Dupont Circle Spectrum Utilization During Peak Hours

A Collaborative Effort of
The New America Foundation and The Shared Spectrum Company

Introduction

On Tuesday, June 10, 2003, Mark McHenry from Shared Spectrum and Max Vilimpoc from New America measured the utilization of the radio frequency spectrum in the immediate vicinity of New America's offices (38°54'43.8"N, 77°02'43.2"W) over a period of several hours.

The location of the measurement site in an urban and highly pedestrian area just north of Dupont Circle offered an ideal vantage from which to measure spectrum utilization during peak business hours. Accordingly, the analysis was performed between the hours of 9AM to 5PM over a range of frequencies covering both civilian and military use.

The purpose of the measurements was to experimentally demonstrate that a large proportion of urban radio spectrum remains unused on a regular basis. The experimental results add additional weight to the policy proposals offered by both participants: that more license-exempt use of spectrum is possible through opportunistic sharing.[1]

Measurement Procedure and Results

Using a Rohde & Schwarz EPSI Spectrum Analyzer connected to a laptop for data gathering purposes, several hours of data were collected over a contiguous range of frequencies between 30MHz and 3GHz. The measurement equipment was placed in an electromagnetically shielded enclosure to ensure the cleanest possible spectrum readings. Two types of antennae, each with particular benefits for use at frequencies above and below 1GHz, were mounted above the highest point of the roof, feeding signals to the spectrum analyzer via several meters of RG-8 coaxial cable.[2]

After the measurement process was complete, the gathered data was analyzed and plotted using MATLAB, a numerical analysis software package. An example plot is included on the following page:

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[1] See: Comments of the New America Foundation, et al. and the Shared Spectrum Company, in FCC ET Docket No. 02-380, "In the Matter of Additional Spectrum for Unlicensed Devices Below 900MHz and in the 3GHz Band"

[2] For more information about the measurement procedure, please consult "Washington DC Spectrum Occupancy Measurements Made on June 10, 2003," available from the Shared Spectrum Company, http://www.sharedspectrum.com

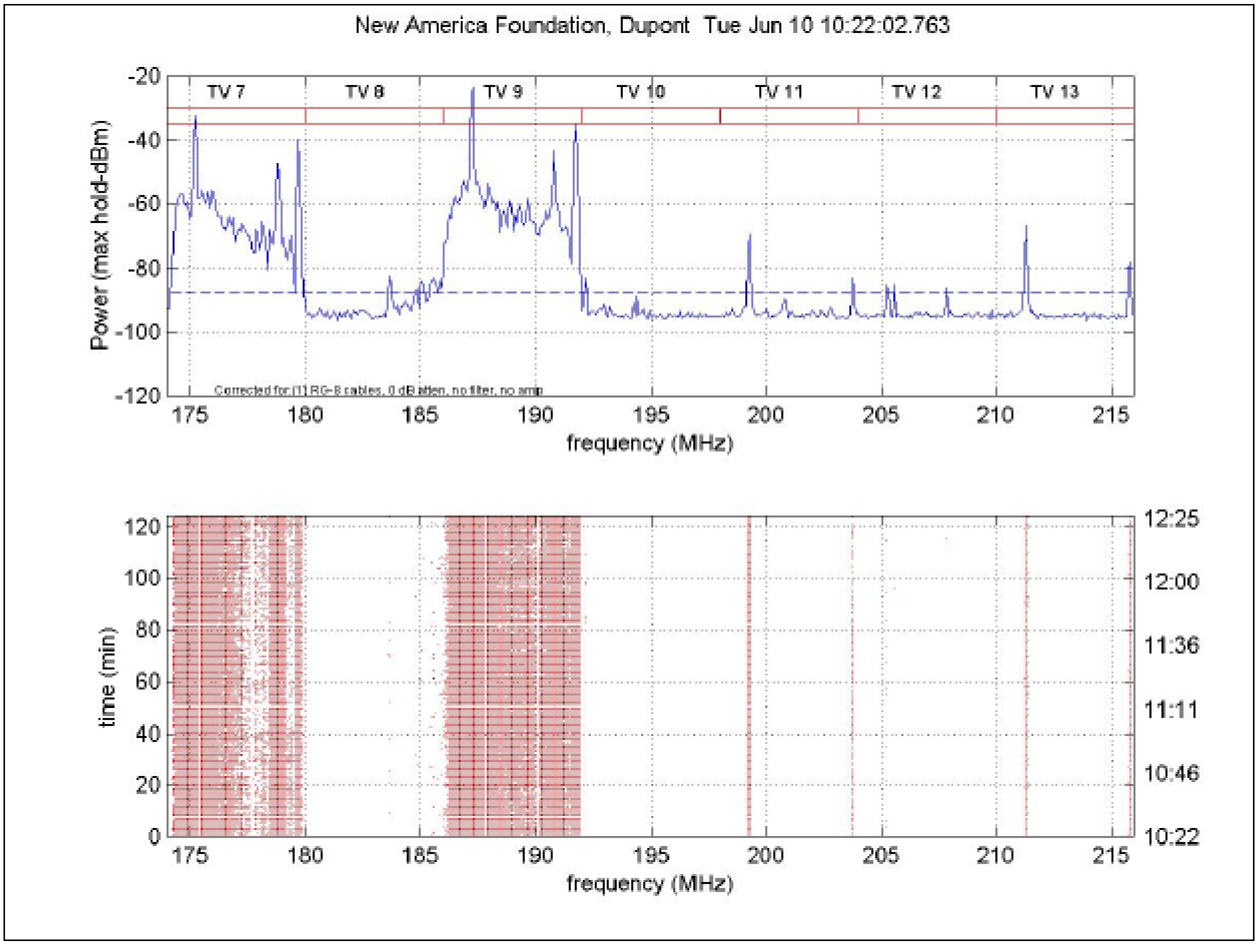

Figure 1: Whitespace Measurement Example

In Figure 1, the top plot shows the strongest signal received on a particular frequency during two hours of measurement in the band containing television channels 7-13. From this plot, we can see that two channels are in full-power operation, while the remaining 5 channels could be reused for other purposes. The bottom plot shows the regularity with which a signal is detected; each red pixel represents a moment in time during which the signal was present. We can see here again that the two channels were in continuous operation from 10:22AM, when the measurement started, until 12:25PM when the experiment was stopped on this band. Over the same period of time, little if any activity was detected in channels 8, 10, 11, 12, and 13.[3]

While the above graphic seems to indicate that finding empty spectrum is easy, making a determination about whether or not other frequency bands were unused required a set standard by which spectrum could be considered empty. For our study, a slice of spectrum is considered whitespace if it remains empty for a period of 10 minutes or more and is equal to or wider than 1 MHz. Additionally, we were careful to note which bands might have significant numbers of hidden users, by considering the types of services and power levels used in particular bands by

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[3] For the complete plot series of frequency bands from 30-960MHz and 1400-2900MHz, see “Washington DC Spectrum Occupancy Measurements Made on June 10, 2003,” available from the Shared Spectrum Company http://www.sharedspectrum.com

licensed users and excluding those with potentially substantial numbers of hidden users (i.e. cellular bands).

There are a number of situations in which spectrum may be used without our knowing. For instance, even if a signal is too weak to measure by our antenna, it may still be usable by its intended recipient. Satellite transmissions fit into this category. Another problem is the potential presence of transmitters or receivers operating at such low signal strength that they are effectively invisible to our measurement. These ‘hidden-nodes’ present two problems: first, by not recognizing their presence, they may experience interference if they receive transmissions not intended for them or if they have greater difficulty interpreting the signals intended for them; second, the potential exists to overload high-gain systems that listen for extremely faint signals.

Two examples of the second problem are the cellular telephone bands at 806-894MHz and the PCS bands at 1850-1990MHz. Our measurement equipment could detect basestation-to-handset spectrum usage because such transmissions occur at higher power. However, we could not directly observe the responses of the handsets because their transmissions occur at much lower power. If the handset-to-basestation spectrum was improperly categorized as whitespace, and opportunistic transmissions permitted, a license-exempt user might end up knocking out the cellular service, which is not acceptable. This is the essence of the ‘hidden-node’ problem, in which a spectrum user may go undetected, even if it is legitimately operating within its licensed parameters. In both cases, we inferred that the frequency use on the handset transmission channels mirrored the occupancy of the basestation transmission channels, since users could be expected to talk as much as to listen.

Following the above standards and careful considerations, our tally of spectrum utilization indicated that *roughly two-thirds of the spectrum is immediately available for shared, license-exempt use*. (See: Appendix A.)

Potential Estimation Errors

Our estimates should not be considered the final word in whitespace calculations. Many variables, such as duty cycle, time of day, location, permitted power levels and others must be examined before a slice of spectrum may be considered used or unused. Because of this variability, it is possible that we actually *underestimate* the amount of whitespace available. By performing our measurements in a population-dense urban area, what we recorded was the worst-case scenario. If our measurements were taken in the middle of a predominantly rural state like West Virginia, the amount of whitespace available would be significantly larger. Power levels would also factor in if a broadcaster were not transmitting at the allowed maximum, which would skew the estimate in favor of additional whitespace since the actual signal coverage area would be a fraction of the theoretical area. Time of day is another factor in spectrum usage, where certain frequencies are only used during the evening newscast, for instance. Looking further along the digital TV transition, once the conversion has been completed, broadcast incumbents are mandated to return the extra channels gained from the Telecommunications Act of 1996. The spectrum landscape that we see now continues to change on both a short and long timescale; therefore, our estimates must adjust accordingly.

It is also possible that we *overestimate* the amount of whitespace available, by counting bands in which legitimate users operate below our threshold of detection. However, bands that exhibit no sign of activity whatsoever for over two hours might just as likely be empty. Even with 50% confidence in this assumption (i.e. an equal chance of the band being filled as being empty), there were simply so many large swathes of spectrum with an appearance of vacancy that the net summation of whitespace would remain sizeable. It is our belief that much of the spectrum that appears to be empty truly *is* empty, and that numerous frequencies "allocated" on paper might actually remain unused in the real world.

Policy Implications

By physically measuring the amount of spectrum that lays fallow, we believe that the evidence gathered in this field study adds greater legitimacy to the call for spectrum allocation reform.

The fact that wide swaths of spectrum lay empty for significant amounts of time is a compelling reason for a much-needed examination and reconsideration of spectrum allocation policy. While the Spectrum Policy Task Force has argued for the allocation of more dedicated unlicensed spectrum, there is reason to believe that the system of rigid allocations is fundamentally broken and inefficient. Allocations that artificially divide up the spectrum, similar to those used for breaking up tangible, exclusive property, create artificial scarcity, ultimately limiting the gain in spectral efficiency achieved via advances in computation, coding, and frequency reuse.

Whereas current policies grant license holders an easement to utilize a portion of public spectrum as much or, more often, as *little* as they choose, forward-looking policies should encourage *more* spectrum utilization by allowing greater sharing and additional non-exclusive access to spectrum.

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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. 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 estimated whitespace are available upon request.