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

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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.

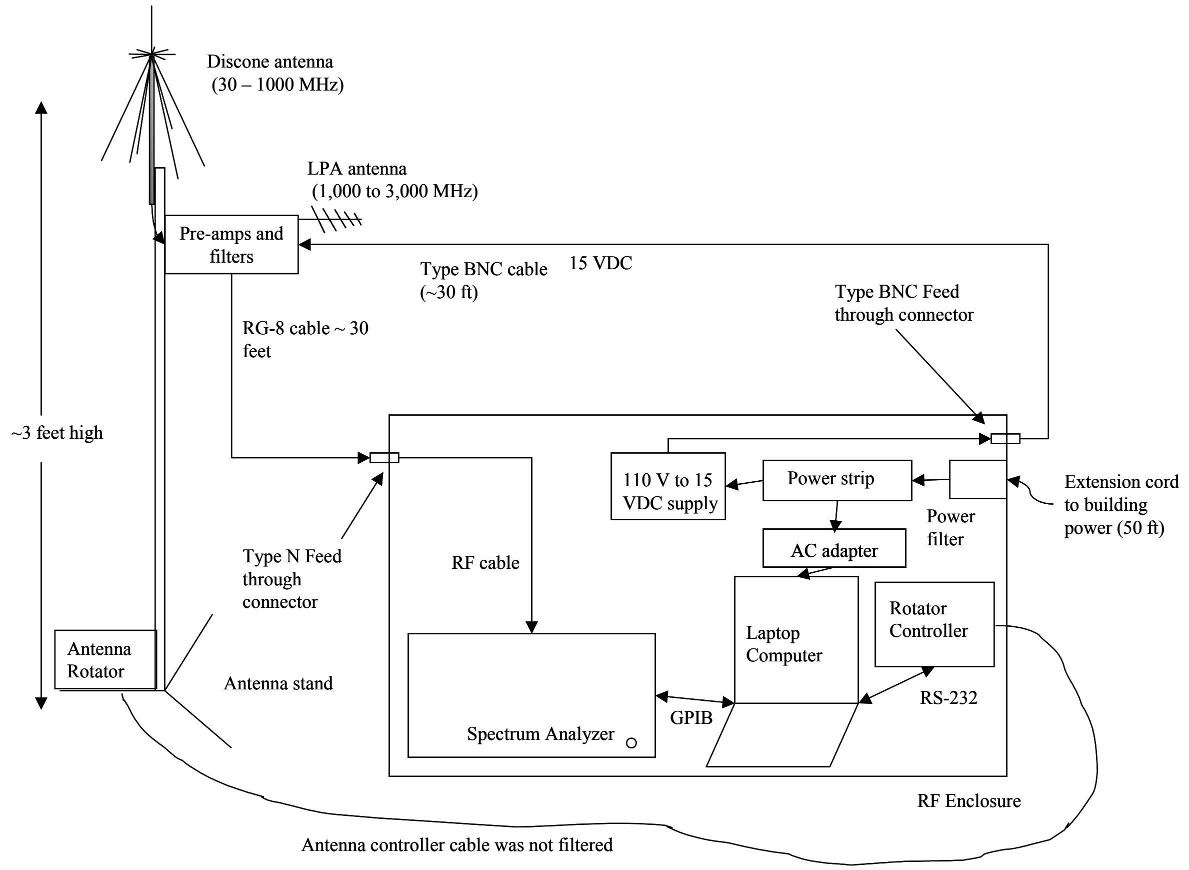

Figure 1: Spectrum occupancy measurement equipment configuration.

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.

Figure 2: RF Shielded Enclosure Used With the Spectrum Analyzer and Laptop Computer

The spectrum analyzer specifications are shown in Table 1.

Table 1. Rohde and Schwarz ESPI Spectrum Analyzer Parameters

Parameter	Value
Frequency Range	9 kHz to 3 GHz
Pre-selector	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 (>2,000 MHz).
Noise Figure	21.5 dB
Input Third Order Intercept Point	+10 dBm (typ), +5 dBm (with pre-selector on)
Input Second Order Intercept Point	+35 dBm (typ), +5 dBm (with pre-selector on)
Phase Noise	-106 dB/Hz at 10 kHz offset
Sweep Time	320 ms sweep time for 100 MHz sweep and 10 kHz RBW, 100 ms sweep time for 10 MHz sweep and 10 kHz RBW.

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, C7RFM3NFNF 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.

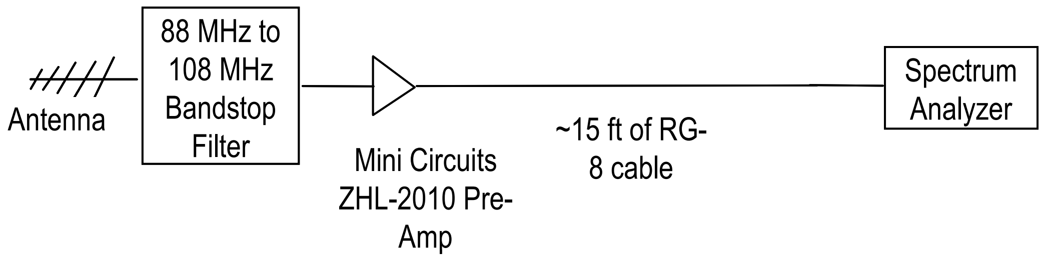

Figure 3: Equipment configuration used for signals below 1,000 MHz.

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.

Figure 5: Directional LPA Antenna (used for frequencies below 1,000 MHz)

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.

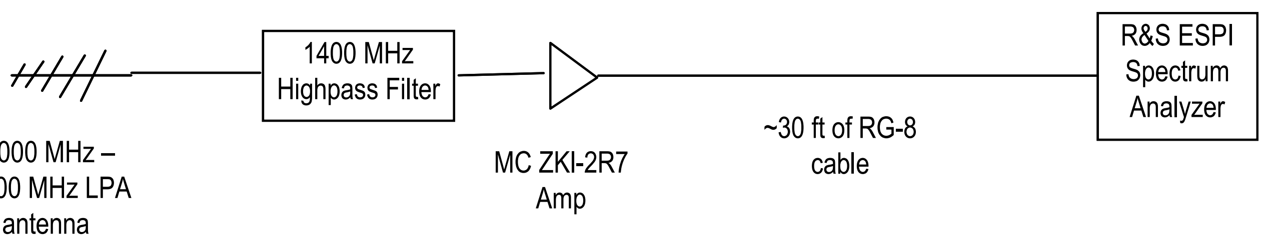

Figure 6: Equipment configuration used for signals above 1,000 MHz.

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

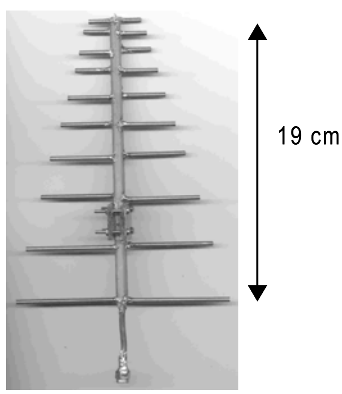

Figure 8: Log-Periodic Array (LPA), Directional Antenna Used for 1,000 MHz to 3,000 MHz.

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 2. General Equipment Configuration Parameters

Parameter	Value
Antenna Type	=0 for no antenna (system noise), =1 for discone, =2 for large LPA, =3 for small LPA
Cable Type	=1 for (1) RG-8 cables, =2 for (2) RG-8 cables, =3 for (3) RG-8 cables, =4 for short orange cable
Attenuation	=Value of fixed attenuator in dB =0 for none, XX dB otherwise, XX > 0
Filter Type	=0 for none, =1 for 30-88 MHz bandpass, =2 for 225-450 MHz bandpass, =3 for 1400 MHz highpass, =4 for FM Bandstop (HLC-700)
Pre-Amplifier Type	=0 for none, =1 for MC ZHL-2010, =2 for (3) MC ERA-5, =3 for MC ZKL-2R7

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

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

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) where 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

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 4. Frequency List Used to Collect Data Below 1,000 MHz

Start Freq (MHz)	Stop Freq (MHz)	Ref Level (dBm)	dB/div	Res_BW (Hz)	Vid_BW (Hz)	Attenuation (dB)	Sweep Time (sec)
30	54	-10	10	1.00E+04	1.00E+04	10	0.3
54	88	-10	10	1.00E+04	1.00E+04	10	0.425
88	108	-10	10	1.00E+04	1.00E+04	10	0.25
108	138	-10	10	1.00E+04	1.00E+04	10	0.375
138	174	-10	10	1.00E+04	1.00E+04	10	0.45
174	216	-10	10	1.00E+04	1.00E+04	10	0.525
216	225	-10	10	1.00E+04	1.00E+04	10	0.1125
225	406	-10	10	1.00E+04	1.00E+04	10	2.2625
406	470	-10	10	1.00E+04	1.00E+04	10	0.8
470	512	-10	10	1.00E+04	1.00E+04	10	0.525
512	608	-10	10	1.00E+04	1.00E+04	10	1.2
608	698	-10	10	1.00E+04	1.00E+04	10	1.125
698	806	-10	10	1.00E+04	1.00E+04	10	1.35
806	902	-10	10	1.00E+04	1.00E+04	10	1.2
902	928	-10	10	1.00E+04	1.00E+04	10	0.325
928	960	-10	10	1.00E+04	1.00E+04	10	0.4

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

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

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

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

Table 7. Spectrum Measurement Files - Stationary

Date	Location	Comment	Freq List Input Filename	Start Time	End Time	File Prefix	Start File Number	End File Number	Number of Files	Duration (sec)
20040407	Riverbend Park	30-960MHz	List B,A	12:34	13:34	nsf	795	907	113	3600
20040507	Riverbend Park	1-3GHz	List_B	15:05	15:55	nsf	985	1056	77	3000

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

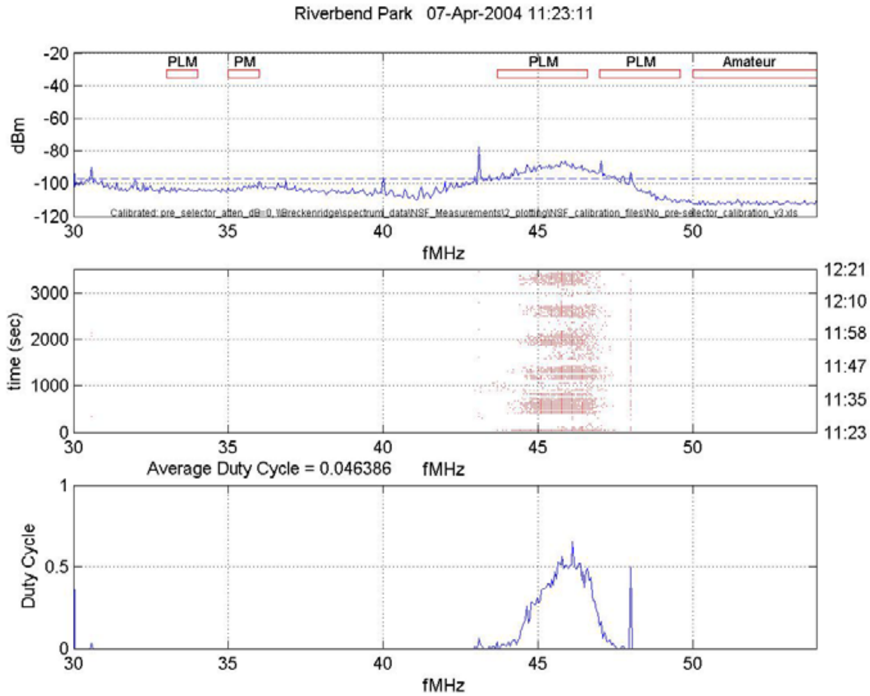

Figure 16: 30 MHz to 54 MHz, Rotating

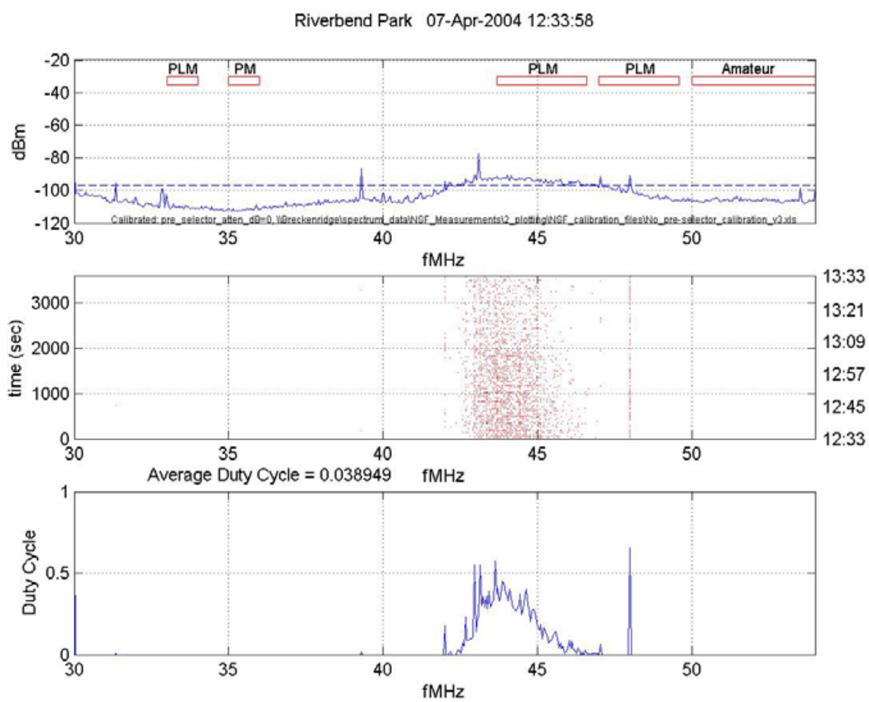

Figure 17: 30 MHz – 54 MHz, Stationary

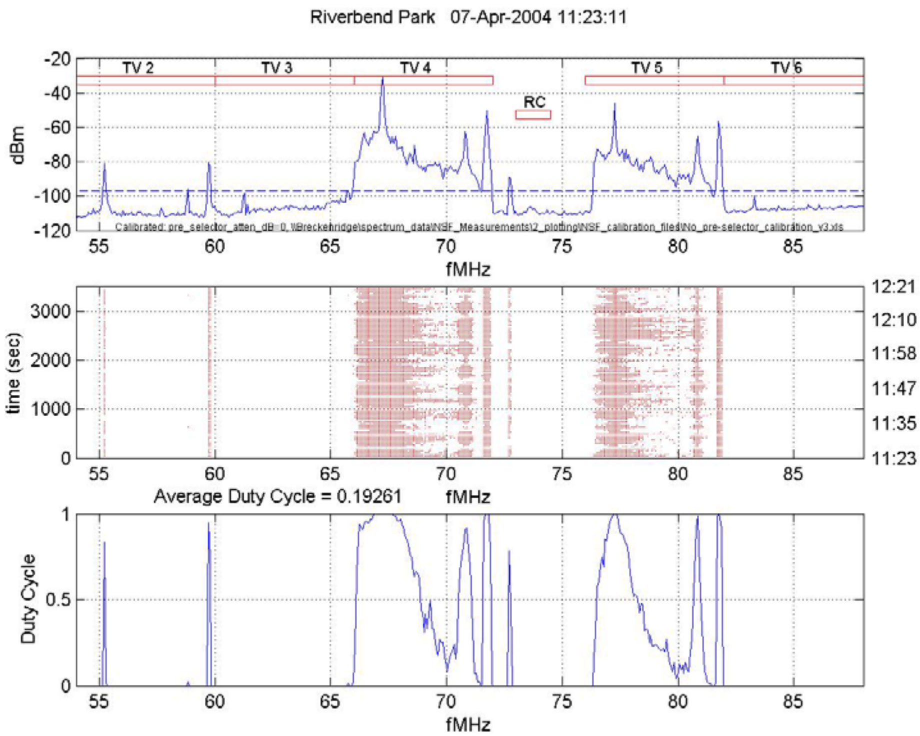

Figure 18: 54 MHz to 88 MHz, Rotating

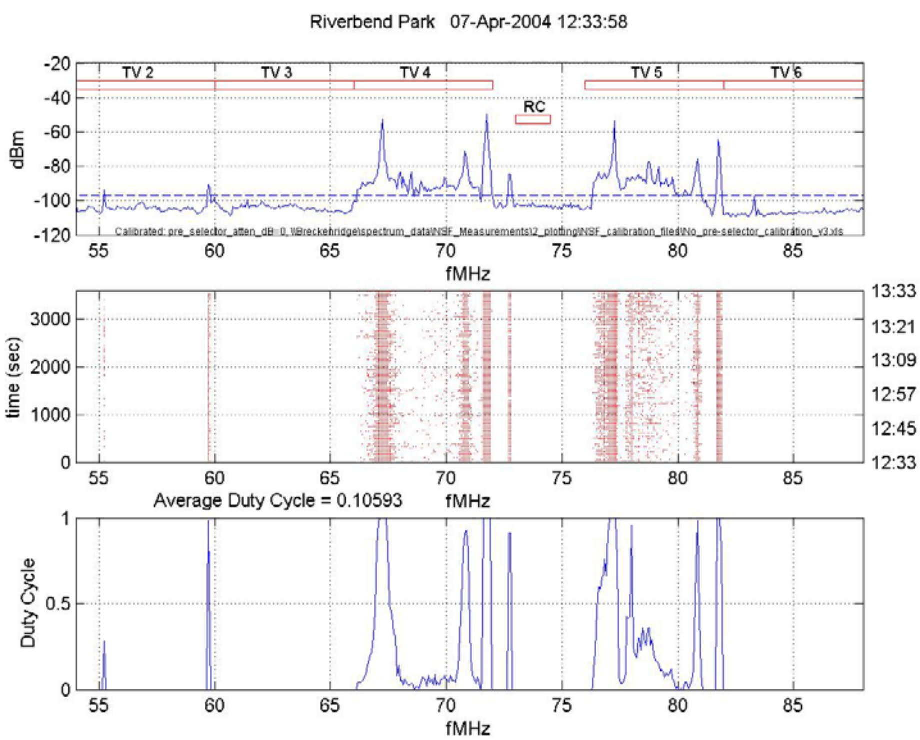

Figure 19: 54 MHz – 88 MHz, Stationary

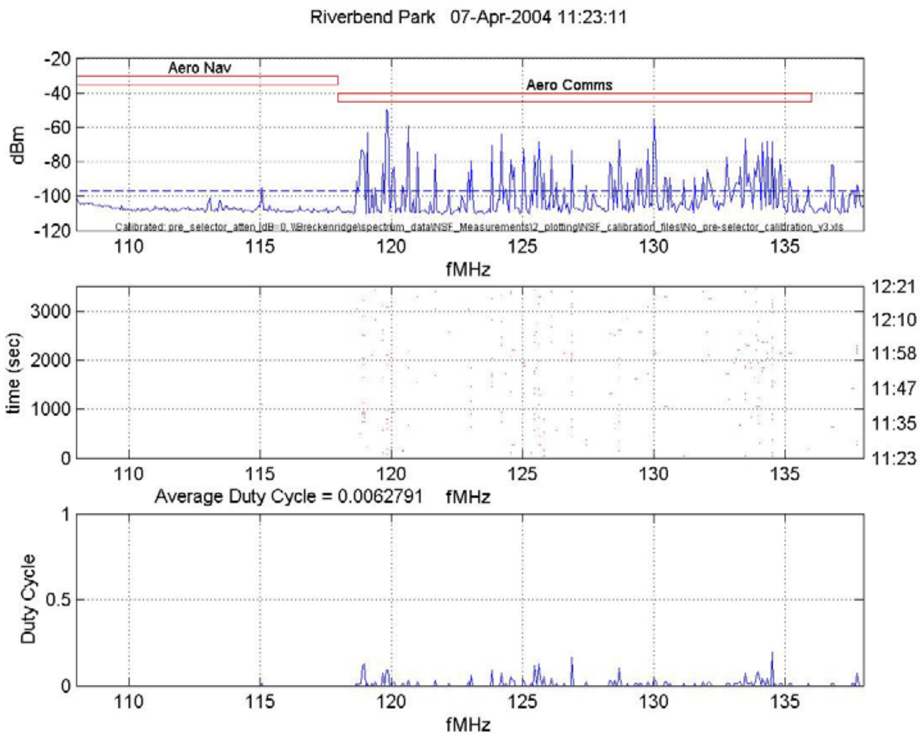

Figure 20: 108 MHz to 138 MHz, Rotating

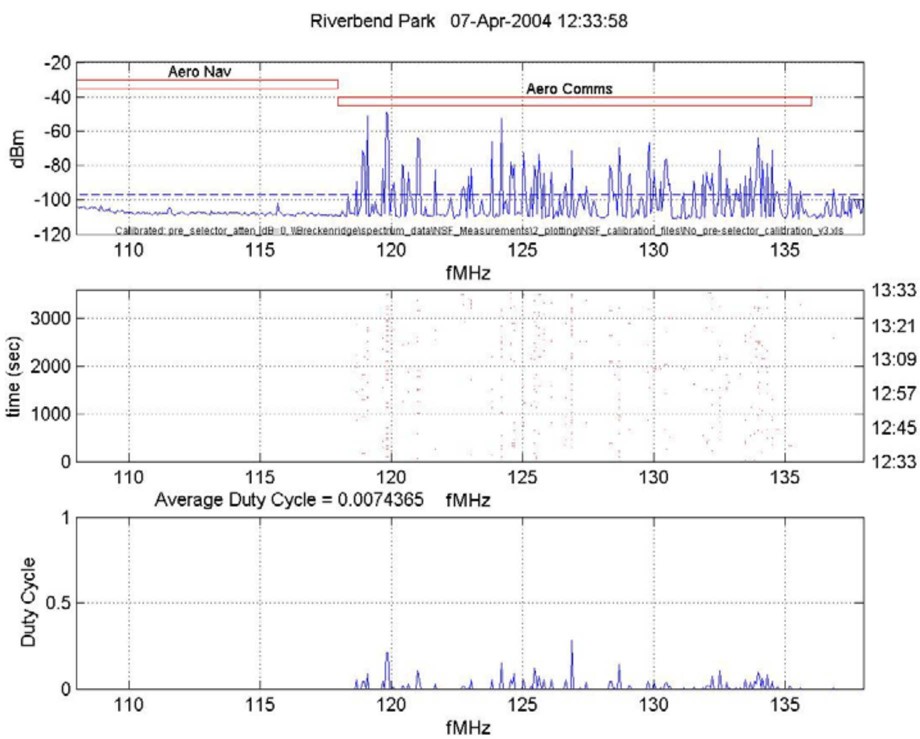

Figure 21: 108 MHz – 138 MHz, Stationary

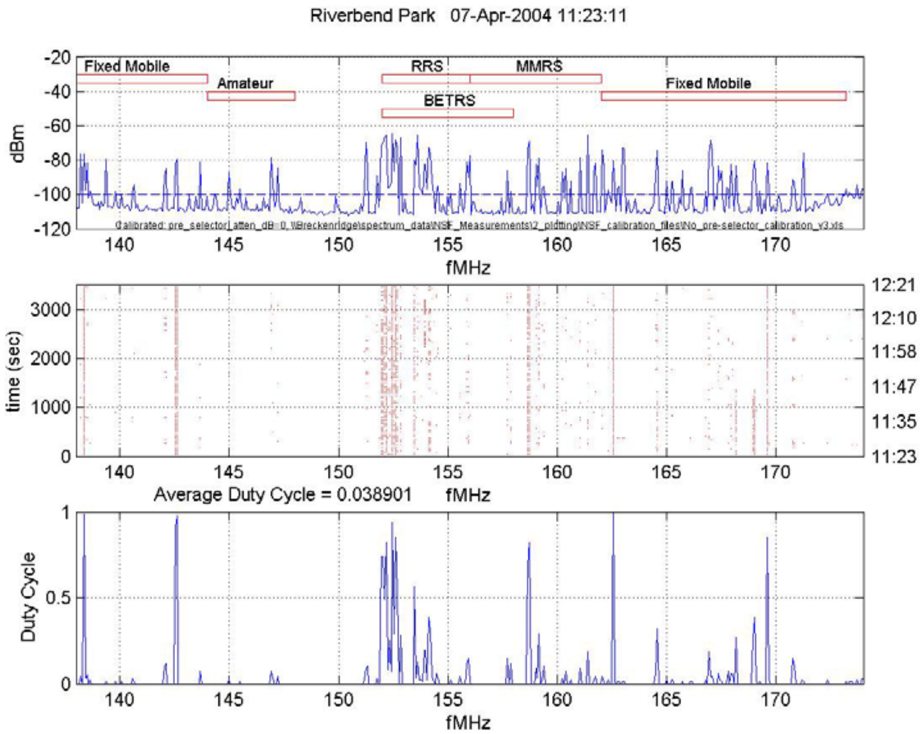

Figure 22: 138 MHz to 174 MHz, Rotating

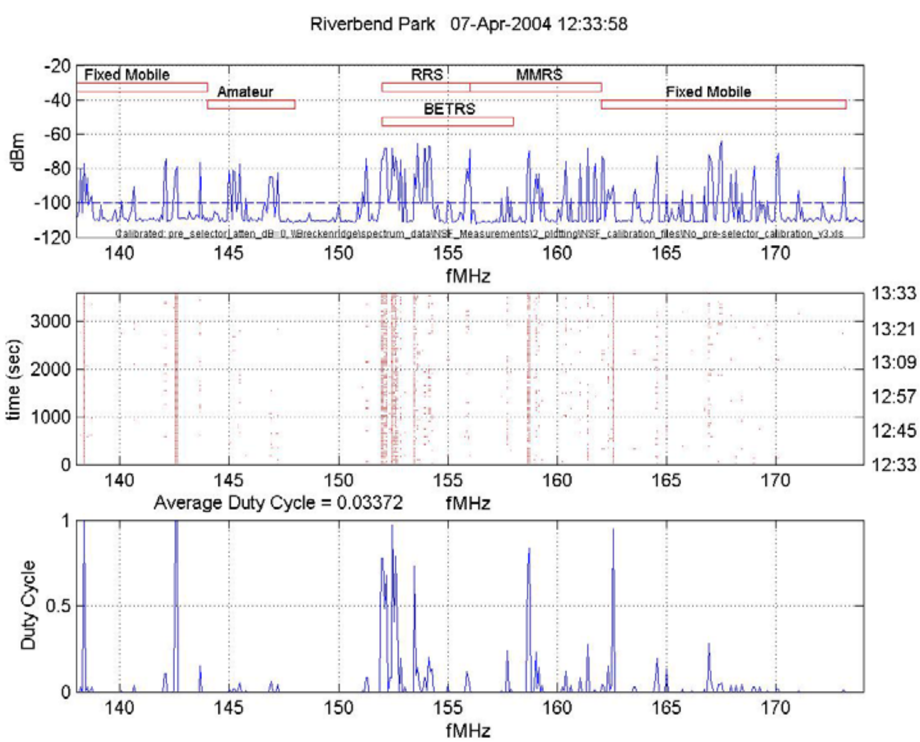

Figure 23: 138 MHz –174 MHz, Stationary

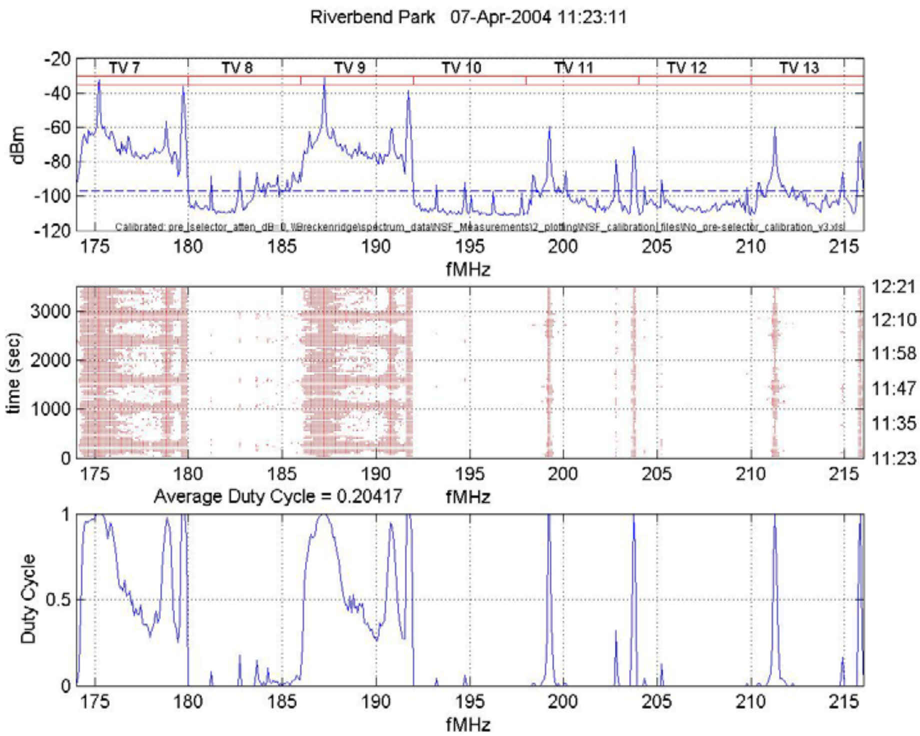

Figure 24: 174 MHz to 216 MHz, Rotating

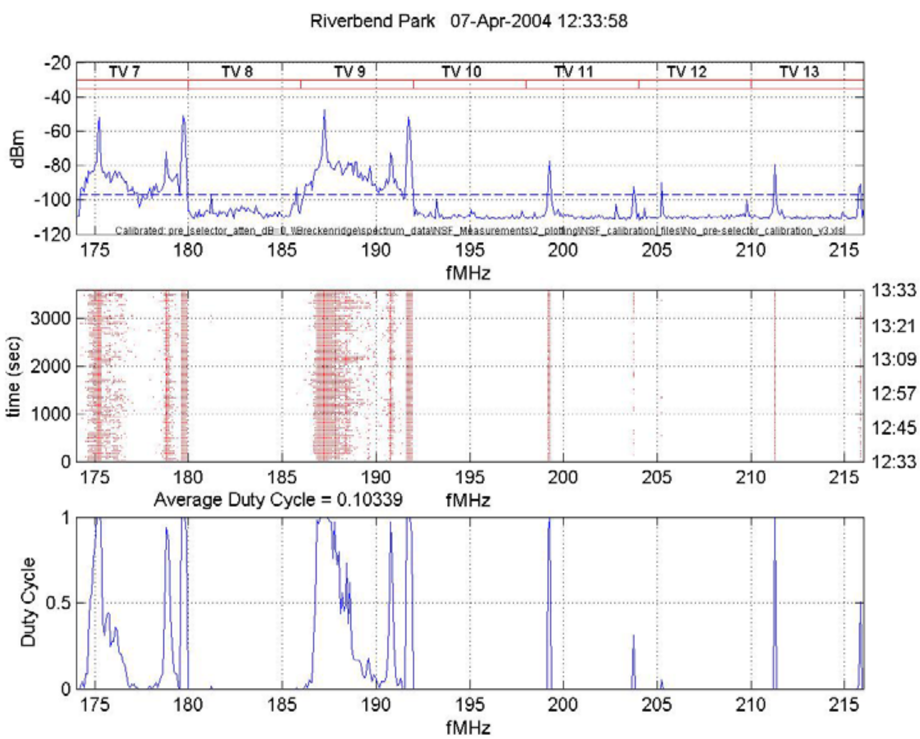

Figure 25: 174 MHz – 216 MHz, Stationary

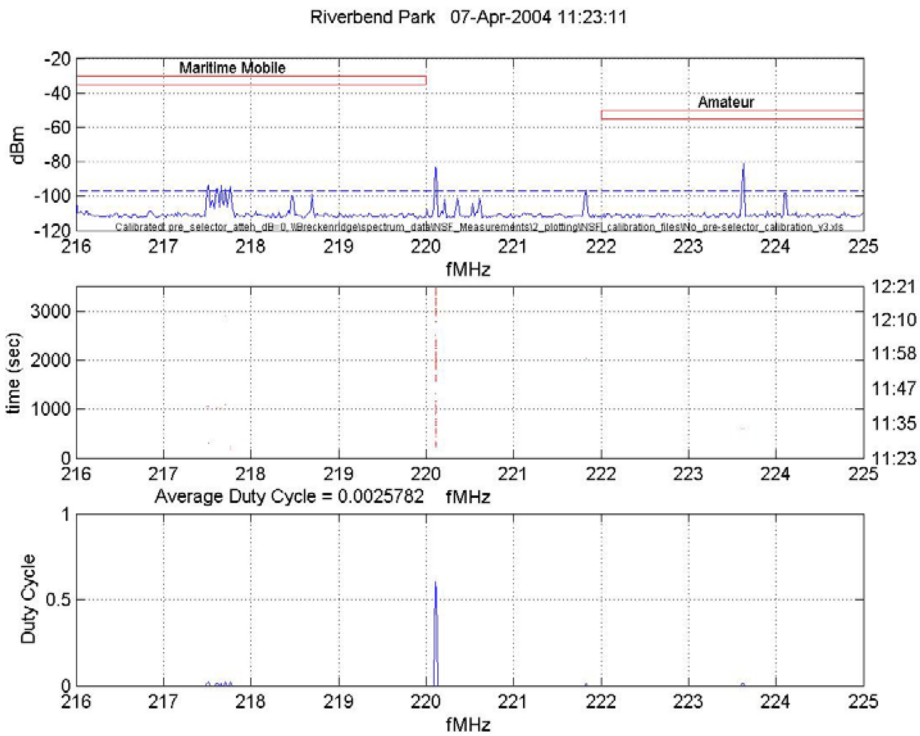

Figure 26: 216 MHz to 225 MHz, Rotating

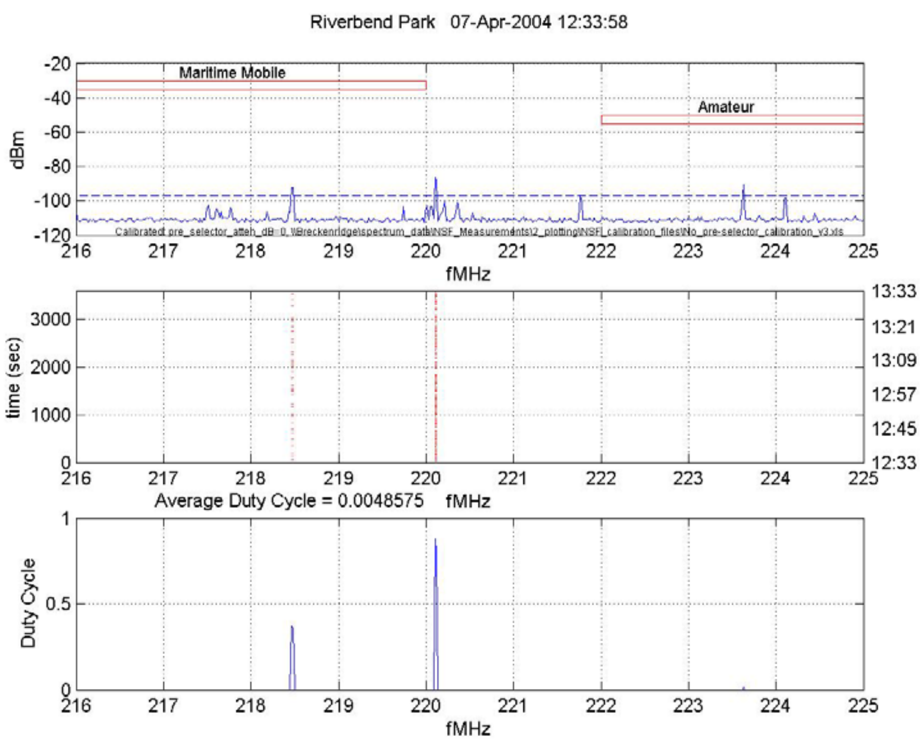

Figure 27: 216 MHz – 225 MHz, Stationary

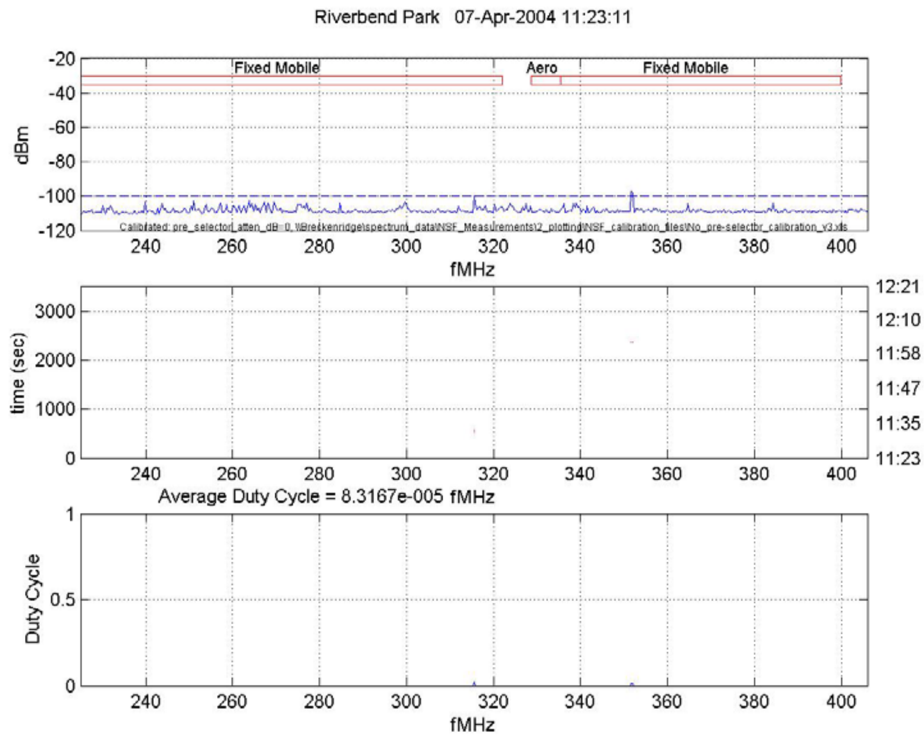

Figure 28: 225 MHz to 406 MHz, Rotating

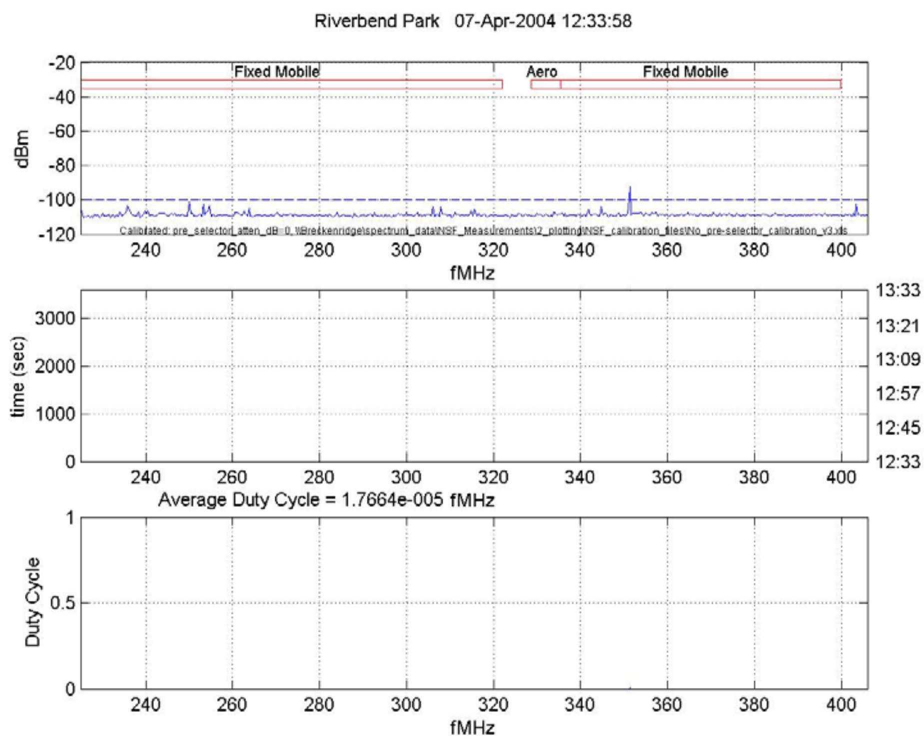

Figure 29: 225 MHz to 406 MHz, Stationary

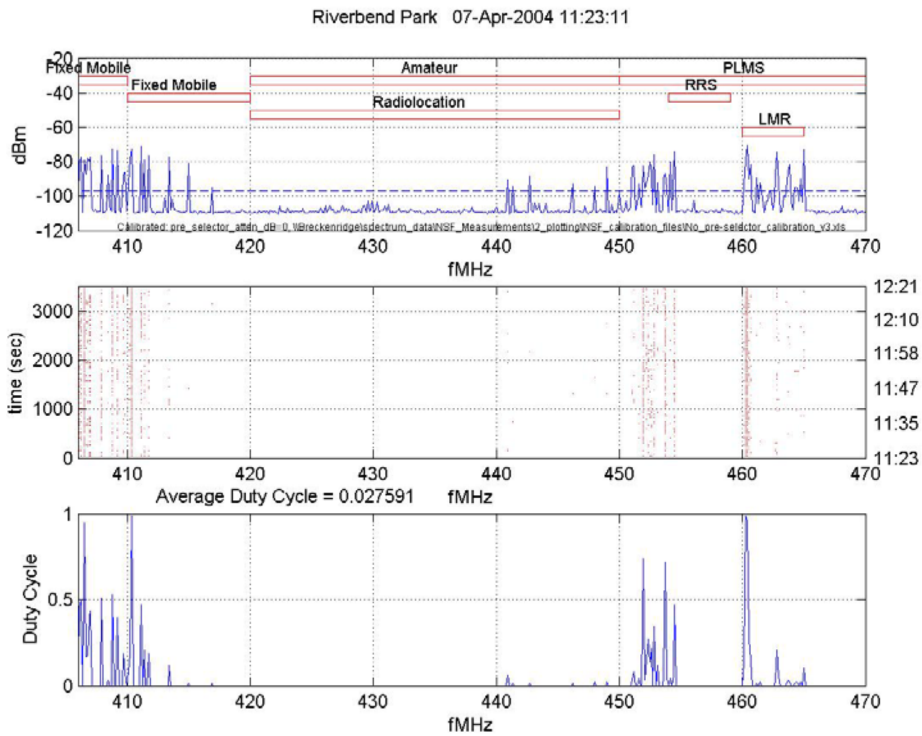

Figure 30: 406 MHz to 470 MHz, Rotating

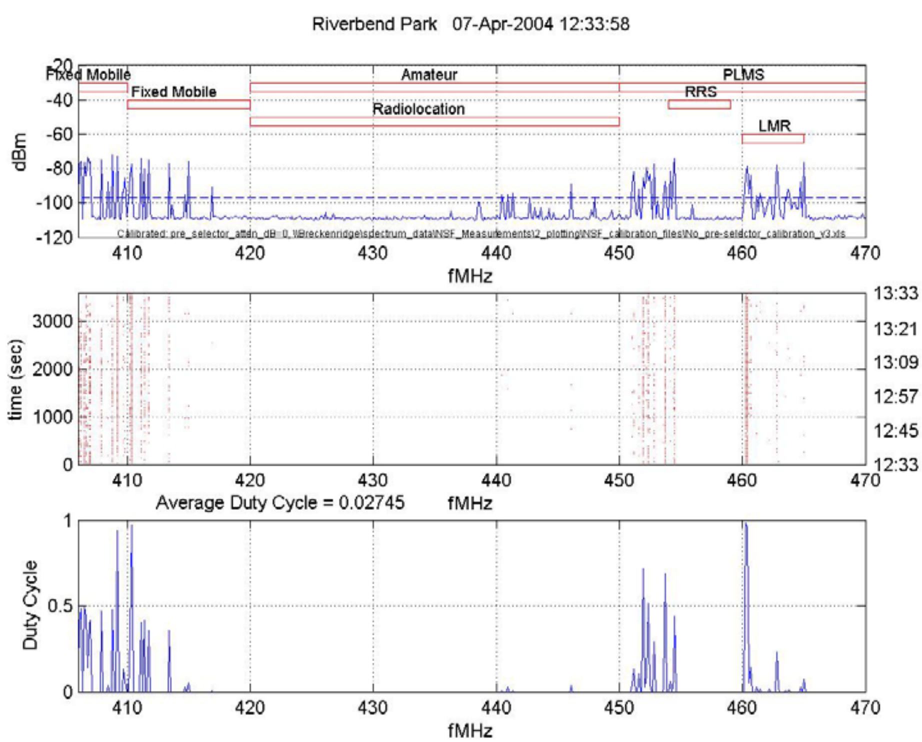

Figure 31: 406 MHz – 470 MHz, Stationary

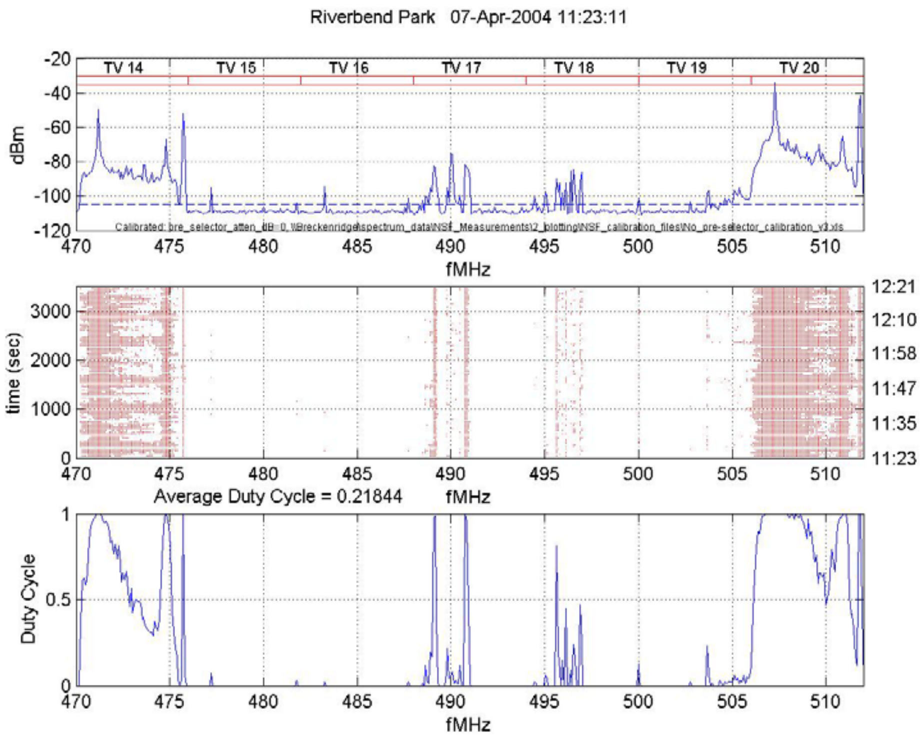

Figure 32: 470 MHz to 512 MHz, Rotating

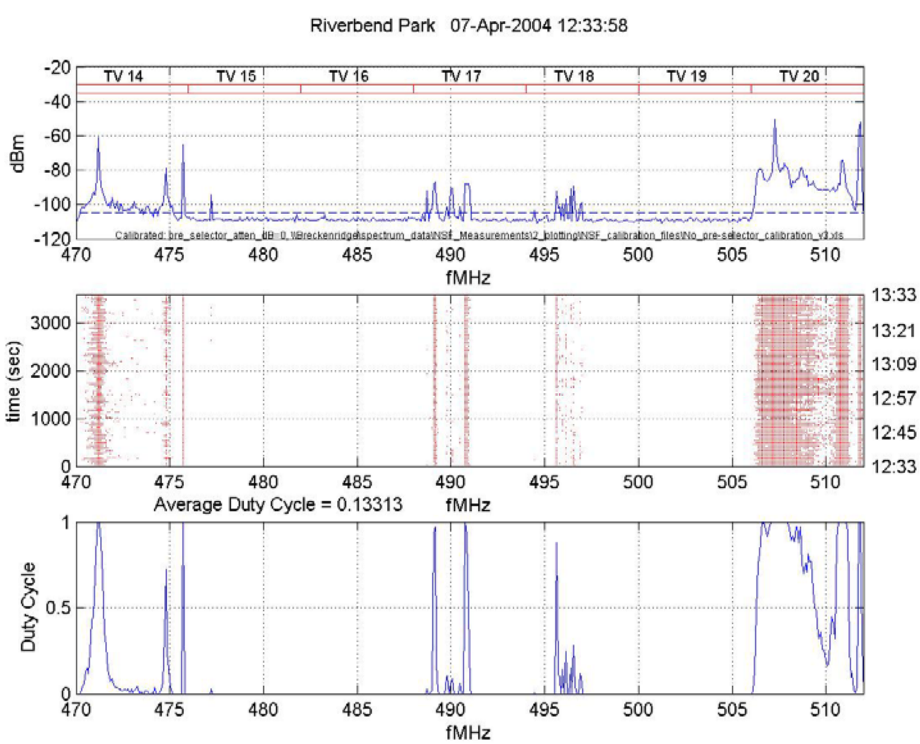

Figure 33: 470 MHz – 512 MHz, Stationary

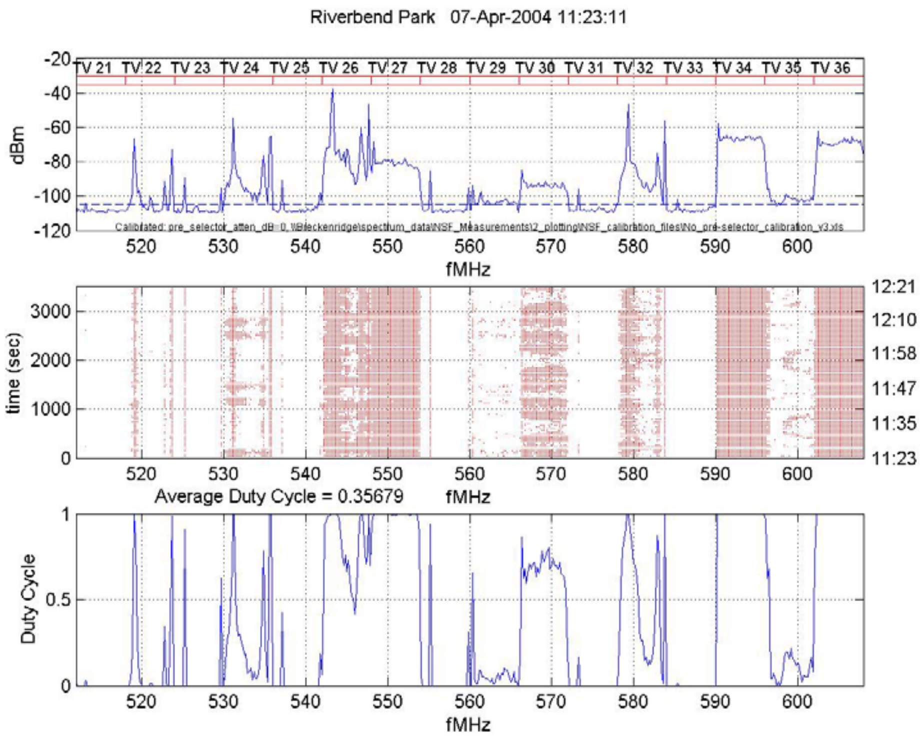

Figure 34: 512 MHz to 608 MHz, Rotating

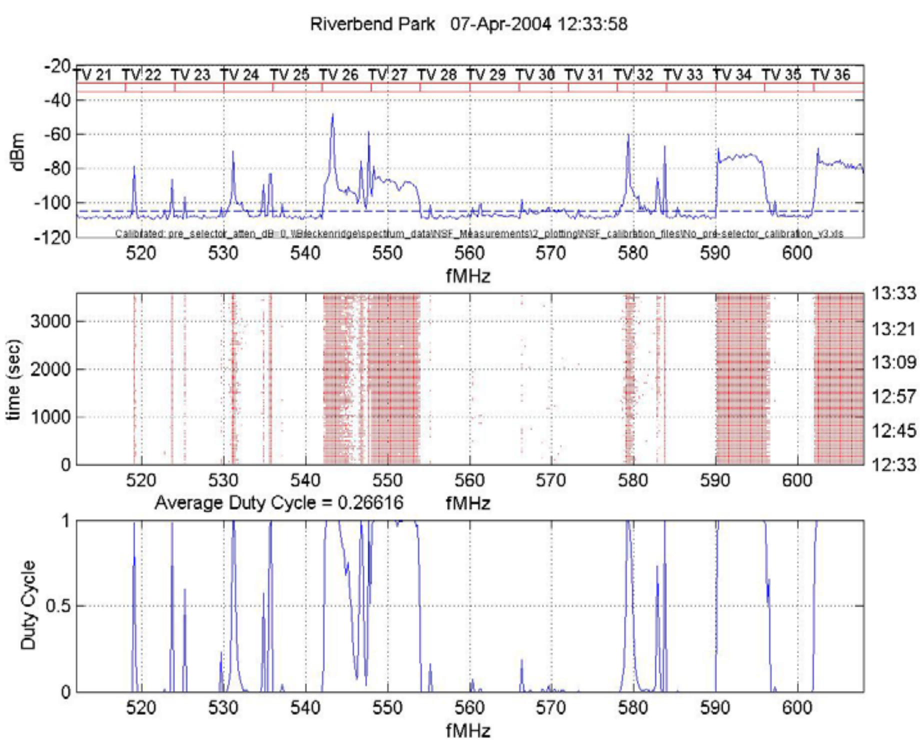

Figure 35: 512 MHz – 608 MHz, Stationary

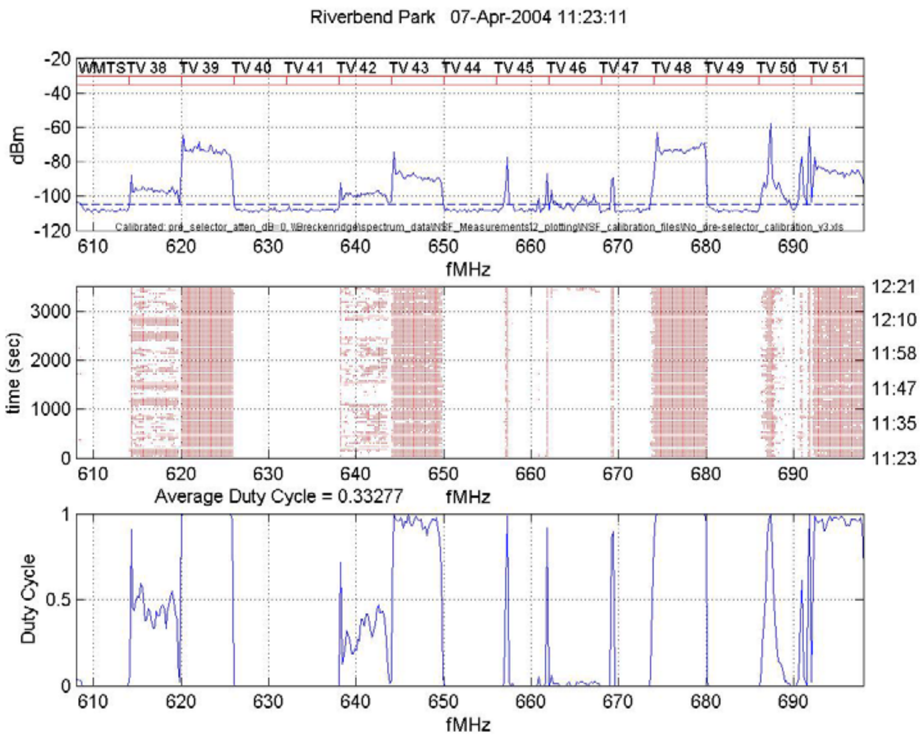

Figure 36: 608 MHz to 698 MHz, Rotating

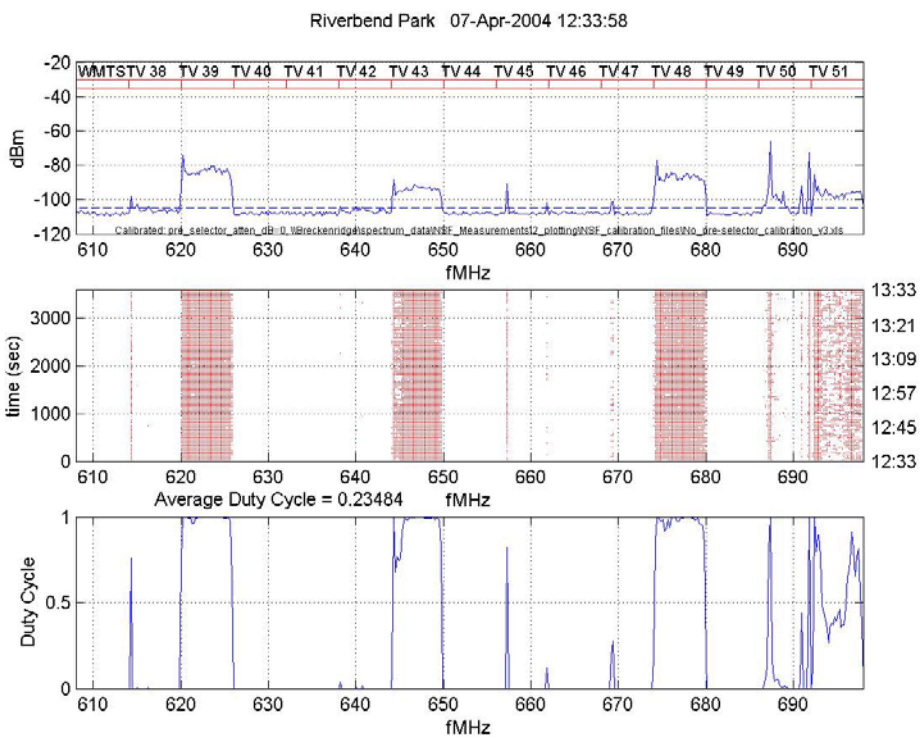

Figure 37: 608 MHz – 698 MHz, Stationary

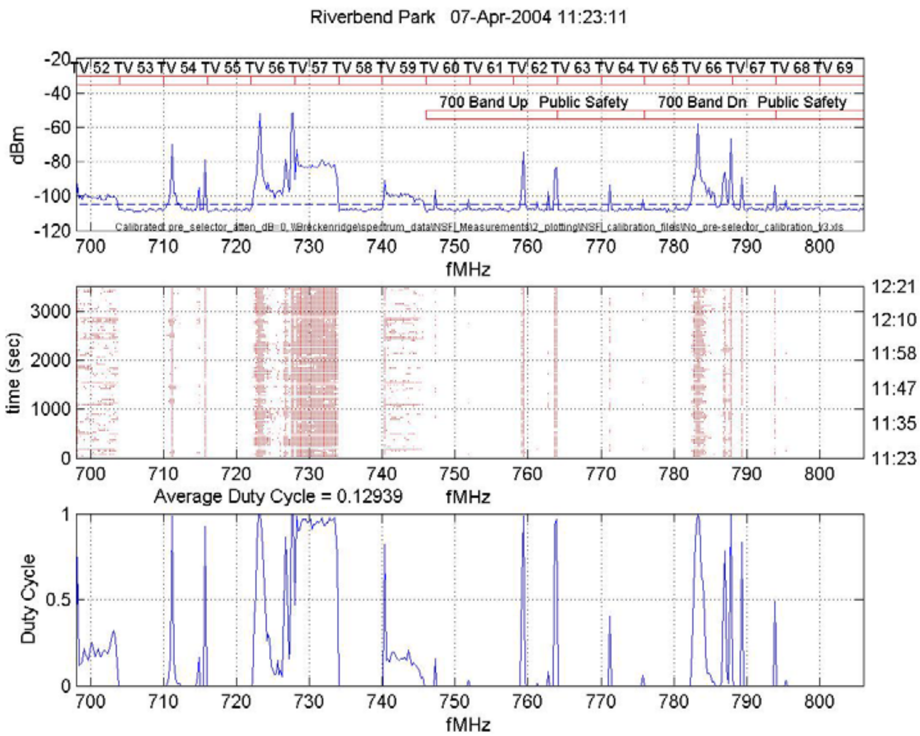

Figure 38: 698 MHz to 806 MHz, Rotating

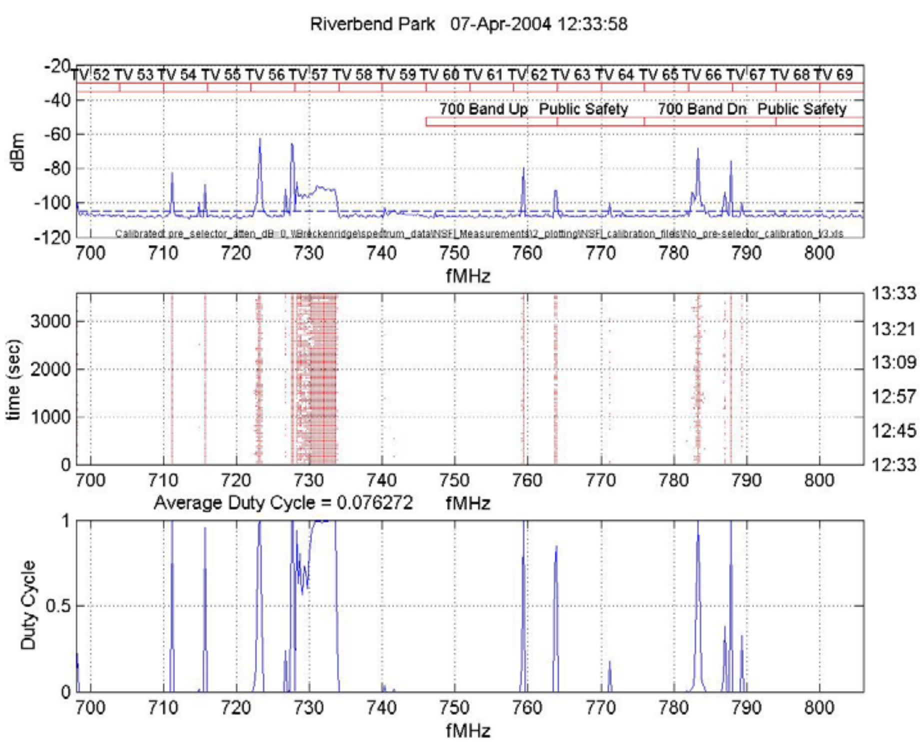

Figure 39: 698 MHz – 806 MHz, Stationary

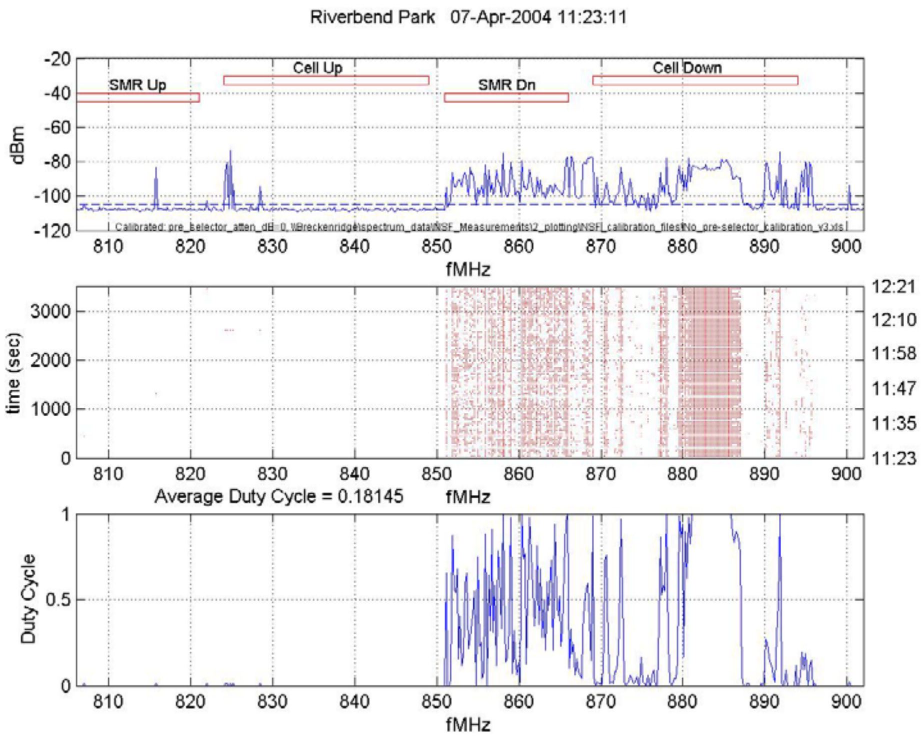

Figure 40: 806 MHz to 902 MHz, Rotating

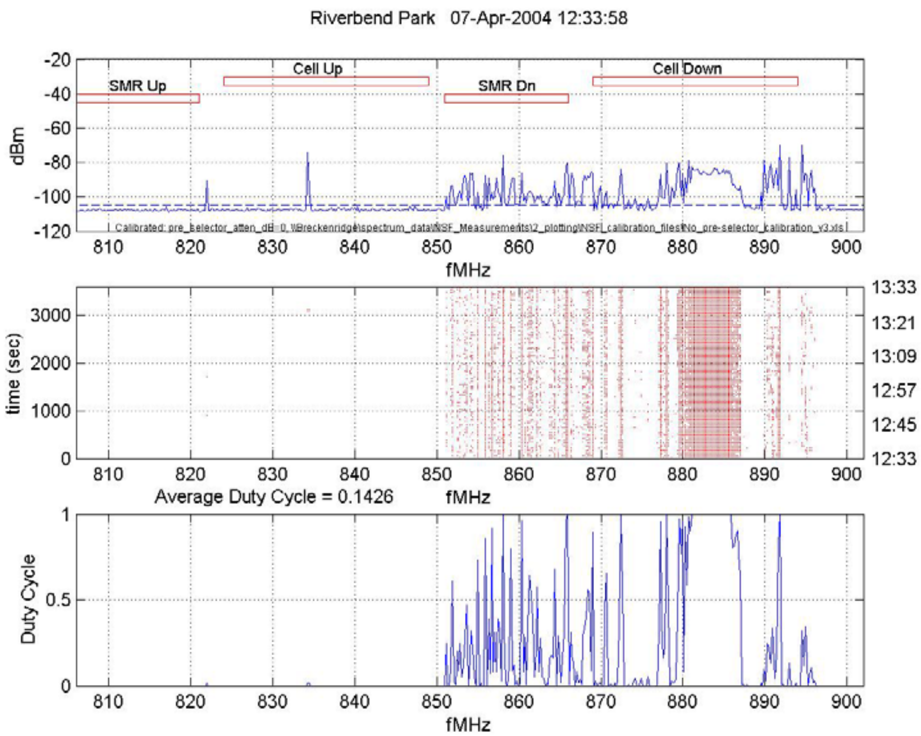

Figure 41: 806 MHz – 902 MHz, Stationary

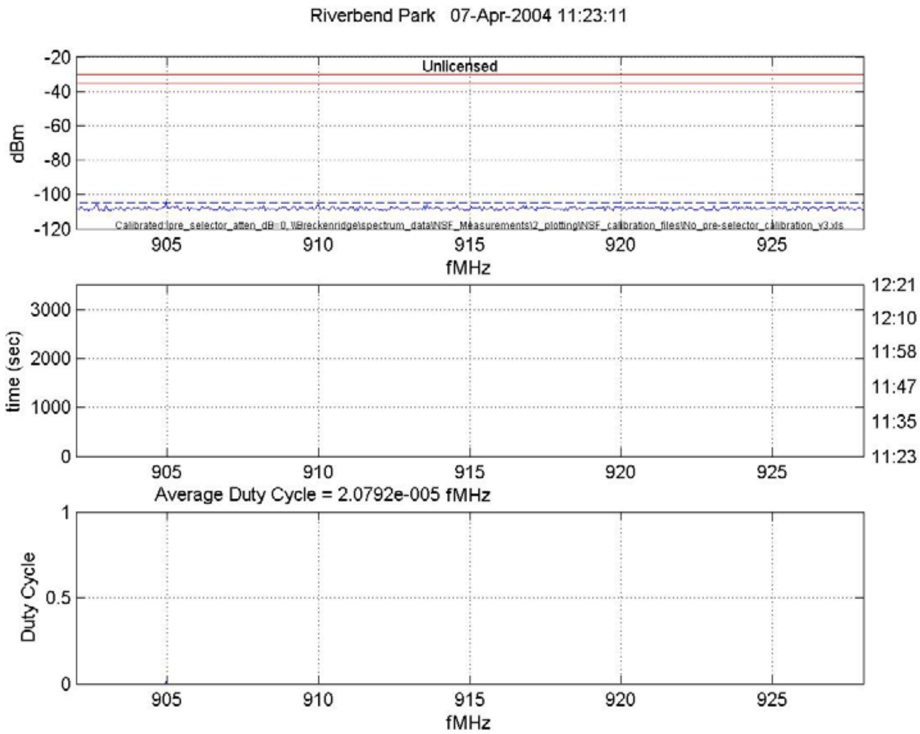

Figure 42: 902 MHz to 928 MHz, Rotating

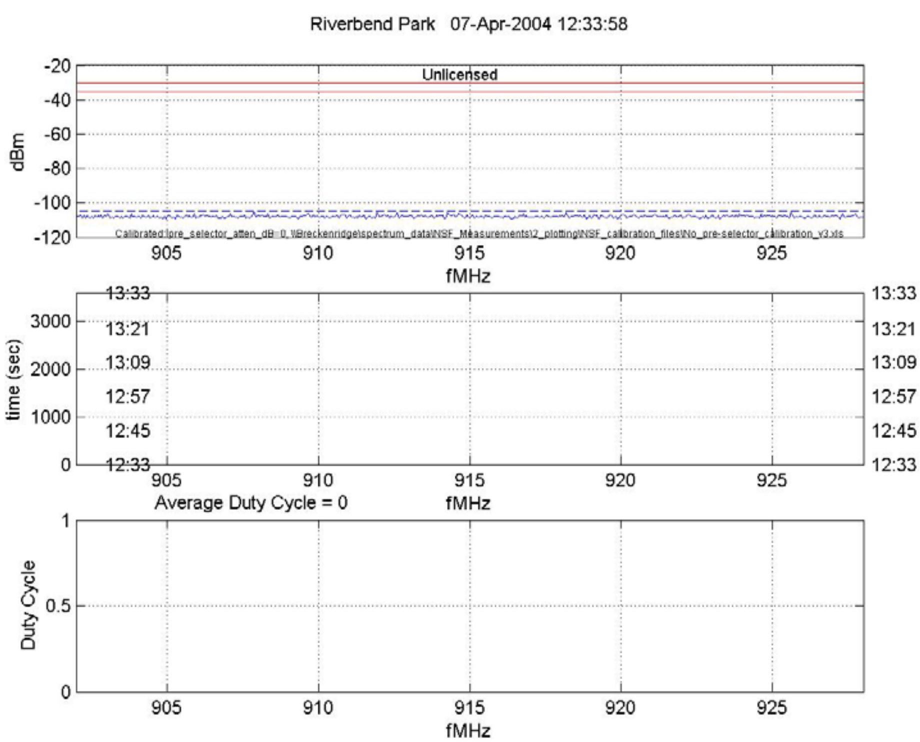

Figure 43: 902 MHz – 928 MHz, Stationary

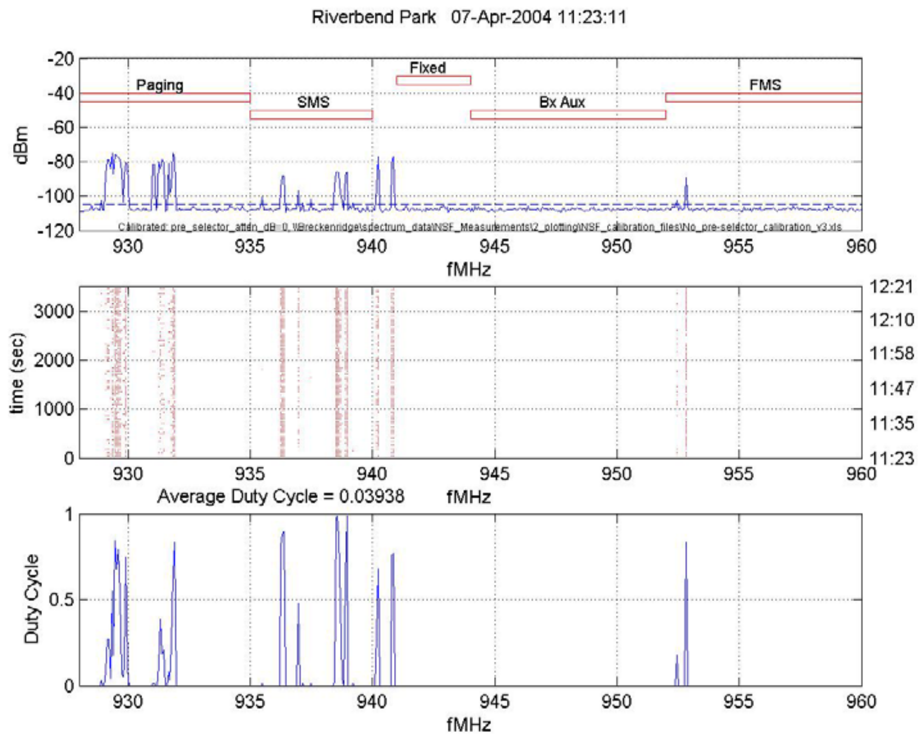

Figure 44: 928 MHz to 960 MHz, Rotating

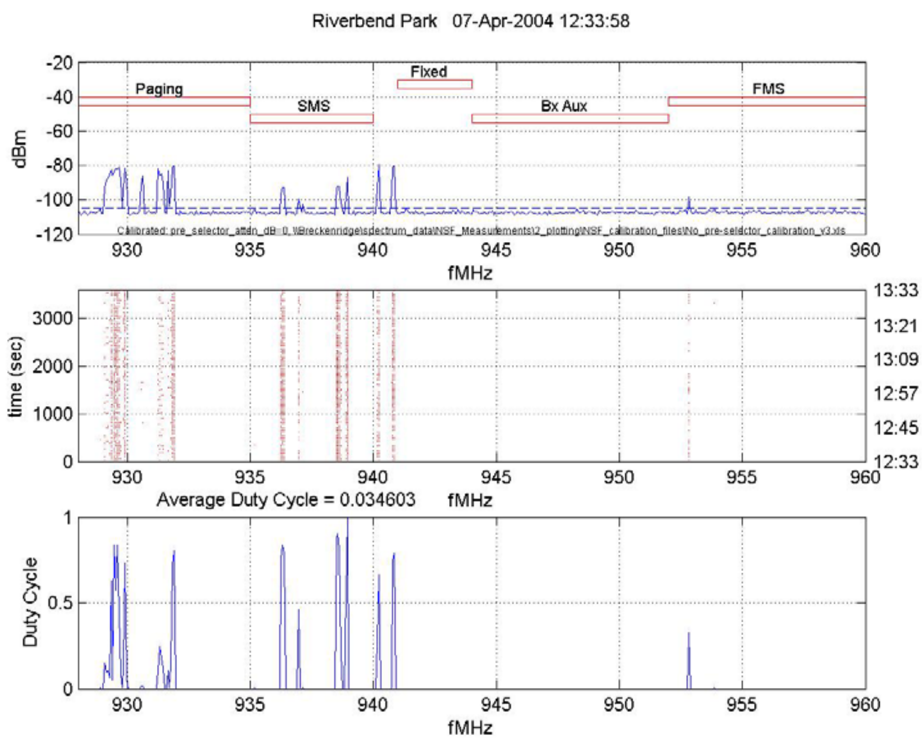

Figure 45: 928 MHz – 960 MHz, Stationary

5.3 Measurements Made Above 1,000 MHz

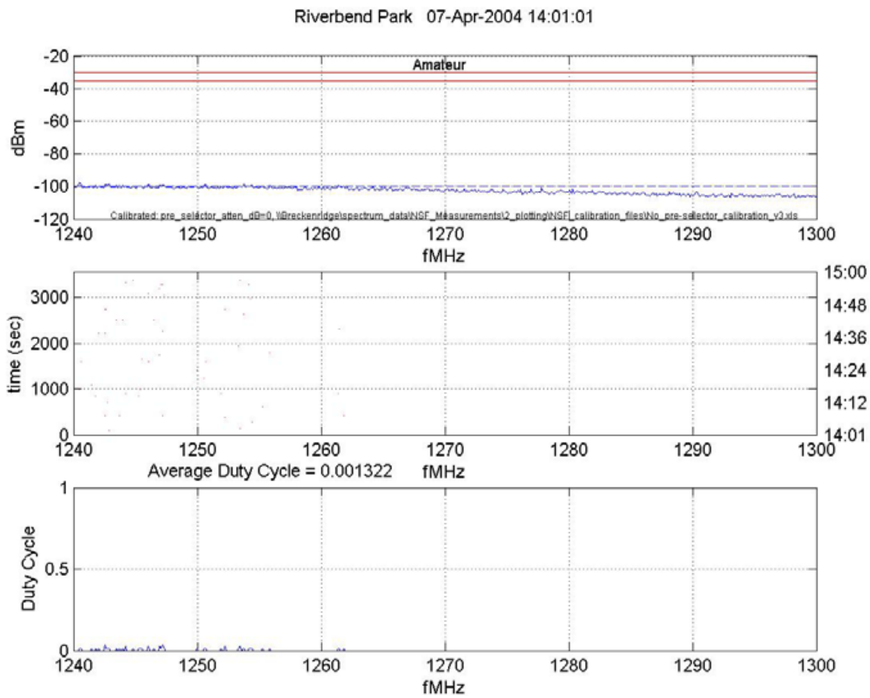

Figure 46: 1240 MHz to 1300 MHz, Rotating

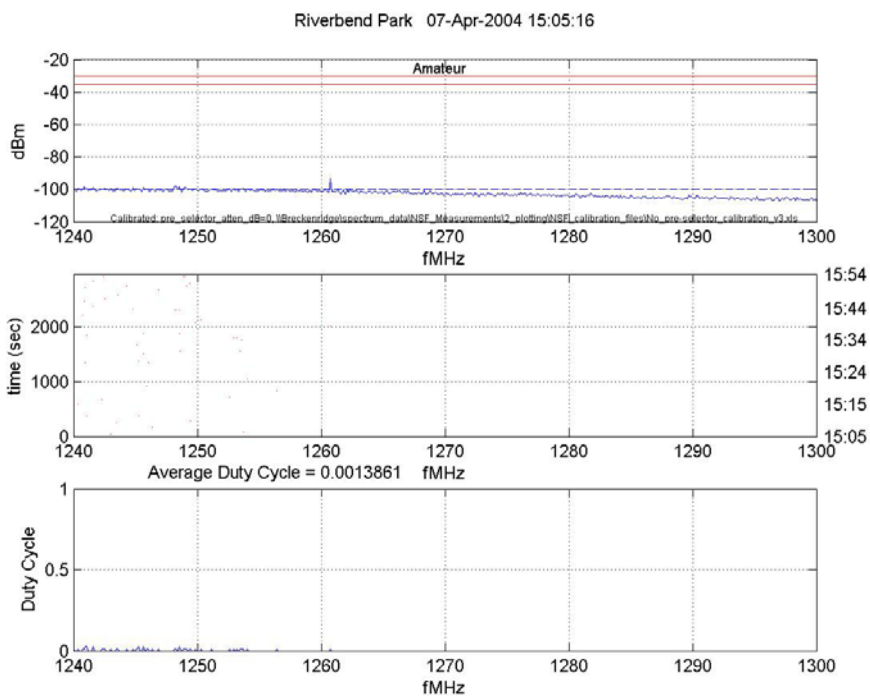

Figure 47: 1240 MHz to 1300 MHz, Stationary

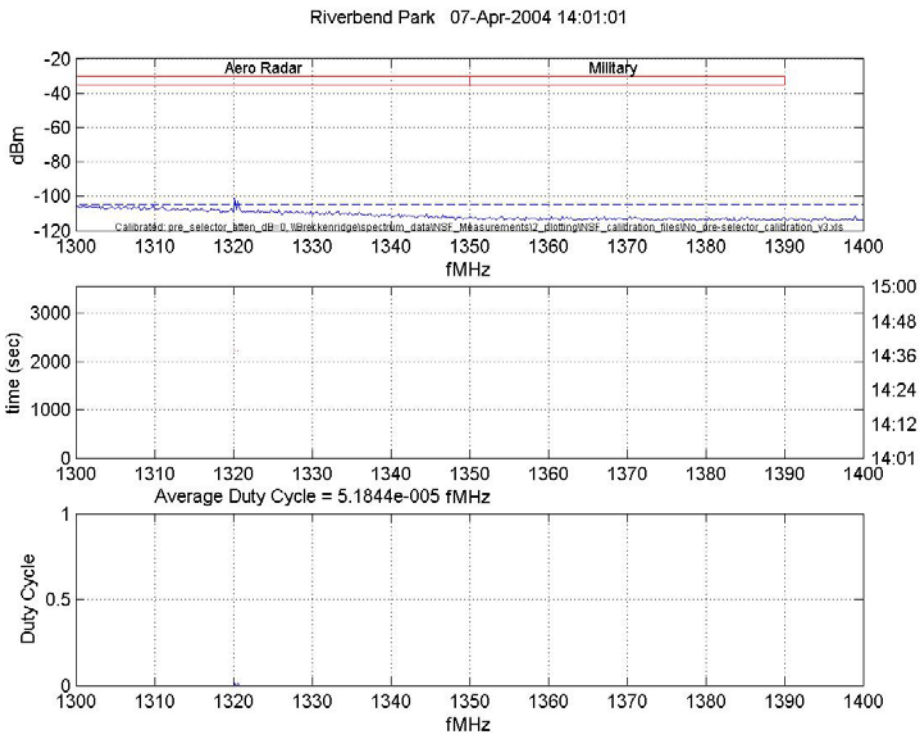

Figure 48: 1300 MHz to 1400 MHz, Rotating

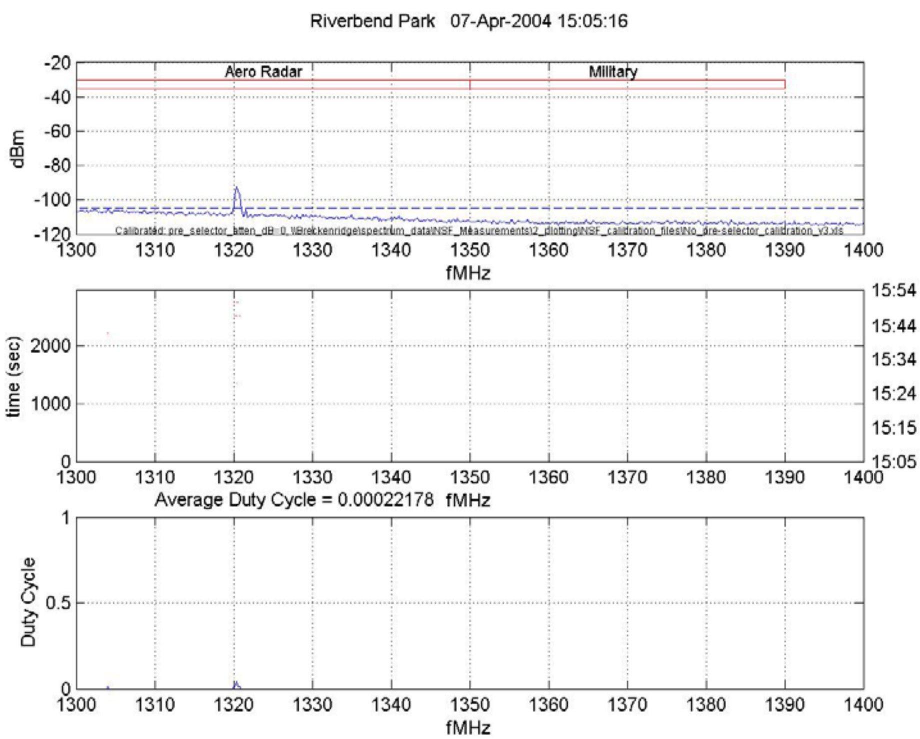

Figure 49: 1300 MHz to 1400 MHz, Stationary

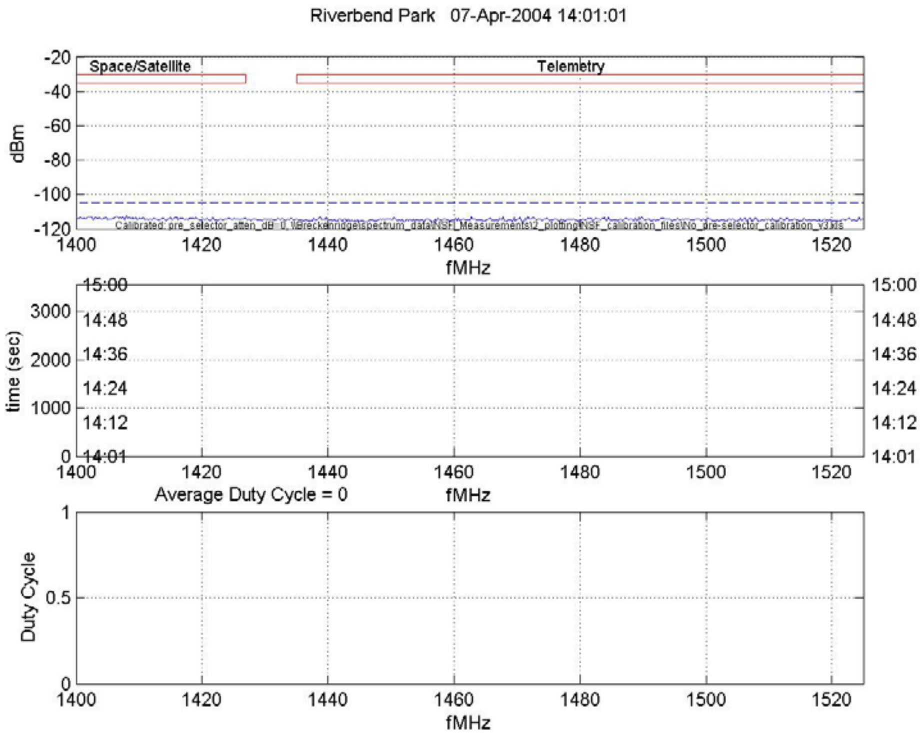

Figure 50: 1400 MHz to 1525 MHz, Rotating

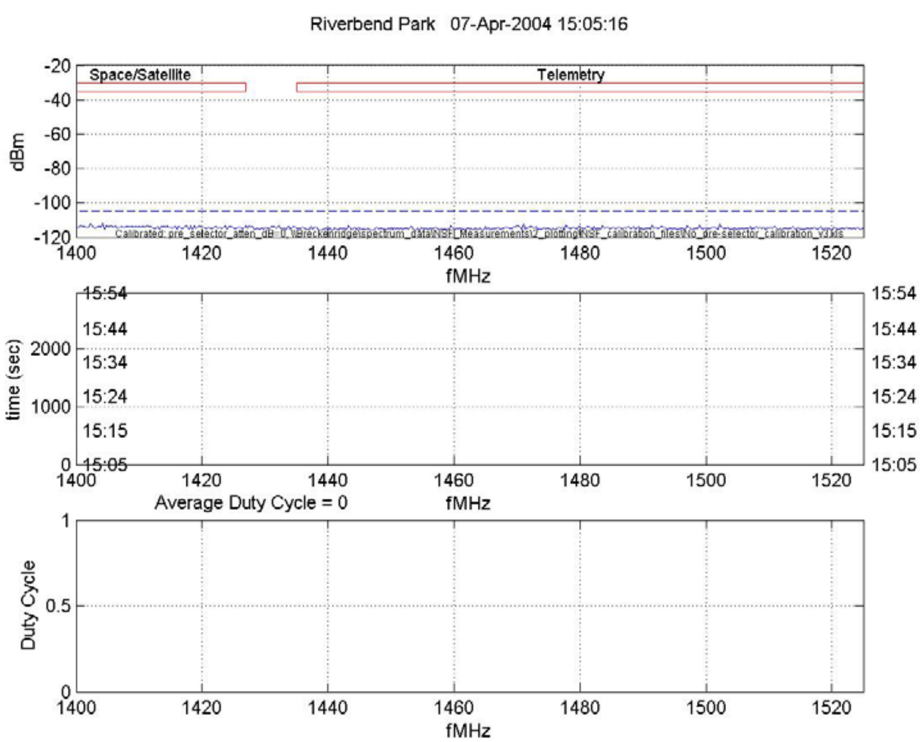

Figure 51: 1400 MHz to 1525 MHz, Stationary

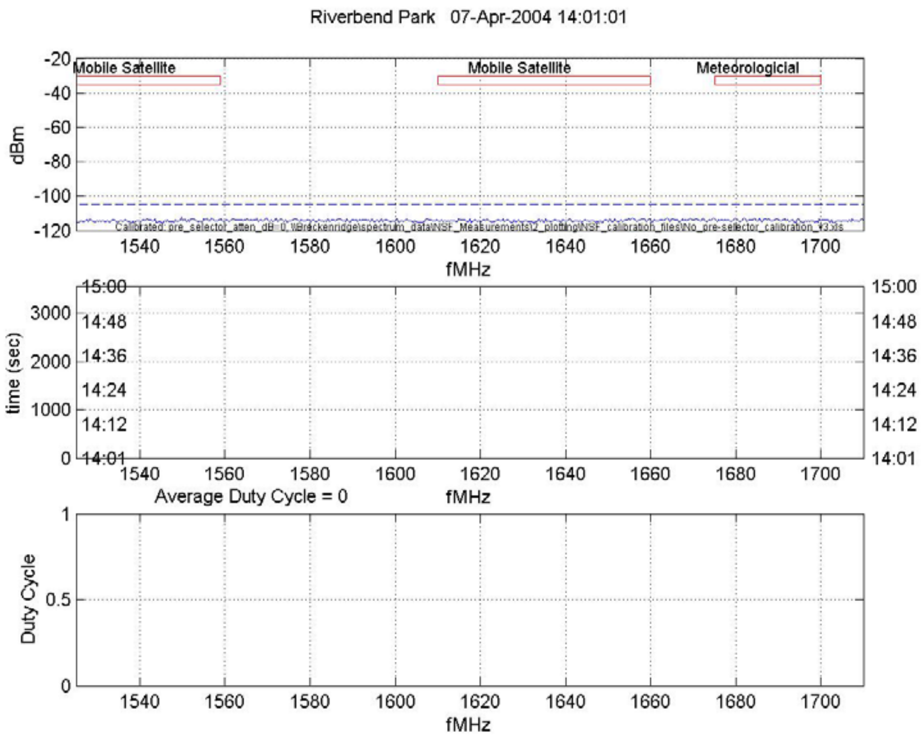

Figure 52: 1525 MHz to 1710 MHz, Rotating

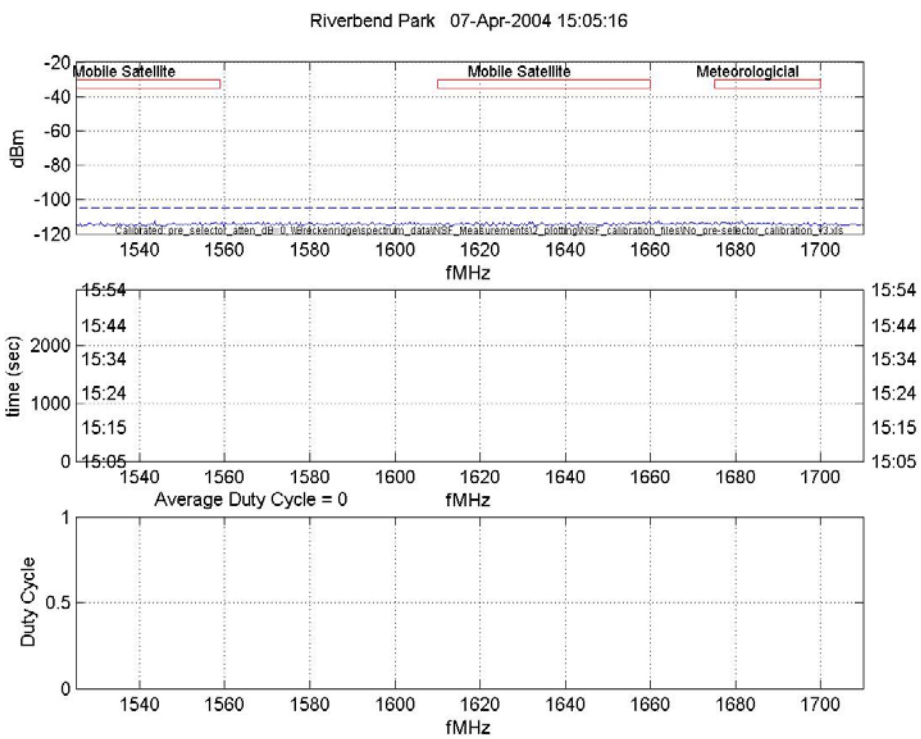

Figure 53: 1525 MHz to 1710 MHz, Stationary

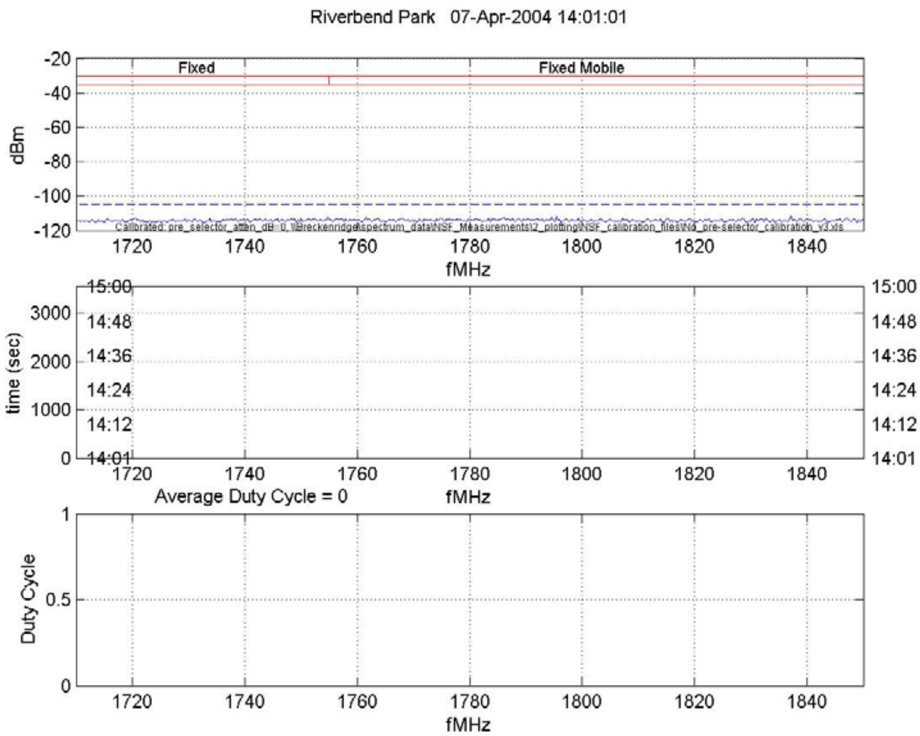

Figure 54: 1710 MHz to 1850 MHz, Rotating

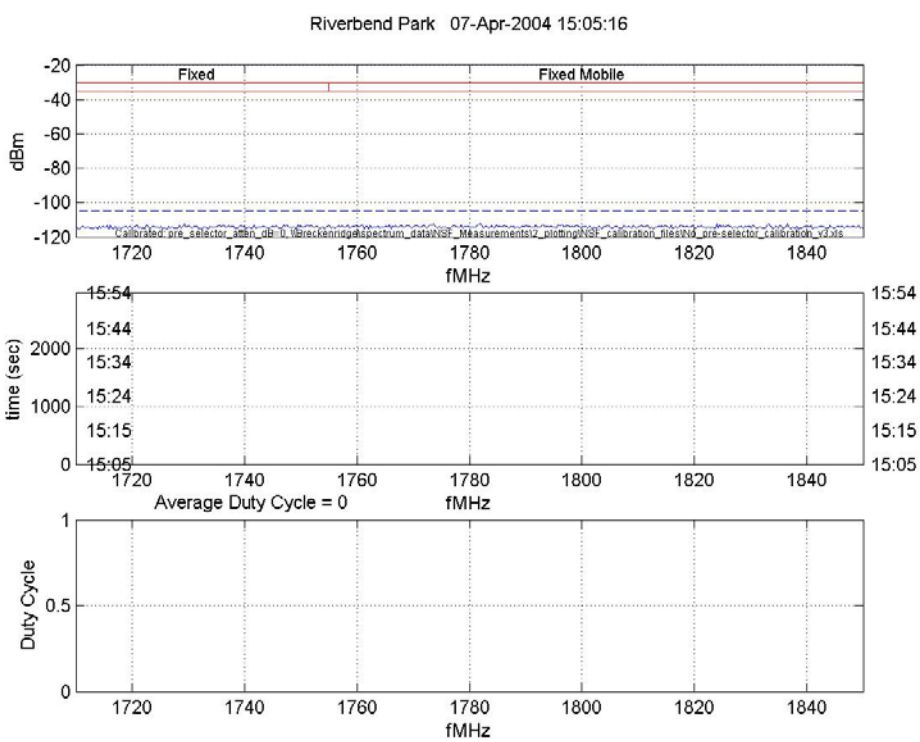

Figure 55: 1710 MHz to 1850 MHz, Stationary

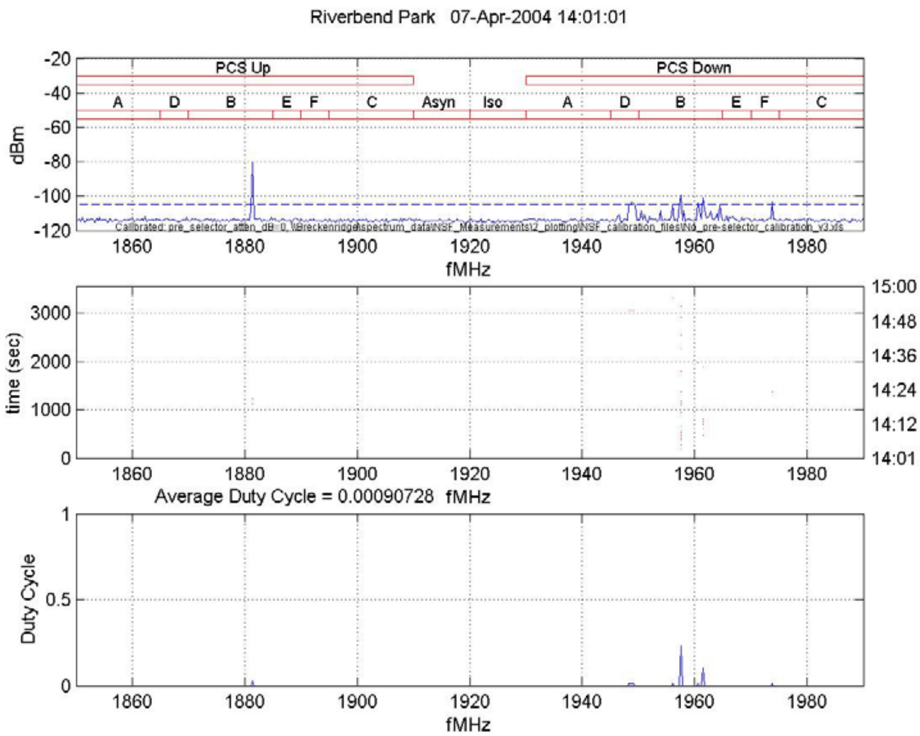

Figure 56: 1850 MHz to 1990 MHz, Rotating

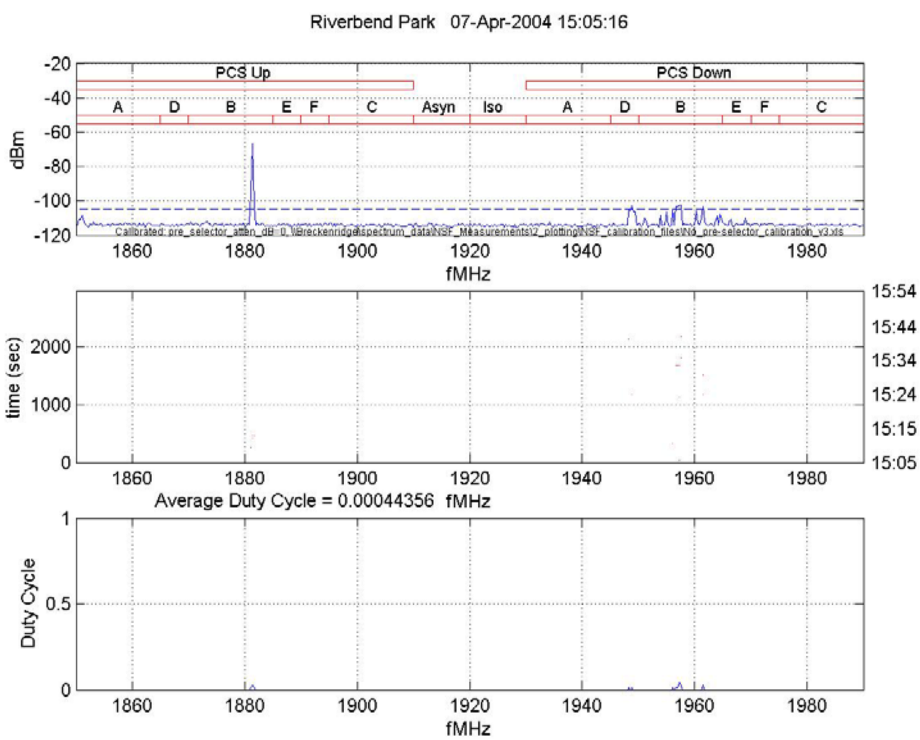

Figure 57: 1850 MHz to 1990 MHz, Stationary

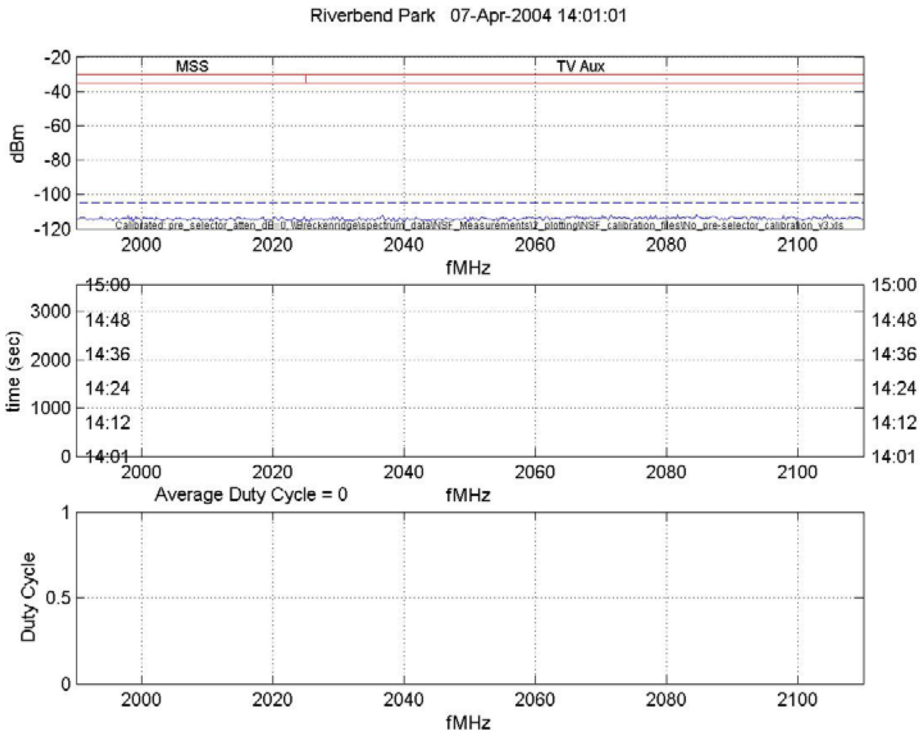

Figure 58: 1990 MHz to 2110 MHz, Rotating

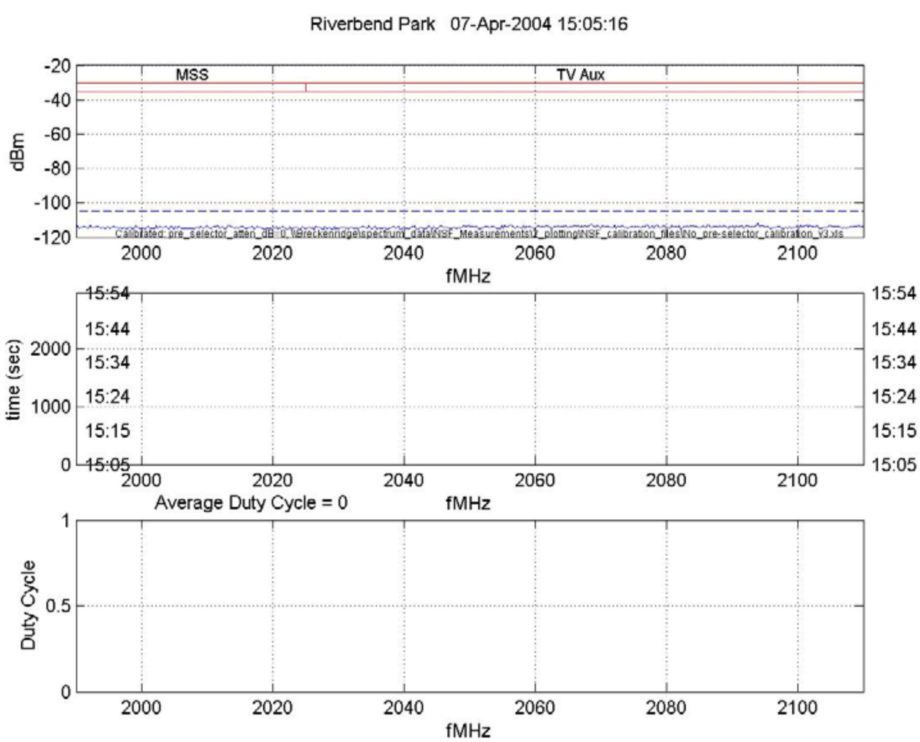

Figure 59: 1990 MHz to 2110 MHz, Stationary

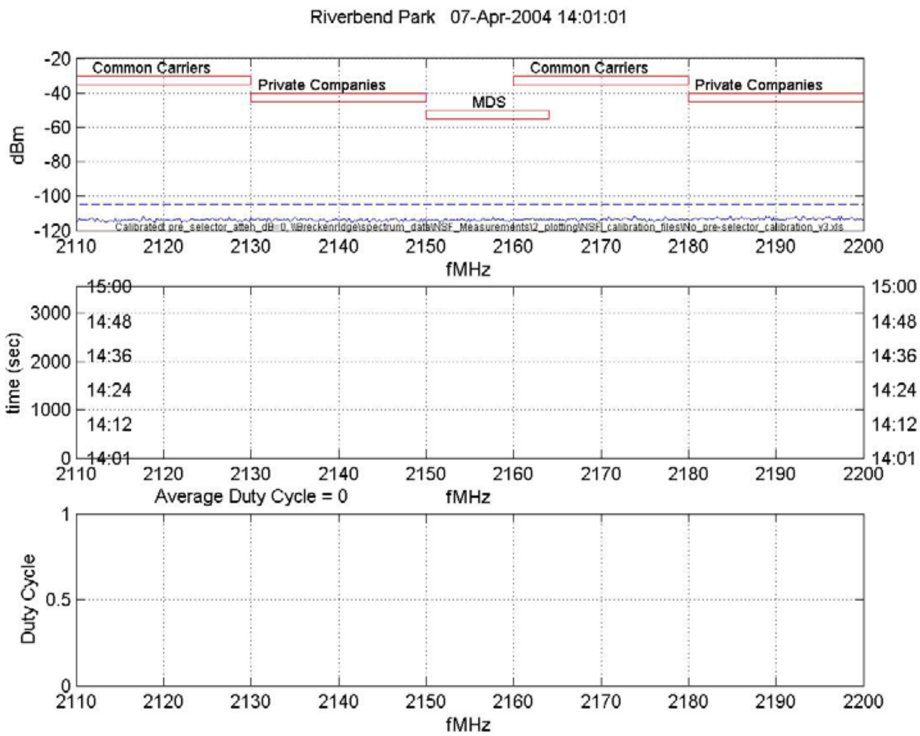

Figure 60: 2110 MHz to 2200 MHz, Rotating

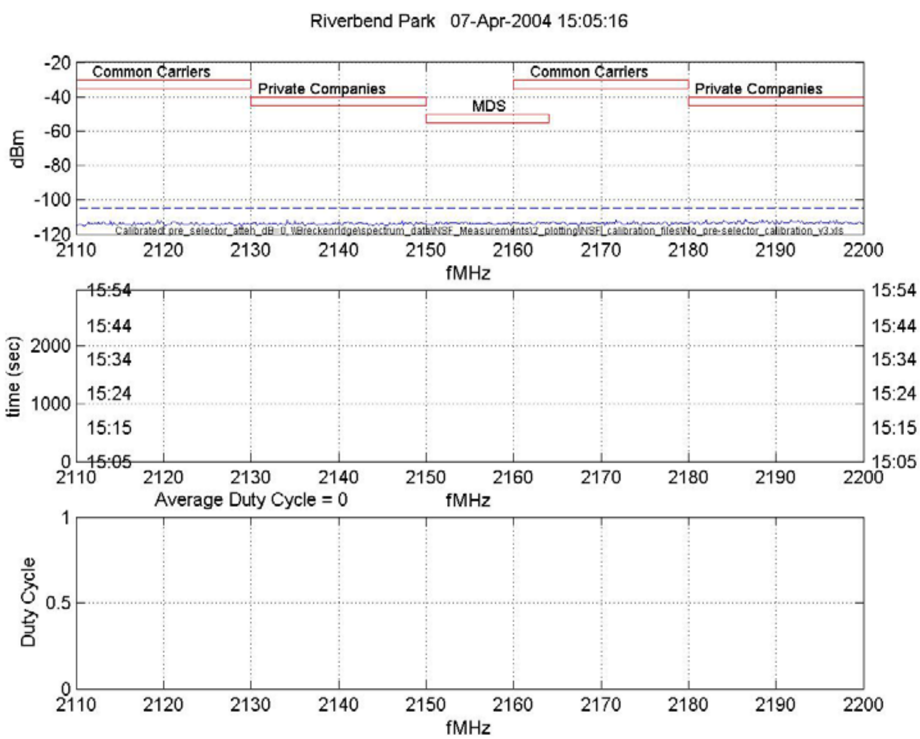

Figure 61: 2110 MHz to 2200 MHz, Stationary

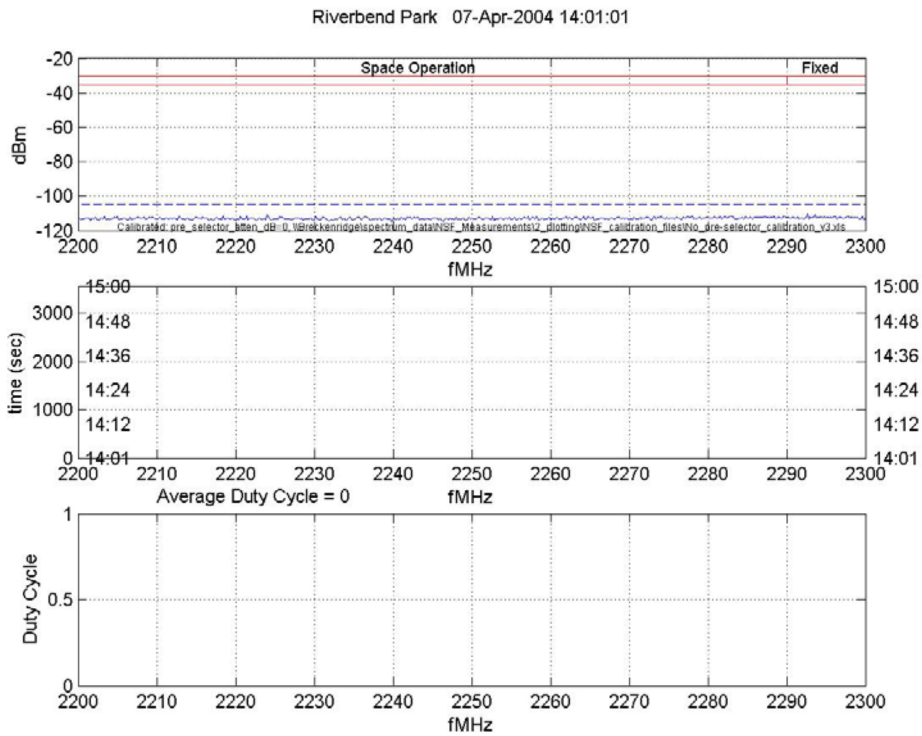

Figure 62: 2200 MHz to 2300 MHz, Rotating

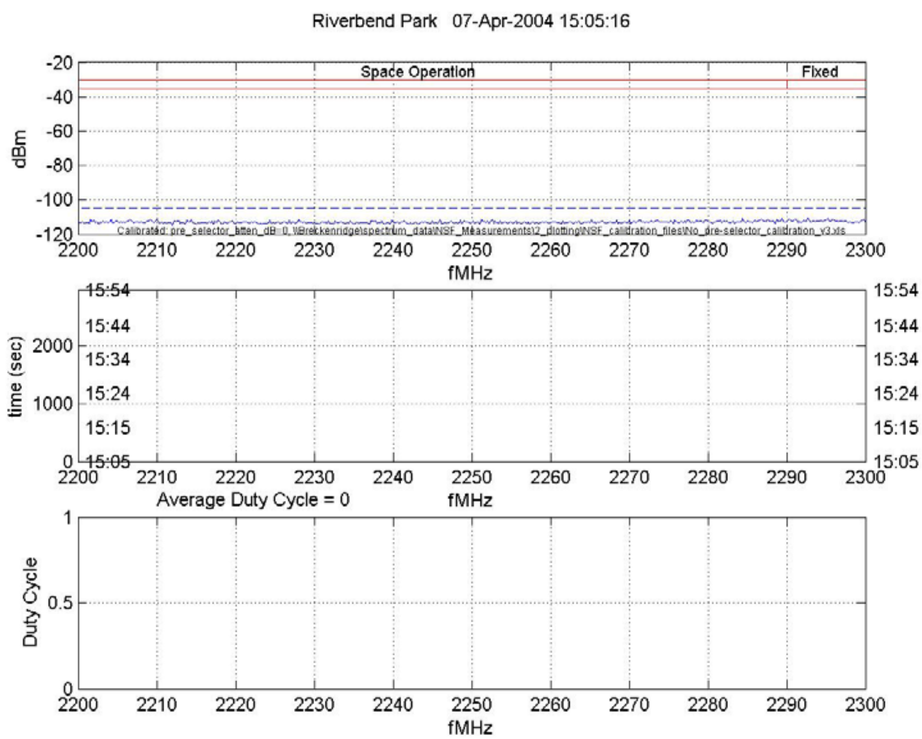

Figure 63: 2200 MHz to 2300 MHz, Stationary

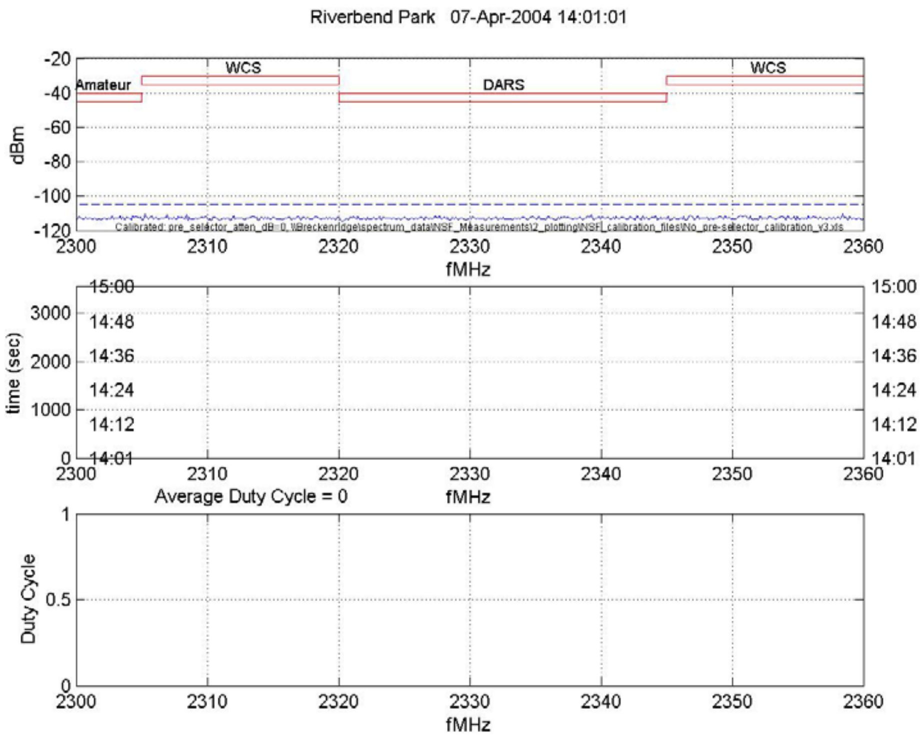

Figure 64: 2300 MHz to 2360 MHz, Rotating

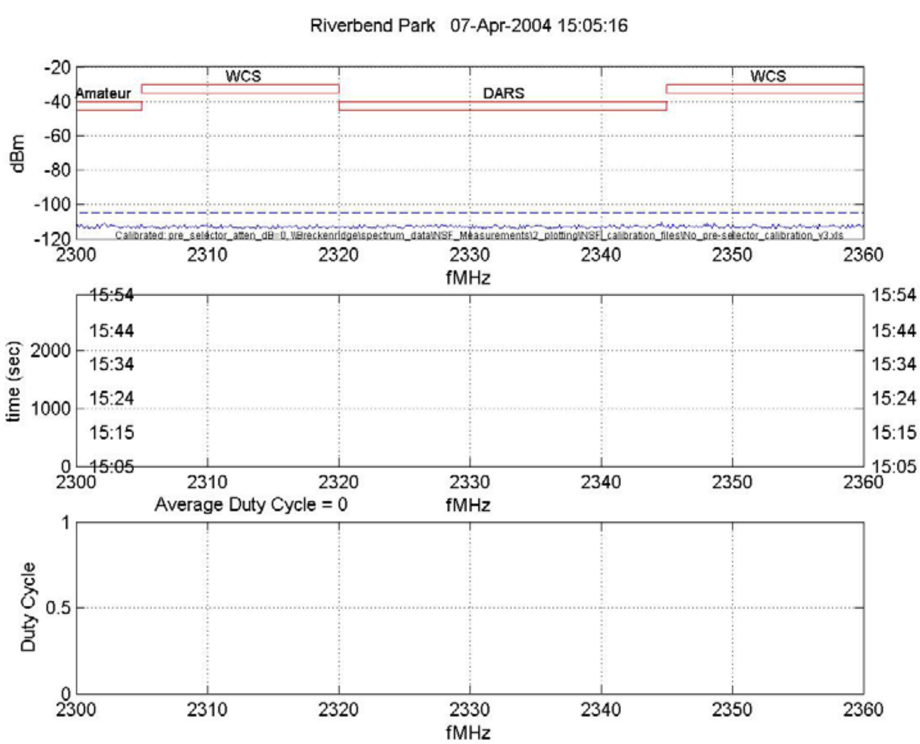

Figure 65: 2300 MHz to 2360 MHz, Stationary

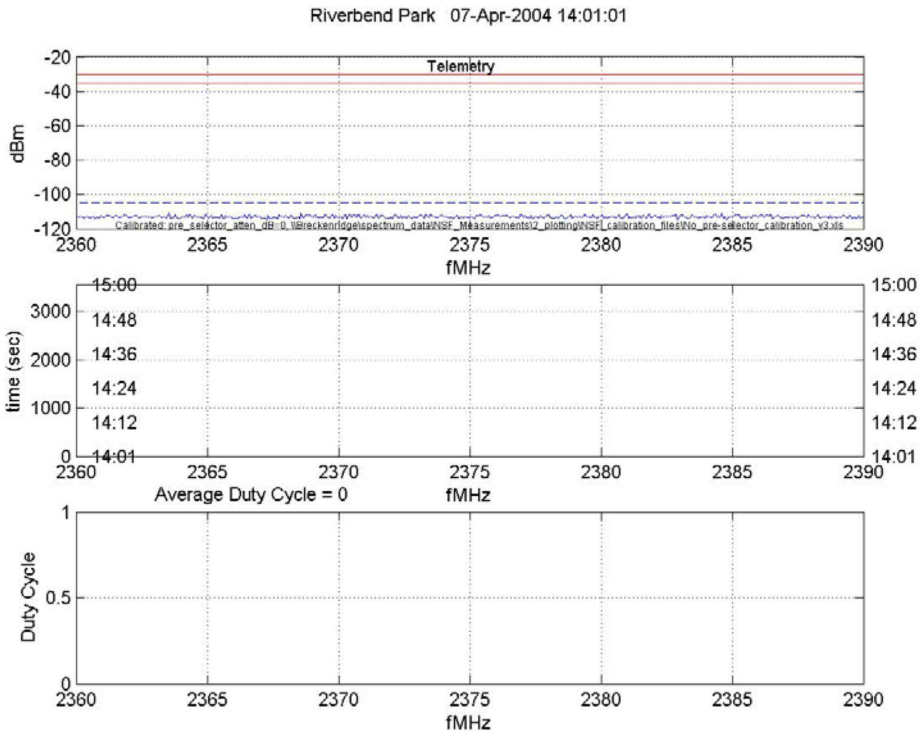

Figure 66: 2360 MHz to 2390 MHz, Rotating

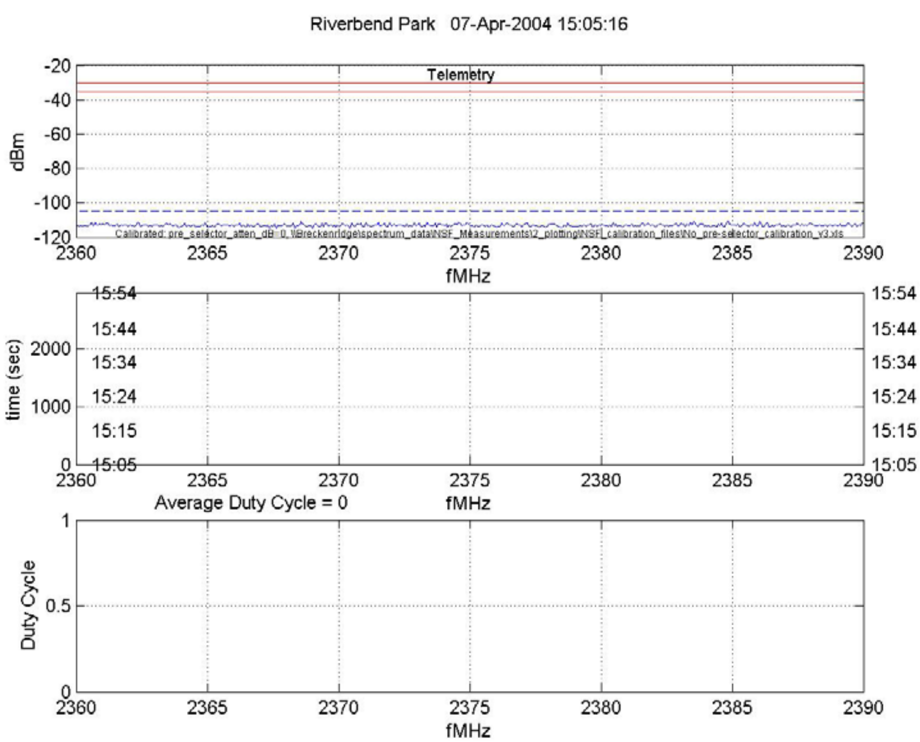

Figure 67: 2360 MHz to 2390 MHz, Stationary

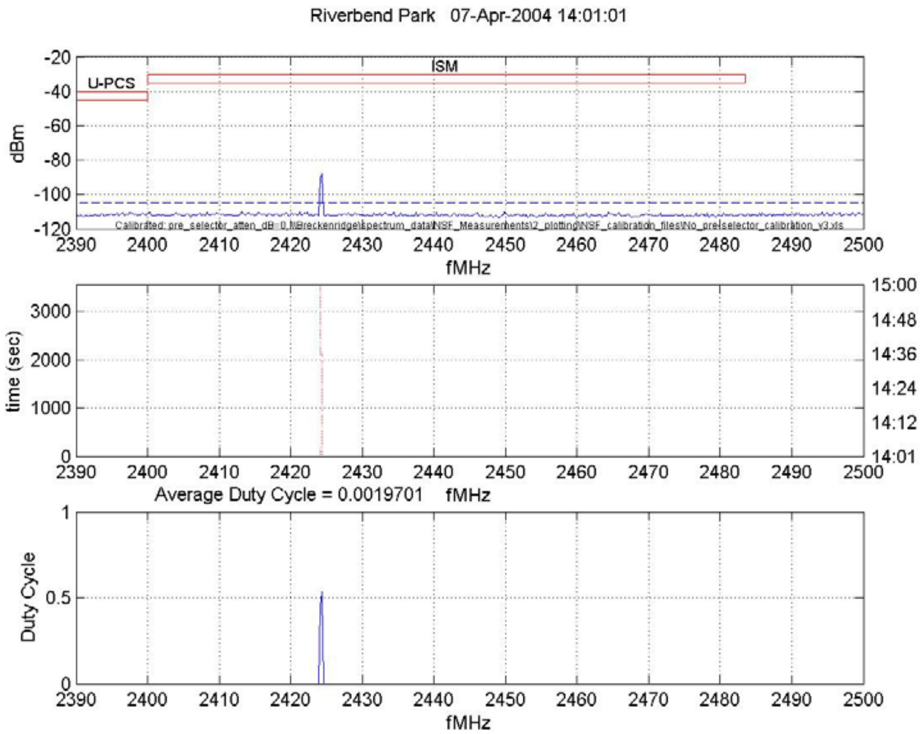

Figure 68: 2390 MHz to 2500 MHz, Rotating

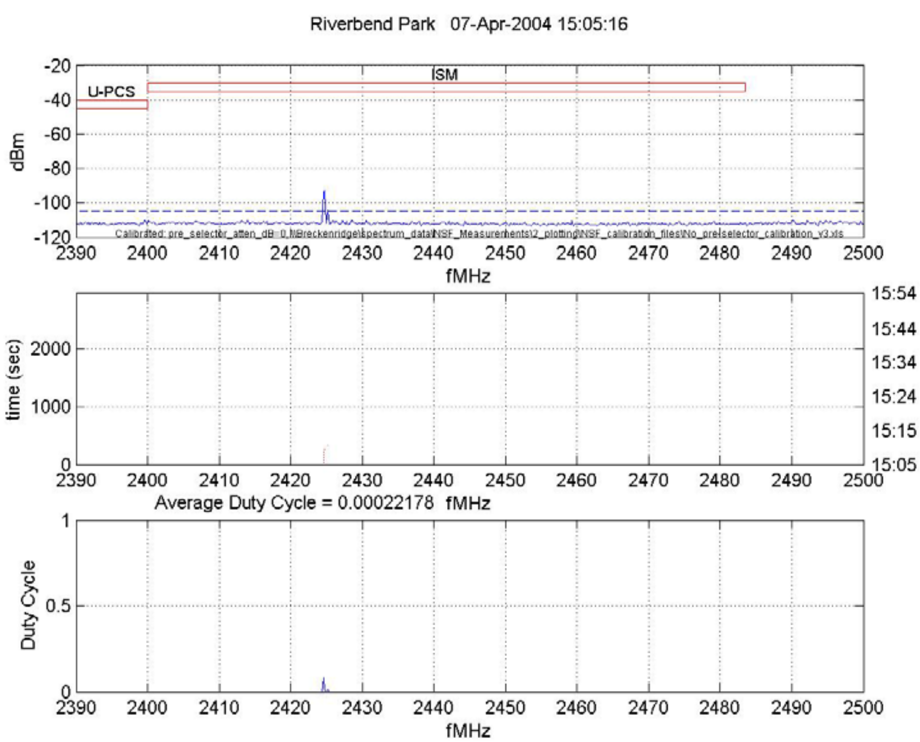

Figure 69: 2390 MHz to 2500 MHz, Stationary

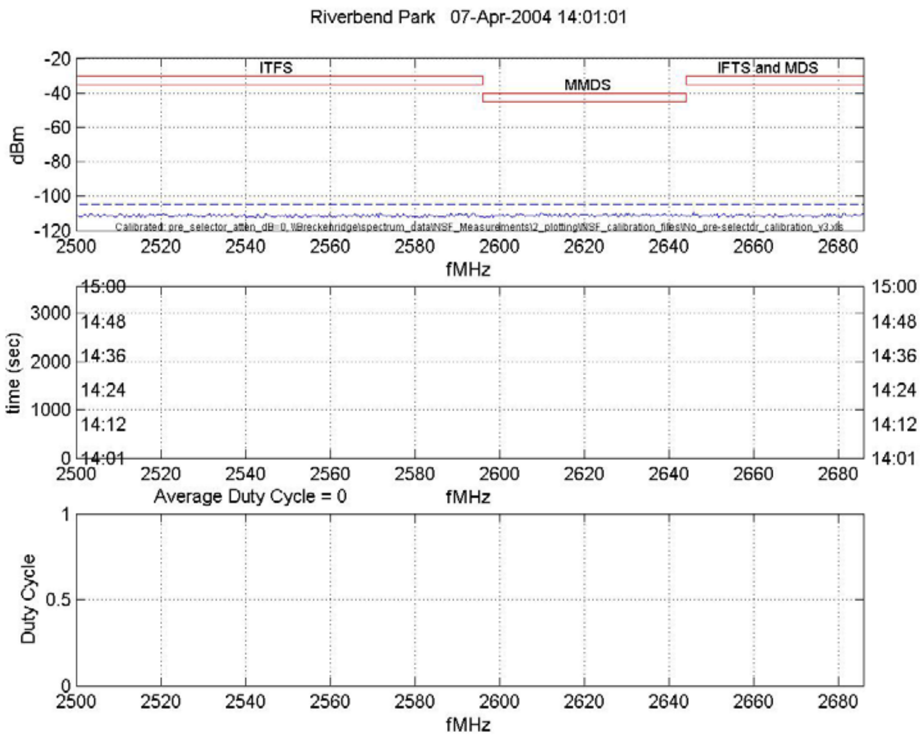

Figure 70: 2500 MHz to 2686 MHz, Rotating

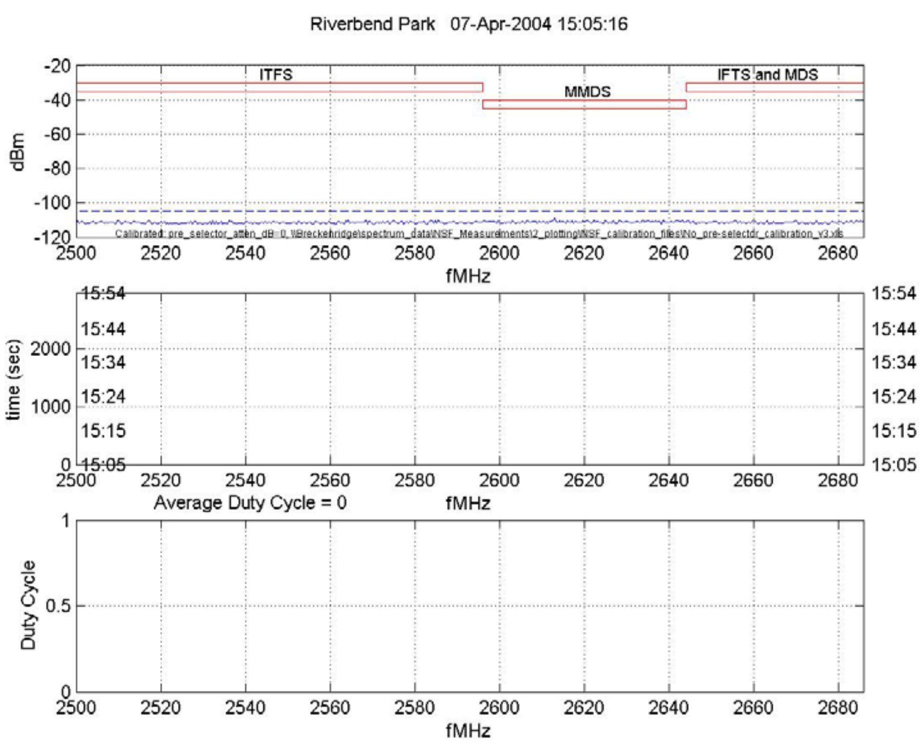

Figure 71: 2500 MHz to 2686 MHz, Stationary

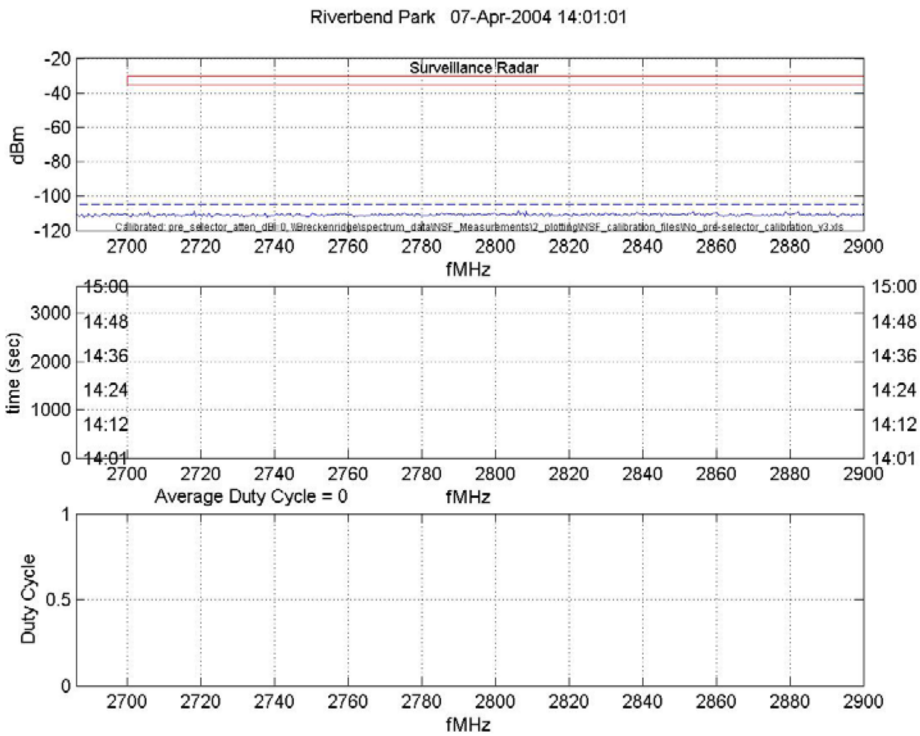

Figure 72: 2686 MHz to 2900 MHz, Rotating

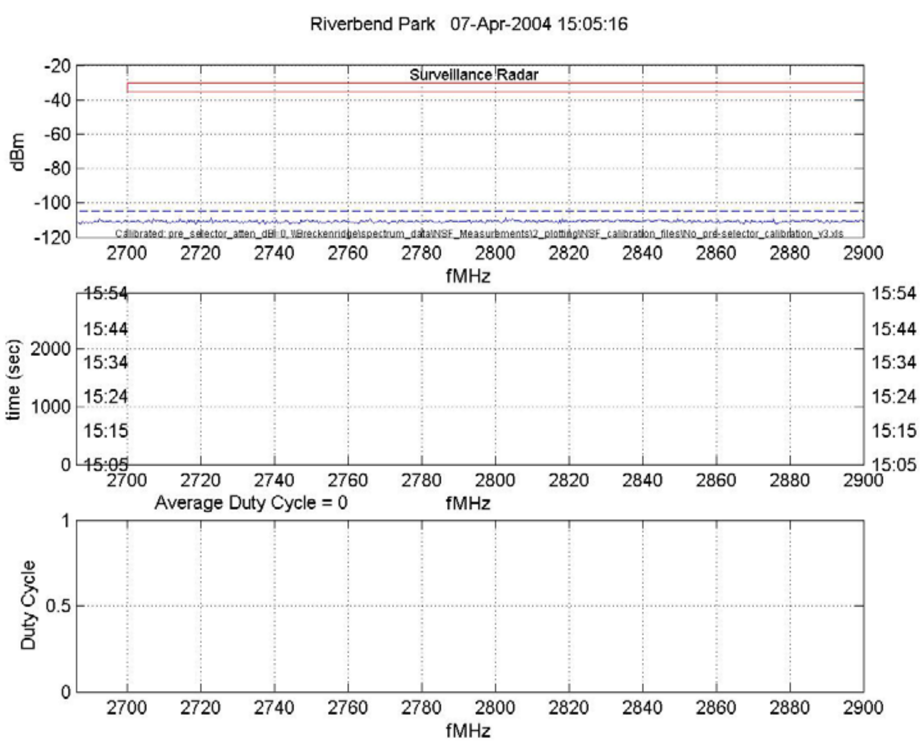

Figure 73: 2686 MHz to 2900 MHz, Stationary

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 8. Summary of Spectrum Occupancy in Each Band

Start Freq (MHz)	Stop Freq (MHz)	Bandwidth (MHz)	Spectrum Band Allocation	Spectrum Fraction Used	Riverbend Occupied Spectrum (MHz)	Average Percent Occupied
30	54	24	PLM, Amateur, others	0.03895	0.93	3.9%
54	88	34	TV 2 -6, RC	0.10593	3.60	10.6%
108	138	30	Air traffic Control, Aero Nav	0.00744	0.22	0.7%
138	174	36	Fixed Mobile, amateur, others	0.03372	1.21	3.4%
174	216	42	TV 7-13	0.10339	4.34	10.3%
216	225	9	Maritime Mobile, Amateur, others	0.00486	0.04	0.5%
225	406	181	Fixed Mobile, Aero, others	0.00002	0.00	0.0%
406	470	64	Amateur, Radio Geolocation, Fixed, Mobile, Radiolocation	0.02745	1.76	2.7%
470	512	42	TV 14-20	0.13313	5.59	13.3%
512	608	96	TV 21-36	0.26616	25.55	26.6%
608	698	90	TV 37-51	0.23484	21.14	23.5%
698	806	108	TV 52-69	0.07627	8.24	7.6%
806	902	96	Cell phone and SMR	0.14260	13.69	14.3%
902	928	26	Unlicensed	0.00000	0.00	0.0%
928	960	32	Paging, SMS, Fixed, BX Aux, and FMS	0.03460	1.11	3.5%
960	1240	280	IFF, TACAN, GPS, others	0.00000	0.00	0.0%
1240	1300	60	Amateur	0.00139	0.08	0.1%
1300	1400	100	Aero Radar, military	0.00022	0.02	0.0%
1400	1525	125	Space/Satellite, Fixed Mobile, Telemetry	0.00000	0.00	0.0%
1525	1710	185	Mobile Satellite, GPS L1, Mobile Satellite, Meteorologicial			
1710	1850	140	Fixed, Fixed Mobile	0.00000	0.00	0.0%
1850	1990	140	PCS, Asyn, Iso	0.00044	0.06	0.0%
1990	2110	120	TV Aux	0.00000	0.00	0.0%
2110	2200	90	Common Carriers, Private Companies, MDS	0.00000	0.00	0.0%
2200	2300	100	Space Operation, Fixed	0.00000	0.00	0.0%
2300	2360	60	Amateur, WCS, DARS	0.00000	0.00	0.0%
2360	2390	30	Telemetry	0.00000	0.00	0.0%
2390	2500	110	U-PCS, ISM (Unlicensed)	0.00022	0.02	0.0%
2500	2686	186	ITFS, MMDS	0.00000	0.00	0.0%
2686	2900	214	Surveillance Radar	0.00000	0.00	0.0%
Total		2850			87.62	
Total Available Spectrum					2570	
Average Spectrum Use (%)					3.4%	