

# Interference to UHF-DTTV Channels by Unlicensed Devices

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**Abstract**—With the transition to digital terrestrial television (DTV) in the U.S. scheduled to be complete by 2009, the Federal Communications Commission (FCC) has issued a notice of proposed rule making (NPRM) that, if adopted, would allow transmission by unlicensed devices on frequencies of vacated television channels. The FCC is required by statute to avoid harmful interference to licensed TV channels. This paper addresses two of the core questions related to the proposed introduction of unlicensed transmissions in the vacated TV channels: **Do the proposed rules provide DTV stations adequate protection from interference from these devices? If not, what rules must be adopted to avoid harmful interference to terrestrial DTV service from these devices?**

**Index Terms**—Unlicensed devices, harmful interference, vacated television channels.

## I. INTRODUCTION

In anticipation of the shutdown of analog television early in 2009, the FCC has proposed that unlicensed devices be allowed to use most of the vacant TV spectrum in the band of channels 2 to 51 as per NPRM 04-113 and ET Docket 04-186. The stated rationale for this action is that it “will provide for more efficient and effective use of the TV spectrum and will have significant benefits for the public by allowing the development of new and innovative types of unlicensed broadband devices and services for businesses and consumers<sup>1</sup>.”

The FCC is required by statute to protect licensed TV broadcasters from harmful interference. The NPRM defines what is harmful interference in terms of the protection ratios applied to DTV and the out-of-band sideband level for unlicensed devices defined in § 15.209(a) of C.F.R (Code of Federal Regulations) 47. Two types of unlicensed devices are proposed, fixed and portable. Table I is a summary of the NPRM’s proposed operation parameters for these devices.

The intent of the proposed rules is to permit an *unrestricted number* of unlicensed devices to operate on *any* vacated TV channel while avoiding harmful interference to digital television. Given the available technology, are the proposed rules consistent with good engineering practice?

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This paper will show that a single such unlicensed device, operating in compliance with the proposed rules, could cause harmful interference to DTV and that the FCC’s definition of “harmful interference” is incompatible with real-world over-the-air reception of DTV. *Further, two devices, operating on two channels neither cochannel or first adjacent channel could create undesirable interference.*

FCC 04-113 and 04-186 Proposed Rules	Fixed $U_F$	Portable $U_P$
Peak EIRP/Device	4W	.4W
Antenna Gain (RMS)	6dBi max.	
RF Mask	See Section II	
Radiation Center	10 meters or actual above ground whichever is highest	2 meters above ground*
Bandwidth	unrestricted	
Polarization	unrestricted	
Propagation Algorithm	F(50,50) “or other appropriate models”***	
Number of devices	unrestricted	
Interference to TV Within 10 meters of Device	ignored	
Cochannel Transmission Inside the TV Protected Contour****	not permitted	
Adjacent Channel Transmission Inside the TV Protected Contour****	permitted if $D/U_F \geq -27 \pm 1$ dB inside protected contour	unrestricted
Cochannel Transmission Outside the TV Protected Contour	permitted if $D/U_F \geq 23$ dB using F(50,50) for D	permitted if $D/U_P \geq 23$ dB using F(50,50) for D
Adjacent Channel Transmission Outside the TV Protected Contour	permitted if $D/U_F \geq -27 \pm 1$ dB using F(50,50) for D	unrestricted

Table I: Proposed Rules for Protection of Terrestrial DTV (D) from Interference by Unlicensed Devices ( $U_F$  and  $U_P$ )

\* Presumably the intended height would be 2m above the floor where the TV set is located.

\*\* F(50,50) does not apply to <10m heights or to distances <31m from the transmitter. Other appropriate models are not specified.

\*\*\* F(50,90)/41 dBu for full-power DTV; F(50,90)/51 dBu for Class A DTV.

\*\*\*\* Desired DTV signal based on F(50,90)/41 dBu or F(90,90), whichever is higher.

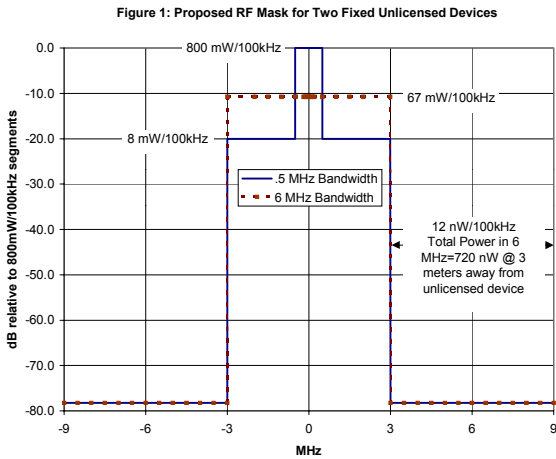
## II. SPECTRAL POWER DENSITY AND RECEIVED POWER

For fixed devices with bandwidth between .5MHz (minimum) and 6MHz, the proposed RF mask in terms of spectral power density over 100kHz segments is shown in Figure 1.

For a device with 6MHz bandwidth and a total EIRP (Effective Isotropic Radiated Power) of 4W, the permitted spectral density is 67mW/100kHz. If the device’s bandwidth were .5MHz, the permitted spectral density would be

800mW/100kHz within its .5MHz bandwidth and 8mW (-20dB) outside its bandwidth but inside the DTV channel in which it operates. In the latter case, the total transmitted power in the 6MHz channel would be 4.44 Watts. The proposed spectral power density for portable devices inside the channel in which it operates is 10 dB below the levels permitted for fixed devices.

At 3 meters away and outside the channel in which the devices operate, the spectral power density of the devices may not exceed 12nW/100kHz or 720nW/6MHz. *There is, however, no restriction on how many devices are allowed. Nor is there any restriction on the maximum spread of the 720nW/6MHz outside the DTV channel in which the unlicensed device would operate.*



Generally, the installed device’s height above average terrain (HAAT) would be within 31m, the minimum height for which FCC(50,50) propagation curves are available. For heights below 31m and excluding obstructions, the appropriate propagation model would be the free-space formula devised by Friis<sup>2</sup>. Excluding polarization discrimination<sup>a</sup> and additional power that might be received through local reflections, the received power ( $P_R$ ) can be expressed in terms of the transmitter power ( $P_T$ ) and distance to the receiver ( $r$ ) or in terms of the field strength ( $E$ ) incident at the receive antenna as follows:

$$P_R (dBm) = P_T (dBm) + G_U (dBi) + G_D (dBi) + 27.56 - 20 \log_{10} [f(MHz) * r(meters)] \quad (1)$$

$$P_R (dBm) = E(dBu) + G_D (dBi) - 77.22 - 20 \log_{10} [f(MHz)] \quad (2)$$

where

$$E(dBu) = 134.77 + 10 \log P_T (watts) - 20 \log_{10} [r(meters)] \quad (3)$$

$G_U$  and  $G_D$  are the antenna gains, respectively, of U (Undesired Device) and D (DTV Set).

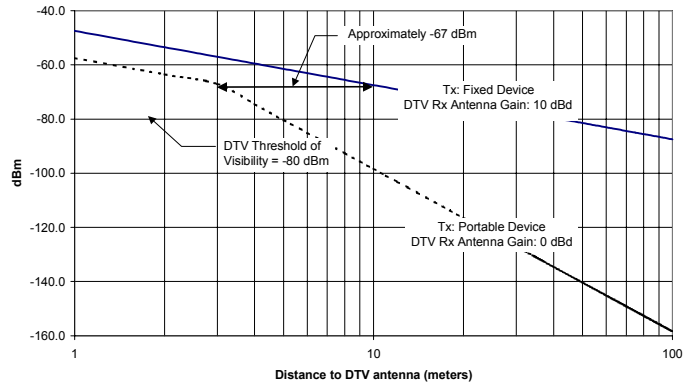
<sup>a</sup> TV stations are permitted to simultaneously transmit horizontal and vertical polarization at the licensed power.

Where free-space or the FCC’s F(L,T) propagation algorithms do not apply, the general model used to determine the average path loss is<sup>3</sup>:

$$L(r) = L(r_0) + 10 \log_{10} \left( \frac{r}{r_0} \right)^n \quad (4)$$

where  $L(r_0)$  is the loss up to  $r_0$ , the free-space radius inside of which  $n=2$ . Inside apartments,  $r_0 < 3$  meters is assumed. Inside buildings where  $r_0 > 3$  meters, and shadowed urban areas,  $n$  rises to between 4 and 6.

Figure 2: Power Received by a DTV Channel as Cochannel Interference from a Single Unlicensed Device on Any Other Channel [nonlinear distortion generated at the receiver not included]



### III. ADJACENT CHANNEL INTERFERENCE INSIDE THE PROTECTED DTV CONTOUR

The adjacent channel interference that degrades the reception of DTV channels<sup>4</sup> is composed of two separate parts. Type I originates from the sideband power of the unlicensed device that appears as cochannel interference to the adjacent DTV channel. Generally, Type I is low-level and does not contribute significantly to intermodulation at the receiver. As stated earlier, the maximum allowable sideband level is a fixed 12nW/100kHz without bandwidth limit regardless of the power radiated by the device. Type II is the combined cross modulation and 3<sup>rd</sup> order intermodulation distortion generated at the receiver when received power of the adjacent channel is high or the 3<sup>rd</sup> order intercept point of the receiver is low. When the received DTV power or the total received power from the undesired devices is sufficiently strong, the intermodulation distortion level would saturate the receiver, blocking all DTV reception. In the interim, the receiver sensitivity would gradually be lowered, blocking some DTV stations. Appendix A provides the variable D/U (Desired/Undesired signal levels) at TOV (Threshold of Visibility at which impairments are noticed) for the entire dynamic range within which DTV receivers are expected to provide service to consumers.

#### III(a): Type I Interference

Depending on the bandwidth occupied by the 720nW/6MHz sideband shown in Figure 1, it may appear as cochannel interference to *all* DTV channels. The sideband power received at the DTV antenna’s terminals from two types of unlicensed devices is shown in Figure 2. One example is a

fixed device operating at the proposed omnidirectional radiating power of 4W and facing the outdoor UHF-DTV antenna specified by the FCC's planning factors. The DTV antenna is 10m above ground and its gain is 10dBd. Free-space propagation would be the appropriate model for the two outdoor antennas in close proximity. For this model the minimum received interference signal level at the antenna terminals would be -67dBm, 13dB above the -80dBm level at TOV.

A second example is that of a portable device radiating .4W separated by 3m<sup>b</sup> from a DTV receiver connected to a settop antenna whose gain is 0dBd. The DTV receiver model with indoor antenna is not specified by the FCC's planning factors. A typical impedance mismatch between the settop antenna and the receiver's front end would raise the noise figure from 7dB to 11dB<sup>5</sup>. The line loss between the settop antenna and the tuner can be assumed close to 0dB. For this model, the minimum received interference signal level would also be -67dBm, well above the -80dBm level at TOV. The appropriate propagation model indoors would be based on equation (4) with n=2 for the first 3m and n=4 for distances greater than 3m.

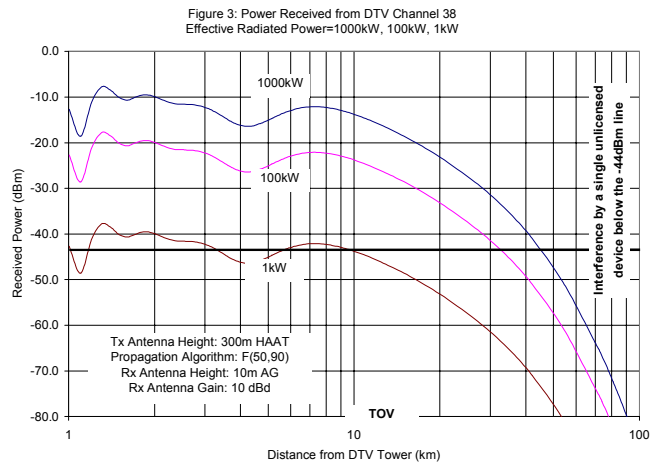
As shown in Figure 2, the received sideband interference power from a fixed device 10m away or from portable device 3m away is approximately the same, -67dBm (within .5dB). Since the sideband of unlicensed devices appears as cochannel interference to the DTV channel, the FCC protection ratio of D/U = 23dB applies. It follows that in order to avoid harmful interference the received DTV signal must be at least -44dBm, 36dB above the protected level of -80dBm at the edge of the protected DTV contour. To avoid harmful interference at the edge of the protected DTV contour, the *total* received sideband power from fixed devices at least 10m away and portable devices at least 3m away must not exceed -103dBm in compliance with the FCC protection ratio of D/U = 23dB.

Figure 3 shows how a single unlicensed device would restrict the service area of three typical DTV stations radiating 1kW to 1,000kW. The entire service area of low-power DTV stations will be subject to harmful interference. For higher power stations, a significant loss of service can be expected. For example, the noise-limited contour of the 1,000kW station would be 102km without interference. With interference from unlicensed devices 10m away from DTV sets, the interference-protected contour will shrink from 102km to 45km. Similarly,

<sup>b</sup> The NPRM specifies that interference to DTV sets within 10 meters be ignored may be reasonable for fixed devices that are installed outdoors. But in urban settings, the 10 meters minimum inside apartments is unreasonable. In most apartments, 10 meters separation between the DTV set and the unlicensed device(s) is not possible. Therefore, the minimum separation criteria used in this paper are 10 meters for outdoor installation of fixed devices and 3 meters for indoor installation of portable devices.

the noise-limited contour of the 100kW station will shrink from 78km to an interference-free contour of 34km.

Since the NPRM does not restrict the number of unlicensed devices per unit volume, it is reasonable to estimate the interference that could be expected if unlicensed devices



with the unlimited sideband bandwidth shown in Figure 1 are allowed to proliferate. Proliferation of these devices should be anticipated for broadband applications such as wireless networking of TV and computers.

In a dense urban environment the volume of a sphere with a radius of 10m and allowing for 25% of the volume dedicated to common space, is equivalent to the volume of 10-15 apartments each with one portable device on a random channel. The average radius of the 15 apartments to the DTV set at the center of the sphere would be 7.94m. The additional received interference power, based on instantaneous voltage addition<sup>c</sup> of 15 devices 8m away is -69dBm. Therefore, in an urban setting the expected total sideband interference from unlicensed devices received by a DTV set would be -65dBm, the sum of one device 3m away and 15 devices with an average distance of 7.94m away. The analysis of this section has shown that the proposed level and the unlimited bandwidth of the sideband will generate significant harmful interference.

### III(b): Type II Interference

The incident field strength at an outdoor DTV antenna with a gain of 10dBd aimed at a fixed device radiating 4W (+36dBm) 10m away would be 120.8dBu and the received power level at the terminals of DTV antenna would be -0.06dBm. Assuming 4dB lead loss, the power at the input to the tuner would be -4.1dBm. Similarly, the received power level at the terminals of an indoor antenna with a gain of 0dBd 3m away from a portable device would be -9.6dBm. Assuming

<sup>c</sup> The probability of continuous coherent addition of broadband channels is low, but the probability of instantaneous addition, enough to cause visible interference may be high.

no lead loss, the power at the input to the tuner would remain  $-9.6\text{dBm}$ .

The level of 3<sup>rd</sup> order intermodulation generated at the DTV receiver by an undesired signal is given by:

$$IM_3(\text{dBm}) = 3U(\text{dBm}) - 2IP_3 \quad (5)$$

where  $IP_3$  is the 3<sup>rd</sup> order intercept point of the receiver.

Higher  $IP_3$  results in a lower level of the undesired  $IM_3$  whereas increasing the gain of the receiver increases the  $IM_3$  level. Therefore, the  $IP_3$  and the noise figure are system performance tradeoffs. Table II provides the estimated level of undesired  $IM_3$  generated into DTV channel N by a single unlicensed device on the first, second and third adjacent. The calculations of the  $IM_3$  levels in channel  $N\pm 2$  assumed the  $IM_3$  level in channel  $N\pm 1$  as the undesired adjacent channel power. Similarly, the  $IM_3$  levels in channel  $N\pm 3$  assumed the  $IM_3$  level in channel  $N\pm 2$  as the undesired adjacent channel power.

The received  $IM_3$  levels of Table II behave as additional noise injected into DTV channel N. Even for a single fixed unlicensed device on channel  $N\pm 2$ , the DTV signal level would have to be at least  $-69+23 = -46\text{dBm}$  to just meet TOV. That is, even a 1,000kW DTV would lose a large portion of its service area by  $IM_3$  generated at the DTV set by a proposed fixed unlicensed device 10m away. From Table II it is clear that operating fixed unlicensed devices on first and second adjacent channels under the rules proposed by the NPRM will cause harmful interference to a licensed DTV station on channel N.

But TOV should not be reached and, as shown in Figure 3, the received DTV level on channel N can easily reach  $-8\text{dBm}$ . As shown in Appendix A, the protection ratio at TOV increases to  $D/U = +2\text{dBm}$  when the DTV signal reaches  $-10\text{dBm}$ . That is a 30dB rise over the protection ratio for weak DTV signals. Therefore, the received signal at the tuner from a single portable device ( $-9.6\text{dBm}$ ) would be at an unacceptable TOV and that from a fixed device ( $-4.1\text{dBm}$ ) would be well above TOV.

The analysis of this section shows that both Type I and Type II adjacent channel interference from the proposed fixed unlicensed devices will cause severe degradation to the interference-free service areas of DTV stations including total failure of reception in some areas by overloading the front-end of DTV receivers. When both desired and undesired signals are strong, a programmable attenuator could be inserted between the antenna and the front-end to reduce the interference to an acceptable level. But that option cannot be applied at locations where the undesired is strong and the desired is weak.

It follows that operation of fixed devices on channels  $N\pm 1$  and  $N\pm 2$  should be prohibited unless these devices are licensed, cognitive and remote-controllable. Their height, pattern and power must be controlled to avoid harmful

interference. Their database of available channels should be updated automatically and transmitted as a beacon to unlicensed portable devices. Prior to transmission, portable unlicensed devices must receive a beacon from a fixed device that lists the available channels. If the front-end filter of the DTV receiver allows channel  $N+2n$  to pass, then channel pairs  $[N\pm n; N\pm 2n]$  should also be prohibited because their  $IM_3$  falls into channel N.

	$U_F = 4W$ Rx antenna gain=10dBd 10m separation 4dB lead loss		$U_P = 0.4W$ Rx antenna gain=0dBd 3m separation 0dB lead loss	
	$IP_3 = +4\text{dBm}$	$IP_3 = +8\text{dBm}$	$IP_3 = +4\text{dBm}$	$IP_3 = +8\text{dBm}$
U on channel $N\pm 1$	-20dBm too high	-28dBm too high	-37dBm too high	-45dBm too high
U on channel $N\pm 2$	-69dBm too high	-77dBm too high	-118dBm ok	-126dBm ok
U on channel $N\pm 3$	negligible	negligible	negligible	negligible

Table II:  $IM_3$  Generated by Unlicensed Devices in a DTV Receiver Tuned to Channel N

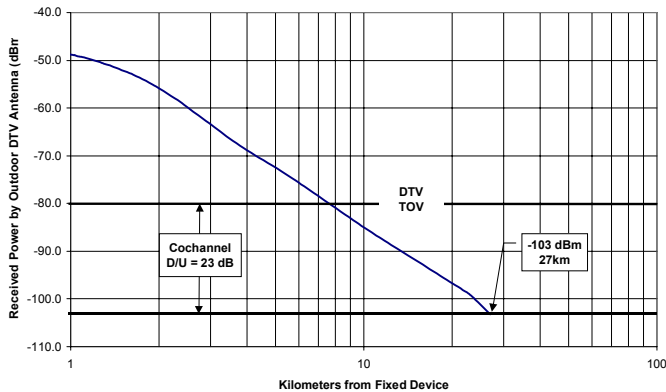
As an example of  $IM_3$  by a pair of channels, consider two DTV stations, one on channel 28 and the other DTV on channel 37. The protected contours of the stations intersect, and inside that intersection, two unlicensed devices transmit on channel 31  $[N+3]$  or  $[N-6]$  and on channel 34  $[N-3]$  or  $[N+6]$ <sup>4,6</sup>. When both devices transmit simultaneously, the resulting  $IM_3$  will fall into DTV channels 28 and 37. The bandwidth of channel 28 through 37, 60MHz, could well be within that of modern tracking filters. Similarly, if unlicensed devices on channel 30 and 32 transmit simultaneously, their combined  $IM_3$  will appear in channel 28 and channel 34, a bandwidth of only 42MHz. Therefore, *cochannel or adjacent channel-like interference is possible from a pair of devices operating on channels neither of which is adjacent or cochannel.*

#### IV. COCHANNEL INTERFERENCE OUTSIDE THE PROTECTED DTV CONTOUR

A 4W transmitter outside the protected contour of a cochannel DTV channel could, depending on its height and radiation pattern, cover a significant area. Figure 4 shows an example of an omnidirectional transmitter at the lowest height, 31m, for which F(50,50) propagation curves are available.

At 1km away, the received power by a rooftop DTV antenna with gain of 10dBd would be  $-48\text{dBm}$ . It would be higher for distances less than 1km from the device. As shown in Figure 4, to maintain a protection ratio of  $D/U=23\text{dB}$ , this device must not be closer than 27km to the  $-80\text{dBm}$  protected contour of the cochannel DTV station. Increasing the height of

Figure 4: Power Received From a Cochannel Fixed Device  
ERP=4W ; HAAT=31m ; F(50,50)



the device would require a separation distance larger than 27km. If a portable device were to replace the fixed device at the same height, a minimum distance of 17km from the -80dBm contour would be required to avoid cochannel interference.

The analysis of this section also shows that fixed devices would have to be licensed under rules that will prevent harmful interference to DTV. Unlicensed portable devices will have to first receive a beacon from a fixed device with a list of permitted channels prior to transmission on a cleared DTV channel. If a fixed device is part of a distributed network of cochannel devices, then the database of allowable channels of each fixed device should be the sum of all the channels that would have been licensed to each individual device.

#### V. RF MASKS FOR FIXED AND PORTABLE DEVICES

Previous sections have established that certain channels must not be used, that fixed devices must be licensed and serve as a beacon for unlicensed portable devices and that the sideband power of these devices must be lowered to comply with the FCC's D/U protection ratio against cochannel interference. It remains to propose the RF mask that will make the devices compliant with these requirements.

An interfering signal of -103dBm, 23dB below the -80dBm DTV noise-limited contour, would cause a .7dB desensitization of the DTV receiver. That is because the minimum noise at the antenna terminal of a DTV set would rise from -95.2dBm to -94.5dBm. This level of interference from a single licensed device should be the maximum acceptable. For the assumed 15 unlicensed portable devices, the corresponding level is -115dBm.

Figure 5 shows the proposed RF masks for licensed fixed and unlicensed portable devices operating on a 6MHz vacated TV or DTV channel. The shown power levels represent the average power in channels  $N\pm 1$  and  $N\pm 2$ . Operation of licensed and unlicensed devices on these adjacent channels would be prohibited, which means that a single 6MHz device channel will effectively occupy 30MHz. In Figure 5,  $P_0$  refers to

the total proposed power in the 6MHz device channel. At the antenna terminals, it would be 0dBm from a single fixed device facing a rooftop DTV antenna 10m away and -9.6dBm from a single portable device facing a settop DTV antenna 3m away.

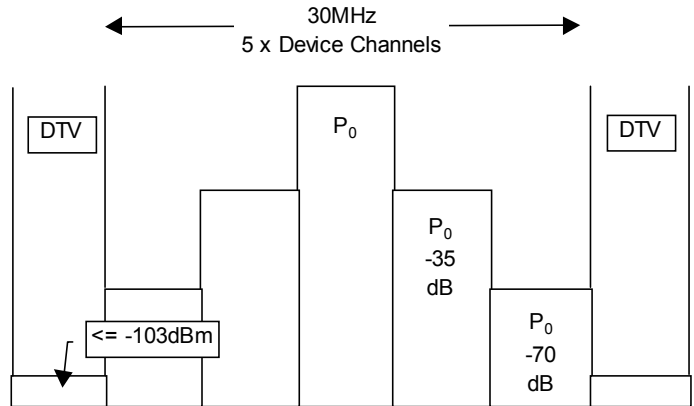


Figure 5: Proposed RF Mask for Licensed Fixed and Unlicensed Portable Devices

#### VI. CONCLUSIONS

Cochannel and adjacent channel interference to DTV channels is insidious. Consumers will have no idea of how close to reception failure they may be or what caused the failure when it occurred. To protect licensed DTV stations from harmful interference the following modifications to the NPRM should be adopted:

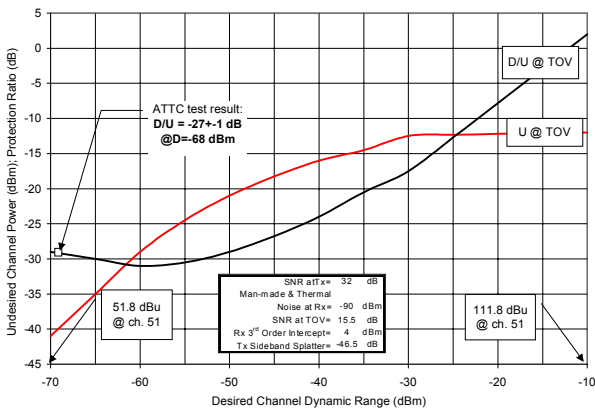
1. Fixed devices should be licensed. Portable devices should receive a beacon from a fixed device with a list of permitted channels prior to transmission.
2. Fixed devices should be cognitive and be remotely controllable with shut down capability. Portable devices should be configured to transmit only upon receiving a beacon signal that lists the available channels from a fixed device. Portable devices should select the strongest beacon above a certain fixed level.
3. The RF mask of unlicensed and licensed devices should conform to the limits shown in Figure 5.
4. Operation of fixed and portable devices inside the protected contour of DTV stations should not be permitted on channels whose 3<sup>rd</sup> order intermodulation distortion falls inside the  $N^{\text{th}}$  DTV channel. They are channels  $N\pm 1$ ,  $N\pm 2$  and, depending on the receiver's bandpass filter, channel pairs  $[N\pm n; N\pm 2n]$ .
5. The adjacent channel interference protection ratio as defined in OET-69 should be revised for fixed licensed devices. The correct variable protection ratio is developed in the APPENDIX to this paper.
6. Statistical methods should not be used to moderate the results of a reasonable worst-case deterministic analysis of interference. Only statistical propagation models now in use to determine DTV service should be permitted.

This paper has shown that in urban areas the use of the vacated TV spectrum for licensed and unlicensed devices will be very inefficient without first repacking the DTV channels in each market into a contiguous channel block<sup>7</sup>. Repacking the DTV channels in each major market into a block of contiguous channels would free large swaths of valuable spectrum and at the same time would provide DTV stations protection from harmful interference.

APPENDIX

The average protection ratio of D/U = -27dB at the threshold of visibility (TOV)<sup>d</sup> of DTV into DTV adjacent channel interference was measured at the Advanced Technology Test Center (ATTC) and was adopted by the FCC in 1998. It was based on a “weak” D = -68dBm. The Desired channel was multipath-free and without man-made noise. As specified in the FCC’s bulletin OET-69, only one unique transmit antenna elevation pattern is permitted for D/U determining compliance and that pattern is assumed for all channels. In other words, the <D/U> = -27 dB applies only to a single antenna shared by all adjacent channels.

Figure A1: Adjacent Channel Protection Ratio at TOV



The measurements at the ATTC could not be extended to strong signals because the “Blue Rack” test receiver failed at signal levels above “moderate.” Consequently, strong D and U signals were ignored. A complete analysis of adjacent DTV into DTV interference published in 2005<sup>e</sup>, covering the entire dynamic range under which the receiver is expected to operate, demonstrated that the experimental results at the ATTC were predictable.

Figure A1 shows how the D/U ratio at TOV varies with the received Desired and Undesired levels. Although the dynamic range at the receiver may theoretically vary from -80dBm to -5dBm (1,000 kW stations), a practical range would be generally confined to between -70dBm and -10dBm. The

<sup>d</sup> FCC OET-69. The ±1dB difference relative to upper/lower adjacent channel is most likely experimental error.  
<sup>e</sup> See reference 4.

lone experimental point, measured at the ATTC in 1998, is highlighted.

The D/U plot shows that the D/U ratio has a “sweet spot” for D = -55dBm (≈67dBu @ ch.51) and U = -24dBm (≈98dBu @ ch.51). For higher signal levels the D/U ratio increases rapidly from -31dB at D levels below -60dBm to +3dB at D = -10dBm. This is due to the increase in the noise floor of the Desired channel by the nonlinear distortion generated by all adjacent channels at the receiver.

For computational ease the two plots can be fitted with polynomial equations as follows:

Undesired level [U dBm @ TOV]:  
 $U = .0001D^3 + .001D^2 - .0529D - 12.609$       D in dBm

D/U [D/U dB @ TOV]:  
 $D/U = .0119D^2 + 1.5015D + 16.8$       D in dBm

When adjacent channels broadcast from separate towers, the D/U protection ratio at the receiver is no longer fixed or under the control of the stations. Therefore the entire dynamic range at the Desired receiver, as specified by the FCC planning factors, is subject to adjacent channel interference. In addition to the raised noise due to multipath and man-made noise, each signal, arriving from a different height and from a different antenna pattern, is subjected to different local reflections and short term fading. These factors must be accounted for so that TOV is not reached.

The D/U plot of Figure A1 should be viewed as a basis ratio to which a certain margin must be added so that actual D/U at the receiver, subject to multipath and several undesired channels from separate towers, is not breached. Thus,  
 $[D/U]_{\text{PROTECTION}} = [D/U]_{\text{BASIS}} - \text{MARGIN}$

$\text{MARGIN} = \Delta_{\text{NEQ}} + \Delta_{\text{FS}_{\text{AZPATT}}} + \Delta_{\text{FS}_{\text{REF}}} + \Delta_{\text{FS}_{\text{FADE}}}$   
 $\Delta_{\text{NEQ}} =$  Noise added by multipath equalizer, typically 2dB<sup>f</sup>.  
 $\Delta_{\text{FS}_{\text{AZPATT}}} = \pm 2\text{dB}$  orientation difference of omnidirectional antennas. This factor applies only to antennas filed as omnidirectional (RMS Gain=0dB, approximately .8 voltage in the shown pattern).  
 $\Delta_{\text{FS}_{\text{FADE}}} =$  Relative short-term fading. Measured at  $\pm 1.5\text{dB}$ <sup>g</sup>  
 $\Delta_{\text{FS}_{\text{REF}}} =$  Field strength variation due to local reflections near the receiver. Following the FCC’s .6 reflection coefficient<sup>h</sup>, the field variation would be ±6dB. This is borne out by standard field strength measurements taken over a 100 feet run.

Therefore, in the worst-case, the margin required to protect consumers from interference by undesired adjacent DTV

<sup>f</sup> See reference 5.  
<sup>g</sup> See reference 4.  
<sup>h</sup> FCC bulletin OET-65.

channels on separate towers with omnidirectional antennas is 21dB above the basis ratio. Where all adjacent channels share an antenna the margin drops to 2dB. These margins are required to maintain a  $[D/U]_{\text{PROTECTION}}$  sufficiently below  $[D/U]_{\text{BASIS}}$ .

The computation of adjacent interference must also comply with the following rules:

1. If more than one undesired signal is present, the sum of all undesired signals would first be added on a voltage basis (rather than power basis) and the sum, converted to dBm or dBu, should be defined as the Undesired signal.
2. At each location where the D/U ratio is to be evaluated, the azimuth and elevation antenna of each station should be used. If both the desired and undesired channels use directional antenna patterns, the required margin cited above would be lowered by 4 dB ( $\Delta F_{\text{AZPATT}}$ ) from 21dB to 17dB.

## REFERENCES

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<sup>1</sup> FCC 04-113. Adopted May 13, 2004. Released May 25, 2004.

<sup>2</sup> H.T. Friis, "A note on simple transmission formula," Proc. IRE, May 1946, pp.254-256.

<sup>3</sup> J.W. Mark and Weihua Zhuang, "Wireless Communications and Networking," Prentice Hall, 2003.

<sup>4</sup> O. Bendov, "Interference to DTTV Reception by First Adjacent Channels," IEEE Transactions on Broadcasting, Volume 51, March 2005.

<sup>5</sup> O. Bendov, "Planning Factors for Fixed and Portable DTTV Reception," IEEE Transactions on Broadcasting, Volume 50, September 2004.

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