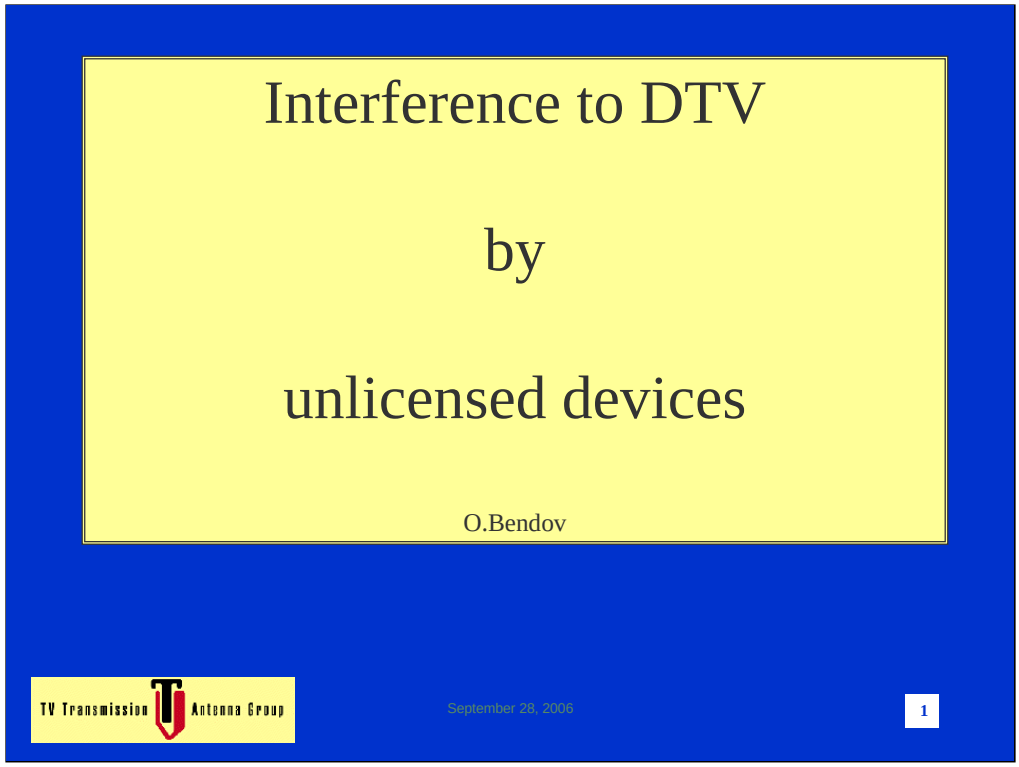


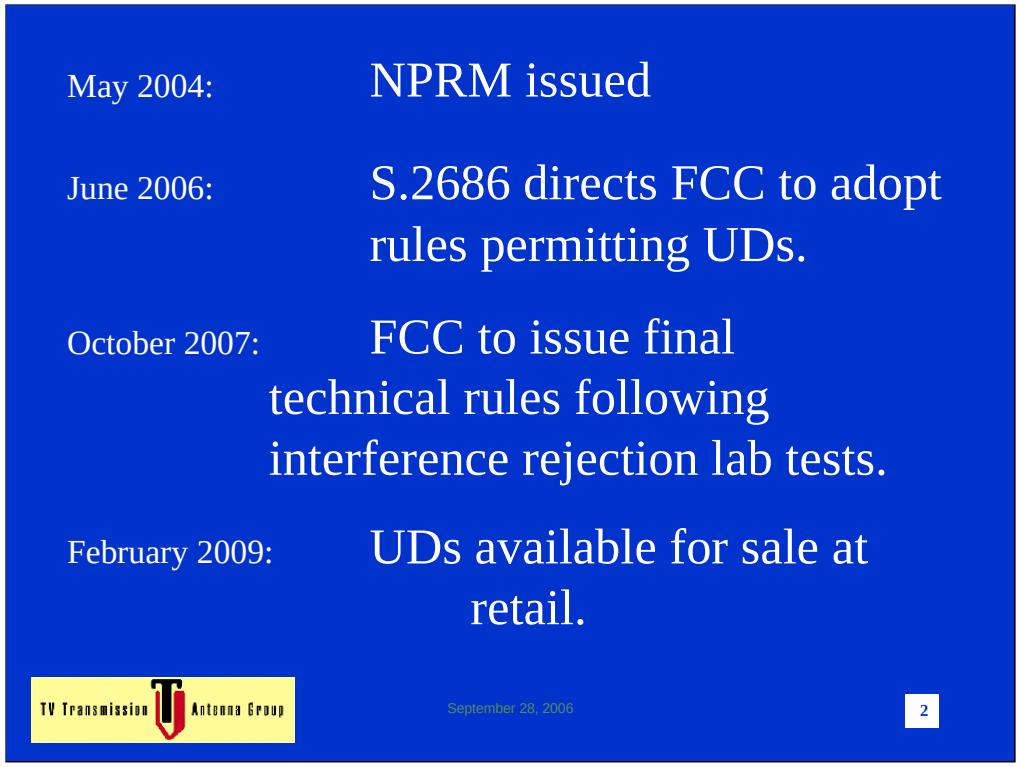
The debate about how to make the unused TV channels available to unlicensed services has been ongoing for several years.

I got interested when I realized that none of the organizations involved, least of all the FCC, have provided adequate engineering analyses or experiments in support of their positions.

This paper is not about taking sides. It is an analysis of the expected interference from unlicensed devices,or UDs for short, if the proposed FCC rules were adopted. It is not intended to be a comprehensive analysis. Rather, it is limited to allow some conclusions to be drawn.

For the record: I believe that a far more efficient use of the TV spectrum is possible but the rules now on the table make no technical sense to this end, not even in rural areas.

So what is the status of the FCC rules regarding unlicensed devices?



The Notice of Proposed Rule Making is almost 2-1/2 years old. Dozens of comments and replies, with new claims and counterclaims have been filed without clear resolution in sight.

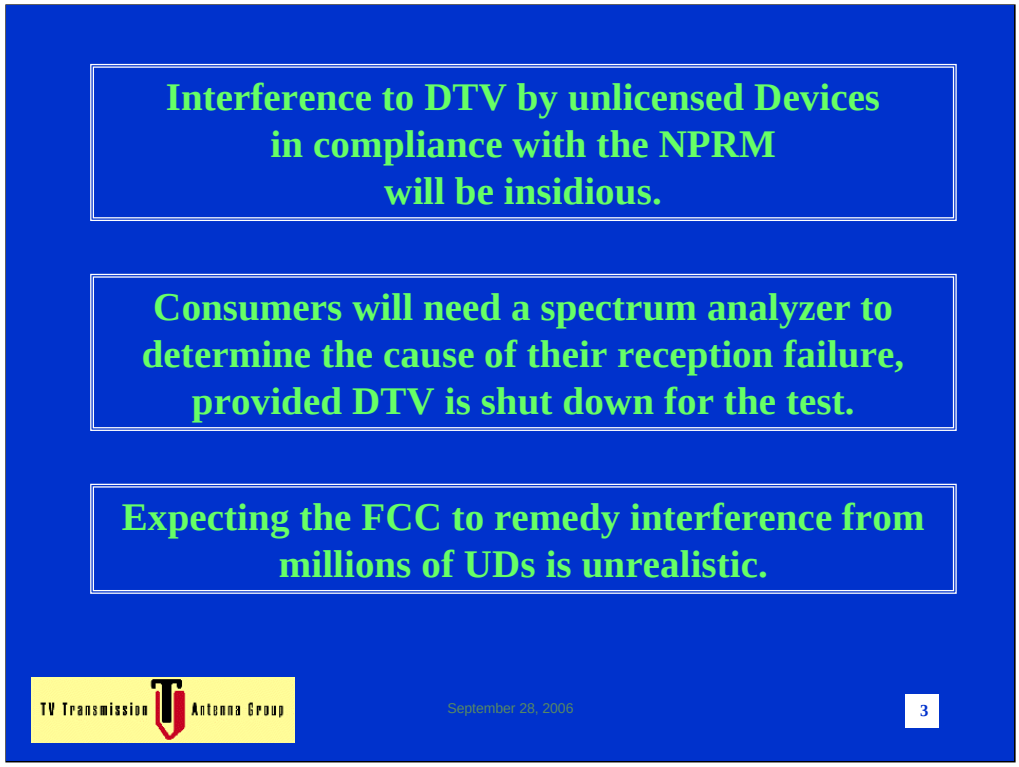
[<>] Congress has come to the FCC's rescue. The latest bill in the Commerce Committee directs the FCC to act. So what is the FCC's plan?

[<>] It was issued two weeks ago. It calls for an unspecified lab test of potential interference to be completed next March and reported next July. No mandated field tests would be required.

[<>] By next December applications for certification will be accepted in time for UD products to become available for retail in February 2009.

My question is: How could the software that is supposed to control the transmission power, channels and time slices of thousands of UDs be certified without mandated field tests of actual networks?

Even without interference analysis, three facts should be obvious:



1……..

[<>] Why? Because…..an unlikely premise

[<>] and third, because…

Let's start by looking at some of the proposed rules for the two types of UDs.

Proposed rules for protection of terrestrial DTV (D) from interference by unlicensed devices (U_F and U_P)

FCC 04-113 and 04-186 Proposed Rules	Fixed U_F	Portable U_P
Peak EIRP/Device	4W	0.4W
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 F(50,50) for D	permitted if $D/U_P \geq 23$dB F(50,50) for D
Adjacent Channel Transmission Outside the TV Protected Contour	**permitted if $D/U_F \geq -27$dB±1dB using F(50,50) for D**	unrestricted

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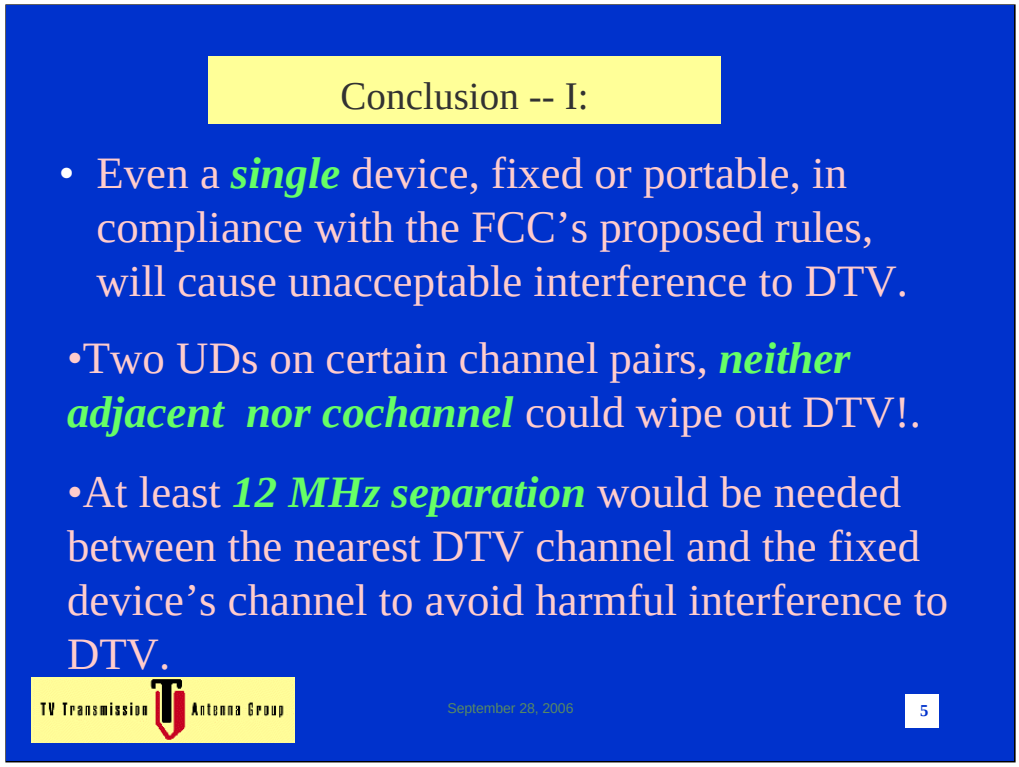
The 4W device, designated as FIXED, would serve as the gateway for the .4W device designated as PORTABLE.

There would be no limit on the number of these devices. In major markets there could be millions. Today we'll focus on the interference by a single device.

Cochannel operation would be permitted only outside the DTV protection contour, but adjacent channel operation would be permitted inside the DTV contour. The fixed 27 dB adjacent channel protection ratio, highlighted in red, was borrowed from the FCC's DTV planning factors and that ratio applies only to collocated adjacent channels and only to weak to moderate signals. We'll discuss this issue in more detail later.

For the purpose of interference calculations the FCC proposes 10m as the minimum distance between the UDs and the DTV antenna. But is 10m realistic for portable devices inside apartments? I think that less than 3m is far more realistic.

Of course the argument can be made that indoor reception with portable antenna has not been a concern to the FCC as evident by the planning factors for DTV. But the reality is that such reception is crucial to the survival of OTA television.

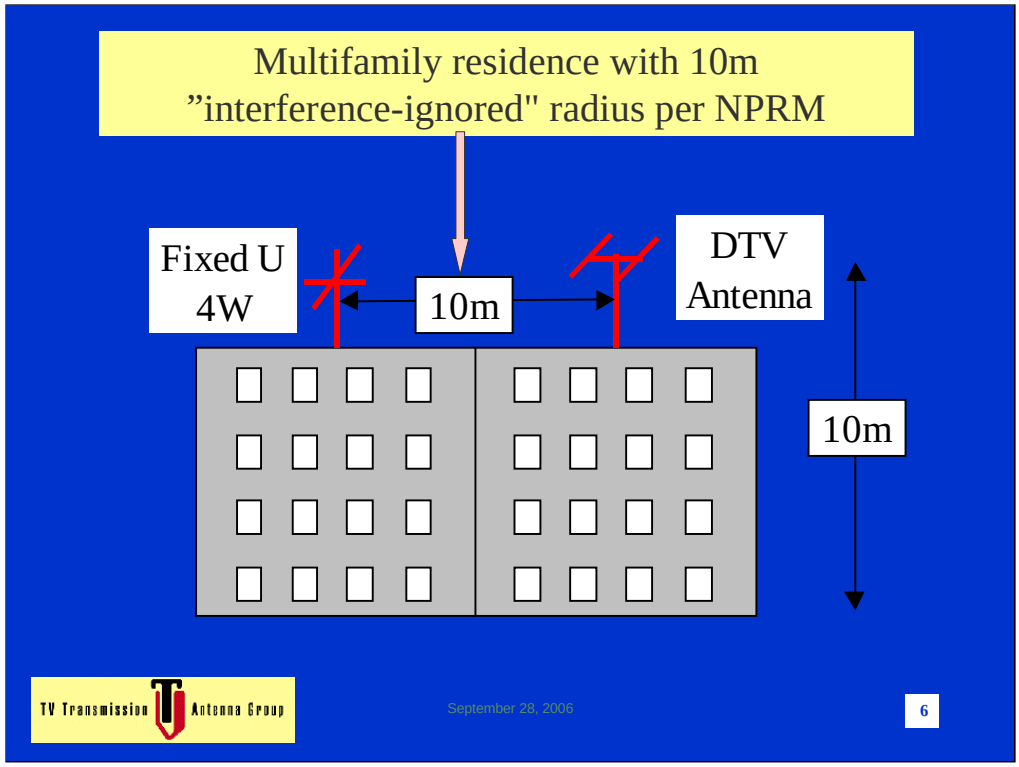


My conclusions come in two parts. This first part is presented ahead so you can better follow the analysis.

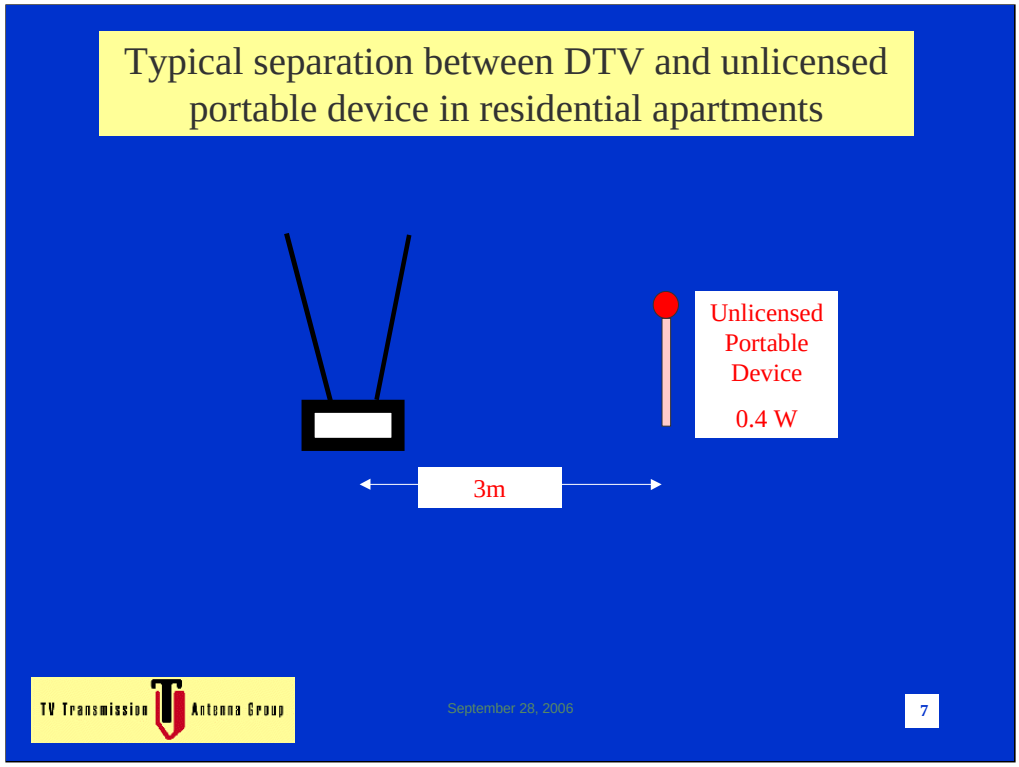
First-------

[<>] Second-------This case has not even been recognized by the FCC.

[<>] Third----------



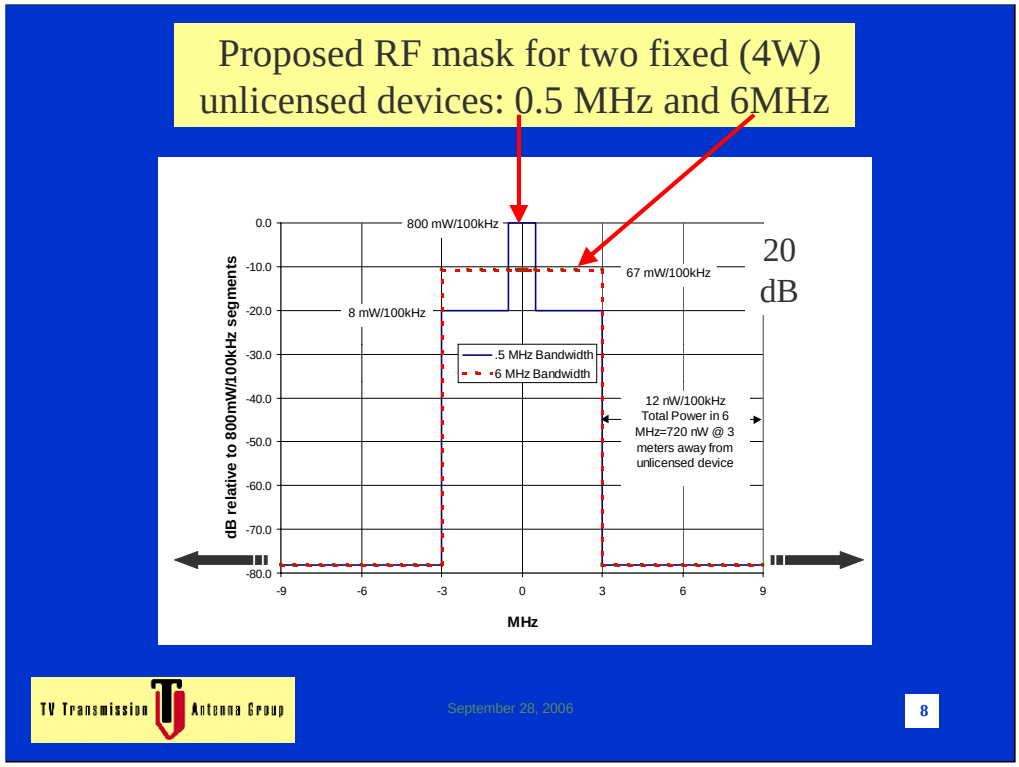
I’m going to show the interference levels based on two modes. The first is based on a single FIXED device facing an outdoor DTV antenna as per the FCC planning factors.



The second is based on a single PORTABLE device facing an indoor DTV antenna.

As you can see, I chose 3m as the separation distance. The FCC proposes 10m, which would be really difficult to fit into indoor situations, and impossible in many apartments.

Next, let's examine the proposed RF mask.



A fixed device radiating 4W could occupy a bandwidth of .5 to 6MHz.

This mask shows the spectral power density of two fixed devices, one with a bandwidth of .5 MHz and one with 6Mhz. The respective spectral power densities are 800mW and 67mW/100kHz.

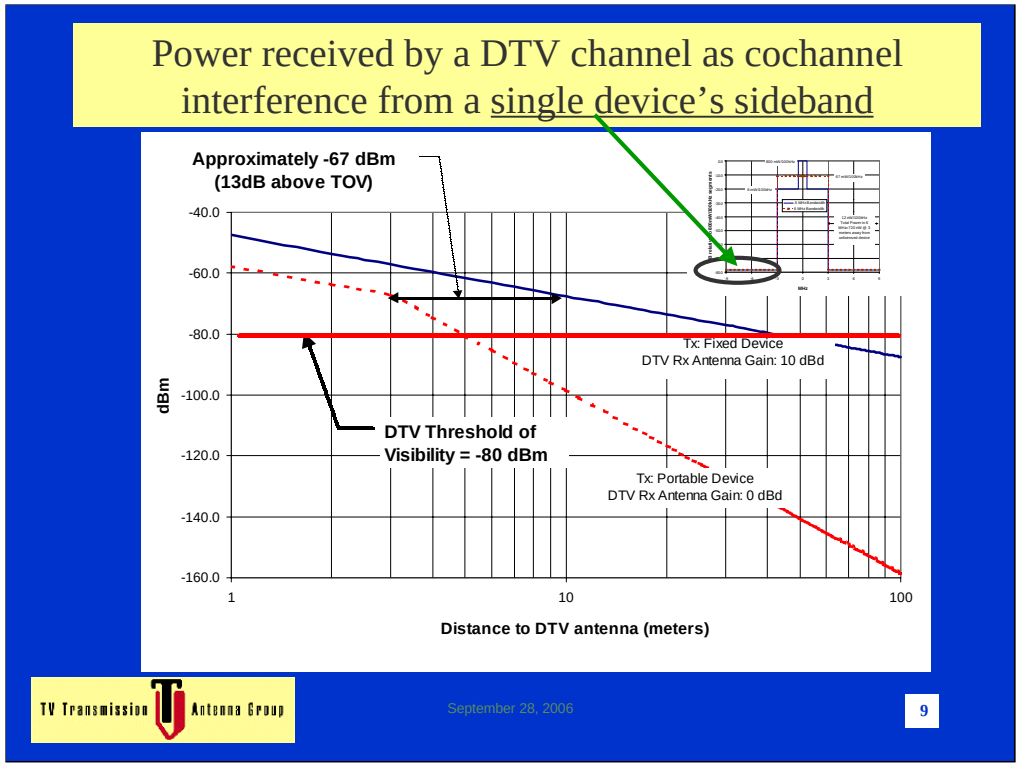
[<>] If the device's intended bandwidth occupies less than 6 MHz, as is the case for the .5MHz device, the power in the remainder of the channel has to be 20 dB lower.

⇨ **show**

The mask for a portable device is 10dB below that of fixed device with one exception: The allowable sideband level is the same for both types.

[<>] And here's the curious part: there's no bandwidth limit to the sidebands. They can stretch through the entire TV band and cause interference to any TV channel.

The permitted spectral power density of the sideband, 3m from the device, is only 12nW/100khz, or 720nW/6MHz. This seems rather low but, as you will see in the next two slides, this sideband alone could create harmful interference to any DTV channel.



If you calculate the sideband power received from a portable device 3m away from an indoor DTV antenna whose gain is 0dBd you get -67dBm. Approximately the same power is received from a fixed device 10m away from a rooftop antenna whose gain is 10dBd. BTW these calculations assume DTV channel 38, approximately midband UHF.

⟹ **show**

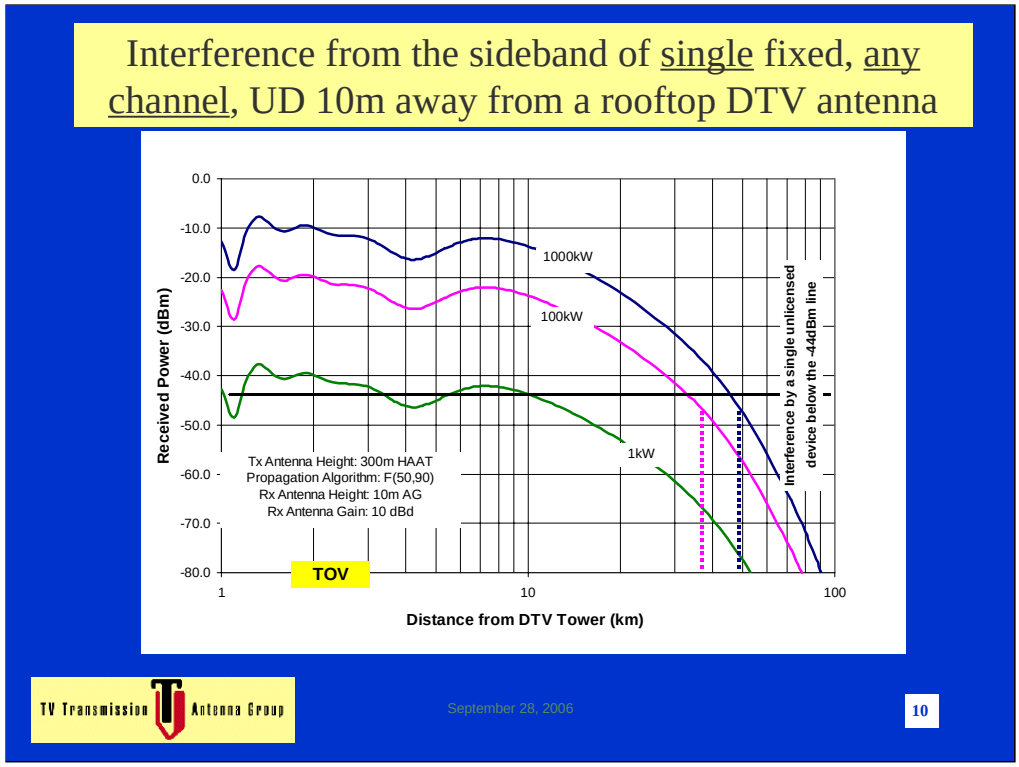
According to the FCC planning factors, the DTV threshold of visibility is -80dBm at the antenna terminals or -84dBm at the tuner's input.

So if the rules regarding UDs are adopted, their -67dBm sideband level alone would be 13dB above TOV.

⟹ **Show**

But is TOV without margin safe enough? And what about multiple devices?

In the next slide we'll look at the potential loss of coverage due to this one sideband.



Here you can see the received power at the terminals of a rooftop antenna as a function of distance from three DTV stations. One station is LPTV with 1 kW ERP. The other two stations are 100kW and 1 MW. All three are on channel 38.

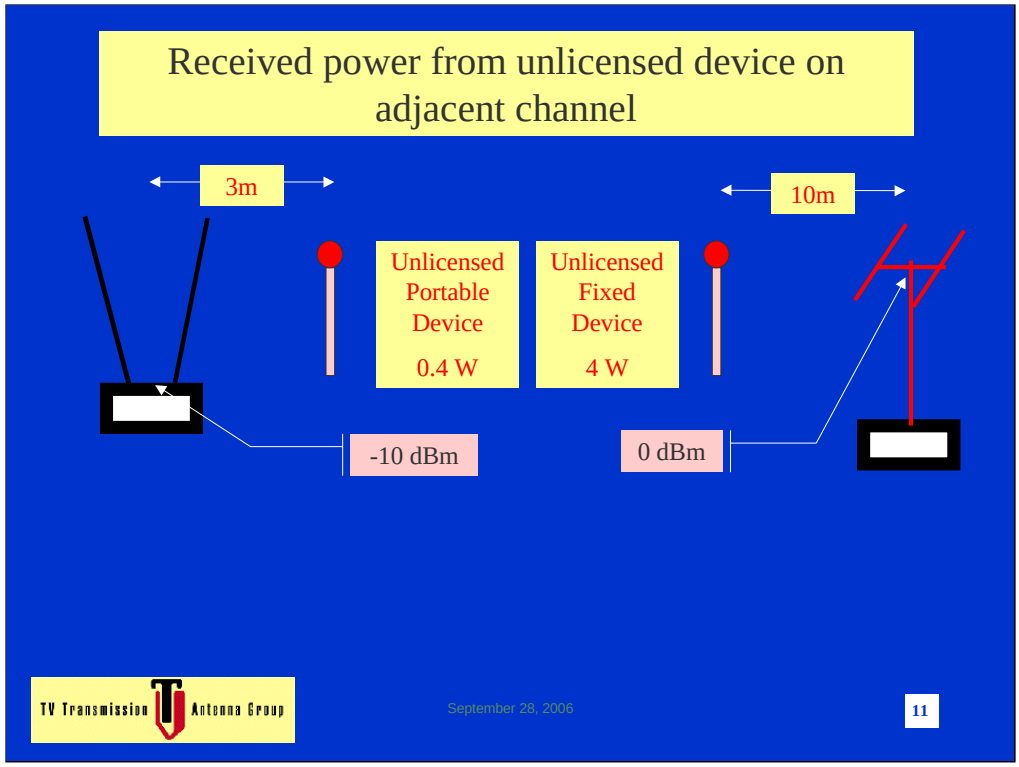
Remember that the received interference from the sideband power was -67dBm. This power appears as cochannel interference. According to the FCC's OET-69 the protection ratio against CCI is 23dB for SNR<28dB. Since a typical SNR at the Tx output is already 28dB, most receivers will see SNR<28dB so that the 23 dB protection ratio would apply everywhere inside the DTV contour.

That means that the DTV signal must be at least 23 dB higher than the -67dBm interference, or be higher than -44dBm to avoid interference.

Now compare the black line of the required minimum DTV signal of -44dBm and the TOV line at the bottom. You can see that in all three cases the protected DTV contour has effectively shrunk and in the case of LPTV, most of the service area would be subject to harmful interference.

⟹ **show**

This is just one of 4 types of interference we'll review. Next we'll address adjacent channel interference.



If you calculate the power received from a fixed device 10m away you find out that it is 0dBm at the rooftop antenna's terminals . By comparison, the maximum received level from 1MW DTV Tx a mile away is only -8dBm.

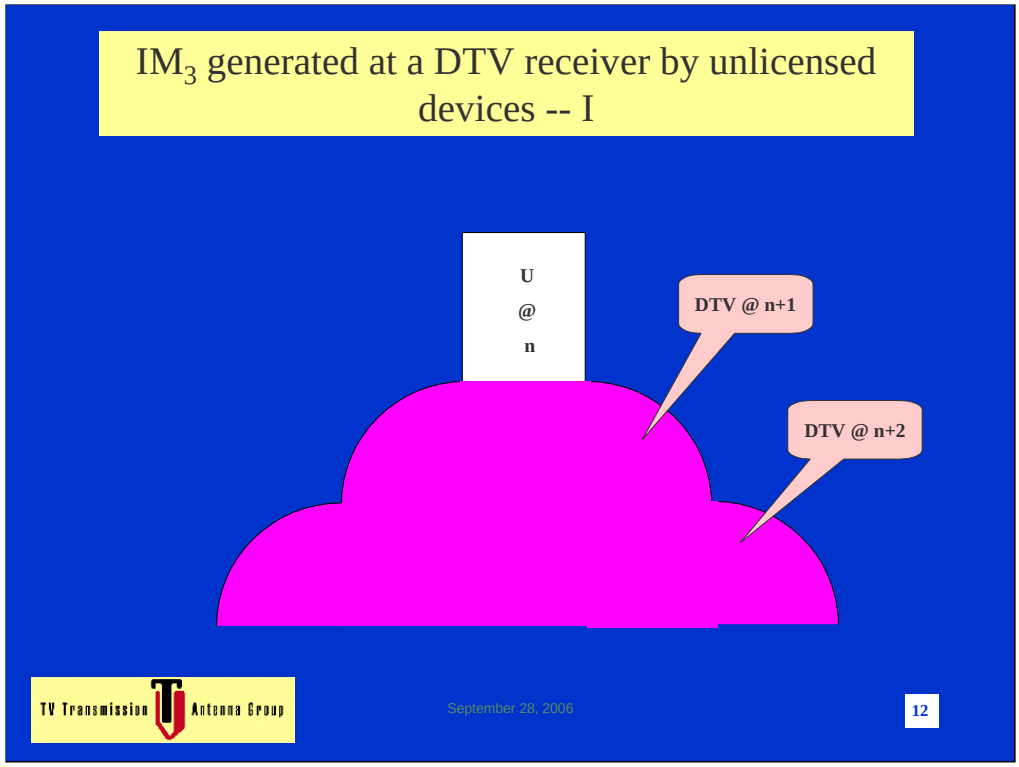
You might argue that this 8dB difference is less than the FCC protection ratio of 27dB, but that ratio applies only to collocated channels. Collocation guarantees the same power differential between the two channels at the Tx and at the Rx.

But UDs will not be collocated with DTV Txs. Further out from the Tx the DTV signal grows weaker whereas the UD signal is unchanged. At the fringe, the UD signal could be 80dB stronger than the DTV signal or 53dB higher than the allowable protection ratio.

What's more, you will soon see that the DTV protection ratio, in addition to not being applicable to non-collocated transmitters, as well does not apply to the strong signals expected from UDs.

The situation with the portable device is not much better. The received power at the terminals of an indoor antenna with a gain of 0dBd 3m away would be -10dBm.

Now that we know the received power, we can calculate the UD sideband level generated at the DTV receiver in the first three adjacent channels. Remember that these sidebands can be viewed as CCI imposed on the adjacent DTV channel.



Let's say a single UD is on channel N and a DTV station is on either channel N+1, N+2 or N+3. The UD channel and the DTV channel are within the passband of the tracking filter at the front end of the DTV receiver.

At the tuner, 3rd order non-linear distortion is created in channel N+1 which, in turn, creates another lower level of 3rd order distortion in channel N+2 and similarly on N+3. So we have a simplified model of interference by a UD on adjacent channels N+1 to N+3.

Note that to simplify the analysis the unknown sideband levels generated by the UD transmitter have been ignored.

When the intermodulation sideband, generated at the Rx, overlaps the desired DTV channel, it can be treated as CCI.

Our first task is to calculate the level of these sidebands.

IM_3 generated by unlicensed devices at a DTV receiver tuned to channel N-- II

	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= +4dBm	IP_3= +8dBm	IP_3= +4dBm	IP_3= +8dBm
UD on channel N±1	-20dBm too high	-28dBm too high	-37dBm too high	-45dBm too high
UD on channel N±2	-69dBm too high	-77dBm too high	-118dBm ok	-126dBm ok
UD on channel N±3	negligible	negligible	negligible	negligible

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This table shows the interference levels generated at the DTV tuner by fixed and portable UDs.

The DTV channel varies from 1st to third adjacent channel as shown in the leftmost column.

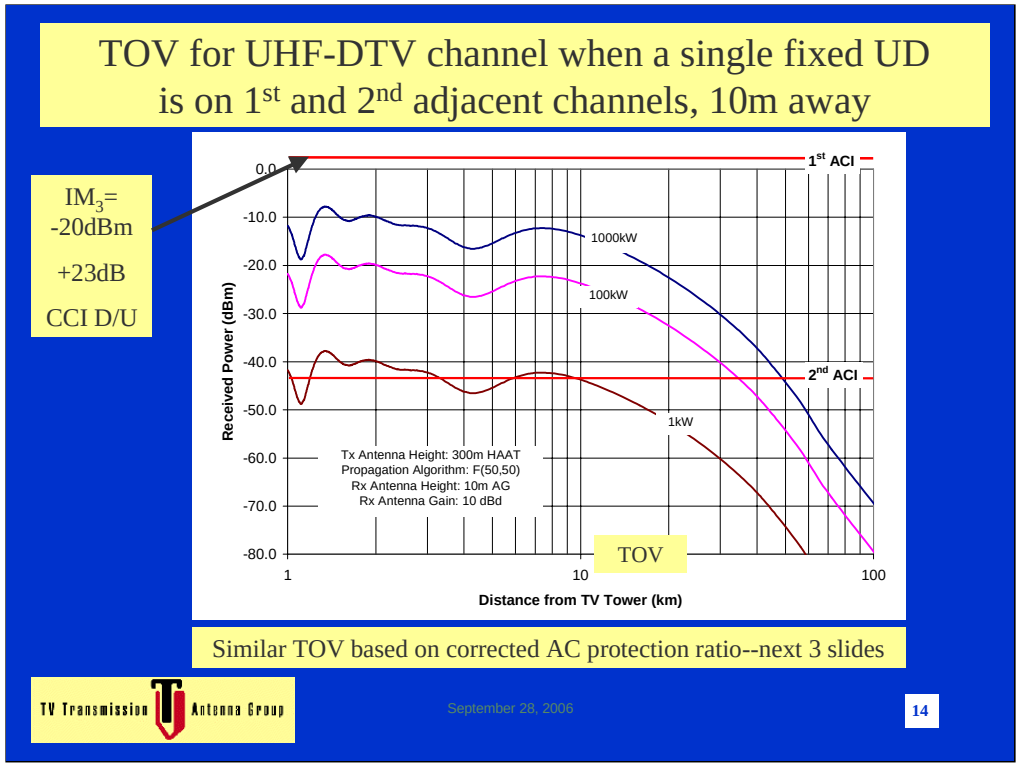
Recall from the previous slide that the fixed UD power at the terminals of the DTV antenna is 0dBm when it is 10m away from a rooftop antenna whose gain is 10dBd. Such power on the 1st AC will generate -20dBm of CCI assuming a receiver with Intercept Point of +4dBm.

→ **show**

Earlier we have seen that the DTV signal must be at least 23 dB stronger to avoid CCI. So if you add 23dB to all the interference levels in the table you can see that at least two empty 6MHz channels must separate these UDs from any operating DTV channel.

→ **show**

You're probably interested in how these interference levels would affect the DTV service area.



And here it is, based on F(50,50) as specified by the proposed rules.

[<>] If you add the 23dB protection ratio to the -20dBm interference generated at the DTV tuner you get +3dBm for the minimum DTV signal as shown by the top red line. So even 1MW DTV station will be strongly interfered with by a fixed device on the 1st adjacent channel and 10m away from a roof top antenna.

Even if the UD is on a second adjacent channel, as shown by the lower red line, the service area of the full-power DTV stations will be shrunk and that of the LPTV will be severely affected.

⟹ **show**

[<>] If we were to use the DTV AC protection ratio, then the DTV level would have to be at least -27dBm. That would not be much of a relief, but as I will explain next, that ACI protection ratio from DTV into DTV was misappropriated for UDs.

-27dBm=0(fixed device)-27dB(U/D ratio)

FCC's fixed DTV-DTV AC protection ratio is meaningless for unlicensed devices

FCC 04-113 and 04-186 Proposed Rules	Fixed U_F	Portable U_P
Adjacent Channel Transmission Inside the TV Protected Contour	**permitted if $D/U_F \geq -27 \pm 1dB$ inside protected contour**	**unrestricted**
Adjacent Channel Transmission Outside the TV Protected Contour	**permitted if $D/U_F \geq -27dB \pm 1dB$ using F(50,50) for D**	**unrestricted**

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This is the AC excerpt from the table of proposed parameters shown earlier.

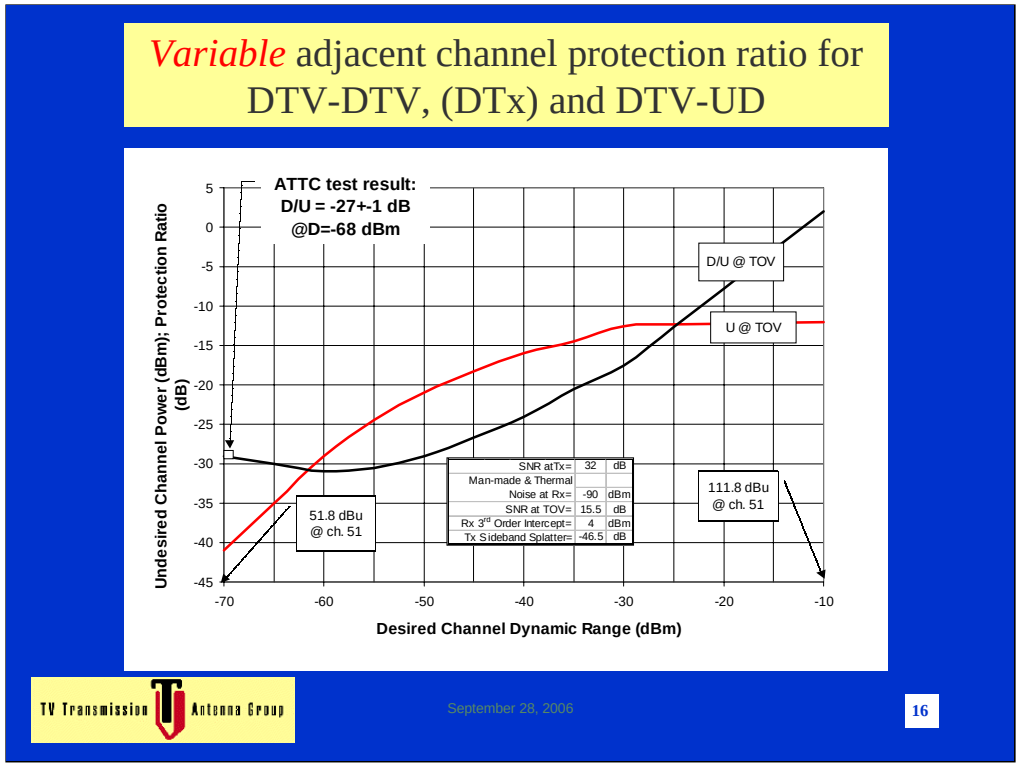
The proposal would allow unlimited use of portable devices on the 1st AC within the DTV service area. We already saw in a previous slide that even one portable device would need one channel separation and one fixed device would need two. But what about the DTV protection ratio that would permit a fixed UD on AC to be 27 dB stronger than the DTV signal?

That ratio, borrowed from OET-69, makes no sense in the environment of UDs for two reasons mentioned earlier:

1. It was measured at a weak DTV signal level of -68dBm and as you will see on the next slide, it's off by 30dB from what it should be when strong signals are present.

2. It assumes that the two AC are collocated. More precisely, that the two AC signals emanate from the same antenna in order to keep the same fixed protection ratio at all receivers.

In the case of UDs, their signal can be as strong as 0dBm everywhere and the DTV signal could be from -8dBm near the station to -80dBm toward the fringe. Therefore, even if the ratio of-27dB were correct for strong signals, and it is not, it could not be maintained everywhere within the DTV service area.



Here we show how the protection ratio must vary when the signal level of the desired DTV channel increases from -70dBm to -10dBm.

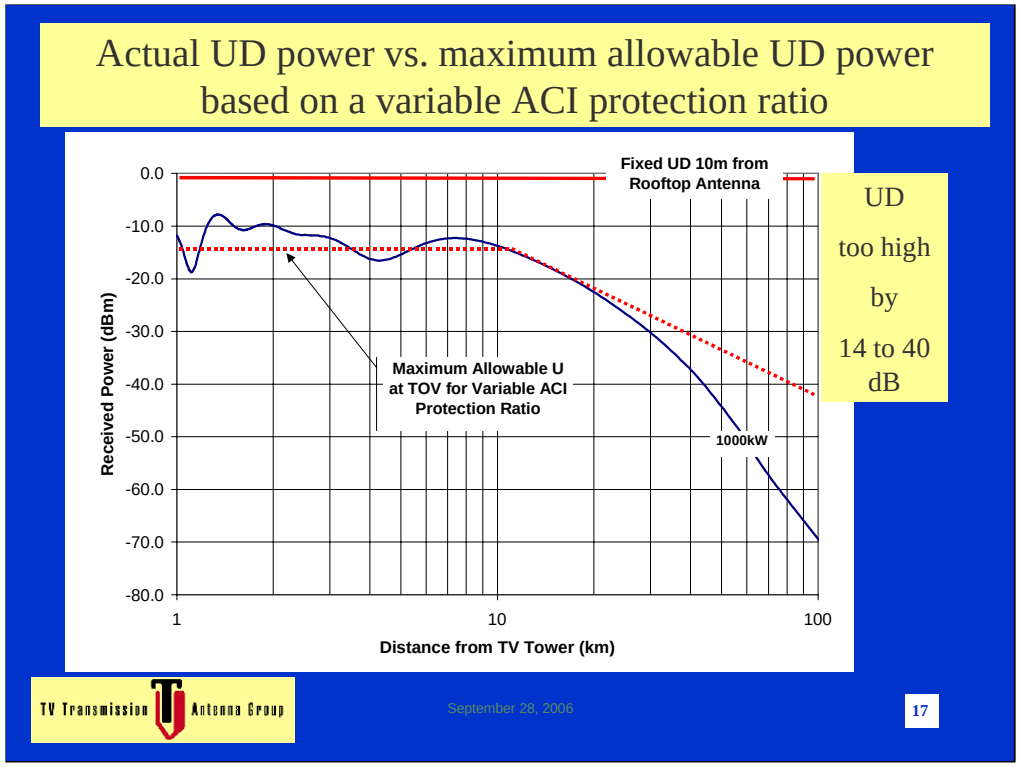
show

This is a theoretical calculation. Fortunately, we have the ATTC test result which was adopted by the FCC to compare with. That measurement for a -68dBm weak signal is plotted very near to the ordinate and it agrees exactly with the calculation. But a calculation allows us to extend the analysis to strong signals, something that the ATTC was unable to do because the blue rack receiver could not operate with strong signals.

Anyway, it shows that as the desired signal increases from -70 dBm to -10 dBm, the protection ratio increases to +2dB. That is, instead allowing the undesired to be 27dB higher as per the FCC, it must in fact be lower than the desired by 2dB if the desired is strong. That is a 30 dB error.

show

We will next apply this variable AC protection ratio to the service area of our 1MW DTV station.

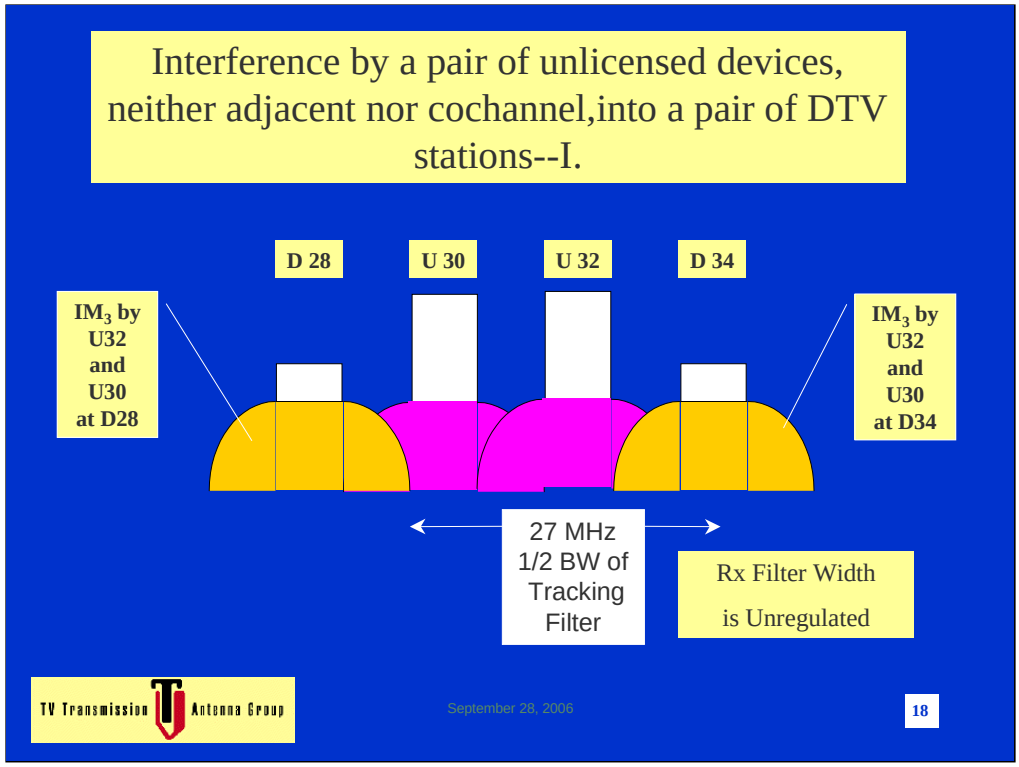


If we apply the calculated variable protection ratio for ACI instead of considering the sideband spillover as CCI, we find that almost everywhere within the service area a fixed UD on 1st AC will overwhelm the DTV signal.

[<>] In the case shown on this slide, even if the DTV station operates at an ERP of 1MW, the UD signal would be 14 to 40 dB higher than what it should be to avoid harmful interference.

⇒ **show**

You can imagine what would be the effect on DTV stations operating at less than 1MW, but I'll not go there...



Previously we have covered the interference by the transmitted sideband of one UD and by the ACI generated at the receiver on the 1st - 3rd adjacent channels.

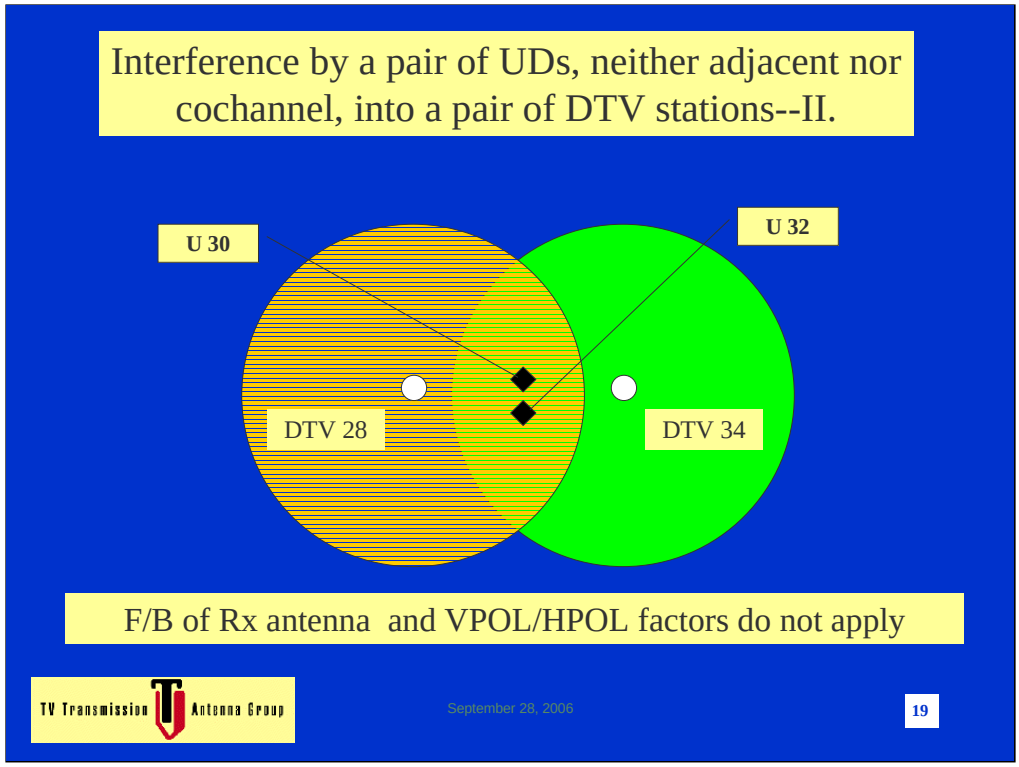
There is yet another type of interference created by a pair of UDs, neither one of which is on 1st AC or on CC. You may find it odd, but this mode of interference has been ignored by the FCC.

For example, two strong UDs on channels 30 and 32 will generate 3rd order distortion centered around channels 28 and 34. All you need is for the tracking filter at the receiver to be at least 54 MHz wide.

[<>] We don't know how wide the front-end passband of commercial DTV sets is because that is a closely held secret. But the critical point here is that the maximum allowable passband is neither regulated by the FCC nor specified by the ATSC. The choice by the manufacturer of the DTV set is wide open--no pun intended.

Let me make a prediction: The passband of the proposed $40 STBs, if a $40 STB will ever be available, will be worse than that of presently available Rxs.

There are other issues with this mode of interference and that is the subject of the next slide



Let's assume that the two UDs are inside the intersected service area of the two DTV stations.

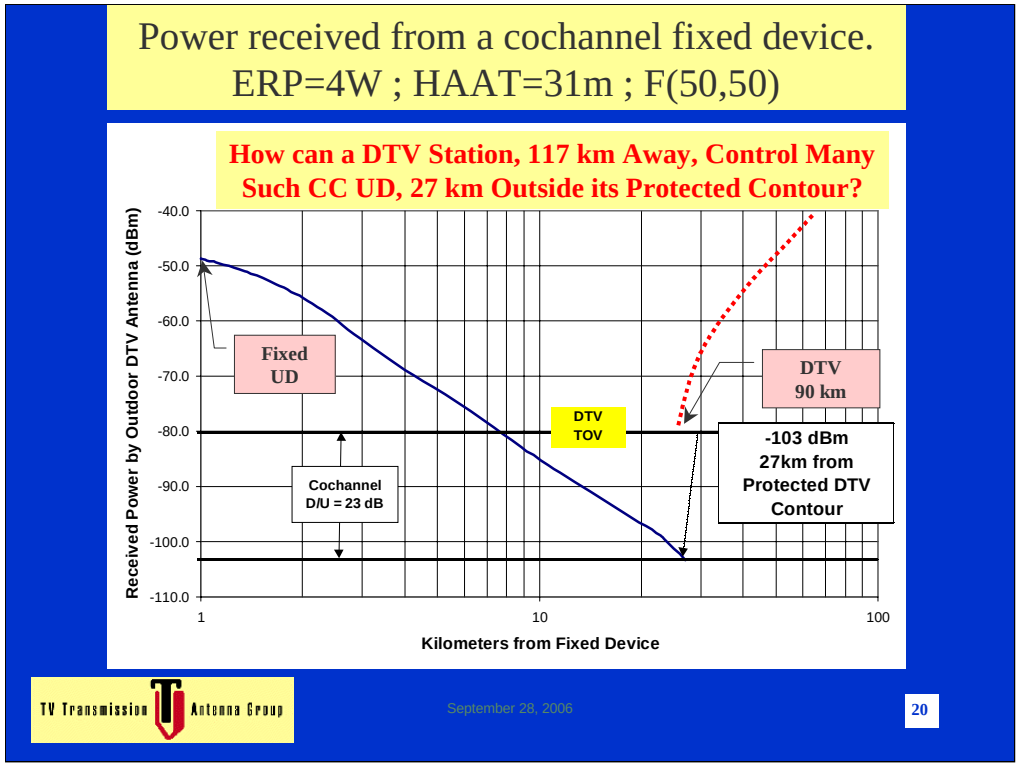
The NPRM does not allow CC operation inside the DTV protection contour, but as this slide shows, effective CC interference within the DTV service area by two UDs would be possible under the proposed rules.

[<>] What's more, in the situation shown, consumers will not benefit from the F/B ratio of roof top antennas.

→ **show**

Nor can polarization discrimination be a factor because DTV stations are permitted to transmit equal ERP in the vertical and horizontal planes.

So far we have described three potential sources of harmful interference: Sideband of UDs, ACI and a pair of stations neither of which is CC or AC. Next we'll review the fourth and last source: Uncontrollable CC operation outside the DTV contour.



According to the NPRM, CC operation of UDs would be permitted outside the DTV protected contour provided that each device's power level is lower by 23dB than the DTV signal at the protected contour.

In other words, at the DTV contour the UD signal could not exceed -103dBm. That level of interference would degrade the SNR at the DTV contour by .7dB

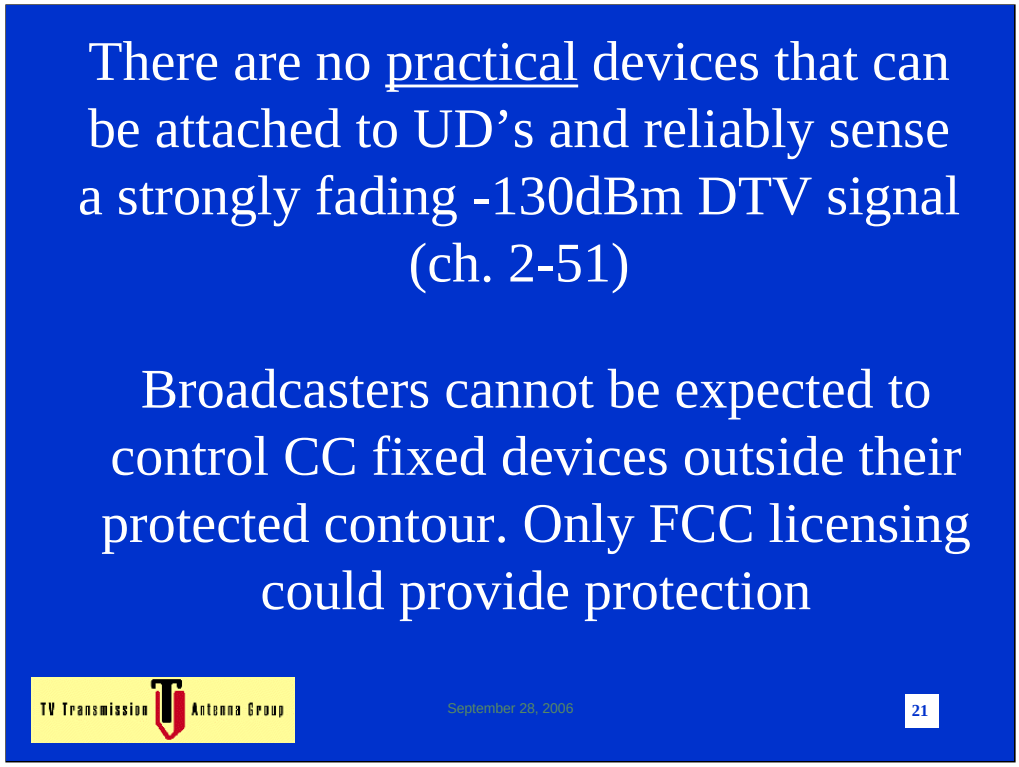
If the fixed UD is on a 100' tower, that tower will have to be 27km away from the DTV contour whose radius is 90km assuming a 1MW DTV station on a 1000' tower.

⟹ **show**

[<>] In other words, this single UD would be 117km away from the DTV transmitter. There could of course be many such devices, each of which would have to have a capability of reliably sensing strongly fading DTV signals down to -130dBm and communicate with each other in such a way that would limit the yet to be determined total interference.

You may have heard statements to the effect that a narrowband measurement of a -130dBm DTV pilot in strongly fading environment is possible with practical devices, but absent demonstration, that is just an opinion.

Is it realistic to expect that DTV service can be protected from harmful interference in such a scenario?



The answer is clearly no for the following reasons:

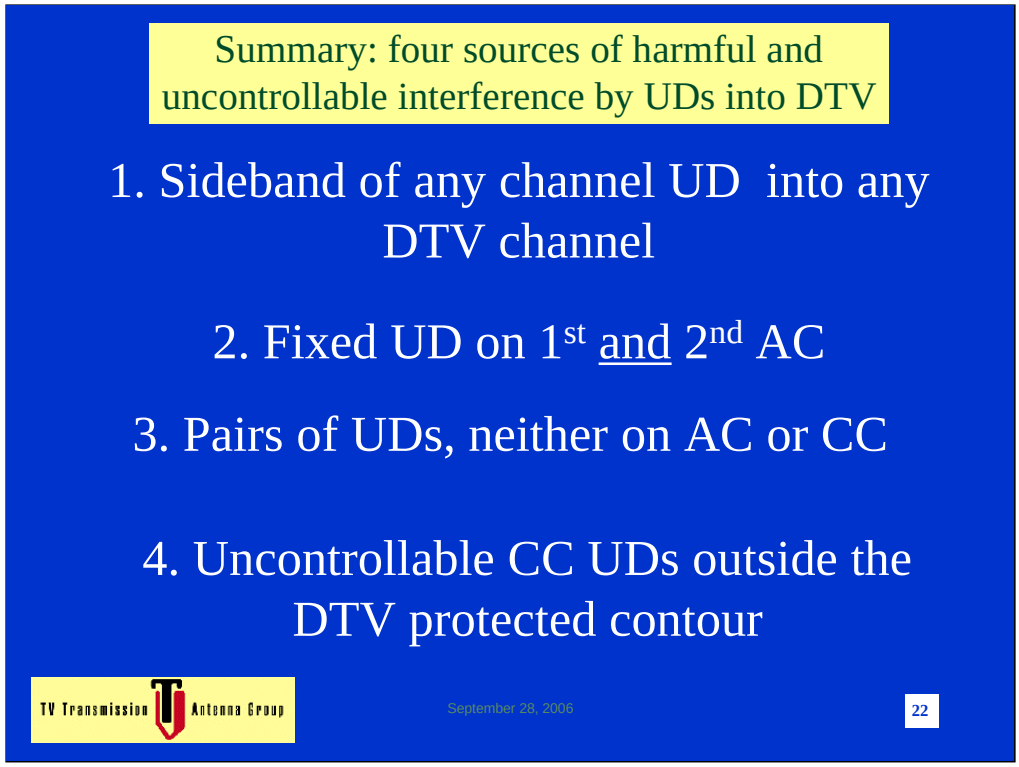
1. While you may be able to detect a weak DTV pilot with a low-noise, narrow bandwidth spectrum analyzer equipped with special software, there are no known sensors that can reliably detect -130dBm and be part of practical UDs.

2. There has been no demonstration, not even theoretically, that multiple CC UDs distributed around the DTV contour can communicate and control each other for the purpose of limiting the total CCI into the DTV protected contour.

[<>] What's more, it would be unrealistic to have broadcasters locate and shut interferors outside their protected contour.

Likewise, it would be unrealistic to expect that the FCC would have the capability to police the operation of these UDs.

It follows that fixed devices should be licensed, with power and radiation patterns controlled just like any other DTV station.



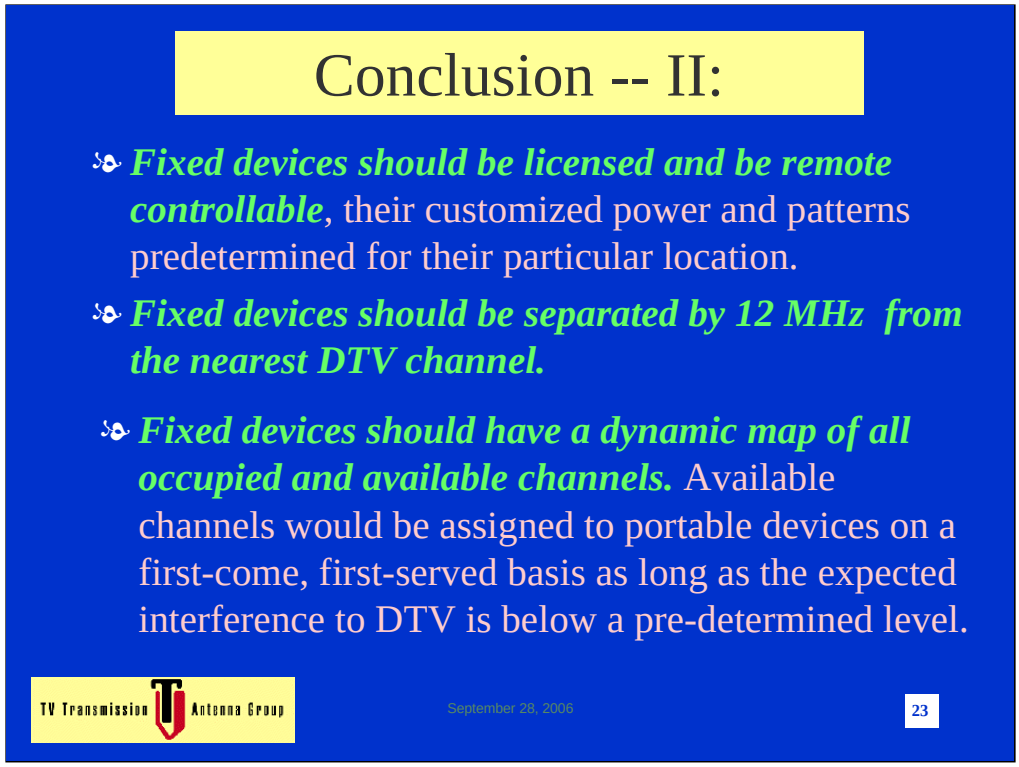
In summary we have shown that based on the proposed FCC rules, four sources of harmful interference to DTV can be expected:

[<>] First------

[<>] Second---------

[<>] Third-----------

[<>] And fourth----------



In conclusion...

and

[<>] ----------

and

[<>] ----------

Recommendation

To accommodate the new devices in major markets:

1. Pack all DTV channels into a contiguous spectrum, first priority channels 7-13, second priority channels 16-2X

2. Perform real-world experiments of actual UD networks in typical environments <u>before finalizing the rules</u>

Finally, a two-fold recommendation: ----------

Let’s hope that this presentation serves as a wake-up call to whoever is concerned with the future of OTA television

Thank You!

Contact:
www.tvantenna.tv