# Spectrum White Space Measurements

Presentation to
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# Presentation Overview

- Purpose
- Experiment Description
- Typical Measurement Results
- White Space Estimates

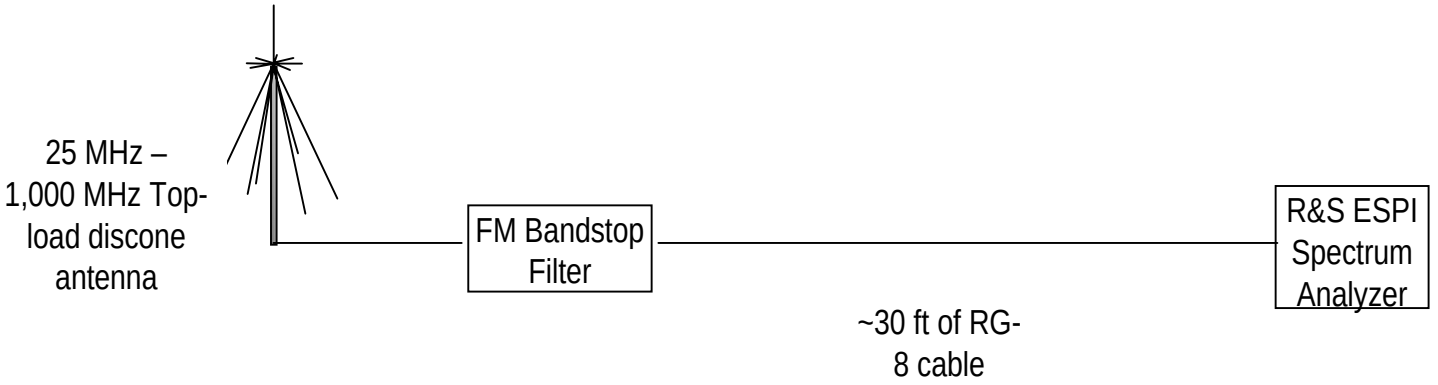
# Experiment Purpose

- Measure amount of under-utilized spectrum 30 MHz to 3,000 MHz
- “Worse case” location
  - Downtown Washington, DC
  - Both government and commercial spectrum use
- Several hour duration during high use periods

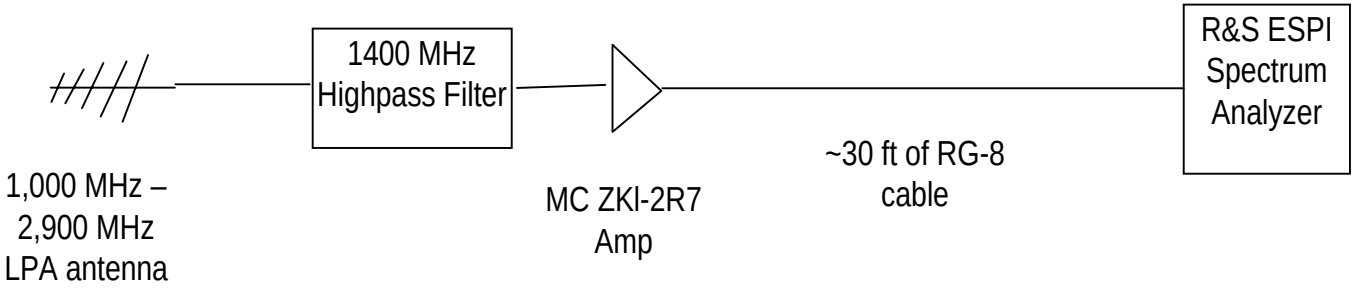
# Spectrum Measurement Equipment

- Elevated location – High detection probability
- High quality RF equipment – Rohde and Schwarz ESPI spectrum analyzer, shielded enclosure

# RF Equipment

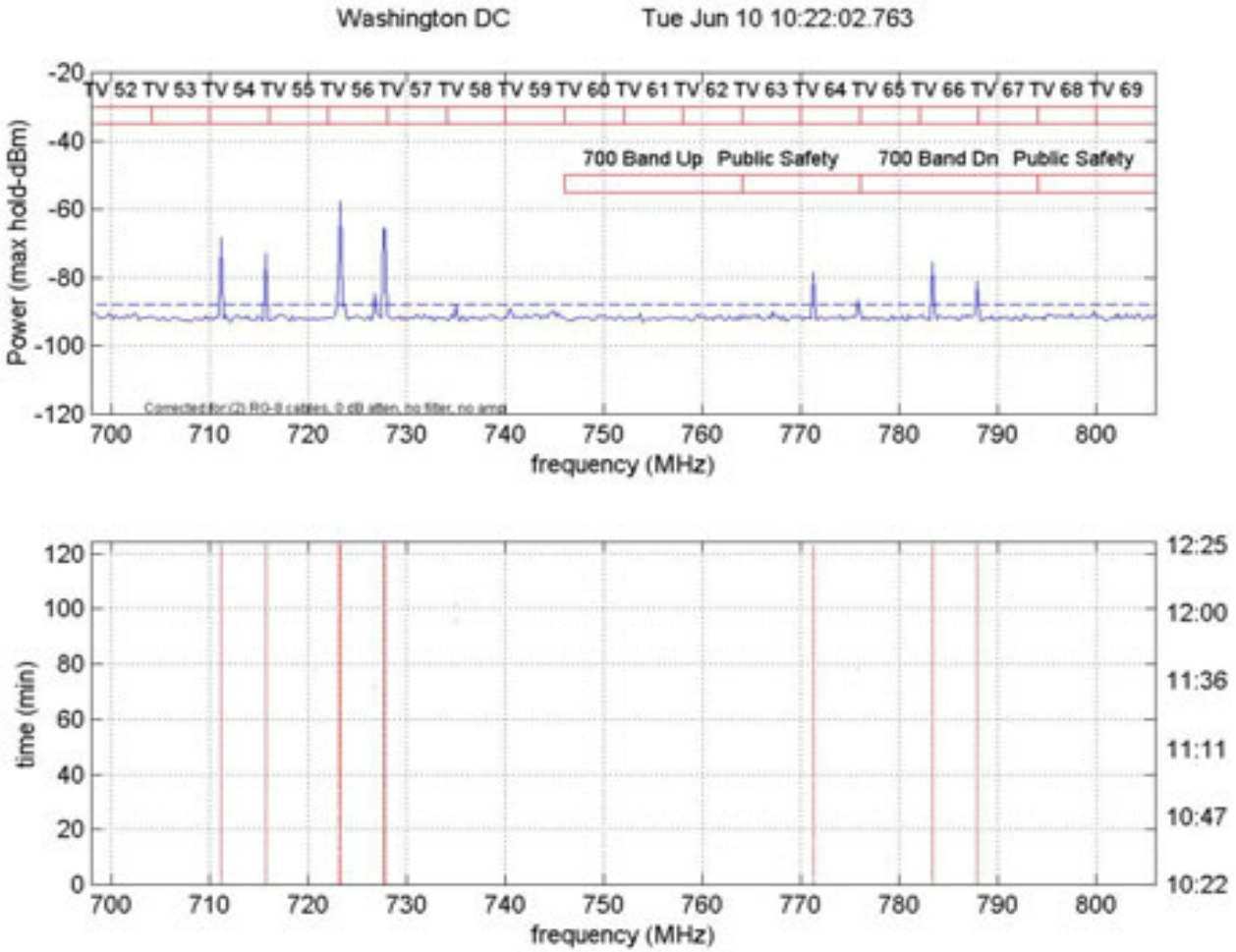



RF Signal Chain for Measurements Below 1,000 MHz

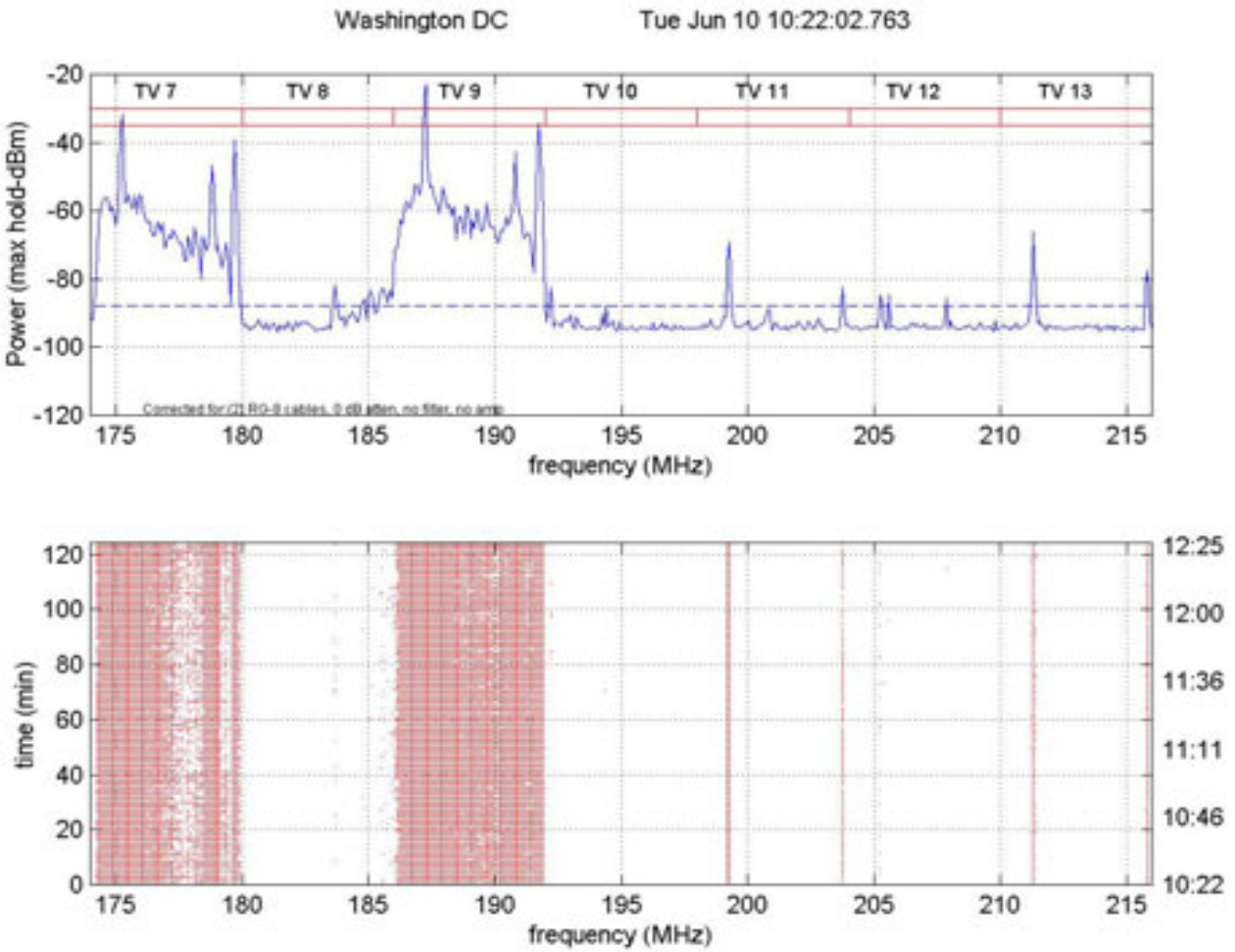



RF Signal Chain for Measurements Above 1,000 MHz

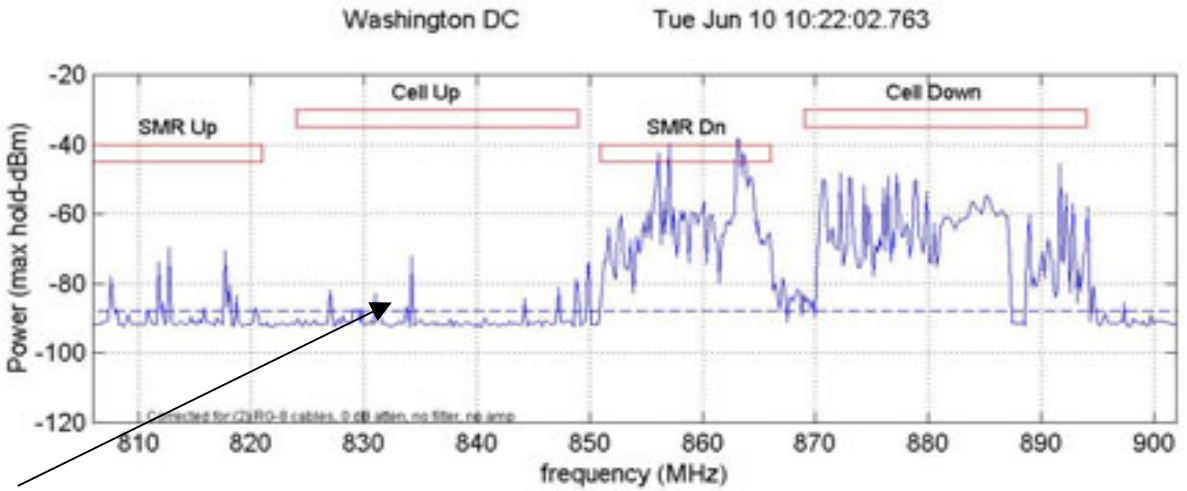
# Low Utilization Example



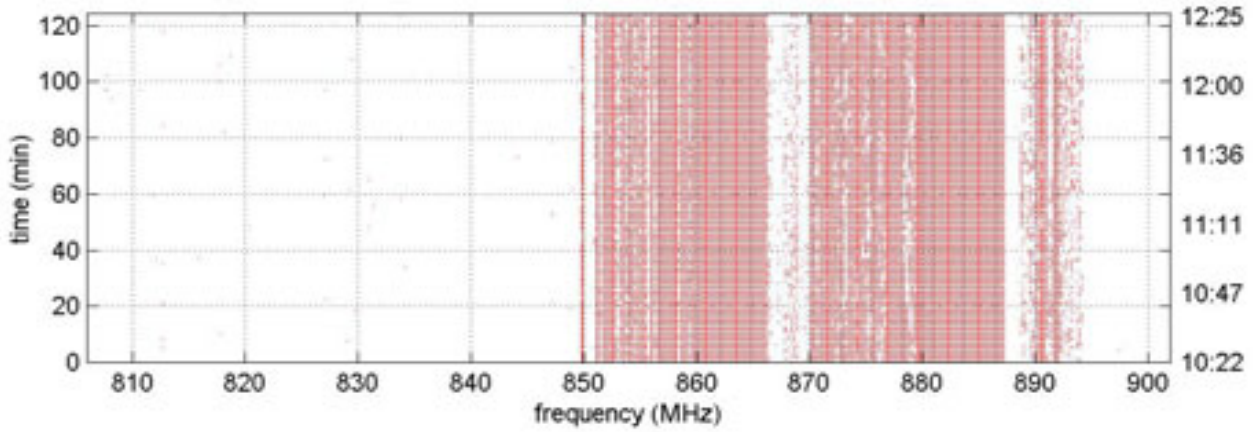
# Medium Utilization Example



# High Utilization Example




Hidden nodes

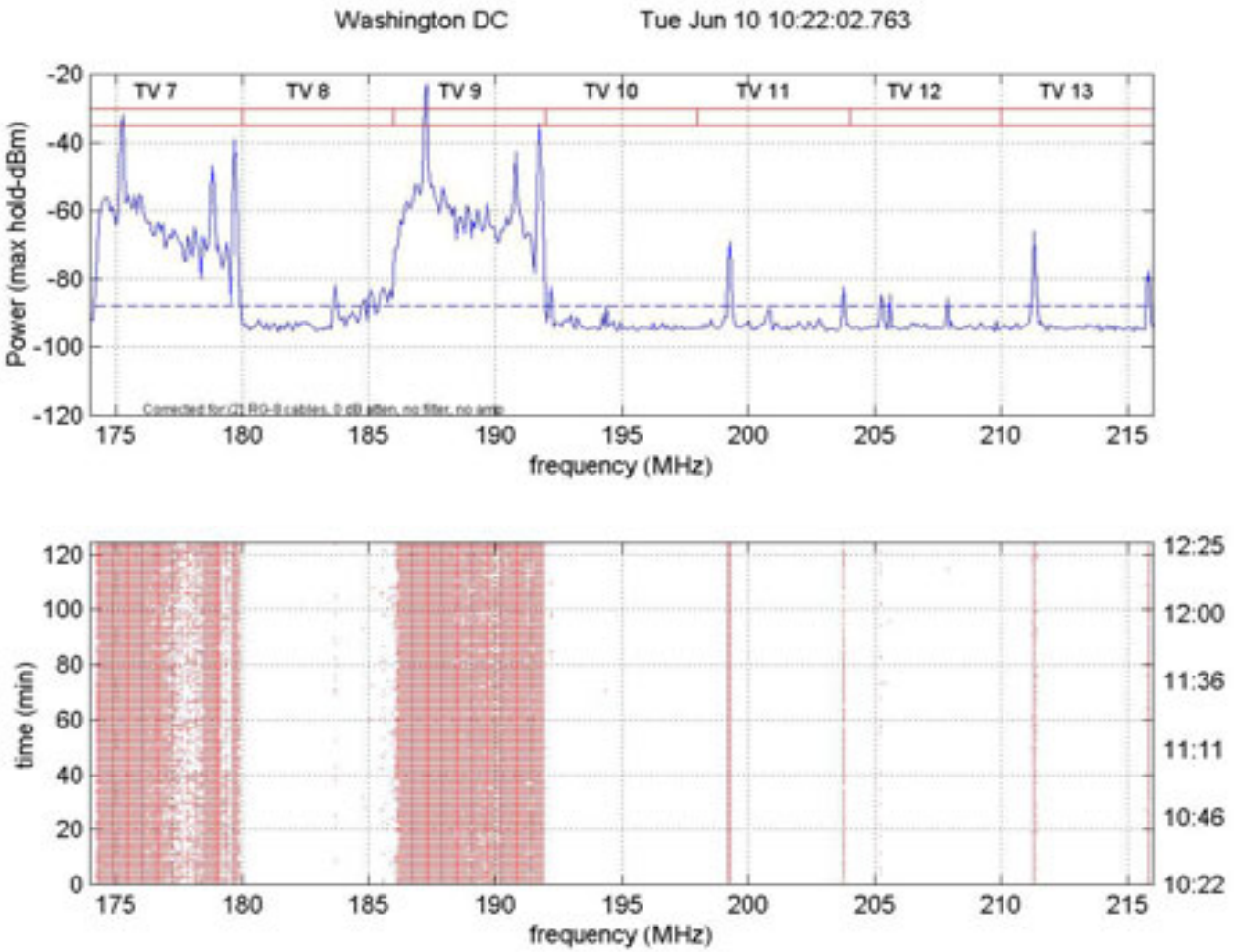


# Worst Case Occupancy Summary

| Start (MHz) | Stop (MHz) | BW (MHz) | Unused Spectrum (MHz) | Spectrum Occupancy (%) | Note |
|---|---|---|---|---|---|
| 30 | 54 | 24.0 | 8.6 | 64.0% | High noise level, PLM, Amateur, others |
| 54 | 88 | 34.0 | 23.8 | 29.9% | CH4, CH5 strong. CH2, 3 empty. CH6 also empty, but heavy inter-modulation distortion from FM from radio. |
| 88 | 108 | 20.0 | 0.3 | 98.4% | FM broadcast |
| 108 | 138 | 30.0 | 28.9 | 3.7% | Air traffic control, Aero Nav has low occupancy, Aero comms has high occupancy |
| 138 | 174 | 36.0 | 32.9 | 8.5% | Fixed Mobile, amateur, others – high occupancy |
| 174 | 216 | 42.0 | 31.1 | 26.1% | CH7, CH9 strong, CH 8, CH10, CH 11, CH 12, and CH 13 weak. |
| 216 | 225 | 9.0 | 8.9 | 1.3% | Two strong, continuous signals at 217.75 and 220.125 MHz, otherwise low occupancy |
| 225 | 406 | 181.0 | 180.6 | 0.2% | Few narrow bandwidth signals, randomly spaced in frequency. Low occupancy |
| 406 | 470 | 64.0 | 59.1 | 7.7% | Amateur, Radio Geolocation, Fixed, Mobile, Radiolocation |
| 470 | 512 | 42.0 | 32.3 | 23.2% | CH14, CH20 strong, CH17, CH19 weak, possible secondary usage of CH 17 and CH 18 by narrowband signals |
| 512 | 608 | 96.0 | 59.4 | 38.1% | CH21-CH36 - 3 digital TV channels, 2 TV analog channels, several unused channels. |
| 608 | 698 | 90.0 | 63.8 | 29.1% | CH37-CH51 - 4 digital TV channels, 1 TV analog channel, many unused channels. |
| 698 | 806 | 108.0 | 106.1 | 1.8% | CH52-CH69 – Several weak out of area TV stations, but otherwise empty |
| 806 | 902 | 96.0 | 61.5 | 36.0% | Cell phone and SMR - Densely used cell signals |
| 902 | 928 | 26.0 | 25.9 | 0.4% | Unlicensed – Low level signals |
| 928 | 960 | 32.0 | 29.8 | 6.8% | Paging – ~50% occupied, SMS high occupancy, Fixed, BX Aux, and FMS had low occupancy. |
| ALL | ALL | 930.0 | 752.9 | 19.0% | |

- Includes all white space including short intervals
- -88 dBm threshold, 192 time samples over 2 hours
- Neglects hidden nodes

# Medium Utilization Example



# Whitespace Estimate

**Appendix A: Estimated Whitespace During Peak Hours**

| 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. CH6 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 – 2360 | 60 | 35 | 25 | 58% | 42% | 2320-2345, DARS; |
| 2360 – 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% | ITFS/MMDS |
| 2690 – 2900 | 210 | 190 | 20 | 90% | 10% | Radar observed at 2840-2860 |
| Totals | 2430 | 1509.5 | 920.5 | 62% | 38% | |

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

# Whitespace

62%

Counted: Bands >=1MHz wide that remained unoccupied for 10 minutes or longer.

# It’s Still a Lot

Regardless of which number you believe, there is still a LOT of whitespace available!