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

	)	
In the Matter of	)	
	)	ET Docket No. 02-380
	)	
Additional Spectrum for Unlicensed Devices	)	
Below 900 MHz and in the 3 GHz Band	)	

COMMENTS OF INTEL CORPORATION

April 7, 2003

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I. INTRODUCTION AND SUMMARY

Intel Corp. (Intel) hereby submits the following comment in response to the Notice of Inquiry released in the Federal Communications Commission's ("FCC" or "Commission") above-captioned proceeding. Intel is the world's largest semiconductor manufacturer and a leader in technical innovation. Intel is also a leading manufacturer of communications and networking chips and equipment.

Intel commends the FCC for initiating this proceeding examining the possibility of permitting unlicensed devices to operate in the television broadcast and other frequency bands. The current allocation process results in many channels being unassigned at the local level. The fixed and well understood nature of the TV transmitters makes it possible for unlicensed devices based on existing technology to coexist even using conservative operating assumptions. Given the attractive propagation characteristics of the TV broadcast bands, their use by unlicensed devices could quickly generate substantial benefits to consumers and businesses including the acceleration of the deployment of broadband services. Preliminary technical analysis conducted by Intel and testing performed by the Communications Research Centre Canada, on Intel's behalf, demonstrate that technically viable broadband services can be operated on a non-interfering basis with both analog and digital TV broadcast services in a major metropolitan area in which many overlapping TV service contours exist. Accordingly, Intel recommends that the Commission expeditiously begin a rulemaking proposing to permit unlicensed use of the broadcast television frequencies. At a minimum, the rulemaking should consider and quickly resolve those issues necessary to enable wireless broadband operation in the TV bands.

II. THE BENEFITS OF UNLICENSED USE

The Commission's Notice of Inquiry outlines the successful history of relatively low power, unlicensed devices sharing frequencies with authorized services. In particular, two significant changes were made to the Commission's Part 15 rules in 1985 and 1989 that fostered innovation and commercial success. First, spread spectrum transmitters were permitted to operate on an unlicensed basis on the ISM bands. Second, unlicensed transmitters were permitted to operate on most frequencies (but not TV broadcast and other restricted bands) provided they met tight emission limits.[1]

The Commission correctly concludes in this Notice that unlicensed use has been a tremendous success.[2] Its cost has been low and its benefits have been high. The opportunity cost of unlicensed use has been low because the use of unlicensed devices has not foreclosed or harmfully interfered with authorized uses. And in the relatively free environment created by the Commission's Part 15 rules, a raft of beneficial, new products and industry standards have been

[1] NOI at paras. 2-4.

[2] *Id* at para. 6.

developed and deployed in a rapid fashion.

The benefits from unlicensed use of the spectrum are nowhere better illustrated than by the marketplace and technical success of wireless LAN devices. Consider the advances made between the initial 802.11 specification and products available today:

- Speeds have increased from 1-2 Mbps to 54 Mbps; range has improved, while the costs of the equipment have plummeted.
- Products have moved from 4-5 chip solutions in 1999 to the 2-chip solutions prevalent today with much more of the radio frequency circuits integrated, allowing broad expansion into a number of products.
- In 1999, 802.11 PC cards and enterprise access points were available. Today, users can choose between 802.11a, 802.11b, 802.11g or dual-band products for enterprise, small offices, or homes.
- Sales have increased from 7.9 million wireless LAN chipsets in 2001 to a projected 23-25 million chipsets in 2002, according to Allied Business Intelligence.[3] Gartner estimated that over $2 billion worth of wireless LAN equipment was sold last year.[4] In-Stat projects that the Wi-Fi hardware market will grow to nearly $4 billion in 2004.[5]Jupiter Research reports that "57% of U.S. companies already support 802.11 networks, with an additional 22% planning to implement and support this technology in the next 12 months."… "[S]mall businesses (with less than $10 million in annual revenue) are leading deployment, with 83% stating that they either support 802.11 networks today or plan to in the next 12 months"… "71% of U.S. large businesses (defined as those generating $100 million or more in annual revenue) are supporting 802.11 networks or will do so in the next 12 months."[6]
- Public access locations are multiplying worldwide from airports to hotels to neighborhood coffee shops, and most recently, onboard commercial aircraft. Public Internet Project.org detected the presence of nearly 14,000 access points in Manhattan alone.[7] In the United States, AT&T Wireless, Wayport, T-Mobile and others sell access for notebook users with Wi-Fi capability.

The FCC Spectrum Task Force undertook a thorough review of spectrum policy

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[3] http://www.alliedworld.com/prhtml/wlic03pr.pdf.html

[4] "Wireless LAN Equipment: Worldwide, 2001-2007", Gartner, January 2003.

[5] "It's Cheap and It Works: Wi-Fi Brings Wireless Networking to the Masses", Instat, December 2002.

[6] Jupiter Research press release 3/27/03 http://www.internet.com/corporate/releases/03.03.17-80211mobility.html

including the merits of unlicensed use.[8] Many parties that participated in the Task Force's review stated that more spectrum should be made available to unlicensed devices. In its report the Task Force recognized advances in technology now make it possible to use spectrum more intensively:

> [G]iven the increased ability of new technologies to monitor their local RF environment and operate more dynamically than traditional technologies, the predictive models used by the Commission can be updated, and perhaps eventually replaced, by techniques that take into account and assess actual, rather than predicted, interference. … By operating in so-called white – or unused –spaces in the spectrum, software-defined radios can enable better and more intensive use of the radio spectrum.[9]

Use of TV broadcast spectrum by unlicensed devices presents just such an opportunity. New technologies and techniques could enable devices that would not generate harmful interference to the authorized users and would create the opportunity for valuable new uses for consumers and businesses. Moreover the characteristics of unlicensed devices could be compatible with digital television (DTV). New unlicensed devices capable of receiving ancillary DTV services could significantly boost their demand.

III. THE SUITABILITY OF THE BROADCAST TV BAND FOR UNLICENSED USE

Use of the television broadcast bands is well understood; the fixed nature of TV transmitters makes it possible for unlicensed devices based on existing technology to coexist in the same band even using conservative assumptions; broadcast channels are frequently vacant; and the propagation characteristics of the TV broadcast spectrum make it highly suited to a variety of uses.

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[7] http://publicinternetproject.org/research/research_sum.html

[8] Spectrum Policy Task Force Report ET Docket No. 02- 135 November 2002

[9] *Id*. at p. 14

Developing unlicensed devices to share TV bands is made easier by the fact that the TV bands and the receivers operating in them have been doing so for half a century. There is a huge body of data characterizing, analyzing and profiling the environment in which these devices will operate. The signal strength contours of service areas and receiver design and operation are well understood. In particular, the extensive DTV research, deployment and five years of operational experience are highly relevant to the development of wireless broadband devices which are likely to have characteristics similar to those of DTV.

Also the static, fixed nature of TV broadcasting makes sharing much easier than would be the case for services operating on an intermittent or mobile basis. As articulated in the NOI one method available for minimizing the potential interference of sharing devices is determining physical location and adapting their performance accordingly. This is possible because the operation and contours of existing TV broadcasters is well documented and centrally located in the Commission's database.

Sharing spectrum in this well-defined, stable environment is a manageable task for today's radio devices. The rapid advances in microprocessors have enabled nimble devices that can easily execute the algorithms necessary for mitigating interference.[10] Unlike the more ambitious wireless architectures envisioned by smart-agile radios, the technology required to implement sharing in the TV band by existing wireless broadband devices is much more modest than what is already incorporated in many wireless devices today. For example, current cell

[10] Indeed, smart radios have been developed that not only share spectrum in the TV band, but share an active TV channel. SIGFX http://www.sigfx.com has developed an SDR enabled system that actually shares spectrum with active TV stations to enable communications during inactive portions of the TV picture. The system is currently operating a trial of this technology in Mississippi USA.

phones already perform dynamic power control and execute sophisticated algorithms for coordination and roaming to implement spread spectrum modulation.

Examination of the overlapping coverage of multiple TV broadcast stations in the San Francisco Bay Area illustrates that 19 vacant TV channels exist even during the transition to DTV. The analysis in Appendix A ",Spectrum Sharing of Vacant TV Channels," demonstrates that in very conservative scenarios unlicensed devices can operate over ranges comparable to existing ISM band WLAN devices. For example, devices can operate within the grade B of one TV transmitter and within a few miles of the other transmitter and not interfere with TV receivers operating on the adjacent channels. Moreover, the number of vacant channels will increase as analog TV transmissions are phased out.

The attractive propagation characteristics of the TV broadcast bands make them highly suited to a variety of uses, particularly longer distance transmission. In rural areas and smaller metropolitan centers there are many vacant channels and operation on channels further removed from the adjacent channel will be possible and facilitate increased ranges. Fortuitously, in less congested rural areas, longer distance transmission might be most feasible and beneficial as an alternative means of providing last-mile broadband connections.

IV. PRELIMINARY TECHNICAL ANALYSIS

Preliminary technical analysis performed by Intel demonstrates that unlicensed use is technically feasible. In Appendix A",Spectrum Sharing of Vacant TV Channels," Intel provides the results of preliminary data studying the possibility of vacant channels. Appendix B, "Results of the Laboratory Evaluation of the Impact of Narrow and Wideband Signals Adjacent to TV Channels," undertaken by the Communications Research Centre Canada, an agency of Industry Canada, provides measurement data using off-the-shelf TV receivers that demonstrate that the desired-to-undesired (D/U) ratios used in Appendix A are applicable.

The feasibility study in Appendix A uses FCC criteria for digital TV (DTV) interference within a highly congested area:

- The Geographic area studied was San Francisco Bay area. This area includes three overlapping coverage areas and therefore creates severe near-far problems.
- FCC established D/U ratios for the planning of analog TV (NTSC) and DTV allotments in the US. These D/U ratios were verified to be applicable to candidate unlicensed waveforms by independent measurements, see Appendix B. For completeness multiple bandwidths were studied to gauge the appropriateness of various services in a sharing scenario.
- Power and other operating parameters were first calculated based on static "dumb" operation under worst case near-far scenarios and then adjusted for assumed smart device capabilities. The worst case near-far conditions considered one adjacent TV channel at the edge of the Grade B coverage contour (to establish the maximum power permitted at the unlicensed device), and the other within 10 kilometers of a 1 megawatt TV transmitter (to establish the interference environment in which unlicensed device must operate).

Based on this analysis, Intel believes that even in apparently congested areas significant white spaces exist that would permit unlicensed devices to provide valuable new services. Specifically, a digital broadband use appears suitable to a sharing scenario in the San Francisco Bay Area. Such broadband services would be possible on 19 channels. The range of the channels is dependent on the type of the adjacent TV channels (analog or digital) and the location of the unlicensed device with respect to the Grade B coverage contour. It was determined that ranges of 10 to 30 meters can be expected when the adjacent TV broadcast transmitters are widely separated and when the unlicensed device is close to the Grade B contour of one of the TV stations. Under more favorable conditions, applying to 13 of the 19 possible channels, ranges of up to 100 meters should be achievable. Thirteen good channels would provide very efficient frequency reuse. The Intel analysis demonstrates that both narrow and wideband services are possible.

V. SCOPE OF THE RULEMAKING

Accordingly, Intel believes that the Commission should begin a rulemaking proposing rules that would permit unlicensed devices to operate on the TV broadcast bands. At a minimum, the rulemaking should expeditiously consider and resolve those issues necessary to enable wireless broadband operation in the TV bands:

- Location based technology parameters for ascertaining grade B contours and the proximity of other primary users of the TV band spectrum.
- Dynamic Frequency Selection (DFS) Threshold values for non-interfering operation. The NPRM should focus on relative, rather than absolute parameters.
- Rules authorizing the use of "smart antennas" that would allow devices using non-integrated antennas to determine operating parameters and orientation of antennas that can physically interface to the device.

Below are Intel's answers to selected questions raised in the NOI.

- WHAT POWER AND/OR FIELD STRENGTH LIMITS ARE NECESSARY FOR UNLICENSED TRANSMITTERS WITHIN THE TV BANDS TO PREVENT INTERFERENCE TO TV RECEPTION? COULD UNLICENSED DEVICES OPERATE IN TV BANDS WITH A POWER GREATER THAN THE 1 WATT MAXIMUM PERMITTED FOR PART 15 DEVICES IN THE ISM BANDS OR POWER GREATER THAN THE GENERAL PART 15 LIMIT?

The power permitted should be dependent on the field strength and the type, analog or digital, of the two adjacent channel TV signals. For instance, if one or both DTV signals are at the limits prescribed for the grade B coverage, then a power level of -5 dBm might be appropriate for broadband unlicensed devices. If both TV signals are at higher levels, then the permitted unlicensed device power should be correspondingly greater.

- WHAT SEPARATION DISTANCES OR D/U RATIOS SHOULD BE ESTABLISHED BETWEEN UNLICENSED DEVICES AND THE SERVICE OF ANALOG, DIGITAL, CLASS A AND LOW POWER TV AND TV TRANSLATOR STATIONS?

Intel recommends using values equivalent to those used by the FCC for planning DTV allotments.

Mode	Recommended D/U
Lower unlicensed device into NTSC	-17
Upper unlicensed device into NTSC	-12
Lower unlicensed device into DTV	-26
Upper unlicensed device into DTV	-28

Table 1 Adjacent Channel D/U Ratio

- WHAT ASSUMPTIONS SHOULD BE USED TO DETERMINE THESE PROTECTION CRITERIA? SHOULD TV STATIONS BE PROTECTED ONLY WITHIN THEIR GRADE B OR NOISE LIMITED SERVICE CONTOURS, OR SHOULD UNLICENSED DEVICES BE REQUIRED TO PROTECT TV RECEPTION FROM INTERFERENCE REGARDLESS OF THE RECEIVED TV SIGNAL STRENGTH?11 IS PROTECTION NECESSARY ONLY FOR CO-CHANNEL AND ADJACENT CHANNEL STATIONS? WHAT SPECIAL REQUIREMENTS, IF ANY, ARE NECESSARY TO PROTECT TV RECEPTION IN AREAS WHERE A STATION'S SIGNAL IS WEAK?

DTV picture quality degrades rapidly as the signal to interference ratio degrades below a threshold of –55dBm. The grade B contours are established based on this threshold and hence interference, from unlicensed devices outside of the grade B contour, should not be discernable from the background noise.

Protecting TV reception from interference regardless of the received TV signal strength would destroy the vast majority of the economic value that could be derived from a reasonable sharing regime. Intel believes the Commission should take a balanced approach to evaluating the total benefit and not impose unduly stringent requirements that would cripple the deployment of

[11] *See* 47 C.F.R. §§ 73.683(a), 73.633(e) and 73.6010(a) and (c). Low power TV stations, TV translator and TV booster stations may not cause interference to analog or digital TV stations regardless of the quality of the reception or the strength of the signal used. *See* 47 C.F.R. § 74.703(b).

these high-value devices.

- WHAT ARE THE SPECIFIC CAPABILITIES THAT AN UNLICENSED TRANSMITTER SHOULD HAVE TO SUCCESSFULLY SHARE SPECTRUM WITH LICENSED OPERATIONS IN THE TV BROADCAST BAND WITHOUT INTERFERENCE?

The unlicensed device must have the capability to determine what TV channels are in use at its location. Based on consideration of the signal strength and type of TV signal applicable to each channel, it should have the ability to select and prioritize the TV channels that could be used on a non-interfering basis.

The rulemaking should focus on dynamic, rather than static characteristics and attributes. For example, the recent agreement between industry and the U.S. government regarding DFS detection thresholds in the 5250-5350 MHz and 5470-5725 MHz bands limits power as function of the possibility of interference as determined by the threshold value. A device must operate at a lower power when it has a threshold with lower sensitivity. Although the lower sensitivity means that the device could operate in closer proximity to a radar installation, its lower power level also means that transmissions will be smaller, and hence the over-all possibility for interference remains small.

Such an approach is especially well suited for wireless broadband devices, which are often deployed as a system in a small physical location. Many devices are used at very short range of a few meters and can therefore operate with very low power resulting in minimal potential for interference. Such devices should be allowed broadest possible freedom. Accordingly, the rulemaking should explore permitting power to vary as a function of the device's potential for interfering—either based on the threshold of received signal or physical location relative to active channels.

- SHOULD ANY ANTENNA REQUIREMENTS BE IMPOSED? CAN TECHNOLOGIES SUCH AS "SMART

ANTENNAS", WHICH AUTOMATICALLY CHANGE THEIR DIRECTIVITY AS NECESSARY, ASSIST UNLICENSED DEVICES IN SHARING THE TV BANDS? SHOULD UNLICENSED DEVICES BE REQUIRED TO USE AN INTEGRATED TRANSMITTING ANTENNA AND BE PREVENTED FROM USING EXTERNAL AMPLIFIERS AND ANTENNAS?

"Smart antennas", which automatically change their directivity as necessary, may assist unlicensed devices in sharing the TV bands and therefore rules should not preclude their use. However, to assure non-interfering operation unlicensed devices will need to be cognitive of the parameters and orientation of their antennas. Intel believes that it is not necessary to impose antenna requirements on the unlicensed devices operating in the TV band. This will allow system designers the flexibility to develop services that most effectively utilize this additional spectrum. Intel does not believe that developers should be prevented from using external amplifiers and antennas in applications where SAR is not an issue.

VI. CONCLUSIONS

For the reasons set forth above, Intel recommends that the Commission expeditiously begin a rulemaking proposing to permit unlicensed use of the television frequencies. At a minimum, the rulemaking should consider and quickly resolve those issues necessary to enable wireless broadband operation in the TV bands.

Respectfully submitted

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APPENDIX A

SPECTRUM SHARING OF VACANT TV CHANNELS

I. REFERENCES

(1) JTCAB-97-03 Digital Television Service Considerations and Allotment Principles.

(2) JTCAB-98-05 Addendum to Digital Television Service Considerations and Allotment Principles.

(3) FCC Final DTV Channel Allotment Plan

II. INTRODUCTION

In responding to the recent FCC NOI regarding the possible use of vacant TV channels for unlicensed use, it is useful to first explore the constraints that would be imposed by the existing TV allotments. These constraints will be most severe in metropolitan areas where there is a high density of broadcast TV channels. In rural areas there will be few constraints. In anticipation of identifying a service that could be implemented universally, it is appropriate to first examine the constraints applicable within a typical metropolitan area. From such an exploration it is possible to estimate the nature of channels that might typically be available and from there to examine the power levels that would be permissible to use on a non-interfering basis. Once these constraints are understood the nature of any universal services that might be provided by Vacant Channel Devices (VCDs) can be examined.

This approach does not preclude the possibility of designing VCD systems that could usefully serve the rural areas using system parameters that would not be useable in metropolitan areas. This study should therefore be viewed as complementary to, rather than competitive with, the comments of Shared Spectrum Company.

III. GENERAL CONSTRAINTS

The TV channel allocations are a primary service and will therefore be required to be protected from interference from any users of vacant TV channels. From a legal perspective this protection may be limited to the assigned coverage area of each TV station. Typically, this is 88.5 kms. But from a practical perspective the protection will likely have to apply to fringe areas in which many TV users enjoy reception from remote TV stations, up to 120 kms away. Today, this applies to analog NTSC channels in which the picture quality degrades gracefully with the signal to noise ratio. Since many of these fringe area receivers already experience some picture quality degradation it may be difficult for them to associate any further degradation with the use of vacant channel devices. For the digital DTV services, which are just now emerging, the picture quality degrades very rapidly. A study by Industry Canada, Reference 1, reports that "the picture degrades from barely perceptible degradation to unusable with a reduction in the signal to noise ratio of only 1 dB." It should therefore be anticipated that DTV users will readily associate and protest any interference due to vacant channel devices.

IV. VACANT CHANNELS

The major allotment of TV channels is in large metropolitan areas, particularly in those areas where there are multiple city centers. Such a representative area is the Bay Area of California. The Bay Area includes four city locations from which there is some degree of overlapping coverage. A fifth location at Salinas provides some overlapping coverage, but does not affect the primary coverage areas. A complete listing of existing NTSC and proposed DTV allotments from the four sites is shown in Annex A.

The separation between inter-city sites is typically 100 to 130 kms and the 90/90 coverage range from the transmitter sites ranges from 50 to 115 kms. This results in an area of about 25,000 square kms in which there would be good coverage from all four sites, see Figure 1. Within this area it can be seen from the table in Annex A that in the LO and Hi VHF bands virtually all channels are allotted. However in the UHF band there are a number of isolated channels, channel pairs and a few groups of three or more channels in which sharing may be considered. Because there are many more situations where there will be TV allotments in the adjacent TV slot, it is first worth considering the conditions under which operation in the adjacent slot might be possible on a non-interfering basis. A less constraining condition will exist where the shared channel is in the second adjacent channel, but there are few instances where this is possible.

V. SERVICE REQUIREMENTS

The FCC has established the following service conditions for a land mobile service operating in the TV and DTV bands. Note the land mobile services are narrow band voice and data channels operating within a 25 kHz or lower bandwidth.

§ 27.60 TV/DTV interference protection criteria.

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

(1) The minimum D/U ratio for co-channel stations is 40 dB at the hypothetical Grade B contour (64 dB μV/m) (88.5 kilometers (55 miles)) of the TV station or 17 dB at the equivalent Grade B contour (41 dB μV/m) (88.5 kilometers (55 miles)) of the DTV station.

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

Considering the co-channel situation, this means that the maximum permissible interfering contour from a narrow band VCD at the limit of the TV protected service area is:

analog: 64 - 40 = 24dBμV/m
DTV: 41 - 17 = 24dBμV/m

Likewise, for adjacent-channel situations, the maximum permissible interfering contour from a narrow band VCD at the limit of the TV protected service area is:

analog: 64 - 0 = 64dBμV/m
DTV: 41 – (-23) = 64dBμV/m

For a second adjacent channel assignment there will be some further increase in the level of the interfering contour that can be tolerated, but this is dependent on the selectivity of the receiver. Although not explicitly defined by the FCC, a value may be inferred from the D/U ratio which has been defined for the Taboo channels N-2 and N+2. Thus, for DTV into NTSC, the field strength in the 2^{nd} adjacent channel could be 6 db in excess of the adjacent channel and for NTSC into DTV the 2^{nd} adjacent channel it would change to 14 dB.

For wideband interferers the data used by Industry Canada to determine protection ratios between analog and digital TV channels clearly show that the necessary protection ratios are less severe than for narrow band interferers, see reference 1.
Specific adjacent channel protection ratios used between NTSC and DTV are:

Mode	Measured D/U	D/U used for the channel allotment plan
Lower DTV into NTSC	-17.43	-16
Upper DTV into NTSC	-11.95	-12
Lower NTSC into DTV	-47.73	-48
Upper NTSC into DTV	-48.71	-49
Lower DTV into DTV	-41.98	-27.2*
Upper DTV into DTV	-43.17	-27.2*

Table 1 Adjacent Channel D/U Ratio

*Values revised in accordance with
AHG_ADD003K Issue 1, May 26 1998 Addendum to
Digital Television Service Consideration and Allotment Principles

Table 1 indicates that in the adjacent channel the following field strength for wideband interfering signals may be acceptable:

NTSC 64-(-12) = 76 dB μV/m
DTV 41-(-27) = 68dBμV/m

Further testing to determine the values applicable to candidate wideband waveforms is planned.

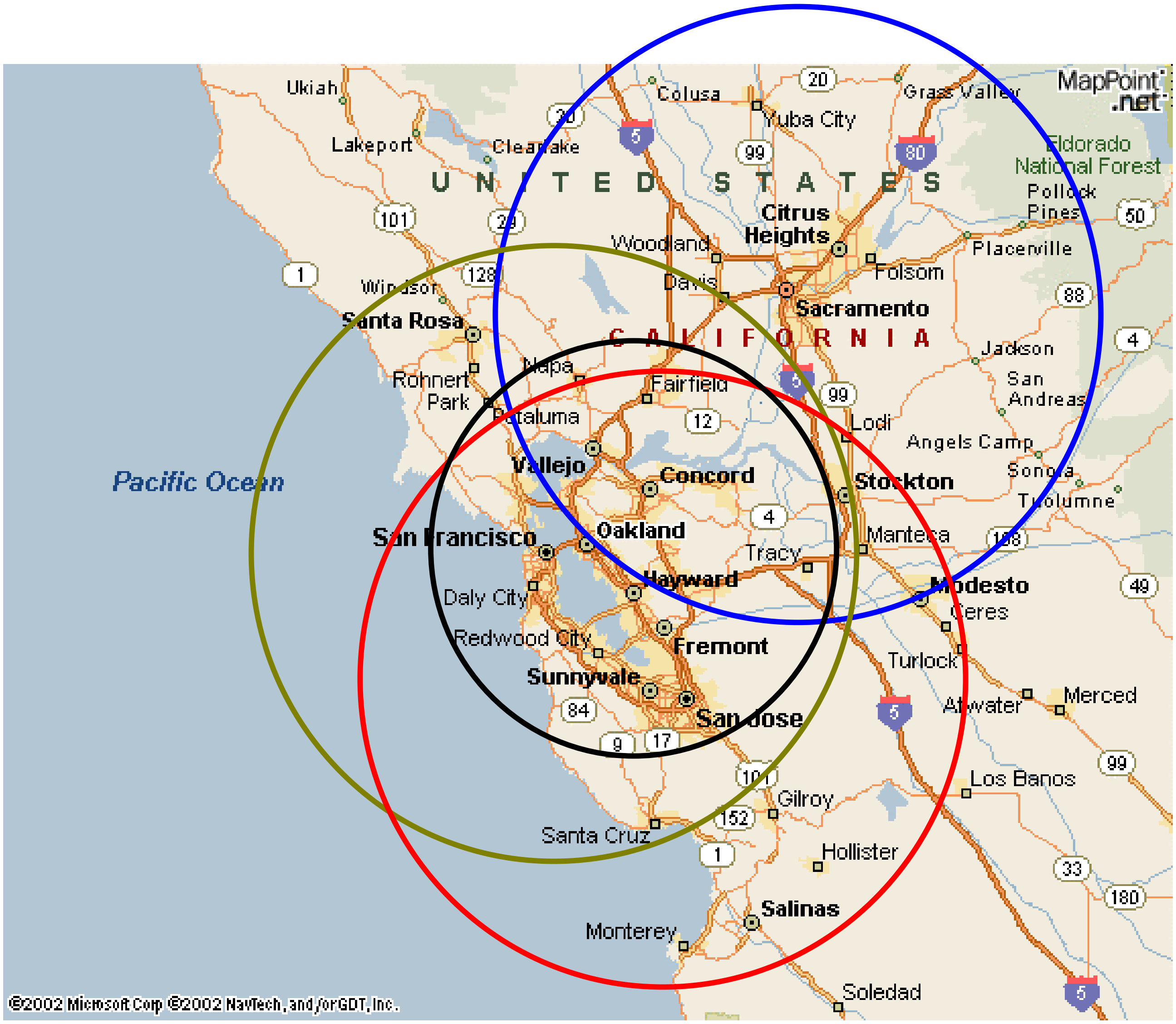
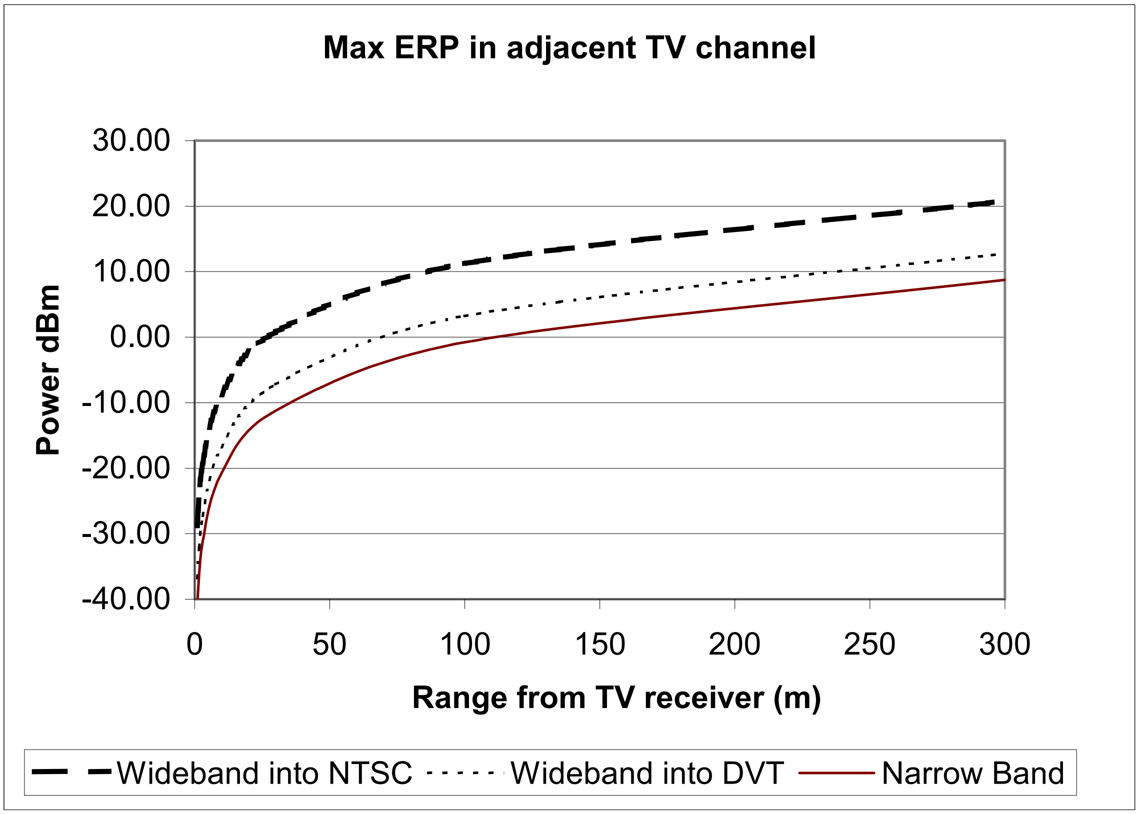


Figure1 Bay Area TV Coverage

VI. VACANT CHANNEL SERVICE CONSTRAINTS

A. VCD Transmit Power

Assuming that dynamic power control is not provided within the Vacant Channel Device, the maximum allowable power levels that would likely be permitted in a slot adjacent to a TV channel will be determined by the field strengths at the edge of the grade B coverage contour and the separation of the VCD from the TV receiver antenna. Based on the field strengths and protection ratios discussed in Section V, the allowable ERPs are as shown in Figure 2.



Figure

Figure 2 Non-interfering VCD Transmitter Power*

* For free space propagation VCD Power (dBm)=30+10log(E^2R/30

Where E= permissible field strength in volts /meter (64 dBμV/m=.0016 V/m)

R = range in meters

B. VCD Receive Signal Strength

The power assigned to the most of the allotted UHF TV channels varies from a few hundred kilowatts up to nearly 4 megawatts. For this first analysis a median value of 1 megawatt will be used. The adjacent channel emissions in a 500 kHz bandwidth are shown by the FCC emission masks as being 60 to 78 dB below peak power for DTV and 60 to 88 dB for NTSC signals. The signal strength required to achieve a 20 dB signal to noise ratio in the presence of a TV signal in the adjacent channel is dependent on the VCD bandwidth, the TV transmitter power and the range from that transmitter. The minimum signal strengths required in a 25 kHz, 500 kHz and 5 MHz slot close to a 1 megawatt TV channel are shown in Figure 3. Figure 4 shows the equivalent VCD transmitter powers required to generate the required signal level at the VCD receiver as a function of VCD to VCD range assuming perfect isotropic VCD antennas.

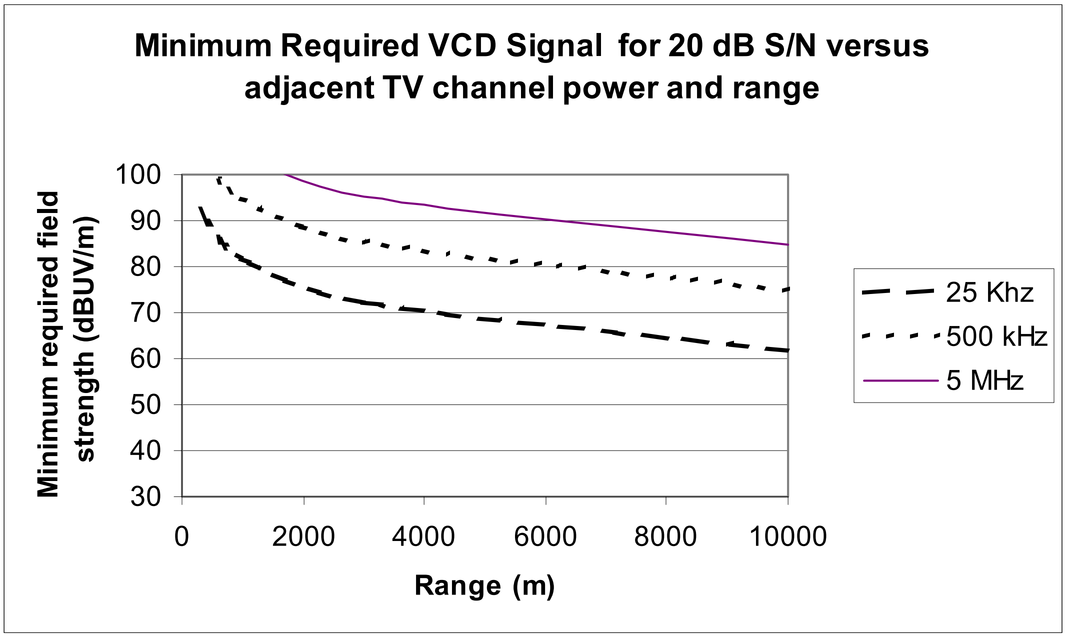


Figure 3 Signal strength required at VCD receiver for 20 dB S/N

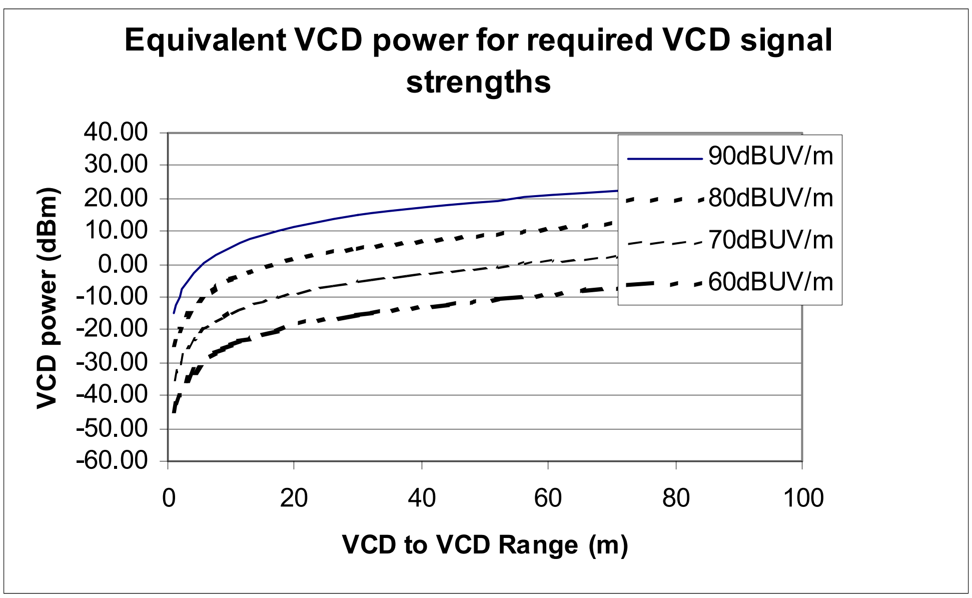


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Figure 4 Power required by VCD transmitter

VII. DISCUSSION

A. Adjacent channels

From the channel allocation tables, it can be seen that several situations can exist surrounding the vacant channels. The worst case is where the adjacent TV channels are located in widely separated locations and at least one channel is a DTV signal. The best case is where the adjacent channels are collocated and both operate NTSC. Under the worst case scenario, one TV channel should be assumed at the fringe of its coverage area. This will limit the power permitted in the VCD. The other will be assumed to be at about

10 % of the range of the TV station (10 Km). This will determine the minimum usable signal for the VCD.

From Figure 2 the maximum VCD power that would be allowed at 50 meters from a TV receiver antenna on the fringe of the TV coverage area would be –8 dBm for a narrow band VCD. Up to +5 dBm may be permitted for a wideband VCD adjacent to a NTSC channel and -4 dBm adjacent to a DTV channel.

From Figure 3 it can be seen that, for a 20 dB signal to noise ratio, the required narrow band VCD field strength is close to 70 dBUV/m when the VCD is at a distance of 10km from a 4 megawatt TV transmitter. From Figure 4 the maximum range of the narrow band VCD transmitter when operating at –8 dBm is about 20 meters. This range is compatible with the operation of a PAN but the narrow band channel supports a much lower data rate than existing PANs such as Bluetooth.

The equivalent ranges for wideband systems operating at a power level of –4 dBm is about 10 meters when next to a DTV channel and 30 meters when operating at +5 dBm next to NTSC channels.

Under more favorable conditions greater ranges can be achieved. For example, improvements in VCD system performance can be achieved by intelligently exploiting other situations. This points to the use of a cognitive radio rather than a conventional radio. A particular example that comes to mind and can be easily exploited is the case where the adjacent TV allotments are co-sited. In this case the TV signal strength increases as the VCD approaches the TV transmitters. This allows the radiated power from the VCD to be increased as the TV signal strength increases without causing interference to a nearby TV receiver. This should allow ranges of up to 100 meters in many cases. In order to perform this function it is necessary to know that the two adjacent TV channels are collocated. This can be derived from the known position of the VCD and a simple look up table or it can be inferred from a measurement of the two adjacent TV channel field strengths. In either case it is necessary to know the two signal strengths in order to know by how much the VCD power can be increased. We believe that measuring the signal strength will prove to be the most cost effective solution.

B. Second adjacent channels.

Where there are groups of three or more vacant TV channels one or more of this group will not be subject to the constraints as discussed above. Based on the emissions mask applicable to the TV transmitters, the second adjacent channel emissions are at least 20 dB below the adjacent channel emissions. Also, TV receiver susceptibility is expected to be reduced by at least 10 dB, but this number is less well known as the TV receiver performance is less strictly regulated. The system link budget for the VCD is therefore increased by a minimum of 20 and possibly as much as 30 dB. This would increase the range by a factor of 30 :1 in free space and approximately 10 to 1 under NLOS conditions.

VIII. VCD CHARACTERISTICS

A. Bandwidth

Based on the nature of the services to be provided a number of possible channel bandwidths for the VCD will be considered. These are:

1. Single channel voice or low rate data at in a 25 kHz channel. This option could allow as many as 240 25 kHz channels in a 6 MHz TV channel slot. Making allowances for guard bands a more realistic number is 200 channels. With worst case VCD to VCD ranges of less than 60 meters when closer than 10 kms to nearest adjacent channel TV transmitter this bandwidth is expected to find few useful applications.

2. a) Medium rate data at 500 kHz bandwidth. This option could provide up to 12 channels, although the two outside channels would be of reduced quality. A more conservative system

design would be based on 10 channels. Worst case, VCD to VCD ranges of about 50 meters should be achievable at data rates of up to 1 Mbits/s. (Higher data rates are possible but would require more complex modulation.) This is comparable with high power Bluetooth PANs and, as with Bluetooth, it is only likely to find user acceptance if the VCD's are extremely low cost. Thus, a VCD system may employ very simple modulation and detection techniques with actual data rates being in the range of 200 kbps. This could be useful for embedded applications in domestic appliances in which the channel is preset based on a known fixed operating position.

b) Mobile applications are also possible but will require a cognitive device in order to select usable channels based on location. This cognitive capability can be used to facilitate automatic adjustment of power thus providing increased range.

3. a) High throughput 6 MHz channels. At this bandwidth the minimum signal required is 10 dB greater than the 500 kHz option and the worst case range is around 10 meters for DTV and 30 meters for NTSC.

   b) Through the use of cognitive techniques, which will enable higher power output and a lower signal threshold to be exploited, ranges of 100 meters or more should be available through out much of the TV service area. The cognitive VCDs would also facilitate a means of intelligent frequency division multiple access for the VCD services, through the use of different vacant TV channels, and would therefore relieve much of the congestion experienced with 802.11b based LANs.

4. Contiguous multiple 6 MHz channels. Very few sets of contiguous channels are available so that there is little opportunity to exploit this option. In any case the range would be inferior to the adjacent channel case of option 3 and would have few applications.

5. Non-contiguous multiple 6 MHz channels. This option requires a very complex VCD transmitter and receiver. As the range would be comparable to the adjacent channel case of option 3 this option is not expected to be very useful.

It should be noted that the desired to undesired protection (D/U) ratios were taken from Reference 2, JTCAB-98-05 Addendum to Digital Television Service Considerations and Allotment Principles. These D/U ratios are less stringent than the protection ratios used by the FCC for narrow band interferers. JTCAB values were used for analysis of both the 500 kHz and the 5MHz cases in 2 and 3 above. This results in the unexpected result that shows wideband devices having comparable range to the narrow band devices. The increased range may however be dependent on the modulation characteristics and further work is required before the range can be more accurately determined.

IX. CONCLUSIONS

The analysis undertaken by Intel has shown that in a large metropolitan area a significant number of vacant (white space) TV channels exist. For the most part, an active TV Channel will be found on the lower, upper or sometimes both adjacent channels to the white space. An analysis of the current TV channel allotment plan clearly illustrated the different near far conditions that would be applicable to the various channels. The worst case is when the upper and lower adjacent TV transmitters are widely separated in distance and an unlicensed device is close to one and very far from the other. A more favorable situation exists when the upper and lower adjacent TV transmitters are geographically collocated.

Based on the published D/U ratios and the field strength at the Grade B coverage contour, the analysis shows (as a function of range) the maximum power that could be transmitted by an unlicensed device operating within the adjacent white space without causing interference to a nearby TV receiver. Receive power levels between –5 and +5 dBm were considered to be feasible for DTV and NTSC channels respectively.

The analysis then considered the minimum signal strength required for the unlicensed device to operate correctly throughout the coverage area of a high power TV station. From the permissible power levels and minimum signal strength requirements, it was shown that both narrow band and wideband unlicensed devices could be expected to achieve a minimum range of 10 meters under worst case conditions and ranges of up to 100 meters under more favorable conditions.

From the above information it can be concluded that operation of unlicensed devices in the TV band white space is feasible and that significant performance enhancements are possible through the use of "smart" solutions. These devices need to be able to adapt their channel and output power in accordance with their location with respect to the existing TV transmitters.

a) Annex A- Listing of allotted TV channels in the San Francisco Bay Area

from Reference 3

Frequency (MHz)	CITY	CHAN #	CHAN TYPE
54-60	OAKLAND	2	NTSC
60-66	SACRAMENTO	3	NTSC
66-72	SAN FRANCISCO	4	NTSC
76-82	SAN FRANCISCO	5	NTSC
82-88	SACRAMENTO	6	NTSC
174-180	SAN FRANCISCO	7	NTSC
180-186		8	
186-192	SAN FRANCISCO	9	NTSC
192-198	SACRAMENTO	10	NTSC
198-204			

SAN JOSE

11
NTSC

204-210

SAN JOSE

12
DTV

210-216

13

470-476

SAN FRANCISCO +

14
NTSC

SACRAMENTO

14
DTV

476-482

SAN FRANCISCO

15
DTV

482-488

16

488-494

17

494-500

SAN FRANCISCO

18
DTV

500-506

SAN FRANCISCO

19
DTV

506-512

SAN FRANCISCO

20
NTSC

512-518

SACRAMENTO

21

518-524

22

524-530

23

530-536

SAN FRANCISCO

24

DTV

536-542

25

542-548

SAN FRANCISCO

26

NTSC

548-554

SAN FRANCISCO

27

DTV

554-560

SAN FRANCISCO

28

DTV

560-566

SACRAMENTO

29

NTSC

566-572

SAN FRANCISCO

30

DTV

572-578

SACRAMENTO

31

NTSC

578-584

SAN FRANCISCO

32

NTSC

584-590

SACRAMENTO

33

DTV

590-596

OAKLAND

34

DTV

596-602

35

602-608

SAN JOSE

36
NTSC

608-614

37

614-620

SAN FRANCISCO

38
NTSC

620-626

SAN FRANCISCO

39
DTV

626-632

SACRAMENTO

40
NTSC

632-638

41

638-644

42

644-650

43

650-656

SAN FRANCISCO

44
NTSC

656-662

SACRAMENTO

45
DTV

662-668

46

668-674

SAN JOSE

47
DTV

674-680

SAN JOSE

48
NTSC

680-686

SAN JOSE

49

DTV

686-692

SAN JOSE

50

DTV

692-698

51

698-704

52

704-710

SACRAMENTO

53

DTV

710-716

SAN JOSE

54

NTSC

716-722

SAN JOSE

55

DTV

722-728

56

728-734

SAN FRANCISCO

57

DTV

734-740

58

740-746

SACRAMENTO

59

746-752

60

752-758

SAN FRANCISCO

61

DTV

758-764

	62
	764-770
	63
	770-776
	64
	776-782
SAN JOSE	65 NTSC

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ADDENDUM
DIGITAL TELEVISION

Service Considerations
and
Allotment Principles

Prepared by
JTCAB Ad Hoc Group on DTV Planning Parameters

January 1998
ADDENDUM
DIGITAL TELEVISION
Service Considerations and Allotment Principles

Introduction

This addendum provides an update of the planning criteria presented in the planning document issued in August 1997. The DTV to DTV adjacent channel criteria is improved as a result of information derived from recent tests. A summary of the final planning criteria used to prepare the Transition Plan is given.

Adjacent Channel Criteria

Background

The technical planning factors of the planning document AHG_DTV003K for adjacent channel interference (same as used by FCC) are based on the performance of the ATSC DTV system measured under laboratory conditions. In the adjacent channel interference tests, the interfering DTV signal had little or no out-of-band emissions with the result that the emissions were well below the proposed RF Mask limiting sideband emissions. Recent adjacent channel interference tests (done after the issue of the FCC Report and the Planning Document AHG_DTV003K) were conducted using a DTV signal with out-of-band emissions which approximated the shape of the RF emission mask. The evaluation clearly demonstrated that the planning factors underestimated adjacent channel DTV to DTV interference by as much as 22 dB.

Investigation and Results

The results of the adjacent channel interference analysis showed the need for new protection ratios. CRC and the planning committee investigated first adjacent channel DTV-DTV and DTV-NTSC interference using different channel filters which provide rejection of out-of-band emissions greater than that required by the FCC emission mask. New protection ratios matched with the filter characteristics were developed to meet the adjacent channel interference threshold. The results show that filtering alone cannot provide the necessary discrimination to meet the DTV to DTV adjacent channel protection requirements. The DTV-DTV adjacent channel protection ratio was established at -27 dB for the "tight mask" filter and for higher order and more expensive filters, the protection ratios were -29 dB for a 7 th order Chebychev filter and -37 dB for a 6 th order elliptic filter. In addition, in a report on tests of an actual transmitter installation it is shown that transmitter optimization for correction and linearity can achieve as much as 13 dB reduction below the FCC mask for the out-of-band emissions at the channel band edge and beyond. Thus with this optimization improvement, it may be possible to reduce adjacent channel interference criteria and in many cases the external filtering required would be much less. For the DTV to NTSC case, use of the "tight mask" (see appendix 3 of Planning Document AHG_DTV003K) provides the required margin. The results of this investigation are included in Appendix 1 of this Addendum.

New Adjacent Channel Planning Criteria

Based on the results of the investigation, the planning committee adopted new DTV-DTV adjacent channel protection ratios and the use of the "tight mask" for the RF Emission Mask for the allotment planning of adjacent channel placements. The protection ratio for adjacent channel DTV to DTV interference was set at -27 dB for both upper and lower adjacent channels. Based on this protection ratio, revised Canadian Separation Distance Tables were produced and used for the development and allotment of the DTV channels in the transition plan.

Planning Criteria Summary

General

The primary objective in allotment planning for the introduction of Over the Air (OTA) Digital Television (DTV) is to provide a DTV channel for each existing NTSC TV assignment and allotment and to provide a DTV coverage comparable to the existing TV broadcasting service. Each DTV channel is allotted/assigned based on service replication of the coverage of the existing NTSC allotment or station using the maximum parameters for the class of the existing allotment or station or the present parameters if less. The DTV channel is paired with the NTSC station or allotment and assumed to be located at the same site as the paired NTSC station or allotment. A flex factor of 8 km is included for the location of the DTV transmitter to allow for cases where the DTV service cannot be accommodated at the existing NTSC site. Protection from interference to both NTSC and DTV services extends to the coverage contours based on their maximum parameters. The planning approach will attempt to minimize interference into both NTSC and DTV equally. The service availability is based on providing coverage in a service area with an availability of (90,90) i.e. at 90% of the locations and 90% of the time.

Receiving Considerations

For DTV service in Canada, the figure of 5 dB is used (achieved by the use of a low noise preamplifier installed on the antenna mast to minimize down lead loss effect). For the final allotment planning in Canada, the following receiving system parameters are used.

Parameter	Low VHF	High VHF	UHF
Frequency MHz	69	195	645
Antenna Gain (dipole) dB	6	8	10
Front to Back Ratio dB	6	12	16
Downlead Loss dB	1.05	1.81	3.29
Balun 300/75 Loss dB	0.5	0.5	0.5
Receiver Noise Figure dB	5	5	10
Man made Noise dB (Ta equiv.)	8.2	1	0
LNA Noise Figure (dB)	5	5	5
LNA Gain (dB)	20	20	20

Based on partitioning equally divided between noise and interference, a C/N = C/I = 19.5 dB is proposed at the DTV protected contour. The minimum required field strength for the three TV bands using the parameters proposed for the final Canadian allotment planning is **35 dBµV/m** for the low VHF band, **33 dBµV/m** for the high VHF band and **39 dBµV/m** for the UHF band compared to 47, 56 and 64 dBµV/m respectively for NTSC. The protection ratios adopted for Canadian allotment planning are based upon the values resulting from analysis of noise partitioning and interference for co-channel and first adjacent channel and the values from the measurements and tests of the Grand Alliance DTV system.

DTV/NTSC System Protection Ratios

Parameter	Value(dB)
Carrier-to-Noise Ratio	+19.5
Co-channel D/U Ratio	
DTV into NTSC	+33.8
NTSC into DTV	+7.2
DTV into DTV	
Adjacent Channel D/U Ratio	+19.5
Lower DTV into NTSC	-16
Upper DTV into NTSC	-12
Lower NTSC into DTV	-48
Upper NTSC into DTV	-49
Lower DTV into DTV	-27.2

Upper DTV into DTV	-27.2

Transmitting Considerations

The necessary ERP to produce the required field strength for the noise limited contour at a given distance for the different classes of stations assuming replacement channels in the three TV bands, low VHF, high VHF and UHF, was selected for the required time and location availabilities. Separation Tables Separation distances provide an efficient and effective means for managing interference between NTSC stations and DTV allotments and this approach was used to determine the technical acceptability of DTV channel allotments. The separation tables are based on an equal partitioning between noise and interference in the DTV to DTV case and to keep a degree of balance between interference from NTSC to DTV and from DTV to NTSC. The tables give the separation distances required to protect the TV services of the different classes of stations and form the basis for allotting the frequencies to the DTV service areas.

Short Spacing of Channels

Although most of the channels in the transition plan were originally selected using the appropriate separation distances and an 8 km siting flexibility, the addition of the remaining channels led to a majority being short-spaced. To permit review of the most serious cases without excessive delay, the following guidelines were set:

a) regular stations (DTV or NTSC) - interference up to 10% of the service area (calculated at maximum parameters for the class) is permitted.

b) low power stations or unused allotments - interference up to 20% of the service area is permitted.

All cases not meeting these guidelines were studied using PREDICT and MAPINFO and areas not over Canadian land were eliminated. If the guidelines were still not met, appropriate power reductions were indicated or if the interference was between two DTV channels, one or both were designated as a transition channel only. In a few cases, a low power station is permitted higher power as an alternate to limiting a regular station’s power.

APPENDIX B

Results of
The Laboratory Evaluation
of the Impact of
Narrow and Wide band Signals Adjacent to TV Channels

Final Report
(Version 3.0)

Prepared by the

COMMUNICATIONS RESEARCH CENTRE CANADA

For

INTEL CORPORATION

April 10, 2003

Communications Research Centre
Centre de recherches sur les communications

EXECUTIVE SUMMARY

The Communications Research Centre Canada (CRC) carried out laboratory tests to evaluate the effect of the interference from narrow (700 kHz) and wide band (5.4 and 6 MHz) signals on digital (ATSC 8-VSB) and analog (NTSC) signals transmitted on TV Channels. The Intel test signals are representative of OFDM signals used in some classes of unlicensed devices and have not been designed to minimize interference to TV receivers. It was subsequently discovered that the Intel test signals used in the tests exhibited a 5 dB tilt and a further test was conducted to determine how this tilt may have affected the measured D/U ratios.

The main results from the laboratory tests are summarized below:

<u>DVT Channels</u>

- Meets the lower and upper adjacent channel protection ratios of DTV into DTV for the USA (see Appendix C). for wide band (5.4 and 6 MHz channel BW) and narrow band interference signals

<u>NTSC Channels</u>

- Meets the upper adjacent channel protection ratios of DTV into NTSC for the USA (see Appendix C). for wide band (5.4 and 6 MHz channel BW) and narrow band interference signals
- Does not meet the lower adjacent channel protection ratios of DTV into NTSC for the USA (see Appendix C). for wide band (5.4 and 6 MHz channel BW) and narrow band interference signals

One possible explanation as to why the wide band signals doesn't meet the protection ratio for the lower adjacent channel into NTSC is the tilt in the INTEL signal's spectrum. The upper side is around 5 dB higher than the lower side. Also the side lobes created in the first MHz of the upper adjacent channel is around 6 to 8 dB higher than the lower adjacent channel. If the test results for the INTEL signal of 5.4 MHz channel bandwidth are corrected by this 6 to 8 dB they will be very close to meeting the FCC protection ratio requirements. Subsequent test conducted with a flattened 6MHz test signal indicates that the tilt is a factor.

In the case of the narrow band signal, it could be the side lode of –35 dB in the first adjacent channel is too high for N+2 to meet the upper adjacent channel protection ratio of DTV into NTSC. It is also too high to meet the entire protection ratio in the case of N+1.

The test results indicate that when signals representative of the type used in many unlicensed devices are operated in the adjacent TV channel they can be expected to cause no more interference than TV signals in the adjacent channel.

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1 INTRODUCTION

The Communications Research Centre Canada (CRC) carried out a preliminary laboratory evaluation in response to a request from INTEL. This report outlines the results of the laboratory evaluation on the effects of interference from narrow and wide band signals on digital (ATSC 8-VSB) and analog (NTSC) signals transmitted on TV Channels. The tests were carried out in March 2003.

2 PROJECT DESCRIPTION

In response to the shortage of available spectrum the FCC and other worldwide regulatory bodies are considering the sharing of vacant TV channels with other services. Given the existing allotment plans these services would in all probability be located in channels adjacent to existing television services. These television services could be based on any of the current analog television standards or the emerging digital standards. In order to determine the viability of providing alternative services in vacant TV channels it is necessary to understand the susceptibility of TV receivers to adjacent channel interference. To date most studies have focused on the interference from adjacent channel TV signals or from narrow band (12.5 kHz) land mobile signals. The purpose of the measurements defined in this proposal is to characterize the TV receiver susceptibility to narrow and wide band signals sources such as may be applicable to low power WLAN applications.

To do so, INTEL and CRC have conducted preliminary laboratory tests to determine the robustness of a DTV and NTSC terrestrial system against narrow and wide band OFDM signals on an adjacent channel.

The Intel furnished test signals were based on OFDM type signals used in certain classes of unlicensed devices. The wide band signal consisted of 23 equally spaced carriers each QPSK modulated with a pseudo random data stream employing raised cosine filtering. The overall bandwidth was 6 MHz. To investigate the effect of a guard band a derivative of the wide band signal was used with 21 sub carriers resulting in a bandwidth of 5.4 MHz. Constraints on the equipment setup precluded the use of out of band sub carriers for purposes of defining interference levels either side of the primary signal spectrum. However the spectrum plots show that the out of band emissions are 40 dB below the intended emissions which is comparable to many unlicensed devices

3 LABORATORY SET-UP

The narrow and wide band signals interference are generated using an Arbitrary Function Generator (AFG) equipment provided by CRC. INTEL provided CRC with the three signal files (700 kHz, 5.4 MHz and 6 MHz) to operate the AFG. The interfering signal generated from the AFG is up-converted and inserted on the lower and the upper adjacent channel of the desired DTV or NTSC signal.

The laboratory set-up for the evaluation of the narrow and wide band interference signals is presented in Figure 1. The set-up is divided in three sections: Transmitter, Channel and Receiver.

3.1 Transmitter

The DTV signal is obtained from a Rohde & Schwarz SFQ modulator on RF channel 2 (54 –60 MHz). The NTSC signal is obtained from a Drake VM2550A modulator also on RF channel 2.

The INTEL narrow and wide band signals are obtained from the AFG Tektronix AWG2021. The IF output of the AFG at 9 MHz is up-converted on RF channel 2.

3.2 Channel

The desired and undesired signals are connected to a very accurate attenuator to adjust the RF power level. Both signals are connected to the combiner. An HP89440A vector analyzer is used to calibrate the RF system.

3.3 Receiver

The output signal from the combiner is connected to the NTSC or DTV receivers. Two NTSC receivers and two DTV receivers are used in the tests (see Appendix A for the description of the receivers). The video output of the DTV receivers is connected to a video monitor.

3.4 Interfering signals

The test signals provided by Intel are representative of OFDM signals employed in some classes of unlicensed devices. The wide band signal consists of 23 equally spaced sub carriers each QPSK modulated by a pseudo random data stream employing raised cosine filtering. The resulting spectrum has a bandwidth of 6 MHz equivalent to the DTV signal. To investigate the effect of guard bands a second version of the wide band signal was generated using 21 sub carriers with a resulting bandwidth of 5.4 MHz.

The narrow band signal was generated in the same manner using 5 sub carriers. An additional modulated sub carrier at a level of –35 dB was placed on either side so as to generate out of band emissions at the same level as prescribed by Part 15 of the Federal regulations.

3.5 Test conditions

The tests are done on RF channel 2 (54 - 60 MHz) for the desired DTV and NTSC signals.

The undesired narrow and wide band signals are up-converted to the selected RF frequency to create the interference on the upper or lower adjacent channel.

The Threshold of visibility (TOV) for DTV desired signal and the ITU-R grade 3 levels or the Threshold of audibility (TOA) for NTSC were recorded for each interference tests by 2 expert viewers. The expert viewers are at a distance of 4 times the height of the screen (4H).

Five-grade scale	
Quality	Impairment
5 Excellent	5 Imperceptible
4 Good	4 Perceptible, but not annoying
3 Fair	3 Slightly annoying
2 Poor	2 Annoying
1 Bad	1 Very annoying

Table 1. ITU-R quality and impairment scales

An HP89440A vector signal analyzer is connected at the combiner output, to make the average power measurements of the INTEL, DTV and NTSC signals.

The NTSC signal used for the power measurement is the RF carrier modulated by a composite video signal with a black level of 0 IRE units. The correction factor for the NTSC average power to the visual carrier peak power is +2.25 dB.

For the NTSC desired signal, the aural carrier is adjusted to 5% (13 dB below) of the visual carrier peak power.

The NTSC and DTV RF signals are adjusted at the weak level (-68 dBm for DTV, -55 dBm for NTSC).

The NTSC video signals are Color Bars and a taped video sequence. The NTSC audio signal is a 400 Hz tone.

The tests are done on RF channel 2 (54 - 60 MHz).

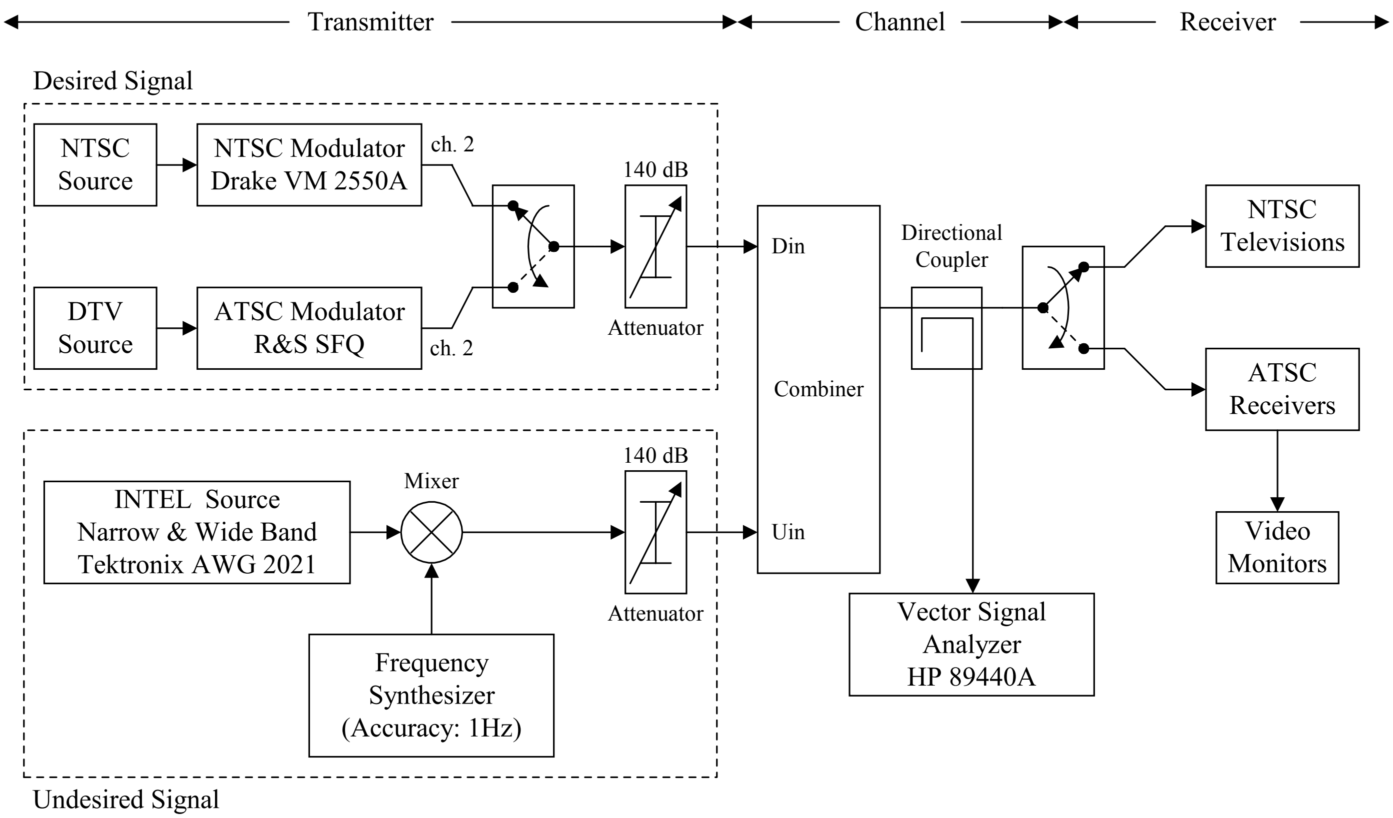


Figure 1. Set-up for the Laboratory Evaluation of narrow and wide band signals interference.

4 TEST PROCEDURES AND RESULTS

The laboratory measurement of the Desired to Undesired ratio (D/U) is done for the Lower and Upper Adjacent Channel interference from the narrow and wide band signals into TV (DTV and NTSC).

The tests will be done for the:

-Interference from the INTEL signals in the Upper Adjacent channel.
-Interference from the INTEL signals in the Lower Adjacent channel.

4.1 RF signals spectrum

The purpose of these tests is to verify the spectral characteristics of the DTV, NTSC and INTEL narrow and wide band signals.

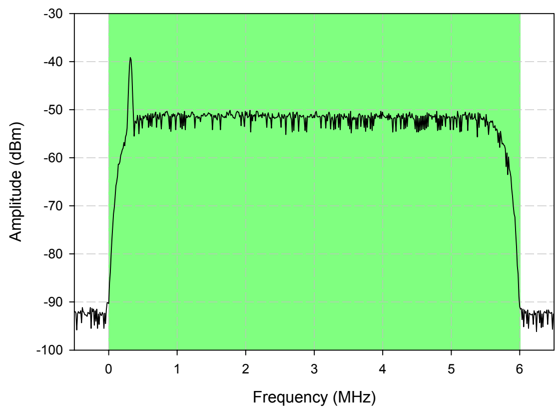


Figure 2a DTV ATSC-8VB signal

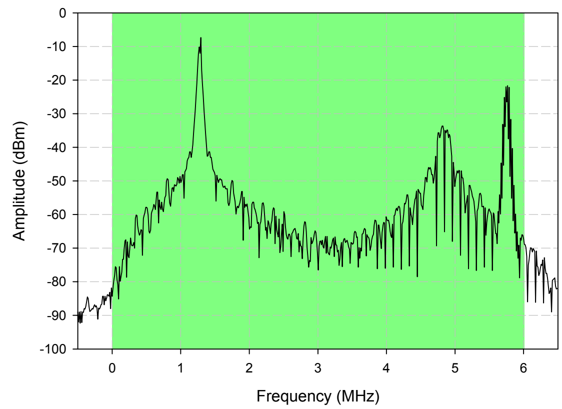
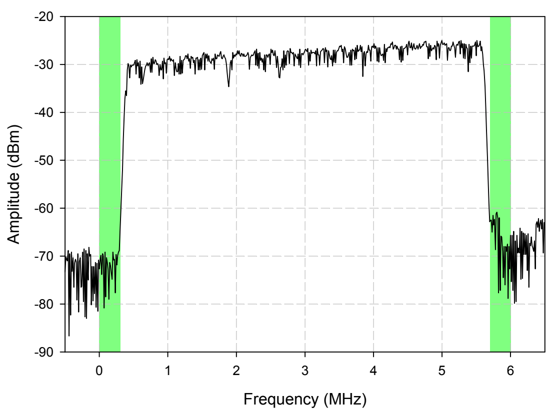


Figure 2b NTSC signal



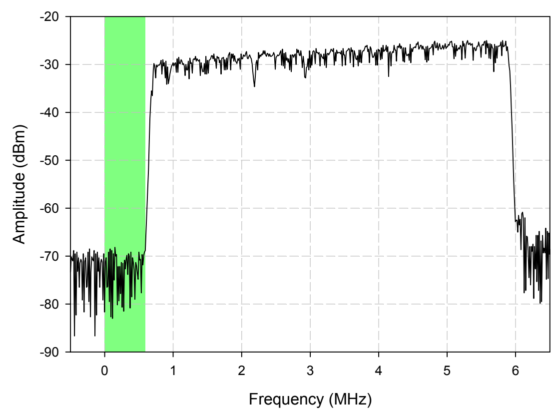


Figure 2e. INTEL wide band signal. (5.4 MHz channel BW and 300 kHz guard band on each side of the spectrum).

Figure 2f. INTEL wide band signal. (5.4 MHz channel BW and 600 kHz guard band on the lower side of the spectrum).

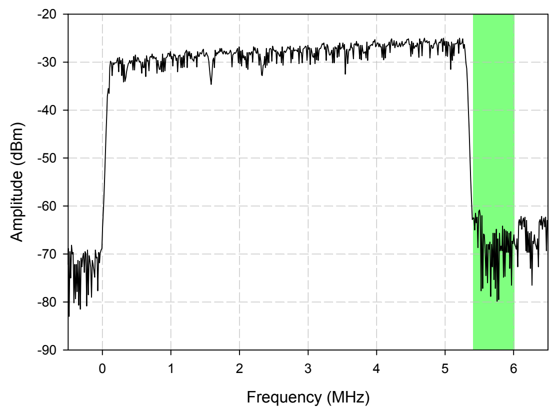


Figure 2g. INTEL wide band signal (5.4 MHz channel BW and 600 kHz guard band on the upper side of the spectrum).

4.2 Interference from the INTEL signals in the Upper Adjacent channel.

The purpose of these tests is to determine the D/U ratio for the upper adjacent channel from the narrow and wide band signals into DTV and NTSC signals.

4.2.1 INTEL wide band signal into DTV (ATSC 8-VSB)

The DTV RF signal is adjusted at the weak level (-68 dBm). The wide band signal level is increased until TOV is reached and the D/U value is recorded.

INTEL Signal		DTV Signal	D/U @ TOV (dB)	
Channel BW (MHz)	**Center frequency (MHz)**	**Center frequency (MHz)**	**Receiver A**	**Receiver B**
6 ***	63 (N+1)	57	**-31.8**	**-27.8**
6	63 (N+1)	57	**-31.8**	**-28.3**
5.4	63 (N+1)*	57	**-37.2**	**-34.2**
5.4	63.3(N+1)**	57	**-38.2**	**-32.7**

* : 300 kHz guard band on each side of the INTEL signal spectrum.
** : 600 kHz guard band on the lower side of the INTEL signal spectrum.
*** : New signal to compensate for the tilt in the RF spectrum

Table 2. Results of upper adjacent channel interference from INTEL wide band signals into DTV.

4.2.2 INTEL wide band signal into NTSC

The NTSC RF signal is adjusted at the weak level (-55 dBm). The wide band signal level is increased until ITU-R grade 3 level or the Threshold of audibility (TOA) is reached and the D/U value is recorded.

INTEL Signal		NTSC Signal	D/U @ TOV (dB)	
Channel BW (MHz)	**Center frequency (MHz)**	**Center frequency (MHz)**	**Receiver A**	**Receiver B**
6***	63 (N+1)	57	**-11.5**	**N/A**
6	63 (N+1)	57	**-11.5**	**-11.5**
5.4	63 (N+1)*	57	**-13.1**	**-15.1**
5.4	63.3(N+1)**	57	**-14.1**	**-16.1**

* : 300 kHz guard band on each side of the INTEL signal spectrum.
** : 600 kHz guard band on the lower side of the INTEL signal spectrum.
*** : New signal to compensate for the tilt in the RF spectrum

Table 3. Results of upper adjacent channel interference from INTEL wide band signals into NTSC.

4.2.3 INTEL narrow band signal into DTV

The DTV RF signal is adjusted at the weak level (-68 dBm). The narrow band signal level is increased until TOV is reached and the D/U value is recorded.

INTEL Signal	DTV Signal	D/U @ TOV (dB)	
Center frequency (MHz)	**Center frequency (MHz)**	**Receiver A**	**Receiver B**
60.35 (N+1)	57	**-24.6**	**-17.1**
60.45	57	**-27.1**	**-19.1**
60.55	57	**-29.6**	**-21.6**
60.65	57	**-33.1**	**-25.1**
60.70	57	**-34.1**	**-27.1**
61.05 (N+2)	57	**-37.1**	**-31.1**
61.40	57	**-37.6**	**-28.1**
61.75 (N+3)	57	**-37.6**	**-28.6**
62.10	57	**-38.1**	**-28.6**

Table 4. Results of upper adjacent channel interference from INTEL narrow band signal into DTV.

4.2.4 INTEL narrow band signal into NTSC

The NTSC RF signal is adjusted at the weak level (-55 dBm). The narrow band signal level is increased until ITU-R grade 3 level or the Threshold of audibility (TOA) is reached and the D/U value is recorded.

INTEL Signal	NTSC Signal	D/U @ ITUR-3 (dB)	
Center frequency (MHz)	**Center frequency (MHz)**	**Receiver A**	**Receiver B**
60.35 (N+1)	57	**4.4***	**-1.6***
60.45	57	**1.4***	**-5.6***
60.55	57	**-0.6***	**-10.6***
60.65	57	**-4.6***	**-14.6***
60.70	57	**-6.6***	**-14.6***
60.85	57	**-11.6**	**-15.6**
61.05 (N+2)	57	**-11.6**	**-15.6**
61.40	57	**-12.6**	**-15.6**
61.75 (N+3)	57	**-13.6**	**-15.6**
62.10	57	**-14.6**	**-16.6**

* The Threshold of Audibility (TOA) was recorded as the audio was impaired before the video.

Table 5. Results of upper adjacent channel interference from INTEL narrow band signal into NTSC.

4.3 Interference from the INTEL signals in the Lower Adjacent channel.

The purpose of these tests is to determine the D/U ratio for the lower adjacent channel from the narrow and wide band signals into DTV and NTSC signals.

4.3.1 INTEL wide band signal into DTV (ATSC 8-VSB)

The DTV RF signal is adjusted at the weak level (-68 dBm). The wide band signal level is increased until TOV is reached and the D/U value is recorded.

INTEL Signal		DTV Signal	D/U @ TOV (dB)	
Channel BW (MHz)	Center frequency (MHz)	Center frequency (MHz)	Receiver A	Receiver B
6***	51 (N-1)	57	**-27.8**	**-25.8**
6	51 (N-1)	57	**-28.3**	**-27.8**
5.4	51 (N-1)*	57	**-32.2**	**-31.7**
5.4	50.7(N-1)**	57	**-33.2**	**-32.2**

* : 300 kHz guard band on each side of the INTEL signal spectrum.
** : 600 kHz guard band on the upper side of the INTEL signal spectrum.
*** : New signal to compensate for the tilt in the RF spectrum.

Table 6. Results of lower adjacent channel interference from INTEL wide band signals into DTV.

4.3.2 INTEL wide band signal into NTSC

The NTSC RF signal is adjusted at the weak level (-55 dBm). The wide band signal level is increased until ITU-R grade 3 level or the Threshold of audibility (TOA) is reached and the D/U value is recorded.

INTEL Signal		NTSC Signal	D/U @ TOV (dB)	
Channel BW (MHz)	Center frequency (MHz)	Center frequency (MHz)	Receiver A	Receiver B
6***	51 (N-1)	57	**-7.5**	**N/A**
6	51 (N-1)	57	**-6.5**	**-6.5**
5.4	51 (N-1)*	57	**-9.1**	**-9.1**
5.4	50.7(N-1)**	57	**-9.1**	**-9.1**

* : 300 kHz guard band on each side of the INTEL signal spectrum.
** : 600 kHz guard band on the upper side of the INTEL signal spectrum.
*** : New signal to compensate for the tilt in the RF spectrum.

Table 7. Results of lower adjacent channel interference from INTEL wide band signals into NTSC.

4.3.3 INTEL narrow band signal into DTV

The DTV RF signal is adjusted at the weak level (-68 dBm). The narrow band signal level is increased until TOV is reached and the D/U value is recorded.

INTEL Signal	DTV Signal	D/U @ TOV (dB)	
Center frequency (MHz)	Center frequency (MHz)	Receiver A	Receiver B
53.65 (N-1)	57	**-21.6**	**-22.1**
53.55	57	**-22.6**	**-22.6**
53.45	57	**-24.1**	**-24.6**
53.35	57	**-28.6**	**-26.6**
53.3	57	**-30.1**	**-27.6**
52.95 (N-2)	57	**-38.1**	**-31.6**
52.6	57	**-39.6**	**-32.1**
52.25 (N-3)	57	**-41.6**	**-32.6**
51.9	57	**-42.6**	**-33.1**

Table 8. Results of lower adjacent channel interference from INTEL narrow band signal into DTV.

4.3.4 INTEL narrow band signal into NTSC

The NTSC RF signal is adjusted at the weak level (-55 dBm). The narrow band signal level is increased until ITU-R grade 3 level or the Threshold of audibility (TOA) is reached and the D/U value is recorded.

INTEL Signal	NTSC Signal	D/U @ ITUR-3 (dB)	
Center frequency (MHz)	Center frequency (MHz)	Receiver A	Receiver B
53.65 (N-1)	57	**-8.6**	**-9.6**
53.55	57	**-9.6**	**-10.6**
53.45	57	**-8.6**	**-9.6**
53.35	57	**-8.6**	**-9.6**
53.3	57	**-7.6**	**-9.6**
52.95 (N-2)	57	**-7.6**	**-10.6**
52.6	57	**-11.6**	**-10.6**
52.25 (N-3)	57	**-18.6**	**-10.6**
51.9	57	**-20.6**	**-6.6***

* Serious intermodulation interference into NTSC.

Table 9. Results of lower adjacent channel interference from INTEL narrow band signal into NTSC.

5 CONCLUSION

Based on the above laboratory test results, here some observations:

- The guard band in the wide band signals improves the results by 3.9 to 6.4 dB in the case of interference into DTV.
- The guard band in the wide band signals improves the results by 1.6 to 4.6 dB in the case of interference into NTSC.
- In the case of the narrow band signal, the improvement in D/U ratio from N$\pm$1 to N$\pm$2 is between 9.5 to 16.5 dB for all cases except for the interference from the lower adjacent channel of INTEL signal into NTSC where the improvement is only 1 dB for NTSC Receiver B and a loss of 1 dB for NTSC Receiver A.
- The results for the wide band signals (5.4 and 6 MHz channel BW) interference into the lower and upper adjacent DTV channels meet the adjacent channel protection ratios of DTV into DTV for the USA (see Appendix C) for both DTV receivers.
- The results for the wide band signals (5.4 and 6 MHz channel BW) interference into the upper adjacent NTSC channel meet the adjacent channel protection ratios of DTV into NTSC for the USA (see Appendix C) for both NTSC receivers.
- The results for the wide band signals (5.4 and 6 MHz channel BW) interference into the lower adjacent NTSC channel doesn't meet the adjacent channel protection ratios of DTV into NTSC for the USA (see Appendix C) for both NTSC receivers.
- The results for the narrow band signals interference into the lower and upper adjacent DTV channels for N+2 and N-2 meet the adjacent channel protection ratios of DTV into DTV for the USA (see Appendix C) for both DTV receivers.
- The results for the narrow band signals interference into the upper adjacent NTSC channel for N+2 meet the adjacent channel protection ratios of DTV into NTSC for the USA (see Appendix C) for both NTSC receivers.
- The results for the narrow band signals interference into the lower adjacent NTSC channel for N-2 doesn't meet the adjacent channel protection ratios of DTV into NTSC for the USA (see Appendix C) for both NTSC receivers.

One possible explanation why the wide band signals don't meet the protection ratio for the lower adjacent channel into NTSC is the tilt found in the INTEL signal's spectrum. The upper side of the spectrum is around 5 dB higher than the lower side. Also the side lobes created in the first MHz of the upper adjacent channel is around 6 to 8 dB higher than the one in the lower adjacent channel. If you subtract this 6 to 8 dB from the results, they become very close to meet the protection ratio for the 5.4 MHz INTEL signal. Subsequent test conducted with a flattened 6MHz test signal indicates that the tilt is a factor.

In the case of the narrow band signal, the low D/U observed for small separations from the adjacent TV channel could be due to the side lode of –35 dB in the first adjacent channel. As the frequency separation is increased the D/U ratio increases dB for dB with the fall of the side lobe power.

This points to the possibility that enhanced protection margins may be possible if the out of band emissions of the unlicensed devices are suppressed below those currently required for Part 15 devices.

Description of DTV Receivers		
Receiver	**A**	**B**
Manufacturer	Zenith	Samsung
Model number	HD-SAT520	SIR-T150
Serial number	251-16340860	35PRA02504B
Con./Prof./Exp.	Consumer	Consumer
Channel	2 (54-60MHz)	2 (54-60MHz)

Description of NTSC Receivers		
Receiver	**A**	**B**
Manufacturer	Panasonic	Sony
Model number	PC-29XF10A	KV-27S10
Serial number	CB23440685	A713076
Con./Prof./Exp.	Consumer	Consumer
Channel	2 (54-60MHz)	2 (54-60MHz)

APPENDIX C

ADJACENT CHANNEL PROTECTION RATIOS

PARAMETER	VALUE (dB) for the USA
Lower DTV into DTV	**-26**
Upper DTV into DTV	**-28**
Lower DTV into NTSC	**-17.43**
Upper DTV into NTSC	**-11.85**

Table B1. DTV/NTSC system adjacent channel protection ratios for the USA.