EXHIBIT A

Interference from the Operation of Unlicensed Devices in the Broadcast TV Bands

Engineering Study

(Docket 4-186)

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1. Introduction

The Commission has proposed to amend its rules to allow unlicensed devices to operate in the broadcast television spectrum at locations where the spectrum is "unused" by television stations.[1] Although the Commission's proposal implies that potential interference to the public's television service can be managed, there is serious concern for the theoretical and practical aspect of the Commission's proposal. The proposal does provide some specifics on power limitations for the unlicensed devices but falls short on technical details which would permit a full assessment of interference mechanisms and levels of impact to broadcast television. This engineering study attempts to mitigate the lack of information available in the proposal by addressing more general spectrum and interference issues. There may, however, be subtle mechanisms specific to spectrum masks, modulation techniques, network management strategies, device locations, and other factors that would render significant interference to broadcast television.[2]

The NPRM proposes several mechanisms intended to prevent interference. However, these mechanisms are deemed ineffective in controlling interference. For example, the Commission proposed that a fixed unlicensed device would either use a GPS receiver or have a "professional" installer determine its location relative to the surrounding TV stations using a public or private database. The use of GPS may be problematic if installations are made indoors or in shadowed areas where the satellite signals cannot be reliably received. In either case, a database of occupied TV channels must be provided to the fixed unlicensed device. The database of occupied TV channels may also be problematic since it needs to be accurate and must be updated frequently, if not continuously. This is

[1] *Unlicensed Operation in the TV Broadcast Bands,* Notice of Proposed Rulemaking, ET Docket No. 04-186, FCC 04-113 (released May 25, 2004) (hereinafter "*NPRM*").
[2] Attempting to address these concerns, MSTV filed a Request for Clarification on June 21, 2004. A response to the Request for Clarification was received on July 27, 2004 offered little guidance to clarify these concerns.

especially true during the roll out of the digital TV and the transition to an all digital service, and the possible implementation of new enhancements such as on-channel DTV repeater systems, distributed transmission systems and Enhanced VSB.

The NPRM proposes that portable unlicensed devices monitor a "positive" control signal from a fixed unlicensed transmitter to ascertain which TV channels are vacant. It is possible for the portable unlicensed device to receive a control signal from outside of the operating contour of a fixed transmitter and thus cause interference in a neighboring contour. Since the propagation characteristics between the fixed and portable unlicensed devices are indeterminate, there may be significant discrepancies in signal conditions between the fixed and portable unlicensed devices. This problem may prevent positive control of an unlicensed device network and lead to hidden nodes. Propagation uncertainties at the TV receiver, especially in the case of indoor reception, would lead to incorrect assumptions of the signal conditions at the TV receiver. Signal measurements at the fixed unlicensed devices may not reflect the signal conditions at the TV receiver.

The management of spectrum in the TV broadcast bands would no longer be viable. Since the devices are unlicensed, there is no way for broadcasters and other licensed users of the TV bands to establish ownership of a source of interference. The NPRM does require devices to periodically and automatically transmit a unique identification signal. The uniqueness of the signal, however, is not clear. Unless each unlicensed device has its own unique identification signal, the source of interference could not be identified. If unlicensed devices are part of a network, it is likely that the unlicensed device would be operating intermittently. Even with an identification signal, the lack of licensing makes it difficult, if not impossible, to physically locate the device and identify ownership. The problem is compounded since the TV receiver locations are also indeterminate. It is unlikely that an installer of an unlicensed device could know with precision, the location of TV receivers within the service area of the unlicensed device.

In order to better understand the impact of unlicensed devices on broadcast television service, MSTV commissioned two studies. The first study focused on a laboratory evaluation of interference to both analog and digital broadcast television caused by a portable unlicensed device operating in a close vicinity of television receivers or other licensed devices in this band. The second focused on the availability of so called “vacant channels” for unlicensed fixed/access operation in a number of regions within the continental United States.

The NPRM proposes that the unlicensed device be allowed to operate in a broadcast channel provided that the emissions into other broadcast channels complies with §15.209(a)[3]. §15.209 requires that the field strength in the UHF band at 3 meters must not exceed 200 µV/m (or 46 dBµV/m) within a 120 kHz bandwidth. This interference when transferred from a half-wave dipole to a matched impedance receiver input would provide an input power to the receiver of between –82.6 dBm (on channel 14) and –85.9 dBm (on channel 51) within a 120 kHz bandwidth. The power levels from a directional receive antenna may be higher. These power levels are of concern. If the emission from the unlicensed device is broadband and occupies 5.6 MHz of the 6 MHz TV channel, the total interference power in the channel will be 16.7 dB higher (-65.9 dBm at channel 14 and –69.2 dBm at channel 51). The emissions from a nearby unlicensed device could cause the AGC circuit in the TV receiver to reduce its tuner gain, and thus, de-sensitize the receiver and impair its reception of weak TV signals. The ATSC Recommended Practice for Receiver Performance Guidelines recommends a DTV receiver sensitivity of –83 dBm

[3] 47 C.F.R. § 15.209 (a)

(measured over 6 MHz without noise or multipath)[4]. Since a DTV receiver typically requires a 15 dB S/N, the noise floor of the receiver is –98 dBm. The proposed level of interference is significantly higher than the noise floor of a typical DTV receiver.[5]

The establishment of DTV service in the Sixth NPRM[6] and calculation of service areas in the OET Bulletin 69[7], involve a series of planning factors used to delineate the limits of a DTV service area. These planning factors imply that the DTV receiver will be operating at the limit of its sensitivity of –84.2 dBm (based on the thermal noise floor, required S/N, and Noise Figure of the receiver). In addition, the calculation of service area implies that the DTV receiver will be protected to the limit of its sensitivity. This protection from interference is further emphasized in the Reconsideration of the Sixth Report and Order[8]. The RF emission mask for DTV transmitters was tightened to explicitly address adjacent channel interference concerns. Since no allowance has been made for additional interference within the broadcast television band, there is great concern that unlicensed devices will adversely impact the performance of the TV receiver.

The Commission proposes the use of these portable unlicensed devices within the television service contours of adjacent and taboos channels. Specifically, the NPRM asserts that at a distance less than 10 meters from a TV receiver, unlicensed devices will be under the control of the operator and if they cause interference they could be turned off. The NPRM goes on to infer that beyond 10 meters interference will not be an issue. The

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[4] ATSC Recommended Practice: Receiver Performance Guidelines, Advanced Television Systems Committee Document A/74, p. 11, 18 June 2004.

[5] Similar results were derived for an NTSC receiver.

[6] Sixth Further Notice of Proposed Rule Making, MM Docket No. 87-268, "Advanced Television Systems and Their Impact Upon the Existing Television Broadcast Service," Released: August 14, 1996.

[7] Longley-Rice Methodology for Evaluating TV Coverage and Interference, OET Bulletin No. 69, July 2, 1997.

[8] Memorandum Opinion and Order on Reconsideration of the Sixth Report and Order. MM Docket No. 87-268, "Advanced Television Systems and Their Impact upon the Existing Television Broadcast Service, Paragraph 91, Released: February 23, 1998.

Commission is incorrect on both issues. First, it is unrealistic to assume that the operator will control the interference within 10 meters of a TV receiver since in many urban settings such as apartments, condominiums, office buildings, and suburban homes, a television receiver located 10 meters away from an unlicensed radiator may likely be in an adjacent dwelling. Second, portable operation within the TV service contours of adjacent and taboos channels *will* cause interference to TV receivers at distances beyond 10 meters. Depending on the channel relationship between the unlicensed device and the TV taboo channel, the unlicensed device could cause interference to a TV receiver as far as 138 meters away for NTSC and 25 meters for DTV. Moreover, operating on an adjacent channel could cause interference as far as 1550 meters for DTV and 439 for NTSC.[9] Unfortunately, the Proposal did not take into account the potential for interference from the operation of these devices on taboo channels.

The NPRM proposes the same NTSC-to-DTV and DTV-to-DTV co-channel and adjacent channel interference protection rules (D/U ratios) to allow unlicensed transmitters to operate in the TV bands. The applicability of these TV protection rules for an unlicensed device service is inappropriate. Unlike television transmitters, unlicensed fixed transmitters could be placed anywhere, including within the TV service area of an adjacent channel. NTSC transmitters on the other hand can not be located within the adjacent TV service areas, they must be at least 55 miles- away, while DTV transmitters operating on adjacent channels where intentionally co-located or near co-located as a means of

[9] Using the DTV-to-NTSC D/U ratios in Bulletin OET-69, the following separation distances were computed using a maximum 400 mill watts ERP for the unlicensed transmitter and a free space propagation model: For N+8, 55 meters; N-7, 39 meters; N-4, 44 meters; N-3, 69 meters; N-2, 138 meters; N+2, 87 meters; N+3, 44 meters; N+4, 123 meters; N+7, 16; N+8, 16 meters; N+8, 16 meters; N+14, 49 meters, N+15, 62 meters; N-1, 309 meters; N+1, 437. Using the ATSC A-74 Recommended Practice DTV-to-DTV ratios for taboos, the following separation distances were also computed: For N+1, 1550 meters; N-1, 1231 meters; N+1, 1550 meters; N-2, 25 meters; N-3, 16 meters; N+(6-14), 14 meters; N+15, 13 meters.

controlling propagation characteristics so that proper Desired-to-Undesired (D/U) levels are maintained independent of the DTV receiver location. The propagation path and characteristics for the desired TV channel will be very different from the interfering unlicensed device. These characteristics are sure to vary greatly over a given service area.

The purpose of the laboratory study is to assess the impact that the out-of-channel emission from an unlicensed device would have on a broadcast receiver. Specifically, the laboratory tests consider the potential for de-sensitization of the TV receiver by the unlicensed device at various separation distances through obstructions, such a wall.

The second study is an analysis of potential sites for unlicensed device operation based upon the proposed Commission's rules for co-channel and adjacent channel interference D/U ratios. Specifically, the study looks at the number of available or "vacant" TV channels that could be utilized for unlicensed transmitters in major urban regions of the United States.

2. Laboratory Evaluation of Interference from Unlicensed Devices in the Broadcast TV Band

The goal of the laboratory evaluation is to objectively measure the potential for interference to broadcast TV from unlicensed devices out of band emission. The Communications Research Centre Canada (CRC) performed the tests. The test bed illustrated in Figure 1 was used to create the interference scenario. A broadcast signal is transmitted on either a low UHF channel for NTSC and a high UHF channel for DTV. The laboratory study includes a simulated "unlicensed device" with a "noise-like" emission in the broadcast television channel. The power of the unlicensed device emission is conservatively adjusted so that the power into the broadcast channel is at least 3 dB below

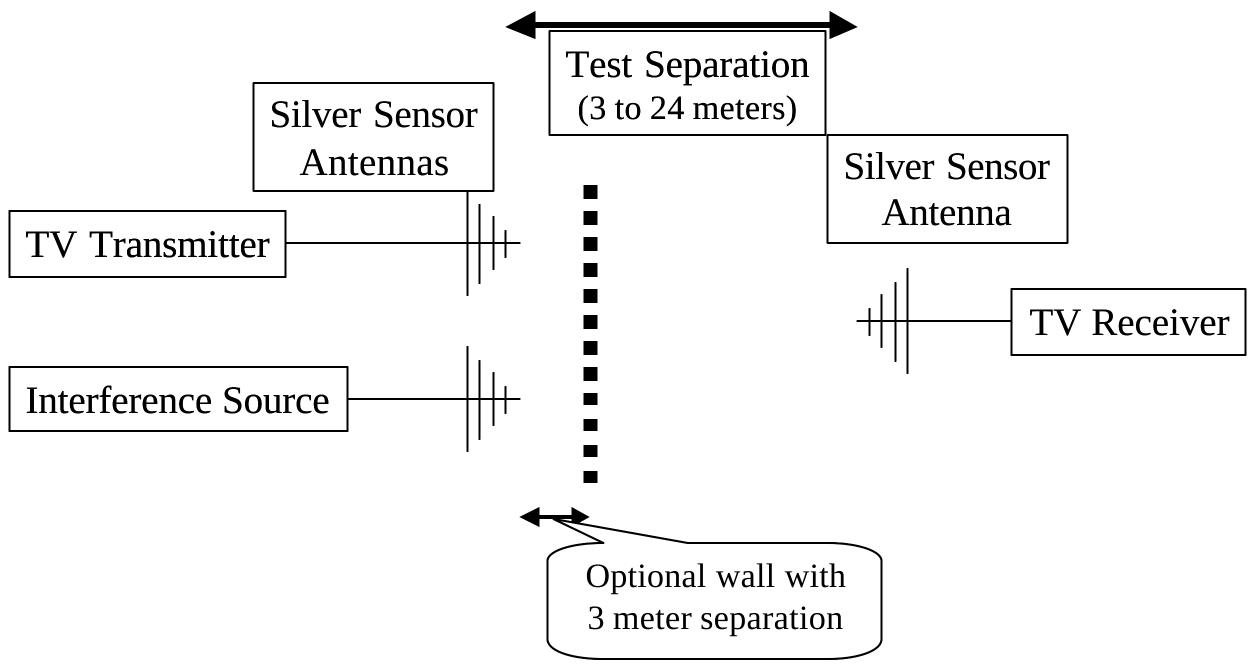

Figure 1 – Laboratory test setup used to evaluate TV receiver de-sensitization resulting from the emission of an "unlicensed device" into the TV channel.

the FCC rule[10] of 200 µV/m (46 dBµV/m) within a 120 kHz bandwidth at 3 meters. The test used a "noise-like" signal with various bandwidths of 0.43, 1.3, and 5.6 MHz to represent bandwidths that may be encountered with "unlicensed-devices." In addition, the unlicensed device antenna was separated from the television receiver antenna at varying distances from 3 to 24 meters – either line-of-sight or with an intervening wall constructed of drywall plaster board with steel studs (typical of apartment or office fire protection walls).

The results and test procedures are presented in detail in Appendix 1 of this report. The findings demonstrate that there is a definite de-sensitization of the TV receiver caused by emission of the unlicensed device into the TV channel. The tests were performed on both NTSC and DTV receivers. Five DTV receivers were tested on channel 48 at distances of 3, 12, and 24 meters from the interfering source. The results are illustrated in Figure 2. It is important to note that the de-sensitization of the DTV receiver continues to be significant

Figure 2 - De-sensitization of DTV receivers by out-of-band interference from a single unlicensed device with a wideband (5.6 MHz) emission into the TV channel.

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10 47 C.F.R. § 15.209 (a)

even at 24 meters by more than 10 dB. Any DTV receiver operating near the limit of its sensitivity, as may be encountered indoors, would be adversely affected by the interference from an "unlicensed device".

A narrowband emission into the TV channel was also found to desensitize the DTV receiver. Figure 3 illustrates the effect of a 0.43 MHz narrowband emission on the five DTV receivers. Although the total power in the TV channel is 11.2 dB less than the 5.6 MHz case, there still remains a significant impact on the sensitivity of the TV receiver even 24 meters from the unlicensed device.

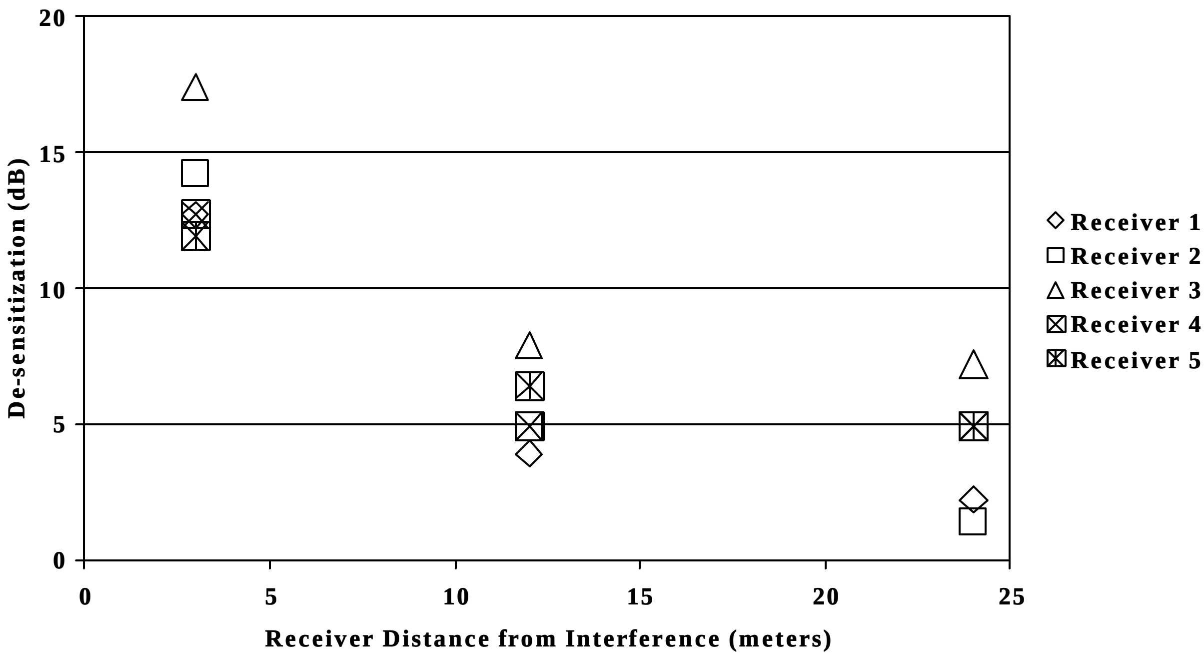


Figure 3 - De-sensitization of DTV receivers by out-of-band interference from a single unlicensed-device with a narrowband (0.43 MHz) emission into the TV channel.

The TV receiver is susceptible to interference even if there is an intervening wall as may be encountered in an office environment or apartment. Figure 4 illustrates the impact of a wall placed between the source of interference and the TV receiver at 12 meters.

Although the wall does attenuate the signal, the DTV receiver is still desensitized by more than 10 dB.

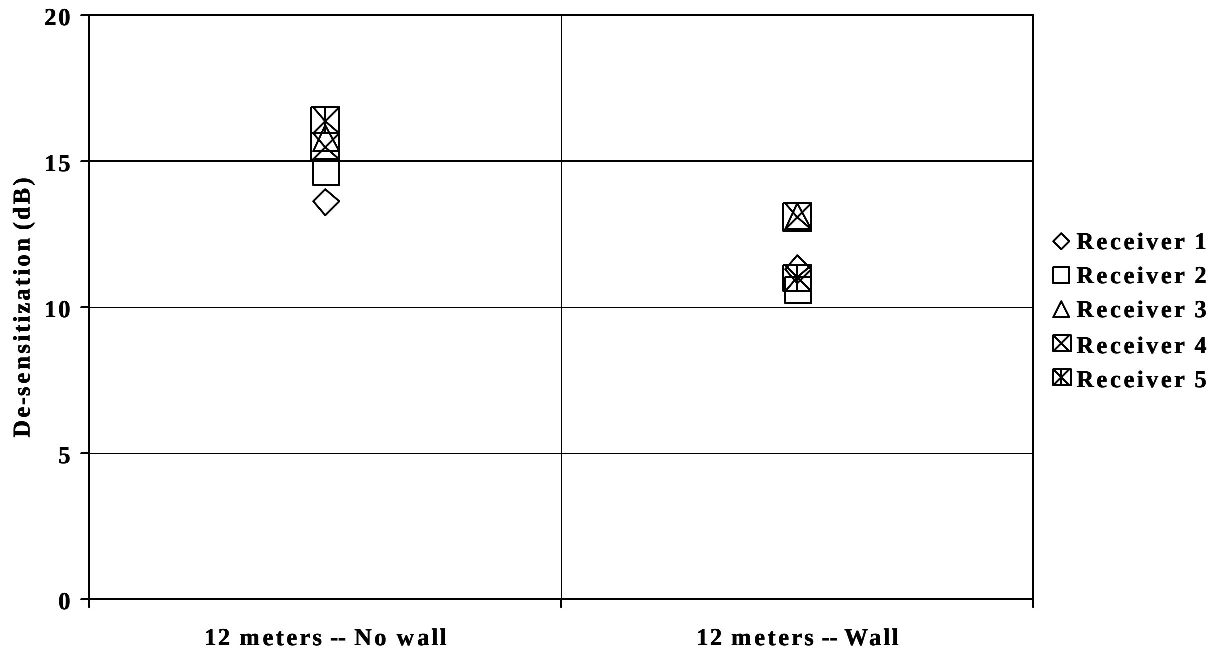


Figure 4 - De-sensitization of DTV receivers by out-of-band interference through a wall from a single unlicensed device with a wideband (5.6 MHz) emission into the TV channel.

The impact of interference on the desensitization of an NTSC receiver is even greater than that for DTV. The interference is so pronounced that the test bed could not provide sufficient desired power to determine the desensitization at the threshold of visibility (TOV). Consequently, the ITU-R Grade 3 ("slightly annoying") criterion was used in the NTSC tests. It should be noted in the test results that the desensitization at TOV is at least 10 dB higher than at ITU-R Grade 3. Figure 5 illustrates the level of desensitization for three NTSC receivers at 6 and 18 meters from the interfering source using ITU-R Grade 3. Even when the NTSC receiver is placed 18 meters from the interfering source, there is a significant adverse impact on TV reception of at least 15 dB.

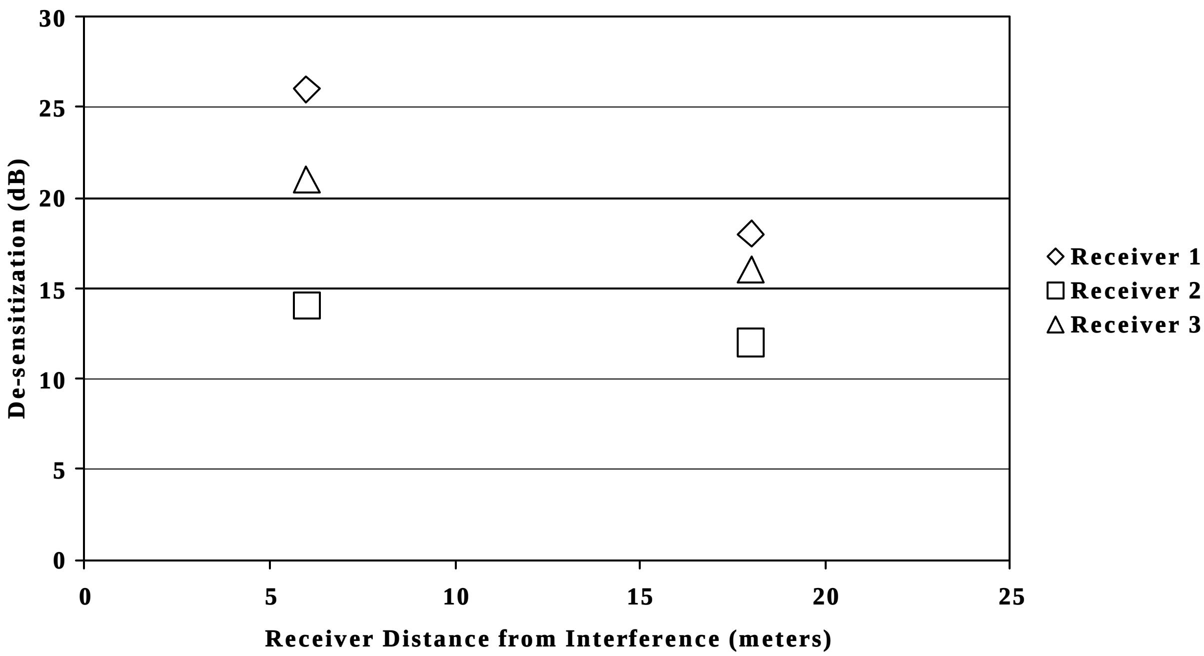


Figure 5 – De-sensitization of NTSC receivers by out-of-band interference from a single unlicensed device with a wideband emission (5.6 MHz) into the TV channel.

3. Assessment of Available Spectrum for Unlicensed Devices

The goal of the spectrum assessment is to objectively determine the geographical range over which spectrum could be available within the broadcast TV bands for use by unlicensed devices. The NPRM proposes to allow fixed unlicensed transmitters to operate in "vacant" TV channels provided various desired-to-undesired (D/U) signal ratios are met at all points within the service area of the unlicensed transmitter. The desired signals are the broadcast TV stations either on co-channel or adjacent channels to the undesired unlicensed transmitter.

TechWare, Inc. of Chantilly, Virginia, was commissioned by MSTV to conduct a study to determine the availability of vacant spectrum within the TV bands for use by these unlicensed devices. The study uses the same propagation curves (FCC broadcast curves) proposed in the NPRM to compute the field strengths for both the desired and the undesired signals to identify the areas where these unlicensed transmitters could be placed. The study modeled a grid of fixed unlicensed transmitters representing a network of unlicensed devices that was superimposed at different geographic regions within the US to determine the number of vacant channels available at these locations. The study used a four watts Effective Radiated Power (ERP) for the unlicensed transmitter with an omni-directional antenna placed at every intersection of a 30-second grid (latitude and longitude) across major populated regions of the United States. The unlicensed transmitter height was set at a **modest height of 30 meters (HAAT)** and the number of available channels was determined for each 30-second grid (i.e. approximately a one square mile area). The proposed protection ratios and service contours describe in Appendix B of the NPRM, §15.244(g) and §15.244(h) were incorporated into the software model and computed on 30-second grid (latitude and longitude) intervals.

Figures 6, 7, 8 and 9 presents maps that show the availability of TV channels for unlicensed devices for the North East region of the US, the states of California, Florida and North Carolina respectively. The maps are color-coded to identify the number of TV channels available for unlicensed device operation in a given location and an olive green-colored background to identify the areas where the software model did not determine the availability of vacant channels. Figure 6 shows that, while some TV channels are available for unlicensed fixed operation in certain rural areas, little if any TV channels are available in congested areas, primarily along the Boston-Richmond corridor.[11] Figures 7, 8 and 9 also show similar results.[12] These maps show that while a limited number of TV channels are available in the rural areas, no channels are available in Los Angeles, San Diego, San Jose, San Francisco, Miami-Fort Lauderdale or the Tampa-Orlando urban areas, as well as Charlotte and Raleigh-Durham urban areas. Other urban areas such as Dallas (Figure 10) and Phoenix (Figure 11) showed similar results. Moreover, the spectrum availability in these states and urban areas varies significantly from one geographical grid to another. As shown in the North East region and the state of North Carolina maps, it is nearly impossible to establish large enough areas with sufficient channels to permit operation of unlicensed device networks in the television broadcast spectrum. Furthermore, identifying these white spaces require complex engineering evaluation and analysis to determine where these devices will be allowed to be located. It will also require the proper design and careful installation of these fixed transmitters. These requirements make it extremely

[11] Our analysis indicates that approximately two-thirds of the population in the Boston-Richmond corridor (Figure 6) will not have access to any spectrum. Another 14% will only have access to one TV channel. At 60 meters HAAT, the number of population without access to spectrum is *significantly* higher.

[12] Our analysis further indicates that approximately three-quarters of the population in the state of California (Figure 7) will not have access to any spectrum. An additional 7% will only have access to one TV channel. At 60 meters HAAT, the number of population without access to spectrum is *significantly* higher.

difficult, if not impossible, for untrained unlicensed device operators to conduct these analysis and/or install these transmitters without proper guidance and/or oversight by the Commission or responsible entities.

Similar findings were observed in other regions of the United States. The Techware analysis generally concluded that, using the FCC proposed parameters for protecting TV reception, little if any TV channels are available for unlicensed device operation within the broadcast TV band in the major metropolitan areas of the United States. Television channels are only available in the less populated and rural areas of the country.

Figure 6: Map Depicts Availability of Unlicensed Devices Channels in the North East Region of the United States

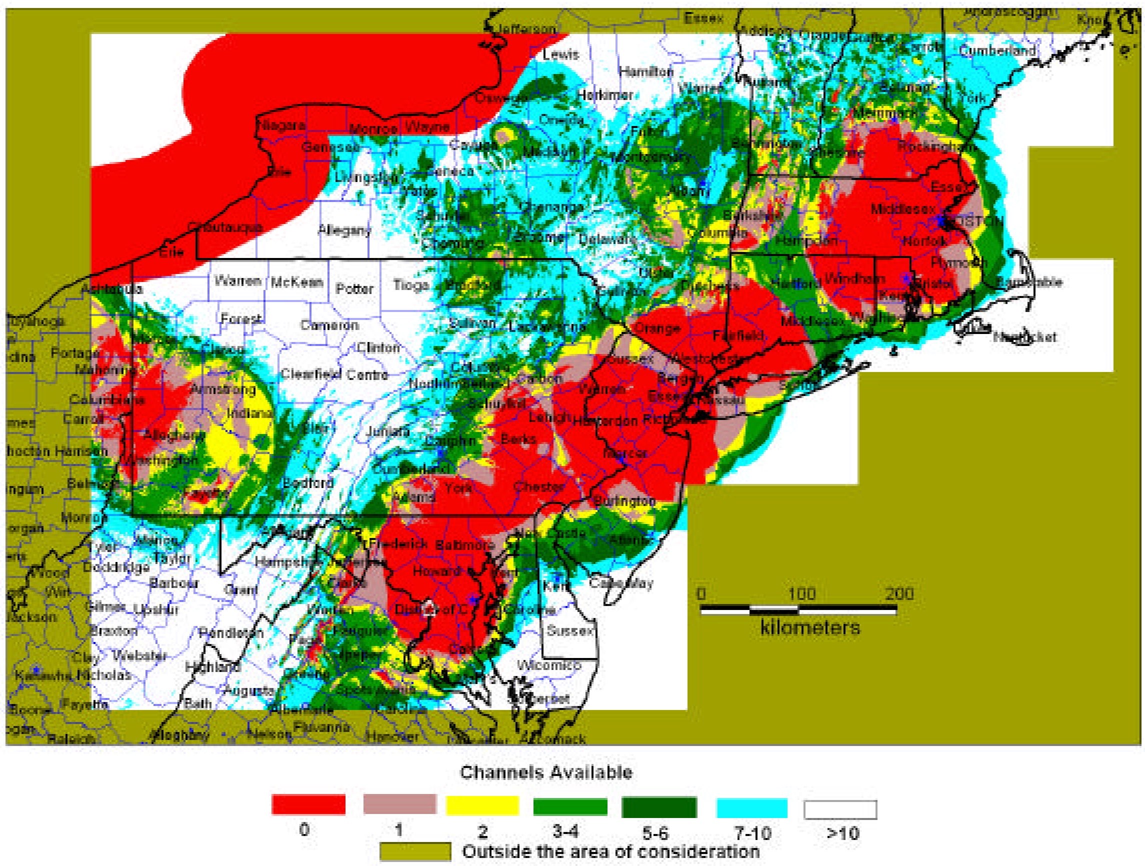


Figure 7: Map Depicts Availability of Unlicensed Devices Channels in the State of California

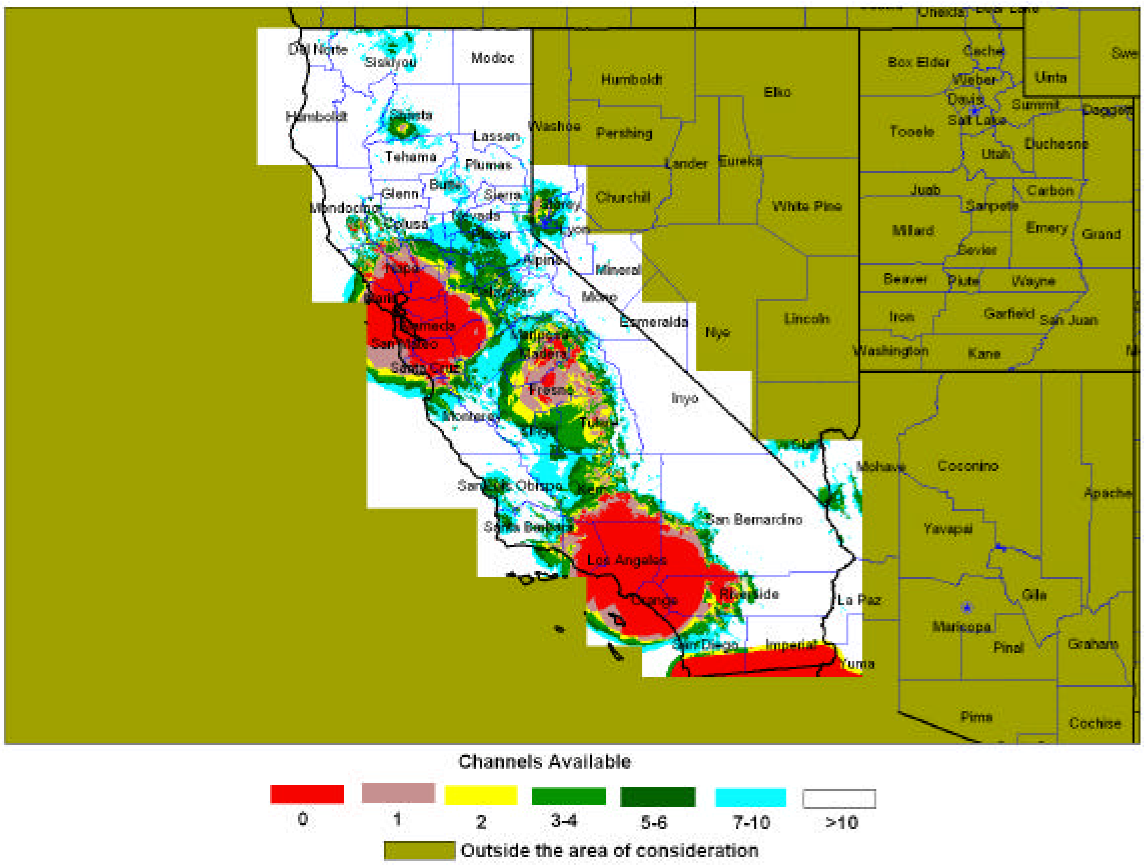


Figure 8: Map Depicts Availability of Unlicensed Devices Channels in the State of Florida

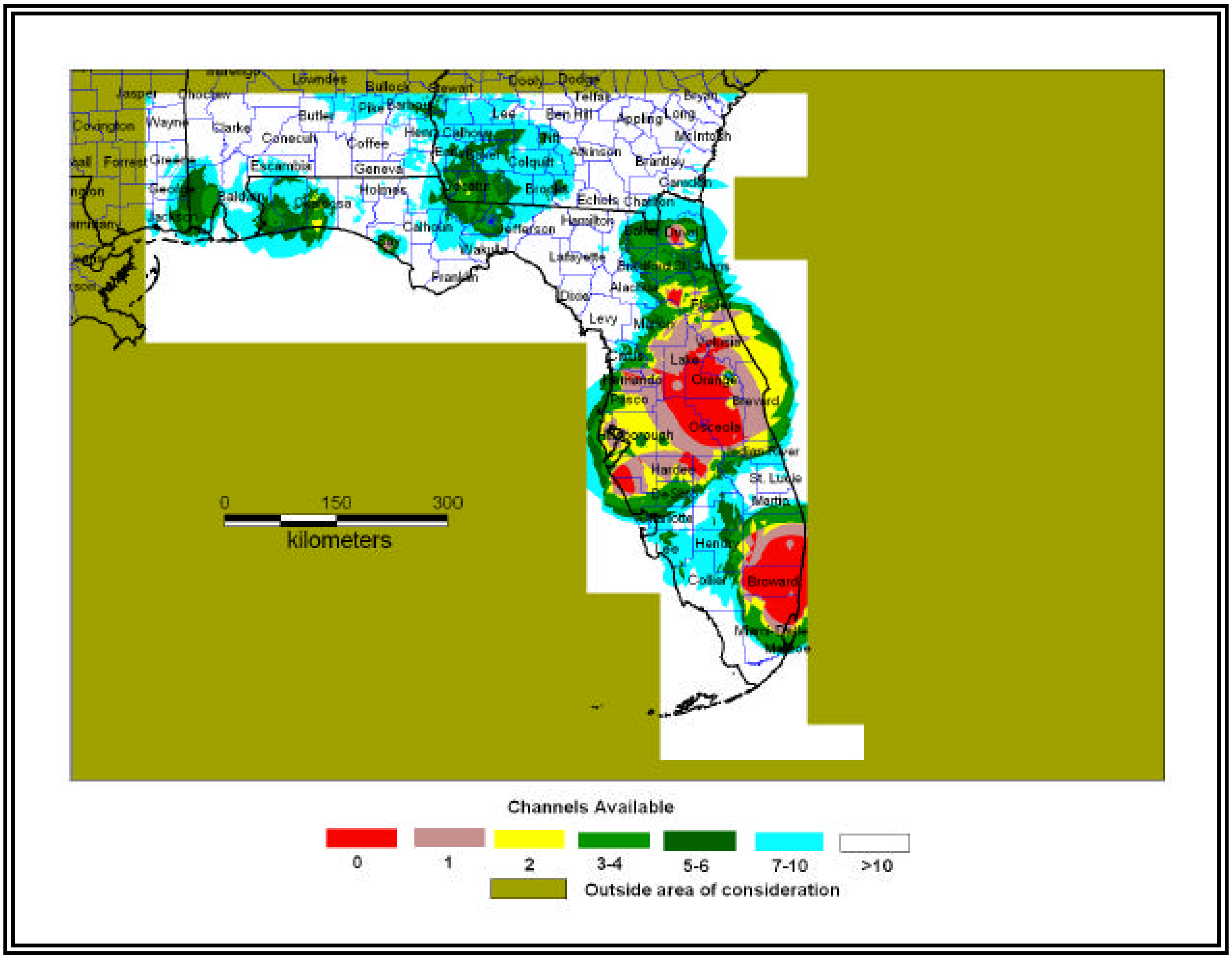


Figure 9: Map Depicts Availability of Unlicensed Devices Channels in the State of North Carolina

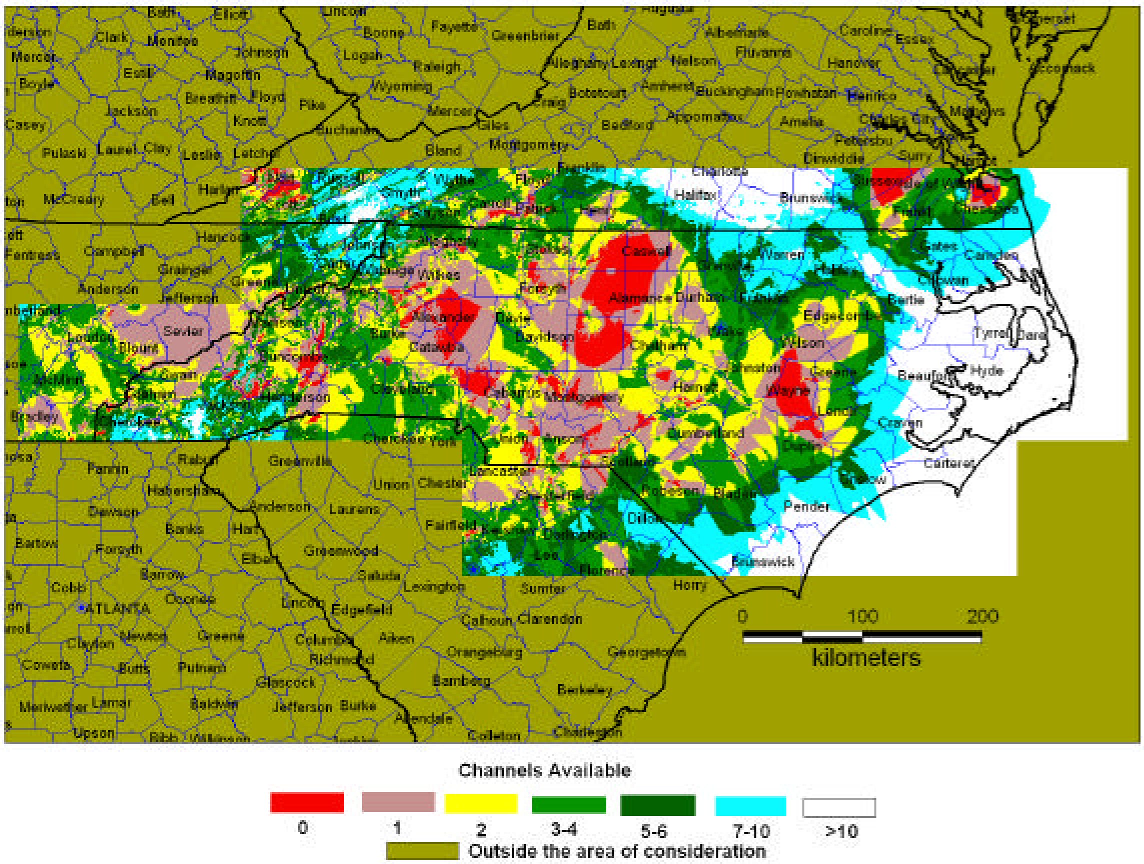


Figure 10: Map Depicts Availability of Unlicensed Devices Channels in the Dallas Urban Area

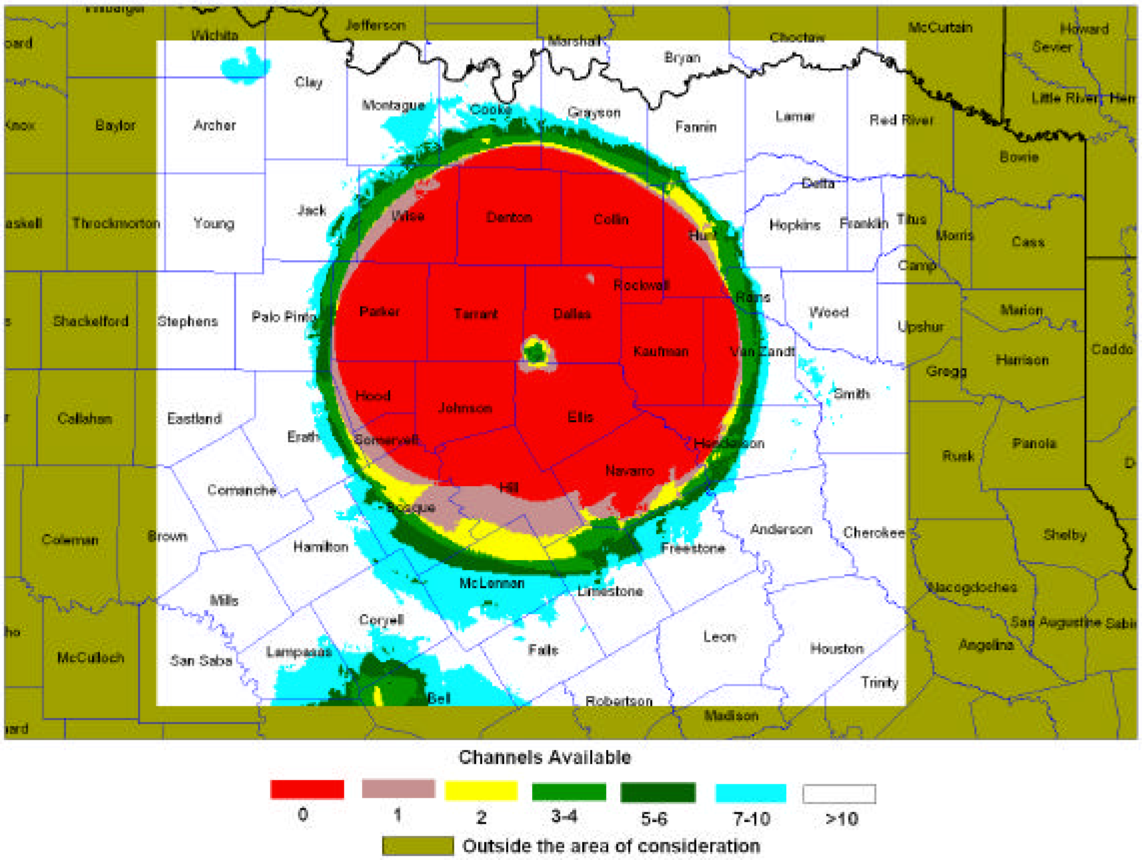
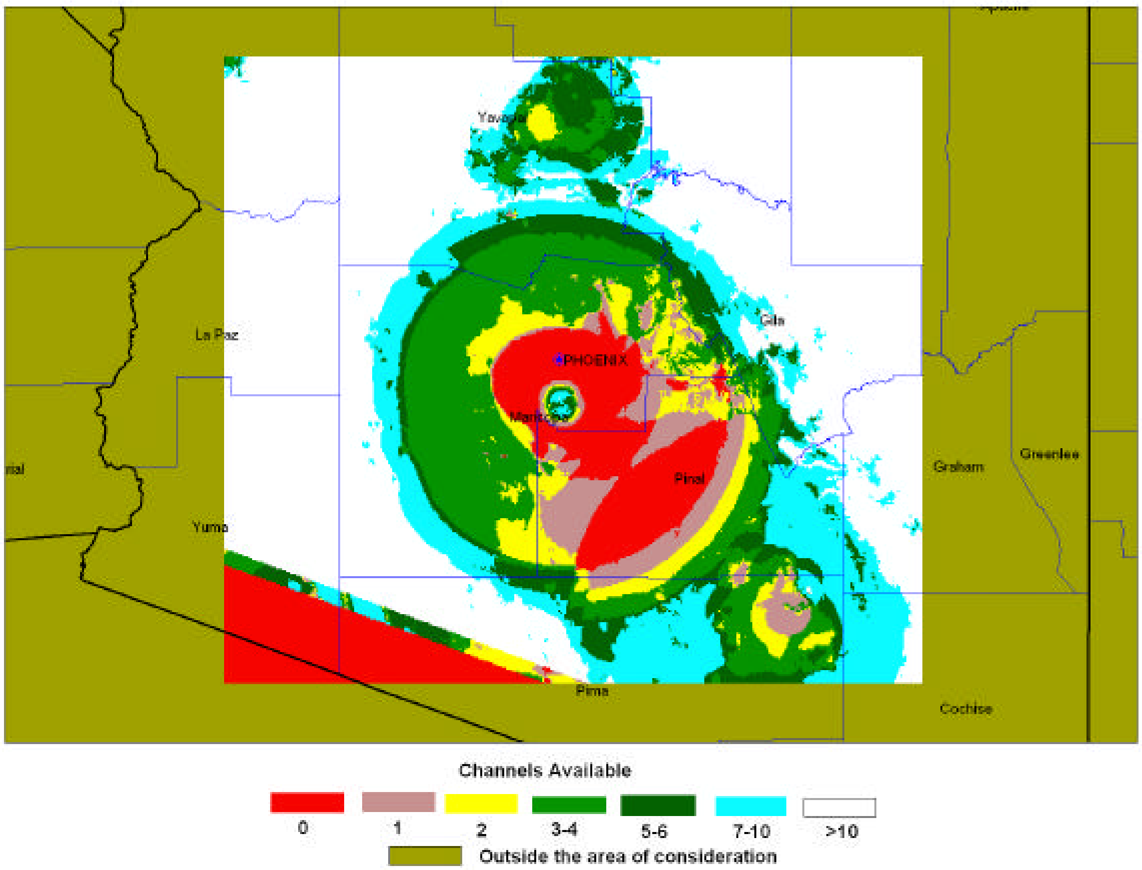


Figure 11: Map Depicts Availability of Unlicensed Devices Channels in the Phoenix Urban Area



4. Conclusions

Unlicensed devices operating in the broadcast TV bands with the proposed levels for out-of-band emissions will cause interference to TV reception. The interference is particularly prevalent for indoor reception where the TV receiver is operating near the limits of its sensitivity. The interference from an unlicensed device desensitizes the TV tuner, thereby reducing the margin for successful reception.

Unlicensed devices operating in the broadcast TV bands are not appropriate for major urban areas. Interference, in the form of receiver desensitization, was found to occur at separation distances likely to be found in office situations, apartments, condominiums, and even suburban environments.

The availability of spectrum within the broadcast TV bands is severely limited for unlicensed devices. It was found that in order to meet the FCC rules for protection contours and protection ratios, there is no spectrum available within major metropolitan areas of the United States.

5. Engineering Credentials

Victor Tawil

Senior Vice-President, Association for Maximum Service Television

Mr. Tawil is Senior Vice President of the Association for Maximum Service Television, Inc. (MSTV), providing technology and telecommunication policy guidance and support to MSTV and its more than 400 member television stations. He was Chairman of the Digital Television Station Project (WHD-TV), sponsored by the television and consumer electronics manufacturing industries and is a member of the Board of Directors of the Advanced Television Systems Committee (ATSC).

Prior to joining MSTV in 1988, Mr. Tawil was with the Federal Communication Commission for fourteen years. He held various positions in a number of Bureaus and the Office of Science and Technology, specializing in the fields of spectrum management, tropospheric propagation and system engineering. He has worked extensively in the areas of broadcasting, satellite, wireless communications and new communication technologies. During his tenure at the FCC, he served as a US delegate on a number of International and ITU Plenipotentiary Conferences, and bilateral negotiations.

Mr. Tawil holds an MSE in Electrical Engineering from the University of Rochester, and a BSE from New York University. He is a member of the International Union of Radio Scientist (URSI), Institute of Electrical and Electronic Engineers (IEEE) and the Society of Motion Picture and Television Engineers (SMPTE) and Tau Beta Pi.

Charles W. Einolf, Jr.

RF Consultant

Dr. Einolf is currently a consultant for the television broadcast industry. He has 36 years of experience in the field of electrical and electronics engineering with extensive experience in the design and development of advanced electronic systems incorporating sensor, computer, communication, and signal processing techniques. Dr. Einolf has provided leadership in broadcast systems, digital TV transmitters, CATV systems, digital microwave, satellite communications, local area networks, personal communication networks, ATM, ISDN, FDDI, analog and digital circuit design, and instrumentation.

Dr. Einolf was the Deputy Executive Director of the Advanced Television Technology Center (ATTC) until the completion of its mission in 2003 to facilitate the transition to Digital Television in the United States. At the ATTC, he was responsible for technical programs that included the improvement of DTV system performance, characterization of signal propagation, and evaluation of audio and video quality.

Dr. Einolf holds the Ph.D. and M.S. degrees in Electrical Engineering from the University of Rochester and a B.S. degree in Electrical Engineering from the Massachusetts Institute of Technology. He has published numerous papers and holds 14 U.S. patents.

Dr. Einolf is a Fellow in the Institute of Electrical and Electronics Engineers and has been awarded the IEEE Centennial and Millennium medals. He is Vice-President of the IEEE Broadcast Technology Society. Dr. Einolf is a Life AdCom member and President-Elect of the IEEE Industrial Electronics Society.

APPENDIX 1

Laboratory Evaluation of Unlicensed Devices Interference to NTSC and ATSC DTV Systems in the UHF Band

REPORT

By

The Communication Research Centre Canada
(CRC)

For

The Association of Maximum Service Television
(MSTV)

November 29, 2004

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Executive Summary

This report presents the results of measurement made to assess the interference potential to DTV and NTSC television reception from the side-lobe emissions of an Unlicensed Device (UD) operating in the UHF band, which comply with the Section §15.209(a) of the FCC Rules. Section §15.209 (a) of the FCC Rules specify a radiated emission limit of 200 uV/m at a measurement distance of 3 meters over frequency range of 215-960 MHz. The emission limit is based on measurement employing an International Special Committee on Radio Interference (CISPR) quasi-peak detector with a measurement bandwidth of 120 kHz.

In general, today's ATSC DTV receiver minimum signal level is in the range of –78 dBm to –83 dBm (over 6 MHz BW), which is equivalent to a noise floor of –93 dBm to –98 dBm. Measurement results show that the proposed Unlicensed Device side-lobe emission limit will cause significant de-sensitisation to DTV and NTSC receivers over a wide area. This is because the proposed emission limit is much higher than the receiver equivalent noise floor (–60 dBm to –70 dBm over a 6 MHz BW). The level of de-sensitisation depends on the interference signal power bandwidth, distance to the interference source, receiver performance, and test environment (indoor, outdoor, etc.).

Tests were conducted in an indoor environment to determine the desensitisation to digital television reception from unlicensed device side-lobe radiated emissions in the clear and when the side-lobe radiated emissions are transmitted through a wall. The data shows that for a distance of 3 meters, an unlicensed device operating with signal bandwidths of 5.6 MHz and 0.43 MHz will de-sensitise DTV receivers an average of 24.5 dB and 13.8 dB, respectively. Similarly, at a distance of 12 meters, the average de-sensitisation is 15.2 dB and 5.6 dB respectively. At 24 meters, the average de-sensitisation is 11.4 and 4.1 dB respectively. Moreover, even when a dry wall is separating an unlicensed device and a DTV receiver, an average de-sensitisation of 19.7 dB and 15.2 dB were measured at distances 5 and 12 meters respectively, when the unlicensed device is operating with a signal bandwidth 5.6 MHz.

Similar test were also conducted for NTSC receivers. The data shows that an even greater desensitisation for NTSC, when compared to DTV. For a wideband interference signal (5.6 MHz) at 18meters from an analog television receiver, assuming ITU-R Grade 3 picture quality, the average desensitisation is 15.3 dB. For a narrowband signal (0.43 MHz), the desensitisation will depend on the location of the interference signal relative to the video and colour carrier of the NTSC signal and generally follows the traditional behaviour of the "S" curve. When placed in the middle of the TV channel, the average de-sensitisation at 18 meters is 5.6 dB. At a 6 meters distance, the desensitisation ranges from 5 dB to 18 dB depending on the location of the interference signal relative to the video and colour carrier of the NTSC signal. If the Threshold Of Visibility (TOV) is used as the picture quality threshold, a 10 dB correction (more desensitisation) should be added over the ITU-R Grade 3 case.

The UD could also cause cable ingress, especially for a single shielded RG-59 cable. The ingress level can be up to –44 dBm regardless of whether the cable is terminated or not.

Introduction

On May 25, 2004, the FCC released a Notice of Proposed Rule Making (NPRM) that proposes to allow unlicensed radio transmitters to operate in the broadcast television spectrum at locations where that spectrum is not being used. CRC was contracted by MSTV to conduct measurements to investigate the possible impact of interference from the unlicensed devices on the current DTV and NTSC services.

Based on the FCC NPRM, the proposed Unlicensed Devices (UD) "radiated emissions that fall outside the TV broadcast channel(s) where the device operates must comply with the radiated emission limits specified in §15.209(a)". Section 15.209(a) of the FCC rules state that *"the radiated emission limits over frequency band of 215-960 MHz is 200 dBuV/m at a measurement distance of 3 meters"*. The emission limit is based on measurement employing a CISPR quasi-peak detector with a *measurement bandwidth of 120 kHz*.

Based on the Commission proposal, CRC conducted measurement to characterise the de-sensitisation of ATSC DTV and NTSC receivers from the side-lobe radiated emissions of an unlicensed portable device. Specifically the following laboratory evaluations were performed:

- De-sensitisation of DTV receivers in an indoor environment.
- De-sensitisation of DTV receivers with UD sideband signals transmitted through a dry wall.
- De-sensitisation of NTSC receivers in an indoor environment.
- De-sensitisation of NTSC receivers with the narrowband signal transmitted across the NTSC channel.
- Cable ingress created by the UD signals.

Laboratory Test Set-up

The Unlicensed Devices interference emissions signals were generated using a COFDM modulator provided by CRC. The UD emission signals were generated by CRC in such a way as to meet the FCC emissions requirement. (i.e. 200 uV/m, or 46 dBuV/m within a 120 kHz bandwidth). The interfering emissions signals were measured at 3 m from the unlicensed devices, within a 120 kHz bandwidth. The UD interfering emitted signal power level was adjusted to 3 dB below the FCC emission requirement to avoid any impact of measurement error on the measurement results. The generated unlicensed devices interference emission signals were up-converted, filtered and inserted on the desired DTV or NTSC channel. List below is a summary of the relevant parameters and calculations used to conduct these tests:

FCC emission limit: 200 uV/m, or 46 dBuV/m within 120 kHz

Convert to dBm: P (dBm) = –75.5 + 46 dBuV/m – 20 log(Frequency in MHz)

= –29.5 – 20 log (Frequency in MHz)

Interference signal parameters:

- Modulation: 64QAM-OFDM;
- 3-dB bandwidth: 5.57 MHz (wideband), 1.29 MHz (mediumband), 3 x 0.43 MHz, and 0.43 MHz (narrowband)
- Number of OFDM carriers: 5616, 324, 324, and 108;
- Guard interval: 1/16; 64QAM modulation.

***To avoid measurement error, the interference level is set at 3 dB below the FCC specified limit,* thus**:

- For CH-48 (677 MHz), the interference level is –29.5 – 20 log (677) – 3 = –89.1 dBm within 120 kHz.
- For CATV CH-66 (477 MHz), the interference level is –29.5 – 20 log (477) – 3 = –86.1 dBm within 120 kHz. (Note: a CATV NTSC modulator is used in the NTSC system test. CATV and off-air TV have different frequency range, but they all use the same 6 MHz NTSC signal. CATV CH-66 is equivalent to UHF off-air Channel 14 and 15.)

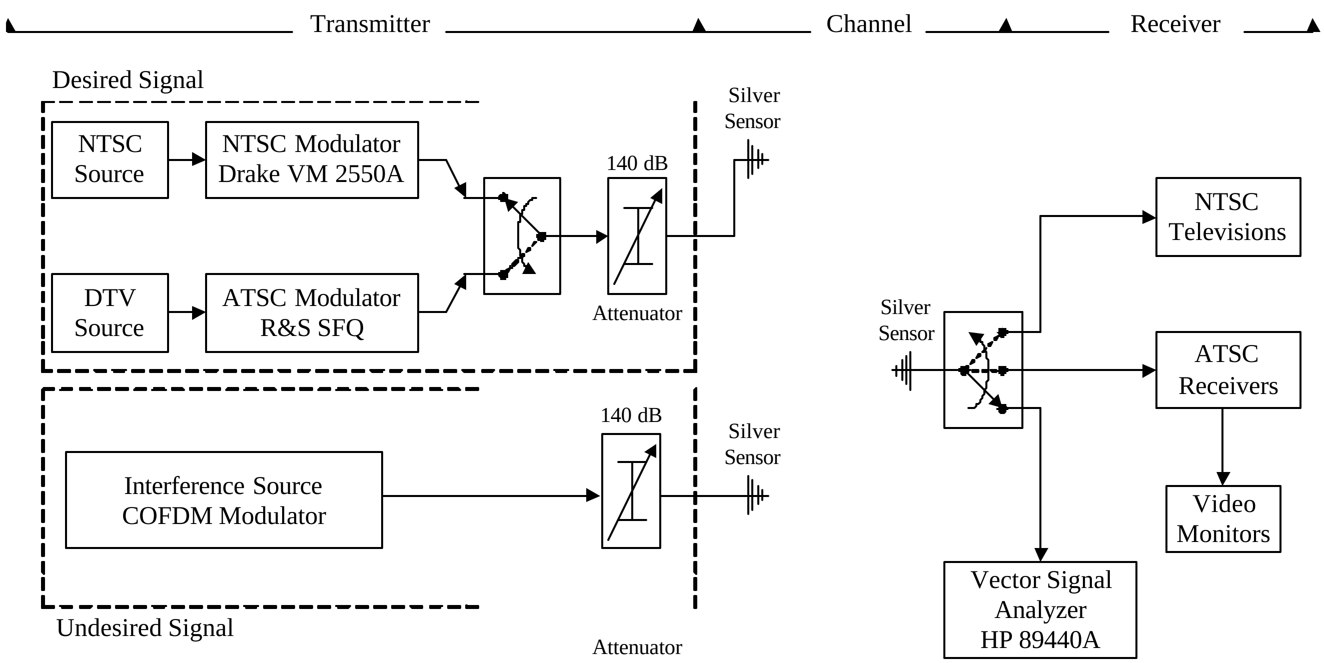


Figure 1 - Laboratory Test Set-up for the Evaluation of UD Emissions Impact on TV Signals.

In the above calculation, a simple dipole antenna is assumed. The emission limit field strength is converted into signal power (dBm). In the laboratory test, the interference power level is adjusted by varying the transmission power. The receiving power calibration is done at 3m from the emission point for the power levels calculated above.

The laboratory set-up for the evaluation of the ATSC 8-VSB receiver is presented in Figure 1. The set-up is divided into three sections: Transmitter, Channel and Receiver.

The laboratory measurements were conducted for distances between the UD and the DTV receivers of 3 m, 12 m and 24 m; for the NTSC case, the distances were 6 m and 18 m. (Note: Since the NTSC signal is more sensitive to interference, the test points for NTSC system is further away than for the DTV system). Tests were also conducted with the undesired signals transmitted through a wall (typical commercial office dry-wall) and the resulting receiver de-sensitisation measurement recorded. The test procedures are attached (Annex 1).

The Threshold of Visibility (TOV) was recorded for viewing DTV pictures over a 20 seconds period. The ITU-R Grade 3 performance (slightly annoying audio, video, colour) for NTSC was also recorded. The power levels recorded were in 1-dB step-size.

The tests were conducted using one video sequence for DTV and one video test pattern for NTSC (colour bar). The tests investigated the de-sensitisation effects due to UD interference using five different DTV receivers and three different NTSC receivers.

The tests were done on Off-Air Channel 48 (674-680 MHz) for DTV. Since only a cable TV NTSC modulator was available, the NTSC tests were performed in the 474 to 480 MHz band (CATV Channel located in the off-air Channel 14 and 15). All NTSC receivers used in the test have cable ready tuner. There are no over-the-air signals on Channel 14 and 15 in the Ottawa area where the tests were conducted.

As a reference, Figure 2 shows the off-air spectrum plots of 674-680 MHz and 474-480 MHz. It is noteworthy that there is no other interference source detected in these spectrum bands.

Four different UD interference signals were used with a 3 dB bandwidths of 5.6 MHz, 1.3 MHz, 3 x 0.43 MHz and 0.43 MHz. The spectrums of the signals are presented in Figures 3, 4, 5 and 6. Based on the spectrum plots, there is little, if any, multipath distortion at a 3m site.

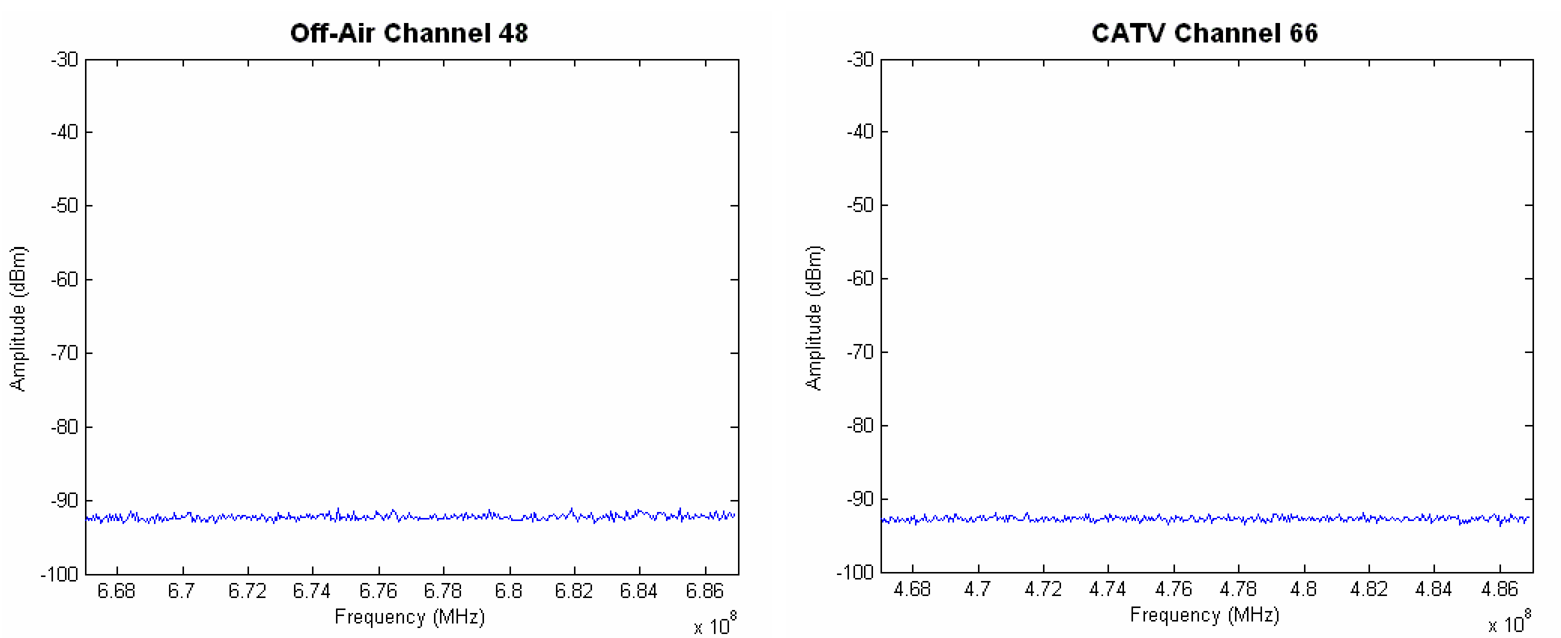


Figure 2. Off-Air Spectrum Plots of 674-680 MHz (DTV Tests) and 474-480 MHz (NTSC Tests)

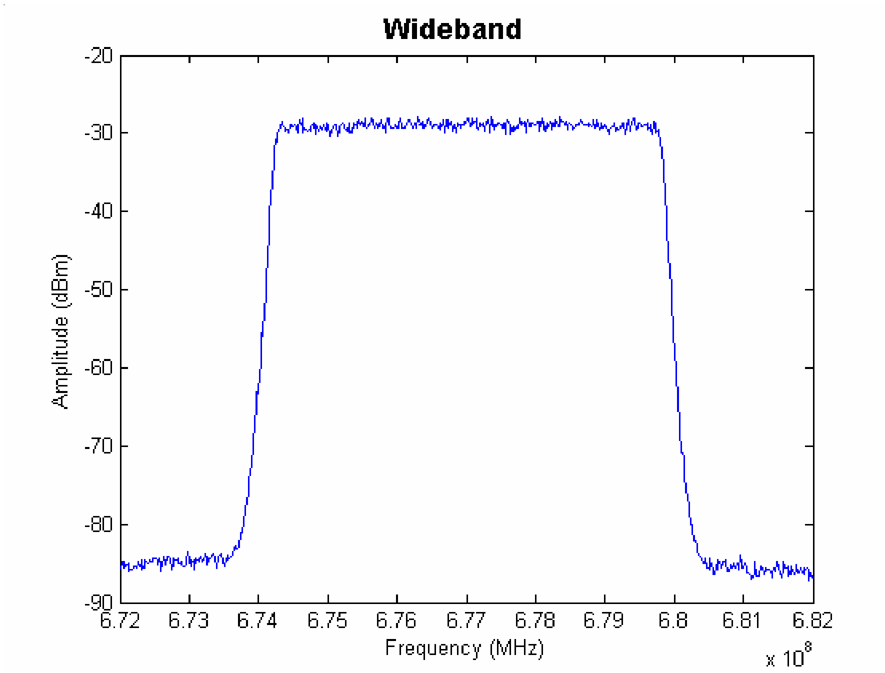


Figure 3. Spectrum of the Wideband Signal with a 3 dB Bandwidth of 5.6 MHz Received at 3 Meters.

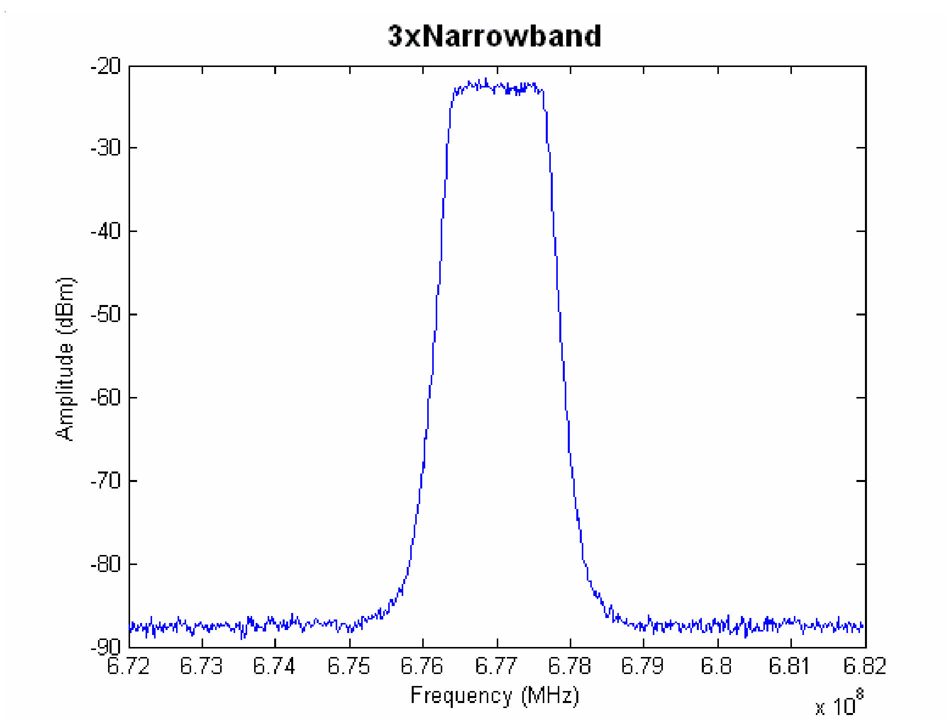


Figure 4. Spectrum of Mediumband Signals with a 3 dB Bandwidth of 1.3 MHz Received at 3 Meters.

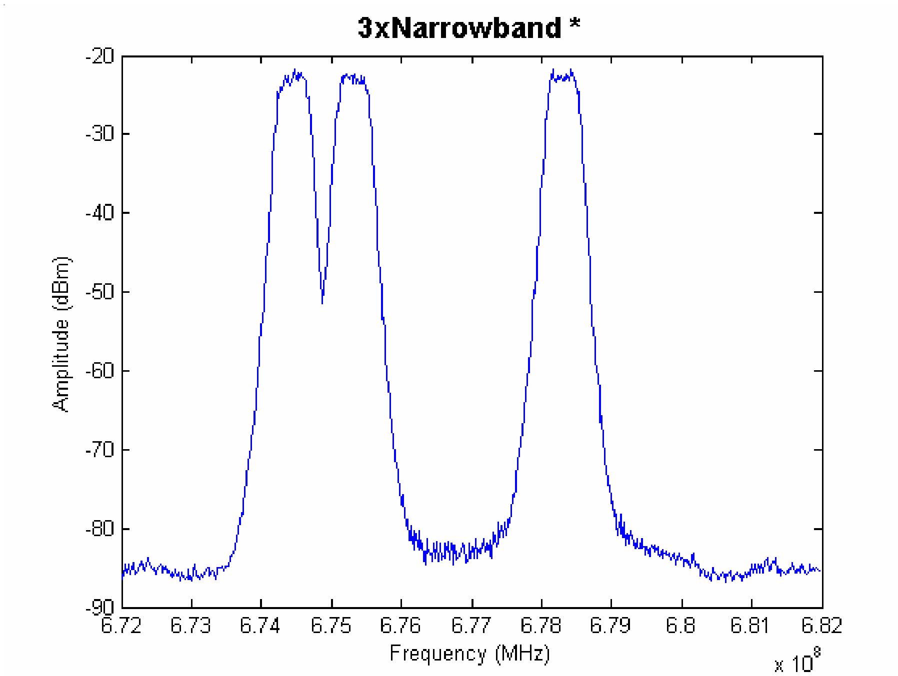


Figure 5. Spectrum of 3 x 0.43 MHz Narrowband Signals Distributed over the DTV Channel Received at 3 Meters.

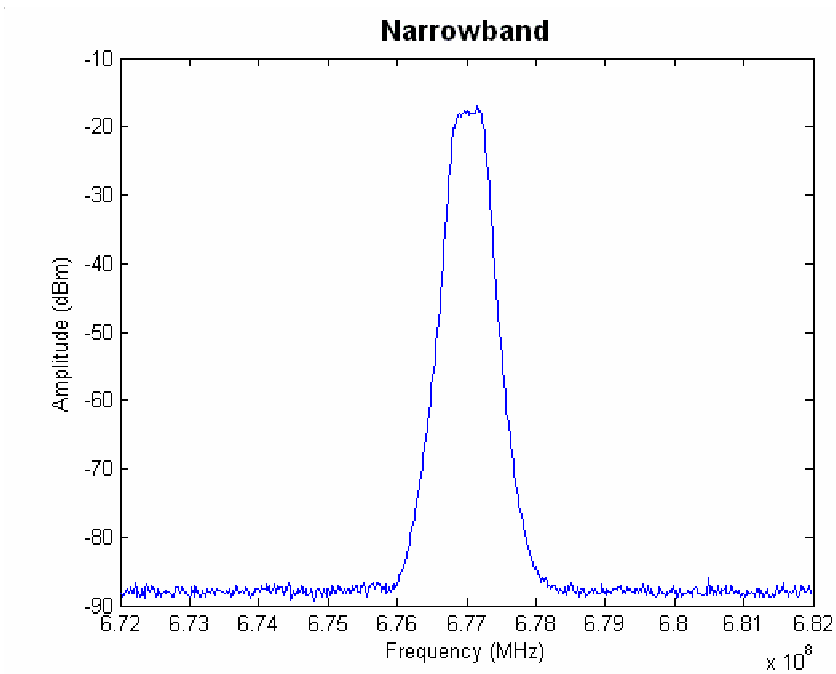


Figure 6. Spectrum of the Narrowband Signal with a 3 dB Bandwidth of 0.43 MHz Received at 3 Meters.

Results Of The Laboratory Test

The results of the following laboratory experiments listed below are presented in this section:

- De-sensitisation of DTV receivers in an indoor environment.
- De-sensitisation of DTV receivers with UD sideband signals transmitted through a dry wall.
- De-sensitisation of NTSC receivers in an indoor environment.
- De-sensitisation of NTSC receivers with the narrowband signal transmitted across the NTSC channel.
- Cable ingress created by the UD signals.

1.1 De-Sensitisation of DTV Receivers In An Indoor Environment

The DTV signal and the UD sideband signals were transmitted and received in the same room. The calibration was done at a distance of 3 m from the DTV receiver as specified by the FCC NPRM and explained in the test procedure in Annex 1. The interference signal power was adjusted to obtain -89.1 dBm/120 kHz at 3 meters.

For the 5.6 MHz wideband signal, the total interference power can be calculated as –89.1 + 10 log (5.6/0.12) = -72.4 dBm. For the 1.3 MHz and 3 x 0.43 MHz bandwidth signals, the total interference power is –89.1 + 10 log (1.3/0.12) = -78.8 dBm. For the 0.43 MHz narrow-band signal, the total interference power is –89.1 + 10 log (0.43/0.12) = -83.6 dBm. In all cases, the interference power levels were more than 50 dB below the recommended portable UD indoor power level at 3m-reference point.

A total of five DTV receivers were used in these tests.

The tests were conducted on Off-Air channel 48 (674 – 680 MHz). The results are presented in Table 1, 2 and 3 for the tests conducted at 3 m, 12 m and 24 m respectively.

Table 1. De-Sensitisation of DTV Receivers At 3 Meters.

Off-Air Channel 48	**DTV Receiver #1**	**DTV Receiver #2**	**DTV Receiver #3**	**DTV Receiver #4**	**DTV Receiver #5**
Rx Sensitivity	-80.5 dBm	-81.0 dBm	-81.9 dBm	-80.6 dBm	-80.1 dBm
De-sensitisation at 3 meters					
Wideband	24.0 dB	24.3 dB	26.6 dB	24.2 dB	23.7 dB
Mediumband	17.7 dB	18.6 dB	21.7 dB	17.7 dB	16.9 dB
3 x Narrowband*	18.1 dB	18.6 dB	22.5 dB	18.3 dB	17.2 dB
Narrowband	12.7 dB	14.2 dB	17.4 dB	12.7 dB	11.9 dB

*Three 0.43 MHz carriers distributed over the 6 MHz TV channel

Table 2. De-Sensitisation of DTV Receivers At 12 Meters.

Off-Air Channel 48	DTV Receiver #1	DTV Receiver #2	DTV Receiver #3	DTV Receiver #4	DTV Receiver #5
Sensitivity	-81.3 dBm	-82.2 dBm	-84.9 dBm	-82.6 dBm	-85.0 dBm
De-sensitisation at 12 meters					
Wideband	13.6 dB	14.5 dB	15.8 dB	15.5 dB	16.4 dB
Mediumband	8.8 dB	9.2 dB	13.2 dB	9.6 dB	10.9 dB
3 x Narrowband*	7.4 dB	7.4 dB	11.7 dB	8.7 dB	9.6 dB
Narrowband	3.9 dB	4.9 dB	7.9 dB	4.9 dB	6.4 dB

*Three 0.43 MHz carriers distributed over the 6 MHz TV channel

Table 3. De-Sensitisation of DTV Receivers At 24 Meters.

Off-Air Channel 48	DTV Receiver #1	DTV Receiver #2	DTV Receiver #3	DTV Receiver #4	DTV Receiver #5
Sensitivity	-81.4 dBm	-79.2 dBm	-84.3 dBm	-83.2 dBm	-83.9 dBm
De-sensitisation at 24 meters					
Wideband	10.4 dB	8.3 dB	14.1 dB	12.1 dB	12.1 dB
Mediumband	6.9 dB	4.7 dB	11.9 dB	8.3 dB	8.9 dB
Narrowband	2.2 dB	1.4 dB	7.2 dB	4.9 dB	4.9 dB

It was noticed that the receiver sensitivity varies in a +/-1 dB range for different test points. This is attributed to one or all of these factors: multipath distortion, noise floor variation and other interference mechanisms. It was also noticed that DTV Receiver #3 always showed a higher de-sensitisation than other DTV receivers. This is attributed to Receiver 3 having a more sensitive tuner and being more susceptible to the multipath distortion (requiring a higher S/N under multipath environment).

It was also observed that signal reflection within the building created standing waves. The result of this phenomenon was that the received signal could be up to 3 dB higher than what it would be for free-space propagation. There were also signal "nulls" in the room, which could result in signal level drops of several dB over small changes in location. Moreover, multipath effects were observed to increase as the distance from the transmitter was increased.

1.2 De-Sensitisation of DTV Receivers by UD Sideband Signals Transmitted Through A Wall.

In these tests, the interference signals were transmitted through one wall before reaching the DTV receivers. The walls are typical interior office fire protective dry wall.

The calibration was done at 3 m as explained in the test procedure in Annex 1. Tests were conducted on Off-Air channel 48 (674 – 680 MHz). The interfering signal power was adjusted to be at -89.1 dBm/120 kHz at 3 meters from the receivers. The receivers tested using this interference source are listed in Annex 2.

The results of the test using the various DTV receivers each separated from the interference source by one wall such that the DTV receiver was 5 m from the interference source, which was 3m from the wall, are presented in Table 4.

Table 4. De-Sensitisation of DTV Receivers for Interfere nce Signals Transmitted through One Dry Wall at a Distance of 5 Meters.

Off-Air Channel 48	DTV Receiver #1	DTV Receiver #2	DTV Receiver #3	DTV Receiver #4	DTV Receiver #5
Sensitivity	-80.2 dBm	-81.5 dBm	-82.8 dBm	-80.7 dBm	-82.7 dBm
De-sensitisation at 5 meters (1 wall)					
Wideband	18.1 dB	19.4 dB	21.6 dB	18.6 dB	20.9 dB
Mediumband	11.6 dB	12.6 dB	15.8 dB	11.9 dB	13.6 dB
Narrowband	7.6 dB	8.8 dB	12.6 dB	7.5 dB	9.1 dB

Similarly, tests were conducted at 12 m the results of which are shown in Table 5. For this case the test were conducted with and without a wall between the interference source and the DTV receivers.

The test results show that the interference signal is attenuated by about 3-6 dB, when going through a typical fire rated office drywall.

Table 5. De-Sensitisation of DTV Receivers for Interference Signals Transmitted and Not Transmitted Through One Dry Wall at a Distance of 12 Meters.

Off-Air Channel 48	DTV Receiver #1	DTV Receiver #2	DTV Receiver #3	DTV Receiver #4	DTV Receiver #5
Sensitivity	-80.8 dBm	-81.1 dBm	-82.4 dBm	-82.0 dBm	-81.1 dBm
De-sensitisation at 12 meters (No wall)					
Wideband	13.6 dB	14.6 dB	15.8 dB	15.5 dB	16.4 dB
De-sensitisation at 12 meters (1 wall)					
Wideband	11.3 dB	10.6 dB	13.1 dB	13.1 dB	11.0 dB

1.3 De-Sensitisation of NTSC Receivers in an Indoor Environment

The NTSC and the interference signals were transmitted and received in the same room. The calibration was done at 3m as explained in the test procedure in Annex 1. The interference signal power was adjusted to obtain -86.1 dBm/120 kHz at 3 meters. The lists of the NTSC receivers used in the tests are also presented in Annex 2.

The de-sensitisation tests were carried out on CATV channel 66 (474 – 480 MHz) equivalent to UHF off-air Channel 14 and 15. (Note: a cable TV NTSC modulator was used in the test, as an off-air NTSC modulator was not available. However, this should have no impact on the test results, since there is only a slight frequency range difference, the signal modulation is the same). The results are presented in Tables

6 and 7 for tests conducted for distance of 6m and 18m respectively. The greater than sign ">" indicates that de-sensitisation was beyond the limits of the test-bed.

Table 6. De-Sensitisation of NTSC Receivers at 6 Meters.

CATV Channel 66	NTSC Receiver #1		NTSC Receiver #2		NTSC Receiver #3	
	TOV	ITU-R Grade 3	TOV	ITU-R Grade 3	TOV	ITU-R Grade 3
Sensitivity	-51.5 dBm	-61.5 dBm	-41.5 dBm	-51.5 dBm	-45.5 dBm	-58.5 dBm
De-sensitisation at 6 meters						
Wideband	> 23 dB	26 dB	> 13 dB	14 dB	> 17 dB	21 dB
Narrowband	14 dB	15 dB	2 dB	3 dB	14 dB	14 dB

Table 7. De-Sensitisation of NTSC Receivers at 18 Meters.

CATV Channel 66	NTSC Receiver #1		NTSC Receiver #2		NTSC Receiver #3	
	TOV	ITU-R Grade 3	TOV	ITU-R Grade 3	TOV	ITU-R Grade 3
Sensitivity	-51.5 dBm	-61.5 dBm	-41.5 dBm	-51.5 dBm	-45.5 dBm	-58.5 dBm
De-sensitisation at 18 meters						
Wideband	> 8 dB	18 dB	> 4 dB	12 dB	> 7 dB	16 dB
Narrowband	8 dB	8 dB	2 dB	1 dB	7 dB	8 dB

The test results show that there is more desensitisation for NTSC than that of DTV. This is most likely because the NTSC system requires a higher S/N to operate.

The test also shows that the NTSC Receiver 2 requires 5-10 dB more power (sensitivity) than Receiver 1 and 3 for TOV and ITU-R Grade 3.

1.4 De-Sensitisation of NTSC Receivers with the Narrowband Signal Transmitted Across NTSC Band

The purpose of this test was to study the impact of a narrowband interfering signal positioned at various frequencies across the NTSC channel would have on the NTSC signal itself.

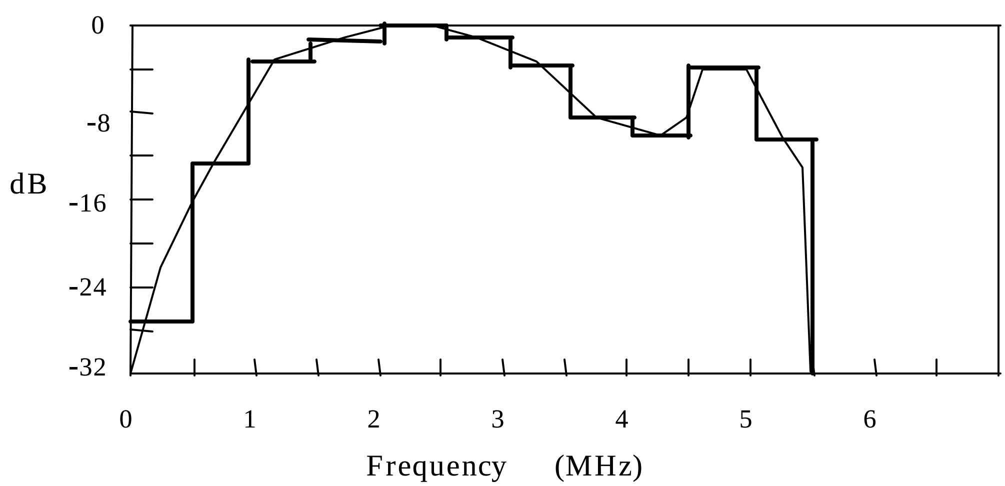
The NTSC signal and the narrowband interference signal were transmitted and received in the same room. The calibration was done at 3m as in previous cases. The interference signal power was then adjusted to obtain -86.1 dBm/120 kHz at 3 meters. The test for this case was completed with only the NTSC receiver #1 (see the list of the NTSC receivers in Annex 2).

Again, CATV Channel 66 (474 – 480 MHz), which is equivalent to UHF off-air Channels 14 and 15, was used for the test. Table 8 presents the test results at 6m and at different frequencies across the NTSC channel. An NTSC visual signal RF subjective weighting curve shown in Figure 7 was used as reference for the interference calculation. Figure 7 shows that the NTSC visual signal is most sensitive to interference positioned between 1.5 and 2.5 MHz above the lower channel edge.

Table 8. De-Sensitisation of NTSC Receivers At 6 Meters For The Narrowband Signal Transmitted Across The NTSC Band

CATV Channel 66	NTSC Receiver #1				
	Center Frequency of the narrowband interference signal				
	474.5 MHz (At 0.5 MHz)	476 MHz (At 2.0 MHz)	477 MHz (At 3.0 MHz)	478 MHz (At 4.0 MHz)	478.75 MHz (At 4.75 MHz)
De-sensitisation at 6 meters					
TOV	4 dB	16 dB	14 dB	14 dB	18 dB
ITUR-3	5 dB	18 dB	15 dB	15 dB	18 dB

Figure 7. NTSC Visual Signal RF Subjective Weighting Curve ("S" Curve).



The test results match well with the NTSC visual signal weighting curve ("S" curve), except at the colour sub- carrier location (about 4.75 MHz from the lower channel edge), where it is more sensitive to the interference. This is because the colour-bar test pattern, which is very sensitive to the colour sub-carrier interference, was used for the subjective assessment.

1.5 Cable Ingress Created by the UD Sideband Signals

The purpose of these tests was to determine the possible cable ingress created by the interfering signals.

For these tests, an indoor portable UD was assumed. This UD was set to transmit a 100-mW wideband signal through a Silver Sensor antenna with about 5-dB gain. The closest distance between the antenna and the cable was about 1 meter. Two types of cable were used. One being an RG-6 double shielded cable; and the other an RG-59 single shielded cable. The length of the cable used in the test was about 10 meters. The cable was stretched across a room with one end connected to a Vector signal analyser for ingress signal power measurement. Tests were conducted with the other end of the cable either terminated in its characteristic impedance or un-terminated. The results of the tests are presented in Table 9.

Table 9. Cable Ingress Created by Wideband Emission Signal.

CABLE INGRESS MEASURED POWER				
FREQUENCY	RG-6 CABLE		RG-59 CABLE	
	NOT TERMINATED	TERMINATED	NOT TERMINATED	TERMINATED
195 MHz	-46 dBm	-69 dBm	-44 dBm	-48 dBm
515 MHz	-55 dBm	-68 dBm	-44 dBm	-46 dBm

The results confirmed, as expected, that the double-shielded RG-6 cable will pick up interference, if it is not terminated (in our test the un-terminated cable end is about 5m away from the transmitting antenna). RG 6 cable is probably the most widely used cable for home installation of cable TV and Satellite TV systems. For the case of the single shielded RG-59 cable, the test show that regardless of weather it is terminated or not, significant ingress interference was detected. Non-professionals to install additional cable outlet at home often use RG 59.

Findings & Observations

1. To avoid measurement errors, the interference signal level was set at 3 dB below the FCC recommended emission limit, thus, the actual receiver desensitisation could be up to 3 dB higher than the measurement results.

2. For different interfering signal bandwidth, the results are very much proportional to the interference signal bandwidth. For example, the wideband interference signal, 5.6 MHz BW, will cause 10 log (5.6/0.43) = 11.1 dB more desensitisation than narrowband interference signal with a 0.43 MHz bandwidth. Test results show that, for each DTV receiver, the discrepancy is within +/- 1 dB over calculated results (see Table 1, 2, and 3). When desensitisation is small as shown in Table 3, the power calculation method is not accurate, since the receiver noise floor will impact the desensitisation. For example, if the interference is at the same level as the receiver noise floor, the desensitisation will be 3 dB rather than 0 dB.

3. It is interesting to note that a 1.3 MHz bandwidth interfering signal has almost the same impact as three individual 0.43 MHz (3 x 0.43 = 1.29 MHz) interference signals (+/- 1 dB accuracy) spread across a TV channel as shown in Tables 1 and 2.

4. Indoor multipath reflection forming standing waves, which results in signal peaks and nulls over few inches distance (RF frequency dependent) were observed. The peak can be 3 dB above free space propagation curve, while nulls can easily cause several dB of signal loss. The further away from the UD, the greater the potential for multipath reflection, which could cause possible desensitisation in extended areas.

5. There was more desensitisation for the case of NTSC than for that of DTV. This result is expected, since the NTSC system requires higher S/N than the DTV system to operate.

6. A narrow band interference signal located in an NTSC channel follows the behaviour of the "S" curve.

ANNEX 1: TEST PROCEDURE

Test Procedure for Unlicensed Devices Interference Signal Emissions into the ATSC DTV and NTSC Channel.

Set Up:

- Select an RF channel between CH14 and 51.

-Make sure there is minimum off-air interference in co- and first adjacent channels.

- Interference emissions signals:
  1. Wideband emission signal, 5.6 MHz BW
  2. Narrowband emission signal, 0.429 MHz BW
  3. Mediumband emissions signals, 1.3 MHz BW
  4. Three narrowband emissions signals distributed over the 6 MHz channel, 3x0.43 MHz
- Interference signal power level set up:
  - FCC emission requirement: 200 uV/m, or 46 dBuV/m within a 120 kHz BW.
  - Convert to dBm: P(dBm) = -75.5 + dBuV/m – 20 log(Frequency in MHz)
  - The emission signal level should be measured at 3m from the unlicensed devices, within a 120 kHz BW.
  - The signal level should be 3 dB below the above calculated emission level P(dBm) to avoid possible measurement errors. Since allowed interference signal power is calculated and fed to the receiver directly, the type of antenna used for transmission and reception is irrelevant.

- Wanted signal:
  - ATSC DTV and NTSC.
  - TOV is used as the test threshold.
  - Test point: 3m, 12m and 18m away from the unlicensed devices.
  - Tests will also be done with signals transmitted thought a wall.
  - Television channel multipath distortion should be minimum.

DTV TEST

1. Test at 3m with wideband and narrowband interference emissions signals:

- At 3m, measure the off-air interference level (co- and first adjacent-channels), and the equipment noise level in 6 MHz and in 120 kHz bandwidth;
- Adjust interference emission signal power level, measured 3m away, to be P(dBm) – 3 dB over the 120 kHz BW;
- Turn off the interference, transmit ATSC DTV, and find TOV, record the transmitted signal power level in 6 MHz and in 120 kHz bandwidth;
- Turn on the interference emission signal. If DTV reception is not possible, increase the DTV signal power level until TOV, record the DTV Tx signal power level in 6 MHz and 120 kHz bandwidth. The difference between the DTV signal power level with and without the interference emission signal is the receiver de-sensitisation.

2. Test at 12m:

- Keep the interference emission signal power unchanged and moves the test point to 6m.
- Repeat the 3m tests.

- The result will be the de-sensitisation at 6m.

3. Test at 24m:

- Keep the interference emission signal power unchanged and moves the test point to 24m,
- Repeat the 3m tests.
- The result will be the de-sensitisation at 24m.

NTSC TEST

- Keep the interference emission signal power unchanged, repeat test at 6m, and 18m with NTSC as the wanted signal.
- For narrowband interference test, the interference emission signal should be transmitted at several in-band frequency locations across 6 MHz channel.
- NTSC signal power is measured as peak average power.

ANNEX 2: LIST OF RECEIVERS

DTV Receiver #	Type
1	Consumer
2	Professional
3	Consumer
4	Consumer
5	Consumer

NTSC Receiver #	Type
1	Consumer
2	Consumer
3	Consumer

ANNEX 3: OFFICE DRY WALL AND PHOTOS OF TEST EQUIPMENT

Figure A3-1: Office dry wall Side A (signal goes through white-board).

Figure A3-2: Office dry wall Side B (signal goes through white-board).

Figure A3-3: UD and DTV/NTSC Transmission Systems.

Figure A3-4: Five DTV Receivers and Reception System Set Up.