Spectrum Occupancy Measurements
Location 4 of 6:
Republican National Convention, New York City, New York
August 30, 2004 - September 3, 2004
Revision 2

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National Radio Research Testbed (NRRNT)
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1. Introduction

1.1 Summary

Under the National Science Foundation National Radio Network Research Testbed (NRNRT) program, Shared Spectrum Company made extensive spectrum occupancy measurements from August 30 to September 3, 2004 in one of the most densely populated areas in the United States – New York City. The measurements were made there during the Republican National Convention, a period of unusually high spectrum use due to intense media participation and extraordinary post-911 security measures, causing heavy communications use.

The measurements obtained in this study cover a range from 30 MHz to 3000 MHz. Measurements taken within the Public Safety bands\(^1\) are of special interest, as these data were collected with higher resolution when compared to the other bands studied. Measurements were taken from the rooftop of a Stevens Institute of Technology building in Hoboken, New Jersey, which provided excellent line-of-sight coverage across the New York City skyline.

1.2 Report Organization

The report is organized into eight sections, as follows:
- Section 0 Introduction
- Section 2 Description of measurement equipment
- Section 3 Measurement site and surrounding environment
- Section 4 Frequency Collection Lists
- Section 5 Plots for long duration spectrum measurements
- Section 6 Plots for small frequency resolution measurements
- Section 7 Plots for large signal data measurements
- Section 8 Plots for short duration spectrum measurements
- Section 9 Conclusions

1.3 Measurement Goals

The need to assure access to radio spectrum is at a crossroads. More and more technological alternatives are becoming available and demand from both public and private sectors is increasing very rapidly, if not exponentially. Increasingly, there is recognition that the root of the problem is that most of the spectrum is actually unused, and the present system of spectral regulation is grossly inefficient. Current spectral regulation is based upon the premise that slices of the spectrum, representing uses within specified upper and lower frequency bounds, must be treated as exclusive domains of single entities – who are the recipients of exclusive licenses to use specific frequency bands.

A primary goal of the New York City study was to identify spectrum bands with low occupancy. Occupancy was quantified as the amount of spectrum detected above a certain received power threshold level.

\(^1\) Public Safety Bands are assigned within the 138 MHz to 174 MHz and 406 MHz to 470 MHz range.
Two data sets were collected, each having different frequency resolutions. The first set had a large frequency resolution of greater than 100 kHz, and covered all of the spectrum bands of interest. Spectrum occupancy statistics from this measurement set provided an upper bound on the actual occupancy levels. This is because the transmitter bandwidth in most bands was much smaller than the measurement frequency resolution. The second measurement set had a small frequency resolution of 10 kHz, and covered a subset of the spectrum bands of interest. Spectrum occupancy statistics from this measurement set provided a more accurate upper bound on the actual occupancy levels, because the transmitter bandwidth in most bands was larger than the measurement frequency resolution.

A secondary goal of the study was to collect data for future analysis of the spectrum and temporal gap widths, the number of transmitters, the transmitter’s mobility, the transmitter’s duty cycle, and the transmitter’s bandwidths. Shared Spectrum Company believes that many of these parameters can be partially inferred from these data. To that end, we are making the raw measured data set obtained from the SSC study available to NSF for future analysis.

1.4 The National Radio Networking Research Testbed (NRNRT)

Measurements contained in this report are part of the National Radio Network Research Testbed (NRNRT) project. The NRNRT is a National Science Foundation (NSF) project that supports research and development of new radio devices, services, and architectures, providing a valuable facility for use by the research and development community in testing and evaluating their systems.

The NRNRT consists of:
(1) a field measurement and evaluation system for long-term radio frequency data collection, and an experimental facility for testing and evaluation of new radios;
(2) an accurate emulation/simulation system that incorporates long-term field measurement, for use in evaluating new wireless network architectures, policies, and network protocols; and
(3) innovative experimentation with wireless networks that integrate analysis, emulation/simulation, and field measurements.

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2 Electronic copies of the data provided in this report may be requested from NRNRT by contacting Professor Gary Minden, University of Kansas, Information and Telecommunication Technology Center, Center for Research, Inc., (email: gminden@ittc.ku.edu; tel: 785-864-4834), or Dr. Mark McHenry, Shared Spectrum Company, (email: mmchenry@sharedspectrum.com; tel: 703-761-2818 x-103)
2. Measurement Equipment

2.1 Equipment Description

The equipment used for measurement in this study consisted of a spectrum analyzer, pre-selector, omni-directional discone antenna, a small log periodic array (LPA) for frequencies greater than 1000 MHz, and a laptop computer. A 20-foot RG8 cable was used to connect the Pre-selector box, which is then connected to both of the antennas. Power was provided to the equipment using an extension cord plugged into a 120 volt AC outlet.

The antennas, cables, filters, fixed attenuators, and pre-amplifiers were varied in each measurement location to optimize the dynamic range of the measurements.

The discone was used for measuring signals below 1 GHz and LPA for measuring signals above 1GHz. The LPA antenna was tilted at 45 degrees to the horizontal.

The equipment configuration used in this effort is further depicted in Figure 1, Figure 2 and Figure 3, below.

![Figure 1: Spectrum Measurement Equipment Configuration](image-url)
Figure 2: Antennas, Pre-selector Box, and Connections

Figure 3: RF Shielded Box Used to Reduce Emissions from Laptop and Spectrum Analyzer
Before each official measurement was taken at the site, test data was collected within the frequencies designated for this experiment. The test data was examined to ensure that all equipment was operating properly, as well as to identify strong signals that could potentially overload the pre-amplifier or the spectrum analyzer. The equipment was then reconfigured based on the test data.

After the equipment configuration was finalized, long duration collections were made using the designated frequency lists described later in this report. Separate files were created for each collection on a frequency list. The file size was dependent upon the number of frequency bands.

Official measurements began on August 31, 2004. Day 1 of the study took place over a 24-hour data-collection period from August 31 through September 1. Day 2 took place over a second 24-hour collection period from September 1 through September 3.
2.2 Pre-Selector Description

The Pre-selector configuration is illustrated in the block diagram shown in Figure 4 below.

As illustrated in Figure 4, there are four ports of logic lines that control the Pre-selector. Port A (bits 0 and 1) controls the amplifier regulators and the band select filter that switches between the < 1 GHz and >1 GHz antennas. Port B (bits 0, 1, 2, and 3) control the digital attenuators for both band.
2.3 Equipment Settings

Table 1 shows the equipment settings used for all bands.

### Table 1 Equipment Settings for Each Spectrum Band

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<tr>
<th>Start Freq (MHz)</th>
<th>Stop Freq (MHz)</th>
<th>BS</th>
<th>Atten</th>
<th>Filter A</th>
<th>RBW (kHz)</th>
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<td>10</td>
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<td>-20</td>
<td>ESPI</td>
</tr>
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</table>
2.4 Data Calibration

The plotted spectrum data is calibrated to the power level at the antenna input using the following procedure:

- The recorded power levels measured by the spectrum analyzer are provided in dBm relative to the analyzer input.
- The difference between the power level at the analyzer input and the power level at the antenna input is due to the losses and gain of the RF cables, filters, and amplifiers associated with the Pre-selector.
- To correct for this difference, the Pre-selector loss was measured using a network analyzer in each spectrum band at the conclusion of the measurements.
- The Pre-selector loss versus frequency data values (in dB) were then added to the measured values (via an interpolation process) when plotting the spectrum data in this report.

Thus, the plotted power level values are the absolute value in dBm at the antenna input.
3. Measurement Site

3.1 Location

The measurements were made on the roof of the Stevens Institute of Technology building in Hoboken, New Jersey next to New York City. A map showing the measurement location is shown in Figure 5.

![Map of Hoboken, New Jersey showing the location of the Stevens Institute of Technology](attachment:image.png)

Figure 5: Location of the Measurement Site
3.2 Views from Measurement Site

As evidenced in the photographs below, the measurement location had good line of sight in nearly all directions. Figure 6, Figure 7, Figure 8 and Figure 9 below show the view looking out from the measurement antenna location in different directions.

![Figure 6: View Towards the North](image-url)
Figure 7: View Towards the East

Figure 8: View Towards the South
Figure 9: View Towards the West
4. Frequency Collection Lists and Data Files

4.1 Frequency Lists

Four frequency lists were used as detailed in the tables below:

- List A – Public Safety Bands, as shown in Table 2,
- List B – Other Band Usage, as shown in Table 3,
- List C – High Resolution Frequency Sweep, as shown in Table 4, and
- List D – Strong Signal Bands, as shown in Table 5.

Table 2: Frequency List A – Public Safety Bands

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<th>Start Freq (MHz)</th>
<th>Stop Freq (MHz)</th>
<th>Ref Level (dBm)</th>
<th>Band Width (MHz)</th>
<th>Frequency Bin Size (kHz)</th>
<th>dB/div</th>
<th>Res_BW (Hz)</th>
<th>Vid_BW (Hz)</th>
<th>Attenuation (dB)</th>
<th>Pre-Selector</th>
<th>Sweep Time (sec)</th>
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Table 3: Frequency List B – Other Band Usage

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### Spectrum Occupancy Measurements
Republican National Convention, New York City, NY

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**Table 4: Frequency List C – High Resolution Frequency Sweep**

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### Spectrum Occupancy Measurements

**Republican National Convention, New York City, NY**

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<td>355</td>
<td>360</td>
<td>5</td>
<td>10</td>
<td>3000</td>
<td>3000</td>
</tr>
<tr>
<td>340 345</td>
<td>360</td>
<td>365</td>
<td>5</td>
<td>10</td>
<td>3000</td>
<td>3000</td>
</tr>
<tr>
<td>345 350</td>
<td>365</td>
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<td>5</td>
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<td>350 355</td>
<td>370</td>
<td>375</td>
<td>5</td>
<td>10</td>
<td>3000</td>
<td>3000</td>
</tr>
<tr>
<td>355 360</td>
<td>375</td>
<td>380</td>
<td>5</td>
<td>10</td>
<td>3000</td>
<td>3000</td>
</tr>
<tr>
<td>360 365</td>
<td>380</td>
<td>385</td>
<td>5</td>
<td>10</td>
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<td>3000</td>
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<td>365 370</td>
<td>385</td>
<td>390</td>
<td>5</td>
<td>10</td>
<td>3000</td>
<td>3000</td>
</tr>
<tr>
<td>370 375</td>
<td>390</td>
<td>395</td>
<td>5</td>
<td>10</td>
<td>3000</td>
<td>3000</td>
</tr>
<tr>
<td>375 380</td>
<td>395</td>
<td>400</td>
<td>5</td>
<td>10</td>
<td>3000</td>
<td>3000</td>
</tr>
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<td>380 385</td>
<td>400</td>
<td>405</td>
<td>5</td>
<td>10</td>
<td>3000</td>
<td>3000</td>
</tr>
<tr>
<td>Public Safety</td>
<td>405</td>
<td>410</td>
<td>5</td>
<td>10</td>
<td>3000</td>
<td>3000</td>
</tr>
<tr>
<td>Public Safety</td>
<td>410</td>
<td>415</td>
<td>5</td>
<td>10</td>
<td>3000</td>
<td>3000</td>
</tr>
<tr>
<td>Public Safety</td>
<td>415</td>
<td>420</td>
<td>5</td>
<td>10</td>
<td>3000</td>
<td>3000</td>
</tr>
<tr>
<td>Public Safety</td>
<td>420</td>
<td>425</td>
<td>5</td>
<td>10</td>
<td>3000</td>
<td>3000</td>
</tr>
<tr>
<td>Public Safety</td>
<td>425</td>
<td>430</td>
<td>5</td>
<td>10</td>
<td>3000</td>
<td>3000</td>
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<tr>
<td>Public Safety</td>
<td>430</td>
<td>435</td>
<td>5</td>
<td>10</td>
<td>3000</td>
<td>3000</td>
</tr>
<tr>
<td>Public Safety</td>
<td>435</td>
<td>440</td>
<td>5</td>
<td>10</td>
<td>3000</td>
<td>3000</td>
</tr>
<tr>
<td>Public Safety</td>
<td>440</td>
<td>445</td>
<td>5</td>
<td>10</td>
<td>3000</td>
<td>3000</td>
</tr>
<tr>
<td>Public Safety</td>
<td>445</td>
<td>450</td>
<td>5</td>
<td>10</td>
<td>3000</td>
<td>3000</td>
</tr>
<tr>
<td>Public Safety</td>
<td>450</td>
<td>455</td>
<td>5</td>
<td>10</td>
<td>3000</td>
<td>3000</td>
</tr>
<tr>
<td>Public Safety</td>
<td>455</td>
<td>460</td>
<td>5</td>
<td>10</td>
<td>3000</td>
<td>3000</td>
</tr>
<tr>
<td>Public Safety</td>
<td>460</td>
<td>465</td>
<td>5</td>
<td>10</td>
<td>3000</td>
<td>3000</td>
</tr>
<tr>
<td>Public Safety</td>
<td>465</td>
<td>470</td>
<td>5</td>
<td>10</td>
<td>3000</td>
<td>3000</td>
</tr>
<tr>
<td>Public Safety</td>
<td>470</td>
<td>475</td>
<td>5</td>
<td>10</td>
<td>3000</td>
<td>3000</td>
</tr>
<tr>
<td>TV Ch 19 and Ch 20</td>
<td>500</td>
<td>505</td>
<td>5</td>
<td>10</td>
<td>3000</td>
<td>3000</td>
</tr>
<tr>
<td>TV Ch 19 and Ch 20</td>
<td>505</td>
<td>510</td>
<td>5</td>
<td>10</td>
<td>3000</td>
<td>3000</td>
</tr>
<tr>
<td>TV Ch 19 and Ch 20</td>
<td>510</td>
<td>515</td>
<td>5</td>
<td>10</td>
<td>3000</td>
<td>3000</td>
</tr>
</tbody>
</table>
4.2 Mode of Operation

Collection of measurements took place over a several day long period, and alternated between collection Frequency List A (Public Safety) and collection Frequency List B (Other Bands) as shown in Table 6 below. This mode of operation provided improved resolution for the Public Safety frequency bands, as compared to the other frequency bands utilized in this study.

For each band, two measurement plots are provided. Data for the first plot was collected during a 22-hour period from 4:30 pm on August 31, 2004 to 2:30 pm on September 1, 2004. Data for the second plot was collected during a 36-hour period from 8:30 pm September 1, 2004 to 2:18 am September 3, 2004.

Both measurement periods occurred during the Republican National Convention. It is also notable that the Presidential Address given by George W. Bush occurred during the second collection period at approximately 10:00 pm, September 2, 2004.
Table 6: Long Duration Measurement Plan

<table>
<thead>
<tr>
<th>Frequency List</th>
<th>List Measurement Time (sec)</th>
<th>Repetitions</th>
<th>Duration (sec)</th>
<th>Experiment Duration (hours)</th>
<th>Experiment Duration (sec)</th>
<th>Number of Measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>5</td>
<td>40</td>
<td>200</td>
<td></td>
<td></td>
<td>5760</td>
</tr>
<tr>
<td>B</td>
<td>100</td>
<td>1</td>
<td>100</td>
<td></td>
<td></td>
<td>144</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>300</td>
<td>12</td>
<td>43200</td>
<td>144</td>
</tr>
</tbody>
</table>

A second experiment was performed to improve the frequency resolution of selected bands using List C. This experiment is summarized in Table 7.

Table 7: Experiment Performed with Frequency List C

<table>
<thead>
<tr>
<th>Frequency List</th>
<th>List Measurement Time (sec)</th>
<th>Repetitions</th>
<th>Cycle Duration (sec)</th>
<th>Experiment Duration (hours)</th>
<th>Experiment Duration (sec)</th>
<th>Number of Measurements</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>300</td>
<td>1</td>
<td>300</td>
<td></td>
<td></td>
<td>48</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>300</td>
<td>4</td>
<td>14400</td>
<td>48</td>
</tr>
</tbody>
</table>

4.3 Data Files

Table 8 describes all data files showing the frequency list, and the start time.

Table 8: File Numbers Used for Each Run

<table>
<thead>
<tr>
<th>Start Time</th>
<th>Location</th>
<th>Comment</th>
<th>Freq List</th>
<th>Start File</th>
<th>End File</th>
<th>Num Files</th>
<th>Duration (sec)</th>
<th>Antenna Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>8/31/04 4:00 pm</td>
<td>SE corner</td>
<td></td>
<td>List A</td>
<td>7617</td>
<td>16605</td>
<td>8989</td>
<td>79200</td>
<td>1</td>
</tr>
<tr>
<td>8/31/04 4:00 pm</td>
<td>SE corner</td>
<td></td>
<td>List B</td>
<td>228</td>
<td>441</td>
<td>214</td>
<td>79200</td>
<td>3</td>
</tr>
<tr>
<td>9/1/04 8:35 pm</td>
<td>SE corner</td>
<td></td>
<td>List A</td>
<td>16608</td>
<td>27527</td>
<td>10919</td>
<td>107280</td>
<td>1</td>
</tr>
<tr>
<td>9/1/04 SE Corner</td>
<td></td>
<td></td>
<td>List B</td>
<td>452</td>
<td>724</td>
<td>273</td>
<td>107290</td>
<td>3</td>
</tr>
</tbody>
</table>
5. Long Duration Spectrum Measurements

This section contains plots of the spectrum occupancy measurements.

5.1 Plot Format Description

Each of the plots in section Error! Reference source not found., below, has three spectrum occupancy sub-plots. The upper sub-plot is the maximum power value versus frequency measured during the period. The power values are corrected for cable losses, filters, and attenuators, and represent the received power level at the antenna terminals. The time in the plot title is the measurement start time.

The middle sub-plot is a waterfall-type plot with occupancy plotted versus time and frequency. Occupancy is determined when the power level exceeds a threshold. One overall threshold value was intentionally selected for each run, and is shown as a dotted line on the upper plot. Note that, in some cases, the noise level exceeds the threshold, causing inflated occupancy levels. This was not corrected because it would have been necessary to manually select the threshold for each plot. The time shown on the right side vertical axis of each figure is the measurement time.

The last sub-plot shown in section 4.2 is the fraction of time the signal is above the threshold versus frequency. A fraction of time value of “1” means that the signal was measured above the threshold for the entire duration of the measurement period.
5.2 Measurements Made Below 960 MHz

Figure 10: August 31 to September 1, 30 MHz – 54 MHz

Figure 11: September 1 to September 3, 30 MHz – 54 MHz
Figure 12: August 31 to September 1, 54 MHz – 88 MHz

Figure 13: September 1 to September 3, 54 MHz – 88 MHz
Figure 14: August 31 to September 1, 108 MHz – 138 MHz

Figure 15: September 1 to September 3, 108 MHz – 138 MHz
Figure 16: August 31 to September 1, 138 MHz – 174 MHz

Figure 17: September 1 to September 3, 138 MHz – 174 MHz
Figure 18: August 31 to September 1, 174 MHz – 216 MHz

Figure 19: September 1 to September 3, 174 MHz – 216 MHz
Figure 20: August 31 to September 1, 216 MHz – 225 MHz

Figure 21: September 1 to September 3, 216 MHz – 225 MHz
Figure 22: August 31 to September 1, 225 MHz – 406 MHz

Figure 23: September 1 to September 3, 225 MHz – 406 MHz
Figure 24: August 31 to September 1, 406 MHz – 470 MHz

Figure 25: September 1 to September 3, 406 MHz – 470 MHz
Figure 26: August 31 to September 1, 470 MHz – 512 MHz

Figure 27: September 1 to September 3, 470 MHz – 512 MHz
Figure 28: August 31 to September 1, 512 MHz – 608 MHz

Figure 29: September 1 to September 3, 512 MHz – 608 MHz
Figure 30: August 31 to September 1, 608 MHz – 698 MHz

Figure 31: September 1 to September 3, 608 MHz – 698 MHz
Figure 32: August 31 to September 1, 698 MHz – 806 MHz

Figure 33: September 1 to September 3, 698 MHz – 806 MHz
Figure 34: August 31 to September 1, 806 MHz – 902 MHz

Figure 35: September 1 to September 3, 806 MHz – 902 MHz
Figure 36: August 31 to September 1, 902 MHz – 928 MHz

Figure 37: September 1 to September 3, 902 MHz – 928 MHz
Figure 38: August 31 to September 1, 928 MHz – 960 MHz

Figure 39: September 1 to September 3, 928 MHz – 960 MHz
5.3 Measurements Made Above 960 MHz

Figure 40: August 31 to September 1, 960 MHz – 1240 MHz

Figure 41: September 1 to September 3, 960 MHz – 1240 MHz
Figure 42: August 31 to September 1, 1240 MHz – 1300 MHz

Figure 43: September 1 to September 3, 1240 MHz – 1300 MHz
Figure 44: August 31 to September 1, 1300 MHz – 1400 MHz

Figure 45: September 1 to September 3, 1300 MHz – 1400 MHz
Figure 46: August 31 to September 1 1400 MHz – 1525 MHz

Figure 47: September 1 to September 3, 1400 MHz – 1525 MHz
Figure 48: August 31 to September 1, 1525 MHz – 1710 MHz

Figure 49: September 1 to September 3, 1525 MHz – 1710 MHz
Figure 50: August 31 to September 1, 1710 MHz – 1850 MHz

Figure 51: September 1 to September 3, 1710 MHz – 1850 MHz
Spectrum Occupancy Measurements
Republican National Convention, New York City, NY

Figure 52: August 31 to September 1, 1850 MHz – 1990 MHz

Figure 53: September 1 to September 3, 1850 MHz – 1990 MHz
Spectrum Occupancy Measurements
Republican National Convention, New York City, NY

Figure 54: August 31 to September 1, 1990 MHz – 2110 MHz

Figure 55: September 1 to September 3, 1990 MHz – 2110 MHz
Figure 56: August 31 to September 1, 2110 MHz – 2200 MHz

Figure 57: September 1 to September 3, 2110 MHz – 2200 MHz
Figure 58: August 31 to September 1, 2200 MHz – 2300 MHz

Figure 59: September 1 to September 3, 2200 MHz – 2300 MHz
Figure 60: August 31 to September 1, 2300 MHz – 2360 MHz

Figure 61: September 1 to September 3, 2300 MHz – 2360 MHz
Figure 62: August 31 to September 1, 2360 MHz – 2390 MHz

Figure 63: September 1 to September 3, 2360 MHz – 2390 MHz
Spectrum Occupancy Measurements
Republican National Convention, New York City, NY

Figure 64: August 31 to September 1, 2390 MHz – 2500 MHz

Figure 65: September 1 to September 3, 2390 MHz – 2500 MHz
Figure 66: August 31 to September 1, 2500 MHz – 2686 MHz

Figure 67: September 1 to September 3, 2500 MHz – 2686 MHz
Spectrum Occupancy Measurements
Republican National Convention, New York City, NY

Figure 68: August 31 to September 1, 2686 MHz – 2900 MHz

Figure 69: September 1 to September 3, 2686 MHz – 2900 MHz
6. Small Frequency Resolution Spectrum Measurements

6.1 Introduction

The purpose of these spectrum measurements was to more accurately measure the spectrum occupancy of a subset of the frequency bands. To increase the spectrum occupancy accuracy, frequency bin sizes that are smaller than the signal bandwidths of interest are required. The measurements in Section 4.3 used frequency bin sizes that varied from 18 kHz to 559 kHz (Table 3). If a 25 kHz bandwidth signal was detected, the entire frequency bin was declared to be occupied. Thus, the actual spectrum occupancy could be 25 kHz/559 kHz = 0.045 smaller that what is shown in Section 6.

The spectrum analyzer had a limited number of frequency bins, and it was not practical to measure all of the spectrum bands using small frequency bins. Hence, a subset of the spectrum bands were measured with the small frequency bins to determine how much lower the actual spectrum usages was compared to the Section 4.3 plots.

The measurements used frequency collection List C (Table 4). The measurements where made over a four hour period from 4:30 pm to 8:30 pm, September 1, 2004. The bands were selected because they contained signals without broadcast or high transmit duty cycle signals. Each figure below contains 5 MHz of bandwidth. The spectrum analyzer used (Rhode and Schwarz EPSI) provides 501 points in the spectrum trace. Hence, the frequency bin size was 10 kHz. This provides a more accurate upper bound on the spectrum occupancy compared to those in Section 6 because the typical signal bandwidths were 25 kHz or larger.
6.2 Small Frequency Resolution Measurements

This section contains plots of the measured spectrum occupancy of select bands using a small (10 kHz) frequency bin size.

![Small Frequency Resolution, 30 MHz – 35 MHz](image1)

**Figure 70: Small Frequency Resolution, 30 MHz – 35 MHz**

![Small Frequency Resolution, 35 MHz – 40 MHz](image2)

**Figure 71: Small Frequency Resolution, 35 MHz – 40 MHz**
Figure 72: Small Frequency Resolution, 40 MHz – 45 MHz

Figure 73: Small Frequency Resolution, 45 MHz – 50 MHz
Figure 74: Small Frequency Resolution, 50 MHz – 55 MHz

Figure 75: Small Frequency Resolution, 55 MHz – 60 MHz
Figure 76: Small Frequency Resolution, 70 MHz – 75 MHz

Figure 77: Small Frequency Resolution, 110 MHz – 115 MHz
Figure 78: Small Frequency Resolution, 115 MHz – 120 MHz

Figure 79: Small Frequency Resolution, 120 MHz – 125 MHz
Figure 80: Small Frequency Resolution, 125 MHz – 130 MHz

Figure 81: Small Frequency Resolution, 130 MHz – 135 MHz
Figure 82: Small Frequency Resolution, 135 MHz – 140 MHz

Figure 83: Small Frequency Resolution, 140 MHz – 145 MHz
Figure 84: Small Frequency Resolution, 145 MHz – 150 MHz

Figure 85: Small Frequency Resolution, 150 MHz – 155 MHz
Figure 86: Small Frequency Resolution, 155 MHz – 160 MHz

Figure 87: Small Frequency Resolution, 160 MHz – 165 MHz
Figure 88: Small Frequency Resolution, 165 MHz – 170 MHz

Figure 89: Small Frequency Resolution, 170 MHz – 175 MHz
Figure 90: Small Frequency Resolution, 190 MHz – 195 MHz

Figure 91: Small Frequency Resolution, 195 MHz – 200 MHz
Figure 92: Small Frequency Resolution, 215 MHz – 220 MHz

Figure 93: Small Frequency Resolution, 220 MHz – 225 MHz
Figure 94: Small Frequency Resolution, 225 MHz – 230 MHz

Figure 95: Small Frequency Resolution, 230 MHz – 235 MHz
Figure 96: Small Frequency Resolution, 235 MHz – 240 MHz

Figure 97: Small Frequency Resolution, 240 MHz – 245 MHz
Figure 98: Small Frequency Resolution, 245 MHz – 250 MHz

Figure 99: Small Frequency Resolution, 250 MHz – 255 MHz
Figure 100: Small Frequency Resolution, 255 MHz – 260 MHz

Figure 101: Small Frequency Resolution, 260 MHz – 265 MHz
Figure 102: Small Frequency Resolution, 265 MHz – 270 MHz

Figure 103: Small Frequency Resolution, 270 MHz – 275 MHz
Figure 104: Small Frequency Resolution, 275 MHz – 280 MHz

Figure 105: Small Frequency Resolution, 280 MHz – 285 MHz
Figure 106: Small Frequency Resolution, 285 MHz – 290 MHz

Figure 107: Small Frequency Resolution, 290 MHz – 295 MHz
Figure 108: Small Frequency Resolution, 295 MHz – 300 MHz

Figure 109: Small Frequency Resolution, 300 MHz – 305 MHz
Figure 110: Small Frequency Resolution, 305 MHz – 310 MHz

Figure 111: Small Frequency Resolution, 310 MHz – 315 MHz
Figure 112: Small Frequency Resolution, 315 MHz – 320 MHz

Figure 113: Small Frequency Resolution, 320 MHz – 325 MHz
Figure 114: Small Frequency Resolution, 325 MHz – 330 MHz

Figure 115: Small Frequency Resolution, 330 MHz – 335 MHz
Figure 116: Small Frequency Resolution, 335 MHz – 340 MHz

Figure 117: Small Frequency Resolution, 340 MHz – 345 MHz
Figure 118: Small Frequency Resolution, 345 MHz – 350 MHz

Figure 119: Small Frequency Resolution, 350 MHz – 355 MHz
Figure 120: Small Frequency Resolution, 355 MHz – 360 MHz

Figure 121: Small Frequency Resolution, 360 MHz – 365 MHz
Figure 122: Small Frequency Resolution, 365 MHz – 370 MHz

Figure 123: Small Frequency Resolution, 370 MHz – 375 MHz
Figure 124: Small Frequency Resolution, 375 MHz – 380 MHz

Figure 125: Small Frequency Resolution, 380 MHz – 385 MHz
Figure 126: Small Frequency Resolution, 385 MHz – 390 MHz

Figure 127: Small Frequency Resolution, 390 MHz – 395 MHz
Figure 128: Small Frequency Resolution, 395 MHz – 400 MHz

Figure 129: Small Frequency Resolution, 400 MHz – 405 MHz
**Figure 130:** Small Frequency Resolution, 405 MHz – 410 MHz

**Figure 131:** Small Frequency Resolution, 410 MHz – 415 MHz
Figure 132: Small Frequency Resolution, 415 MHz – 420 MHz

Figure 133: Small Frequency Resolution, 420 MHz – 425 MHz
Figure 134: Small Frequency Resolution, 425 MHz – 430 MHz

Figure 135: Small Frequency Resolution, 430 MHz – 435 MHz
Figure 136: Small Frequency Resolution, 435 MHz – 440 MHz

Figure 137: Small Frequency Resolution, 440 MHz – 445 MHz
Figure 138: Small Frequency Resolution, 445 MHz – 450 MHz

Figure 139: Small Frequency Resolution, 450 MHz – 455 MHz
Figure 140: Small Frequency Resolution, 455 MHz – 460 MHz

Figure 141: Small Frequency Resolution, 460 MHz – 465 MHz
**Figure 142:** Small Frequency Resolution, 465 MHz – 470 MHz

**Figure 143:** Small Frequency Resolution, 470 MHz – 475 MHz
Figure 144: Small Frequency Resolution, 500 MHz – 505 MHz

Figure 145: Small Frequency Resolution, 505 MHz – 510 MHz
Figure 146: Small Frequency Resolution, 510 MHz – 515 MHz

Figure 147: Small Frequency Resolution, 515 MHz – 520 MHz
Figure 148: Small Frequency Resolution, 925 MHz – 930 MHz

Figure 149: Small Frequency Resolution, 930 MHz – 935 MHz
Figure 150: Small Frequency Resolution, 935 MHz – 940 MHz

Figure 151: Small Frequency Resolution, 940 MHz – 945 MHz
Figure 152: Small Frequency Resolution, 945 MHz – 950 MHz

Figure 153: Small Frequency Resolution, 950 MHz – 955 MHz
Figure 154: Small Frequency Resolution, 955 MHz – 960 MHz

Figure 155: Small Frequency Resolution, 960 MHz – 965 MHz
7. Large Signal Level Spectrum Measurements

7.1 Introduction

This section describes measurements made with no filters and pre-amplification so that the absolute power in all spectrum bands can be determined. Note that in the other measurements, FM band-stop filters were used, which didn’t allow the total signal power to be measured.

The figures presented in section 6.2, below, plot spectrum occupancy measurements made on August 30, 2004, using frequency collection List D (Table 10). The measurements were made 11:30 am to 12:09 pm, during a weekday. Each of the plots below reflect 250 MHz of bandwidth.

The plots are corrected for the RF cable loss between the antenna and the spectrum analyzer. This loss was measured using a network analyzer.
7.2 Large Signal Level Measurements

These following figures contain plots of the measured spectrum occupancy of select bands using a large (499 kHz) frequency bin size.

Figure 156: Large Signal Data, 0 – 250 MHz

Figure 157: Large Signal Data, 250 MHz – 500 MHz
Figure 158: Large Signal Data, 500 MHz – 750 MHz

Figure 159: Large Signal Data, 750 MHz – 1000 MHz
Figure 160: Large Signal Data, 1000 MHz – 1250 MHz

Figure 161: Large Signal Data, 1250 MHz – 1500 MHz
Figure 162: Large Signal Data, 1500 MHz – 1750 MHz

Figure 163: Large Signal Data, 1750 MHz – 2000 MHz
Figure 164: Large Signal Data, 2000 MHz – 2250 MHz

Figure 165: Large Signal Data, 2250 MHz – 2500 MHz
Figure 166: Large Signal Data, 2500 MHz – 2750 MHz

Figure 167: Large Signal Data, 2750 MHz – 3000 MHz
8. Conclusions

This report documents extensive spectrum occupancy measurements made by Shared Spectrum Company in New York City – one of the most densely populated areas in the United States – during the Republican National Convention of August 30, 2004 through September 3, 2004. This location and event were specifically selected for study of spectrum occupancy during a period of extraordinarily high communications use. Measurements were made in all bands in the 30 MHz to 3000 MHz range.

8.1 Spectrum Occupancy Upper Bounds

Based on results of the study, Shared Spectrum Company concludes that the overall average spectrum usage during the measurement period was 13% or less. Occupancy\(^3\) varied from less than 1% in the 1240-1300 MHz Amateur Band, to 77% in the 174 MHz – 216 MHz, TV Channel 7-13 Band.

Table 9 shows a summary of each average duty cycle for each spectrum band. The average duty cycle of each band is noted on each of the spectrum plots. The average for August 31 through September 1 (Day 1) and the average for September 1 through September 3 (Day 2) are averaged to find the overall Average Duty Cycle. The amount of spectrum occupied is then calculated. The total spectrum occupied divided by the total spectrum in the bands is used to find the overall occupancy value of 0.1312 or 13%. Thus, no more than 13% of the spectrum opportunities (in frequency and in time) were utilized in New York City during a peak use period when measured from an elevated location.

\(^{3}\) Occupancy is defined as the average duty cycle based on the time-frequency product.
### Table 9: Summary of Spectrum Occupancy in Each Band

<table>
<thead>
<tr>
<th>Start Freq (MHz)</th>
<th>Stop Freq (MHz)</th>
<th>Bandwidth (MHz)</th>
<th>Spectrum Band Allocation</th>
<th>NYC Day 1</th>
<th>NYC Day 2</th>
<th>NYC Average</th>
<th>NYC Occupied Spectrum (MHz)</th>
<th>Percent Occupied</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>54</td>
<td>24</td>
<td>PLM, Amateur, others</td>
<td>0.04300</td>
<td>0.06250</td>
<td>0.05275</td>
<td>1.27</td>
<td>5.3%</td>
</tr>
<tr>
<td>54</td>
<td>88</td>
<td>34</td>
<td>TV 2-6, RC</td>
<td>0.52830</td>
<td>0.52080</td>
<td>0.52455</td>
<td>17.83</td>
<td>52.5%</td>
</tr>
<tr>
<td>108</td>
<td>138</td>
<td>30</td>
<td>Air Traffic Control, Aero Nav</td>
<td>0.05270</td>
<td>0.04030</td>
<td>0.04650</td>
<td>1.40</td>
<td>4.7%</td>
</tr>
<tr>
<td>138</td>
<td>174</td>
<td>36</td>
<td>Fixed Mobile, Amateur, others</td>
<td>0.17080</td>
<td>0.16980</td>
<td>0.17030</td>
<td>6.13</td>
<td>17.0%</td>
</tr>
<tr>
<td>174</td>
<td>216</td>
<td>42</td>
<td>TV 7-13</td>
<td>0.77730</td>
<td>0.77950</td>
<td>0.77840</td>
<td>32.69</td>
<td>77.8%</td>
</tr>
<tr>
<td>216</td>
<td>225</td>
<td>9</td>
<td>Maritime Mobile, Amateur, others</td>
<td>0.05860</td>
<td>0.05950</td>
<td>0.05905</td>
<td>0.53</td>
<td>5.9%</td>
</tr>
<tr>
<td>225</td>
<td>406</td>
<td>181</td>
<td>Fixed Mobile, Aero, others</td>
<td>0.00530</td>
<td>0.00370</td>
<td>0.00450</td>
<td>0.81</td>
<td>0.5%</td>
</tr>
<tr>
<td>406</td>
<td>470</td>
<td>64</td>
<td>Amateur, Radio Geolocation, Fixed, Mobile, Radioolocation</td>
<td>0.16610</td>
<td>0.14750</td>
<td>0.15680</td>
<td>10.04</td>
<td>15.7%</td>
</tr>
<tr>
<td>470</td>
<td>512</td>
<td>42</td>
<td>TV 14-20</td>
<td>0.21140</td>
<td>0.21000</td>
<td>0.21070</td>
<td>8.85</td>
<td>21.1%</td>
</tr>
<tr>
<td>512</td>
<td>608</td>
<td>96</td>
<td>TV 21-36</td>
<td>0.35520</td>
<td>0.34270</td>
<td>0.34895</td>
<td>33.50</td>
<td>34.9%</td>
</tr>
<tr>
<td>608</td>
<td>698</td>
<td>90</td>
<td>TV 37-51</td>
<td>0.46160</td>
<td>0.46090</td>
<td>0.46125</td>
<td>41.51</td>
<td>46.1%</td>
</tr>
<tr>
<td>698</td>
<td>806</td>
<td>108</td>
<td>TV 52-69</td>
<td>0.29560</td>
<td>0.30790</td>
<td>0.30185</td>
<td>32.60</td>
<td>30.2%</td>
</tr>
<tr>
<td>806</td>
<td>902</td>
<td>96</td>
<td>Cell phone and SMR</td>
<td>0.46190</td>
<td>0.46450</td>
<td>0.46320</td>
<td>44.47</td>
<td>46.3%</td>
</tr>
<tr>
<td>902</td>
<td>928</td>
<td>26</td>
<td>Unlicensed</td>
<td>0.22270</td>
<td>0.23460</td>
<td>0.22985</td>
<td>5.94</td>
<td>22.9%</td>
</tr>
<tr>
<td>928</td>
<td>960</td>
<td>32</td>
<td>Paging, SMS, Fixed, BX Aux, and FMS</td>
<td>0.23640</td>
<td>0.24370</td>
<td>0.24005</td>
<td>7.68</td>
<td>24.0%</td>
</tr>
<tr>
<td>960</td>
<td>1240</td>
<td>280</td>
<td>IFP, TACAN, GPS, others</td>
<td>0.03560</td>
<td>0.04080</td>
<td>0.03820</td>
<td>10.70</td>
<td>3.8%</td>
</tr>
<tr>
<td>1240</td>
<td>1300</td>
<td>60</td>
<td>Amateur</td>
<td>0.00030</td>
<td>0.00010</td>
<td>0.00020</td>
<td>0.01</td>
<td>0.0%</td>
</tr>
<tr>
<td>1300</td>
<td>1400</td>
<td>100</td>
<td>Aero Radar, military</td>
<td>0.02160</td>
<td>0.00130</td>
<td>0.01145</td>
<td>1.15</td>
<td>1.1%</td>
</tr>
<tr>
<td>1400</td>
<td>1525</td>
<td>125</td>
<td>Space/Satellite, Fixed Mobile, Telemetry</td>
<td>0.01520</td>
<td>0.00050</td>
<td>0.00785</td>
<td>0.98</td>
<td>0.6%</td>
</tr>
<tr>
<td>1525</td>
<td>1710</td>
<td>185</td>
<td>Mobile Satellite, GPS L1, Mobile Satellite, Meteorological</td>
<td>0.00240</td>
<td>0.00130</td>
<td>0.00185</td>
<td>0.34</td>
<td>0.2%</td>
</tr>
<tr>
<td>1710</td>
<td>1850</td>
<td>140</td>
<td>Fixed, Fixed Mobile</td>
<td>0.02350</td>
<td>0.02540</td>
<td>0.02445</td>
<td>3.42</td>
<td>2.4%</td>
</tr>
<tr>
<td>1850</td>
<td>1990</td>
<td>140</td>
<td>PCS, Asyn, Iso</td>
<td>0.33090</td>
<td>0.34430</td>
<td>0.33760</td>
<td>47.26</td>
<td>33.8%</td>
</tr>
<tr>
<td>1990</td>
<td>2110</td>
<td>120</td>
<td>TV Aux</td>
<td>0.01910</td>
<td>0.00820</td>
<td>0.01365</td>
<td>1.64</td>
<td>1.4%</td>
</tr>
<tr>
<td>2110</td>
<td>2200</td>
<td>90</td>
<td>Common Carriers, Private Companies, MDS</td>
<td>0.01820</td>
<td>0.01900</td>
<td>0.01860</td>
<td>1.67</td>
<td>1.9%</td>
</tr>
<tr>
<td>2200</td>
<td>2300</td>
<td>100</td>
<td>Space Operation, Fixed</td>
<td>0.05270</td>
<td>0.06180</td>
<td>0.05725</td>
<td>5.73</td>
<td>5.7%</td>
</tr>
<tr>
<td>2300</td>
<td>2360</td>
<td>60</td>
<td>Amateur, WCS, DARS</td>
<td>0.20220</td>
<td>0.20530</td>
<td>0.20375</td>
<td>12.23</td>
<td>20.4%</td>
</tr>
<tr>
<td>2360</td>
<td>2390</td>
<td>30</td>
<td>Telemetry</td>
<td>0.06200</td>
<td>0.06420</td>
<td>0.06310</td>
<td>1.89</td>
<td>6.3%</td>
</tr>
<tr>
<td>2390</td>
<td>2500</td>
<td>110</td>
<td>U-PCS, ISM (Unlicensed)</td>
<td>0.13470</td>
<td>0.15510</td>
<td>0.14490</td>
<td>15.94</td>
<td>14.5%</td>
</tr>
<tr>
<td>2500</td>
<td>2686</td>
<td>186</td>
<td>ITFS, MMDS</td>
<td>0.10430</td>
<td>0.10420</td>
<td>0.10425</td>
<td>19.39</td>
<td>10.4%</td>
</tr>
<tr>
<td>2686</td>
<td>2900</td>
<td>214</td>
<td>Surveillance Radar</td>
<td>0.02860</td>
<td>0.03090</td>
<td>0.03075</td>
<td>6.37</td>
<td>3.0%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2850</strong></td>
<td></td>
<td></td>
<td><strong>0.0000</strong></td>
<td><strong>0.0000</strong></td>
<td><strong>0.0000</strong></td>
<td><strong>373.97</strong></td>
<td></td>
</tr>
</tbody>
</table>

- **Total Available Spectrum:** 2850 MHz
- **Average Spectrum Use (%):** 13.1%
8.2 Difference Between Above Occupancy Upper Bound and Actual Value

In most of the measurements in this report, the spectrum bin size is larger than the signal bandwidths of interest. Hence, the above occupancy values are upper bounds on the actual values. Figure 168 shows that in the 450 to 455 MHz band, the large spectrum bins significantly overestimate the occupancy. Smaller frequency bins were not used in most of the measurements because of the greatly increased measurement time required.

Figure 168: Comparison of spectrum occupancy measured using large frequency bins and small frequency bins indicates that the large frequency bin measurements overestimate the spectrum occupancy.

![Figure 25: September 1 to September 3, 406 MHz – 470 MHz](image1)

![Figure 139: Small Frequency Resolution, 450 MHz – 455 MHz](image2)

450-455 MHz occupancy of ~0.5 using large frequency bins (139 kHz)

450-455 MHz occupancy of ~0.186 small frequency bins (10 kHz)