

NEW  
AMERICA  
FOUNDATION

***Free the Airwaves:***  
**The Great White Space Debate**

Google Policy Forum

*October 21, 2008*

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New America Foundation



## ***Wireless Future Program***

- **Mission: Pervasive Connectivity**
  - Universal
  - Ubiquitous
  - Affordable
  
- **Means: Openness**
  - Open Spectrum
  - Open Networks
  - Open Technologies
  - Community Networking

# Conventional Wisdom: Spectrum is Scarce

## UNITED STATES FREQUENCY ALLOCATIONS THE RADIO SPECTRUM

### RADIO SERVICES COLOR LEGEND

AIRBORNE MOBILE	AIRSATELLITE	AIRCRAFT/NAVIGATION
AIRBORNE MOBILE SATELLITE	LAND MOBILE	AIRCRAFT/NAVIGATION SATELLITE
AIRBORNE MOBILE/NAVIGATION	LAND MOBILE SATELLITE	RADIOLOCATION
MARITIME	MARITIME MOBILE	RADIOLOCATION SATELLITE
MARITIME SATELLITE	MARITIME MOBILE SATELLITE	RADIOBROADCAST
BROADCASTING	MARITIME RADIOBROADCAST	RADIOBROADCAST SATELLITE
BROADCASTING SATELLITE	METEOROLOGICAL	SPACE OPERATION
BROADCASTING SATELLITE	METEOROLOGICAL SATELLITE	SPACE RESEARCH
FIXED	MOBILE	STUDENT FREED (NOT RESEARCH SATELLITE)
FIXED SATELLITE	MOBILE SATELLITE	STUDENT FREED (NOT RESEARCH SATELLITE)

### ACTIVITY CODE

GOVERNMENT EXCLUSIVE	GOVERNMENT/REGULATORY BARRIERS
NON-GOVERNMENT EXCLUSIVE	

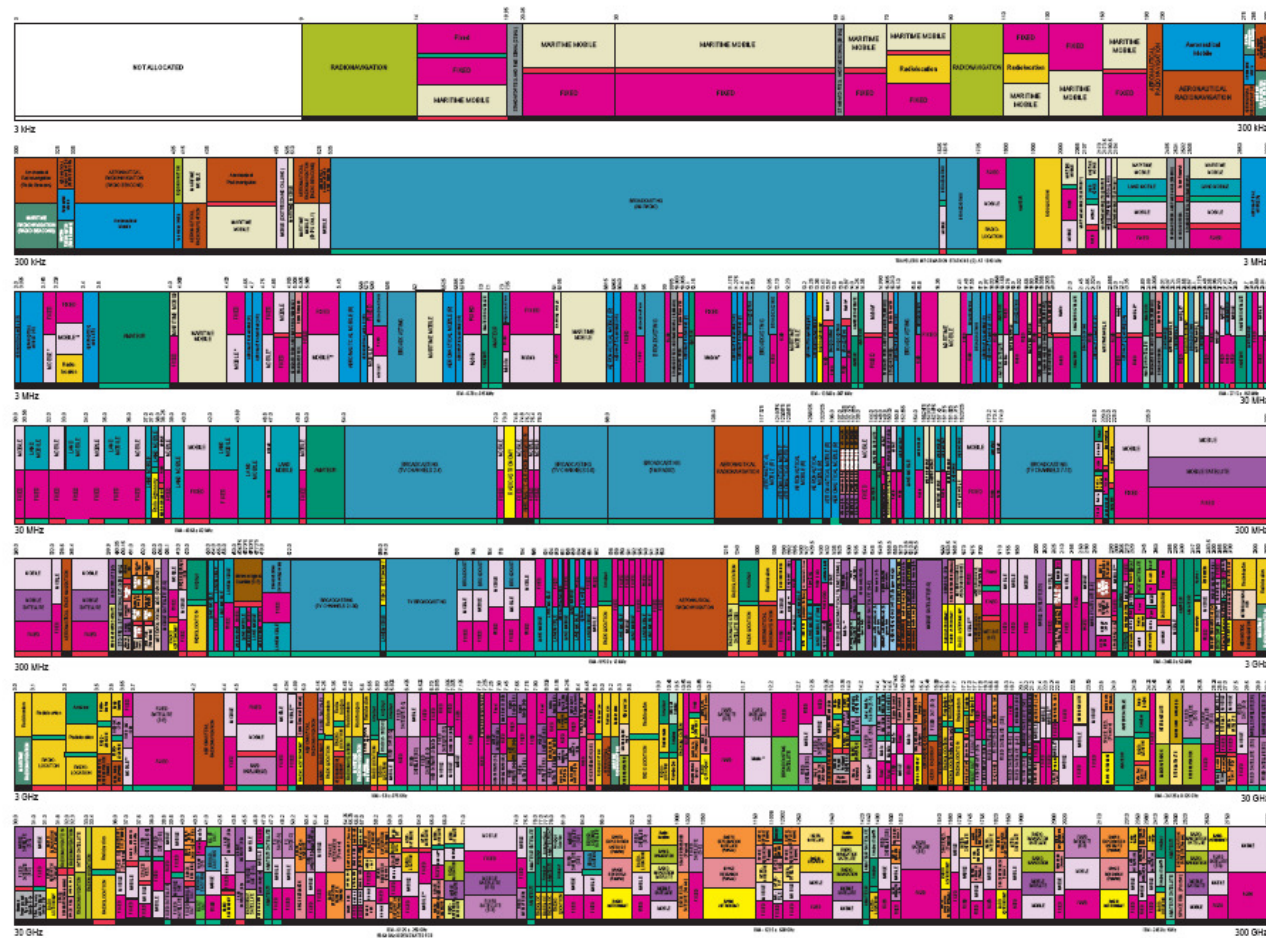
### ALLOCATION USAGE DESIGNATION

SERVICE	EXAMPLE	DESCRIPTION
Primary	F80B	Capital letters
Secondary	M2A	1st Capital with same case letters

This chart is a reference guide to the frequency allocations of the Table of Frequency Allocations used by the FCC and ITU. It is not a substitute for the Table of Frequency Allocations. The Table of Frequency Allocations is the authoritative source for the frequency allocations. The Table is updated by the FCC and ITU. For more information, see the Table of Frequency Allocations.

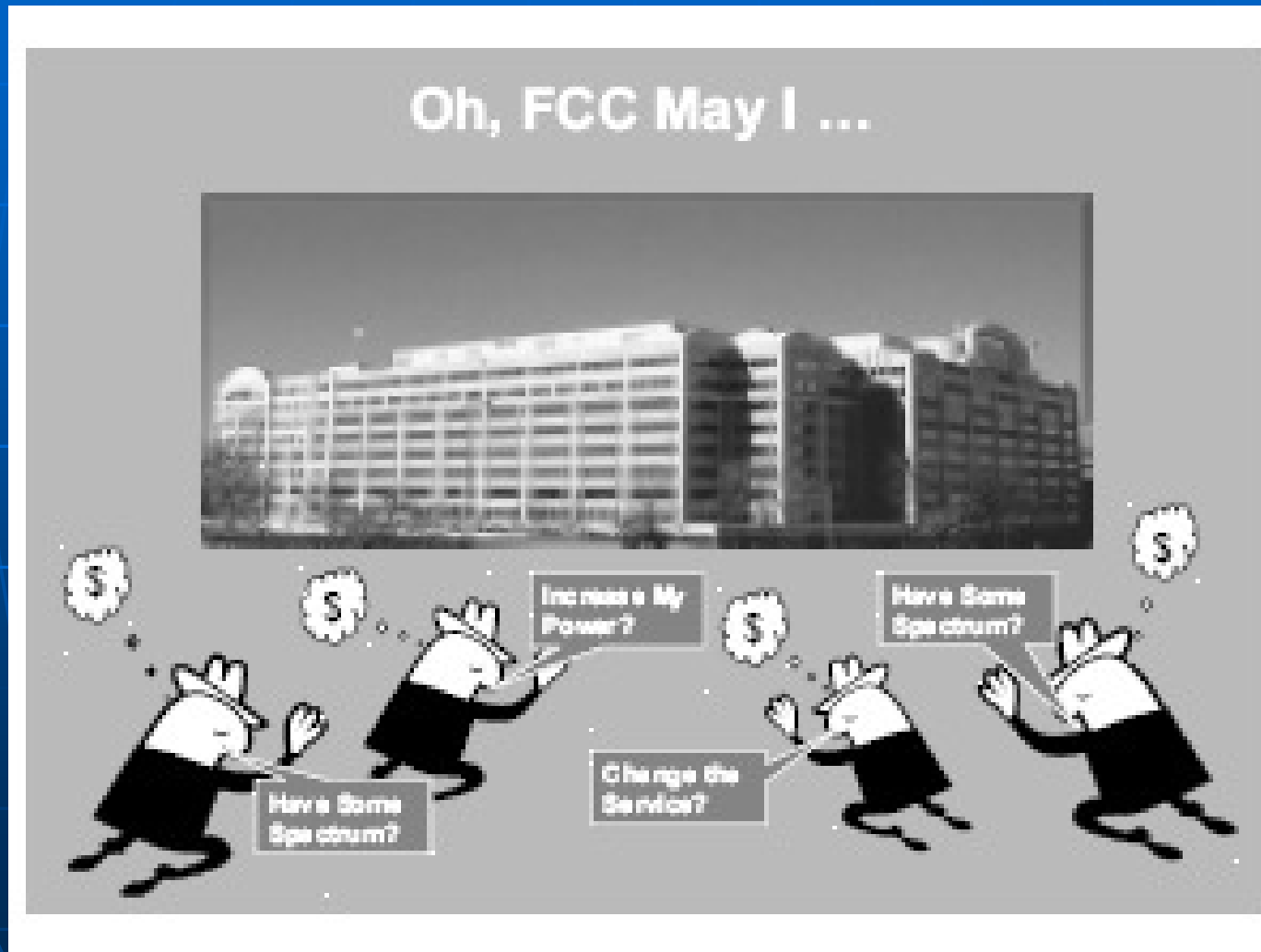


U.S. DEPARTMENT OF COMMERCE  
National Telecommunications and Information Administration  
Office of Spectrum Management  
October 2003

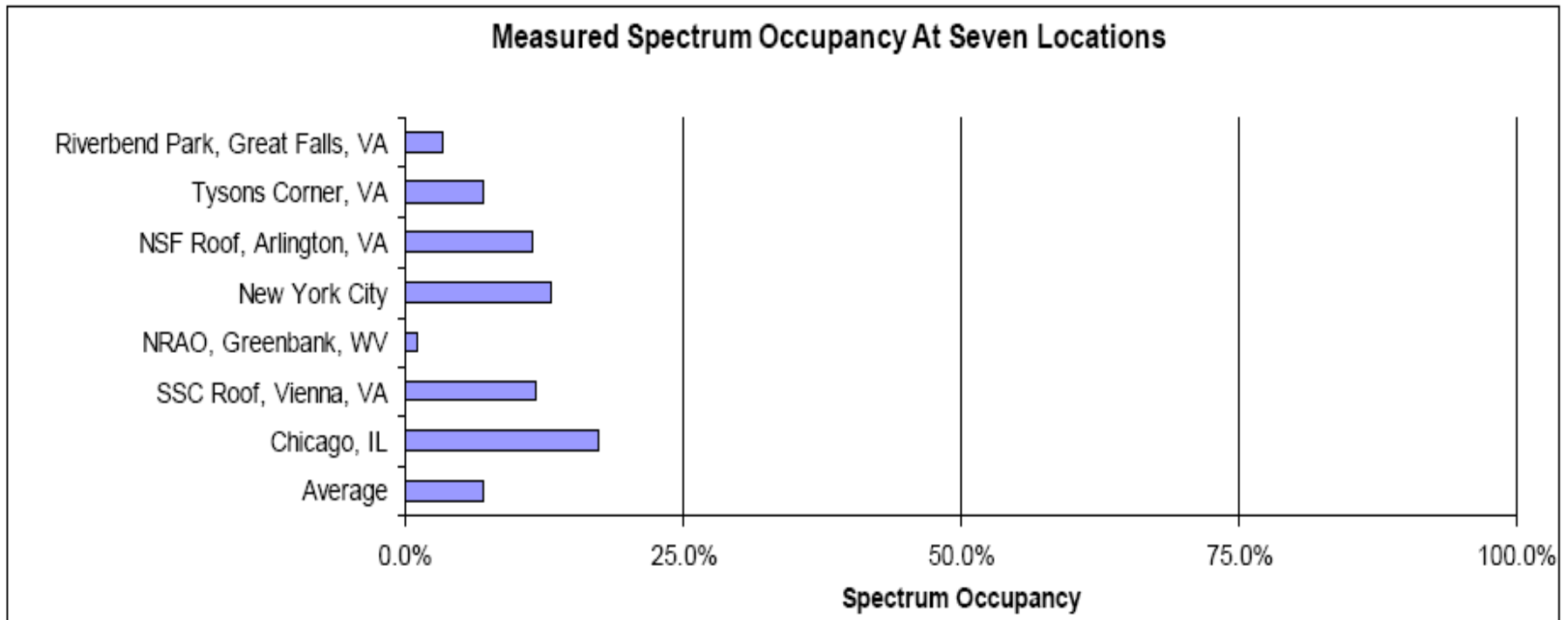


PLEASE NOTE: THE SPACES ALLIOTED TO THE SERVICES LISTED TO THE RIGHT OF THIS CHART ARE SUBJECT TO CHANGE WITHOUT NOTICE.

# Reality: Spectrum Licenses are Scarce

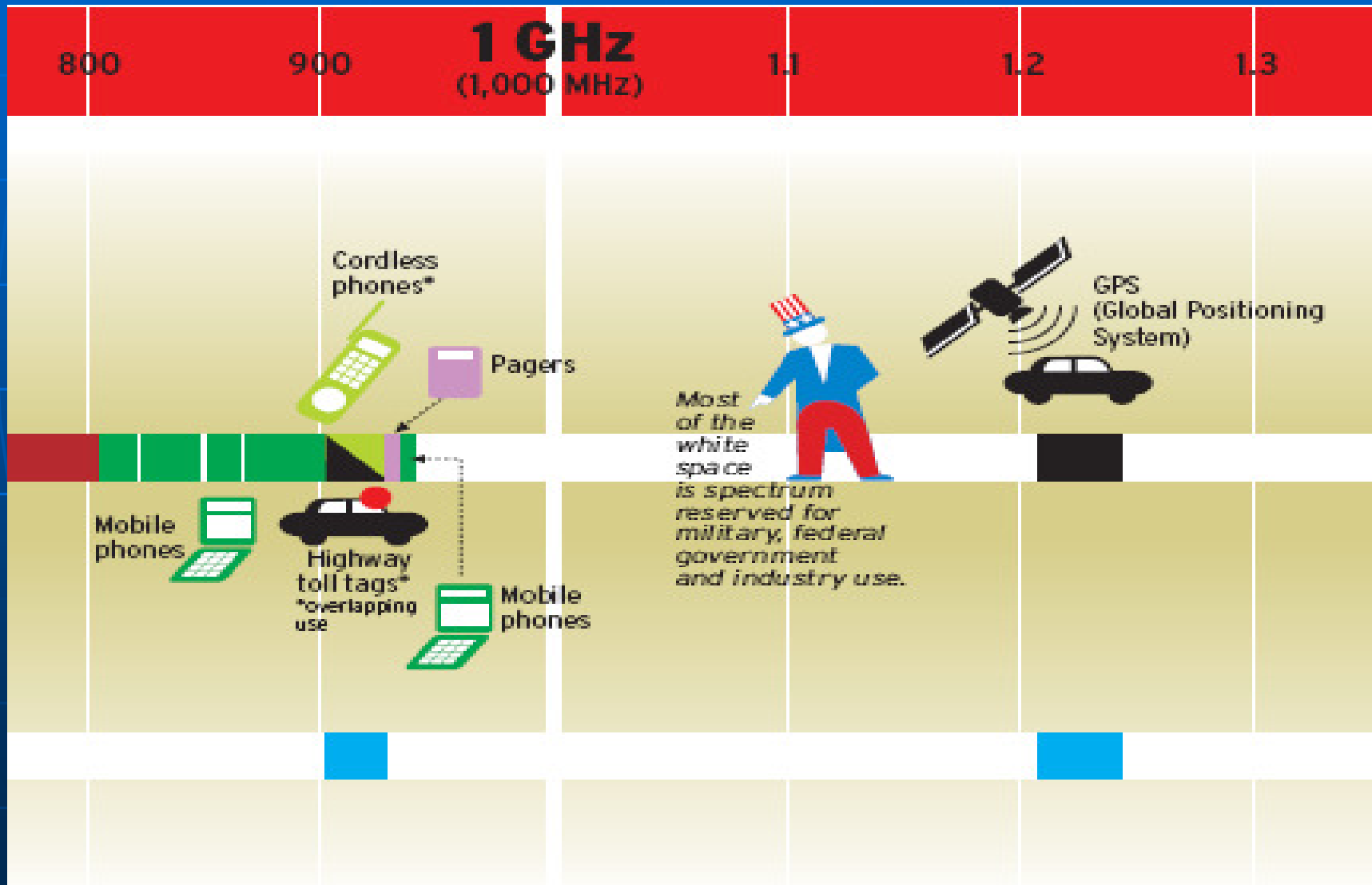


# Reality: Spectrum Bandwidth is Abundant (90% not in use)



**Figure 75 Overall Spectrum Occupancy Measured at Seven Locations**

# Most 'White Space' (wasted bandwidth) is Reserved for Government Use



## Examples of Spectrum Allocated for use by Federal Users

108 – 121 MHz (Aeronautical Mobile and Radionavigation)

138 – 144 MHz (Fixed and Mobile)

**225 – 399 MHz (Fixed and Mobile Air Navigation & Telemetry)**

902 – 928 MHz (Radiolocation)

960 – 1215 MHz (Aeronautical Radionavigation)

1350 – 1390 MHz (Fixed, Mobile and Radiolocation)

1400 – 1427 MHz (Radio Astronomy)

1435 – 1525 MHz (Mobile Aeronautical telemetry)

1525 – 1559 MHz (Mobile-Satellite)

1559 – 1660 MHz (Mobile-Satellite, Radio Astronomy, and Radionavigation)

1675 – 1700 MHz (Meteorological Aids and Satellite)

**1755 – 1850 MHz (Fixed, Mobile and Space Operation)**

2200 – 2290 MHz (Space Operation, Satellite, Fixed and Mobile)

2700 – 2900 MHz (Aeronautical Radionavigation and Meteorological Aids)

*Source: Manual of Regulation and Procedures for Federal Radio Frequency Management, NTIA January 2008*

# Actual Spectrum Use Measurements: Washington, DC



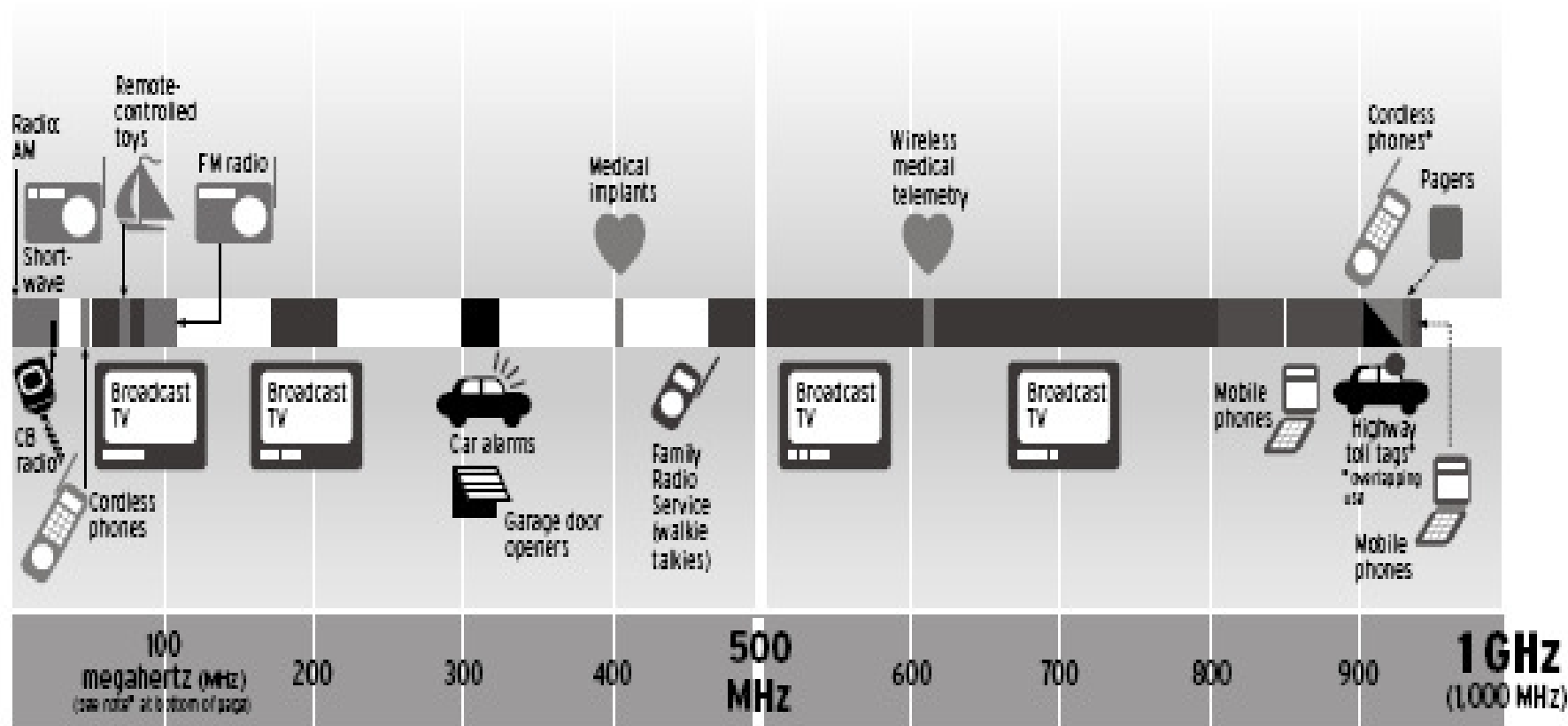
Appendix A: Estimated Whitespace During Peak Hours in an Urban Setting

Frequency Band (MHz)	Bandwidth (MHz)	Whitespace (MHz)	Used (MHz)	Whitespace %	Used %	Notes
30 – 54	24	0	24	0%	100%	
54 – 88	34	22	12	65%	35%	CH4, CH5 strong. CH2, 3 empty. CH8 empty, but heavy interference from FM.
88 – 108	20	0	20	0%	100%	FM band full
108 – 138	30	0	30	0%	100%	Air traffic control, ILS, VOR
138 – 174	36	0	36	0%	100%	Assume aggregate of steady signals ~10MHz
174 – 216	42	30	12	71%	29%	CH7, CH9 strong.
216 – 225	9	7	2	78%	22%	Two strong, continuous signals at 217.75 and 220-221 MHz
225 – 406	181	176	5	97%	3%	Only intermittent signals, randomly spaced in frequency. 225-400 is military.
406 – 470	64	0	64	0%	100%	
470 – 512	42	21	21	50%	50%	CH14, CH20 strong. CH17, CH18 weak.
512 – 608	96	45	51	47%	53%	3 digital channels, 2 analog channels, other stations weak.
608 – 698	90	54	36	60%	40%	4 digital channels, 1 analog channel, balance of spectrum empty.
698 – 806	108	108	0	100%	0%	Out of area TV stations below Grade B.
806 – 902	96	0	96	0%	100%	Cellular and Specialized Mobile Radio
902 – 928	26	26	0	100%	0%	ISM 900
928 – 960	32	19	13	59%	41%	945-960 mostly empty.
1400 – 1525	125	125	0	100%	0%	
1525 – 1710	185	165	20	89%	11%	
1710 – 1850	140	140	0	100%	0%	1710-1755 reallocated, 1755-1850 military allocation
1850 – 1990	140	50	90	36%	64%	U-PCS bands + PCS Block C (Nextwave) unused
1990 – 2110	120	70	50	58%	42%	Satellite uplink + electronic newsgathering
2110 – 2200	90	85	5	94%	6%	2110-2155 reallocated, 2165-2200 space-to-earth downlink.
2200 – 2300	100	85	15	85%	15%	Mostly space-to-earth communications.
2300 – 2380	80	35	25	58%	42%	2320-2345, DARS;
2380 – 2390	30	30	0	100%	0%	
2390 – 2500	110	26.5	83.5	24%	76%	2390-2400, U-PCS; ISM 2400-2483.5; 2483.5 - 2500, space-to-earth satcom
2500 – 2690	190	0	190	0%	100%	TFS/MMDS
2690 – 2900	210	190	20	90%	10%	Radar observed at 2840-2860
<b>Totals</b>	<b>2430</b>	<b>1509.5</b>	<b>920.5</b>	<b>62%</b>	<b>38%</b>	

\*The original data set and plots used to calculate the amount of estimated whitespace are available upon request.

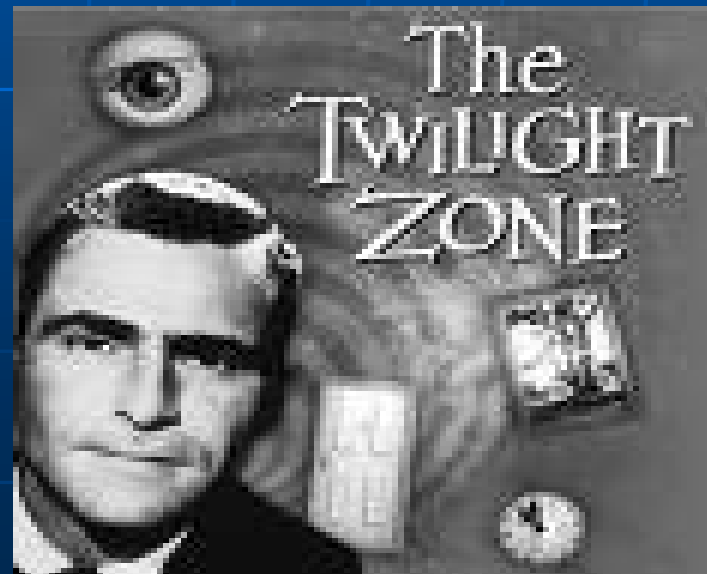
# Prime Low-Frequency Allocations Below 1 GHz

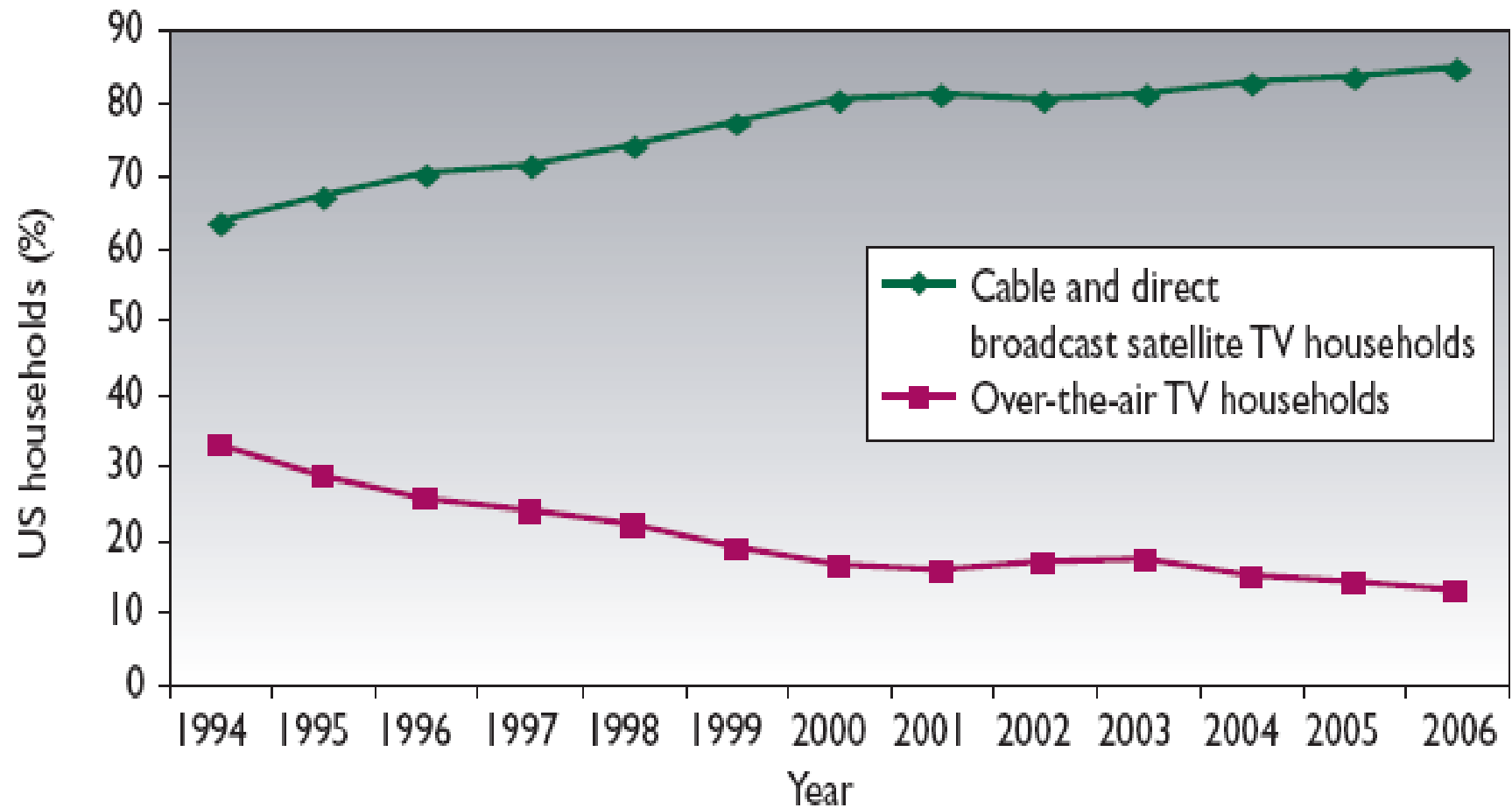
## 40% Exclusively for Television



FREQUENCY ASSIGNMENTS USED BY EVERYDAY DEVICES

# Earth to FCC: It's so not the 1960s





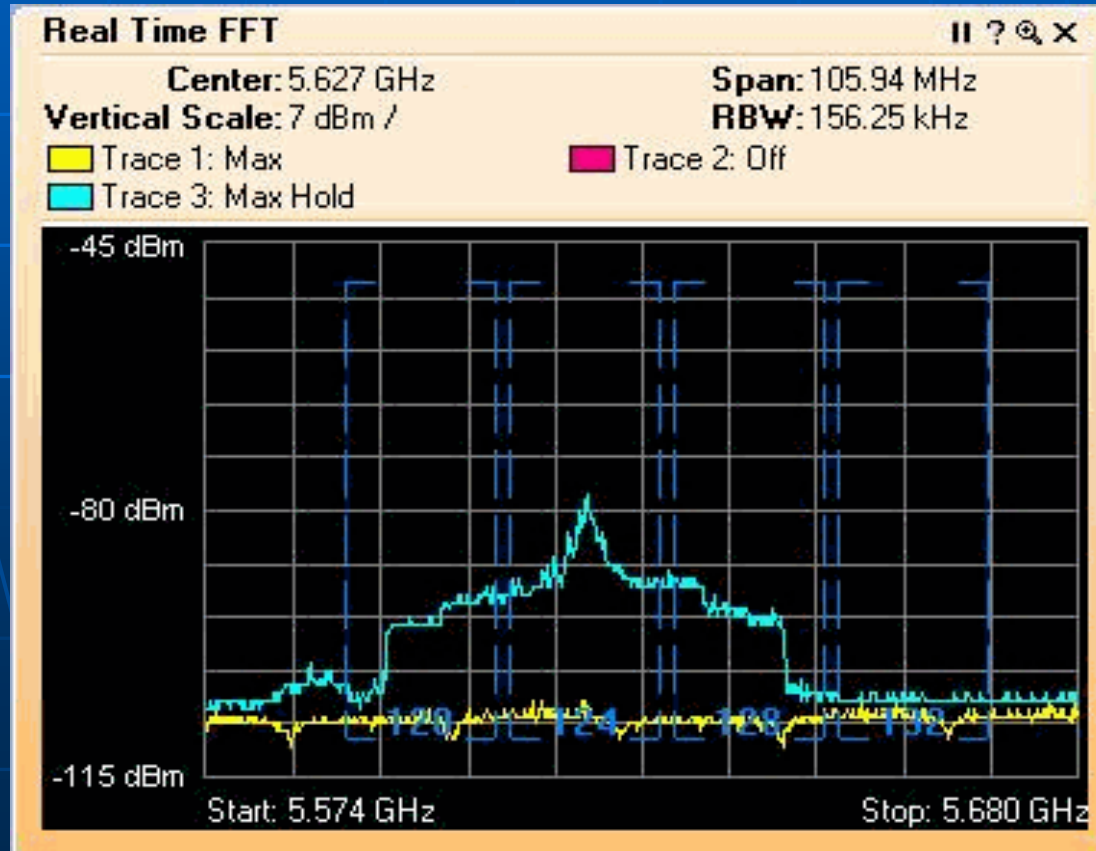
**Over-the-Air or Off-the-Air?** FCC data shows the share of U.S. households relying primarily on over-the-air reception has fallen steadily, to below 15 percent in 2006.

# The Many Ways to Increase Access to Valuable Bandwidth

- Spectrum is an infinitely renewable resource (any bandwidth not used is wasted)
- A band of frequencies can be 'white' (underutilized) and shared on a number of dimensions:
  - Geographically (not in use everywhere)
  - Time (not continually in use)
  - Spatially (in the air, not on the ground)
  - Angle of Reception (directional or 'smart antennas')

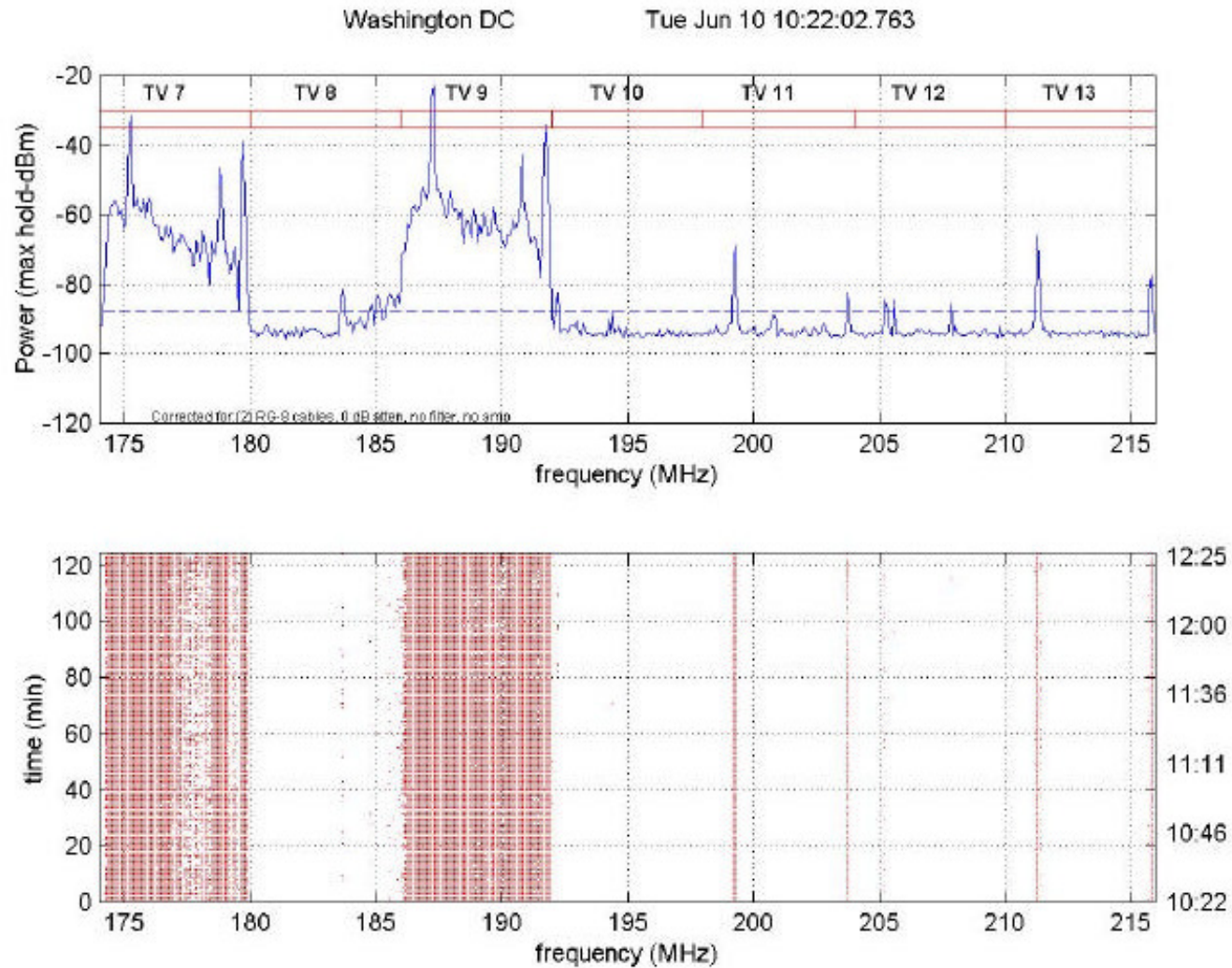
# Underlay: Sharing Underutilized Frequency Band

Example: WiFi Backhaul Shares Upper 5 GHz Band with Military Radar - Listen Before Talk Sensing



# Overlay: Filling Unoccupied Frequencies

## Example: TV Guard Bands ("White Space")



# The TV White Space Dilemma

- Spectrum “Swiss Cheese”: A different pattern of channels available in each of 210 U.S. TV markets.
  - Aggregation: Spectrum not consistently available either between or even within Metro markets.
- Relatively low-power limits on all channels
- 4 Watts: FCC Proposed transmit power limit for fixed broadband transmitters (100 mW for mobile/nomadic units)
  - No operation allowed on adjacent or co-channels
  - Adjacent channel protection by itself reduces the total amount of WS by half.
- 40 milliWatts: FCC Proposed limit for mobile devices operating on adjacent channels
  - No existing business model for multi-radio, spectrum hopping mobile service limited to 40 mW (less than home WiFi!)

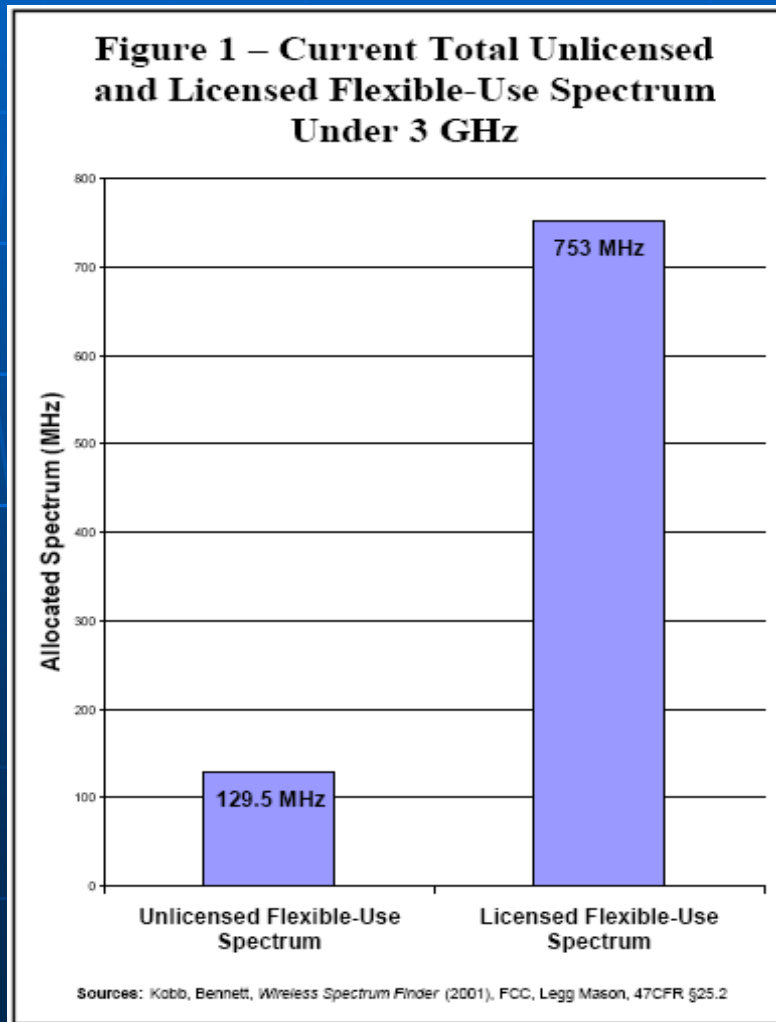
# Cognitive Radio to the Rescue: Low-Power, Unlicensed Sharing

- Majority of TVWS channels not useable above 1 W become useable on an opportunistic, license-exempt basis if:
  - Low Power: Under 100 mW (FCC proposing 40 mW)
  - Cognitive Radio: Occupied channel detection and hopping capability, either
    - Geolocate/database look-up, and/or
    - Listen-Before-Talk sensing
- This results in:
  - Spectrum efficiency: more than twice the bandwidth
  - National availability (even in large Metro markets)
  - Open access for consumers, innovators (no intermediary)
  - Regulatory and business model diversity
- White Spaces: Test case for Opportunistic Access to underutilized government and even commercial bands.

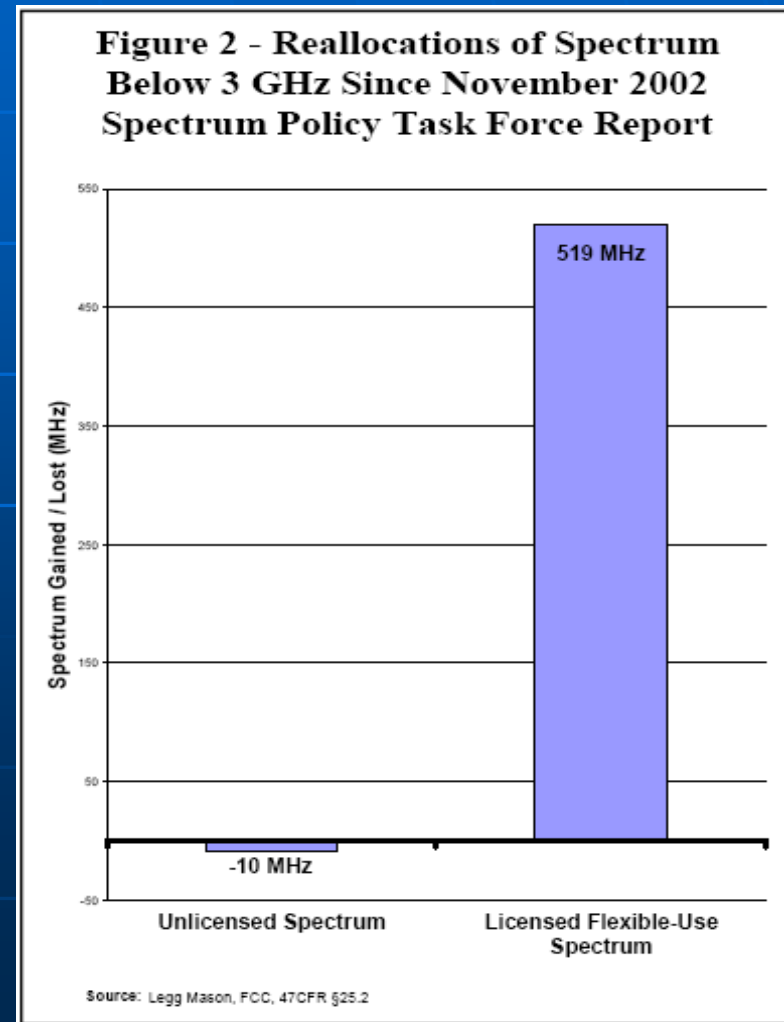
# Needed: A Diverse Spectrum Ecosystem of Unlicensed Spectrum Access

("Location, Location, Location")

➤ **Licensed v. Unlicensed below 3 GHz**



➤ **Unlicensed allocations after Spectrum Policy Task Force**



**Empty  
Beachfront:  
Between 7  
and 40  
channels are  
vacant  
across the  
nation's 210  
local TV  
markets.**

*Table 1. Average white space as a share of the TV band  
in a sample of US media markets after the transition to digital TV.*

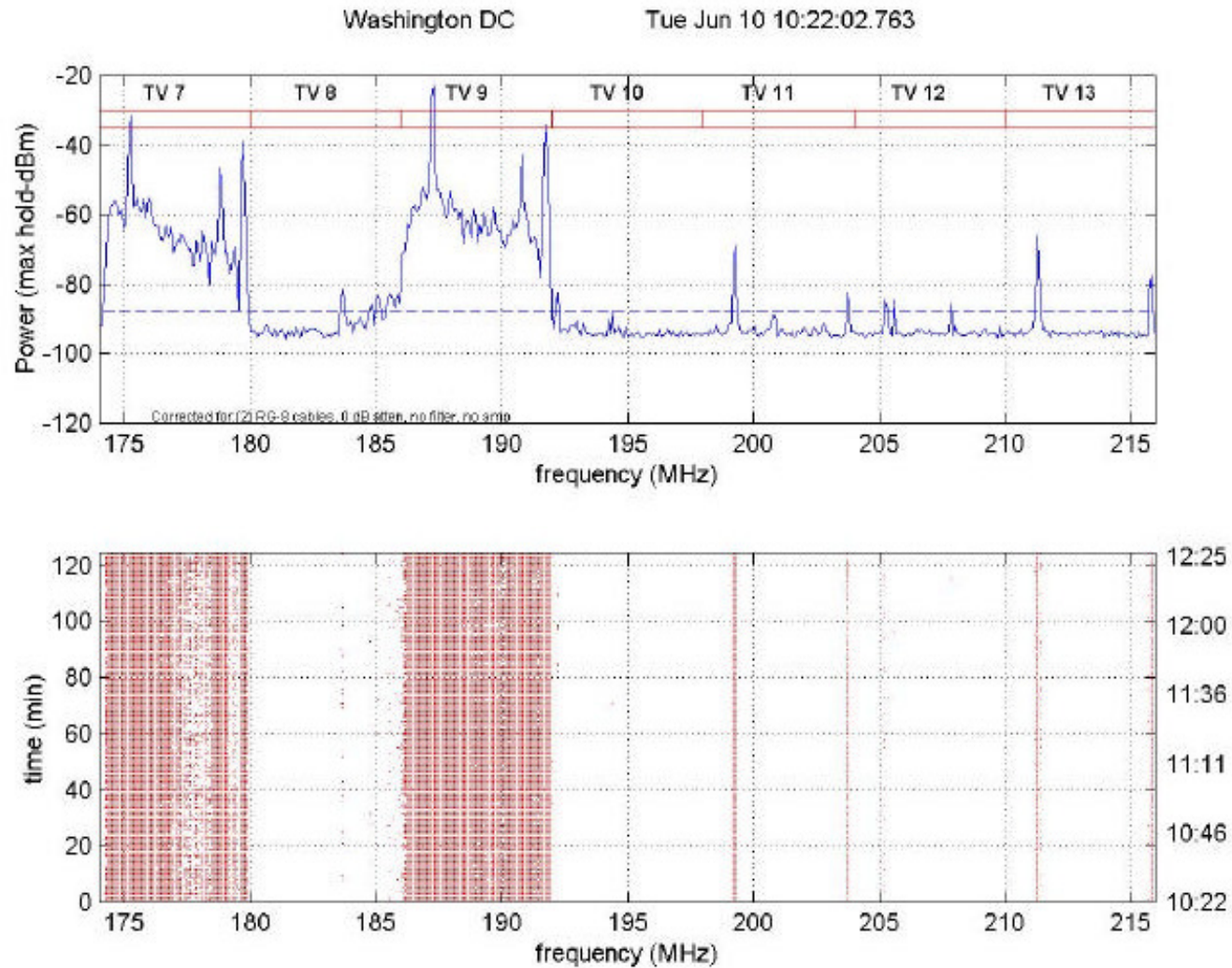
Market	Average MHz available	TV spectrum vacant (%)
New York	52	18
Los Angeles-San Diego	58	20
Philadelphia	61	21
Chicago	74	25
Washington, DC- Baltimore	80	27
Boston-Providence	89	30
Knoxville	93	32
San Antonio	107	36
Portland	112	38
Phoenix	114	39
Birmingham	118	40
Atlanta	120	41
Cincinnati-Dayton	123	42
St. Louis	132	45
Milwaukee	135	46
El Paso-Albuquerque	140	48
Jacksonville	145	49
Des Moines-Quad Cities	148	50
Little Rock	152	52
Alaska	159	54
Spokane-Billings	162	55
Omaha	165	56
Wichita	176	60

Source: Brattle Group from FCC data

# The Trouble with Auctions: Where did all the white space go?

- FCC's proposed 40 mW transmit power limit on adjacent channels suggests:
  - A transmit power that fits any existing commercial business model is considerably above even 100 mW
  - Above 100 mW (and certainly at 1 to 4 W), adjacent and co-channels would remain unused guard bands.
  - Lower VHF channels (2-6) unlikely at higher power due to cable TV pick-up interference (and not useful for mobile due to large antenna size).

# Washington D.C. has about 20 Channels for low-power, Unlicensed use



# DC/Baltimore: Adjacent & Co-Channels

-- Vacant DC Channels 8, 10, 11, 13 not available for licensed use

## Washington, DC- Adjacent and Co-Channel Protection

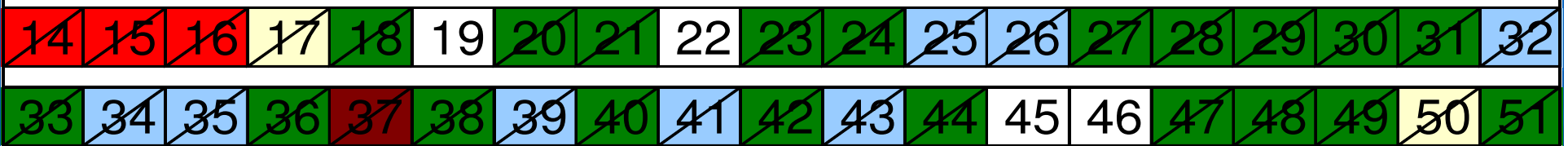
Channel	7	8	9	10	11	12	13	14
ID	WLA(ABC)	<del>Adjacent</del>	WUSA(CBS)	<del>Adjacent</del>	<del>Co-Channel</del>	Avilable	<del>Co-Channel</del>	WFDC(Whivision)

## Baltimore, MD- Adjacent and Co-Channel Protection

Channel	7	8	9	10	11	12	13	14
ID	<del>Co-Channel</del>	Avilable	<del>Co-Channel</del>	<del>Adjacent</del>	WBAL(NBC)	<del>Adjacent</del>	WZ(CBS)	<del>Co-Channel</del>

# Vacant Channels for Unlicensed Use: New York City (7) & Dallas (13)

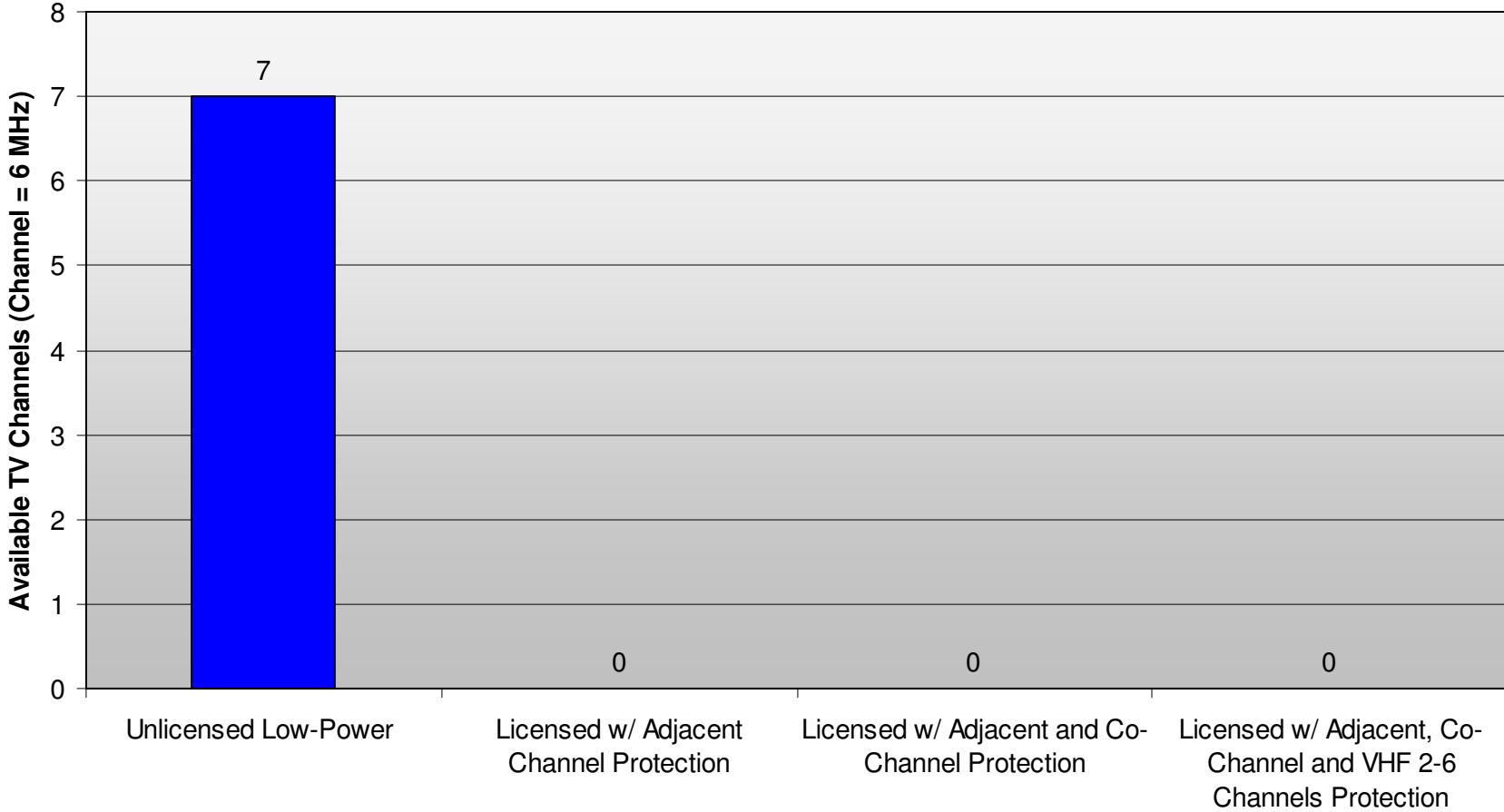
## New York Metro Area - Vacant DTV Channels (14 - 51)



## Dallas/Fort Worth Metro Area - Vacant DTV Channels (14 - 51)

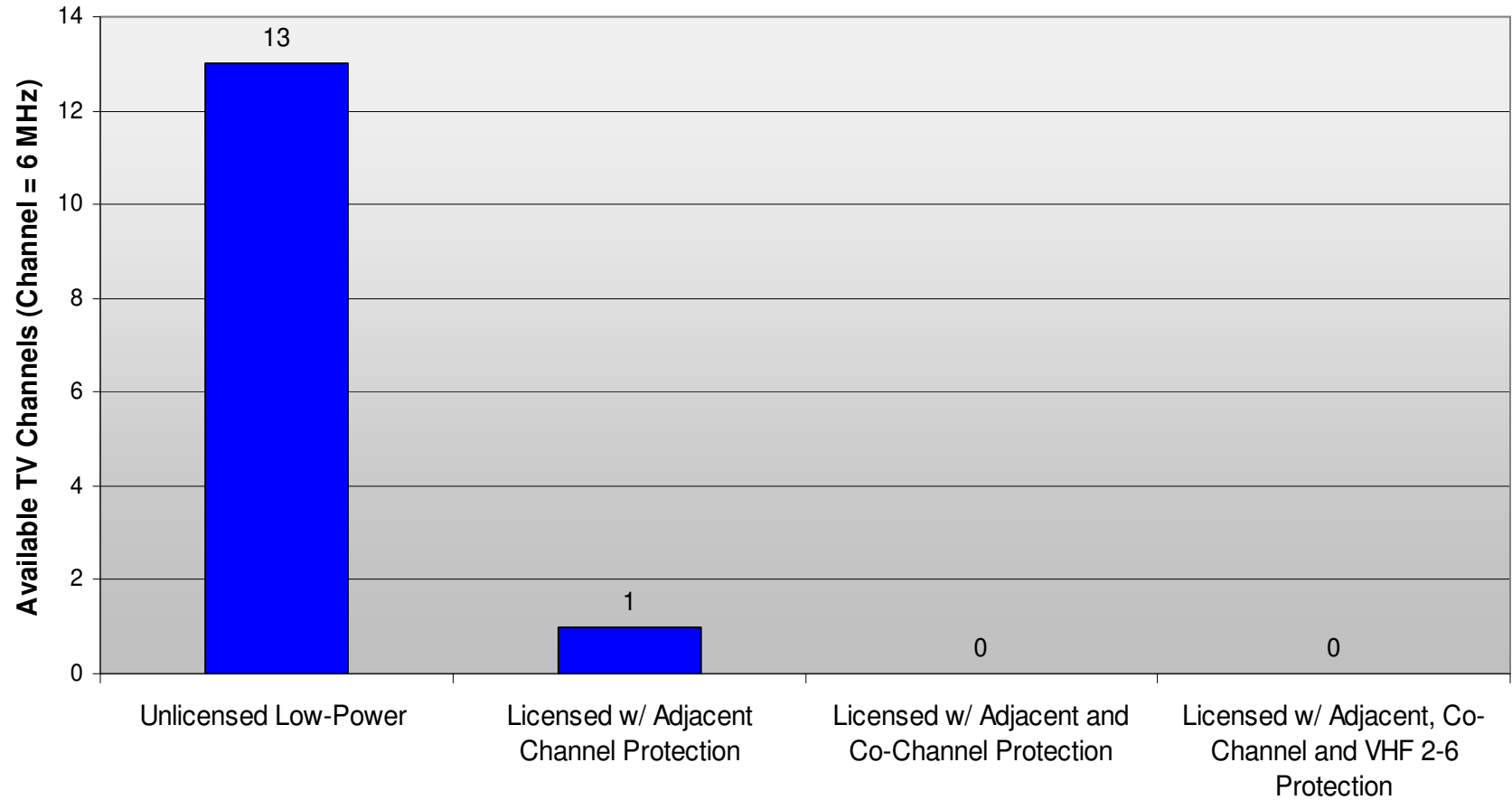


# New York - Metro Area



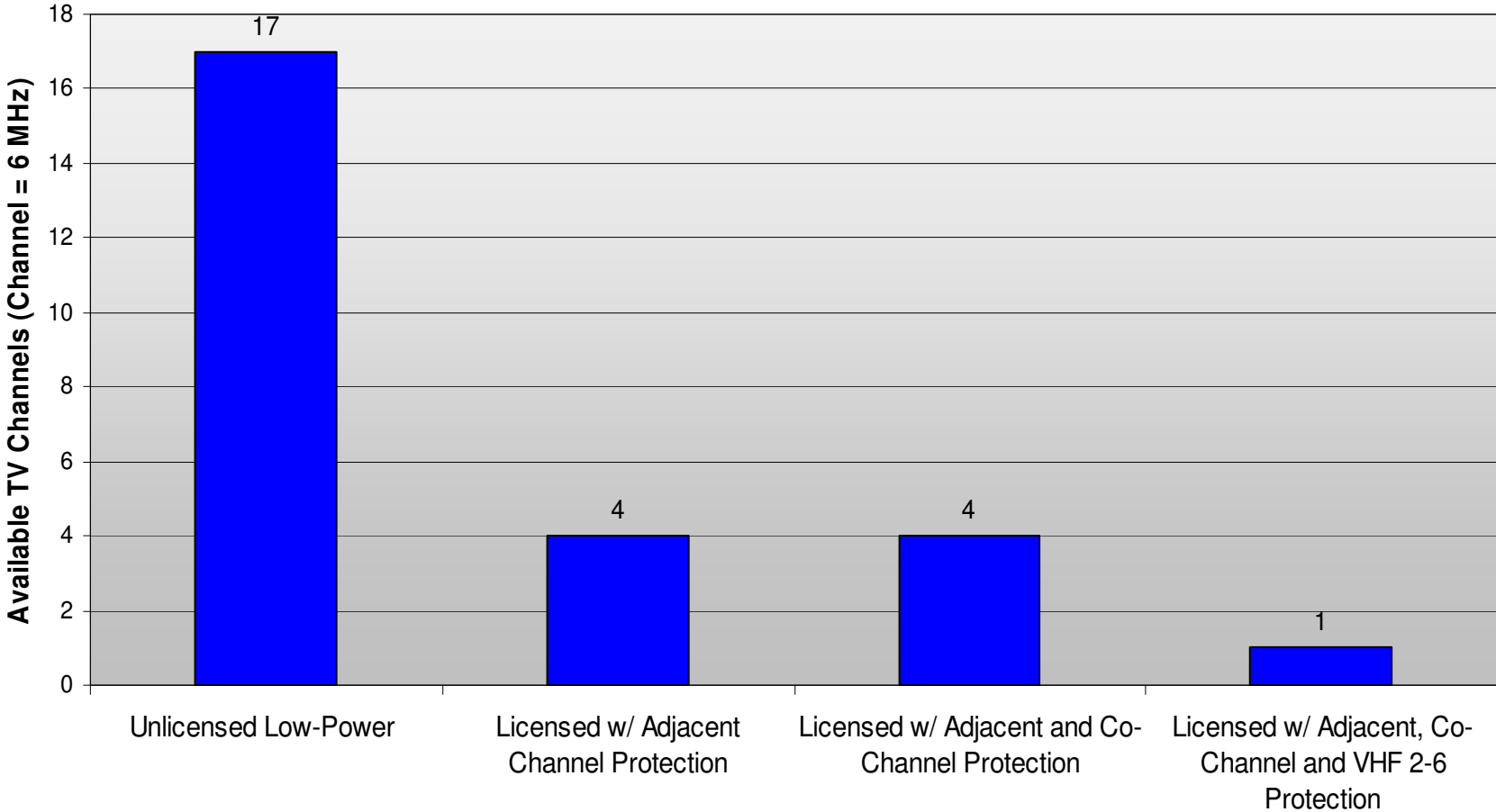
Unlicensed v. Licensed Protections

## Dallas - Fort Worth



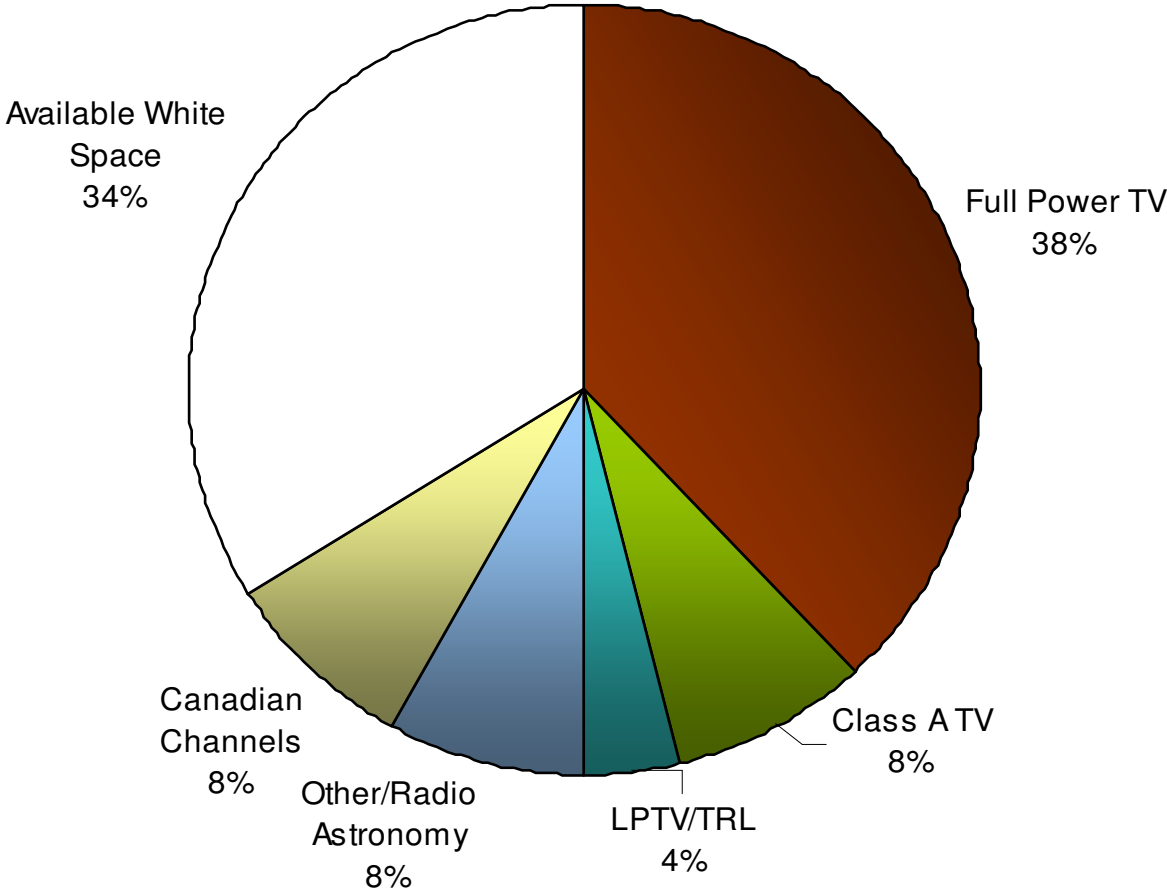
Unlicensed v. Licensed Protections

# Detroit Metro Area

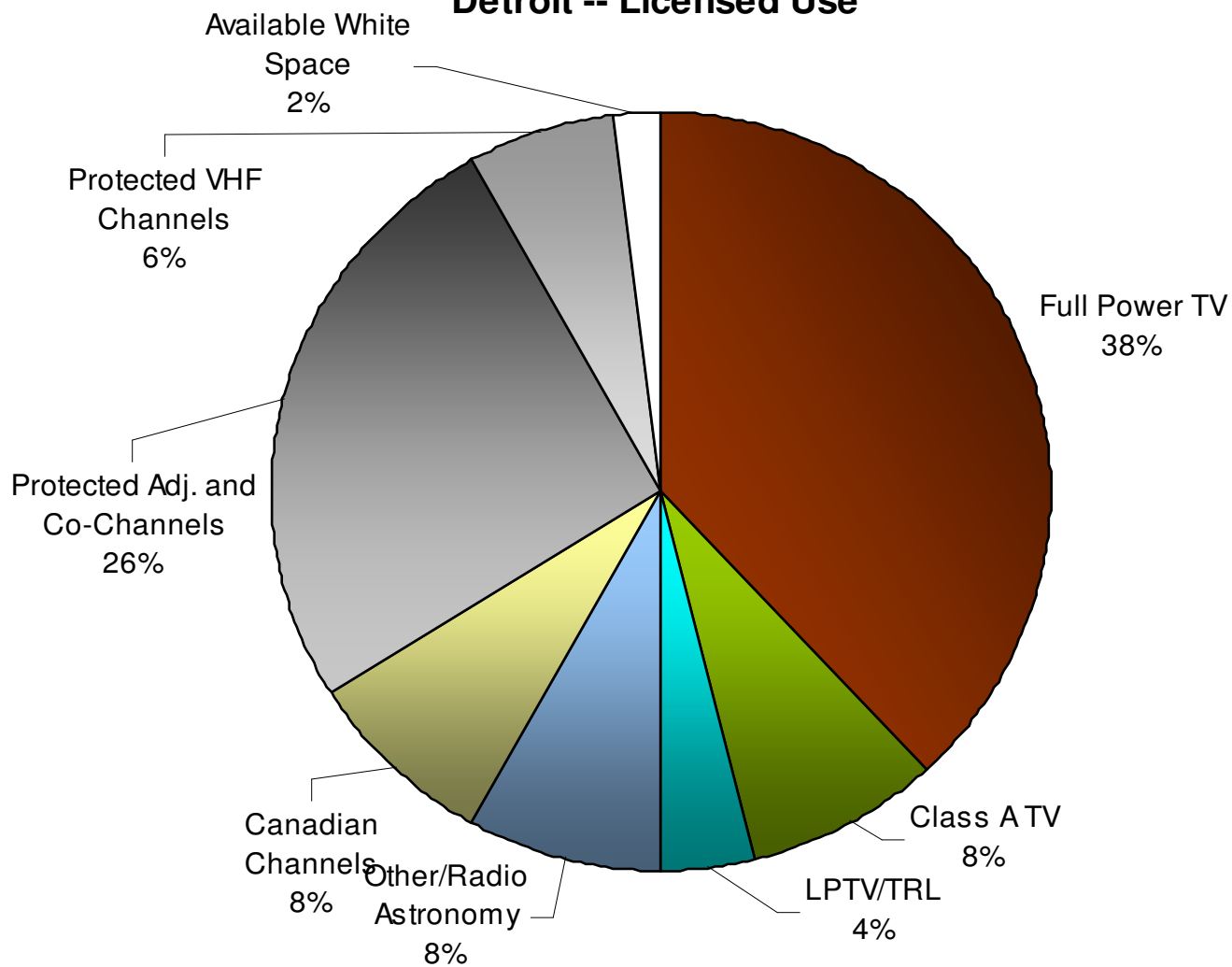


Unlicensed v. Licensed Protections

### Detroit -- Unlicensed Low-Power Use



### Detroit -- Licensed Use

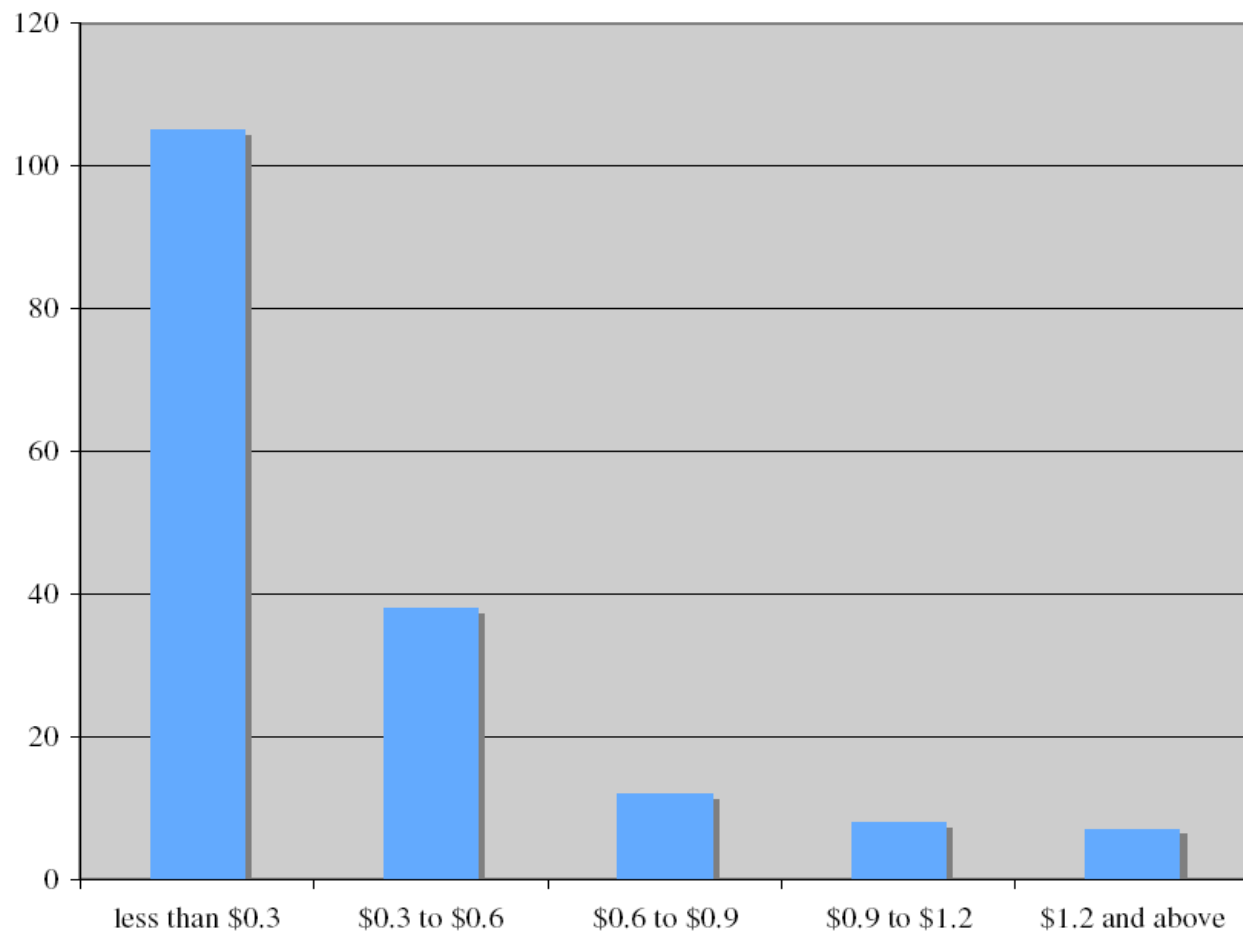


# **Myth: Auctioning White Space will generate \$10–20 billion?**

- **Little availability in most populated markets**
- **'Swiss cheese spectrum': Frequencies not consistently available across media markets.**
  - **Costly to aggregate and to use**
- **Frequencies not consistently available within metro markets**
- **White space spectrum is unpaired, narrow-channeled and still relatively low power where available**
  - **4 W vs. 2000 W for WiMax**
  - **4 W vs. 50,000 W for Qualcomm's MediaFlo**
- **Interference to and from 500,000 wireless microphones**
  - **Geolocate/database?**
  - **Beacons?**

# 700 MHz Auction: Not a Valid Comparable

**Figure 1. Frequency Histogram: No. of Licenses by \$/MHz/Pop, E Block, Auction 73**



## **Myth: Licensing reduces the risk of interference?**

- No reason to believe the power limits proposed by FCC – 4 Watts (non-adj) and 40 mW (adj) – would be relaxed for licensed devices.
- Suggestion that licensees can negotiate payments to stations to tolerate interference is unrealistic: broadcasters have a statutory obligation to provide coverage in return for free spectrum licenses.

# Cognitive Radio: Adjusts Transmit Power in Adjacent channels to Avoid Interference

LCD DTV Displays Error-free KTWU CH 23  
Desired Channel Content

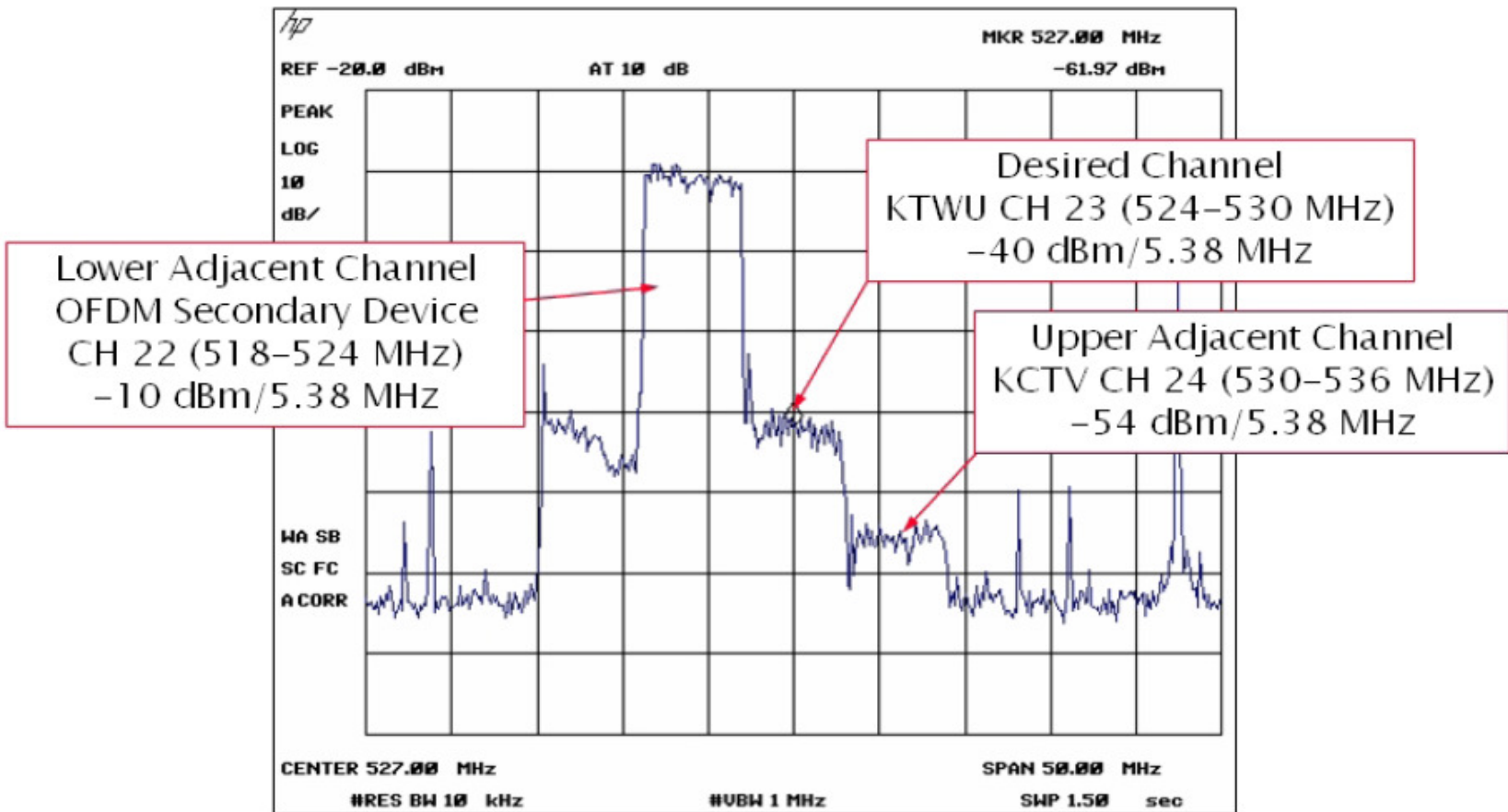


Figure 3 Example of Adjacent Channel Use with White Space Transmitter

# Rules of the Road: Like Public Highways and Ocean Shipping Lanes, Exclusive Licenses are Inefficient for Low-Power Use of the Airwaves

