

New America Foundation Testing of DTV Receivers

Presentation to NTIA
14 November 2006

Executive Summary

- TV WhiteSpaces potential for a wireless broadband is of interest to FCC (04-186) and Senate legislation (Senate Telecom Bill)
- NTIA Tuner Program can impact this opportunity by the selection of receiver specifications/standards
- Key regulatory parameters are Adjacent Channel and Co-Channel interference rejection
- Wireless experts have investigated these parameters at tests at the University of Kansas on consumer receivers
- Preliminary findings indicate that ATSC A/74 standards for Adjacent Channel and FCC 05-199 for Co-Channel interference rejections are both adequate and reasonable

Principal Investigators

- **Dr. Joe Evans - University of Kansas**
 - Former Program Director – NSF
 - Distinguished Professor of Electrical Engineering & Computer Science
 - Director of Research Information Technology
- **Dr. Mike Marcus – Marcus Spectrum Solutions**
 - Former Associate Chief – OET
 - IEEE Fellow
 - Pioneer in Spread Spectrum and Millimeter Wave Commercialization
- **Dr. Paul Kolodzy – Kolodzy Consulting**
 - Former FCC Senior Spectrum Policy Advisor
 - Former DARPA Program Manager in Communications Technology
- **Dan DePardo – University of Kansas**
 - RF Electronics Engineer

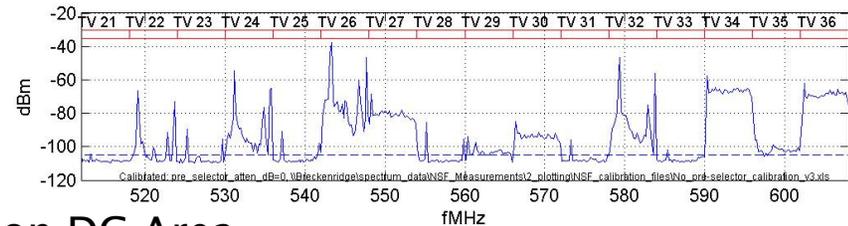
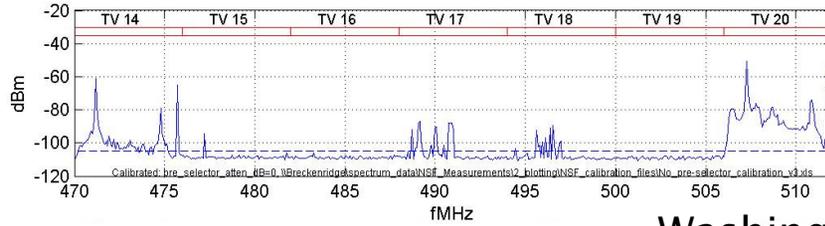
Rationale for Discussion

- The potential use of TV WhiteSpace for wireless broadband is of interest (FCC pending Order and Senate Telecom Bill)
- NTIA DTV Tuner Program and its selection of tuner/receiver parameters should not degrade the potential of using the TV WhiteSpace
- ATSC A/74 Standards provide a basis for specific tuner parameters
- FCC 2004-05 Tests (FCC 05-199) provided a sampling of the range of tuner parameters in consumer products
- Two specific parameters have direct impact to TV WhiteSpace and FCC Rulemakings: Adjacent Channel Rejection (not in FCC) and Co-Channel Rejection (not in A/74)
- Testing at University of Kansas are being conducted specific to those parameters
- This presentation includes the preliminary results from those tests.

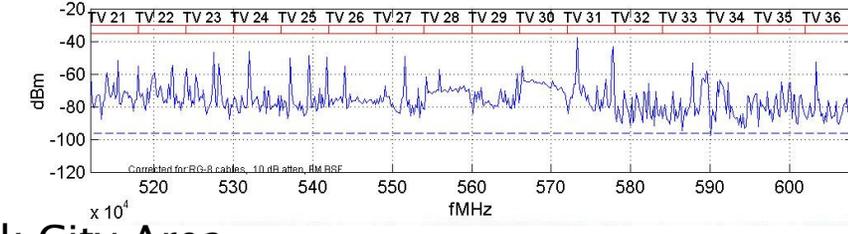
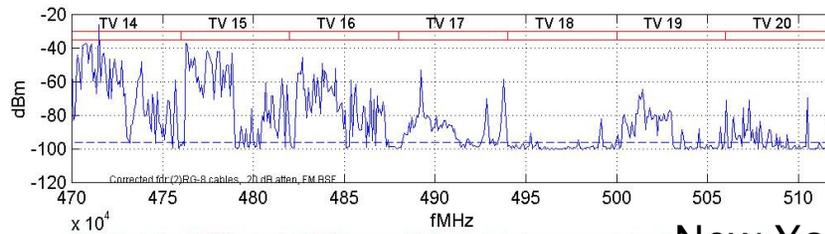
Working Premise

- Receivers and Set-Top-Boxes must work in an environment that can sometimes be rather crowded with other signals, thus immunity standards are key for Set-Top-Boxes in order to get acceptable performance
- While spectrum is crowded in some places near some active channels, there are also real "holes" in the spectrum, especially in rural areas, and these can be used to extend wireless broadband
- Set-Top-Boxes should have immunity comparable to production receivers in order to both enable reception of TV signals in dense environments AND to avoid being susceptible to new spectrum use proposed in Docket 04-186

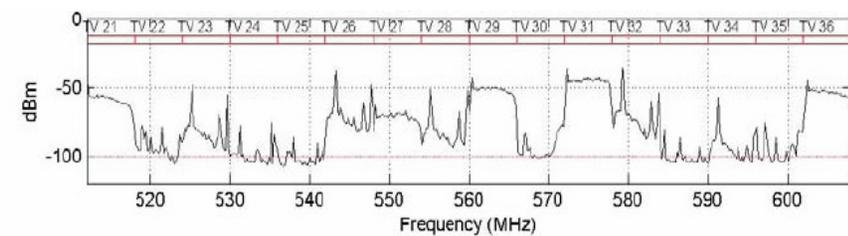
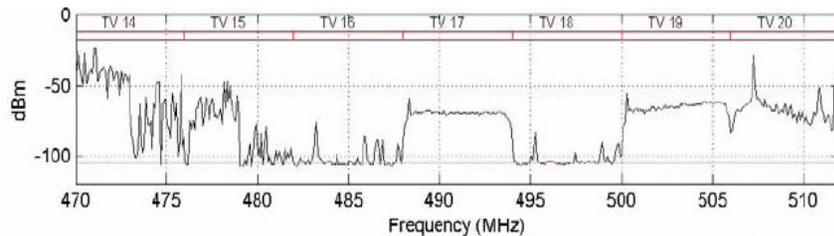
Potential of TV WhiteSpace



Washington DC Area



New York City Area



Chicago Area

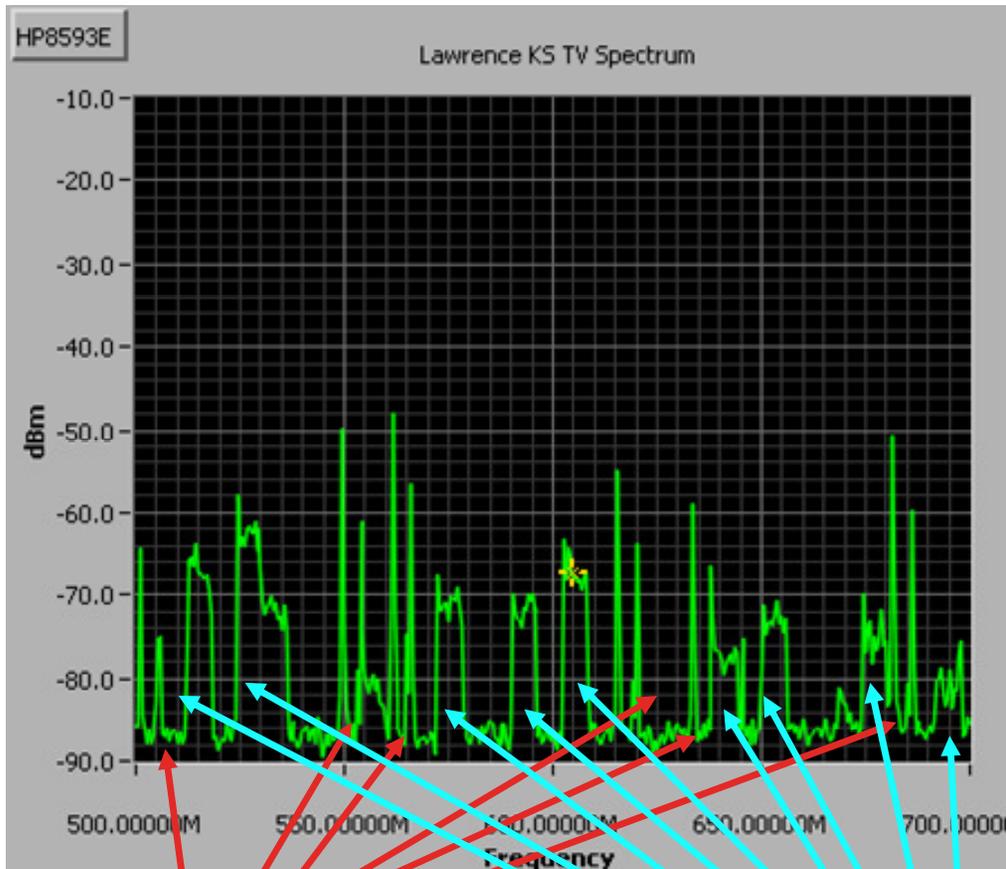
Importance of DTV Tuner Program is to insure that the technical parameters of the tuners maintain the potential for use of TV Whitespace.

Measurements by Shared Spectrum Corp

TV Channels 14-20 include land mobile signals

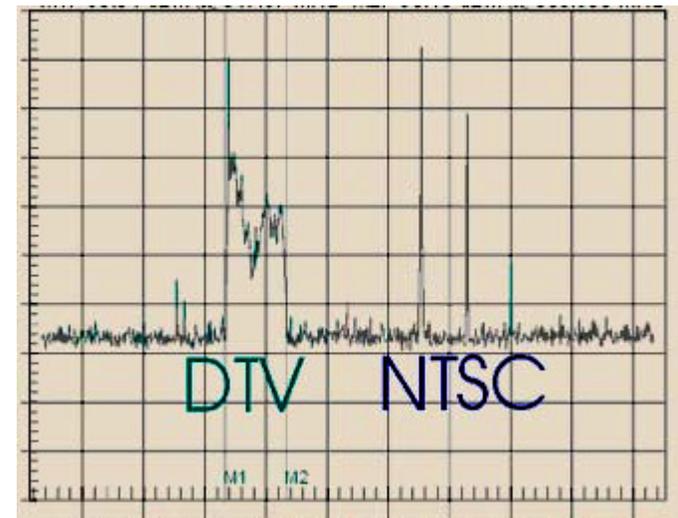
Even in Kansas TV Spectrum is Complex

... but there still WhiteSpaces

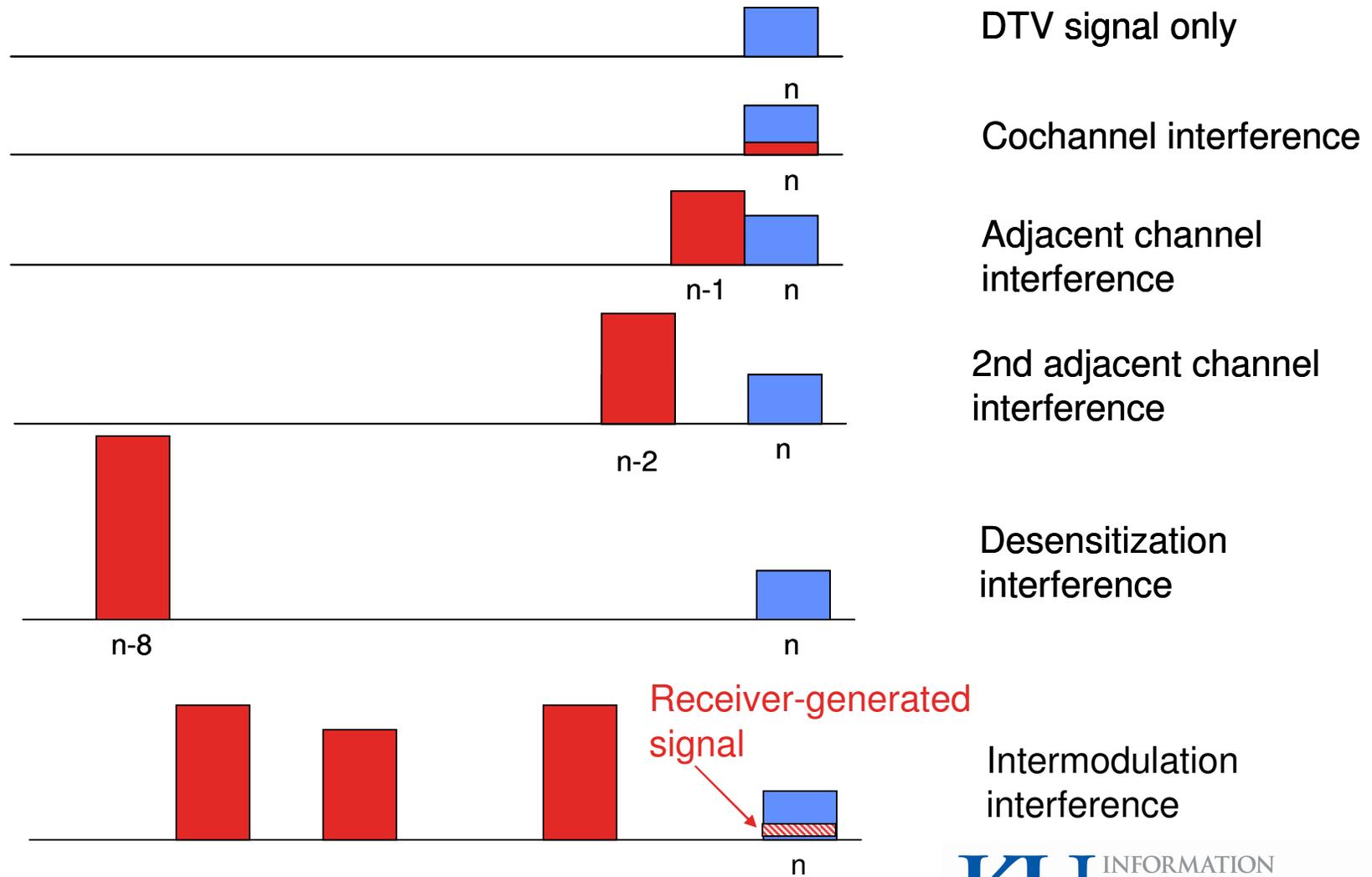


NTSC

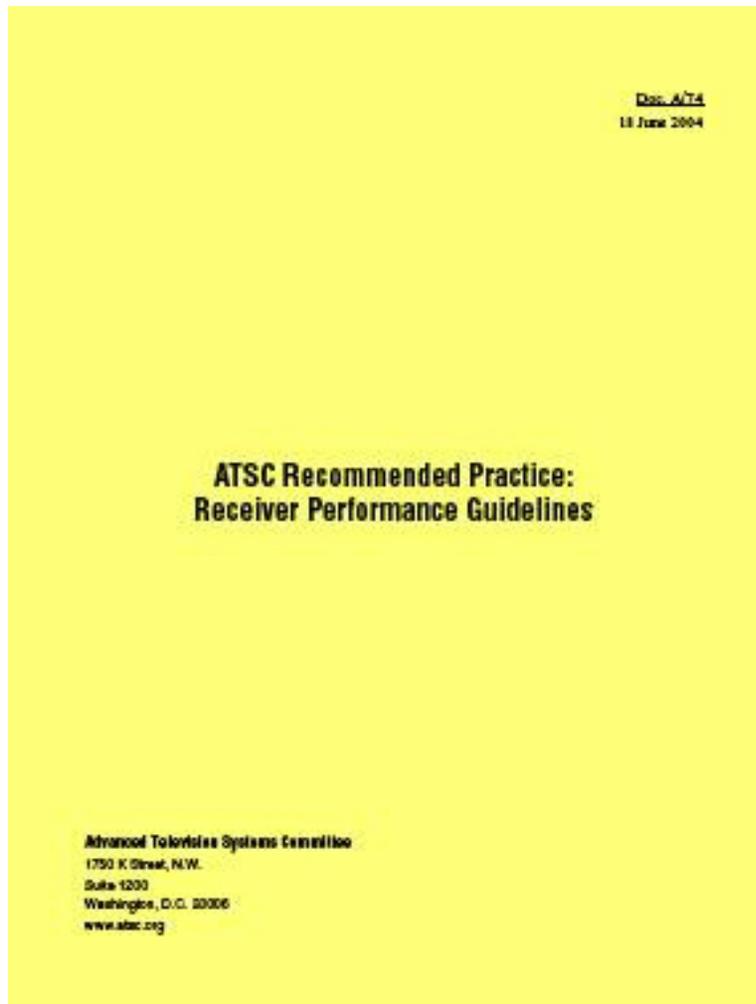
DTV



Types of Interference



ATSC A/74



- NPRM states that boxes must “appropriately process all ATSC RF signals”
- Only reference to RF environment of signals is statement to “take into consideration” the cost of whether box meets ATSC A/74 standards

“This document addresses the front-end portion of a receiver of digital terrestrial television broadcasts. The recommended performance guidelines enumerated in this document are intended to assure that reliable reception will be achieved. Guidelines for interference rejection are based on the FCC planning factors that were used to analyze coverage and interference for the initial DTV channel allotments. Guidelines for sensitivity and multipath handling reflect field experience accumulated by testing undertaken by ATTC, MSTV, NAB, and receiver manufacturers.”

ATSC A/74

Table 4.2 First Adjacent Channel Thresholds

Type of Interference	Adjacent Channel D/U Ratio (dB)		
	Weak Desired (-68 dBm)	Moderate Desired (-53 dBm)	Strong Desired (-28 dBm)
Lower DTV interference into DTV	-33 ⁵	-33 ⁶	-20
Upper DTV interference into DTV	-33	-33 ⁶	-20

Table 4.3 Taboo Channel Rejection Thresholds for DTV Interference into DTV

Channel	Taboo Channel D/U Ratio (dB)		
	Weak Desired (-68 dBm)	Moderate Desired (-53 dBm)	Strong Desired (-28 dBm)
N +/- 2	-44	-40	-20
N +/- 3	-48	-40	-20
N +/- 4	-52	-40	-20
N +/- 5	-56	-42	-20
N +/- 6 to N +/- 13	-57	-45	-20
N +/- 14 and 15	-50 ⁷	-45	-20

ATSC A/74

Table 4.1 Co-Channel Rejection Thresholds

Type of Interference	Co-Channel D/U ³ Ratio (dB)	
	Weak Desired (-68 dBm)	Moderate Desired (-53 dBm)
DTV interference into DTV	+15.5	+15.5
NTSC interference into DTV	+2.5	+2.5
<i>Notes:</i> NTSC split 75% color bars with pluge bars should be used for video source. All NTSC values are peak power; all DTV values are average power		

- **ATSC A/74 only addresses co-channel rejection for TV signals**

CEA/MSTV/NAB Comments

- Emphasize need to meet A/74-like immunity to other signals, not just decode DTV in a “green field” environment
- Appendix A gives suggested criteria
- Channel immunity same as A/74 except for $N\pm 14$ and $N\pm 15$ where spec is tightened
- WE AGREE

http://www.ntia.doc.gov/otiahome/dtv/comments/dtvcoupon_comment0050.pdf

DTV Receivers Tested

Tuner 2 – 2006



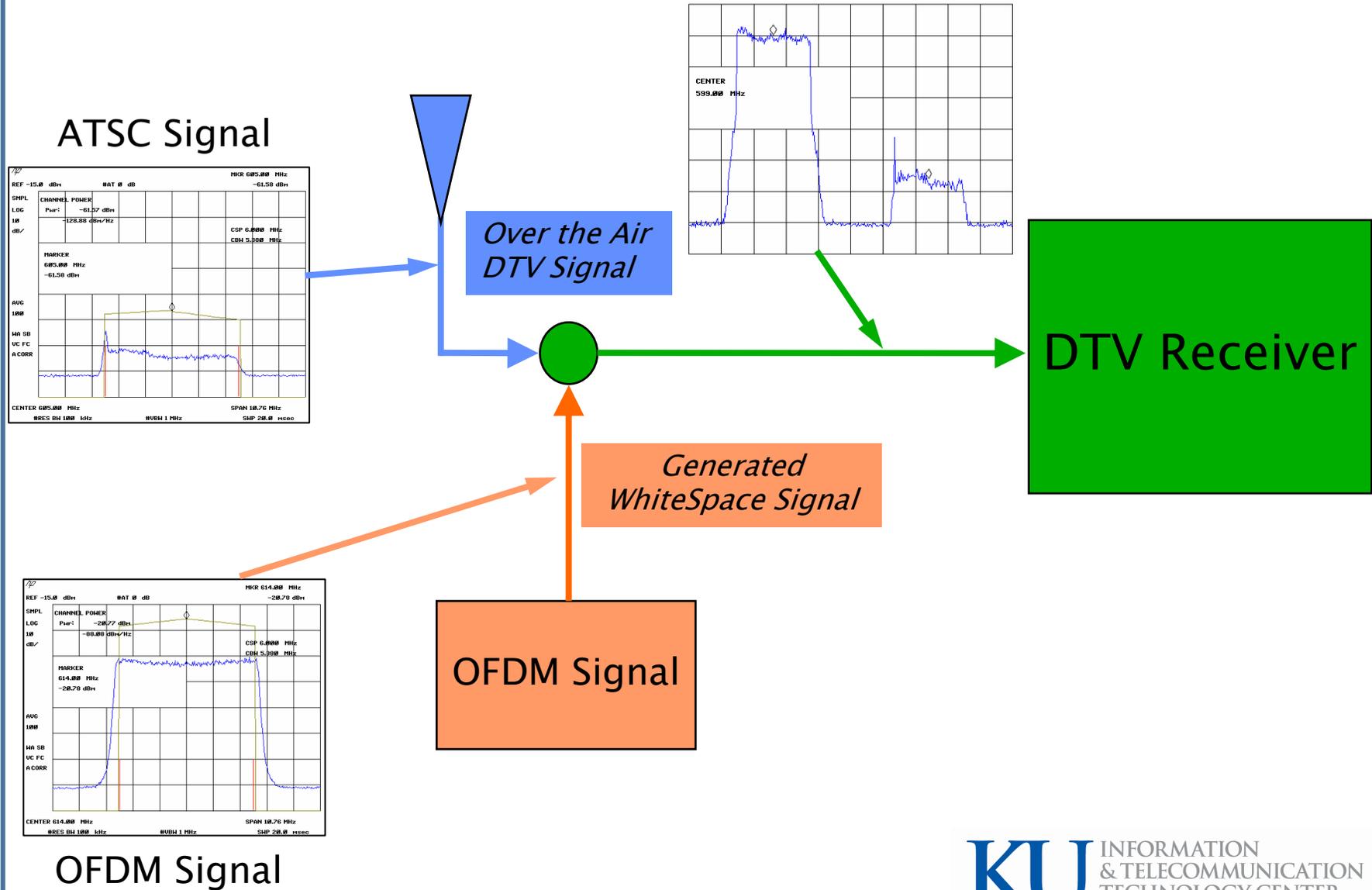
Tuner 1 – 1999



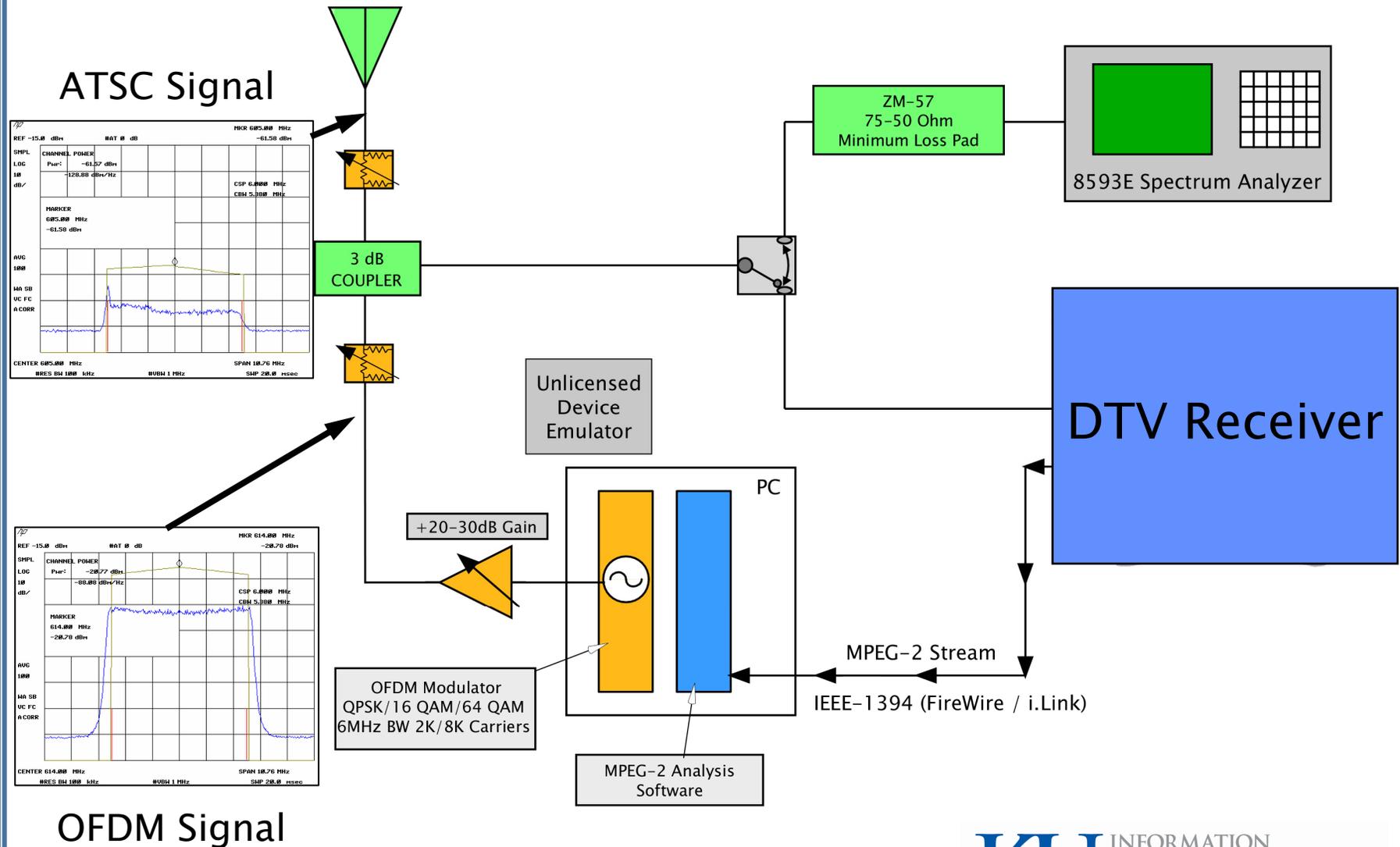
Tuner 3 – 2006



DTV Receiver Test – Functional Diagram



DTV Receiver Test – Engineering Diagram



Example of Observed Errors Caused by Interference

Program Number: 2
PCR on PID 65 (0x0041)
PMT Version: 1
Service name: KCPT 2

Stream Type: 0x02 MPEG-2 Video
Elementary Stream PID 65 (0x0041)

Stream Type: 0x81 AC-3 Audio
Elementary Stream PID 68 (0x0044)

Descriptor: Multiplex Buffer Utilization Descriptor
Bound Valid Flag: 1
LTV Offset Lower: 180 Upper: 180

Descriptor: Maximum Bitrate Descriptor

Active PIDs: Disabled Sort Descending Sort by Rate Sort by PID

- 0x1fff (22.57% ~ 4.55 Mbps)
- 0x0061 (17.78% ~ 3.43 Mbps)*
- 0x0031 (17.78% ~ 3.43 Mbps)*
- 0x0051 (17.78% ~ 3.43 Mbps)*
- 0x0041 (17.78% ~ 3.43 Mbps)*
- 0x0044 (1.02% ~ 196.04 Kbps)*
- 0x0034 (1.01% ~ 195.99 Kbps)*
- 0x0064 (1.01% ~ 195.72 Kbps)*
- 0x0054 (1.01% ~ 195.66 Kbps)*
- 0x1d00 (0.15% ~ 29.91 Kbps)*
- 0x0030 (0.15% ~ 28.83 Kbps)*
- 0x0030 (0.13% ~ 25.00 Kbps)*
- 0x0050 (0.13% ~ 24.98 Kbps)*
- 0x0000 (0.13% ~ 24.98 Kbps)*
- 0x0020 (0.13% ~ 24.98 Kbps)*
- 0x0040 (0.13% ~ 24.87 Kbps)*
- 0x0060 (0.13% ~ 24.82 Kbps)*
- 0x1ffb (0.10% ~ 19.74 Kbps)*
- 0x1e00 (0.03% ~ 5.23 Kbps)
- 0x1d01 (0.02% ~ 3.59 Kbps)
- 0x1e01 (0.01% ~ 1.16 Kbps)*
- 0x1e03 (0.01% ~ 1.05 Kbps)
- 0x1d03 (0.01% ~ 1.05 Kbps)*
- 0x1e02 (0.00% ~ 809 bps)
- 0x1d02 (0.00% ~ 809 bps)
- 0x1e00 (0.00% ~ 324 bps)

General Information
Source: Technisat/B2C2 8VSB
Tuner: Channel 18 (497 MHz)
Signal: Locked SNR: 16.8 dB

Profile: Default
Network Type: ATSC
Run Time: 000:00:56

MPEG-2 Statistics	PAT	PMT	CAT	ETT	PSIP	EIT
Sections	927	4.6k	0	282	591	543
CRC Errors	0	0	0	0	1	6
Continuity Errors:	1678			Mux. bitrate:	19309398 bps	
TEI Errors:	0			Last sec.:	19.728 Mbit	
				In buffer:		
				Out buffer:		

* after the bitrate indicates the PID has continuity errors

Observed Errors

But for DTV, judging interference is much simpler than for NTSC - over a few dB range signal quickly degrades! NTSC interference is very subjective

Numerous errors measured, Numerous errors observed

Preliminary Adjacent Channel Results

Signal Levels that caused I/F (in dBm/6 MHz BW), DTV @ -61 dBm

	ATSC Receiver 1 Set Top Unit	ATSC Receiver 2 LCD DTV	ATSC Receiver 3 Set Top Unit
Adjacent Channel (-1)	-34 dBm	-30 dBm	-29 dBm
1.5 Adjacent Channel (-1.5)	-24 dBm	-18 dBm	-26 dBm
Second Adjacent Channel (-2.0)	-15 dBm	-16 dBm	-22 dBm

- **Preliminary Results (3 meter Separation)**
 - Yellow – 100 mW at 3 meters
 - Green – 1 W at 3 meters
- **Onmi antennas for both transmitter and receiver**

Preliminary Adjacent Channel Results

Signal Levels that caused I/F (in dBm/6 MHz BW), DTV @ -61 dBm

	ATSC Receiver 1 Set Top Unit	ATSC Receiver 2 LCD DTV	ATSC Receiver 3 Set Top Unit
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1.5 Adjacent Channel (-1.5)	-24 dBm	-18 dBm	-26 dBm
Second Adjacent Channel (-2.0)	-15 dBm	-16 dBm	-22 dBm

- **Preliminary Results (10 meter Separation)**
 - Yellow – 100 mW at 10 meters
 - Green – 1 W at 10 meters
- **Onmi antennas for both transmitter and receiver**

Preliminary Adjacent Channel Results

D/U Ratios (in dB)

	ATSC Receiver 1 Set Top Unit	ATSC Receiver 2 LCD DTV	ATSC Receiver 3 Set Top Unit
Adjacent Channel (-1)	-27	-31	-32
1.5 Adjacent Channel (-1.5)	-37	-43	-35
Second Adjacent Channel (-2.0)	-46	-45	-39

- **Preliminary Results (Necessary D/U Ratio for Adjacent Channel)**
 - A/74 is reasonable (green meet or exceed A/74 standards – -33 dB)
 - Receiver 1 is of 1999 Vintage, Receiver 3 is considered “lower quality”
- **A/74 standards could enable 1 Watt transmission power in adjacent-channel**

Adjacent Channel Results - Summary

- Three tuners tested (2006 - Consumer TV, 1999 - Tuner, and 2006 - Tuner) at -61.5 dBm DTV signal
- All tuners had acceptable rejection for 1 W second adjacent channel signal at 10 m.
- All tuners had acceptable rejection for 100 mW adjacent channel signal at 10 m
- All tuners met or exceeded ATSC A/74 Standard for Adjacent Channel rejection for 1½ and 2 channels away.
 - All tuners missed for next adjacent channel

FCC Tests (FCC 05-199) – CoChannel Interference

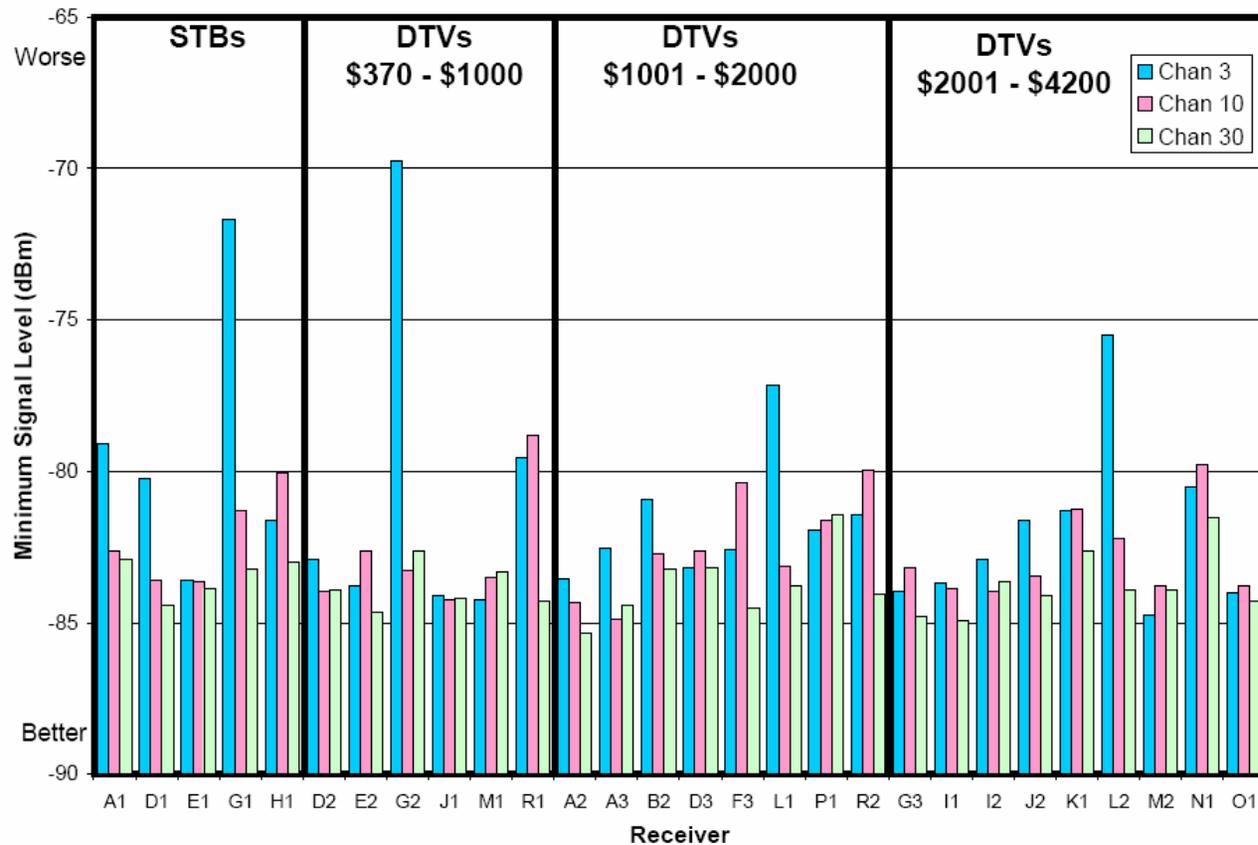
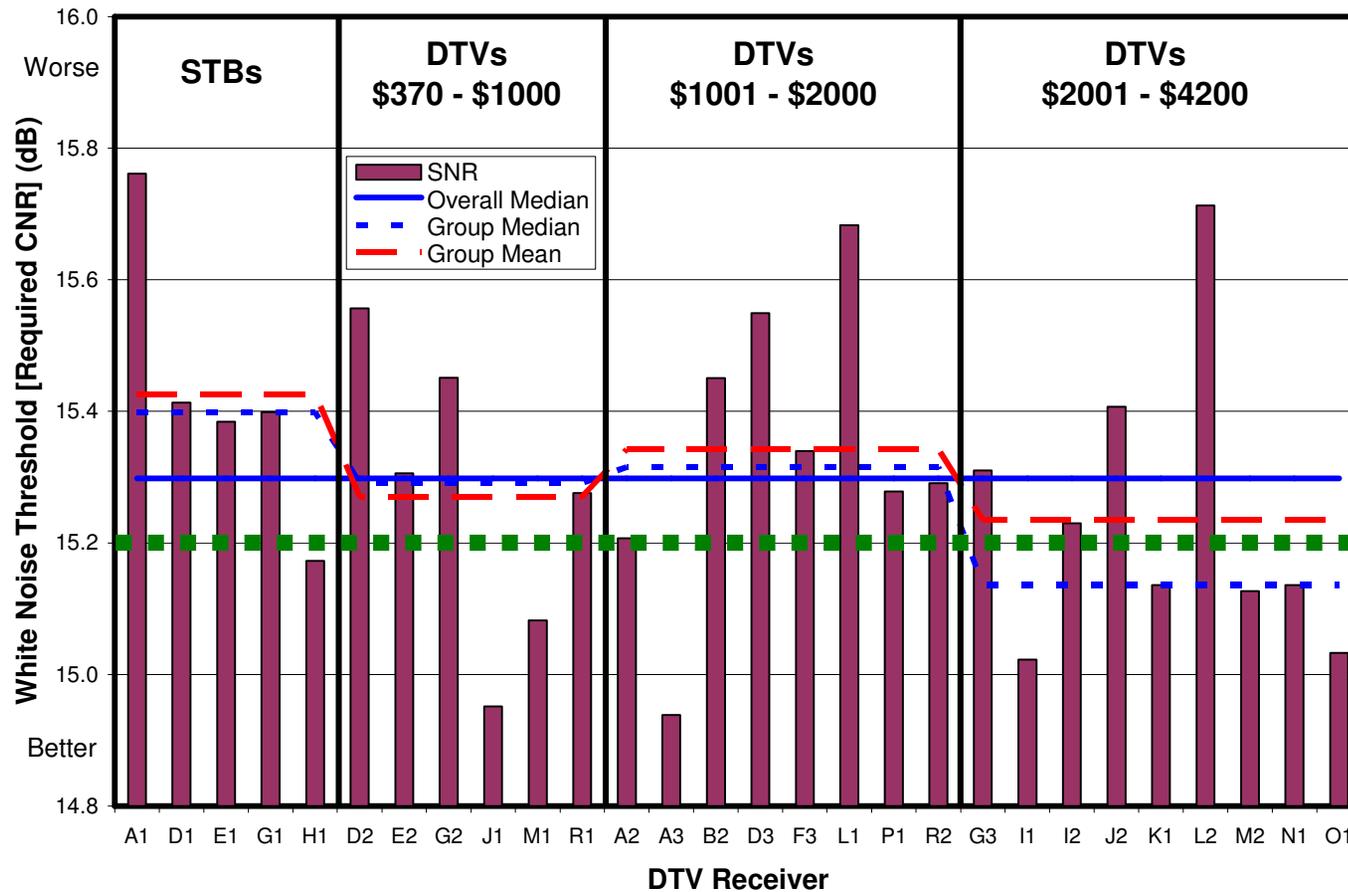


Figure 1. Measured Minimum Signal Level at TOV on Three Channels¹⁴²

- FCC Test looked at minimum signal levels

FCC Tests (FCC 05-199) – CoChannel Interference



- FCC Test addressed white noise co-channel

Preliminary Co-Channel Results

D/U Ratios

ATSC Signal	Tuner 1	Tuner 2	Tuner 3
At Threshold	20 (-102 dBm) Error-free Threshold: -82 dBm/ 6 MHz BW	15 (-96 dBm) Error-free Threshold: -81 dBm/ 6 MHz BW	17 (-97 dBm) Error-free Threshold: -80 dBm/ 6 MHz BW
-68 dBm	13 (-81 dBm)	11 (-79 dBm)	12 (-80 dBm)
-61 dBm	12 (-73 dBm)	11 (-72 dBm)	11 (-72 dBm)

There is no current A/74 standard for D/U for non-TV (ATSC/NTSC) signals

Co-Channel Results - Summary

- Three tuners tested at -61.5, -68.0, and -83.0 dBm (or at TOV) DTV signal
- There is no ATSC A/74 standard for non-TV co-channel signal rejection
- FCC 05-199 Tested white-noise Co-Channel interference rejection
 - Average was 15.2 dB D/U ratio
- All Tuners surpassed the FCC 05-199 results except at TOV

Summary

- **Small number of DTV tuners tested:**
 - Mainline Commercial, 1999 Vintage, and “low cost”
- **Adjacent Channel Standards**
 - A/74 Standards sufficient for potential of 1 W adjacent channel emissions
 - FCC Tests (2004/05) did not test adjacent channel rejection
- **Co-Channel Standards**
 - None exist other than for TV signals
 - Increased Co-channel robustness (lower D/U) provides more options for use of “white spaces”
 - Current has samples that exceeded (except at TOV) FCC 05-199..
- **Recommend use of ATSC A/74 Standards (Adjacent Channel) and FCC 05-199 (Co-Channel) to provide solid performance for consumers and to enable the potential use of TV WhiteSpaces in the future.**