadequate. NAF would require that any interference by an unlicensed device be remedied only periodically. Further, NAF does not define what it means by "periodically" but uses the example of software "expiration," which is usually an annual process. Even if this process were made quarterly, it would be an unacceptable solution. **The basic premise of Part 15 operation is that an unlicensed device cannot cause interference**.[61] NAF's proposed solution of "periodically" attaching to the Internet would have TV viewers wait 90 days or 6 months or even a year to correct interference from unlicensed devices. As NAF suggests, there is little burden to requiring ALL unlicensed devices from being connected to the Internet and including the capability of being remotely accessed and immediately shut-off and/or modified to correct any interference. This is the same requirement that the FCC adopted for all broadband over powerline (BPL) devices and should be the minimum requirement for any unlicensed device operating in the TV band.

The contention that the Equipment Authorization Program would offer protection from, and enforcement of, interference is premised on the following theory: that only devices that fully comply with the Commission' rules are produced; that the Commission has sufficient resources to ensure that non-compliant devices are not introduced into the market; and, in the rare instance that this might occur, to immediately track down and remove those devices from operation and to prosecute those manufacturers that are responsible for those illegal devices. This theory does not reflect reality.

A recent NAB study of Part 15 devices operating in the FM broadcast band shows wide spread non-compliance of these Part 15 devices with the FCC rules.[62] Less than 25% of the devices tested were compliant with the FCC's field strength limits. In February, 2006, the FCC issued a *Notice of Apparent Liability for Forfeiture and Order*, proposing a $1 million forfeiture against Behringer USA, Inc., for apparent violation of the FCC's equipment authorization rules.[63] Behringer apparently violated the FCC rules by marketing at least 50 models of unauthorized digital audio devices. These devices were marketed for more than five years including for more than one year after Behringer was put on Notice of its violations. MSTV is also aware of the illegal marketing of Part 74 two-way radios to the nuclear power industry and others.

These few cases confirm the inability of the Equipment Authorization program to act as an effective deterrent and enforcement mechanism, particularly in the use of unlicensed devices in the TV band. Unlike the typical Part 15 device that operates in bands that are used by microwave ovens, industrial machinery and marine and military radar systems where the probability of interference is negligible or low, unlicensed devices are now being proposed to be operated in the TV bands that are also used by hundreds of millions of consumer devices, i.e., TV sets, that can be easily interfered with. NAF and Intel do not refute this fact. Intel computes that an interference zone of 5 miles for a 100 milliwatt device located beyond the Grade B contour and higher powers have been proposed to be permitted for such devices. Even using Intel's interference radius, this means that an unlicensed device can cause interference over an area of 75 square miles! Clearly, the Equipment Authorization program is not set up to handle the interference that could be caused by both legal and illegal unlicensed devices that would operate in the TV broadcast band. Finally, there is no indication that the FCC has ever been able to recall, or even has the authority to recall, a Part 15 device from consumer use.[64]

VI. Broadcasters Interference Concerns are Valid and Well Founded

NAF asserts in the title of section IV of its paper "broadcasters interference concerns are unfounded and readily avoidable." But a careful reading of the NAF paper suggests otherwise and that broadcasters interference concerns are clearly not unfounded or easily avoided. For example, NAF's latest document acknowledges the following:

1) NAF recognizes MSTV concerns with out-of-band interference. NAF states that out-of-band and desensitization interference "could easily be solved by establishing a new limit on total power in addition to the limit that was proposed on power/120 kHz that was proposed in the NPRM, and that the "FCC could eliminate desensitization concerns by setting a protection distance goal for unlicensed devices and setting a maximum total TV band power limit that the unlicensed device can transfer to a TV receiver at that distance." *NAF fails to acknowledge that there is no such proposed requirement before the FCC nor does it suggest what power limit should be used for such a requirement.*

2) NAF "agrees that interference from devices operating in adjacent channels to TV bands can exist." NAF states that the "FCC needs to establish some rules for adjacent channel protection as it has in many other radio services." *NAF fails to acknowledge that there is no such proposed requirement before the FCC nor does it suggest what specific limit should be used for such a requirement.*

3) NAF suggests requiring that all devices be tested and certified only by the FCC laboratory and that since most devices are expected to be used in conjunction with Internet access "it would not be a significant burden for them to connect the equipment manufacturer or distributor periodically to update their software… ." *NAF fails to acknowledge that there are no such proposed requirements before the FCC.*

4) NAF also fails to address the problem of sensing "The FCC could simply set a sensitivity value for detectors that would give a high confidence that usable TV signals would not be missed." *NAF fails to acknowledge that there is no such proposed requirement before the FCC nor does NAF define what level should be used or what it believes to be a "high confidence" level.*

While NAF's latest document acknowledges the validity of a number of MSTV's interference concerns, NAF continues to cling to the argument that these concerns can be solve by FCC rules and then chastises the Commission for taking the time for appropriate technical solutions to be developed. NAF disparagingly states that the "FCC's proposed rulemaking is pending but currently inactive." This is clearly not the case. The FCC has recently announced a projected schedule to complete the proceeding on unlicensed operation in the TV broadcast bands that includes important and necessary field and laboratory testing.[65]

Good spectrum management like good medical care is premised on “first, do no harm.” Developing technical solutions to unlicensed devices using the TV spectrum without causing interference is a complex problem that needs to be addressed by solid technical analysis backed by field tests, studies and data. NAF and the unlicensed device proponents have supplied none. The important benefits of a successful transition to digital television should not be jeopardized over speculative and unproven unlicensed devices.

MSTV and the broadcast industry have pledged to work with Congressional and government leaders to fashion an approach that would identify and set aside unused broadcast spectrum for the deployment of broadband services in rural areas. The proposed legislation, however, goes far beyond rural broadband and would permit any type of unlicensed device to operate in the TV band including toys, video game controllers and other devices that are unlikely to incorporate the safeguards required to prevent interference to TV viewers.

VII. End Notes

[1] See New America Issue Brief #19, "Why Unlicensed Use of Vacant TV Spectrum Will Not Interfere with Television Reception, dated July 2006, by Michael J. Marcus, Paul Kolodzy and Andrew Lippman. This paper updated an earlier paper, dated October 2005 by the same authors.

[2] For example, NAF does not disagree that "desensitization interference" can occur and states that "(C)onsumer-grade TV receivers are more susceptible to this problem than other types of receivers because they are designed both to receive signals over a large tuning range and receive weak signals." See NAF paper at p. 2. NAF also states "we agree that interference from devices operating in adjacent channels can exist." NAF paper at p. 4.

[3] For the purpose of this paper, out-of-band interference includes both out-of-band and spurious emissions from an unlicensed device that results from the modulation process; harmonic and parasitic emissions; and, intermodulation and frequency conversion products.

[4] All three reports were included as part of the Statement of Robert W. Hubbard, President & CEO, Hubbard Television before the U.S Senate Commerce Committee, Sciences and Transportation, March 14, 2006.

[5] It is worth noting that one reason for conducting additional tests and issuing a second report was to address issues raised by various parties, including NAF, with regard to the first report. Specifically, NAF was critical of the choice of antenna used in the first experiment and stated that the type of "silver sensor" antenna used could exaggerate the interference results. The second set of tests used a reference standard dipole antenna rather than a "silver senor' antenna to eliminate the antenna variable from the tests. Another criticism was the type of signal and choice of bandwidth used to emulate the out-of-band energy. Some parties argued that the use of a modulated signal and the narrow bandwidth of the signal selected may affect the results. The second set of tests attempted to address these criticisms by using a Gaussian White Noise generator rather than an OFDM signal generator to spread the out-of-band energy across five television channels. The results in the second CRC report reaffirm the original findings.

[6] See CEA and Motorola filings in Docket 04-186. and *ex parte* filing by IEEE 802.22. 18 http://gullfoss2.fcc.gov/prod/ecfs/retrieve.cgi?native_or_pdf=pdf&id_document=6518164462

[7] See, for example, Sections 15.239(c), 15.240(c), 15.241(c), and 15.242(c) of the FCC rules.

[8] See Section 15.33 of the FCC rules.

[9] IEEE 802.22 is responsible for developing standards for operating Wireless RANs within the TV bands. In September 2005, it submitted an *ex parte* filing with the FCC to report on its activities and findings to date. The report concluded that unlicensed systems should not operate within a co- and first adjacent channel contour of a DTV station and that the FCC's proposed out-of-band emission requirements are insufficient to protect DTV receivers by some 33 dB for 1 dB desensitization of DTV receivers.

[10] While NAF does not dispute MSTV calculations, the authors apparently try to discredit this work by innuendo by suggesting it comes from an unattributed, undated Powerpoint presentation, although they note it was created by Bruce Franca of MSTV on March 29, 2006. What they fail to disclose is that this draft document was sent to and shared with Mr. Kolodzy by Bruce Franca in response to an April 5th e-mail from Mr. Kolodzy requesting technical discussion on the relevant interference issues. In the spirit of an "open technical dialog," MSTV shared its "draft" technical work that fully described its technical concerns and its analysis on interference. Mr. Franca and Mr. Kolodzy exchanged several telephone calls and e-mails regarding this work. Mr. Kolodzy was fully aware that this presentation was a preliminary draft and who had created it. Further, rather than being "unattributted and undated" as suggested by NAF, this information is contained in the clearly identified MSTV presentation, Unlicensed Devices in the Television Band, dated April 12, 2006, made available to the Senate Committee staff on that same date.

[11] See NAF paper at p. 4.

[12] The FCC proposed that fixed/access unlicensed devices must meet DTV protections on both co- and adjacent channels but that personal/portable devices need only comply with co-channel protections. The adjacent channel analysis contained in this paper shows that this preliminary conclusion by the FCC that the "potential for harmful interference to adjacent channel television operations is sufficiently low that we do not need to impose adjacent channel restrictions on these devices" is incorrect..

[13] See 47 CFR 73.623 and FCC NPRM pp.15 and 28.

[14] Under these criteria, in order that interference is not caused to DTV reception, the interfering signal on an adjacent channel cannot be more than 26 dB greater than the received DTV signal.

[15] For example, Charles W. Rhodes, an independent consultant, presented a paper entitled, *Unlicensed Transmitters Operating on "White Channels within the Broadcast Bands*, dated May 20, 2006, at the annual conference of the National Translator Association. In this paper, Mr. Rhodes states that "(f)irst adjacent

channels to broadcast channels should NOT be considered "white" in the same community due to interference such usage would cause within the station's coverage area." The paper presents detailed analysis of various interference mechanisms that can occur. Mr. Rhodes' July 26, 2006 article, *White Spaces Are There for a Reason,* for TV Technology also explains why adjacent channel operation by unlicensed devices is not possible. He suggests "the most efficient use of the spectrum by white channels would be in a band of their own with a suitable guard band separating it from broadcast spectrum." In addition, experts in IEEE 802.22 have also concluded that adjacent channel operation within a TV service area would create interference to TV viewers and is not feasible.

[16] See, for example, FCC NPRM at para. 30.

[17] See comments of Microsoft Corporation, dated November 30, 2004 at p. 6.

[18] The 90 mile separation distance assumes that the TV station has a service area of 55 miles and the land mobile base station will serve mobiles within 30 miles so that all mobile operations will be at least 5 miles outside the protected contour of the TV stations. While it may be possible to reduce this separation distance of 5 miles to take into account the differences in power between land mobile stations and unlicensed devices, operation of unlicensed devices would still have to be restricted to beyond the protected contour of the TV station in order to avoid interference. For example, as shown in MSTV analysis, a personal/portable unlicensed device would have to be more than 1 kilometer outside the TV station's service area.

[19] NAF points to the current TV-land mobile sharing of TV channels 14-20 in 13 major markets and the FCC requirements that govern such sharing and that prohibit use of the first adjacent channels.

[20] NAF spectrum assessment is based on a Study from Freepress that was attached to the NAF October 2005 Issue Brief.

[21] See NAF working paper #14, "Populating the Vacant Channels," dated August 2006.

[22] MSTV recognizes that radar signals are not continuous and that radars rotate so that the signal may be in a different direction. This fact, however, does not mean that a radar signal is more difficult to detect than a very weak TV signal

[23] The 5 GHz unlicensed device measurement procedures provide an additional 1 dB for the radar detection signal level. This means that the threshold detection is actually -63 dBm (-64 dBm + 1 dB) for unlicensed devices with output power levels of 200 mW or more. The -129 dBm level suggested by Intel and alluded to by NAF is 66 dB less than this -63 dBm level.

[24] In fact, as shown below, this is a level within the range that unlicensed devices produce and use for communications between local devices.

[25] See NAF's cite to Shared Spectrum's reply comments at p. 5 and footnote 31 of NAF's paper. MSTV does not suggest that this threshold value of -129 dBm would be appropriate or would actually protect DTV viewers. As shown below, Intel's detection level analysis is flawed and fails to adequately account for location of the device, building losses, multipath degradation and a number of other factors. MSTV's position is that further analysis and field testing would be required to develop an appropriate detection threshold and to show that this threshold would actually protect TV reception. None of which has been done to date.

[26] This value assumes that both the 5 GHz and TV band unlicensed devices operate with approximately the same bandwidth. Even taking into account the 11 dB difference in power level of the feature detector assumed in the Intel analysis, the difference in detection threshold is still 55 dB or the radar detection is at a power level over 300,000 times the level for operation in the TV band.

[27] NAF 'sassertion that the unlicensed device is tested only over a few seconds is not true. The transmission period for the long pulse radar test signal is 12 seconds and a minimum of thirty trials must be conducted. This is a minimum test period of 6 minutes, considerably longer than the few seconds suggested by NAF.

[28] See Reply Comments of Shared Spectrum Company, FCC Docket No. 04-186, February 1, 2005. This paper also shows that the detection level proposed by Intel and referred to by Shared Spectrum is inadequate to prevent interference to DTV reception.

[29] While MSTV would perhaps take issue that a typical office environment is a high RF noise location, MSTV staff has in fact met with personnel from Shared Spectrum and pointed out challenges that would need to be addressed to make this technology viable. For example, in neighborhoods close to TV transmitters where high RF fields may be present, such signals may mask or "de-sense" the detector making it difficult to detect low level television signals MSTV, for example, has invited Shared Spectrum to test at its facility, which is co-located with WUSA TV Channel 9 in Washington D.C., where this phenomena occurs.

[30] In the radar case, each path between an unlicensed device and a radar system can be considered separately. The fact that there can be multiple unlicensed devices or even multiple radars does not matter. Each unlicensed device is required to protect a radar receiver co-located with a radar transmitter. That protection can be broken down into a single path analysis and each path will be

same in both directions simplifying protection requirements and analysis.

[31] The new DFS regulations also apply to unlicensed devices operations in the 5.25-5.35 GHz band. Applications filed after July 20, 2006 for new unlicensed devices in this band must comply with these requirements. All devices manufactured after July 20, 2007 must also comply. There are no requirements however that prohibit earlier manufactured without this capability from continuing to operate.

[32] One hundred meters or about 330 feet is clearly within the intended communication range of these unlicensed devices. This suggests that the same antenna and receiver functions can be used for both communications between unlicensed devices and detection of the radar signal.

[33] See Intel Comments at Appendix A. This calculation also assumes that there is a 14 dB antenna discrimination factor and a 6 dB attenuation of the interfering signal over this distance.

[34] This is based on an 8 km or 5 mile radius. In this case, since TV receivers can be located in front of the unlicensed device the 14 dB antenna discrimination would not apply and the actual calculated interference area would be much larger.

[35] Because the difference in velocity of an electric wave in free space and the wave on the antenna, the physical length of the antenna does not correspond exactly to the electrical length of the antenna and the physical length can be made somewhat shorter depending on the size of the wire and other factors. For the purposes of this discussion, this small difference between electrical length and physical length was disregarded. See, for example, *Practical Antenna Handbook* by Joseph J. Carr, McGraw-Hill, 2001.

[36] The UHF band after the transition would extend only up to 698 MHz (TV channel 51).

[37] For example, everyone is familiar with the size of classic TV "rabbit ears" and loop or "bow-tie" antennas

[38] It is inferred that NAF and its authors agree with Intel's analysis since they have referenced this value and have not provided any other analysis nor have they suggested that this value is inappropriate. They also cite to a reply comment by Shared Spectrum that references this value.

[39] See Comments of Intel Corporation, in ET-Docket Nos. 04-186 and 02-380, dated November 30, 2004.

[40] Intel states that "(t)his value (*i.e.,* 106) is adjusted to correct for average building losses and backdoor antenna gain. MSTV notes that this "20 dB adjustment" is incorrect and results in a significant reduction in the protection needed to avoid interference to DTV reception. For example, this assumes that the antenna is always pointed at the TV station and away from the unlicensed device. This is not always the case. For example, TV stations in a market may not always be co-located or consumers may desire to receive TV signals from two locations, such as Washington and Baltimore. If this "adjustment" is not included the "free space interference range" or distance the device must be from the protected contour of the TV station goes from 8 km to 40 km.

[41] Intel cites that this value is derived from ITU P.1546-1. As noted above, MSTV takes issue with the 8 km value although Intel's analysis has more fundamental flaws that are addressed in this paper.

[42] See Chart associated with Step 2: Determine the detection threshold to protect potential victim receiver from a 100 mW unlicensed device.

[43] According to Intel, the signal received by the unlicensed device compared to the DTV receiver is less due to a 10 dB difference in antenna gain and an 11 dB difference due to the power in the detection bandwidth versus across the entire 6 MHz DTV signal.

[44] The 23 dB is allotted to account for building loss, multipath and antenna height. Therefore, the -29 dBm - (-10dB (difference in antenna gain) -11dB (difference in power due to detection bandwidth) -23dB) = - 85 dBm.

[45] In the Spring of 2000, thirty broadcast organizations established the VSB/COFDM Project, a testing and research project on the state-of-the-art implementations of VSB and COFDM technologies. Extensive DTV measurements were made at about 200 outdoor and 45 indoor sites. These measurements showed many sites with signal levels of less that -85 dBm. In addition, MSTV completed a year-long extensive RF field measurement program in 1998. This testing encompassed a combination of radials, arcs, grid and cluster measurements of both WHD-TV and WETA-HD. These measurement data show a number of locations where the DTV signal is less than -85 dBm. For example, forty-four of the over three hundred measurements taken for the model DTV station, WHD-TV, showed levels of less than -85 dBm *within* the noise-limited contour of the station. A number of these measurements were less than 30 miles from the transmitting antenna (or more than 20 miles from the edge of the TV service area). In addition, fifty-two of the two hundred and ninety-two measurements of WETA-HD were less than -85 dBm, including one location only 12 miles from the transmitter. These "real world" measured data show that the -85 dBm level does not only occur more than 5 miles from the TV station and refutes completely the basic premise of Intel's analysis and approach. See, *8VSB/COFDM Comparison Report*, VSB/COFDM Project, December, 2000 and *Model HDTV Station Field Test Program, An*

Interim Report for the Model HDTV Station Project, Inc., prepared by the Association for Maximum Service Television, Inc., September 1998.

[46] This request was forwarded to MSTV by Congressman Jay Inslee's staff on behalf of one of his constituents.

[47] In Intel's analysis, the detection threshold is predicated on the fact that the unlicensed device is outside of the DTV service by at least 8 kilometers. In such a case, the unlicensed device will be transmitting into what Intel calls the "backdoor" of the TV antenna and therefore the interfering signal from the unlicensed device can be reduced by 14 dB. Intel also assumes that since the unlicensed device is 8 kilometers beyond the protected contour there will be a 6 dB propagation loss over those 8 kilometers due to buildings and ground clutter. Neither of these would occur if the unlicensed device were at or within the contour. Therefore, there would be a 20 dB shortfall in the detection threshold and in the protection needed to ensure no interference if the unlicensed device was located at the contour rather than 8 kilometers beyond the contour.

[48] See Intel's comments dated November 30, 2004, Appendix A at p.3.

[49] DTV planning factors assume TV reception is based on an outdoor antenna at 30 feet above the ground.

[50] For example, the height of the TV antenna might be greater due to terrain or in the situation of an antenna mounted on a taller building such as an apartment building.

[51] See Intel *ex parte* Power Point Presentation to the Federal Communications Commission, dated November 1, 2004.

[52] Intel notes that fading depth has been quantified by Bullington to be less than 19 dB for 99 percent occurrence over 50 to 70 kilometer paths. See Intel's comments Appendix A at p. 2.

[53] To protect for 2/3rds of all in-building use, the allowance for building attenuation should be a minimum of 14.3 dB.

[54] For example, most individuals have experienced the variability that can occur with radio propagation, such as when using a mobile phone or listening to the radio their vehicle where slight changes in position will make significant changes in signal level or service will vary by time of day or date.

[55] See, for example, *A Computer Program for Calculating Effective Interference to TV Service*, OST Technical Memorandum, FCC/OST TM 82-2, July 1982, prepared by Harry K. Wong.

[56] Intel assumes that the unlicensed device is outside of the DTV service by at least 8 kilometers. In such a case, the unlicensed device will be transmitting into what Intel calls the "backdoor" of the TV antenna and therefore the interfering signal from the unlicensed device can be reduced by 14 dB and that there will be a 6 dB propagation loss over those 8 kilometers due to buildings and ground clutter. Neither of these would occur if the unlicensed device were at or within the contour. Therefore, there would be a 20 dB shortfall in the detection threshold and in the protection needed to ensure no interference if the unlicensed device was located at the contour rather than 8 kilometers beyond the contour.

[57] See Footnote 27 of the NAF paper.

[58] IEEE requires a consensus of 75% of individuals in the committee for passage. To be eligible to vote, an individual must attend at least two week-long Plenary sessions out of the past four and have a recorded participation of in least 75% of all of the Working Group's meetings during those long-week sessions. Moreover, if the individual fails to meet the attendance/participation requirement, they lose their voting rights until eligibility is re-established. Such stringent requirements require a commitment to the standard setting process.

[59] The requirement for allowing individuals rather than organizations to participate and vote is intended to be inclusive rather than exclusive. Rather than disparage the IEEE process, NAF's authors could make the same commitment to participate and have a voice in the process as MSTV has done.

[60] Approval of the WRAN Standard is expected in 2007.

[61] See, for example, Section 15.5, General conditions of operation, of Part 15 of the FCC rules. 47 CFR 15.5.

[62] See, *A Report to National Association of Broadcasters Regarding Study and Measurements of Part 15 Devices Operating in the FM Broadcast Band*, prepared by Dennis Wallace of Meintel, Sgrignoli, & Wallace, dated June 2, 2006.

[63] See, In the Matter of Behringer USA, Inc., *Notice of Apparent Liability for Forfeiture and Order (Notice)*, File No. EB-04-SE-069, adopted February, 16, 2006.

[64] For example, in the Behringer *Notice*, none of the devices that Behringer marketed for the one year after being notified of its violations were recalled from consumers.

[65] See FCC Public Notice, *Office of Engineering and Technology Announces Projected Schedule for proceeding on Unlicensed Operation in the TV Broadcast Bands*, ET Docket No. 04-186, DA 06-1813, released September 11, 2006.