Spectrum Occupancy Measurements
Location 1 of 6:
Riverbend Park, Great Falls, Virginia
April 7, 2004

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National Radio Research Testbed (NRNRT)
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1. Introduction

1.1 Summary

This document describes spectrum occupancy measurements performed by Shared Spectrum Company at Riverbend Park, in Great Falls, Virginia on April 7, 2004. This site was intentionally selected as a rural setting in which to collect spectrum measurements.

1.2 Report Organization

This report is organized into six sections, as follows:
- Section 1 Introduction
- Section 2 Description of measurement equipment
- Section 3 Site and surrounding environment where measurements were taken
- Section 4 Frequency lists used for the spectrum occupancy measurements
- Section 5 Plots showing measured spectrum occupancy for each band.
- Section 6 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.

The goal for the measurements taken at Riverbend Park was to identify spectrum bands with low occupancy. Occupancy was quantified as the amount of spectrum detected above a certain received power threshold.

1.4 The National Radio Network Research Testbed (NRNRT)

Measurements contained in this report are part of the National Radio Network Research Testbed (NRNRT) project.\(^1\) 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;

\(^1\) 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) 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.
2. Measurement Equipment

2.1 Equipment Description

The equipment consisted of an antenna, antenna rotator, filter, pre-amp, shielded enclosure, and a spectrum analyzer as shown in Figure 1.

Figure 1: Spectrum occupancy measurement equipment configuration.

At the Riverbend Park location, the equipment was powered by a 50-foot long extension cord plugged into a gasoline power AC generator. The generator is believed to have added significant noise in the 30 MHz to 54 MHz band centered at 45 MHz.
The spectrum analyzer specifications are shown in Table 1.

**Table 1. Rohde and Schwarz ESPI Spectrum Analyzer Parameters**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency Range</td>
<td>9 kHz to 3 GHz</td>
</tr>
<tr>
<td>Pre-selector</td>
<td>BW=15 MHz (30 MHz to 70 MHz), BW=30 MHz (70 MHz to 150 MHz), BW=60 MHz (150 MHz to 300 MHz), BW=80 MHz (300 MHz to 600 MHz), BW=100 MHz (600 MHz to 1000 MHz), BW=Tracking high pass (1000 MHz to 2000 MHz), BW=Fixed high pass (&gt;2,000 MHz).</td>
</tr>
<tr>
<td>Noise Figure</td>
<td>21.5 dB</td>
</tr>
<tr>
<td>Input Third Order Intercept Point</td>
<td>+10 dBm (typ), +5 dBm (with pre-selector on)</td>
</tr>
<tr>
<td>Input Second Order Intercept Point</td>
<td>+35 dBm (typ), +5 dBm (with pre-selector on)</td>
</tr>
<tr>
<td>Phase Noise</td>
<td>-106 dB/Hz at 10 kHz offset</td>
</tr>
<tr>
<td>Sweep Time</td>
<td>320 ms sweep time for 100 MHz sweep and 10 kHz RBW, 100 ms sweep time for 10 MHz sweep and 10 kHz RBW.</td>
</tr>
</tbody>
</table>
2.2 RF Configuration Used Below 1,000 MHz

The configuration for signals below 1,000 MHz is shown in Figure 3. The FM band stop filter was an Eagle HLC-700, C7RFM3NFF filter.

Two antennas were used. A Create Model CLP-5130-2N log period antenna was used in the horizontal polarization configuration. This antenna has a specified frequency range of 105 MHz to 1.3 GHz and a manufacturer’s specified gain of 11 to 13 dBi. The second antenna was a vertically-polarized “scanner” discone antenna.
Figure 3: Equipment configuration used for signals below 1,000 MHz.

![Equipment configuration diagram]

Figure 4: Omni-Directional Discone Antenna (used for frequencies below 1,000 MHz)

A large LPA antenna was also used as a rotating antenna (Figure 5). The antennas were connected to a Pre-selector and a 20-foot, RG8 cable.
2.3 RF Configuration Used Above 1,000 MHz

Figure 6 shows the equipment configuration used for signals above 1,000 MHz. A highpass filter is used to remove the strong FM and broadcast TV signals. The pre-amplifier is used to improve the system noise temperature.

An LPA antenna was used for all measurements above 1 GHz. It was rotated to a horizontal polarization angle. The antenna was installed on the filter/pre-amplifier module as shown in Figure 7. The antenna size is shown in Figure 8.
Figure 7: Small LPA Antenna and Pre-Amplifier Used for Frequencies Above 1 GHz

Figure 8: Log-Periodic Array (LPA), Directional Antenna Used for 1,000 MHz to 3,000 MHz.

2.4 Equipment Configurations for Each Run

Different equipment configurations were used for each run described below. The antennas, cables, filters, fixed attenuators, and pre-amplifiers were varied to optimize the dynamic range of the measurements. Table 2 provides a list of the equipment parameters and Table 3 provides the configuration used for each measurement run.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antenna Type</td>
<td>=0 for no antenna (system noise), =1 for discone, =2 for large LPA,</td>
</tr>
<tr>
<td></td>
<td>=3 for small LPA</td>
</tr>
<tr>
<td>Cable Type</td>
<td>=1 for (1) RG-8 cables, =2 for (2) RG-8 cables, =3 for (3) RG-8 cables,</td>
</tr>
<tr>
<td></td>
<td>=4 for short orange cable</td>
</tr>
<tr>
<td>Attenuation</td>
<td>=Value of fixed attenuator in dB</td>
</tr>
<tr>
<td></td>
<td>=0 for none, XX dB otherwise, XX &gt; 0</td>
</tr>
<tr>
<td>Filter Type</td>
<td>=0 for none, =1 for 30-88 MHz bandpass, =2 for 225-450 MHz bandpass,</td>
</tr>
<tr>
<td></td>
<td>=3 for 1400 MHz highpass, =4 for FM Bandstop (HLC-700)</td>
</tr>
<tr>
<td>Pre-Amplifier Type</td>
<td>=0 for none, =1 for MC ZHL-2010, =2 for (3) MC ERA-5, =3 for MC ZKL-2R7</td>
</tr>
</tbody>
</table>
Table 3. Description of Runs Showing the Frequency List, the Antenna Type, the Cable Type, the Attenuation Value, the Filter Type, and the Pre-Amplifier Type Used

<table>
<thead>
<tr>
<th>Start Time</th>
<th>Comment</th>
<th>Freq List</th>
<th>Start File</th>
<th>End File</th>
<th>Num Files</th>
<th>Antenna Type</th>
<th>Cable Type</th>
<th>Attenuation (dB)</th>
<th>Filter Type</th>
<th>Pre-Amplifier Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>11:22</td>
<td>rotating</td>
<td>Table 4</td>
<td>699</td>
<td>794</td>
<td>96</td>
<td>2</td>
<td>1</td>
<td>0</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>12:34</td>
<td>stat</td>
<td>Table 4</td>
<td>795</td>
<td>907</td>
<td>113</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>14:00</td>
<td>rotating</td>
<td>Table 5</td>
<td>908</td>
<td>984</td>
<td>77</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>15:05</td>
<td>stat</td>
<td>Table 5</td>
<td>985</td>
<td>1056</td>
<td>77</td>
<td>3</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

2.5 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

The measurements were made at Riverbend Park located in Great Falls, Virginia.

3.1 Location

A map of the measurement location is shown in Figure 4, below. Riverbend Park is indicated by the red star in the center of the map just West of Potomac Falls.

![Figure 9: Map Showing Location of the Measurement Site](image)

3.2 Views from Measurement Site

The five subsequent figures in this section show photographs taken from the measurement antenna location, looking out in different directions. Note that almost all directions were obstructed to some extent by trees.
Figure 10: North East View from Measurement Site

Figure 11: South Eastern View from Measurement Site
Figure 12: Southern View from Measurement Site

Figure 13: Western View from Measurement Site
Figure 14: Northern View from Measurement Site
3.3 Near-By Transmitters and Potential Noise Source

At the Riverbend Park location, there were cars nearby, occasionally passing at approximately 10 meters away that may have been potential noise sources. However, no times were recorded when cars actually did pass by.

Figure 15: Possible Noise Sources - Cars Nearby the Spectrum Measuring Equipment
4. Measurement Frequency Lists

Riverbend Park measurements were from 0-3 GHz with stationary and rotating antennas. Before each measurement, data using a variety of frequency lists were collected to look for strong signals that might overload the pre-amplifier and/or the spectrum analyzer. Also, the data was examined to insure the equipment was operating properly. After the equipment configuration was finalized, long duration collections were made using the frequency lists in Table 4 and Table 5.

4.1 Frequency Collection List Used Below 1,000 MHz

Table 4 shows the frequency list used from 30 MHz to 960 MHz. In addition to the band start and stop frequencies, several spectrum analyzer settings are shown such as the reference level, the number of dB per division, the resolution bandwidth, the video bandwidth, the amount of RF attenuation, and the sweep time.

<table>
<thead>
<tr>
<th>Start Freq (MHz)</th>
<th>Stop Freq (MHz)</th>
<th>Ref Level (dBm)</th>
<th>dB/div</th>
<th>Res BW (Hz)</th>
<th>Vid BW (Hz)</th>
<th>Attenuation (dB)</th>
<th>Sweep Time (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>54</td>
<td>-10</td>
<td>10</td>
<td>1.00E+04</td>
<td>1.00E+04</td>
<td>10</td>
<td>0.3</td>
</tr>
<tr>
<td>54</td>
<td>88</td>
<td>-10</td>
<td>10</td>
<td>1.00E+04</td>
<td>1.00E+04</td>
<td>10</td>
<td>0.425</td>
</tr>
<tr>
<td>88</td>
<td>108</td>
<td>-10</td>
<td>10</td>
<td>1.00E+04</td>
<td>1.00E+04</td>
<td>10</td>
<td>0.25</td>
</tr>
<tr>
<td>108</td>
<td>138</td>
<td>-10</td>
<td>10</td>
<td>1.00E+04</td>
<td>1.00E+04</td>
<td>10</td>
<td>0.375</td>
</tr>
<tr>
<td>138</td>
<td>174</td>
<td>-10</td>
<td>10</td>
<td>1.00E+04</td>
<td>1.00E+04</td>
<td>10</td>
<td>0.45</td>
</tr>
<tr>
<td>174</td>
<td>216</td>
<td>-10</td>
<td>10</td>
<td>1.00E+04</td>
<td>1.00E+04</td>
<td>10</td>
<td>0.525</td>
</tr>
<tr>
<td>216</td>
<td>225</td>
<td>-10</td>
<td>10</td>
<td>1.00E+04</td>
<td>1.00E+04</td>
<td>10</td>
<td>0.1125</td>
</tr>
<tr>
<td>225</td>
<td>406</td>
<td>-10</td>
<td>10</td>
<td>1.00E+04</td>
<td>1.00E+04</td>
<td>10</td>
<td>2.2625</td>
</tr>
<tr>
<td>406</td>
<td>470</td>
<td>-10</td>
<td>10</td>
<td>1.00E+04</td>
<td>1.00E+04</td>
<td>10</td>
<td>0.8</td>
</tr>
<tr>
<td>470</td>
<td>512</td>
<td>-10</td>
<td>10</td>
<td>1.00E+04</td>
<td>1.00E+04</td>
<td>10</td>
<td>0.525</td>
</tr>
<tr>
<td>512</td>
<td>608</td>
<td>-10</td>
<td>10</td>
<td>1.00E+04</td>
<td>1.00E+04</td>
<td>10</td>
<td>1.2</td>
</tr>
<tr>
<td>608</td>
<td>698</td>
<td>-10</td>
<td>10</td>
<td>1.00E+04</td>
<td>1.00E+04</td>
<td>10</td>
<td>1.125</td>
</tr>
<tr>
<td>698</td>
<td>806</td>
<td>-10</td>
<td>10</td>
<td>1.00E+04</td>
<td>1.00E+04</td>
<td>10</td>
<td>1.35</td>
</tr>
<tr>
<td>806</td>
<td>902</td>
<td>-10</td>
<td>10</td>
<td>1.00E+04</td>
<td>1.00E+04</td>
<td>10</td>
<td>1.2</td>
</tr>
<tr>
<td>902</td>
<td>928</td>
<td>-10</td>
<td>10</td>
<td>1.00E+04</td>
<td>1.00E+04</td>
<td>10</td>
<td>0.325</td>
</tr>
<tr>
<td>928</td>
<td>960</td>
<td>-10</td>
<td>10</td>
<td>1.00E+04</td>
<td>1.00E+04</td>
<td>10</td>
<td>0.4</td>
</tr>
</tbody>
</table>
4.2 Frequency Collection List Used Above 1,000 MHz

Table 5 shows the frequency list used from 1,240 MHz to 2,900 MHz.

Table 5. Frequency List Used to Collect Data Above 1,000 MHz

<table>
<thead>
<tr>
<th>Start Freq (MHz)</th>
<th>Stop Freq (MHz)</th>
<th>Ref Level (dBm)</th>
<th>dB/div</th>
<th>Res_BW (Hz)</th>
<th>Vid_BW (Hz)</th>
<th>Attenuation (dB)</th>
<th>Sweep Time (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1240</td>
<td>1300</td>
<td>-10</td>
<td>10</td>
<td>1.00E+04</td>
<td>1.00E+04</td>
<td>0</td>
<td>.6</td>
</tr>
<tr>
<td>1300</td>
<td>1400</td>
<td>-10</td>
<td>10</td>
<td>1.00E+04</td>
<td>1.00E+04</td>
<td>0</td>
<td>1.00</td>
</tr>
<tr>
<td>1400</td>
<td>1525</td>
<td>-10</td>
<td>10</td>
<td>1.00E+04</td>
<td>1.00E+04</td>
<td>0</td>
<td>1.5625</td>
</tr>
<tr>
<td>1525</td>
<td>1710</td>
<td>-10</td>
<td>10</td>
<td>1.00E+04</td>
<td>1.00E+04</td>
<td>0</td>
<td>2.3125</td>
</tr>
<tr>
<td>1710</td>
<td>1850</td>
<td>-10</td>
<td>10</td>
<td>1.00E+04</td>
<td>1.00E+04</td>
<td>0</td>
<td>1.75</td>
</tr>
<tr>
<td>1850</td>
<td>1990</td>
<td>-10</td>
<td>10</td>
<td>1.00E+04</td>
<td>1.00E+04</td>
<td>0</td>
<td>1.75</td>
</tr>
<tr>
<td>1990</td>
<td>2110</td>
<td>-10</td>
<td>10</td>
<td>1.00E+04</td>
<td>1.00E+04</td>
<td>0</td>
<td>1.5</td>
</tr>
<tr>
<td>2110</td>
<td>2200</td>
<td>-10</td>
<td>10</td>
<td>1.00E+04</td>
<td>1.00E+04</td>
<td>0</td>
<td>1.125</td>
</tr>
<tr>
<td>2200</td>
<td>2300</td>
<td>-10</td>
<td>10</td>
<td>1.00E+04</td>
<td>1.00E+04</td>
<td>0</td>
<td>1.25</td>
</tr>
<tr>
<td>2300</td>
<td>2360</td>
<td>-10</td>
<td>10</td>
<td>1.00E+04</td>
<td>1.00E+04</td>
<td>0</td>
<td>0.75</td>
</tr>
<tr>
<td>2360</td>
<td>2390</td>
<td>-10</td>
<td>10</td>
<td>1.00E+04</td>
<td>1.00E+04</td>
<td>0</td>
<td>0.375</td>
</tr>
<tr>
<td>2390</td>
<td>2500</td>
<td>-10</td>
<td>10</td>
<td>1.00E+04</td>
<td>1.00E+04</td>
<td>0</td>
<td>1.375</td>
</tr>
<tr>
<td>2500</td>
<td>2686</td>
<td>-10</td>
<td>10</td>
<td>1.00E+04</td>
<td>1.00E+04</td>
<td>0</td>
<td>2.325</td>
</tr>
<tr>
<td>2686</td>
<td>2900</td>
<td>-10</td>
<td>10</td>
<td>1.00E+04</td>
<td>1.00E+04</td>
<td>0</td>
<td>2.675</td>
</tr>
</tbody>
</table>

4.3 Date Files

Table 6 and Table 7 below show the details of the data files that were generated by our measurements. Separate files were collected for each collection of a frequency list. The file size is 60 k to 70 k, depending on the number of frequency bands.

Table 6. Spectrum Measurement Files - Rotating

<table>
<thead>
<tr>
<th>Date</th>
<th>Location</th>
<th>Comment</th>
<th>Freq List Input Filename</th>
<th>Start Time</th>
<th>End Time</th>
<th>File Prefix</th>
<th>Start File Number</th>
<th>End File Number</th>
<th>Number of Files</th>
<th>Duration (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20040407</td>
<td>Riverbend Park</td>
<td>0-1 GHz Rotating</td>
<td>List B,A</td>
<td>11:22</td>
<td>12:22</td>
<td>nsf</td>
<td>699</td>
<td>794</td>
<td>96</td>
<td>1200</td>
</tr>
<tr>
<td>20040407</td>
<td>Riverbend Park</td>
<td>1-3 GHz Rotating</td>
<td>List B</td>
<td>14:00</td>
<td>15:01</td>
<td>nsf</td>
<td>908</td>
<td>984</td>
<td>77</td>
<td>3660</td>
</tr>
</tbody>
</table>

Table 7. Spectrum Measurement Files - Stationary

<table>
<thead>
<tr>
<th>Date</th>
<th>Location</th>
<th>Comment</th>
<th>Freq List Input Filename</th>
<th>Start Time</th>
<th>End Time</th>
<th>File Prefix</th>
<th>Start File Number</th>
<th>End File Number</th>
<th>Number of Files</th>
<th>Duration (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20040407</td>
<td>Riverbend Park</td>
<td>30-960MHz</td>
<td>List B,A</td>
<td>12:34</td>
<td>13:34</td>
<td>nsf</td>
<td>795</td>
<td>907</td>
<td>113</td>
<td>3600</td>
</tr>
<tr>
<td>20040507</td>
<td>Riverbend Park</td>
<td>1-3GHz</td>
<td>List B</td>
<td>15:05</td>
<td>15:55</td>
<td>nsf</td>
<td>985</td>
<td>1056</td>
<td>77</td>
<td>3000</td>
</tr>
</tbody>
</table>
5. **Spectrum Measurements**

This section contains plots of the spectrum occupancy measurements.

5.1 **Plot Format Description**

The first subplot represents the maximum power value versus frequency measured during the period. The power values are the levels at the antenna port, and are corrected for cable losses, filter losses, and amplifier losses. The time shown on the plot is the measurement start time.

The second subplot is a waterfall-type of plot showing occupancy versus time and frequency. Occupancy is determined when the power level exceeds a threshold. The threshold value was intentionally selected for each run, and is shown as a dotted line on the upper subplot. Note that, in some cases, the noise level exceeds the threshold, causing inflated occupancy levels. To correct this, the threshold would have had to be hand-selected for each plot, which was not done.

The third subplot is the fraction of time the signal is “on”, versus the frequency measured during the period. If the fraction of time is ‘1’, it means that the signal was on during the entire period of measurement collection, and vice versa.

The plots with the rotating antenna had a full 360-degree range of motion. Data was collected each time the antenna moved 20-degrees. For the 0-1,000 MHz, the antenna rotated 20-degrees every 36 seconds. For the 1-3 GHz plots, the antenna rotated 20-degrees about every 47 seconds.
5.2 Measurements Made Below 1,000 MHz

Figure 16: 30 MHz to 54 MHz, Rotating

Figure 17: 30 MHz – 54 MHz, Stationary
Figure 18: 54 MHz to 88 MHz, Rotating

Figure 19: 54 MHz – 88 MHz, Stationary
Spectrum Occupancy Measurements
Riverbend Park, Great Falls, Virginia

Figure 20: 108 MHz to 138 MHz, Rotating

Figure 21: 108 MHz – 138 MHz, Stationary
Figure 22: 138 MHz to 174 MHz, Rotating

Figure 23: 138 MHz – 174 MHz, Stationary
Figure 24: 174 MHz to 216 MHz, Rotating

Figure 25: 174 MHz – 216 MHz, Stationary
Figure 26: 216 MHz to 225 MHz, Rotating

Figure 27: 216 MHz – 225 MHz, Stationary
Figure 28: 225 MHz to 406 MHz, Rotating

Figure 29: 225 MHz to 406 MHz, Stationary
Figure 30: 406 MHz to 470 MHz, Rotating

Figure 31: 406 MHz – 470 MHz, Stationary
Figure 32: 470 MHz to 512 MHz, Rotating

Figure 33: 470 MHz – 512 MHz, Stationary
Figure 34: 512 MHz to 608 MHz, Rotating

Figure 35: 512 MHz – 608 MHz, Stationary
Figure 36: 608 MHz to 698 MHz, Rotating

Figure 37: 608 MHz – 698 MHz, Stationary
Figure 38: 698 MHz to 806 MHz, Rotating

Figure 39: 698 MHz – 806 MHz, Stationary
Figure 40: 806 MHz to 902 MHz, Rotating

Figure 41: 806 MHz – 902 MHz, Stationary
Figure 42: 902 MHz to 928 MHz, Rotating

Figure 43: 902 MHz – 928 MHz, Stationary
Figure 44: 928 MHz to 960 MHz, Rotating

Figure 45: 928 MHz – 960 MHz, Stationary

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5.3 Measurements Made Above 1,000 MHz

Figure 46: 1240 MHz to 1300 MHz, Rotating

Figure 47: 1240 MHz to 1300 MHz, Stationary
Figure 48: 1300 MHz to 1400 MHz, Rotating

Figure 49: 1300 MHz to 1400 MHz, Stationary
Figure 50: 1400 MHz to 1525 MHz, Rotating

Figure 51: 1400 MHz to 1525 MHz, Stationary
Figure 52: 1525 MHz to 1710 MHz, Rotating

Figure 53: 1525 MHz to 1710 MHz, Stationary
Spectrum Occupancy Measurements
Riverbend Park, Great Falls, Virginia

Figure 54: 1710 MHz to 1850 MHz, Rotating

Figure 55: 1710 MHz to 1850 MHz, Stationary
Spectrum Occupancy Measurements
Riverbend Park, Great Falls, Virginia

Figure 56: 1850 MHz to 1990 MHz, Rotating

Figure 57: 1850 MHz to 1990 MHz, Stationary
Figure 58: 1990 MHz to 2110 MHz, Rotating

Figure 59: 1990 MHz to 2110 MHz, Stationary
Figure 60: 2110 MHz to 2200 MHz, Rotating

Figure 61: 2110 MHz to 2200 MHz, Stationary
Figure 62: 2200 MHz to 2300 MHz, Rotating

Figure 63: 2200 MHz to 2300 MHz, Stationary
Figure 64: 2300 MHz to 2360 MHz, Rotating

Figure 65: 2300 MHz to 2360 MHz, Stationary
Figure 66: 2360 MHz to 2390 MHz, Rotating

Figure 67: 2360 MHz to 2390 MHz, Stationary
Figure 68: 2390 MHz to 2500 MHz, Rotating

Figure 69: 2390 MHz to 2500 MHz, Stationary
Figure 70: 2500 MHz to 2686 MHz, Rotating

Figure 71: 2500 MHz to 2686 MHz, Stationary
Figure 72: 2686 MHz to 2900 MHz, Rotating

Figure 73: 2686 MHz to 2900 MHz, Stationary
5.4 Data Issues and Comments

5.4.1 30 MHz to 50 MHz

The existence of wide band noise at 45 MHz was measured at the Riverbend Park location. This was most likely due to the use of our gasoline-powered generator.

5.4.2 88 MHz to 108 MHz

The high noise level in this band is an artifact of the calibration process. An FM band stop filter was used, which increased the RF loss and caused the system noise to be artificially increased, post-calibration.

5.4.3 108 MHz to 138 MHz

The increase in the background noise level is clearly seen in the 108 MHz to 118 MHz portion of the band because of the use of an FM band stop filter.
6. **Conclusion**

6.1 **Introduction**

Shared Spectrum Company concludes that less than 3.4% of the spectrum opportunities, both in frequency and time, were utilized at the Riverbend site on April 7, 2004. Analyses regarding these spectrum occupancy conclusions are provided in Table 8 for each band for the fixed antenna measurements.

6.2 **Occupancy in Each Band**

The percentage occupancy for each band is shown in the right column in Table 8. The average duty cycle (in frequency and time) of each band is noted on the related spectrum plots shown in Section 0. The amount of spectrum occupied is then calculated by multiplying the bandwidth and the corresponding average duty cycle together. Bands with high occupancy include the TV bands, the cell phone/SM band, and the PCS band. Many bands have effectively 0% occupancy.

6.3 **Overall Occupancy**

The overall occupancy at this location (3.4%) is shown in the bottom row of Table 8. The total available spectrum (2570 MHz) is the sum of all of the bands measured (the 960 MHz to 1240 MHz band was not measured at this location). The overall occupied spectrum (87.62 MHz) is the sum from each band. The overall occupancy is the occupied spectrum divided by the total available spectrum.
<table>
<thead>
<tr>
<th>Start Freq (MHz)</th>
<th>Stop Freq (MHz)</th>
<th>Bandwidth (MHz)</th>
<th>Spectrum Band Allocation</th>
<th>Spectrum Fraction Used</th>
<th>Riverbend Occupied Spectrum (MHz)</th>
<th>Average Percent Occupied</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>54</td>
<td>24</td>
<td>PLM, Amateur, others</td>
<td>0.03895</td>
<td>0.93</td>
<td>3.9%</td>
</tr>
<tr>
<td>54</td>
<td>88</td>
<td>34</td>
<td>TV 2 - 6, RC</td>
<td>0.10593</td>
<td>3.60</td>
<td>10.6%</td>
</tr>
<tr>
<td>108</td>
<td>138</td>
<td>30</td>
<td>Air traffic Control, Aero Nav</td>
<td>0.00744</td>
<td>0.22</td>
<td>0.7%</td>
</tr>
<tr>
<td>138</td>
<td>174</td>
<td>36</td>
<td>Fixed Mobile, amateur, others</td>
<td>0.03372</td>
<td>1.21</td>
<td>3.4%</td>
</tr>
<tr>
<td>174</td>
<td>216</td>
<td>42</td>
<td>TV 7-13</td>
<td>0.10339</td>
<td>4.34</td>
<td>10.3%</td>
</tr>
<tr>
<td>216</td>
<td>225</td>
<td>9</td>
<td>Maritime Mobile, Amateur, others</td>
<td>0.00486</td>
<td>0.04</td>
<td>0.5%</td>
</tr>
<tr>
<td>225</td>
<td>406</td>
<td>181</td>
<td>Fixed Mobile, Aero, others</td>
<td>0.00002</td>
<td>0.00</td>
<td>0.0%</td>
</tr>
<tr>
<td>406</td>
<td>470</td>
<td>64</td>
<td>Amateur, Radio Geolocation, Fixed, Mobile, Radiolocation</td>
<td>0.02745</td>
<td>1.76</td>
<td>2.7%</td>
</tr>
<tr>
<td>470</td>
<td>512</td>
<td>42</td>
<td>TV 14-20</td>
<td>0.13313</td>
<td>5.59</td>
<td>13.3%</td>
</tr>
<tr>
<td>512</td>
<td>608</td>
<td>96</td>
<td>TV 21-36</td>
<td>0.26616</td>
<td>25.55</td>
<td>26.6%</td>
</tr>
<tr>
<td>608</td>
<td>698</td>
<td>90</td>
<td>TV 37-51</td>
<td>0.23484</td>
<td>21.14</td>
<td>23.5%</td>
</tr>
<tr>
<td>698</td>
<td>806</td>
<td>108</td>
<td>TV 52-69</td>
<td>0.07627</td>
<td>8.24</td>
<td>7.6%</td>
</tr>
<tr>
<td>806</td>
<td>902</td>
<td>96</td>
<td>Cell phone and SMR</td>
<td>0.14260</td>
<td>13.69</td>
<td>14.3%</td>
</tr>
<tr>
<td>902</td>
<td>928</td>
<td>26</td>
<td>Unlicensed</td>
<td>0.00000</td>
<td>0.00</td>
<td>0.0%</td>
</tr>
<tr>
<td>928</td>
<td>960</td>
<td>32</td>
<td>Paging, SMS, Fixed, BX Aux, and PMS</td>
<td>0.03460</td>
<td>1.11</td>
<td>3.5%</td>
</tr>
<tr>
<td>960</td>
<td>1240</td>
<td>280</td>
<td>IFF, TACAN, GPS, others</td>
<td>0.00000</td>
<td>0.00</td>
<td>0.0%</td>
</tr>
<tr>
<td>1240</td>
<td>1300</td>
<td>60</td>
<td>Amateur</td>
<td>0.00139</td>
<td>0.08</td>
<td>0.1%</td>
</tr>
<tr>
<td>1300</td>
<td>1400</td>
<td>100</td>
<td>Aero Radar, military</td>
<td>0.00022</td>
<td>0.02</td>
<td>0.0%</td>
</tr>
<tr>
<td>1400</td>
<td>1525</td>
<td>125</td>
<td>Space/Satellite, Fixed Mobile, Telemetry</td>
<td>0.00000</td>
<td>0.00</td>
<td>0.0%</td>
</tr>
<tr>
<td>1525</td>
<td>1710</td>
<td>185</td>
<td>Mobile Satellite, GPS L1, Mobile Satellite, Meteorological</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1710</td>
<td>1850</td>
<td>140</td>
<td>Fixed, Fixed Mobile</td>
<td>0.00000</td>
<td>0.00</td>
<td>0.0%</td>
</tr>
<tr>
<td>1850</td>
<td>1990</td>
<td>140</td>
<td>PCS, Asyn, Iso</td>
<td>0.00044</td>
<td>0.06</td>
<td>0.0%</td>
</tr>
<tr>
<td>1990</td>
<td>2110</td>
<td>120</td>
<td>TV Aux</td>
<td>0.00000</td>
<td>0.00</td>
<td>0.0%</td>
</tr>
<tr>
<td>2110</td>
<td>2200</td>
<td>90</td>
<td>Common Carriers, Private Companies, MDS</td>
<td>0.00000</td>
<td>0.00</td>
<td>0.0%</td>
</tr>
<tr>
<td>2200</td>
<td>2300</td>
<td>100</td>
<td>Space Operation, Fixed</td>
<td>0.00000</td>
<td>0.00</td>
<td>0.0%</td>
</tr>
<tr>
<td>2300</td>
<td>2360</td>
<td>60</td>
<td>Amateur, WCS, DARS</td>
<td>0.00000</td>
<td>0.00</td>
<td>0.0%</td>
</tr>
<tr>
<td>2360</td>
<td>2390</td>
<td>30</td>
<td>Telemetry</td>
<td>0.00000</td>
<td>0.00</td>
<td>0.0%</td>
</tr>
<tr>
<td>2390</td>
<td>2500</td>
<td>110</td>
<td>U-PCS, ISM (Unlicensed)</td>
<td>0.00022</td>
<td>0.02</td>
<td>0.0%</td>
</tr>
<tr>
<td>2500</td>
<td>2686</td>
<td>186</td>
<td>ITFS, MMDS</td>
<td>0.00000</td>
<td>0.00</td>
<td>0.0%</td>
</tr>
<tr>
<td>2686</td>
<td>2900</td>
<td>214</td>
<td>Surveillance Radar</td>
<td>0.00000</td>
<td>0.00</td>
<td>0.0%</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>0.00000</td>
<td>0.00</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

Total Available Spectrum: 2850 MHz
Average Spectrum Use (%): 3.4%