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

Published August 15, 2005

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Subcontract No. FY2004-013
The University of Kansas Center for Research, Inc.
Spectrum Occupancy Measurements and Pre-Selector Development
National Radio Research Testbed (NRNRT)
National Science Foundation (NSF) Award Number: ANI-0335272

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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 sky line.

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.[2] 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.

[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.

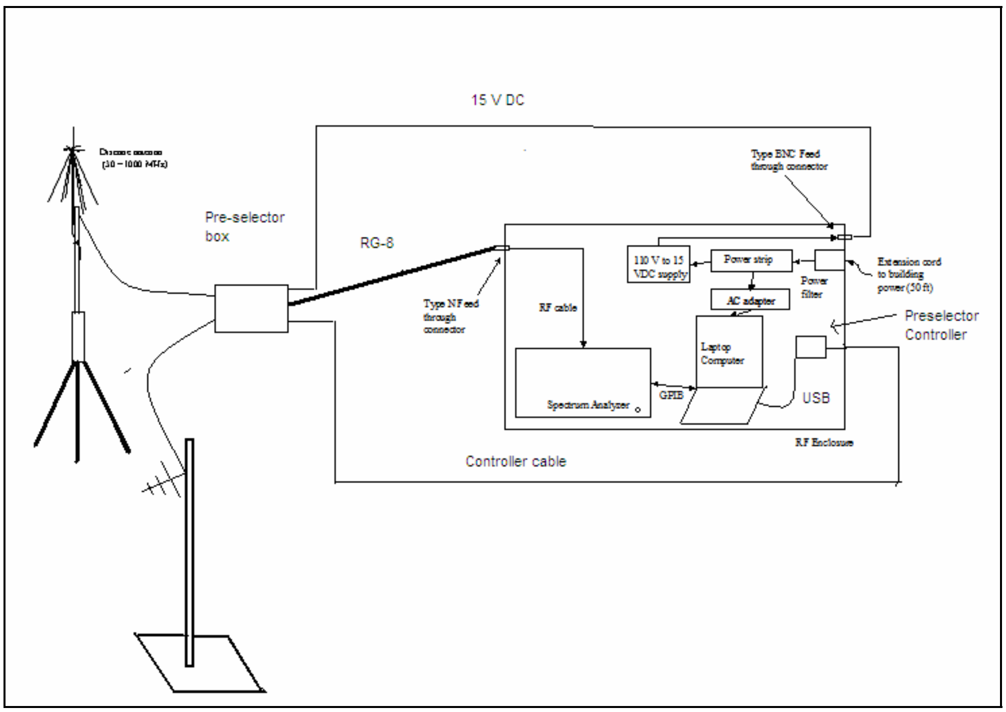

Figure 1: Spectrum Measurement Equipment Configuration

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.

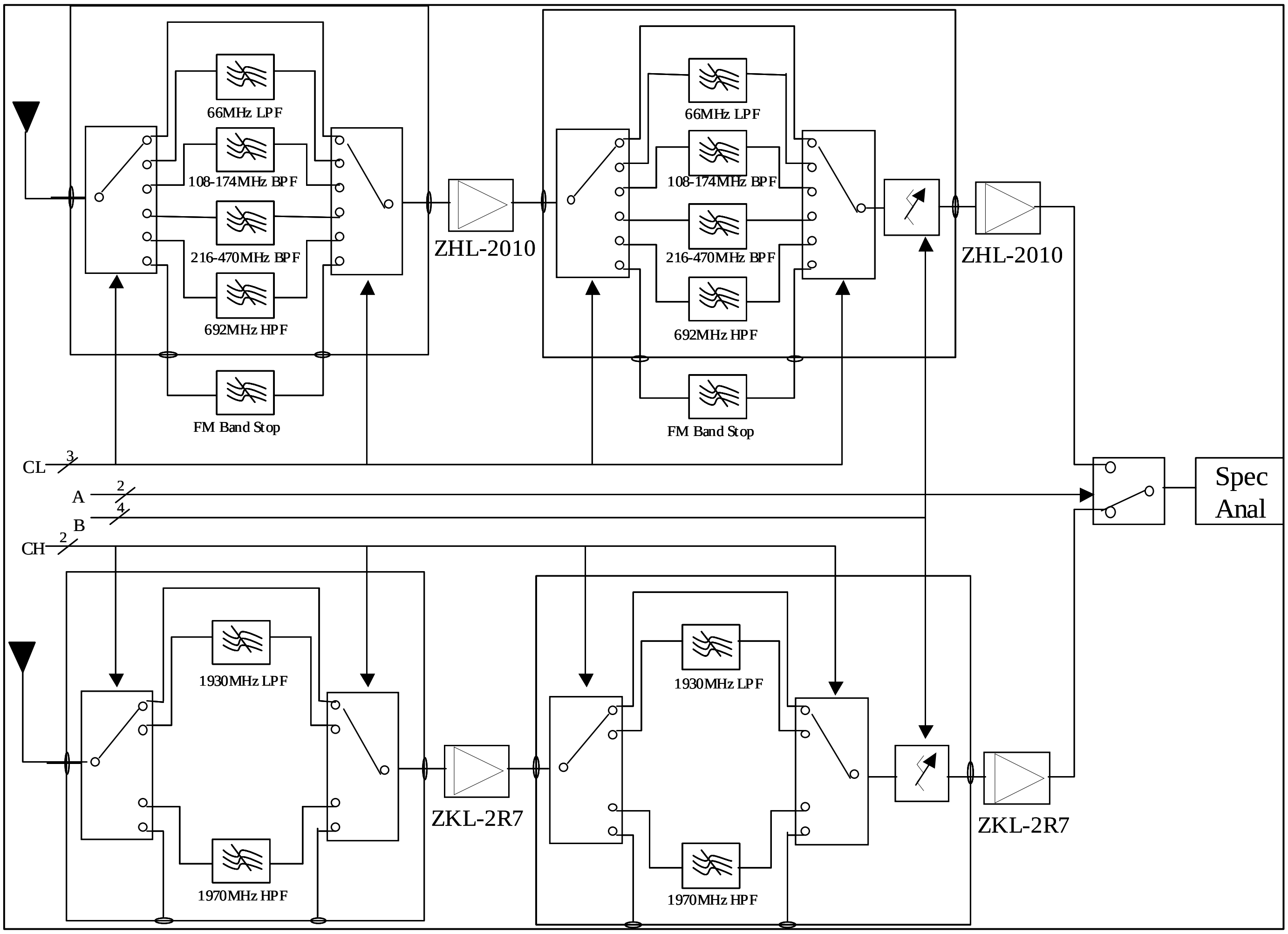

Figure 4: Pre-Selector Block Diagram

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

		Preselector Settings				Spectrum Analyzer Settings				
Start Freq (MHz)	Stop Freq (MHz)	BS	Atten	Filter A	Filter B	RBW (kHz)	VBW (kHz)	Atten (dB)	Ref Level (dBm)	Spectrum Analyzer
30	54	1	15	0	x	10	10	10	-20	ESPI
54	88	1	10	4	x	10	10	10	-20	ESPI
108	138	1	10	2	x	10	10	10	-20	ESPI
138	174	1	15	2	x	10	10	10	-20	ESPI
174	216	1	15	4	x	10	10	10	-20	ESPI
216	225	1	5	3	x	10	10	10	-20	ESPI
225	406	1	5	3	x	10	10	10	-20	ESPI
406	470	1	10	3	x	10	10	10	-10	ESPI
470	512	1	10	4	x	10	10	10	-20	ESPI
512	608	1	10	4	x	10	10	10	-20	ESPI
608	698	1	10	4	x	10	10	10	-20	ESPI
698	806	1	5	5	x	10	10	10	-20	ESPI
806	902	1	10	5	x	10	10	10	-20	ESPI
902	928	1	10	5	x	10	10	10	-20	ESPI
928	960	1	10	5	x	10	10	10	-10	ESPI
960	1240	2	10	x	1	10	10	10	-20	ESPI
1240	1300	2	5	x	1	10	10	10	-20	ESPI
1300	1400	2	5	x	1	10	10	10	-20	ESPI
1400	1525	2	5	x	1	10	10	10	-20	ESPI
1525	1710	2	5	x	1	10	10	10	-20	ESPI
1710	1850	2	5	x	1	10	10	10	-20	ESPI
1850	1990	2	10	x	1	10	10	10	-20	ESPI
1990	2110	2	0	x	2	10	10	10	-20	ESPI
2110	2200	2	0	x	2	10	10	10	-20	ESPI
2200	2300	2	0	x	2	10	10	10	-20	ESPI
2300	2360	2	5	x	2	10	10	10	-20	ESPI
2360	2390	2	5	x	2	10	10	10	-20	ESPI
2390	2500	2	0	x	2	10	10	10	-20	ESPI
2500	2686	2	0	x	2	10	10	10	-20	ESPI
2686	2900	2	5	x	2	10	10	10	-20	ESPI

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) 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

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.

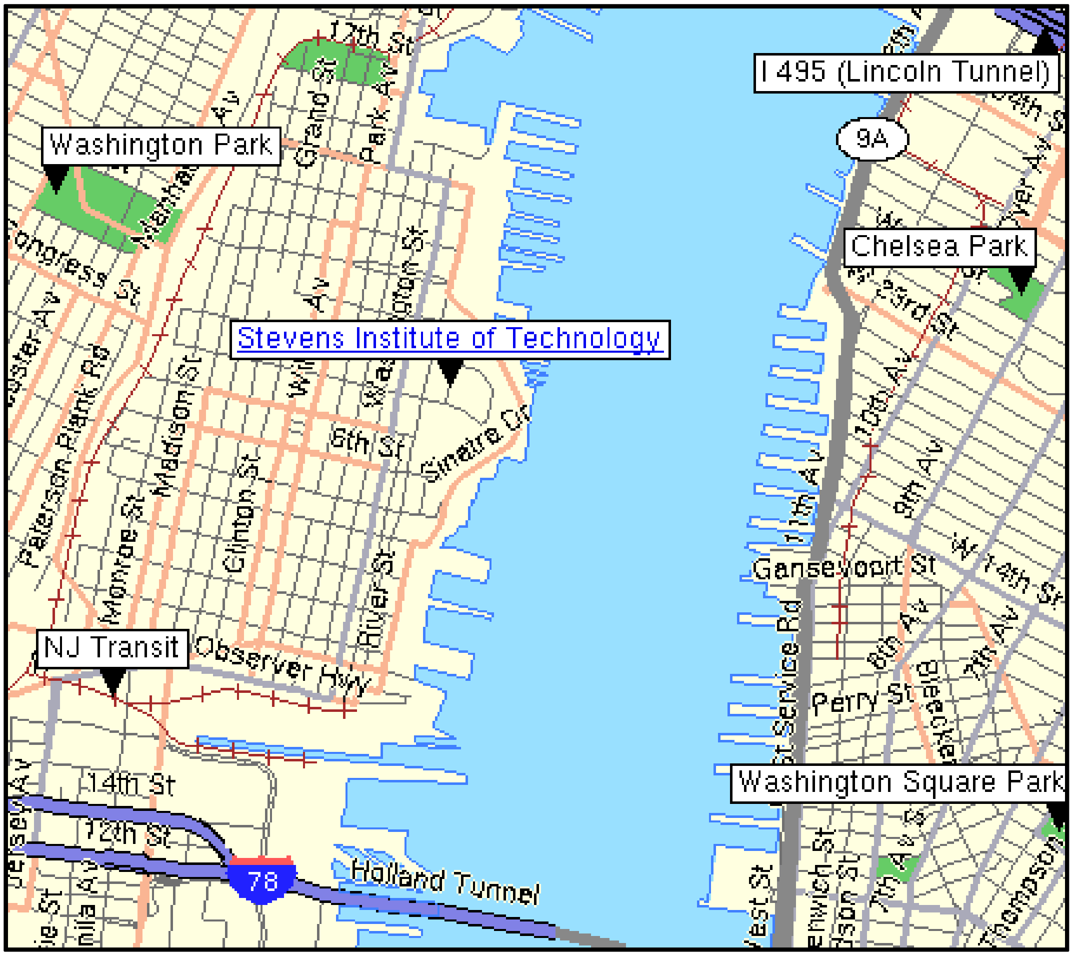

Figure 5: Location of the Measurement Site

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

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

Start Freq (MHz)	Stop Freq (MHz)	Ref Level (dBm)	Band Width (MHz)	Frequency Bin Size (kHz)	dB/div	Res_BW (Hz)	Vid_BW (Hz)	Attenuation (dB)		Sweep Time (sec)
								SA	Pre-Selector	
138	174	-20	36	72	10	10,000	10,000	20	20	0.24
406	470	-20	64	128	10	10,000	10,000	20	10	0.64

Table 3: Frequency List B – Other Band Usage

Start Freq (MHz)	Stop Freq (MHz)	Ref Level (dBm)	Band Width (MHz)	Frequency Bin Size (kHz)	dB/div	Res_BW (Hz)	Vid_BW (Hz)	Attenuation (dB)		Sweep Time (sec)
								SA	Pre-Selector	
30	54	-10	24	48	10	10,000	10,000	10	10	0.3
54	88	-10	34	68	10	10,000	10,000	20	20	0.4
108	138	-10	30	60	10	10,000	10,000	10	10	0.4
174	216	-10	42	84	10	10,000	10,000	20	20	0.5
216	225	-10	9	18	10	10,000	10,000	10	10	0.1
225	406	-10	181	361	10	10,000	10,000	10	10	2.3
470	512	-10	42	84	10	10,000	10,000	20	20	0.5
512	608	-10	96	192	10	10,000	10,000	10	10	1.2
608	698	-10	90	180	10	10,000	10,000	10	10	1.1
698	806	-10	108	216	10	10,000	1.0004	10	10	1.2
806	902	-10	96	192	10	10,000	10,000	10	10	1.2
902	928	-10	26	52	10	10,000	10,000	10	10	0.3
928	960	-10	32	64	10	10,000	10,000	10	10	0.4
960	1240	-10	280	559	10	10,000	10,000	10	20	4.0
1240	1300	-20	60	120	10	10,000	10,000	10	10	0.6
1300	1400	-20	100	200	10	10,000	10,000	10	10	1.0
1400	1525	-20	125	250	10	10,000	10,000	10	10	1.6
1525	1710	-20	185	369	10	10,000	10,000	10	10	2.3
1710	1850	-20	140	279	10	10,000	10,000	10	20	1.8

1850	1990	-20	140	279	10	10,000	10,000	10	20	1.8
1990	2110	-20	120	240	10	10,000	10,000	10	0	1.5
2110	2200	-20	90	180	10	10,000	10,000	10	0	1.1
2200	2300	-20	100	200	10	10,000	10,000	10	0	1.3
2300	2360	-20	60	120	10	10,000	10,000	10	0	0.8
2360	2390	-20	30	60	10	10,000	10,000	10	0	0.4
2390	2500	-20	110	220	10	10,000	10,000	10	0	1.4
2500	2686	-20	186	371	10	10,000	10,000	10	0	2.3
2686	2900	-20	214	427	10	10,000	10,000	10	0	2.7

Table 4: Frequency List C – High Resolution Frequency Sweep

Band	Start Freq (MHz)	Stop Freq (MHz)	Band Width (MHz)	Frequency Bin Size (kHz)	Res_BW (Hz)	Vid_BW (Hz)
	30	35	5	10	3000	3000
	35	40	5	10	3000	3000
	40	45	5	10	3000	3000
	45	50	5	10	3000	3000
	50	55	5	10	3000	3000
	55	60	5	10	3000	3000
Between TV Ch 4 and 5	70	75	5	10	3000	3000
Aviation	110	115	5	10	3000	3000
Aviation	115	120	5	10	3000	3000
Aviation	120	125	5	10	3000	3000
Aviation	125	130	5	10	3000	3000
Aviation	130	135	5	10	3000	3000
Public Safety	135	140	5	10	3000	3000
Public Safety	140	145	5	10	3000	3000
Public Safety	145	150	5	10	3000	3000
Public Safety	150	155	5	10	3000	3000
Public Safety	155	160	5	10	3000	3000
Public Safety	160	165	5	10	3000	3000
Public Safety	165	170	5	10	3000	3000
Public Safety	170	175	5	10	3000	3000
TV Ch 10	190	195	5	10	3000	3000
TV Ch 10	195	200	5	10	3000	3000
	215	220	5	10	3000	3000
	220	225	5	10	3000	3000
	225	230	5	10	3000	3000
	230	235	5	10	3000	3000
	235	240	5	10	3000	3000
	240	245	5	10	3000	3000
	245	250	5	10	3000	3000
	250	255	5	10	3000	3000
	255	260	5	10	3000	3000
	260	265	5	10	3000	3000

Band	Start Freq (MHz)	Stop Freq (MHz)	Band Width (MHz)	Frequency Bin Size (kHz)	Res_BW (Hz)	Vid_BW (Hz)
	265	270	5	10	3000	3000
	270	275	5	10	3000	3000
	275	280	5	10	3000	3000
	280	285	5	10	3000	3000
	285	290	5	10	3000	3000
	290	295	5	10	3000	3000
	295	300	5	10	3000	3000
	300	305	5	10	3000	3000
	305	310	5	10	3000	3000
	310	315	5	10	3000	3000
	315	320	5	10	3000	3000
	320	325	5	10	3000	3000
	325	330	5	10	3000	3000
	330	335	5	10	3000	3000
	335	340	5	10	3000	3000
	340	345	5	10	3000	3000
	345	350	5	10	3000	3000
	350	355	5	10	3000	3000
	355	360	5	10	3000	3000
	360	365	5	10	3000	3000
	365	370	5	10	3000	3000
	370	375	5	10	3000	3000
	375	380	5	10	3000	3000
	380	385	5	10	3000	3000
	385	390	5	10	3000	3000
	390	395	5	10	3000	3000
	395	400	5	10	3000	3000
	400	405	5	10	3000	3000
Public Safety	405	410	5	10	3000	3000
Public Safety	410	415	5	10	3000	3000
Public Safety	415	420	5	10	3000	3000
Public Safety	420	425	5	10	3000	3000
Public Safety	425	430	5	10	3000	3000
Public Safety	430	435	5	10	3000	3000
Public Safety	435	440	5	10	3000	3000
Public Safety	440	445	5	10	3000	3000
Public Safety	445	450	5	10	3000	3000
Public Safety	450	455	5	10	3000	3000
Public Safety	455	460	5	10	3000	3000
Public Safety	460	465	5	10	3000	3000
Public Safety	465	470	5	10	3000	3000
Public Safety	470	475	5	10	3000	3000
TV Ch 19 and Ch 20	500	505	5	10	3000	3000
TV Ch 19 and Ch 20	505	510	5	10	3000	3000
TV Ch 19 and Ch 20	510	515	5	10	3000	3000

Band	Start Freq (MHz)	Stop Freq (MHz)	Band Width (MHz)	Frequency Bin Size (kHz)	Res_BW (Hz)	Vid_BW (Hz)
TV Ch 19 and Ch 20	515	520	5	10	3000	3000
	925	930	5	10	3000	3000
	930	935	5	10	3000	3000
	935	940	5	10	3000	3000
	940	945	5	10	3000	3000
	945	950	5	10	3000	3000
	950	955	5	10	3000	3000
	955	960	5	10	3000	3000
	960	965	5	10	3000	3000

Table 5: Frequency List D – Strong Signal Bands

Start Freq (MHz)	Stop Freq (MHz)	Band Width (MHz)	Frequency Bin Size (kHz)	Res_BW (Hz)	Vid_BW (Hz)
0	250	250	499	10,000	10,000
250	500	250	499	10,000	10,000
500	750	250	499	10,000	10,000
750	1000	250	499	10,000	10,000
1000	1250	250	499	10,000	10,000
1250	1500	250	499	10,000	10,000
1500	1750	250	499	10,000	10,000
1750	2000	250	499	10,000	10,000
2000	2250	250	499	10,000	10,000
2250	2500	250	499	10,000	10,000
2500	2750	250	499	10,000	10,000
2750	3000	250	499	10,000	10,000

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

Frequency List	List Measurement Time (sec)	Repetitions	Duration (sec)	Experiment Duration (hours)	Experiment Duration (sec)	Number of Measurements
A	5	40	200			5760
B	100	1	100			144
Total			300	12	43200	144

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

Frequency List	List Measurement Time (sec)	Repetitions	Cycle Duration (sec)	Experiment Duration (hours)	Experiment Duration (sec)	Number of Measurements
C	300	1	300			48
Total			300	4	14400	48

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

Start Time	Location	Comment	Freq List	Start File	End File	Num Files	Duration (sec)	Antenna Type
8/31/04 4:00 pm	SE corner		List A	7617	16605	8989	79200	1
8/31/04 4:00 pm	SE corner		List B	228	441	214	79200	3
9/1/04 8:35 pm	SE corner		List A	16608	27527	10919	107280	1
9/1//04	SE Corner		List B	452	724	273	107290	3

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

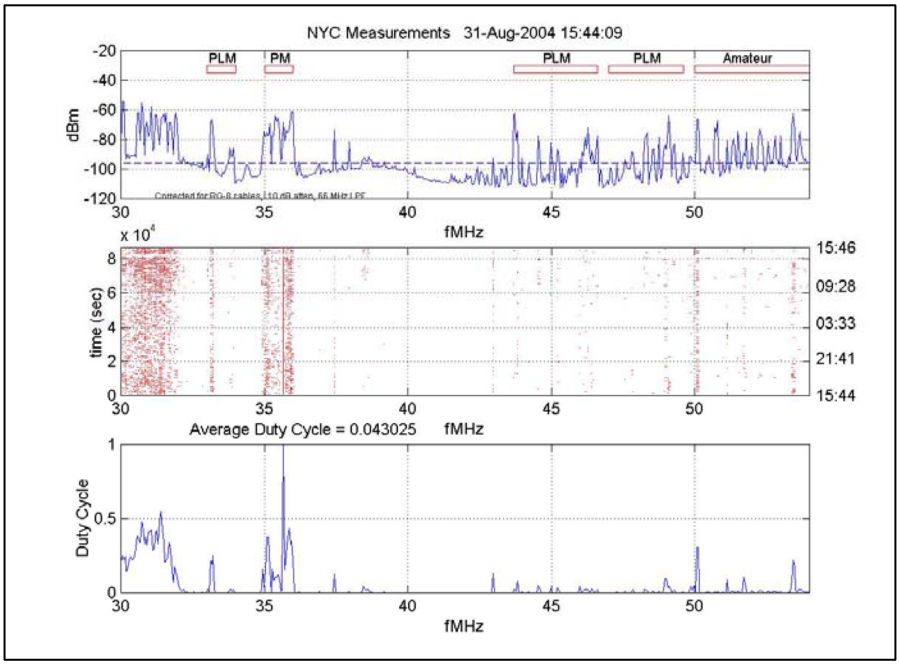

Figure 10: August 31 to September 1, 30 MHz – 54 MHz

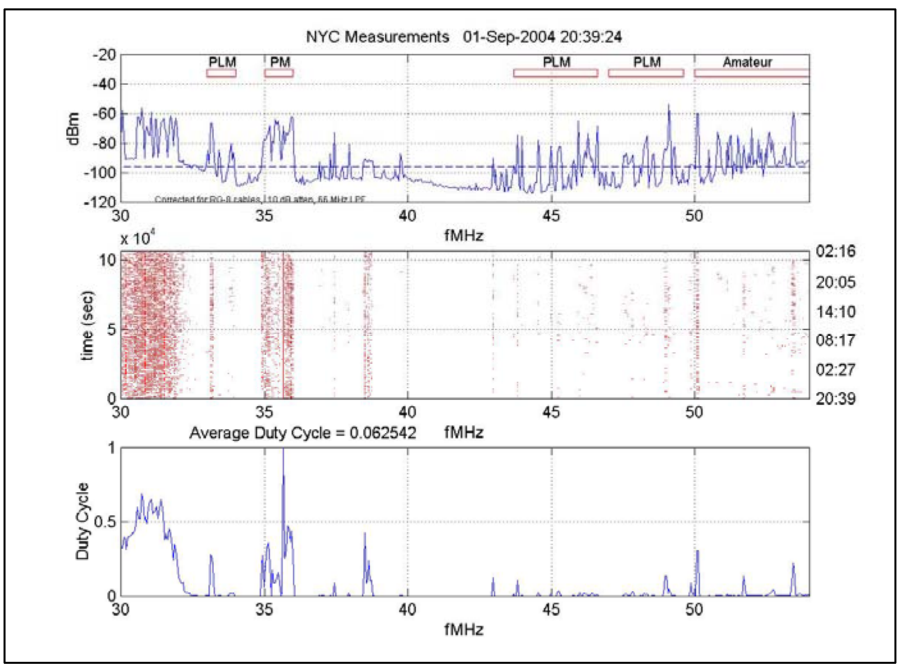

Figure 11: September 1 to September 3, 30 MHz – 54 MHz

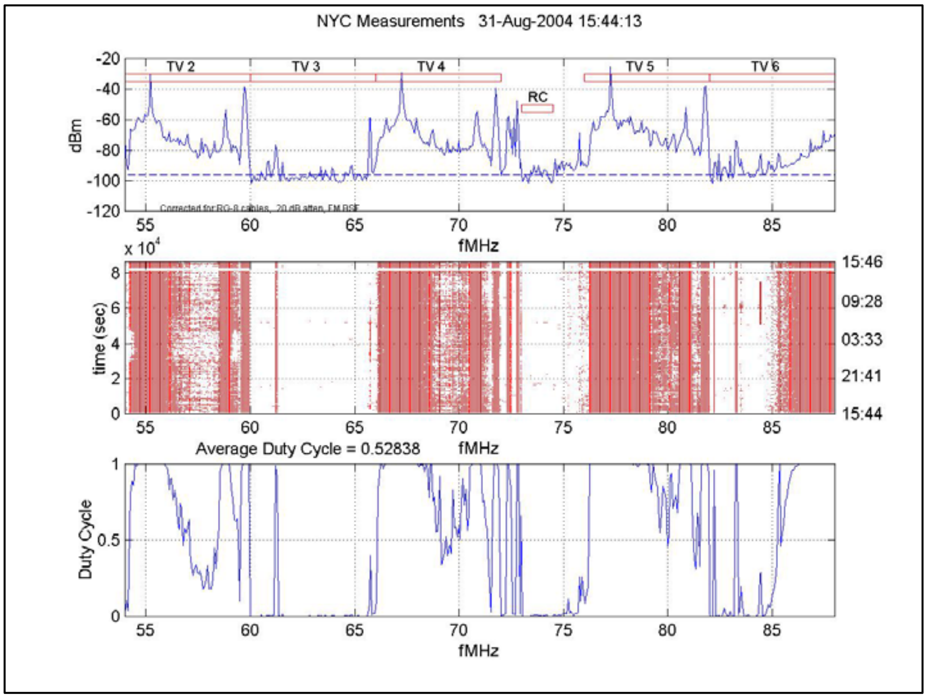

Figure 12: August 31 to September 1, 54 MHz – 88 MHz

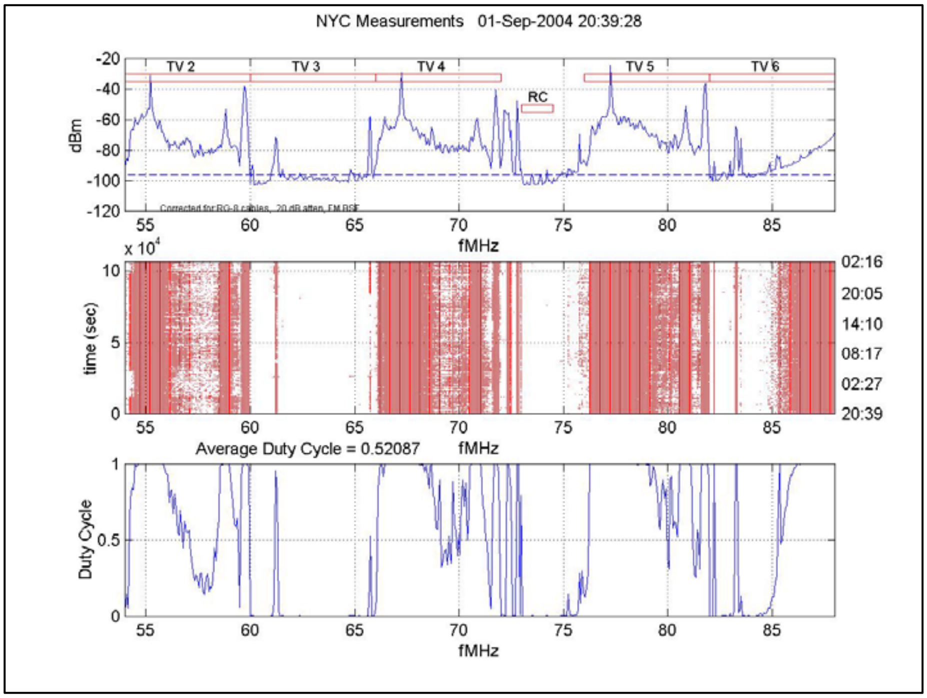

Figure 13: September 1 to September 3, 54 MHz – 88 MHz

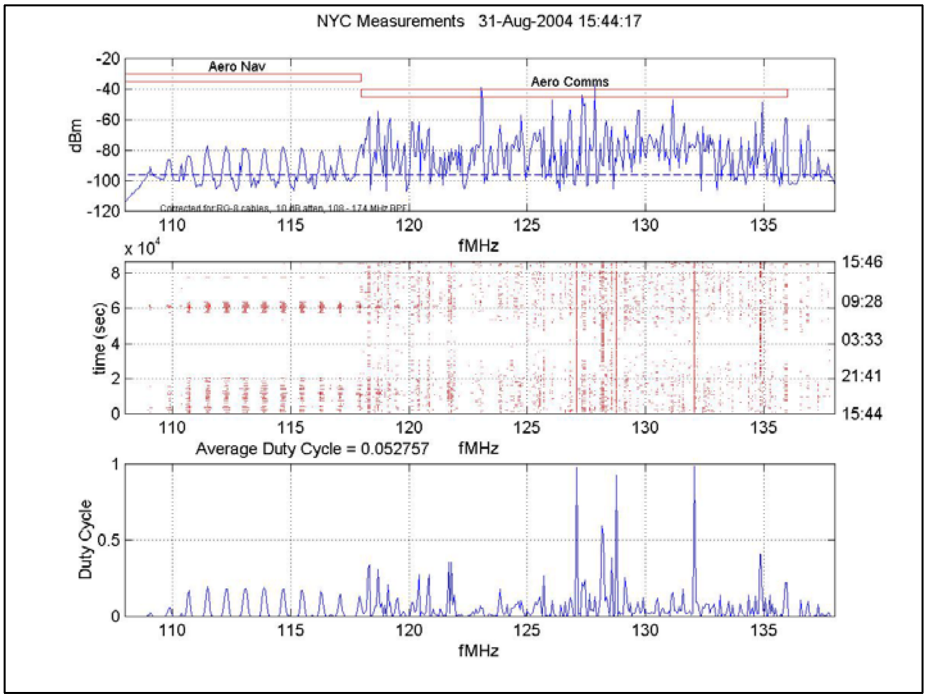

Figure 14: August 31 to September 1, 108 MHz – 138 MHz

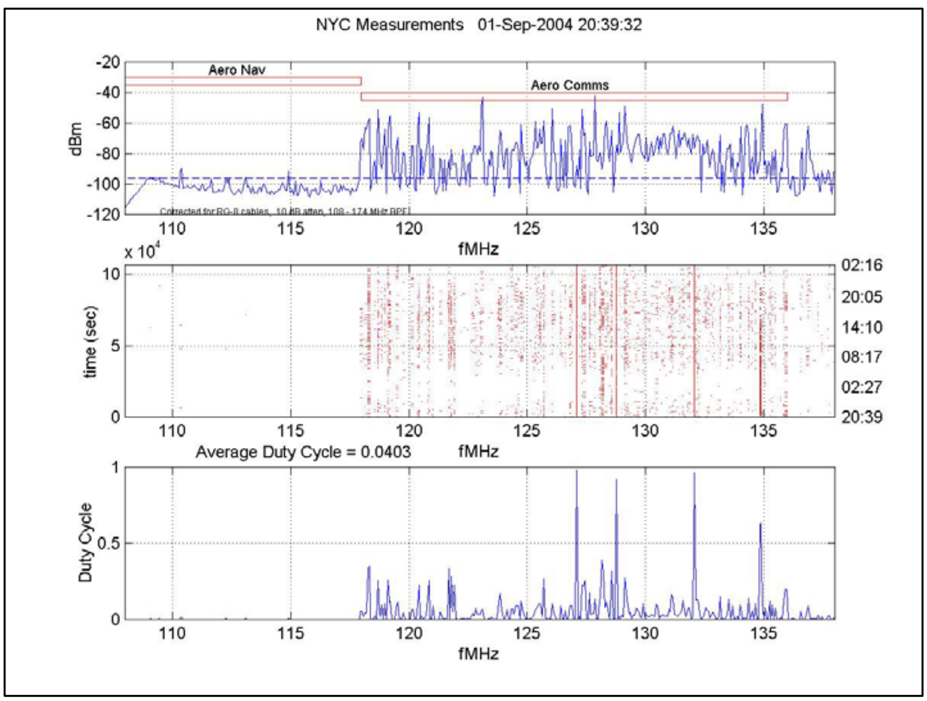

Figure 15: September 1 to September 3, 108 MHz – 138 MHz

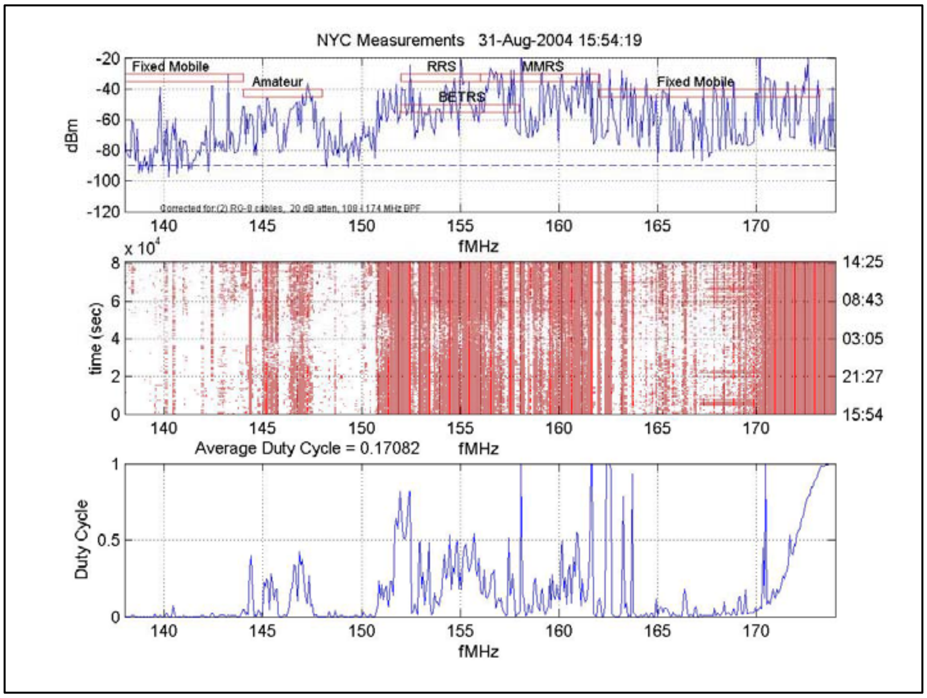

Figure 16: August 31 to September 1, 138 MHz – 174 MHz

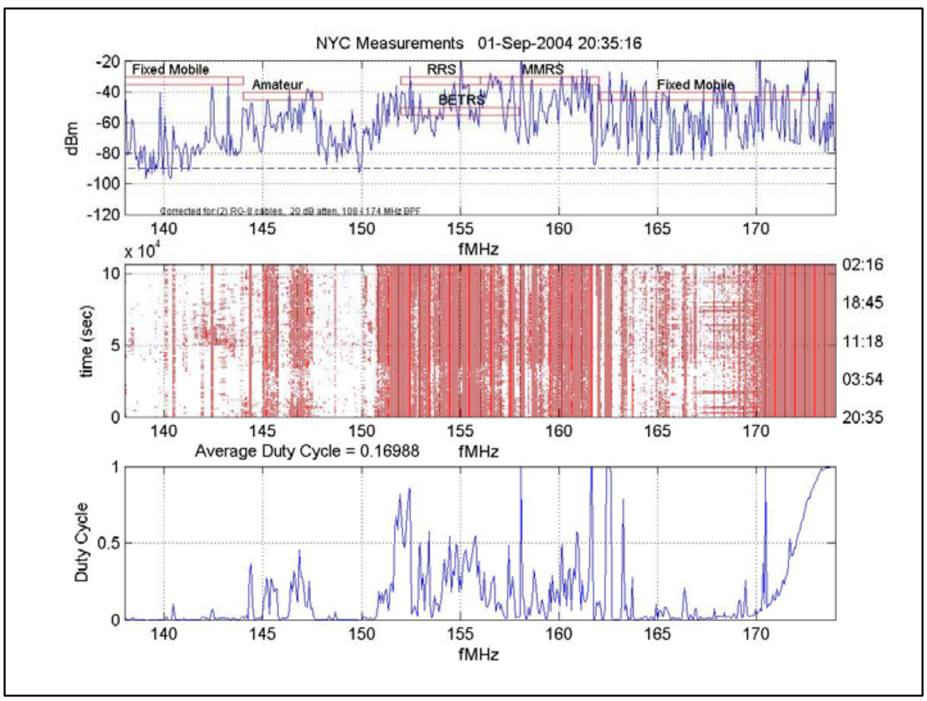

Figure 17: September 1 to September 3, 138 MHz – 174 MHz

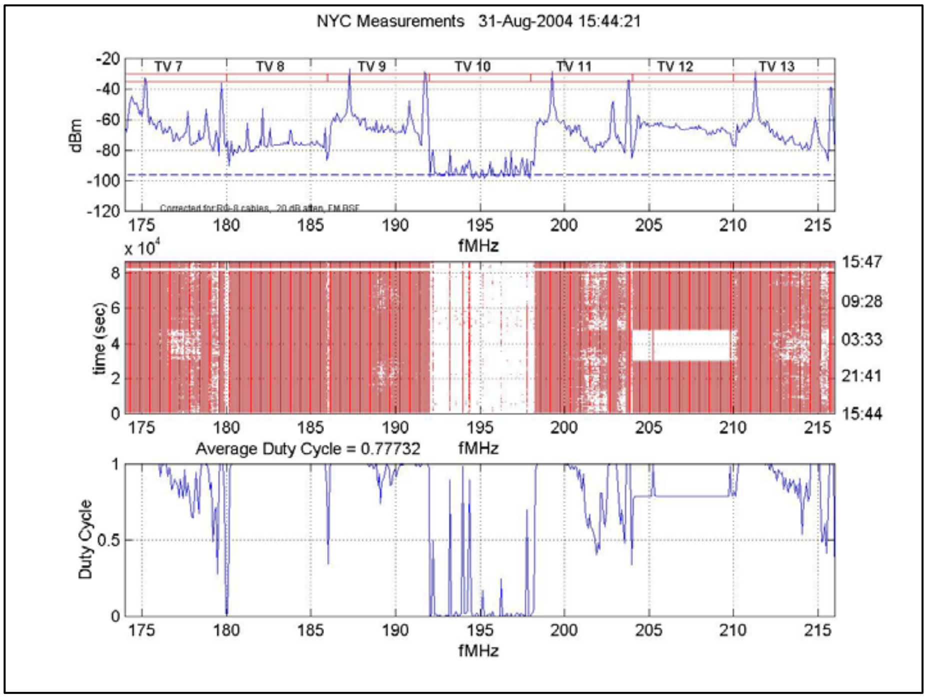

Figure 18: August 31 to September 1, 174 MHz – 216 MHz

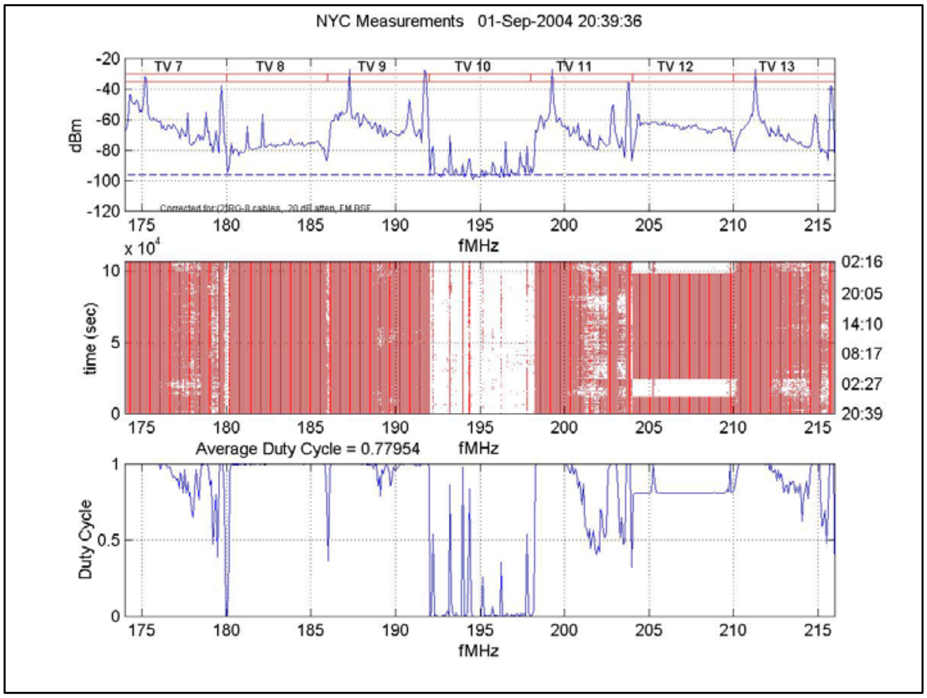

Figure 19: September 1 to September 3, 174 MHz – 216 MHz

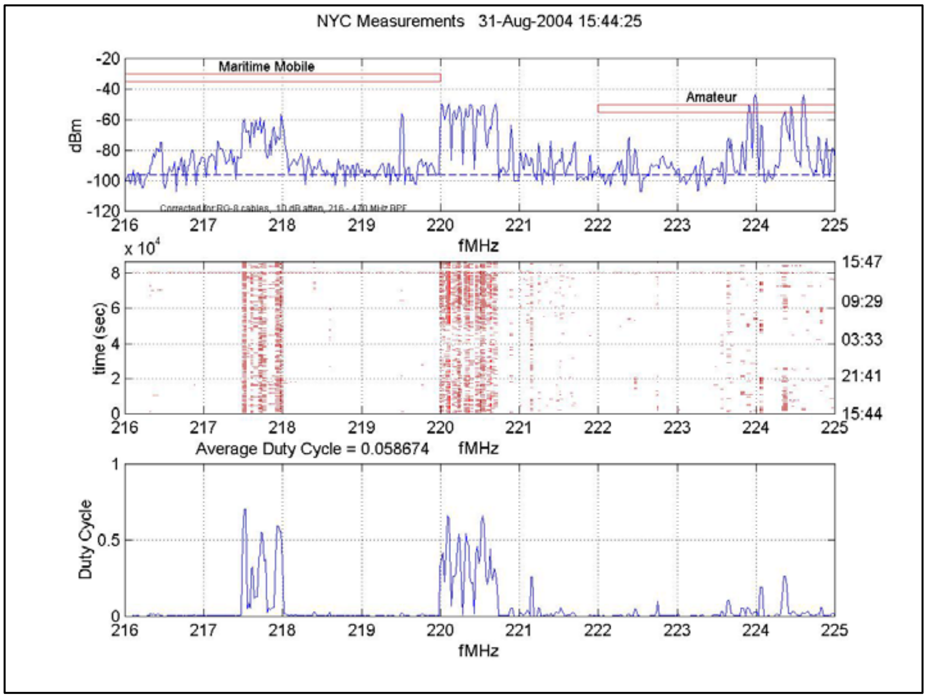

Figure 20: August 31 to September 1, 216 MHZ – 225

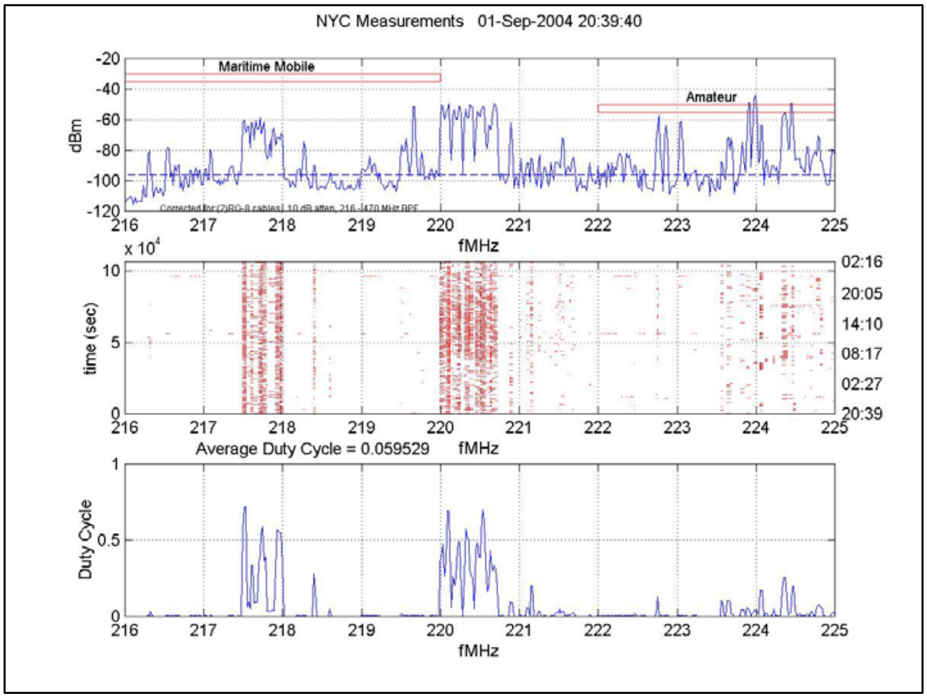

Figure 21: September 1 to September 3, 216 MHz – 225 MHz

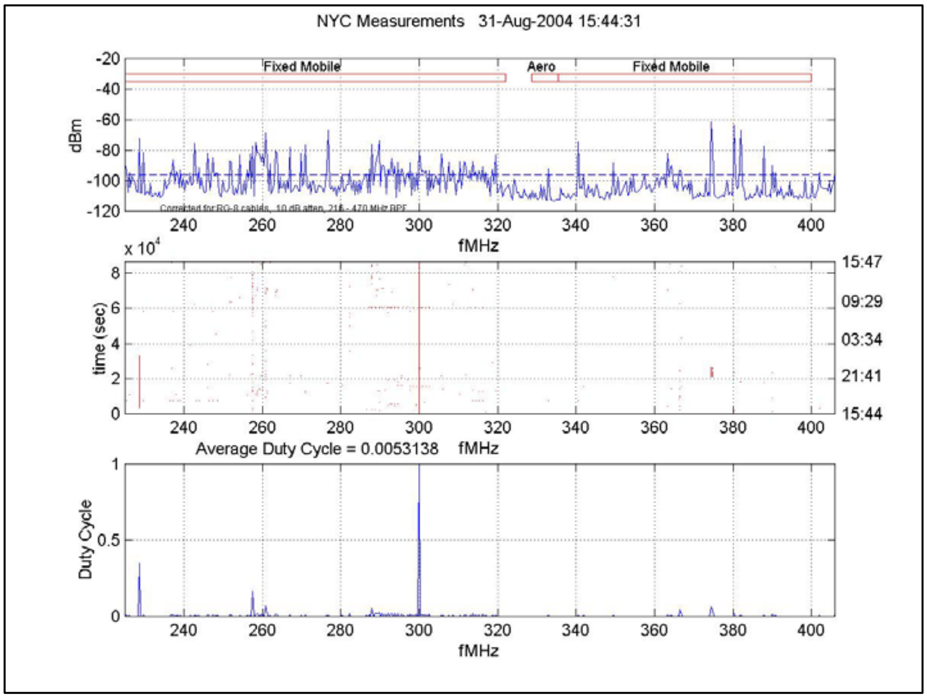

Figure 22: August 31 to September 1, 225 MHz – 406 MHz

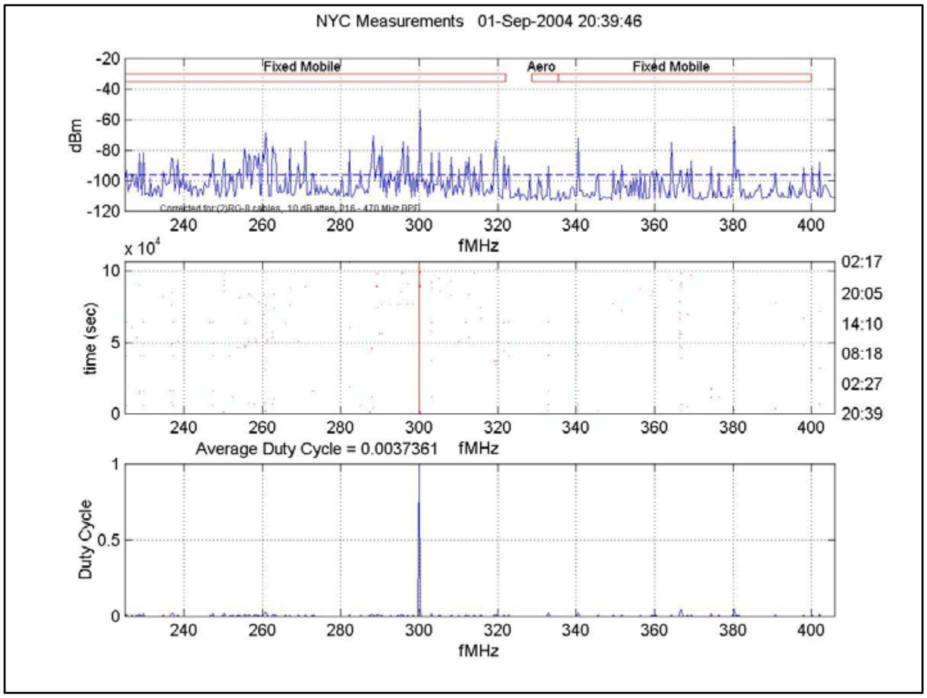

Figure 23: September 1 to September 3, 225 MHz – 406 MHz

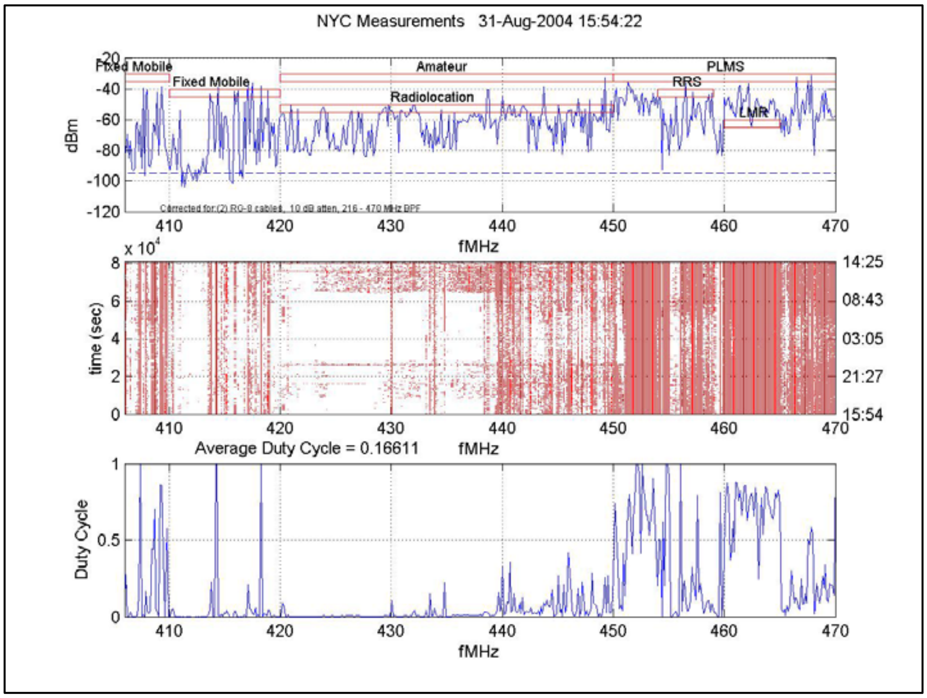

Figure 24: August 31 to September 1, 406 MHz – 470 MHz

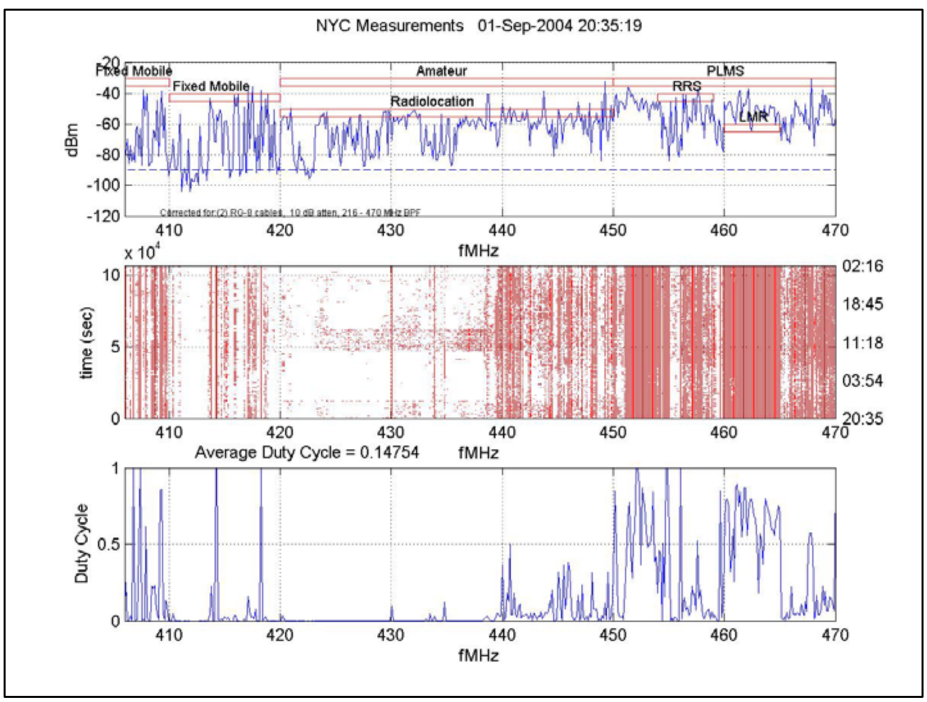

Figure 25: September 1 to September 3, 406 MHz – 470 MHz

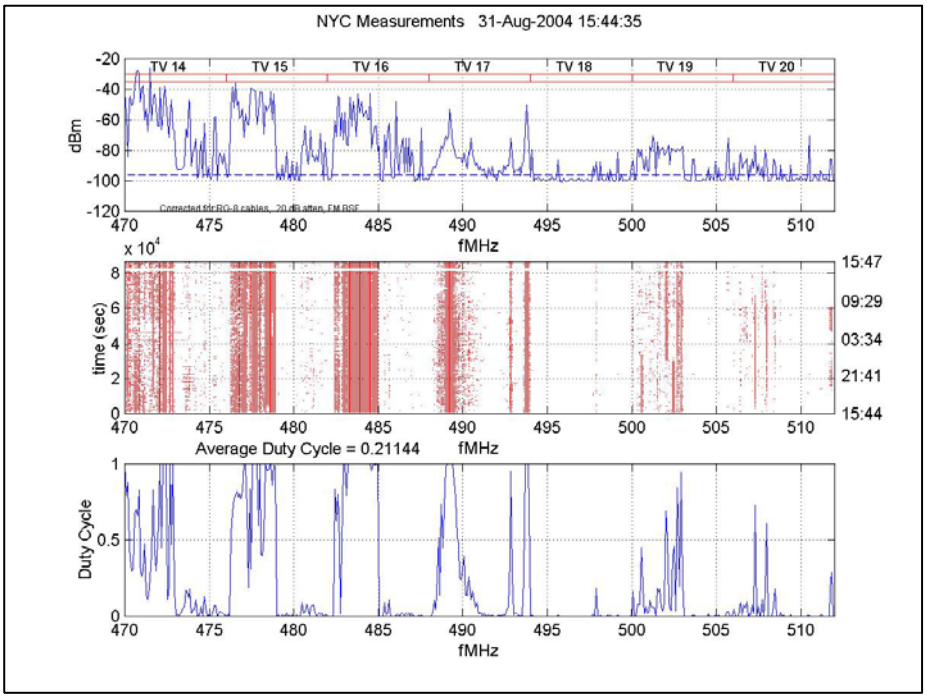

Figure 26: August 31 to September 1, 470 MHz – 512 MHz

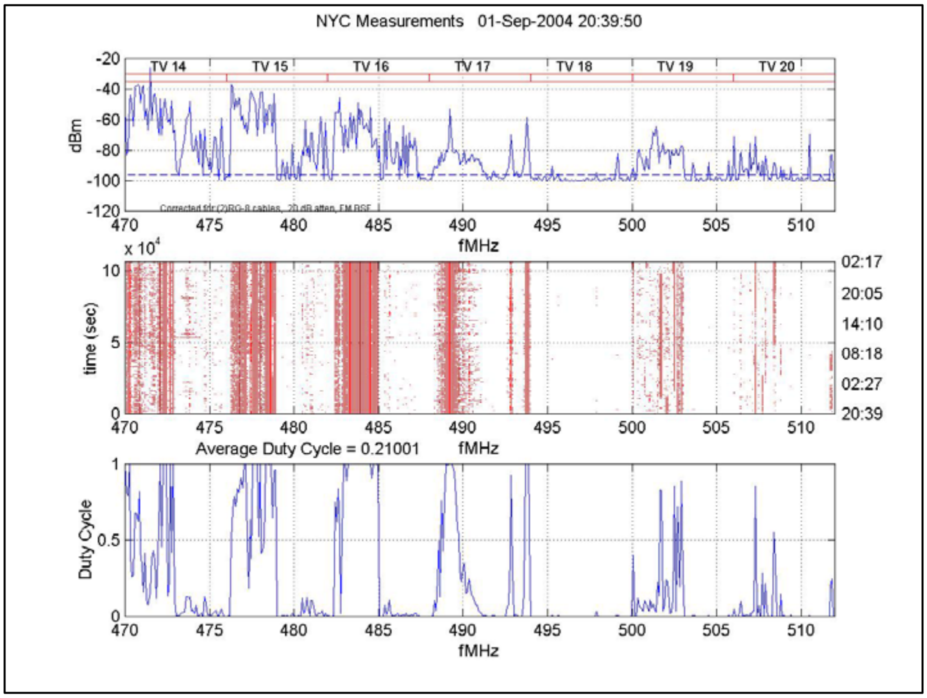

Figure 27: September 1 to September 3, 470 MHz – 512 MHz

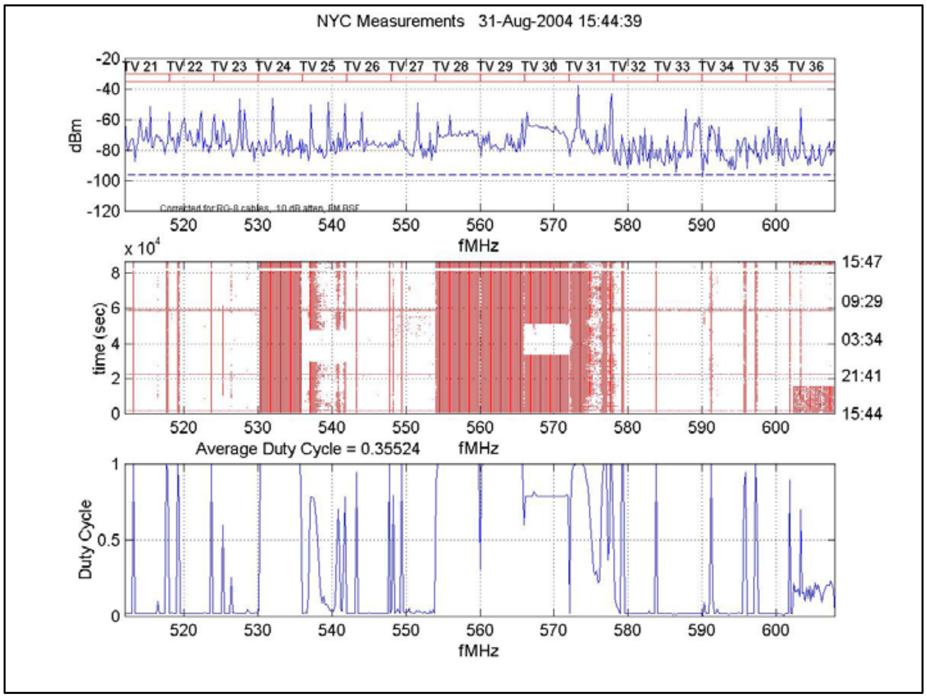

Figure 28: August 31 to September 1, 512 MHz – 608 MHz

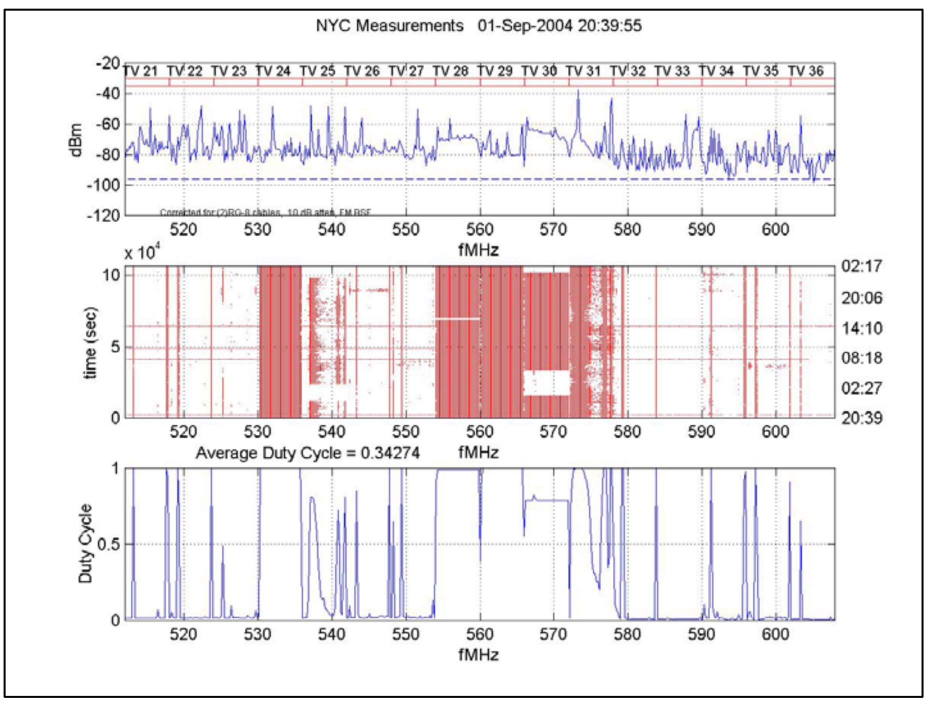

Figure 29: September 1 to September 3, 512 MHz – 608 MHz

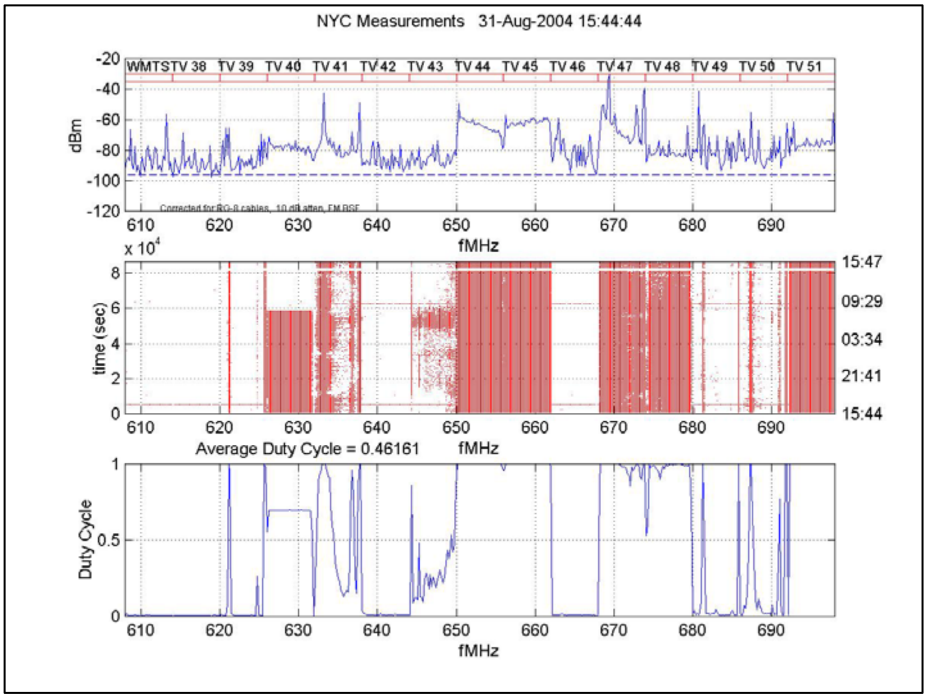

Figure 30: August 31 to September 1, 608 MHz – 698 MHz

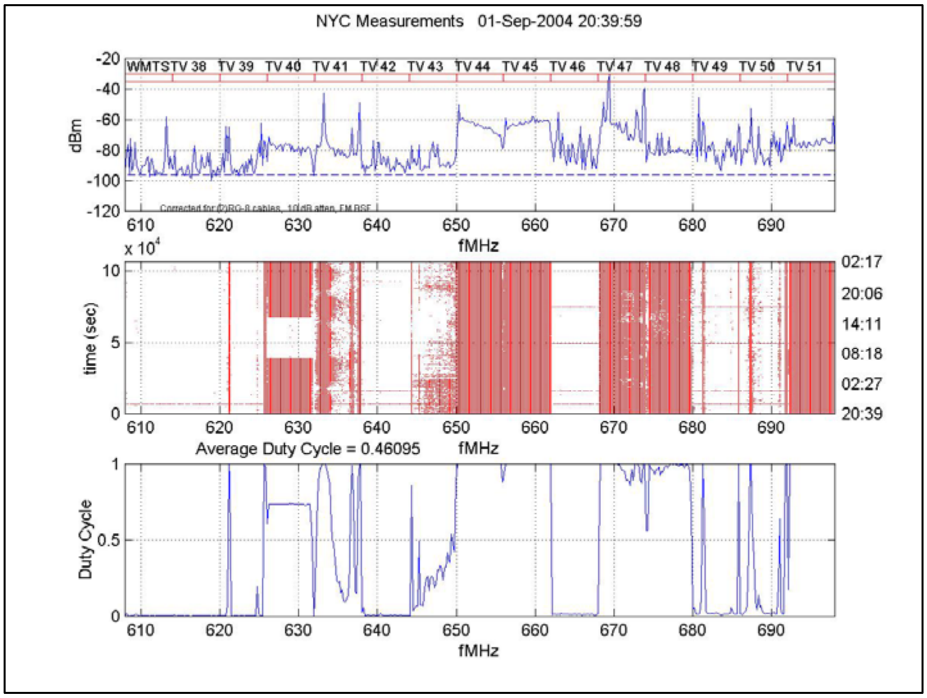

Figure 31: September 1 to September 3, 608 MHz – 698 MHz

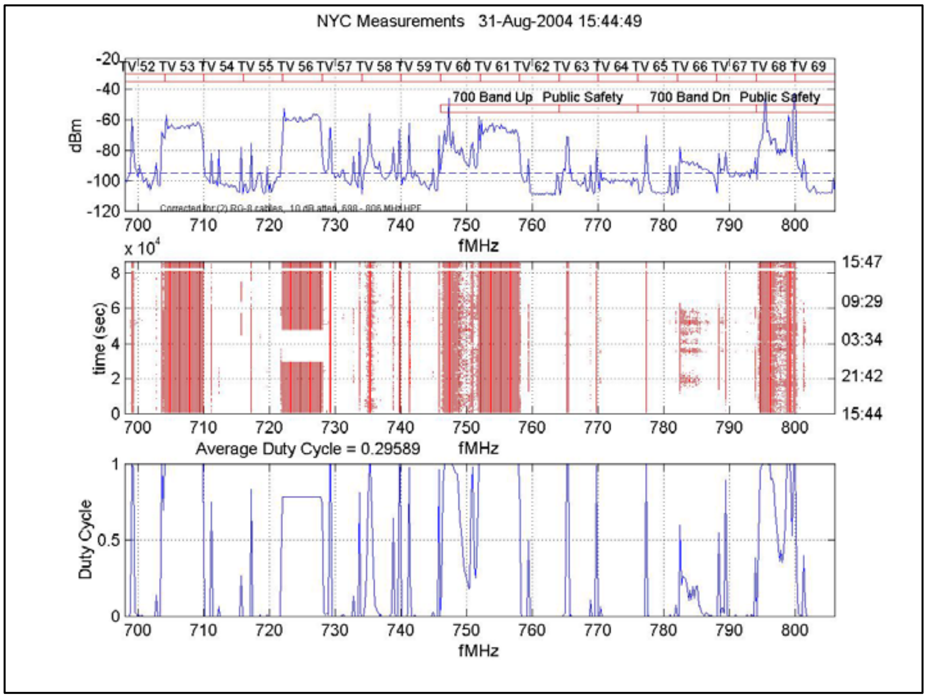

Figure 32: August 31 to September 1, 698 MHz – 806 MHz

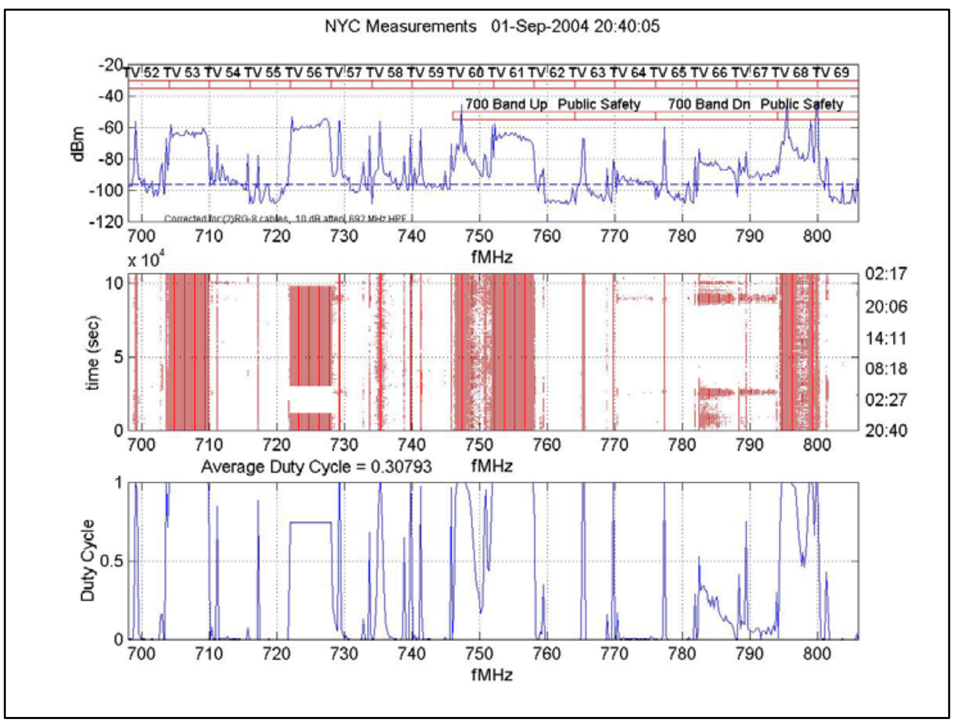

Figure 33: September 1 to September 3, 698 MHz – 806 MHz

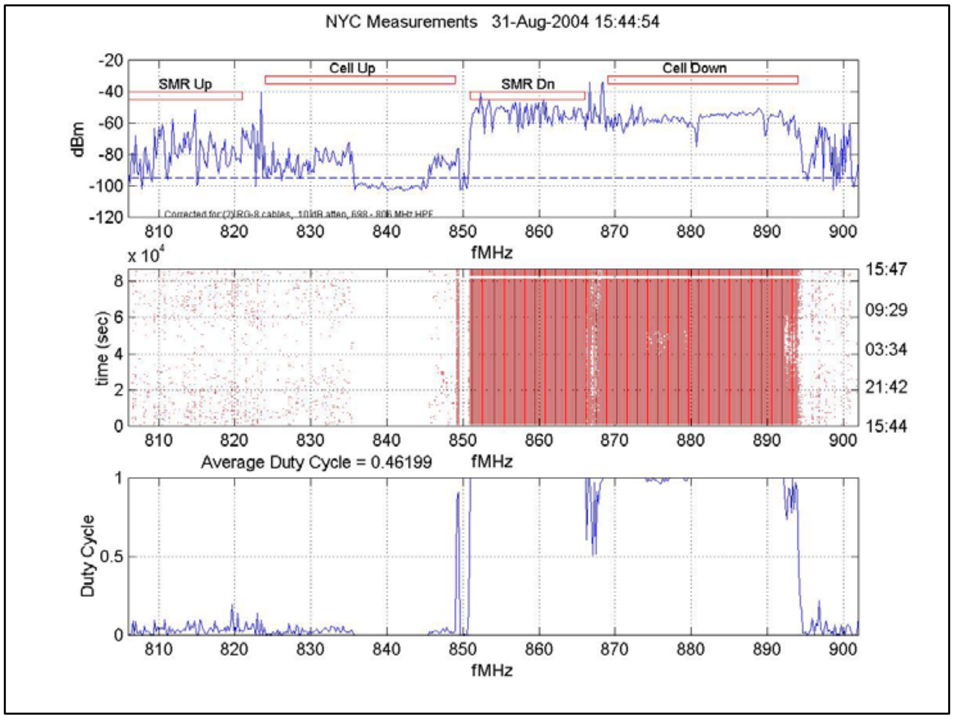

Figure 34: August 31 to September 1, 806 MHz – 902 MHz

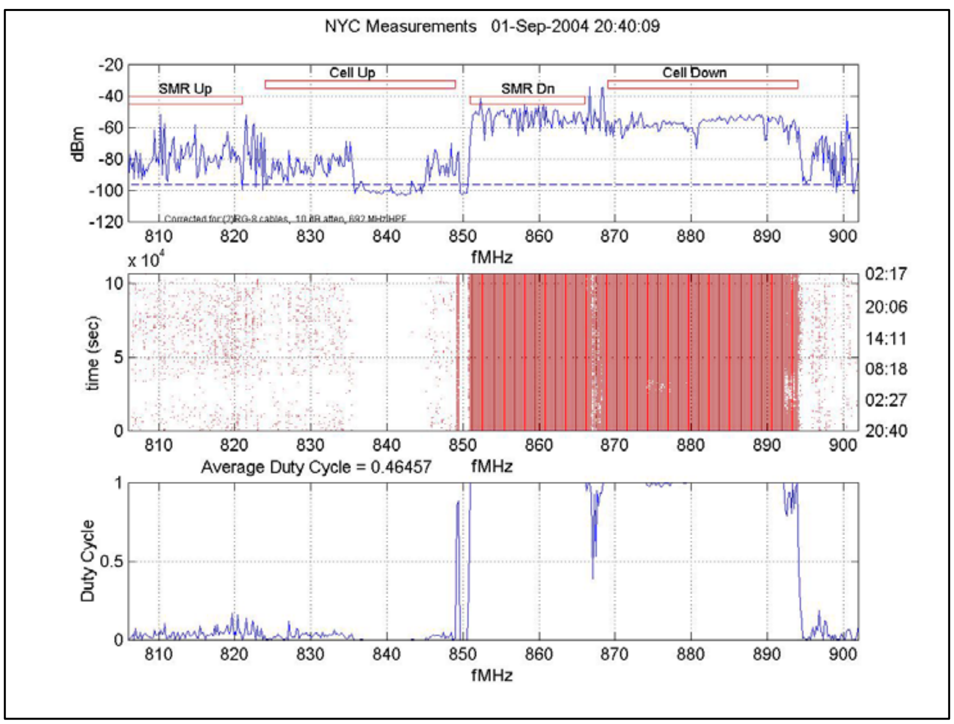

Figure 35: September 1 to September 3, 806 MHz – 902 MHz

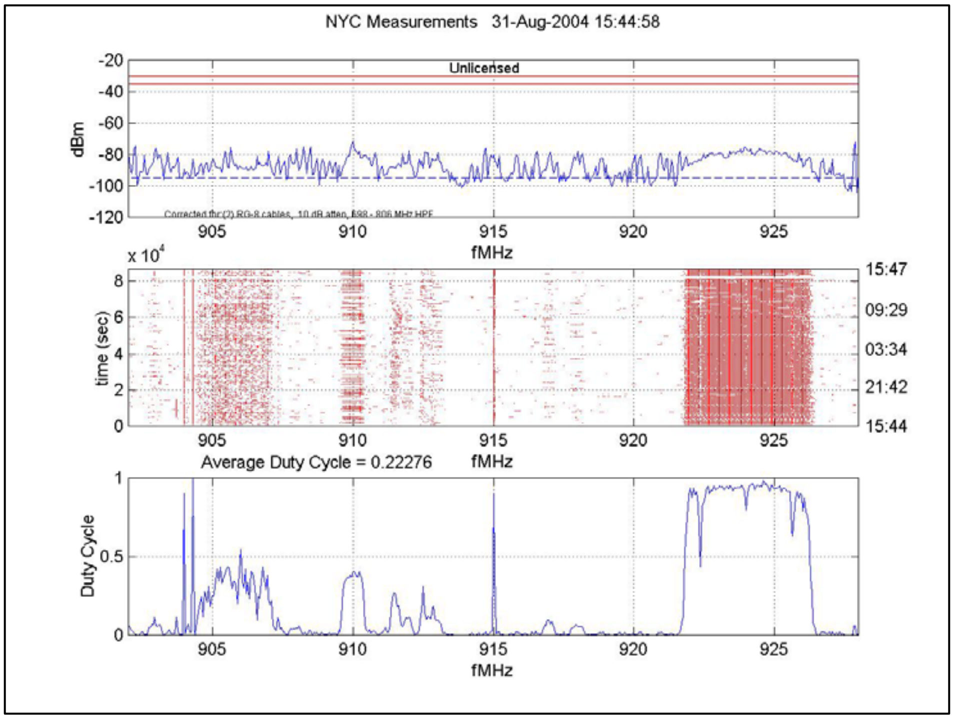

Figure 36: August 31 to September 1, 902 MHz – 928 MHz

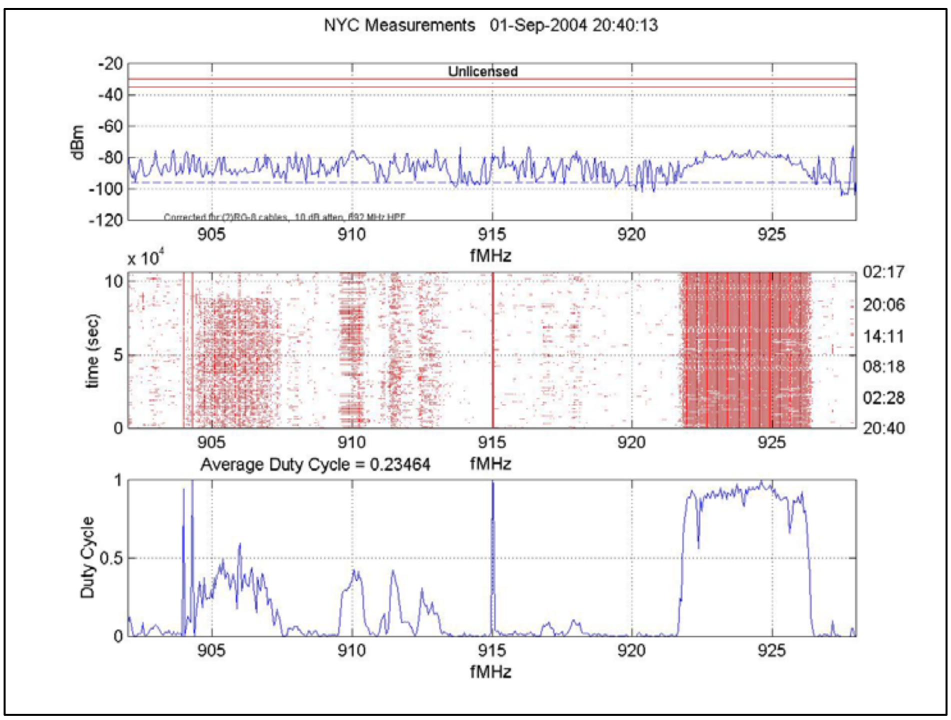

Figure 37: September 1 to September 3, 902 MHz – 928 MHz

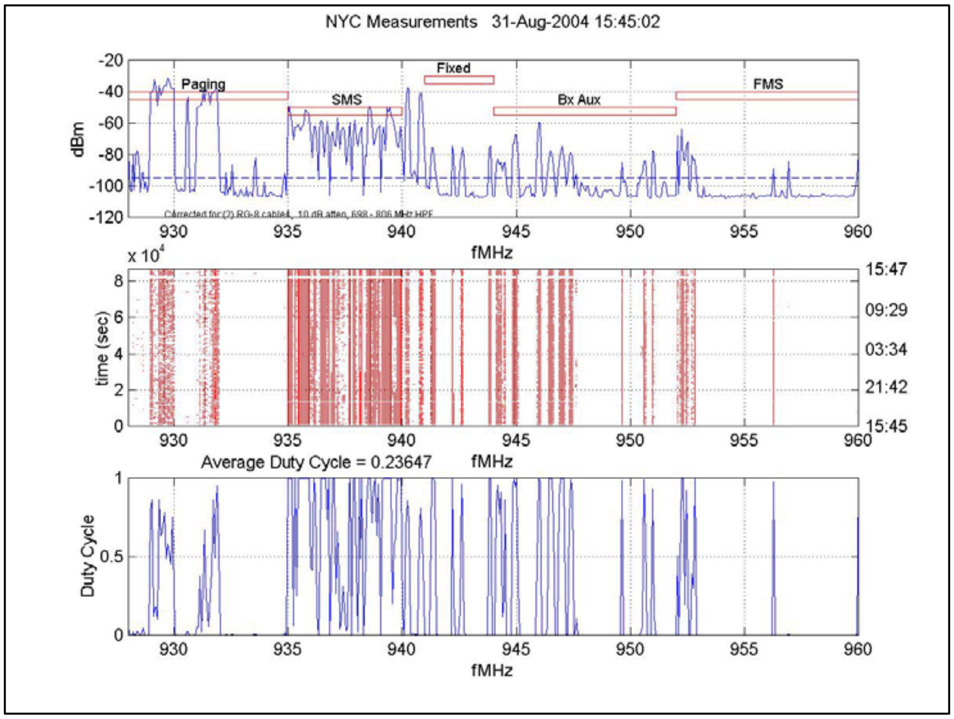

Figure 38: August 31 to September 1, 928 MHz – 960 MHz

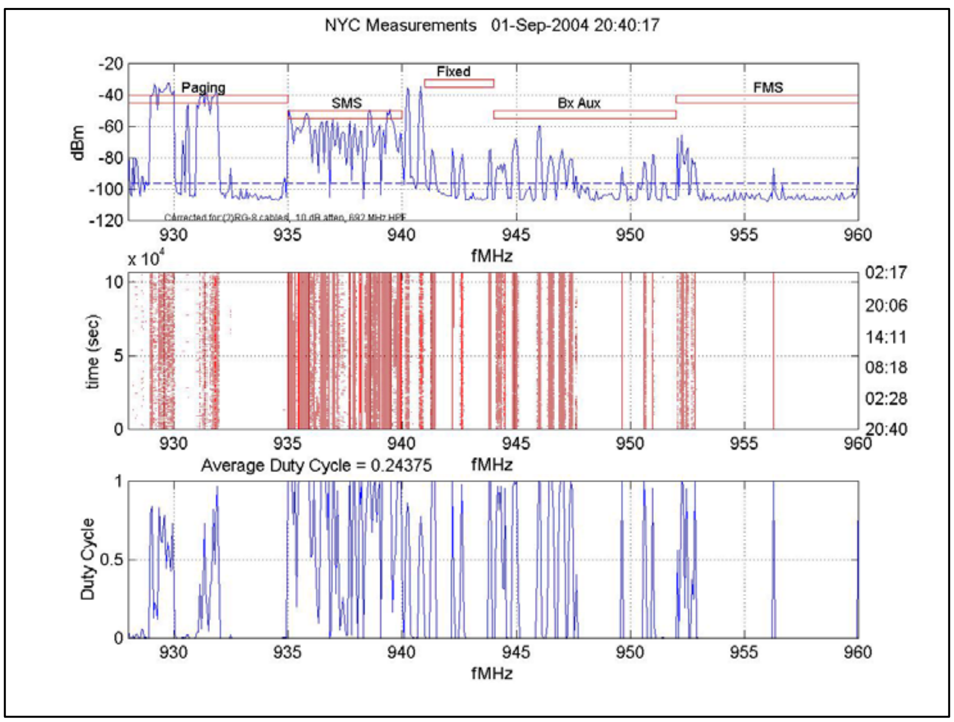

Figure 39: September 1 to September 3, 928 MHz – 960 MHz

5.3 Measurements Made Above 960 MHz

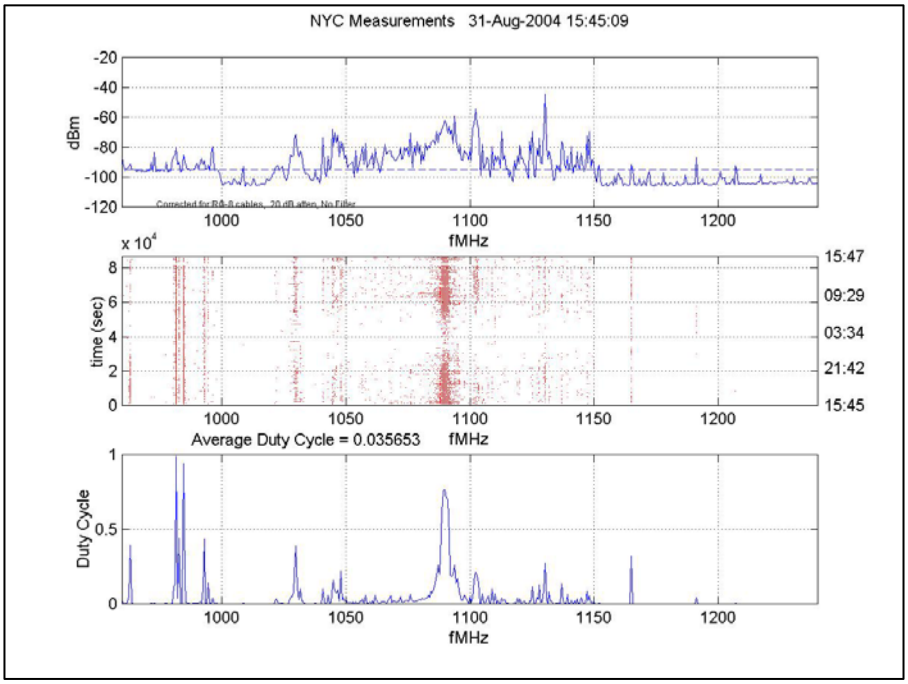

Figure 40: August 31 to September 1, 960 MHz – 1240 MHz

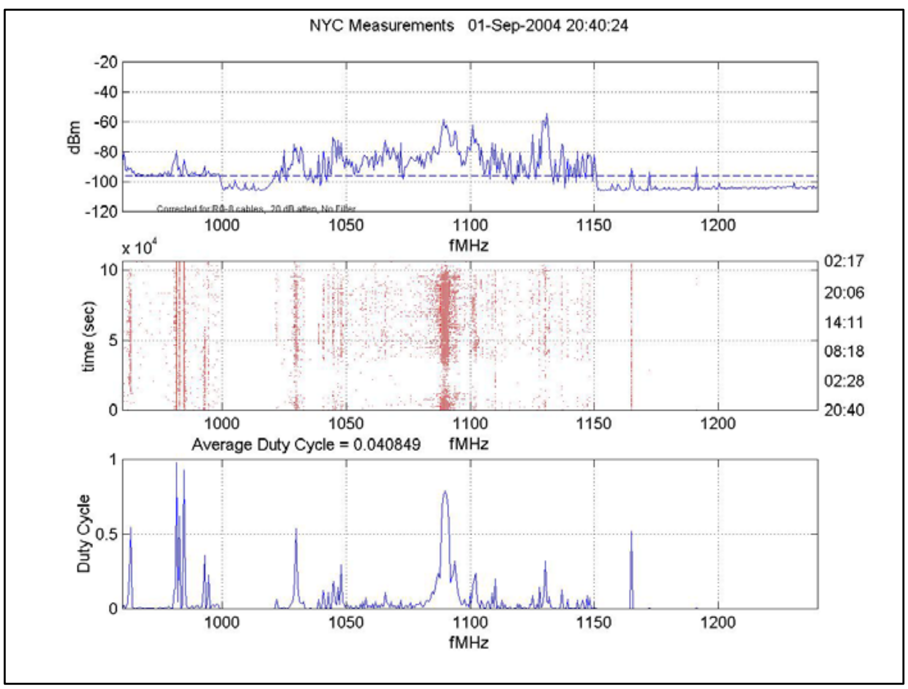

Figure 41: September 1 to September 3, 960 MHz – 1240 MHz

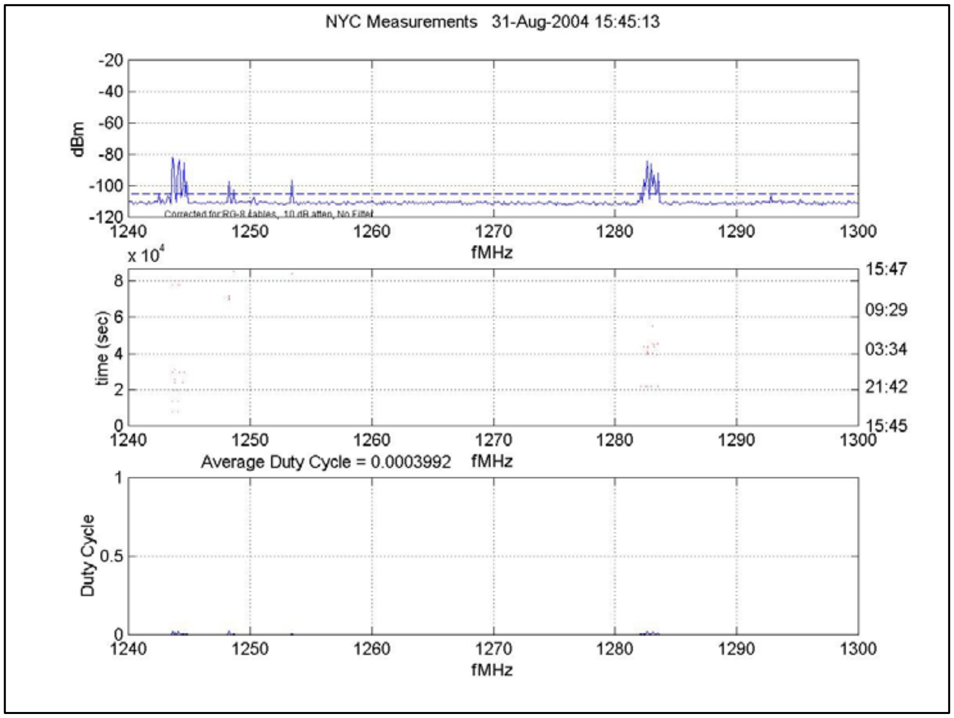

Figure 42: August 31 to September 1, 1240 MHz – 1300 MHz

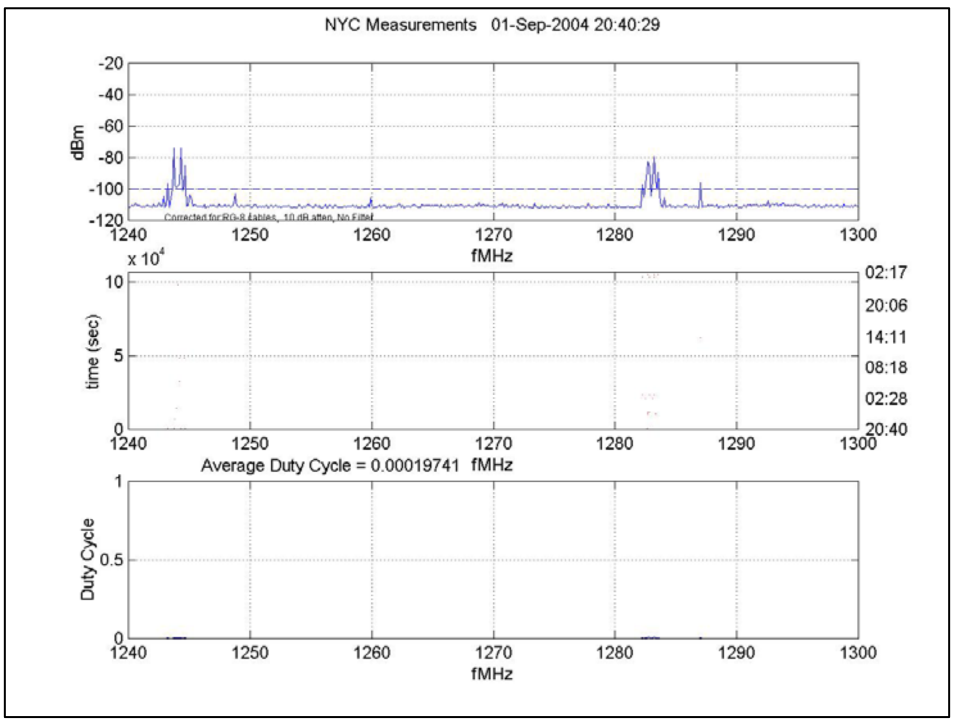

Figure 43: September 1 to September 3, 1240 MHz – 1300 MHz

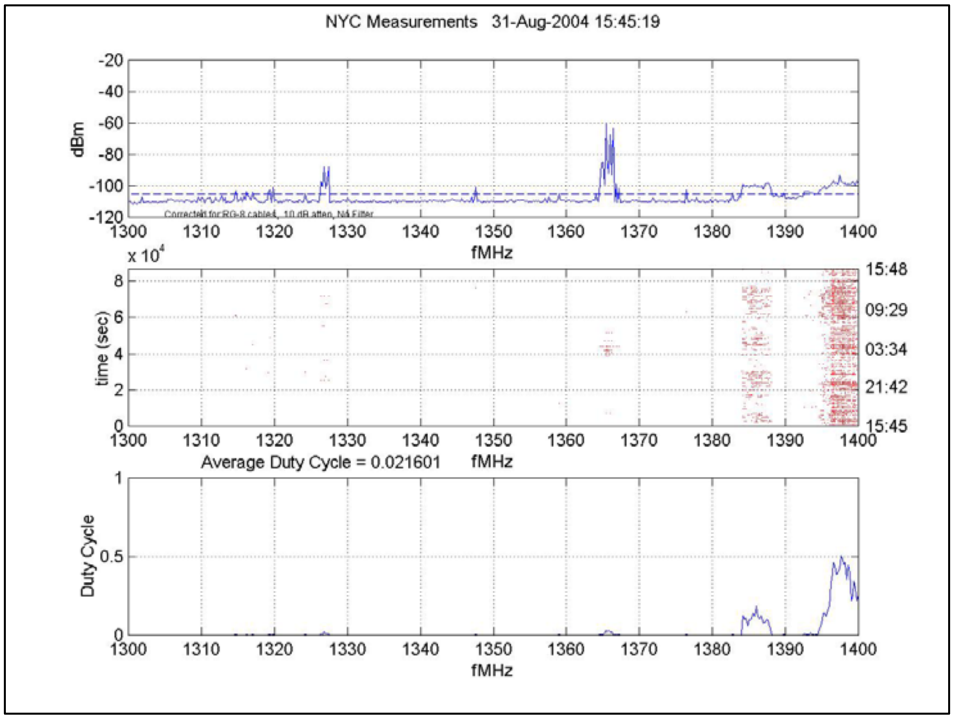

Figure 44: August 31 to September 1, 1300 MHz – 1400 MHz

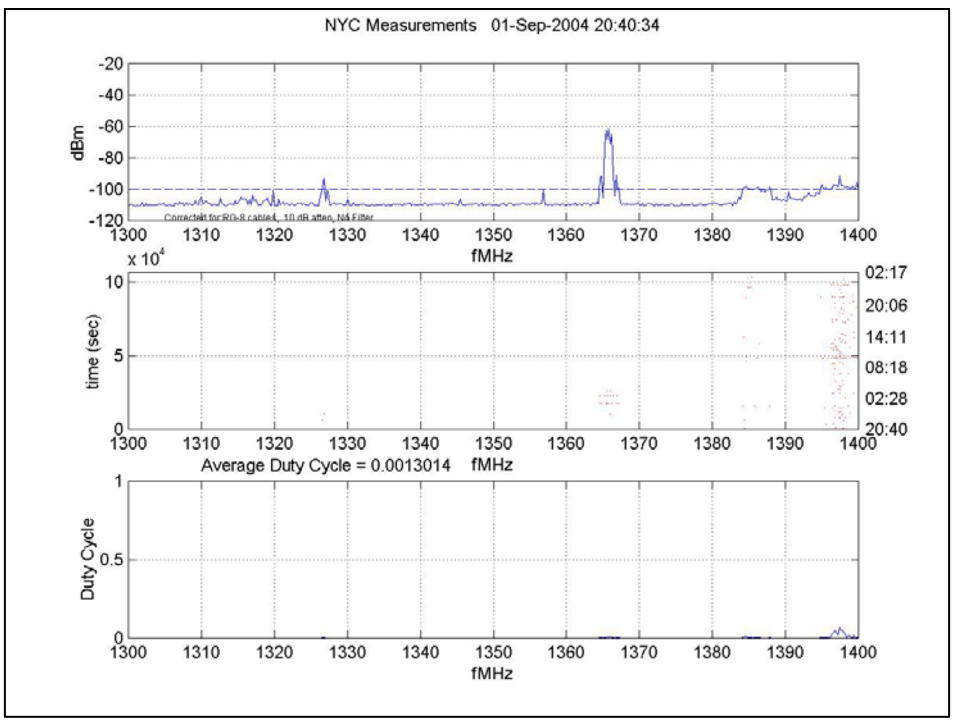

Figure 45: September 1 to September 3, 1300 MHz – 1400 MHz

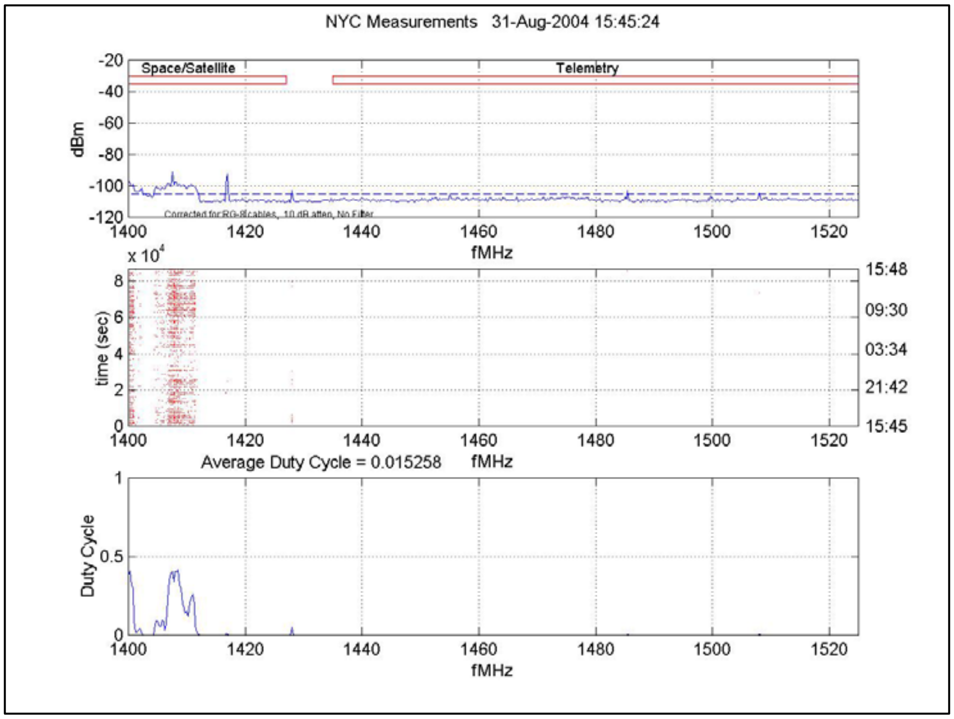

Figure 46: August 31 to September 1 1400 MHz – 1525 MHz

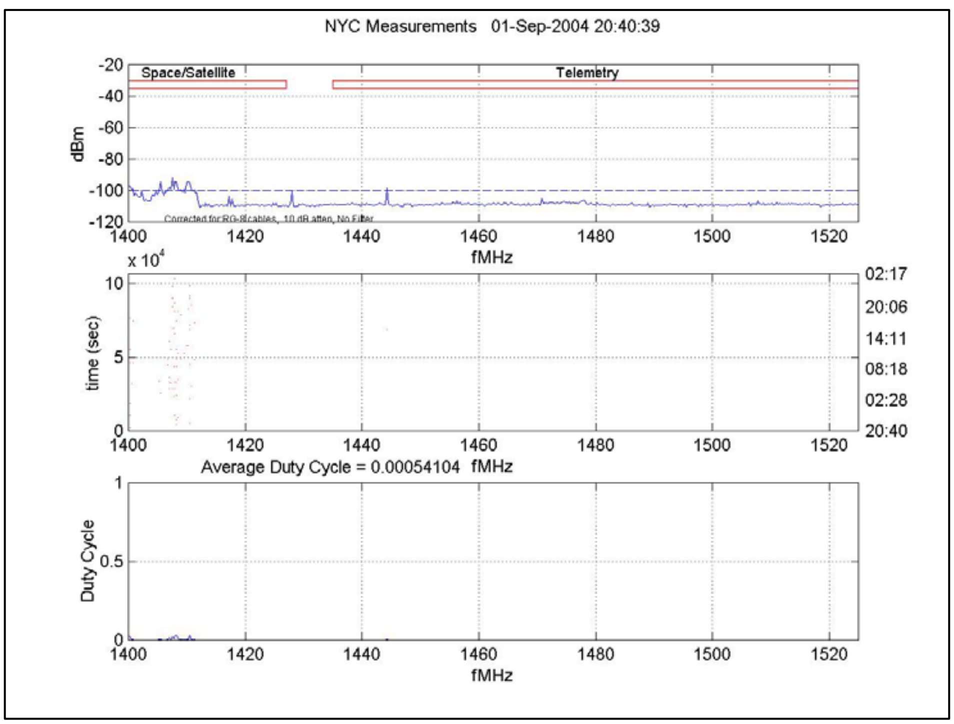

Figure 47: September 1 to September 3, 1400 MHz – 1525 MHz

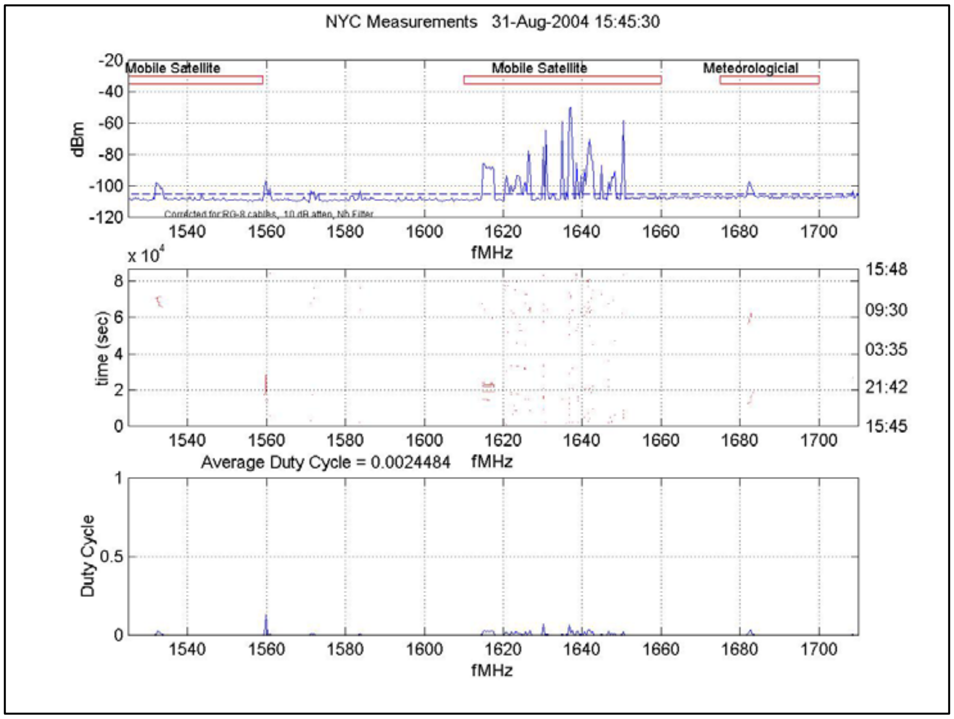

Figure 48: August 31 to September 1, 1525 MHz – 1710 MHz

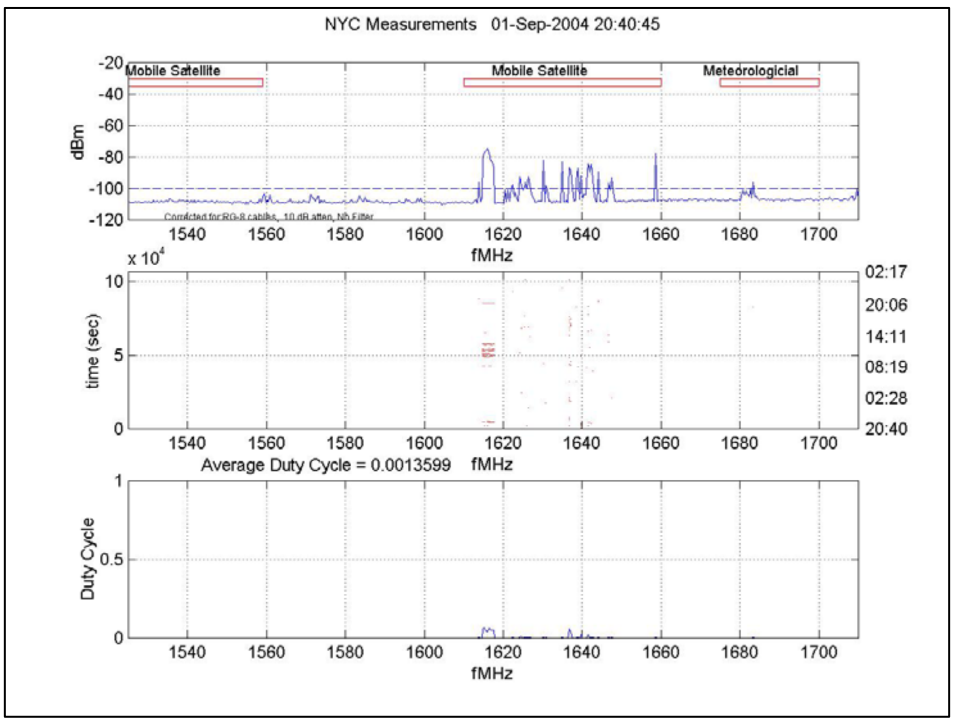

Figure 49: September 1 to September 3, 1525 MHz – 1710 MHz

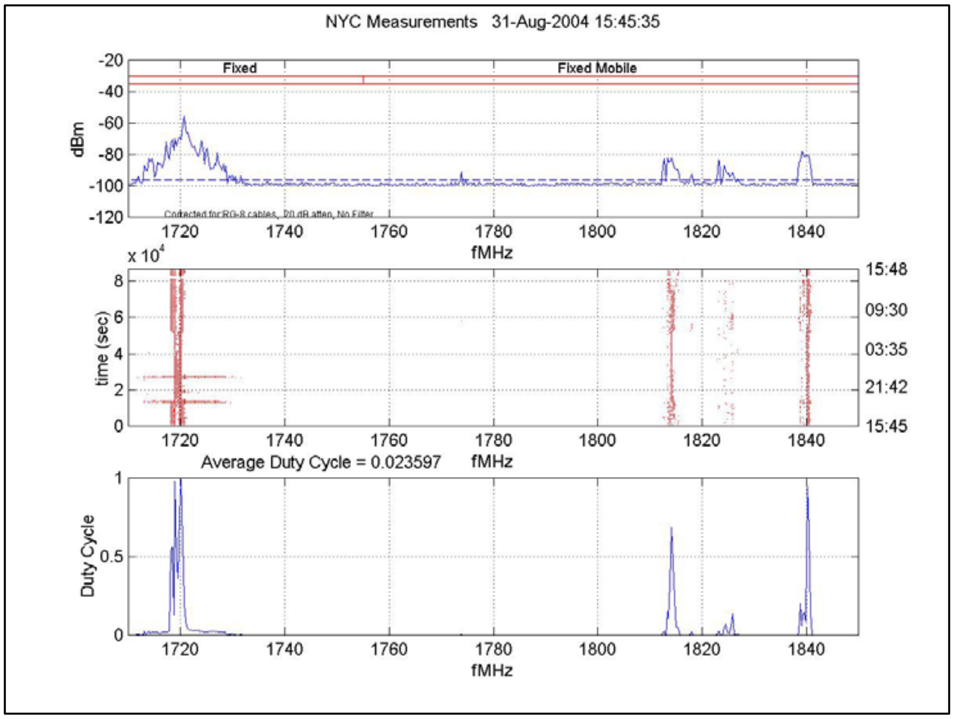

Figure 50: August 31 to September 1, 1710 MHz – 1850 MHz

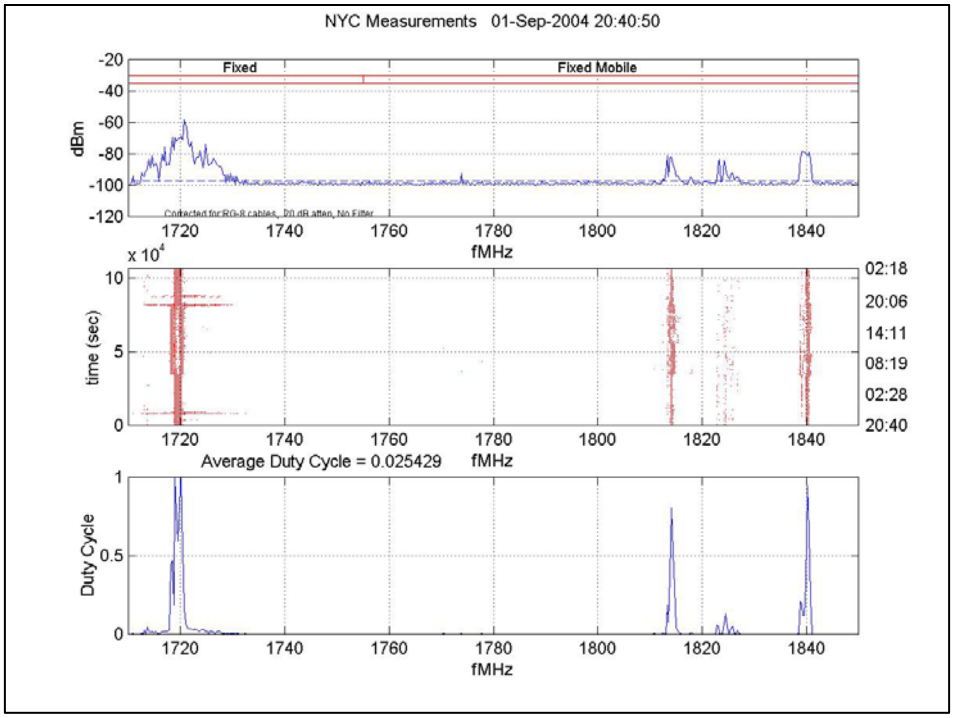

Figure 51: September 1 to September 3, 1710 MHz – 1850 MHz

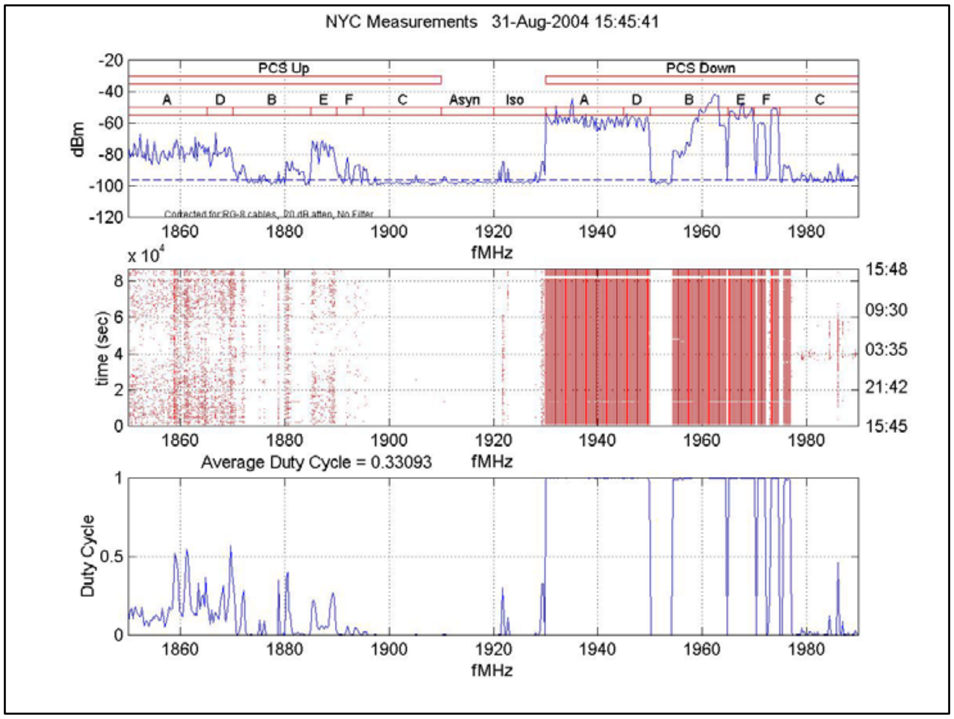

Figure 52: August 31 to September 1, 1850 MHz – 1990 MHz

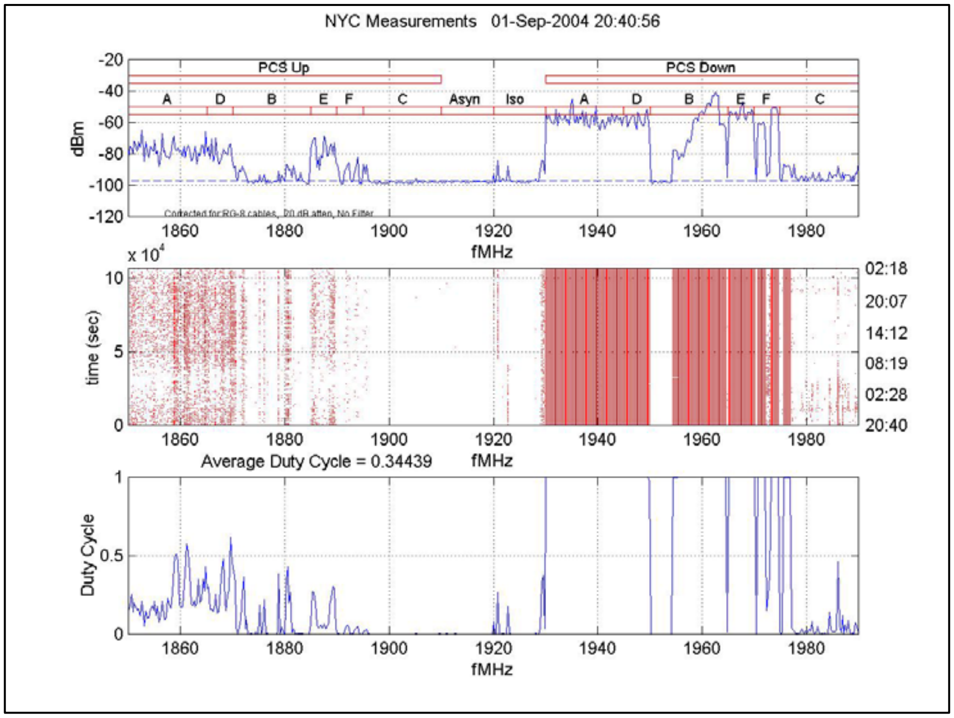

Figure 53: September 1 to September 3, 1850 MHz – 1990 MHz

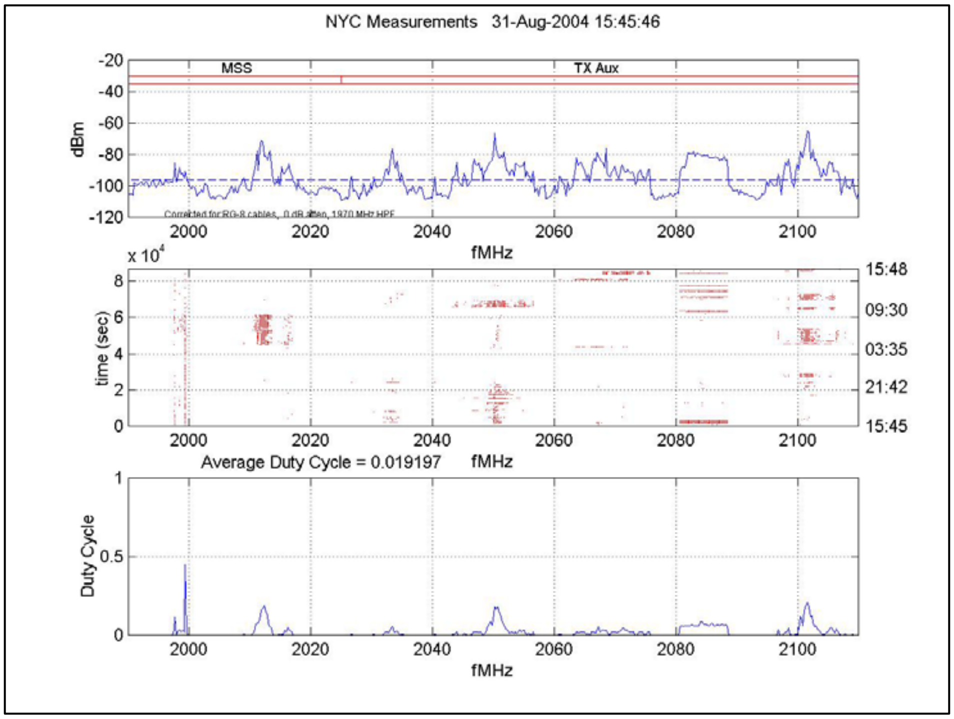

Figure 54: August 31 to September 1, 1990 MHz – 2110 MHz

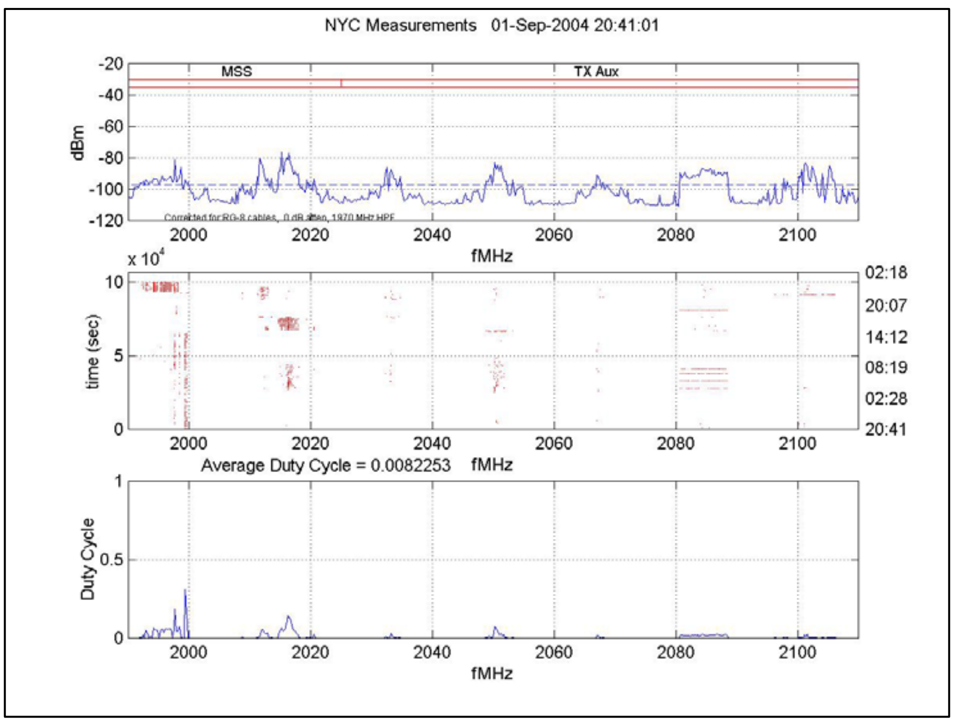

Figure 55: September 1 to September 3, 1990 MHz – 2110 MHz

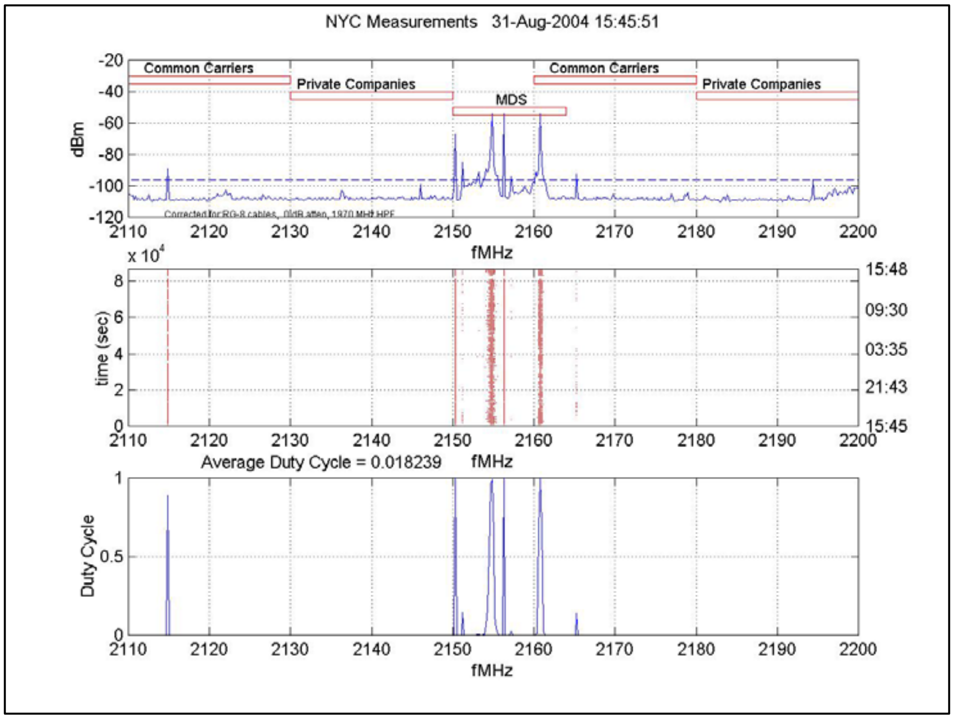

Figure 56: August 31 to September 1, 2110 MHz – 2200 MHz

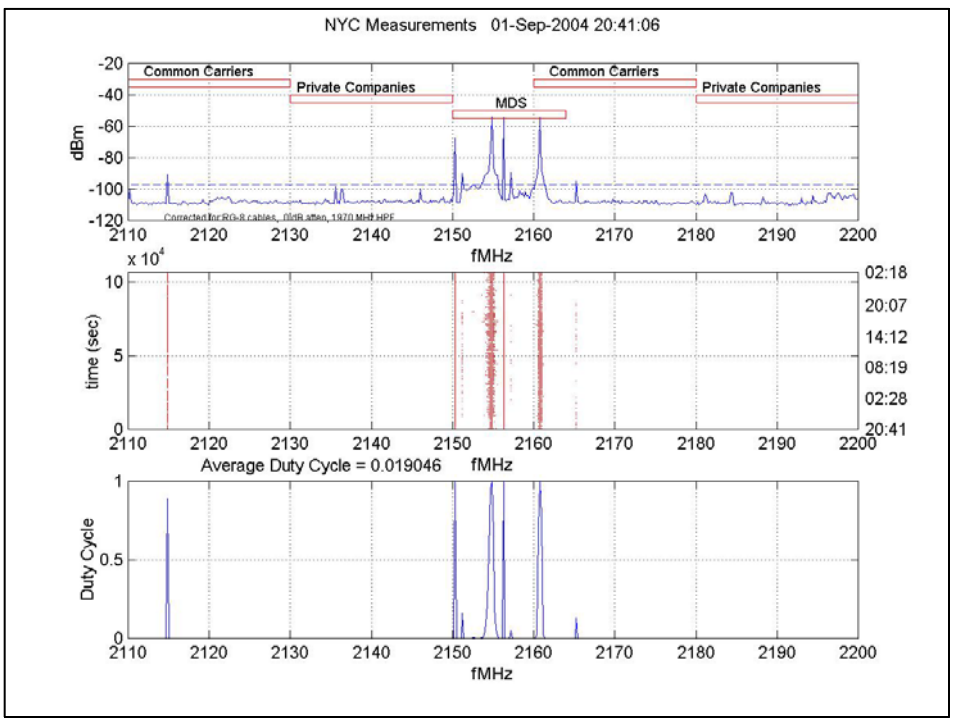

Figure 57: September 1 to September 3, 2110 MHz – 2200 MHz

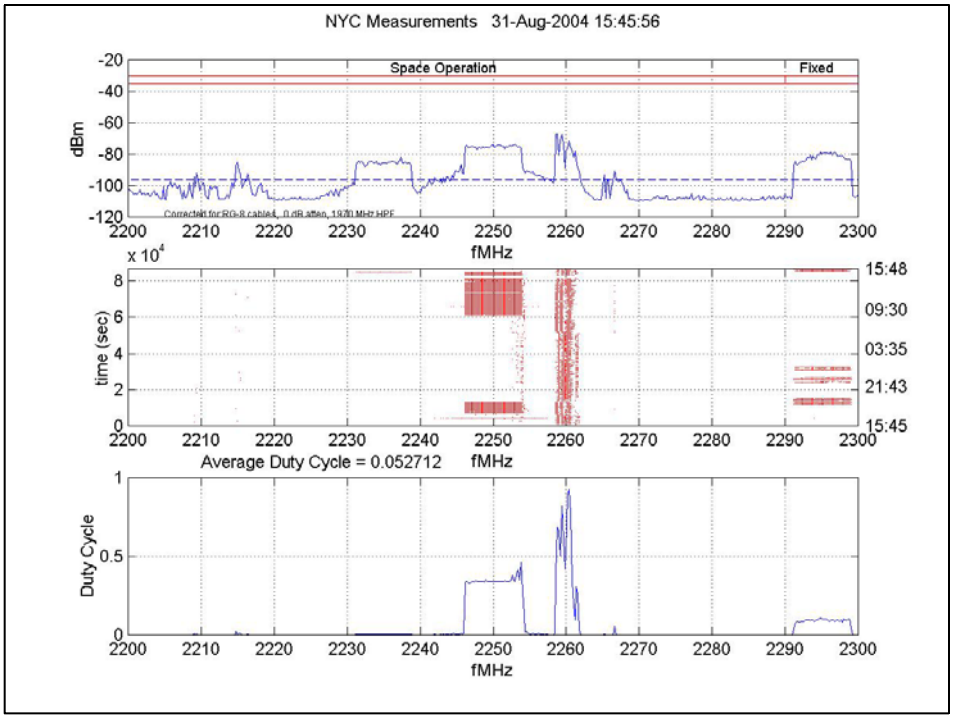

Figure 58: August 31 to September 1, 2200 MHz – 2300 MHz

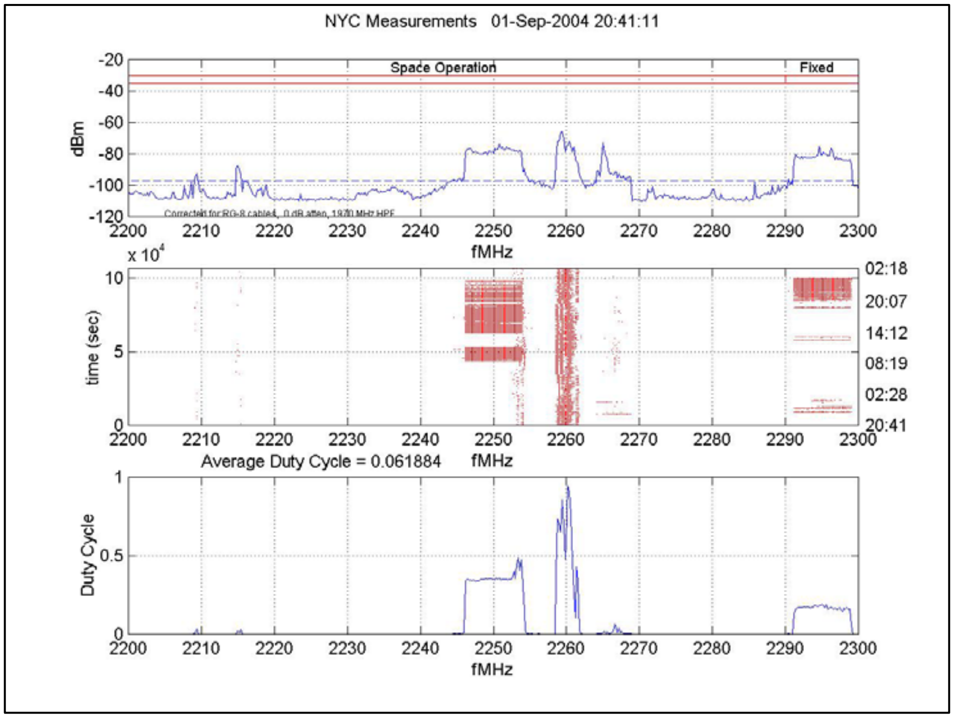

Figure 59: September 1 to September 3, 2200 MHz – 2300 MHz

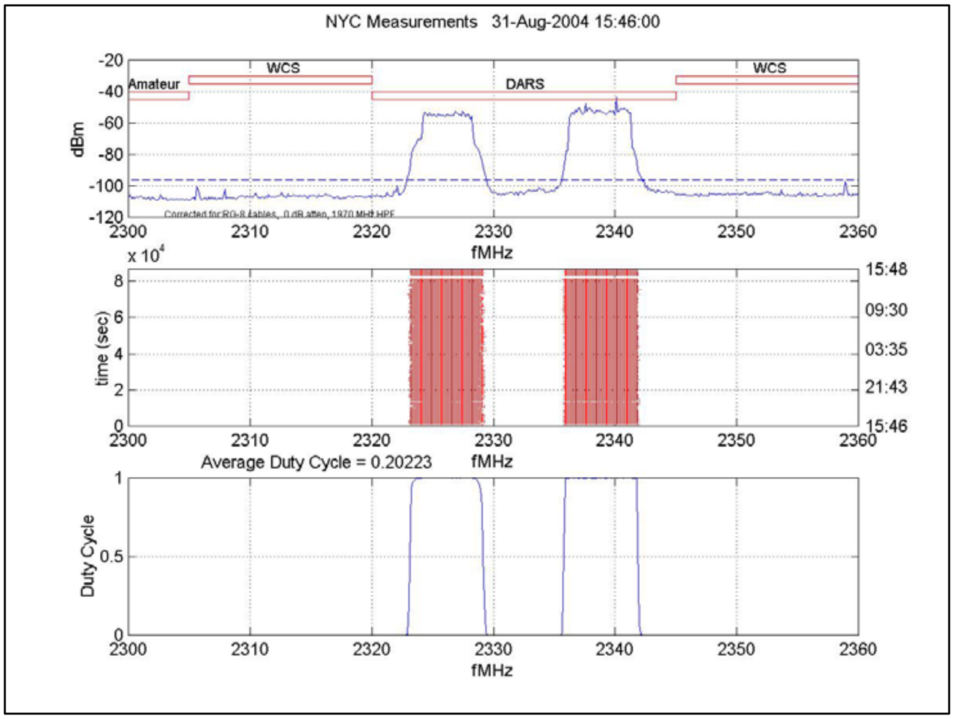

Figure 60: August 31 to September 1, 2300 MHz – 2360 MHz

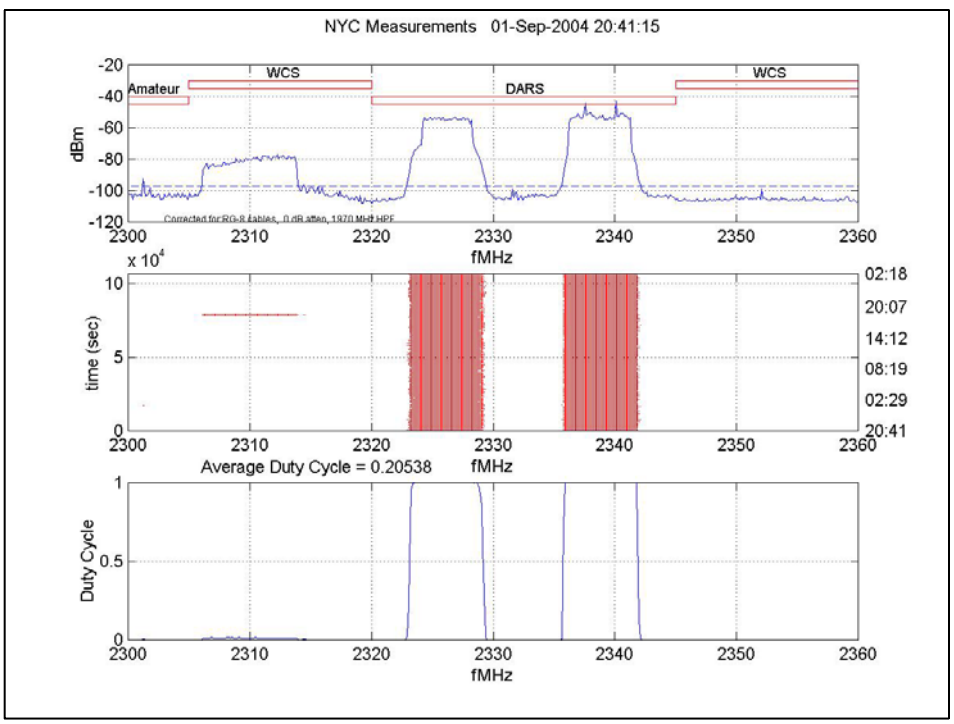

Figure 61: September 1 to September 3, 2300 MHz – 2360 MHz

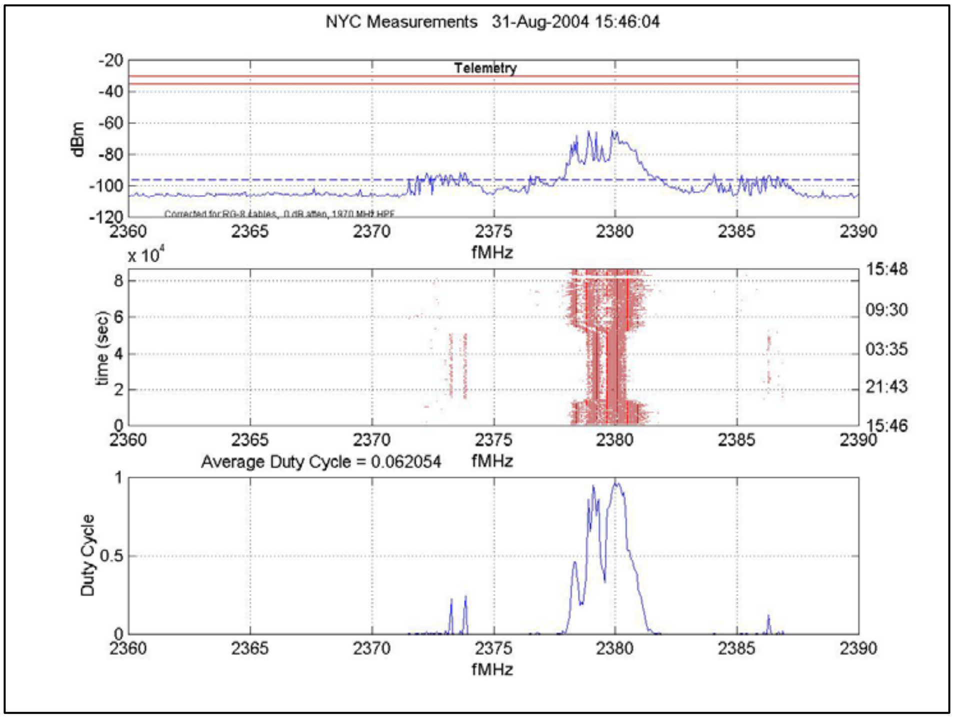

Figure 62: August 31 to September 1, 2360 MHz – 2390 MHz

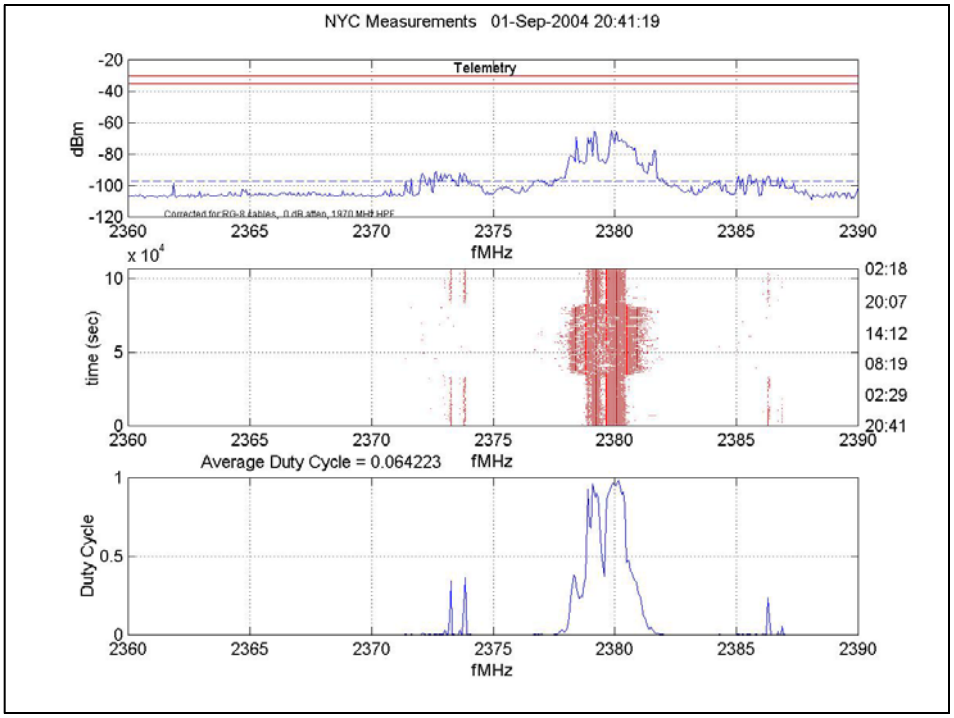

Figure 63: September 1 to September 3, 2360 MHz – 2390 MHz

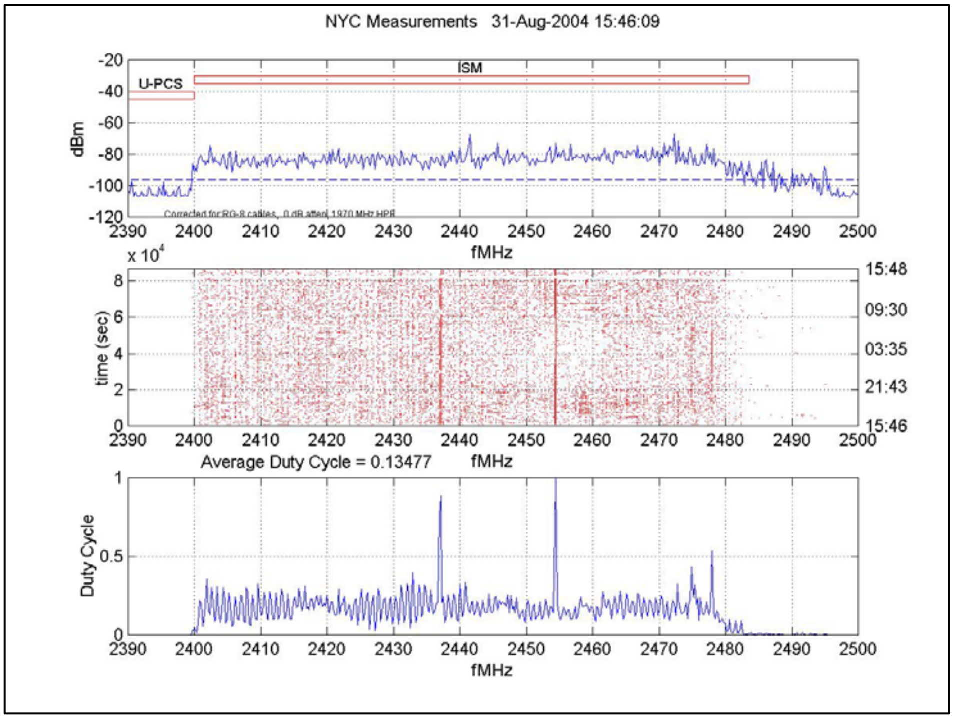

Figure 64: August 31 to September 1, 2390 MHz – 2500 MHz

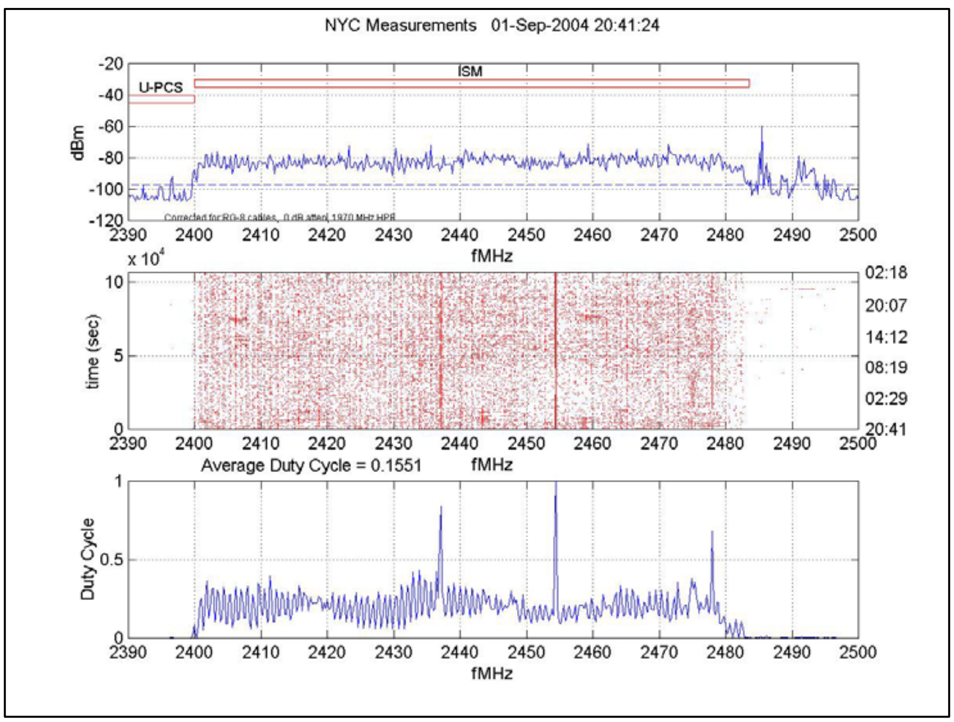

Figure 65: September 1 to September 3, 2390 MHz – 2500 MHz

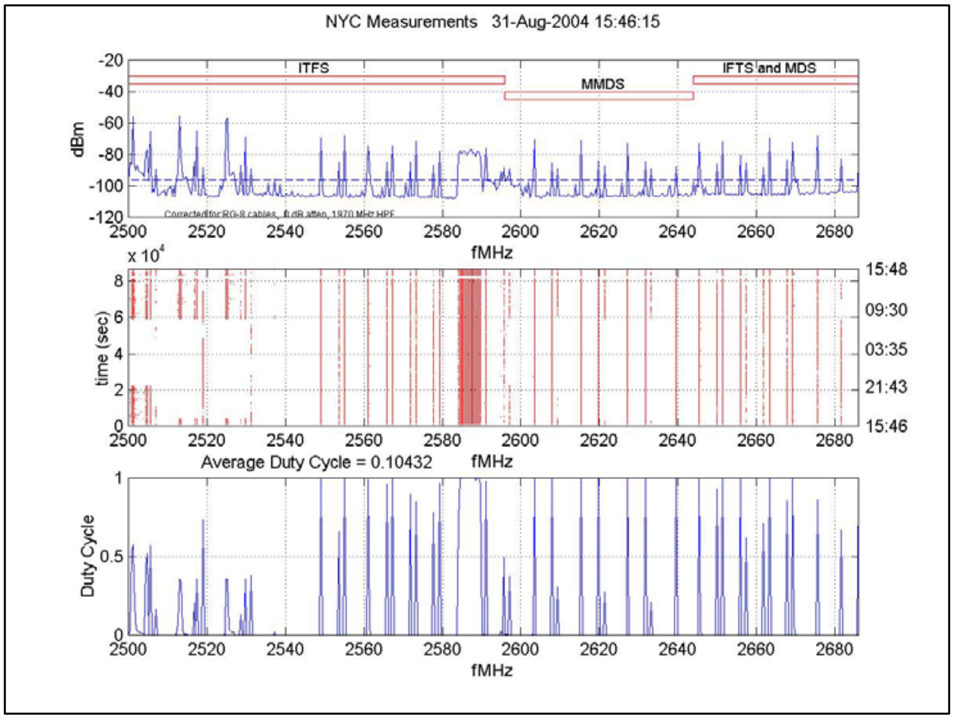

Figure 66: August 31 to September 1, 2500 MHz – 2686 MHz

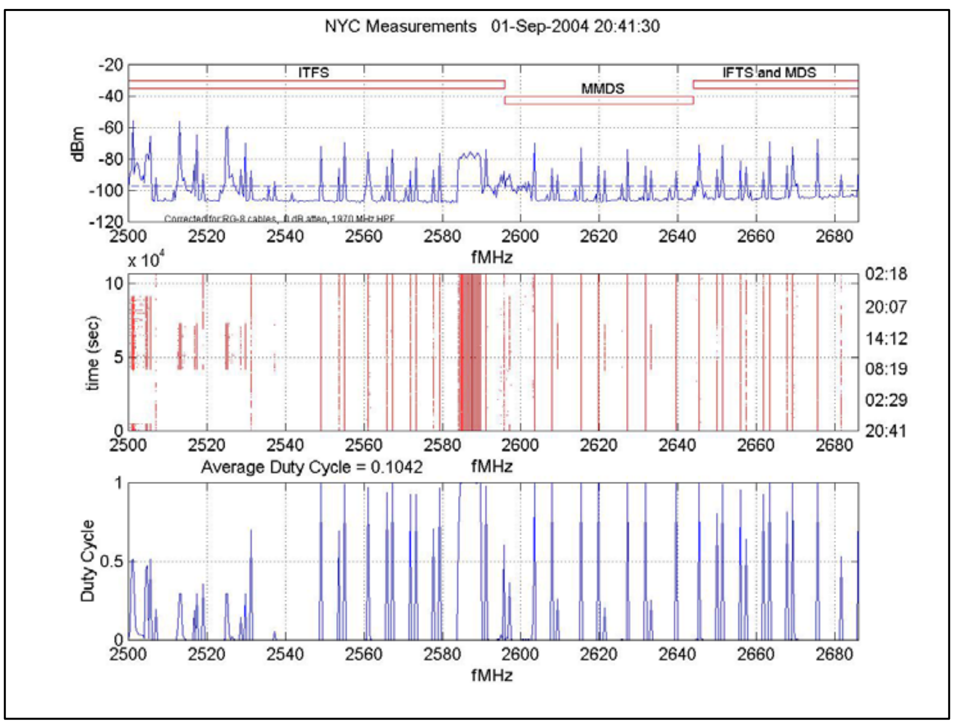

Figure 67: September 1 to September 3, 2500 MHz – 2686 MHz

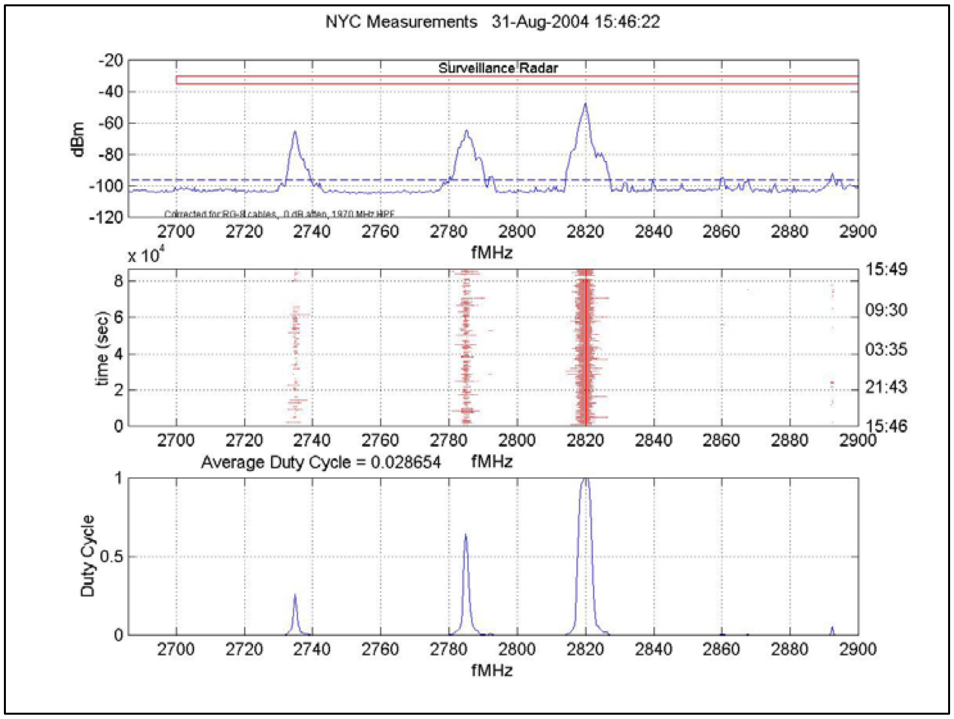

Figure 68: August 31 to September 1, 2686 MHz – 2900 MHz

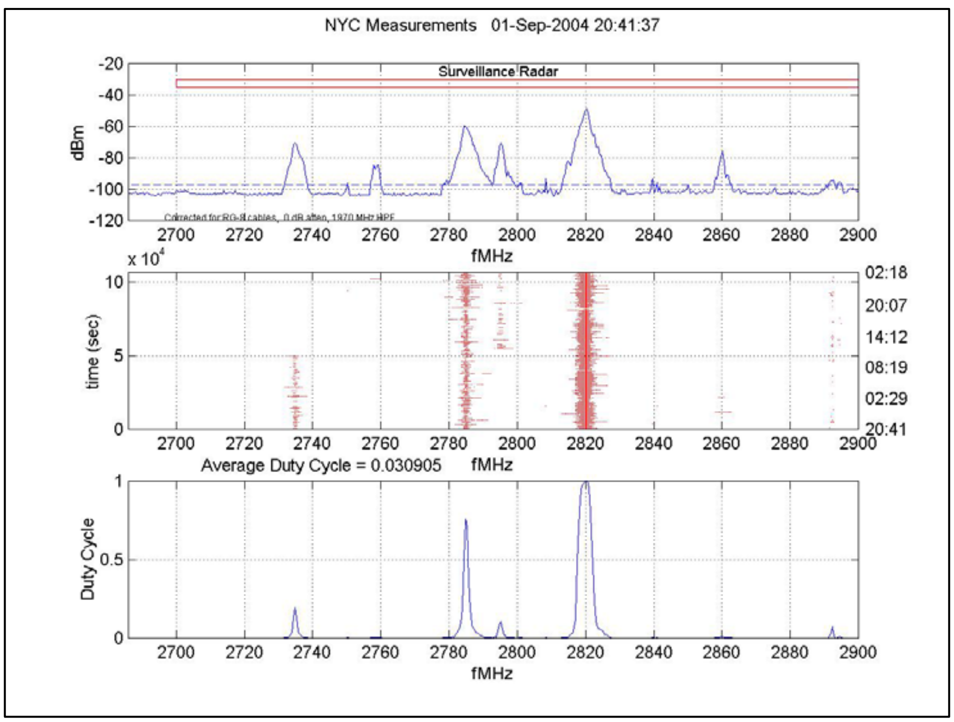

Figure 69: September 1 to September 3, 2686 MHz – 2900 MHz

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.

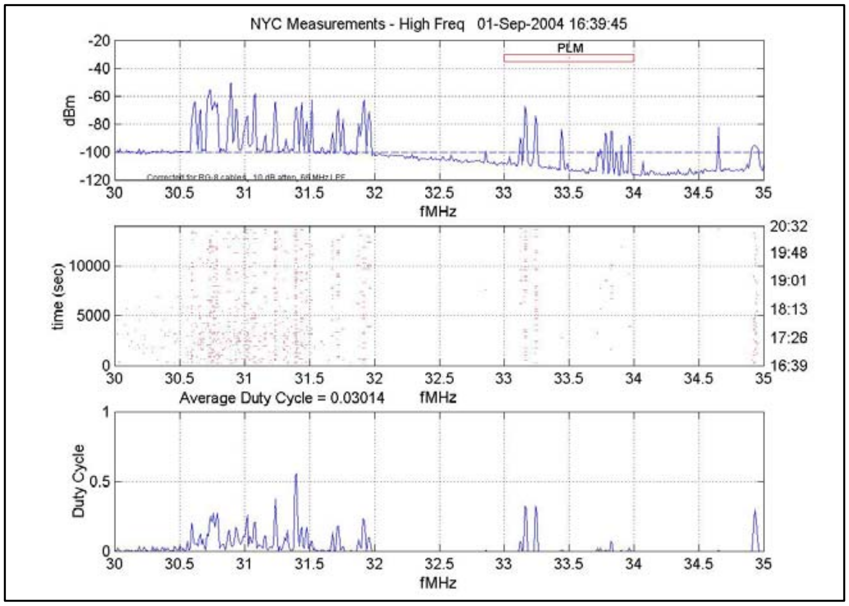

Figure 70: Small Frequency Resolution, 30 MHz – 35 MHz

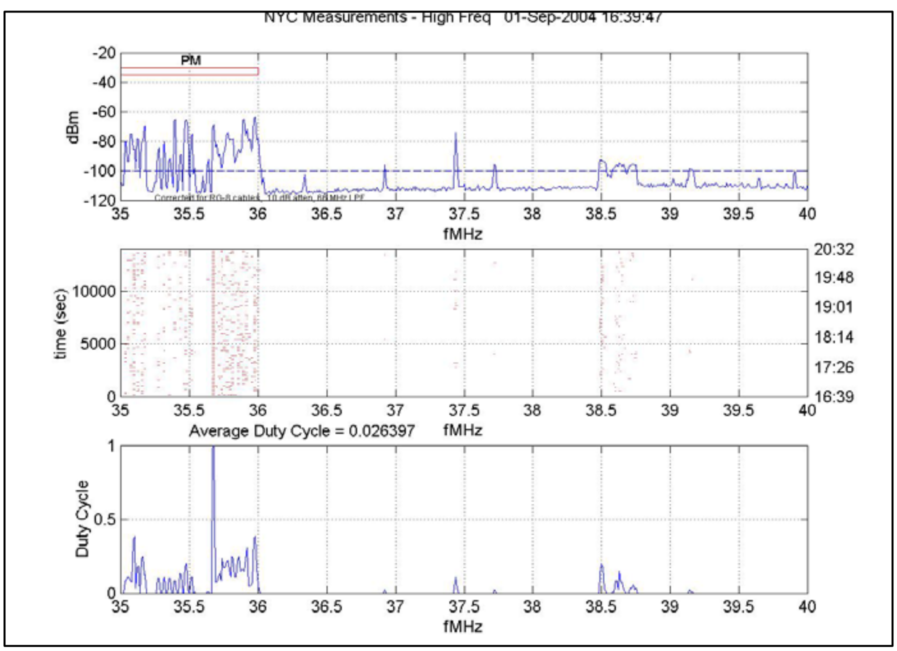

Figure 71: Small Frequency Resolution, 35 MHz – 40 MHz

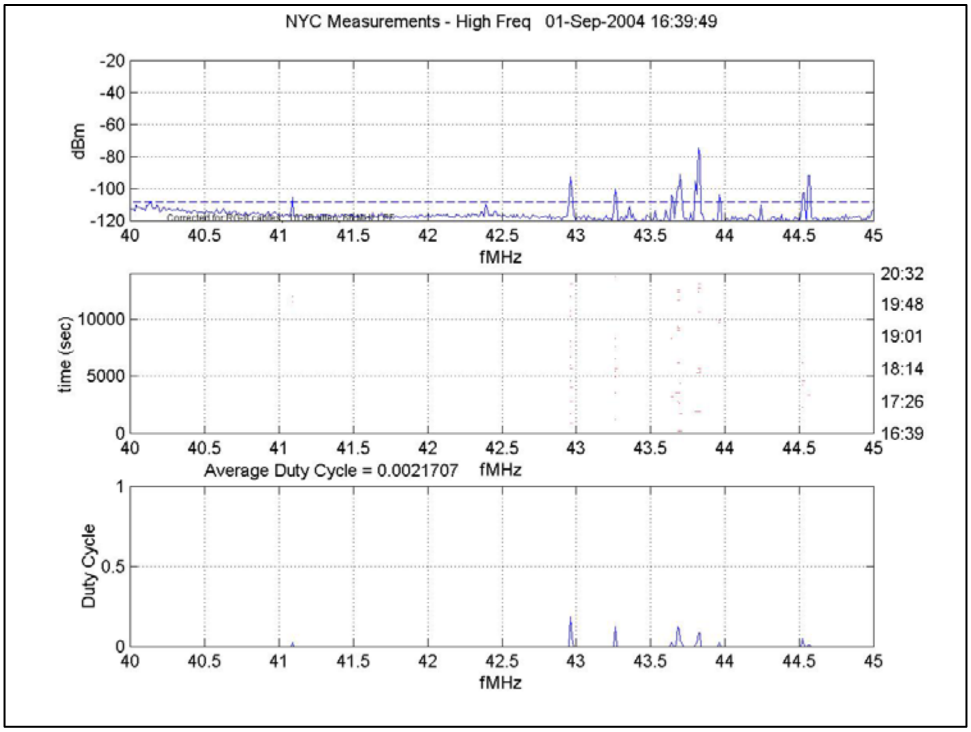

Figure 72: Small Frequency Resolution, 40 MHz – 45 MHz

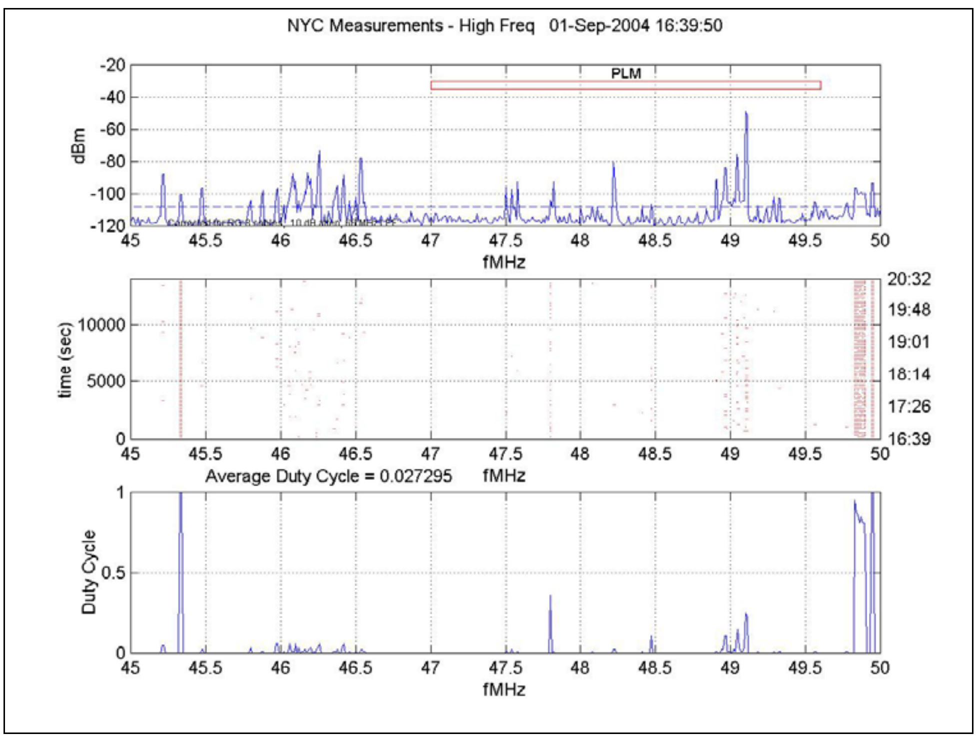

Figure 73: Small Frequency Resolution, 45 MHz – 50 MHz

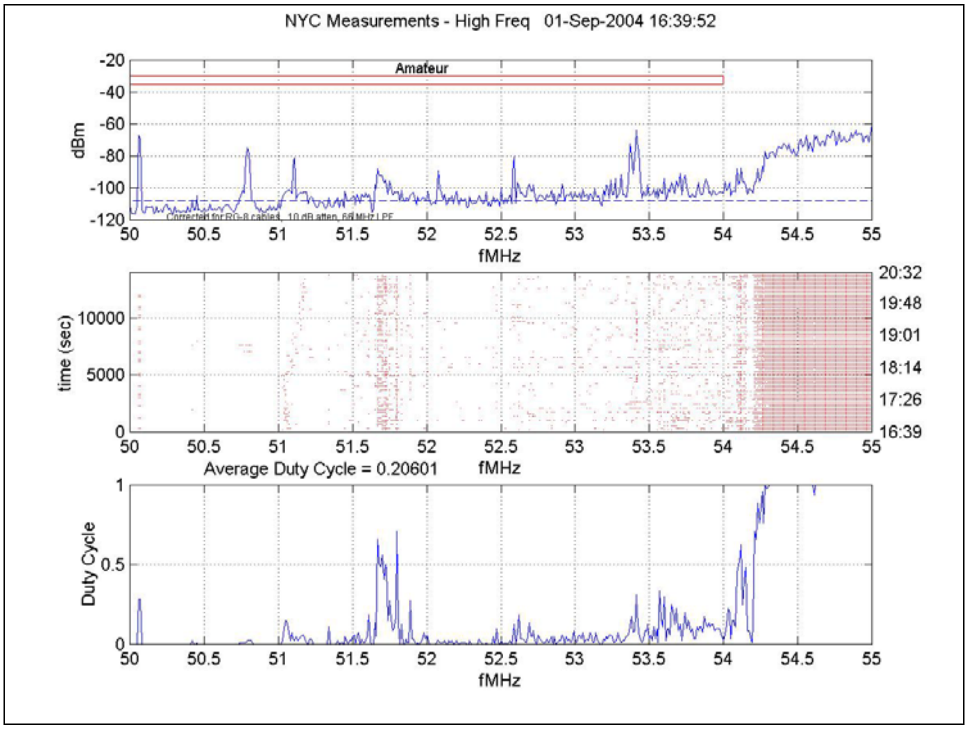

Figure 74: Small Frequency Resolution, 50 MHz – 55 MHz

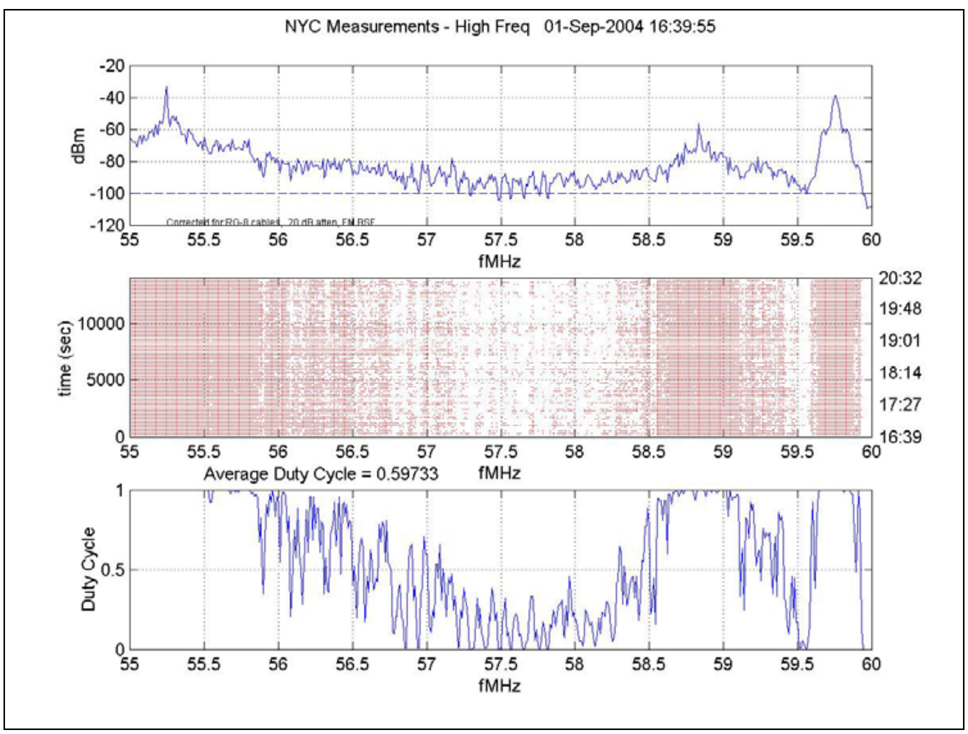

Figure 75: Small Frequency Resolution, 55 MHz – 60 MHz

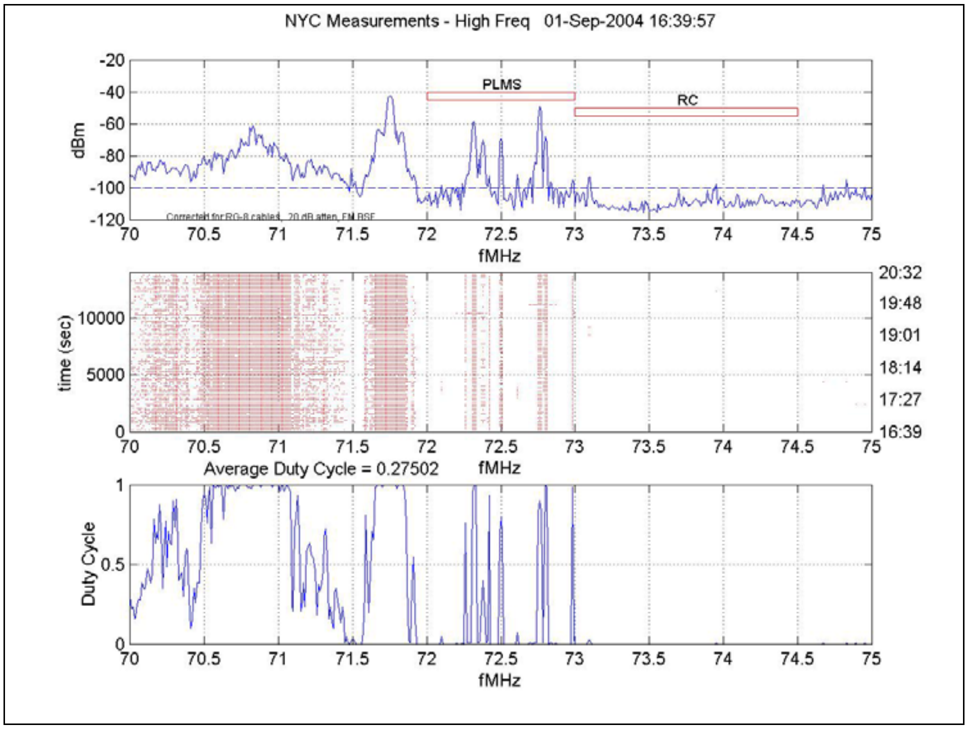

Figure 76: Small Frequency Resolution, 70 MHz – 75 MHz

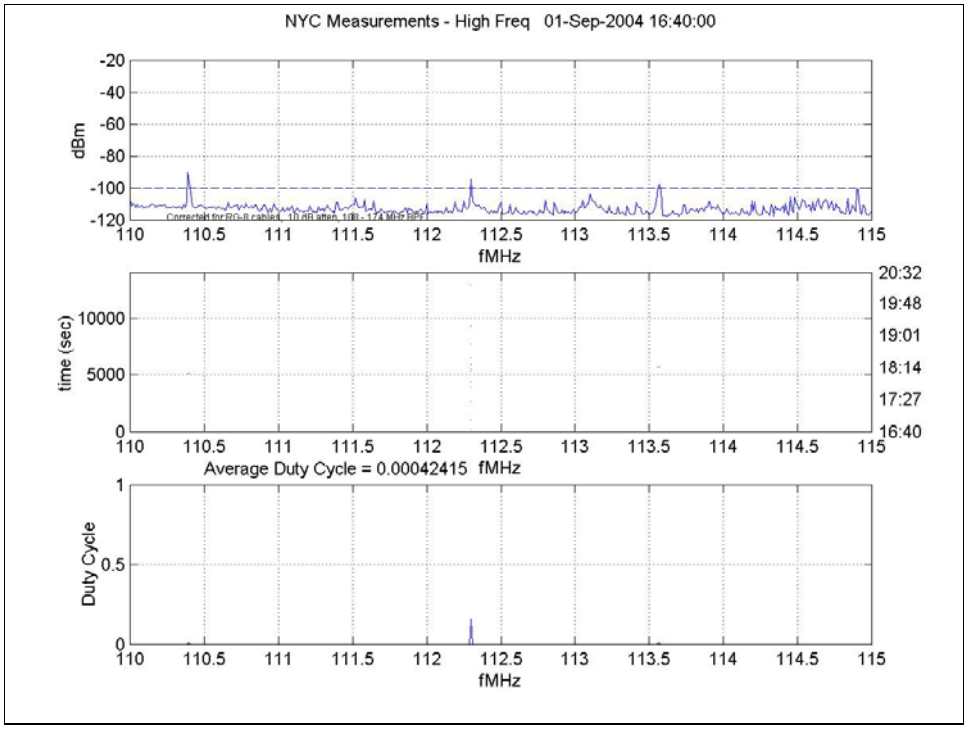

Figure 77: Small Frequency Resolution, 110 MHz – 115 MHz

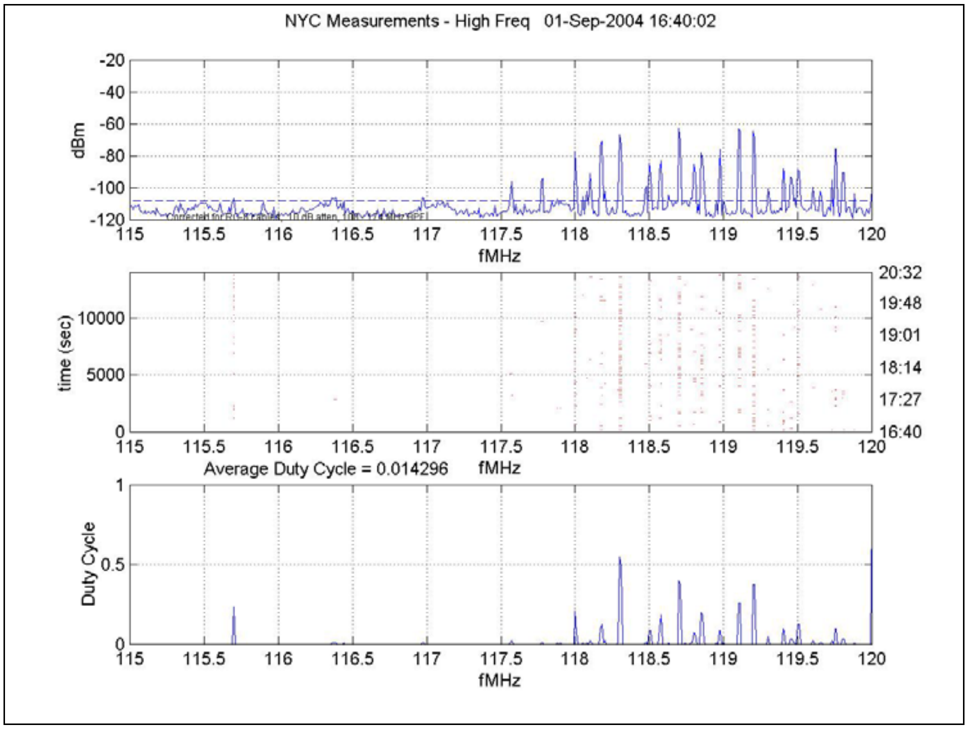

Figure 78: Small Frequency Resolution, 115 MHz – 120 MHz

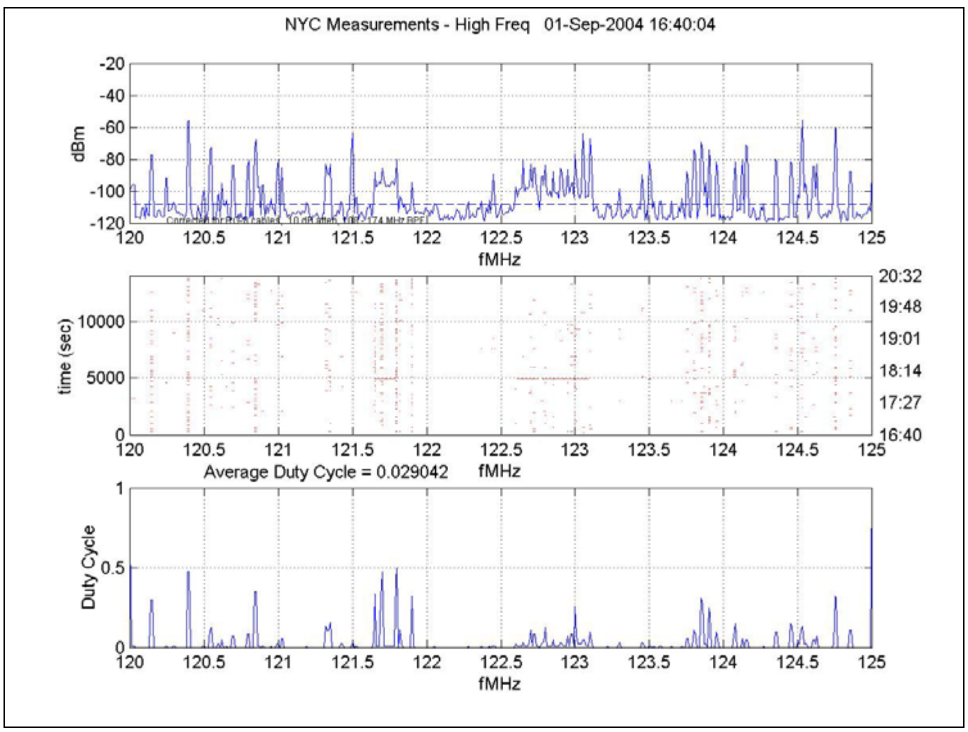

Figure 79: Small Frequency Resolution, 120 MHz – 125 MHz

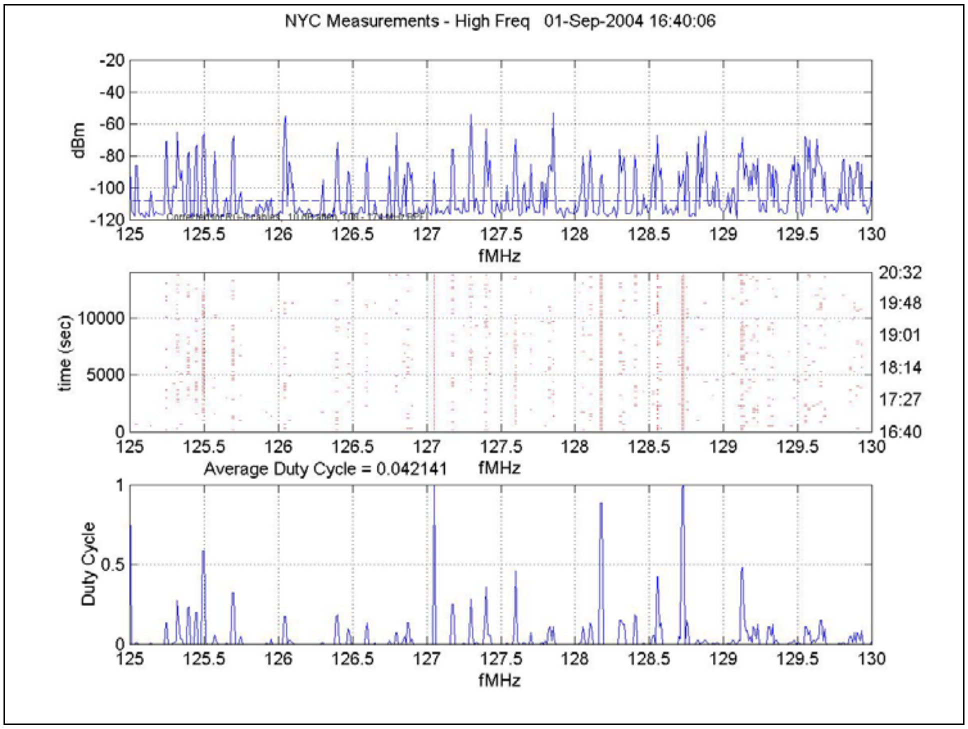

Figure 80: Small Frequency Resolution, 125 MHz – 130 MHz

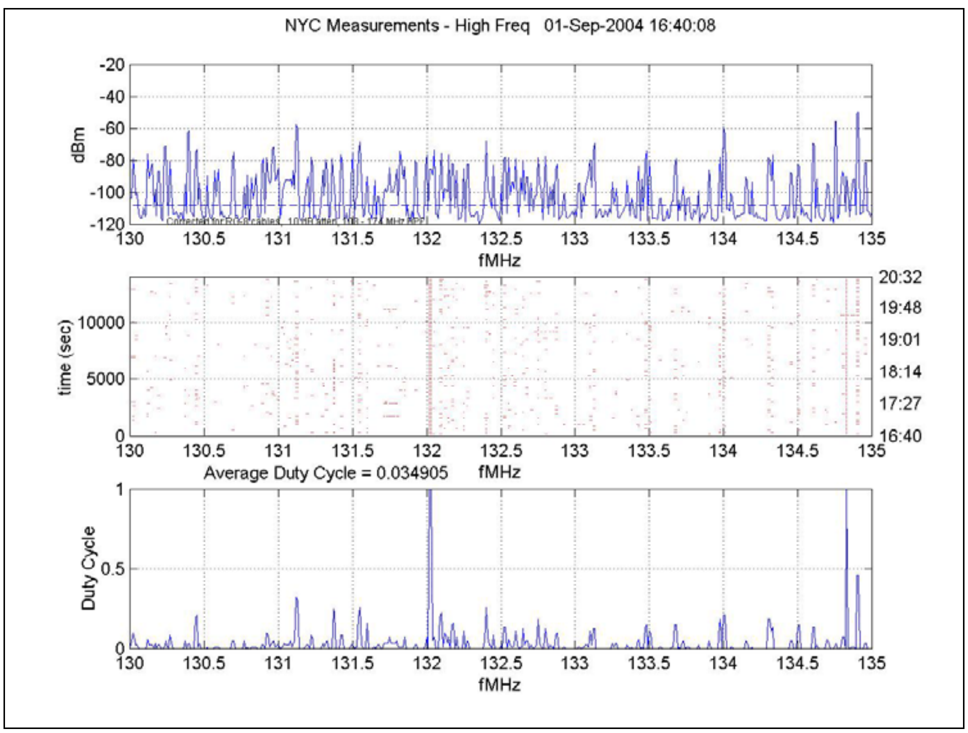

Figure 81: Small Frequency Resolution, 130 MHz – 135 MHz

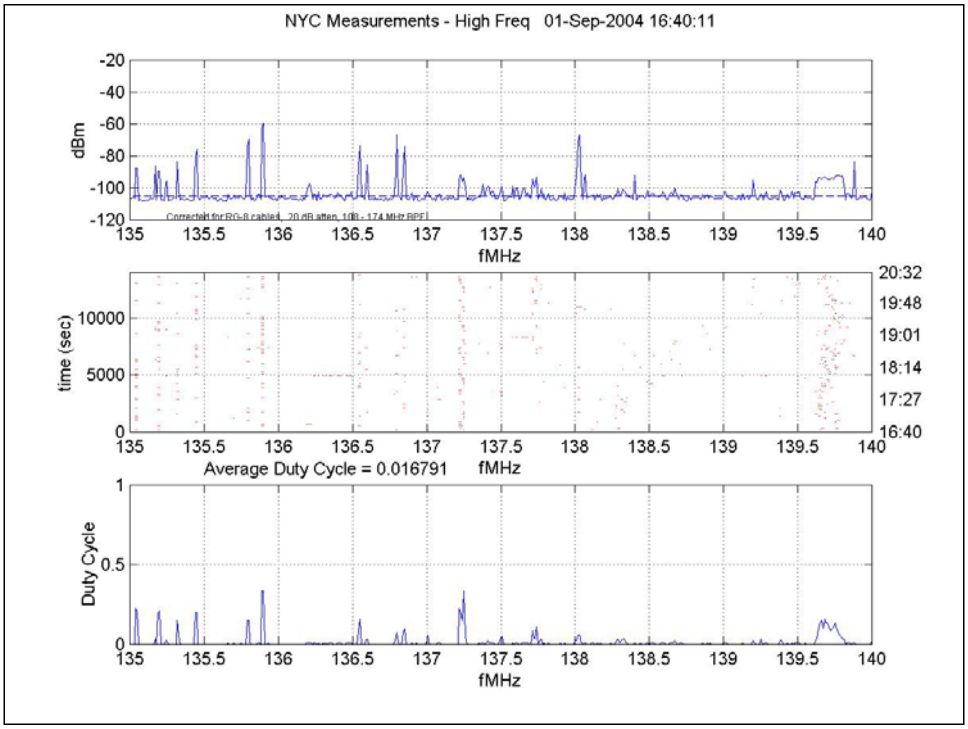

Figure 82: Small Frequency Resolution, 135 MHz – 140 MHz

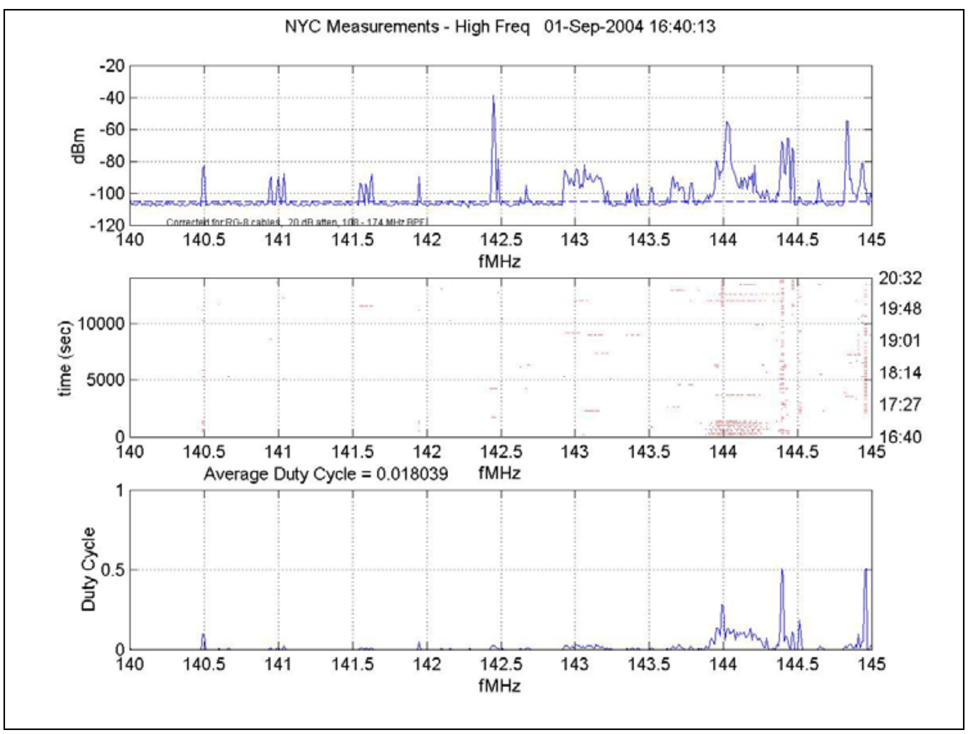

Figure 83: Small Frequency Resolution, 140 MHz – 145 MHz

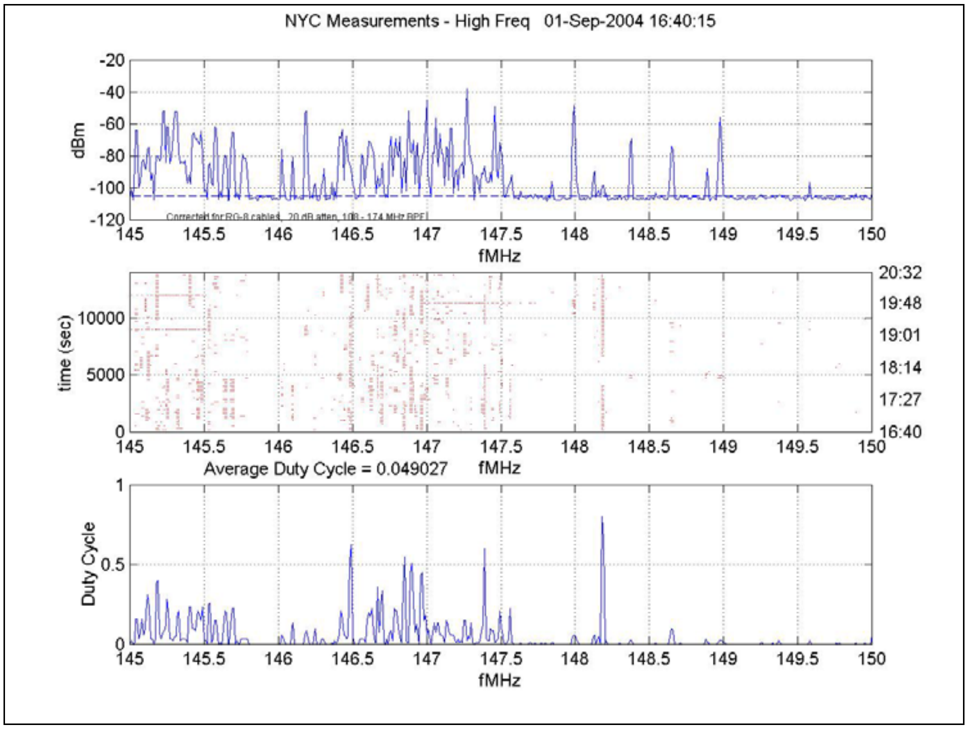

Figure 84: Small Frequency Resolution, 145 MHz – 150 MHz

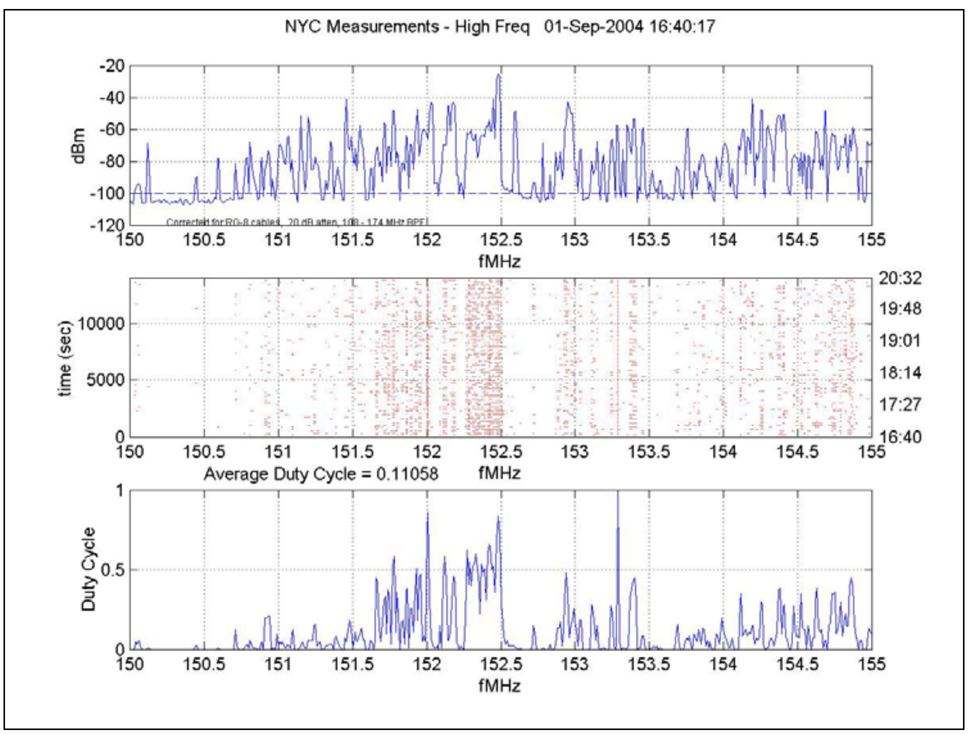

Figure 85: Small Frequency Resolution, 150 MHz – 155 MHz

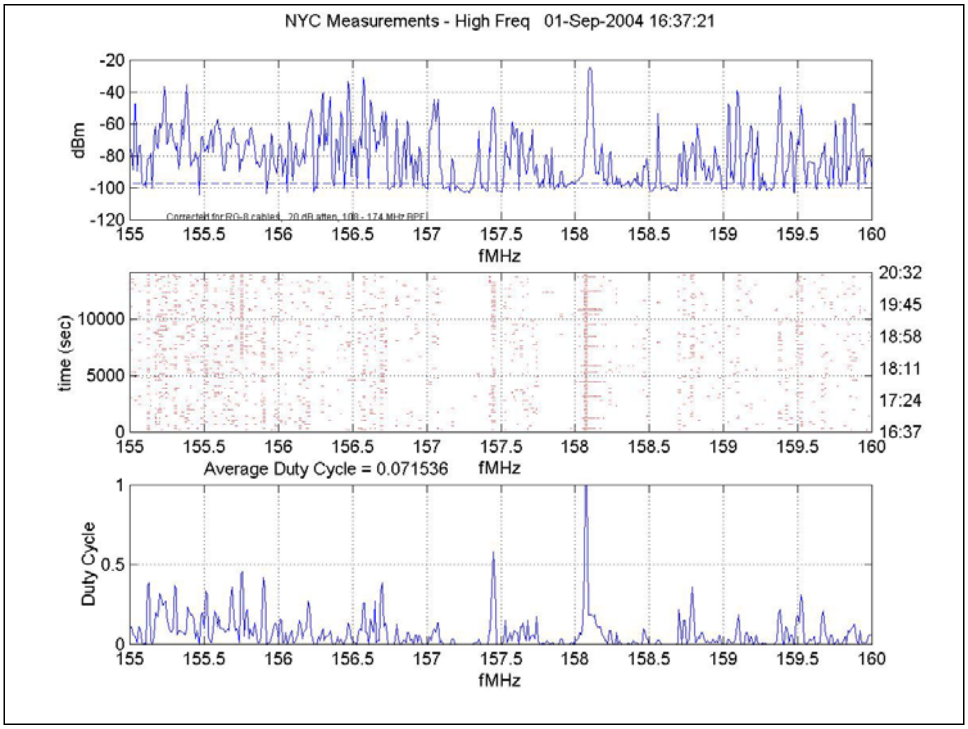

Figure 86: Small Frequency Resolution, 155 MHz – 160 MHz

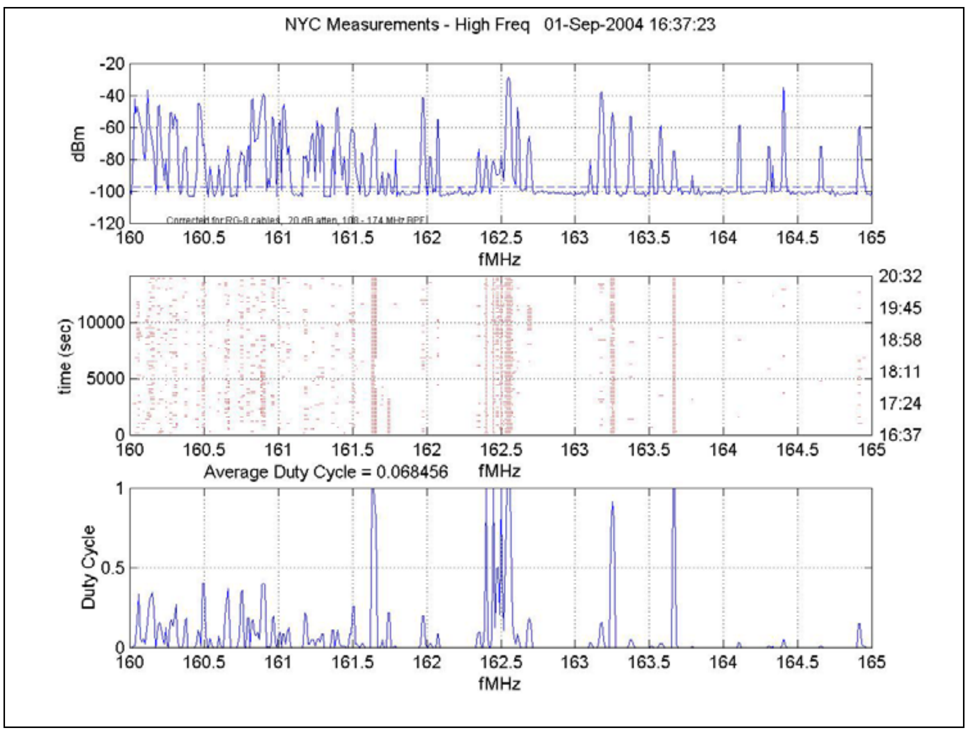

Figure 87: Small Frequency Resolution, 160 MHz – 165 MHz

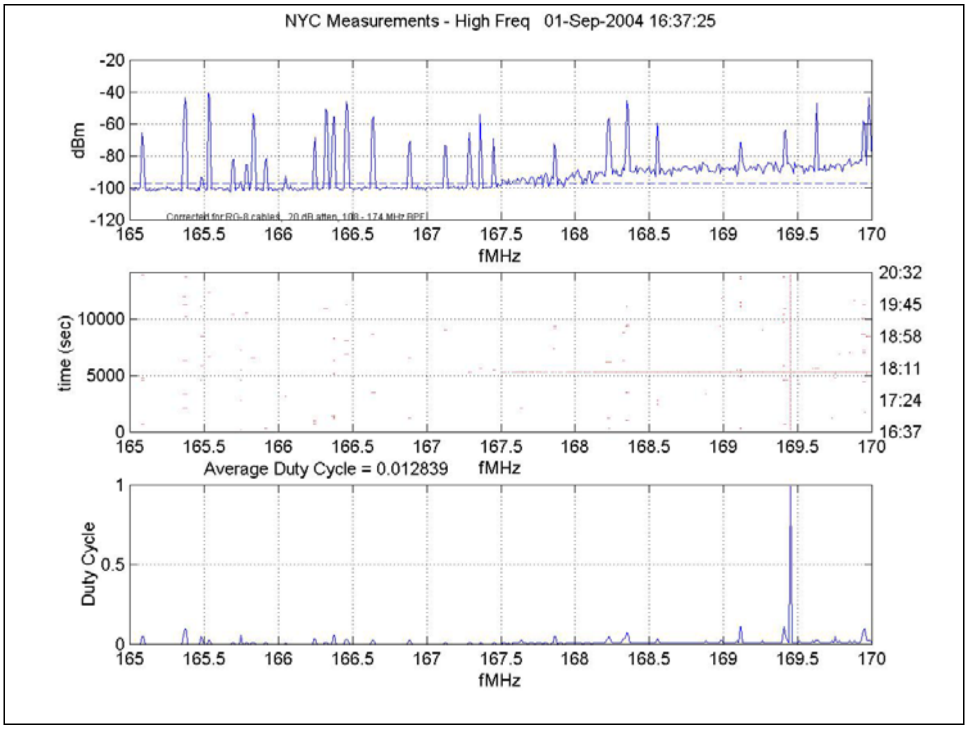

Figure 88: Small Frequency Resolution, 165 MHz – 170 MHz

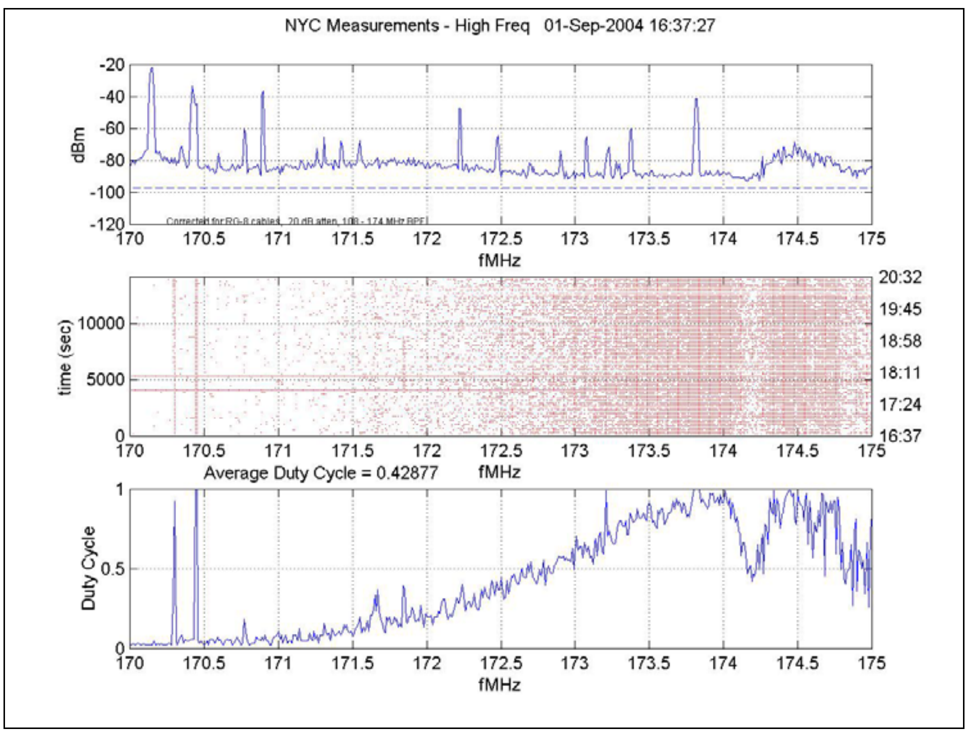

Figure 89: Small Frequency Resolution, 170 MHz – 175 MHz

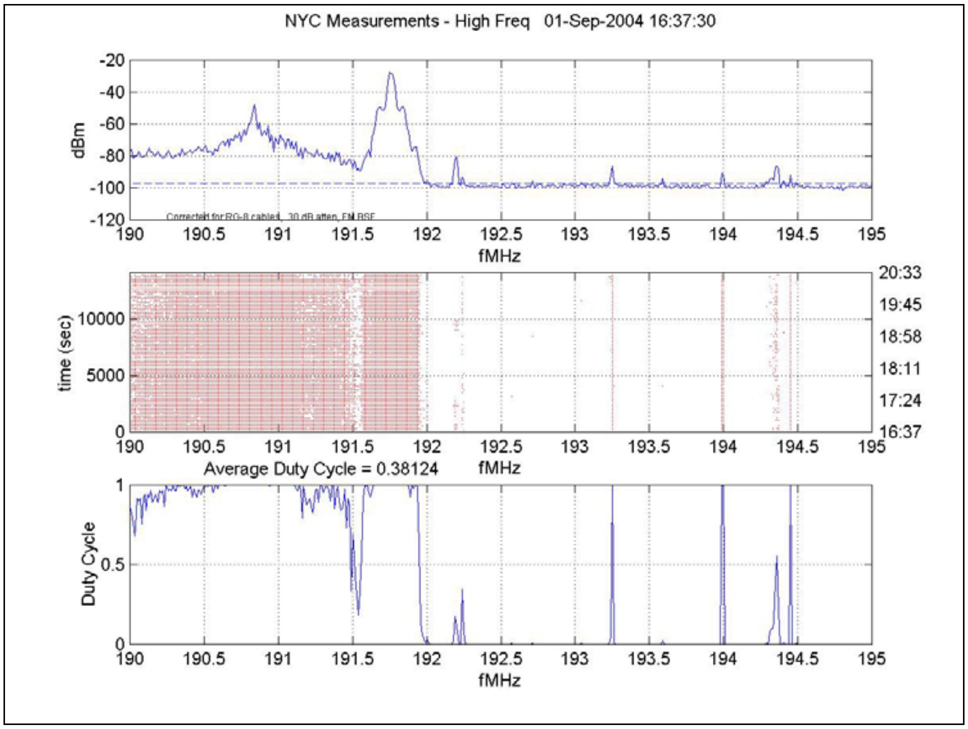

Figure 90: Small Frequency Resolution, 190 MHz – 195 MHz

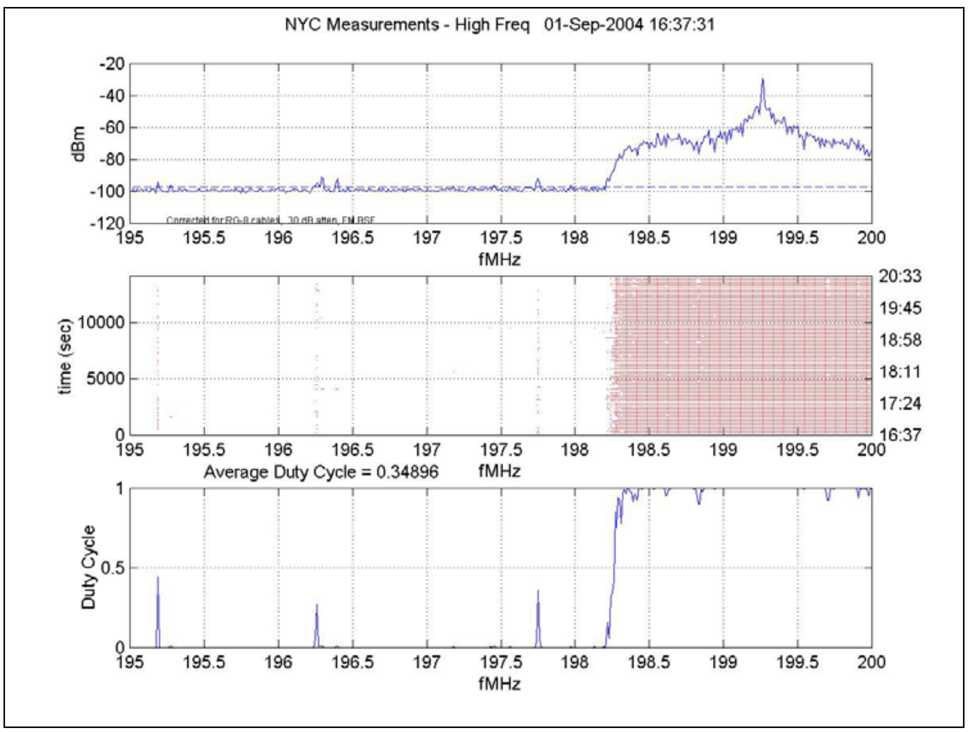

Figure 91: Small Frequency Resolution, 195 MHz – 200 MHz

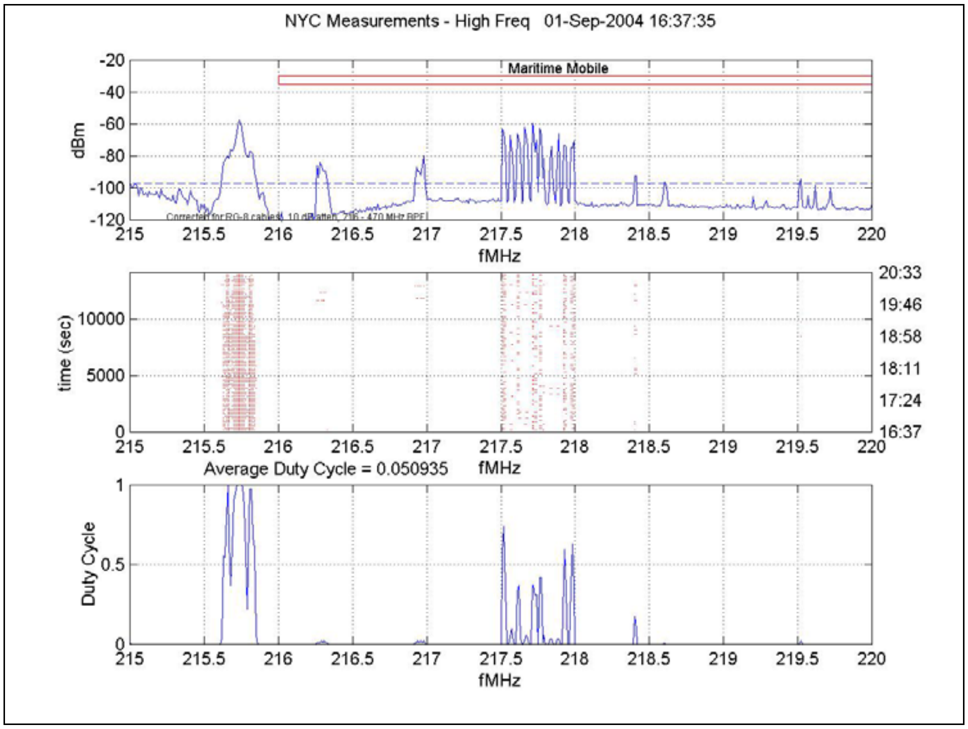

Figure 92: Small Frequency Resolution, 215 MHz – 220 MHz

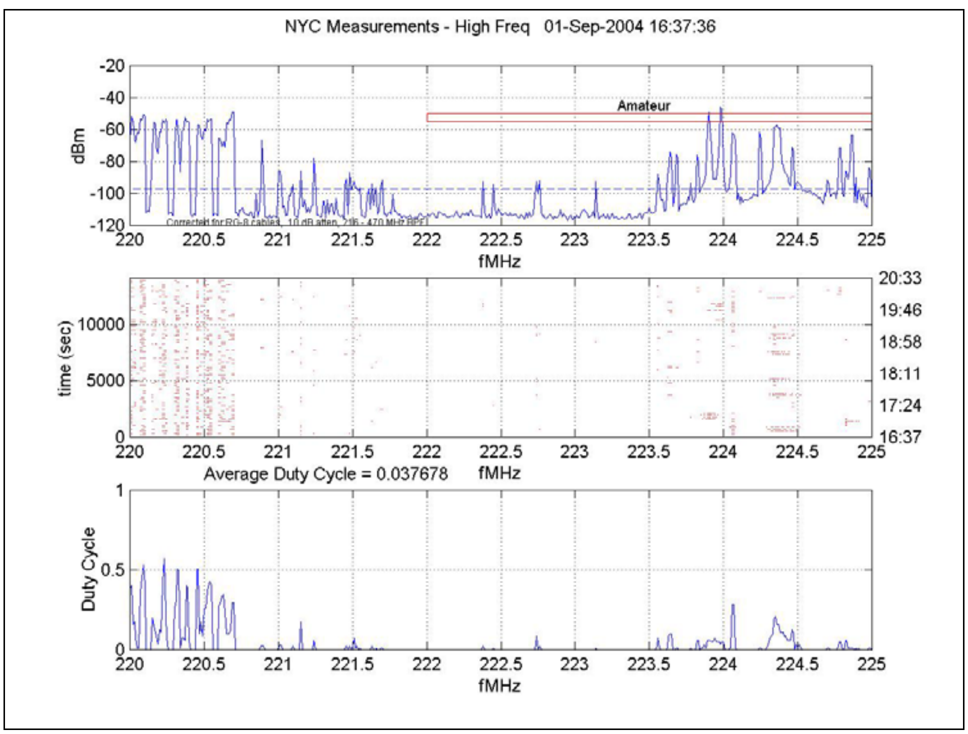

Figure 93: Small Frequency Resolution, 220 MHz – 225 MHz

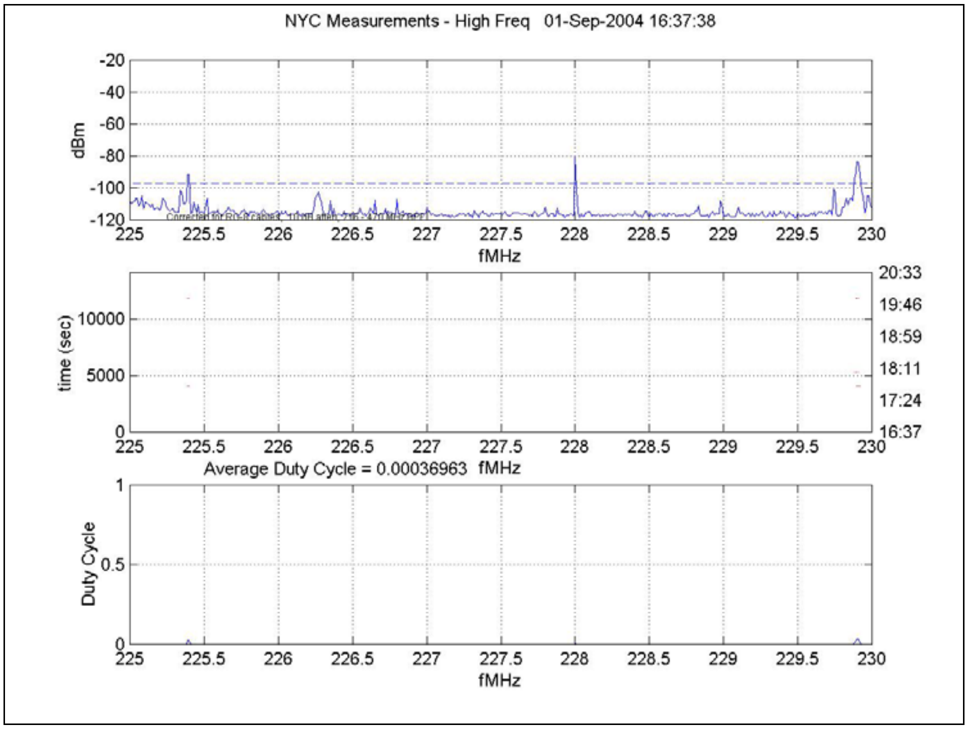

Figure 94: Small Frequency Resolution, 225 MHz – 230 MHz

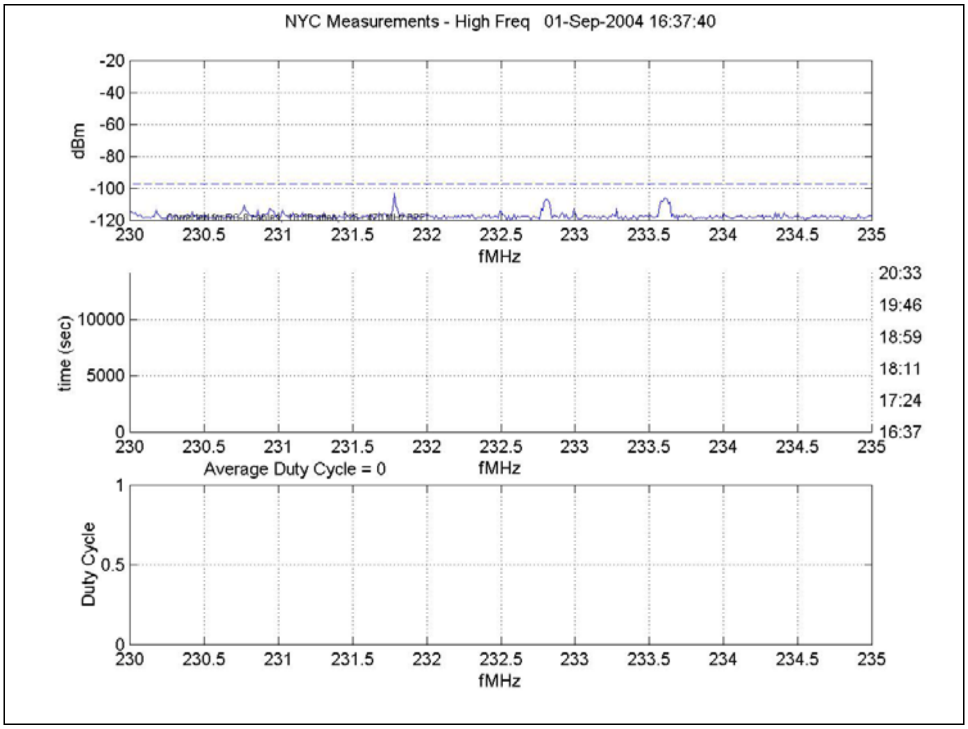

Figure 95: Small Frequency Resolution, 230 MHz – 235 MHz

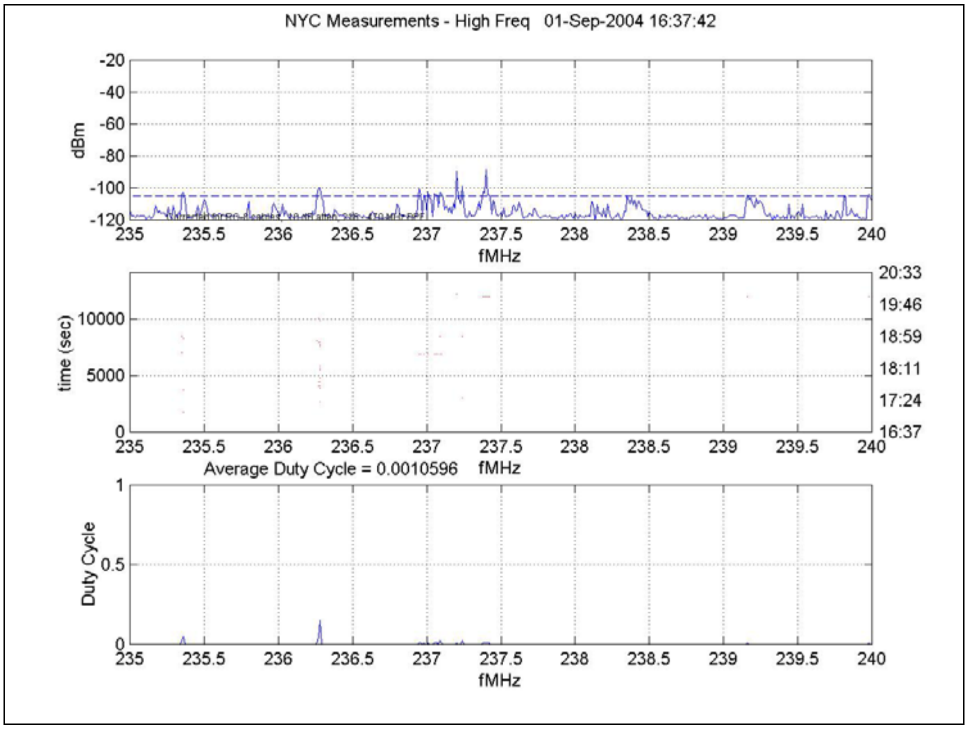

Figure 96: Small Frequency Resolution, 235 MHz – 240 MHz

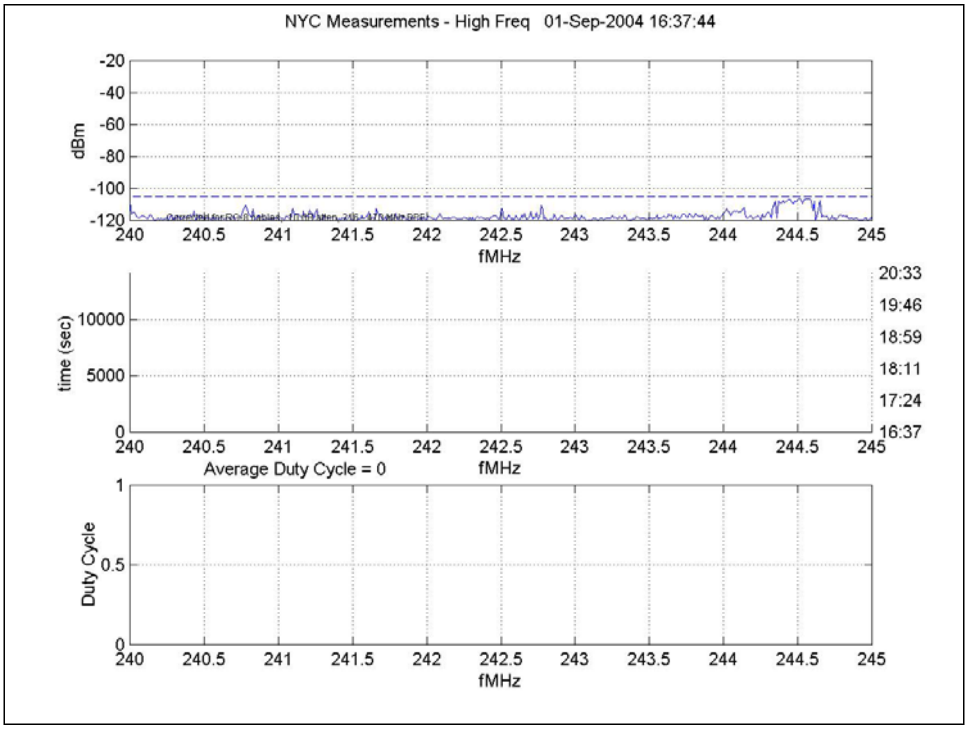

Figure 97: Small Frequency Resolution, 240 MHz – 245 MHz

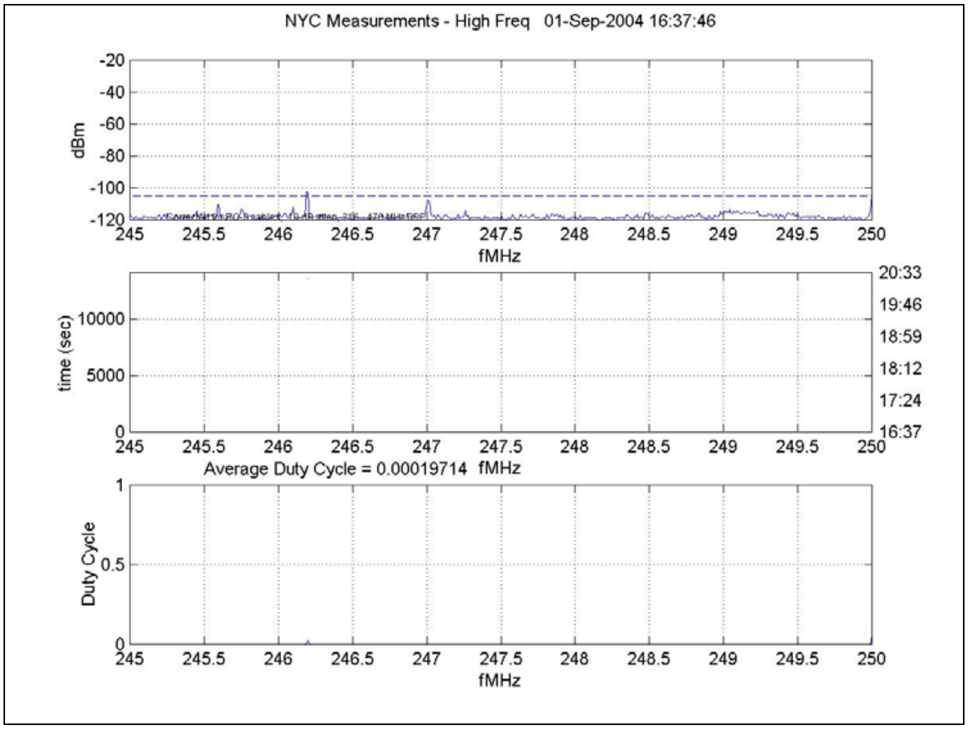

Figure 98: Small Frequency Resolution, 245 MHz – 250 MHz

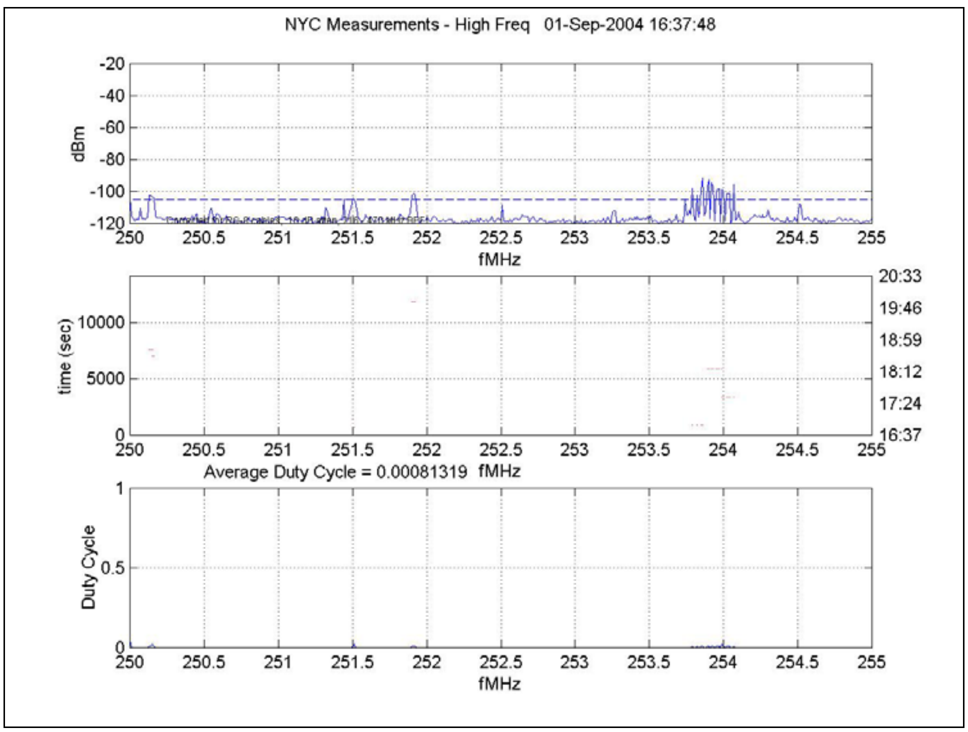

Figure 99: Small Frequency Resolution, 250 MHz – 255 MHz

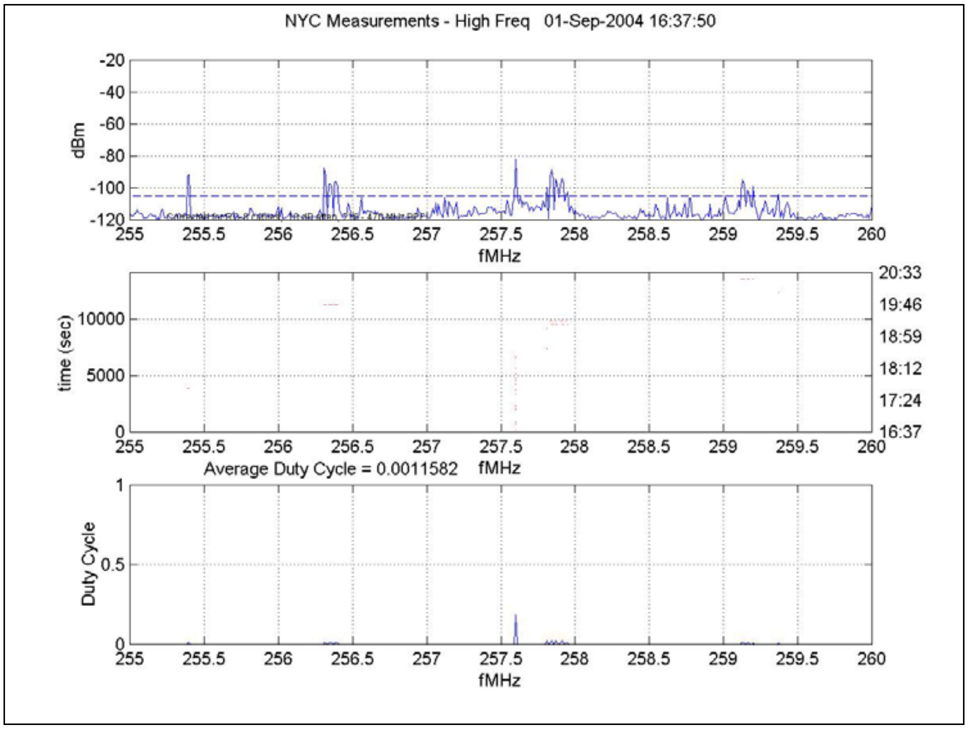

Figure 100: Small Frequency Resolution, 255 MHz – 260 MHz

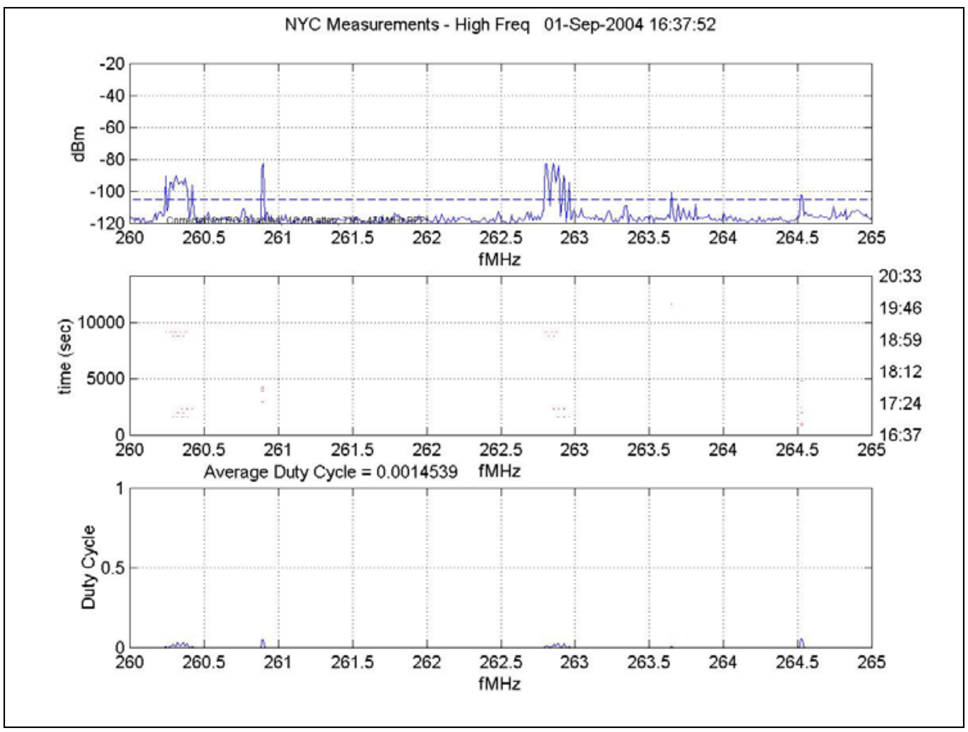

Figure 101: Small Frequency Resolution, 260 MHz – 265 MHz

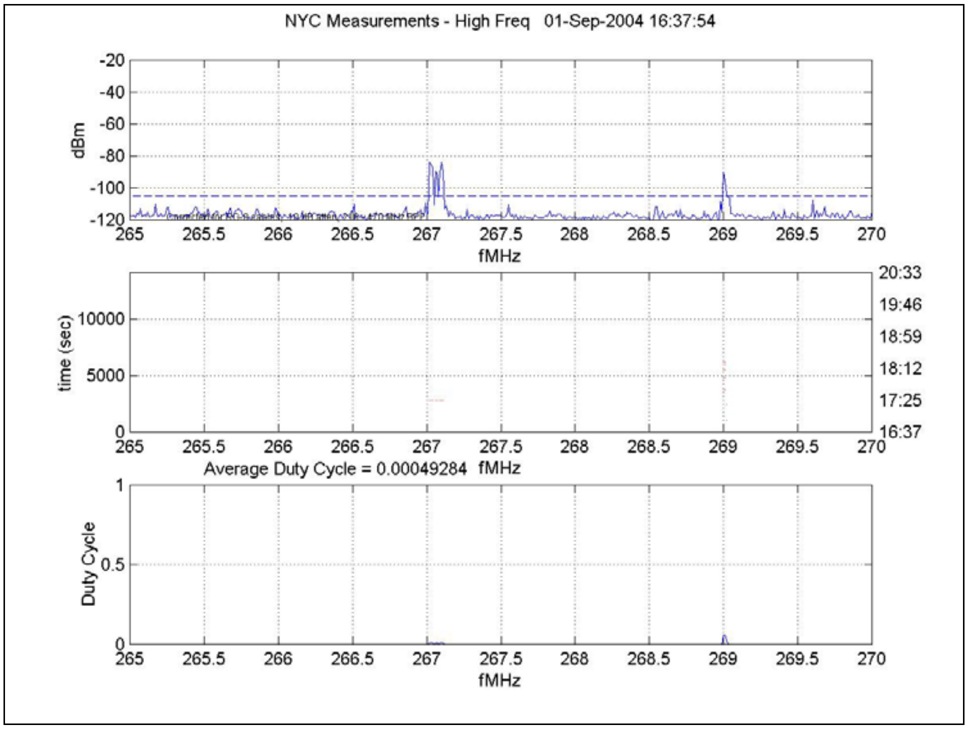

Figure 102: Small Frequency Resolution, 265 MHz – 270 MHz

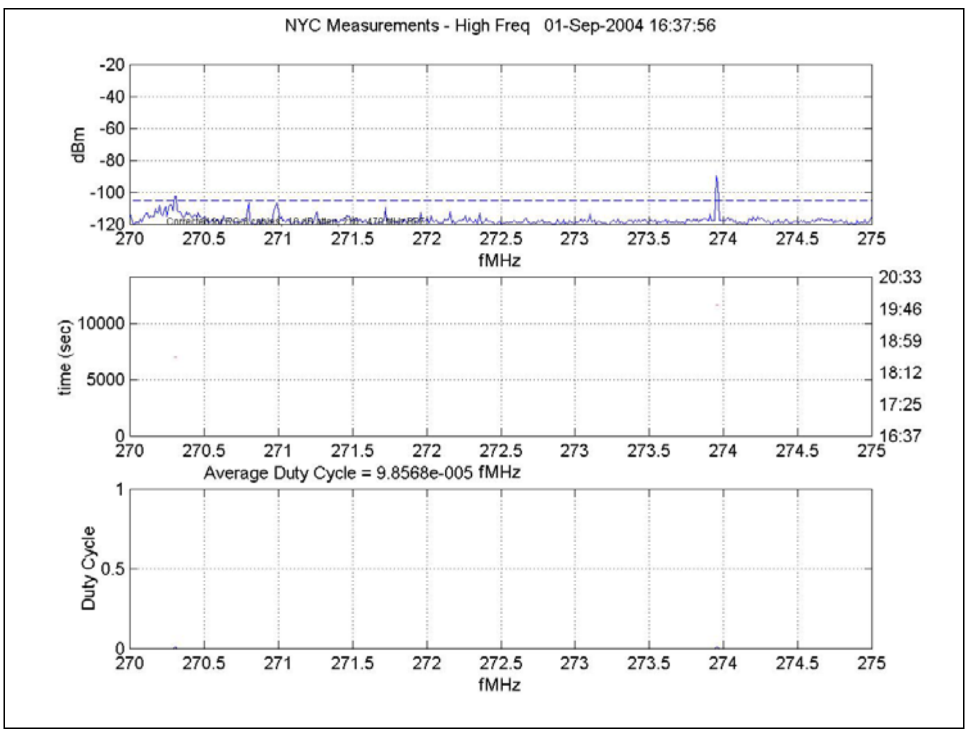

Figure 103: Small Frequency Resolution, 270 MHz – 275 MHz

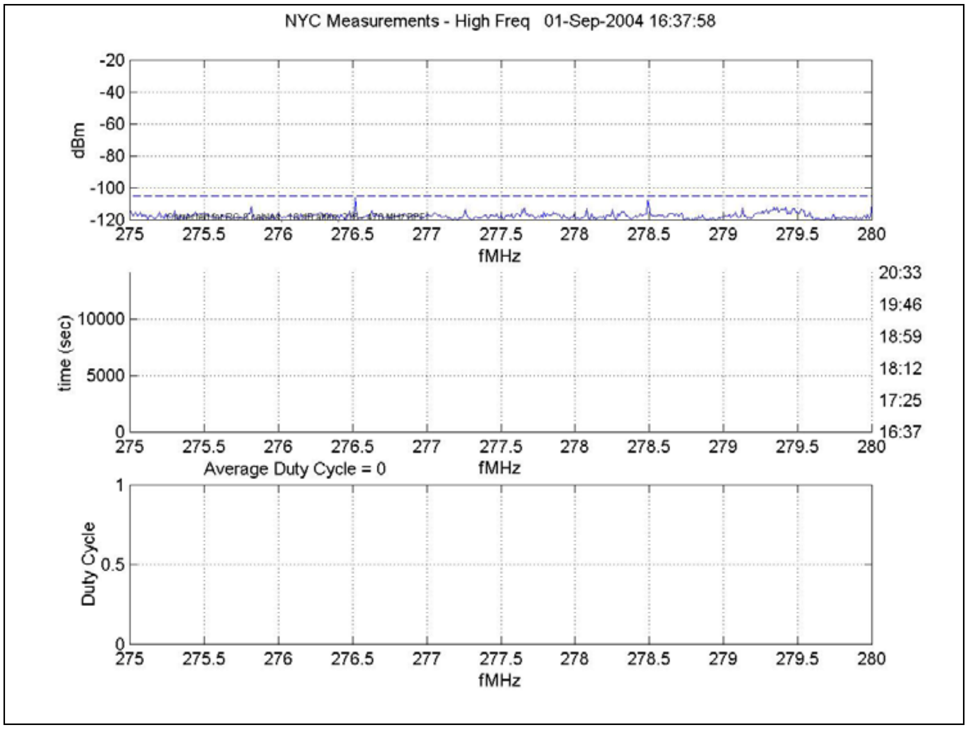

Figure 104: Small Frequency Resolution, 275 MHz – 280 MHz

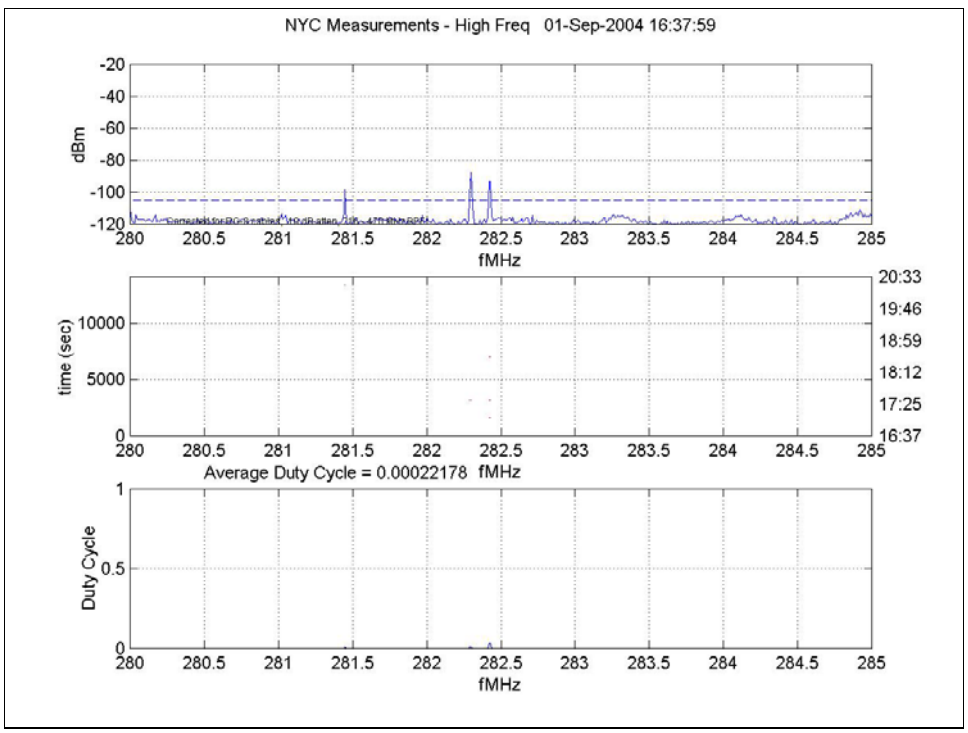

Figure 105: Small Frequency Resolution, 280 MHz – 285 MHz

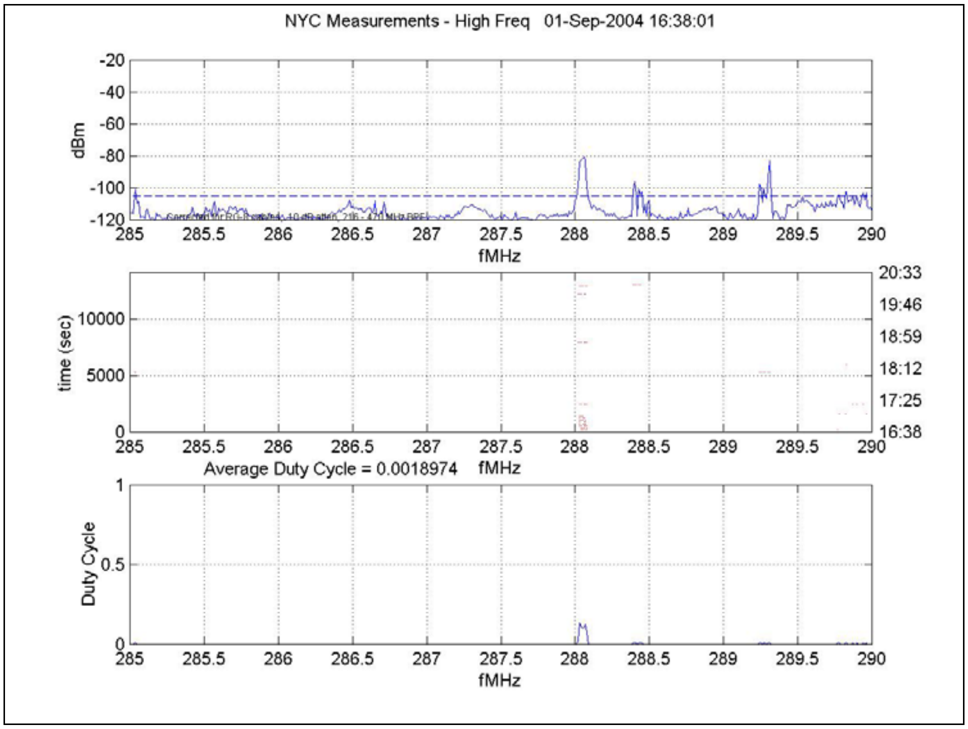

Figure 106: Small Frequency Resolution, 285 MHz – 290 MHz

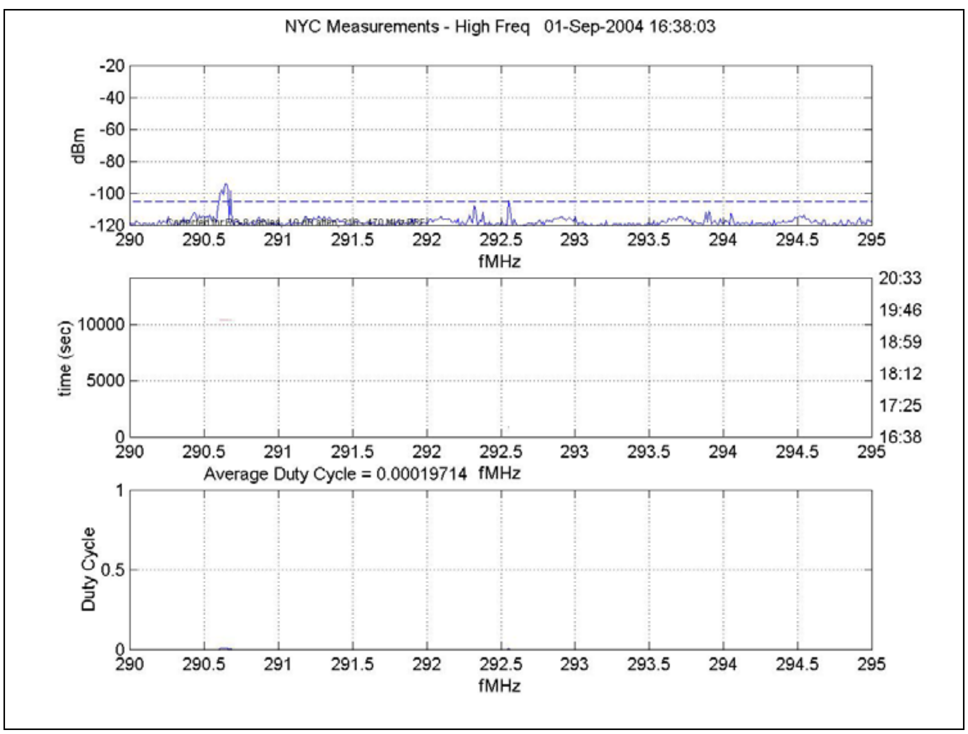

Figure 107: Small Frequency Resolution, 290 MHz – 295 MHz

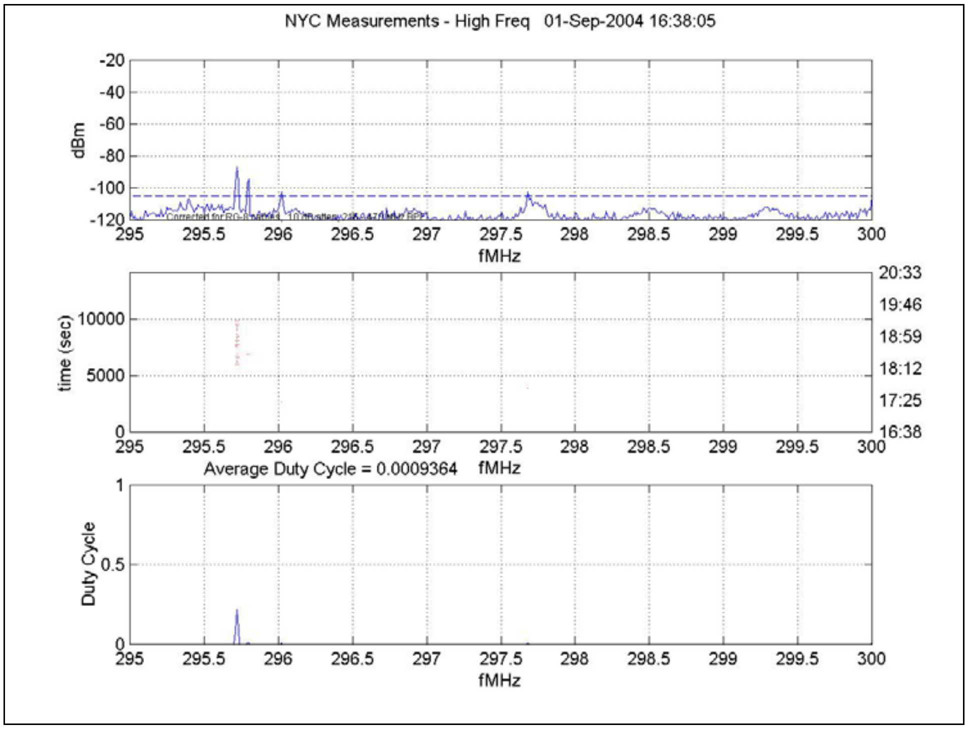

Figure 108: Small Frequency Resolution, 295 MHz – 300 MHz

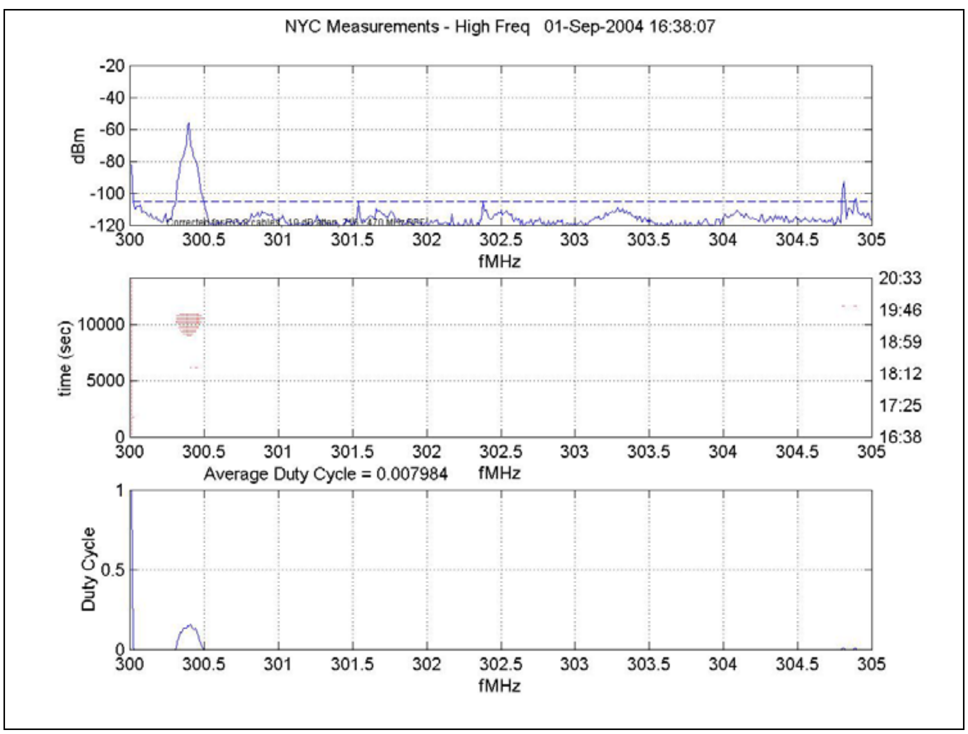

Figure 109: Small Frequency Resolution, 300 MHz – 305 MHz

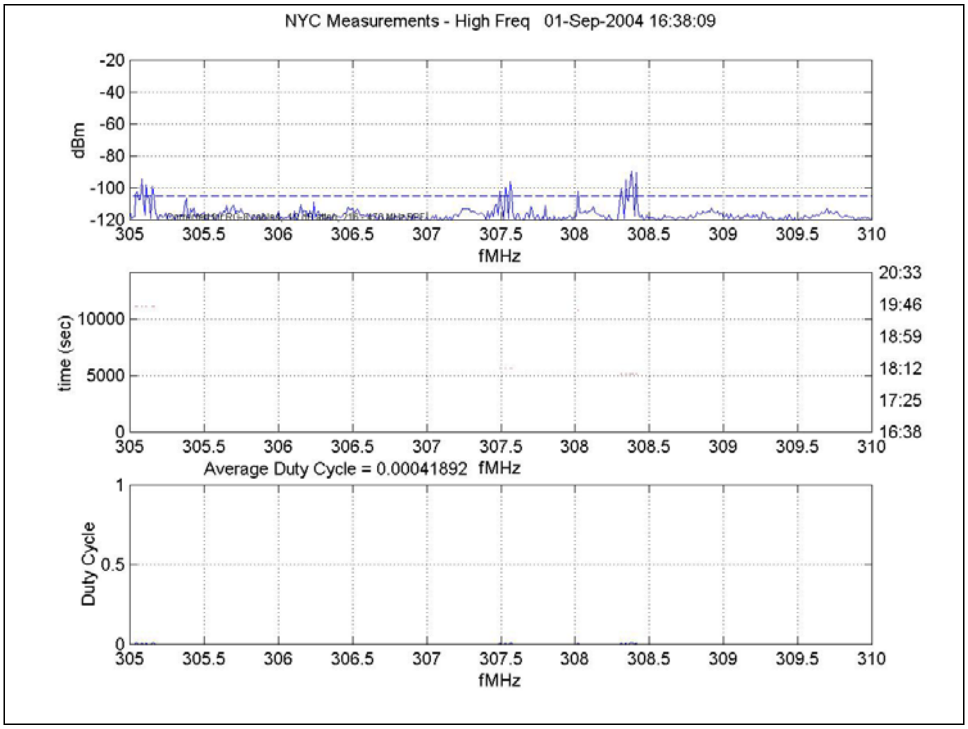

Figure 110: Small Frequency Resolution, 305 MHz – 310 MHz

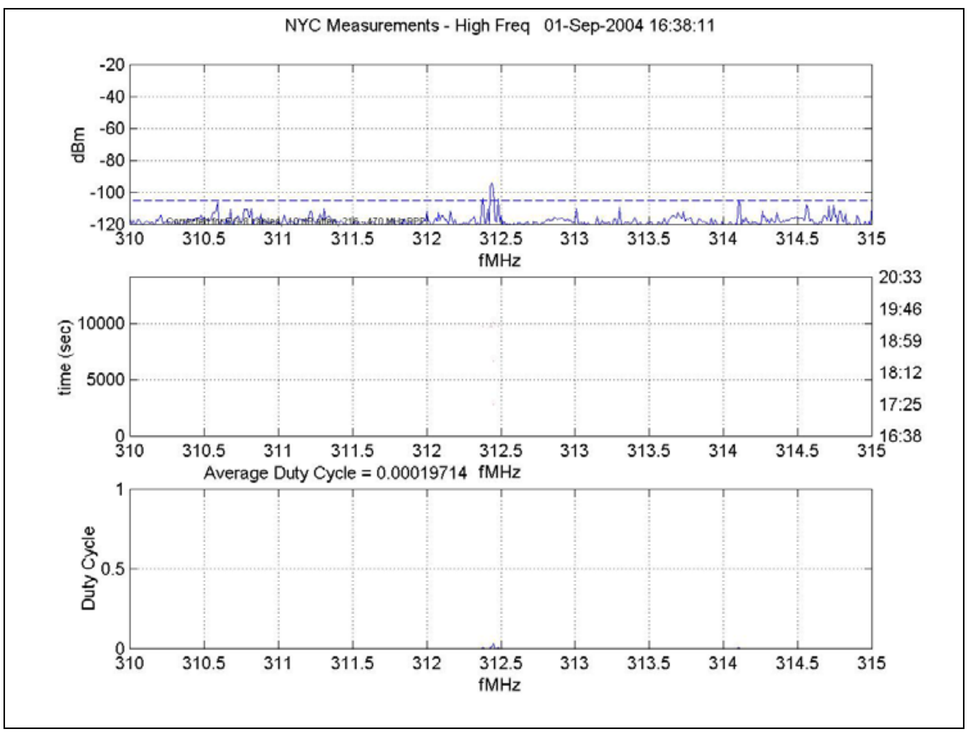

Figure 111: Small Frequency Resolution, 310 MHz – 315 MHz

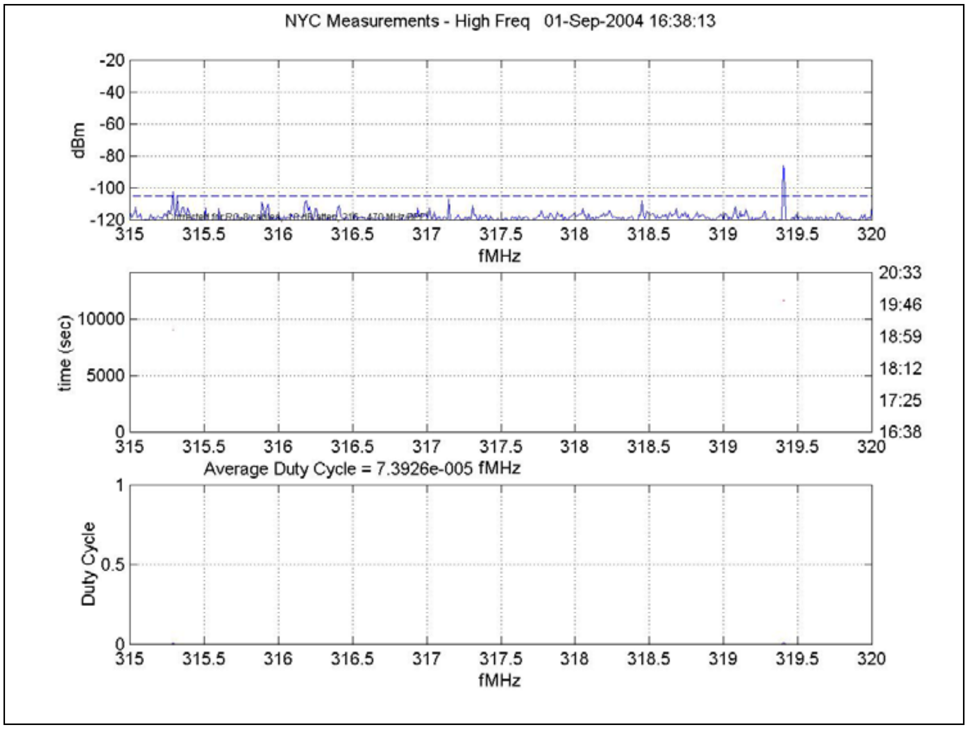

Figure 112: Small Frequency Resolution, 315 MHz – 320 MHz

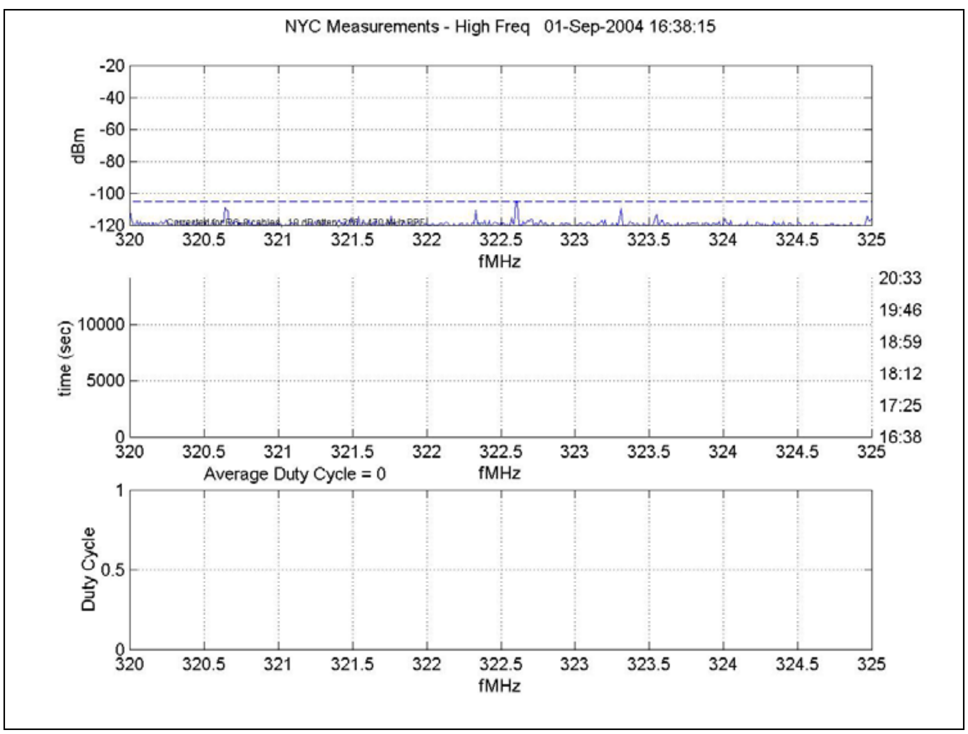

Figure 113: Small Frequency Resolution, 320 MHz – 325 MHz

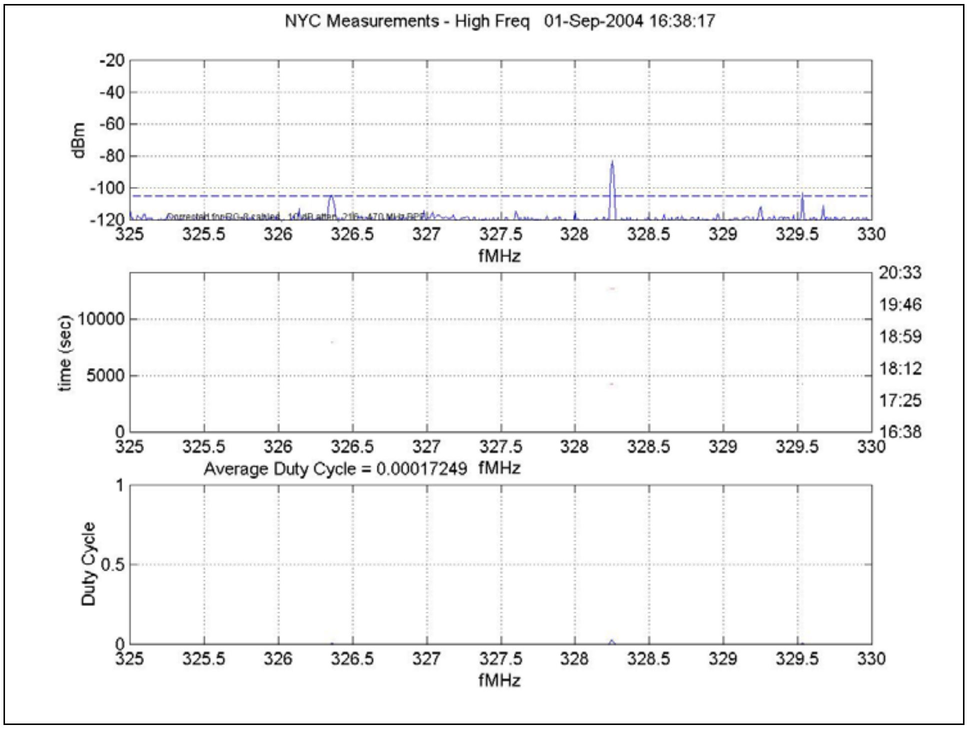

Figure 114: Small Frequency Resolution, 325 MHz – 330 MHz

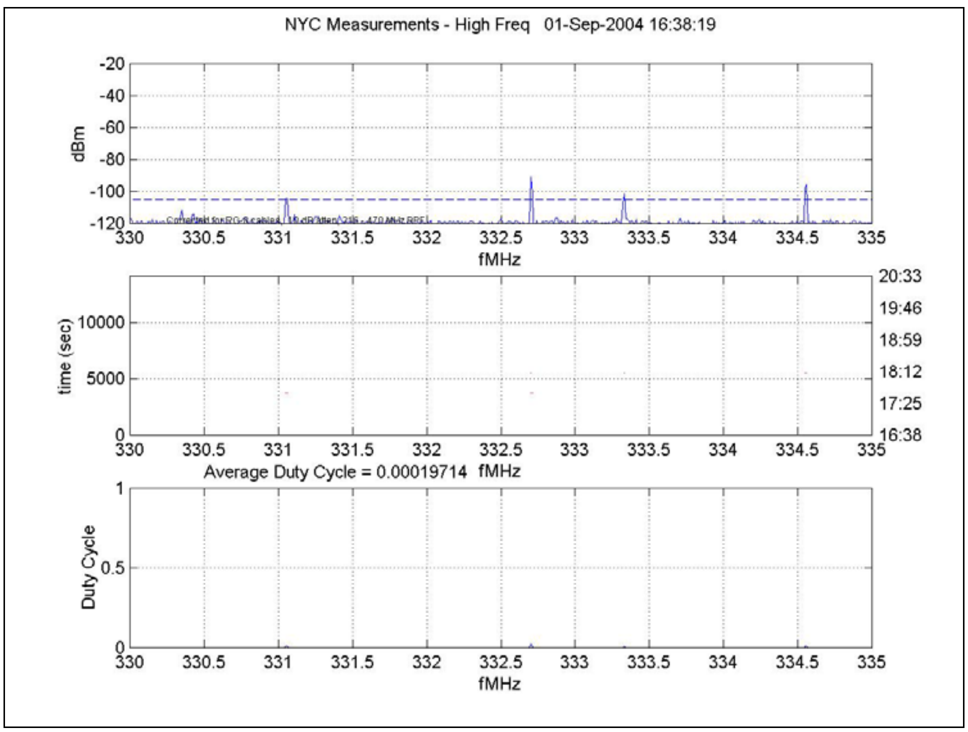

Figure 115: Small Frequency Resolution, 330 MHz – 335 MHz

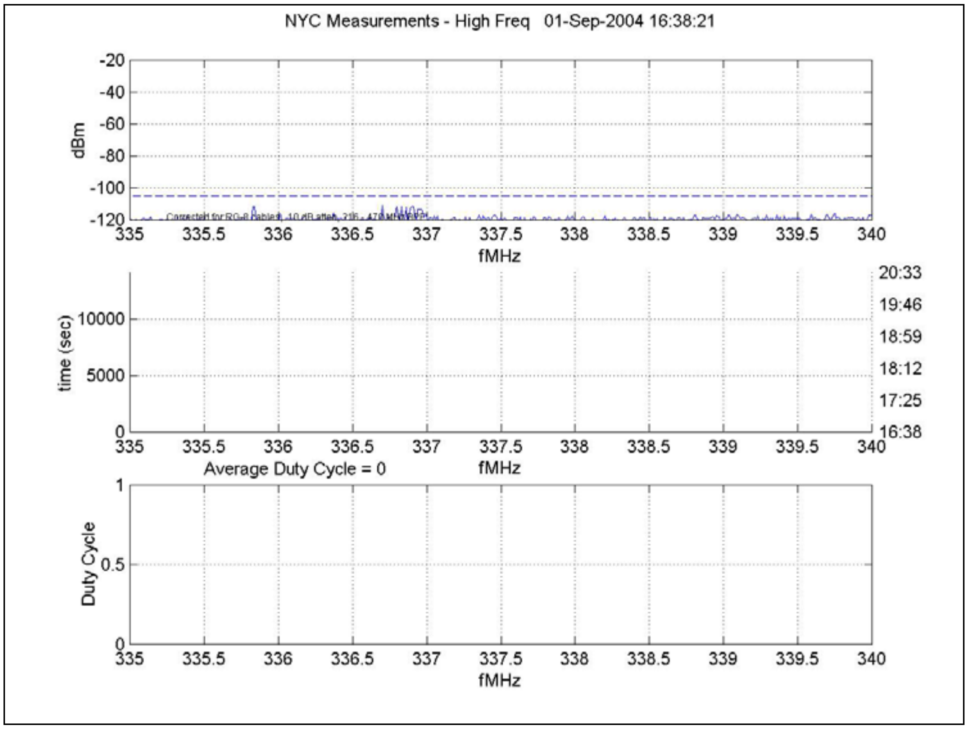

Figure 116: Small Frequency Resolution, 335 MHz – 340 MHz

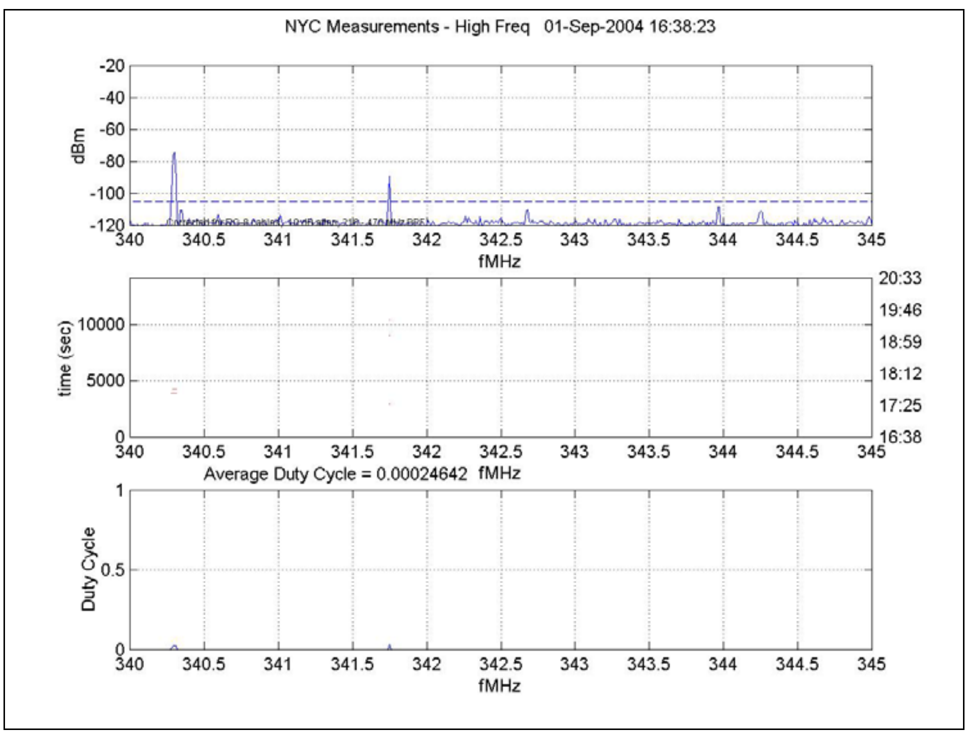

Figure 117: Small Frequency Resolution, 340 MHz – 345 MHz

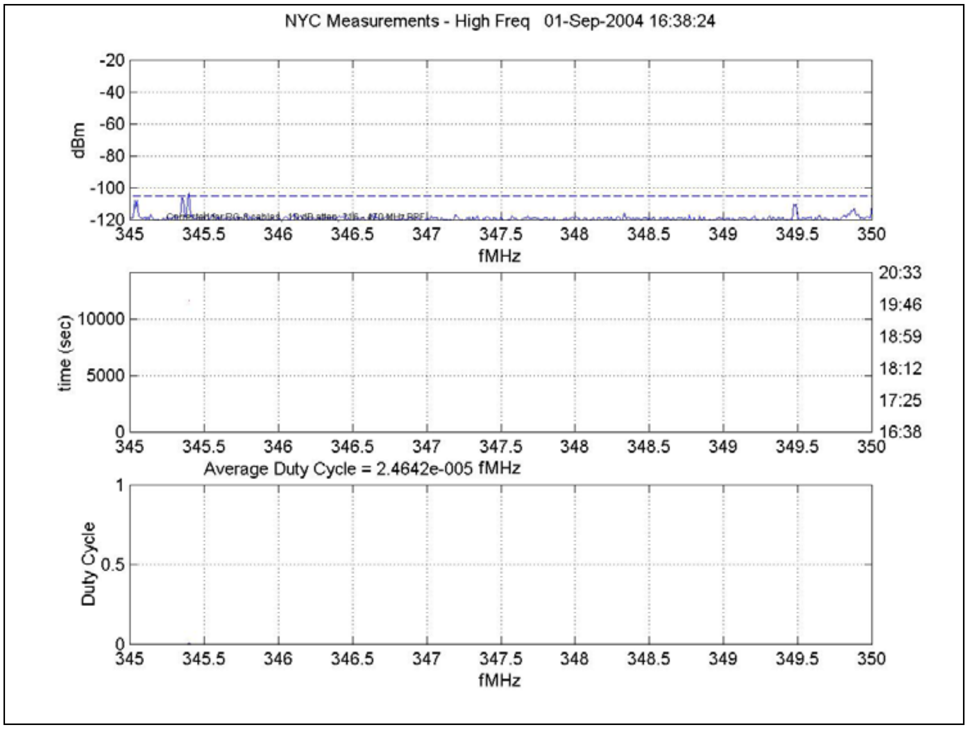

Figure 118: Small Frequency Resolution, 345 MHz – 350 MHz

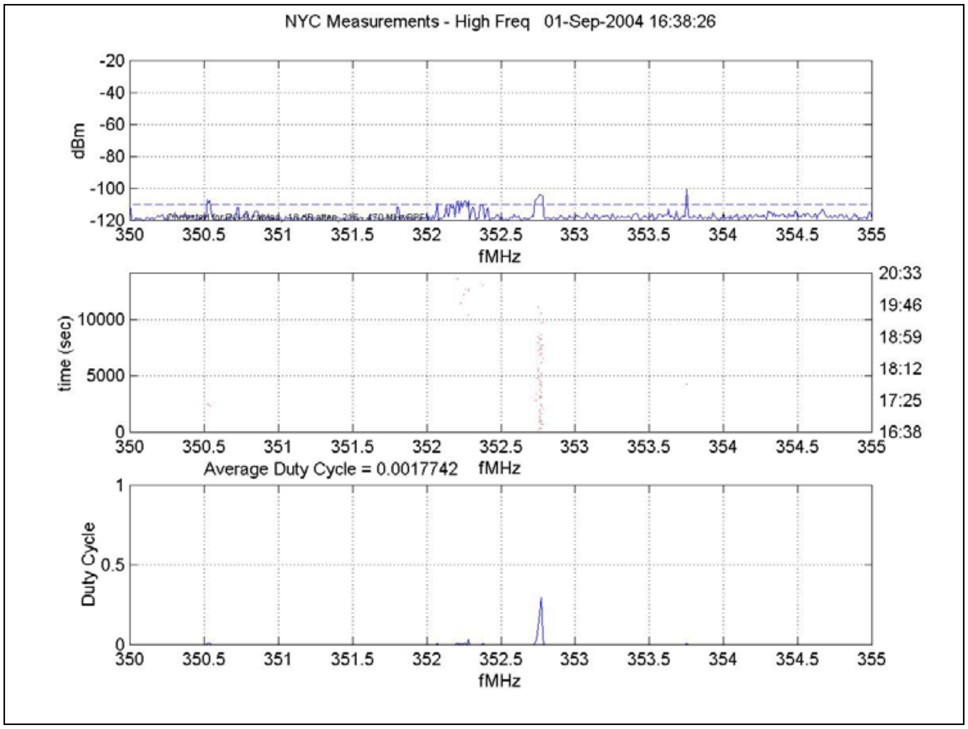

Figure 119: Small Frequency Resolution, 350 MHz – 355 MHz

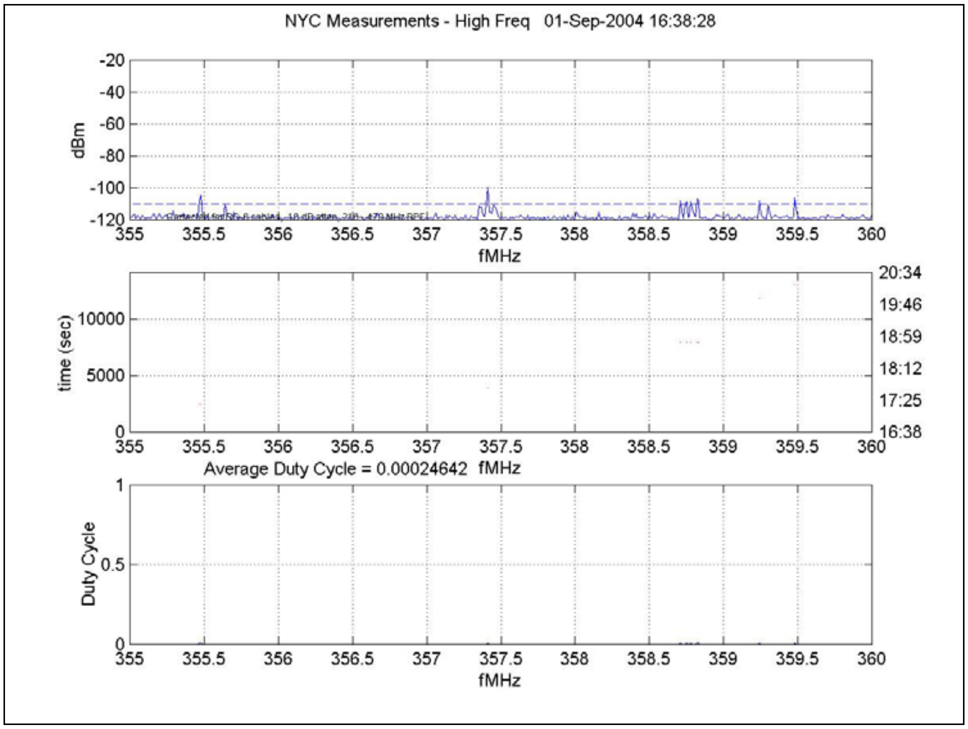

Figure 120: Small Frequency Resolution, 355 MHz – 360 MHz

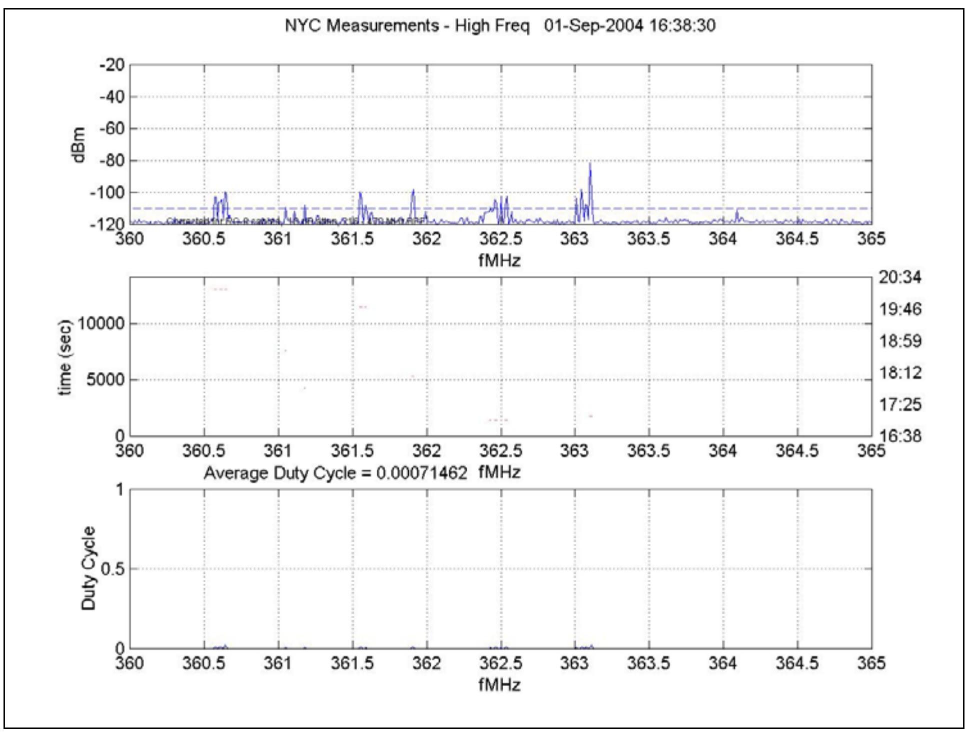

Figure 121: Small Frequency Resolution, 360 MHz – 365 MHz

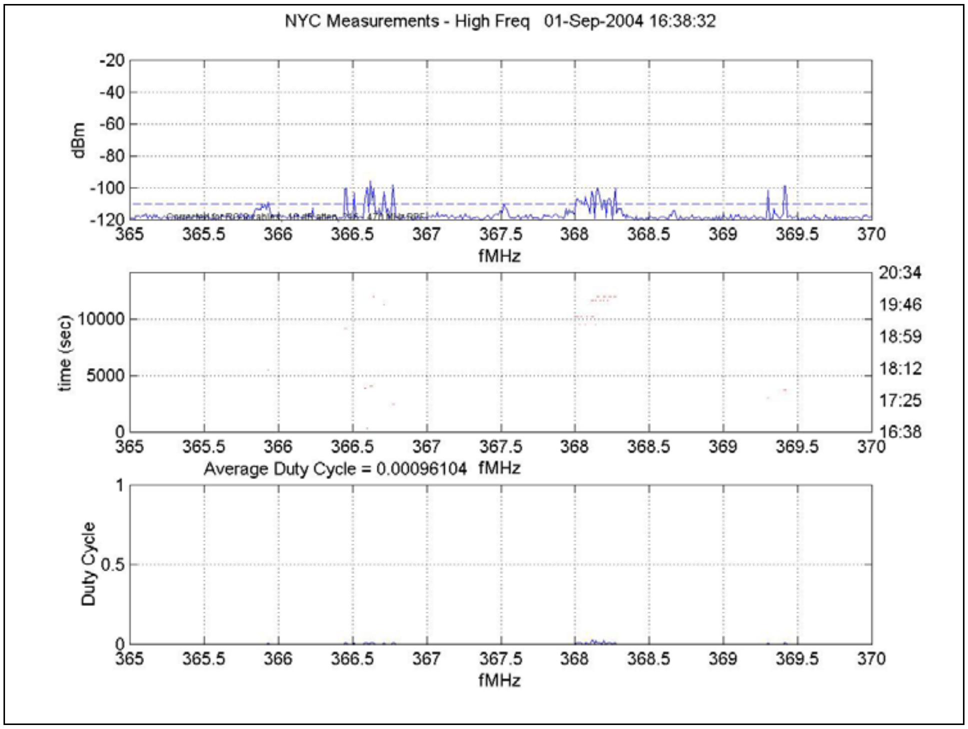

Figure 122: Small Frequency Resolution, 365 MHz – 370 MHz

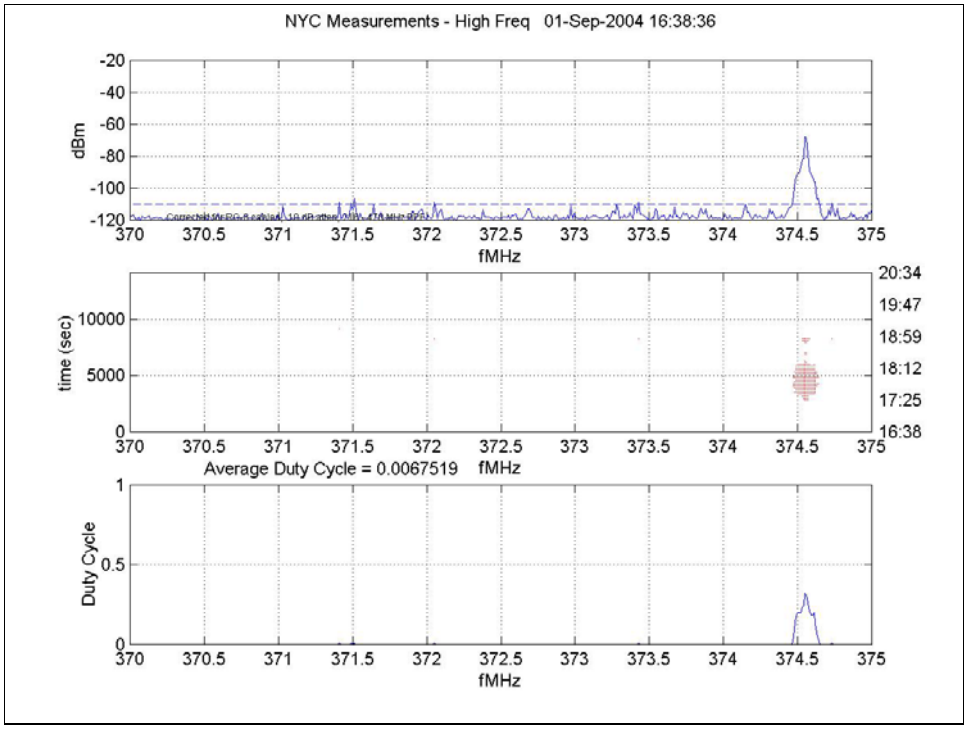

Figure 123: Small Frequency Resolution, 370 MHz – 375 MHz

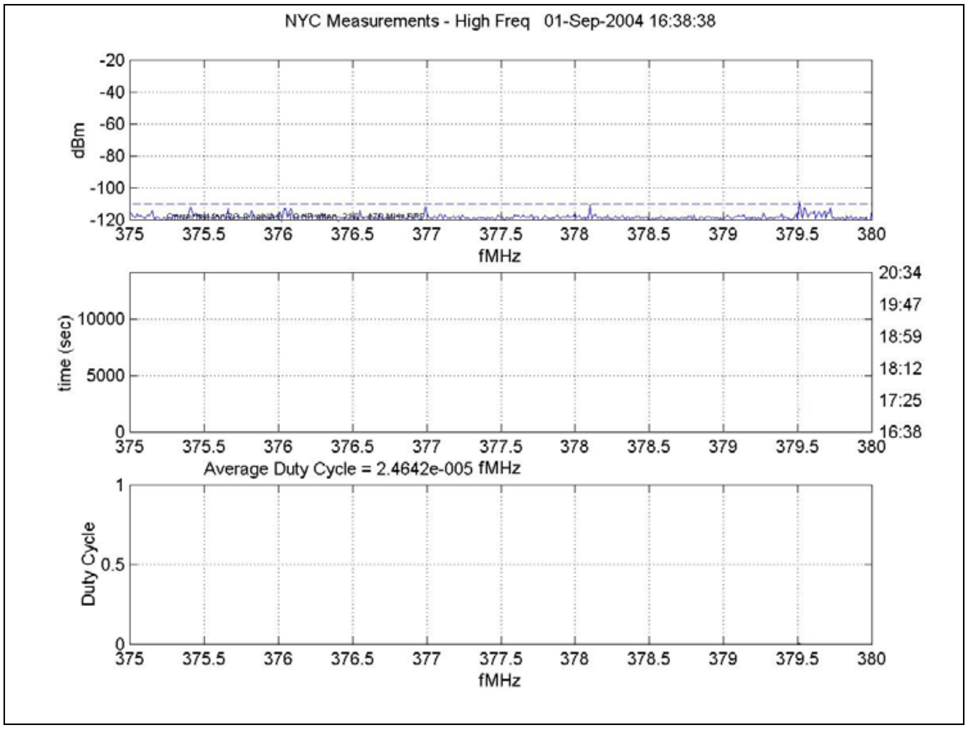

Figure 124: Small Frequency Resolution, 375 MHz – 380 MHz

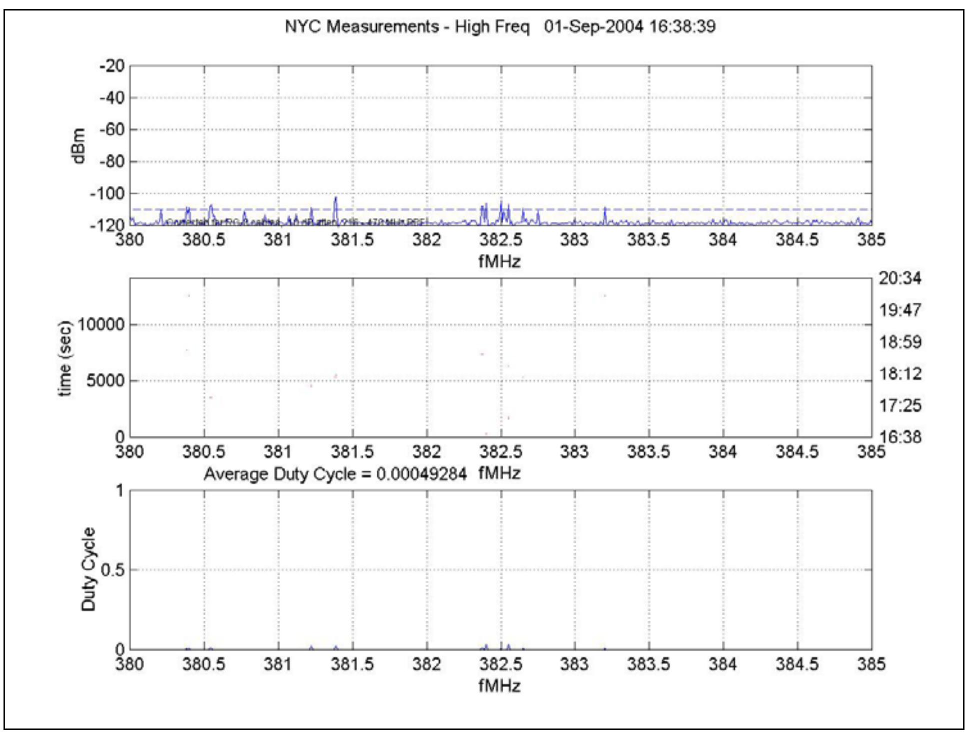

Figure 125: Small Frequency Resolution, 380 MHz – 385 MHz

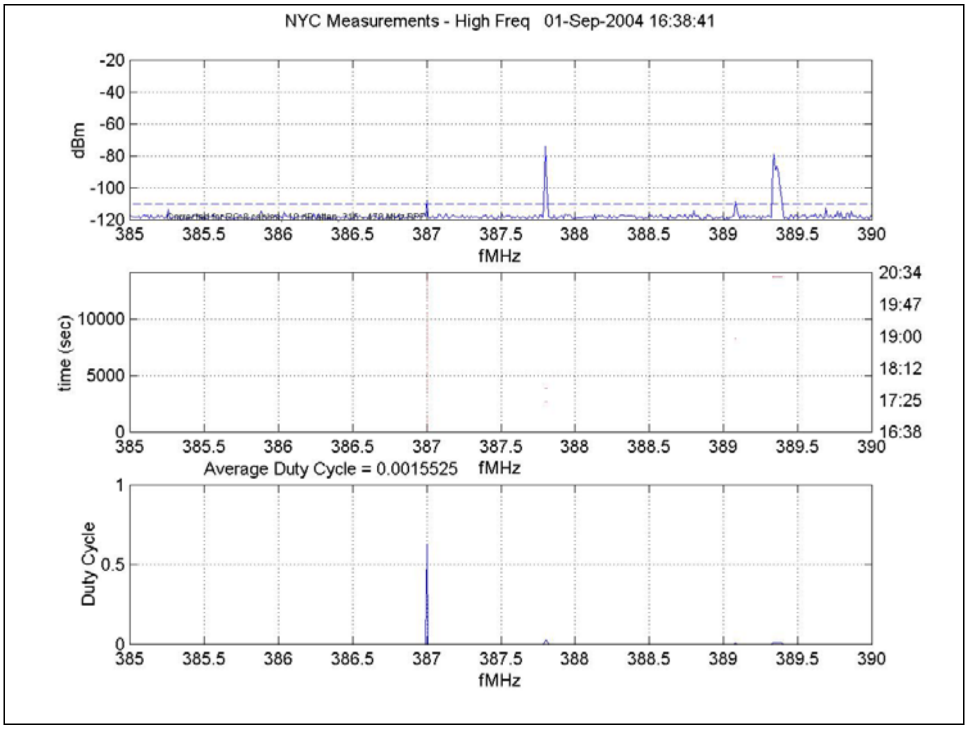

Figure 126: Small Frequency Resolution, 385 MHz – 390 MHz

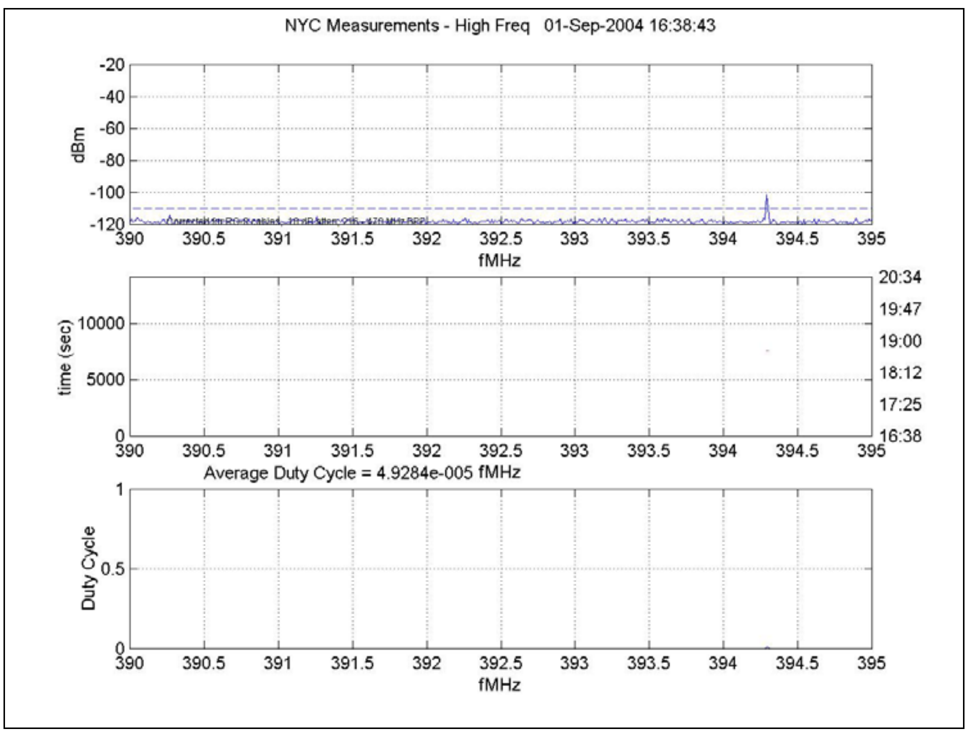

Figure 127: Small Frequency Resolution, 390 MHz – 395 MHz

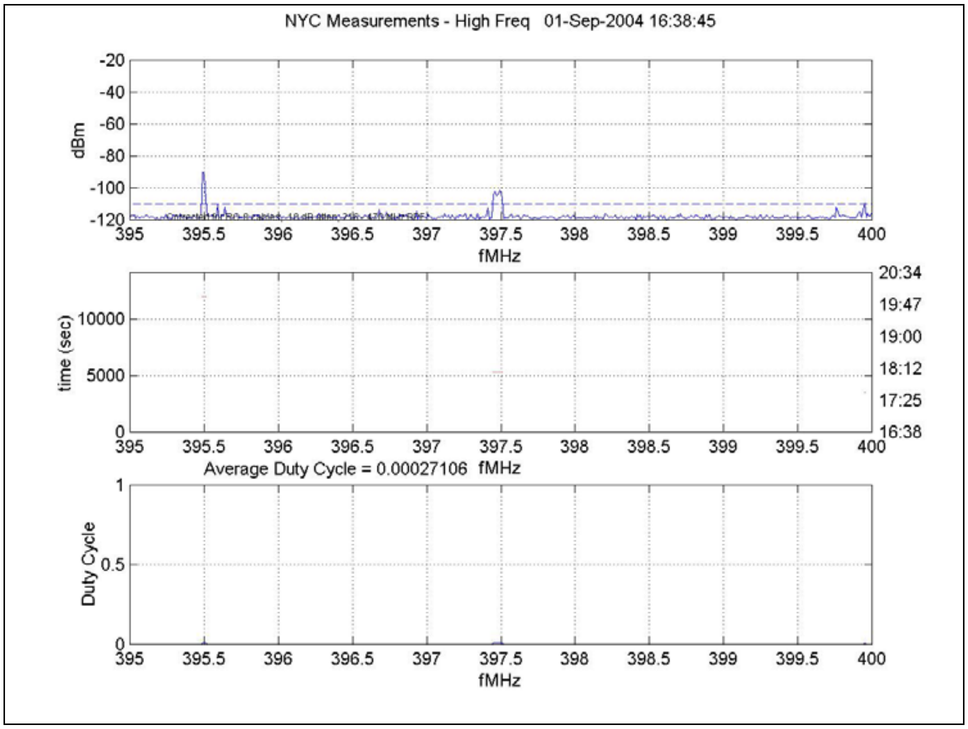

Figure 128: Small Frequency Resolution, 395 MHz – 400 MHz

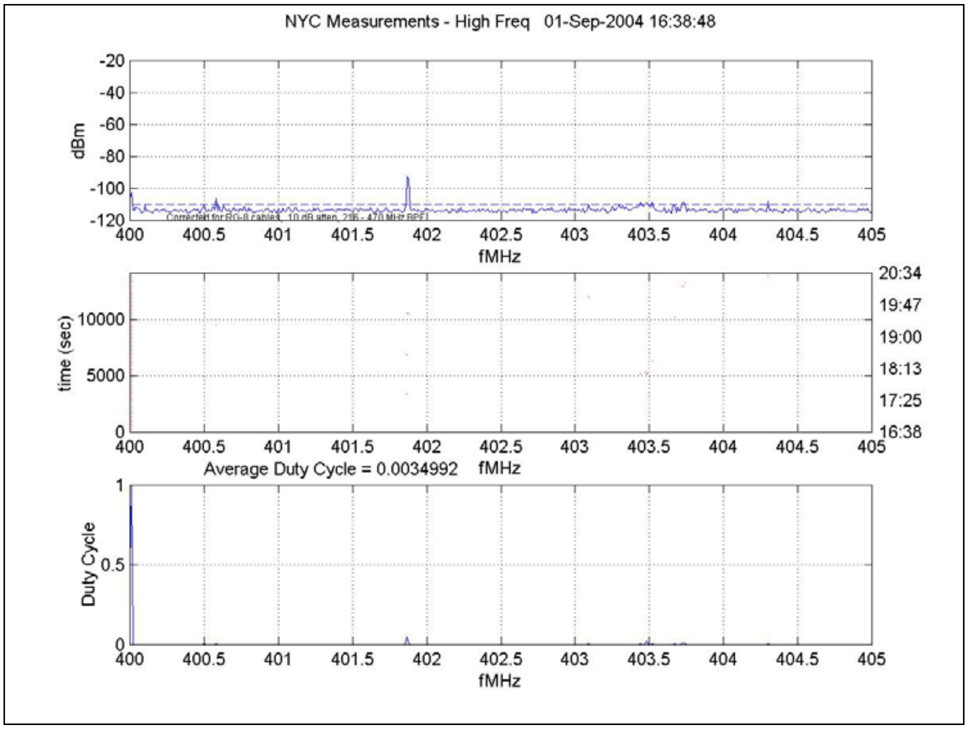

Figure 129: Small Frequency Resolution, 400 MHz – 405 MHz

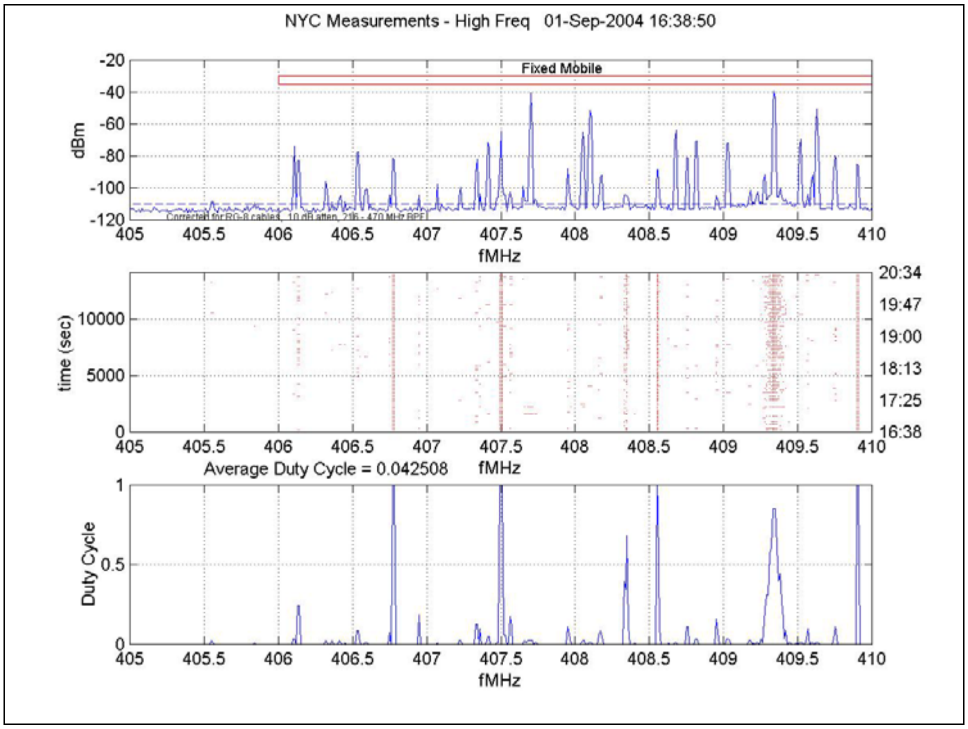

Figure 130: Small Frequency Resolution, 405 MHz – 410 MHz

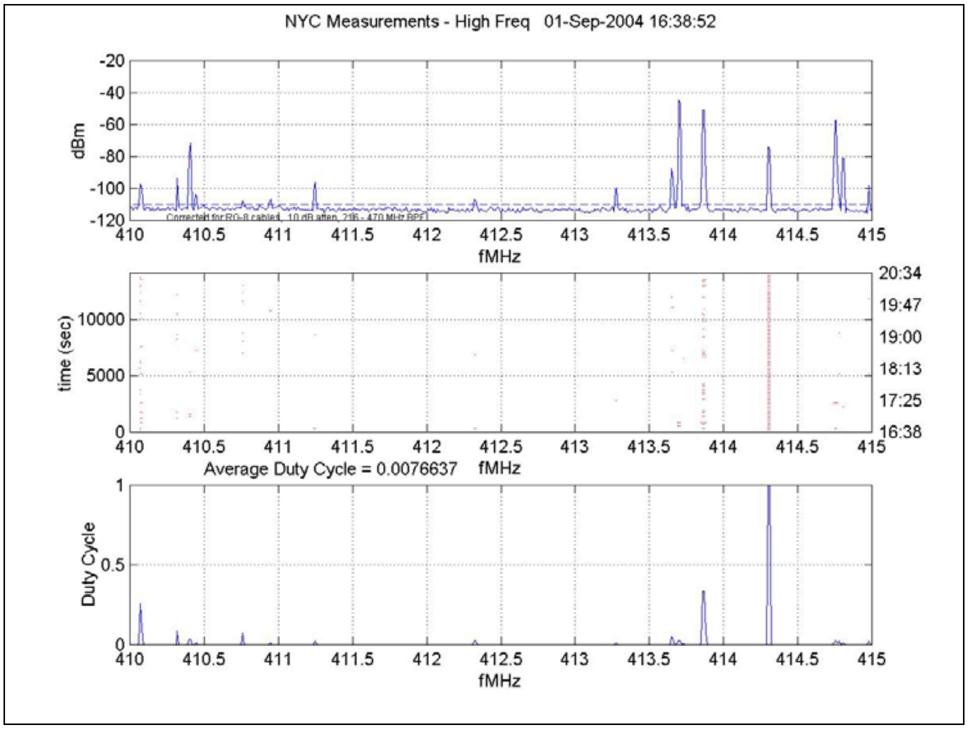

Figure 131: Small Frequency Resolution, 410 MHz – 415 MHz

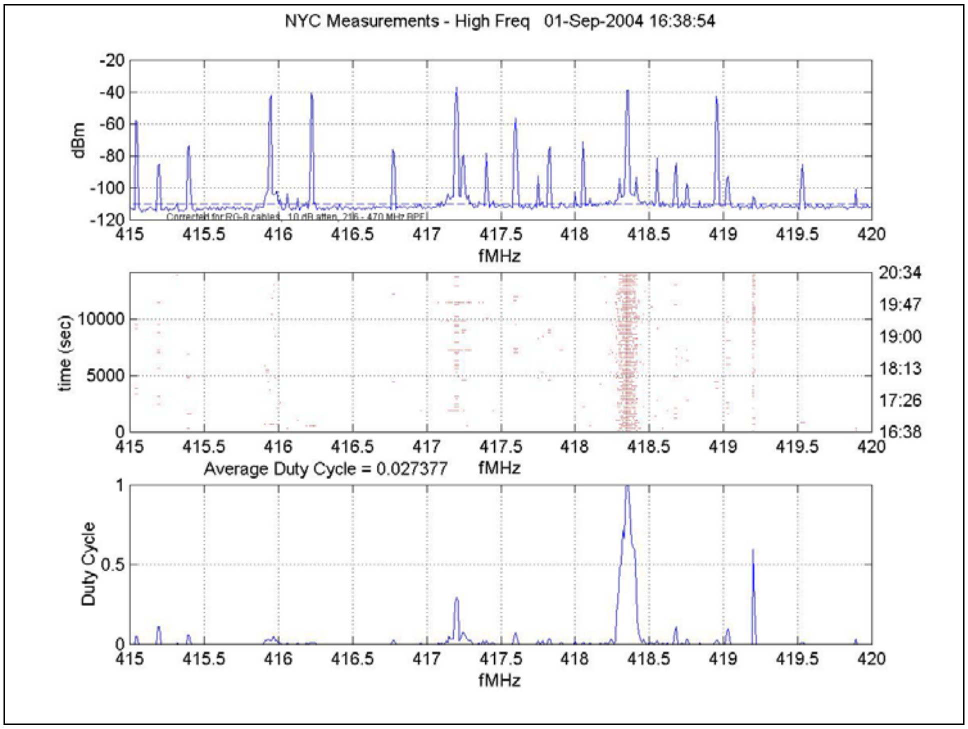

Figure 132: Small Frequency Resolution, 415 MHz – 420 MHz

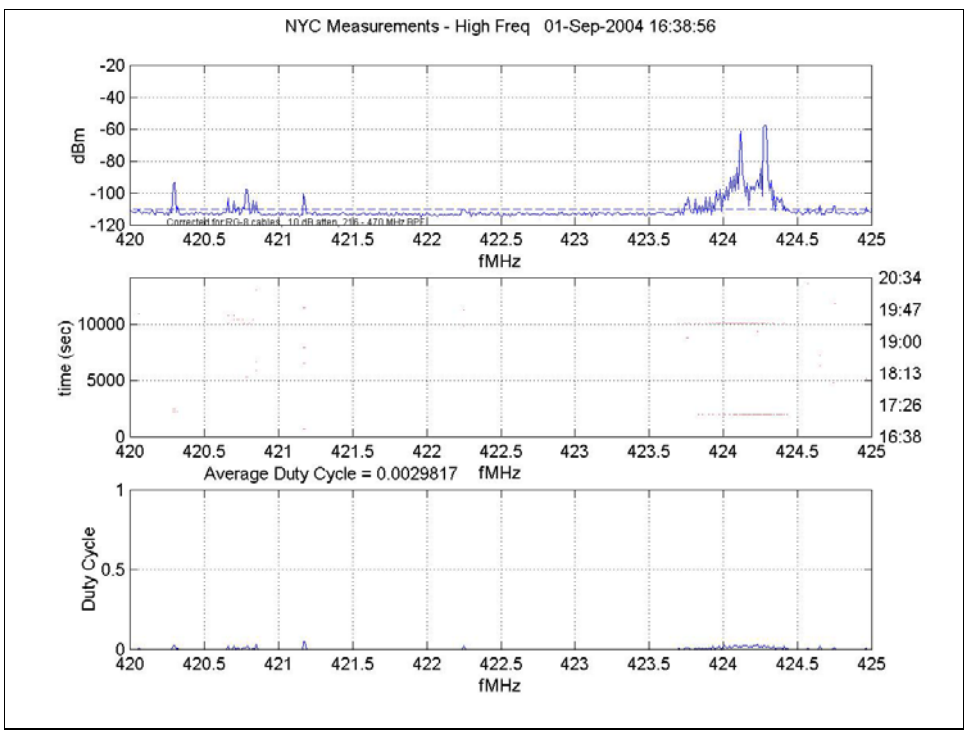

Figure 133: Small Frequency Resolution, 420 MHz – 425 MHz

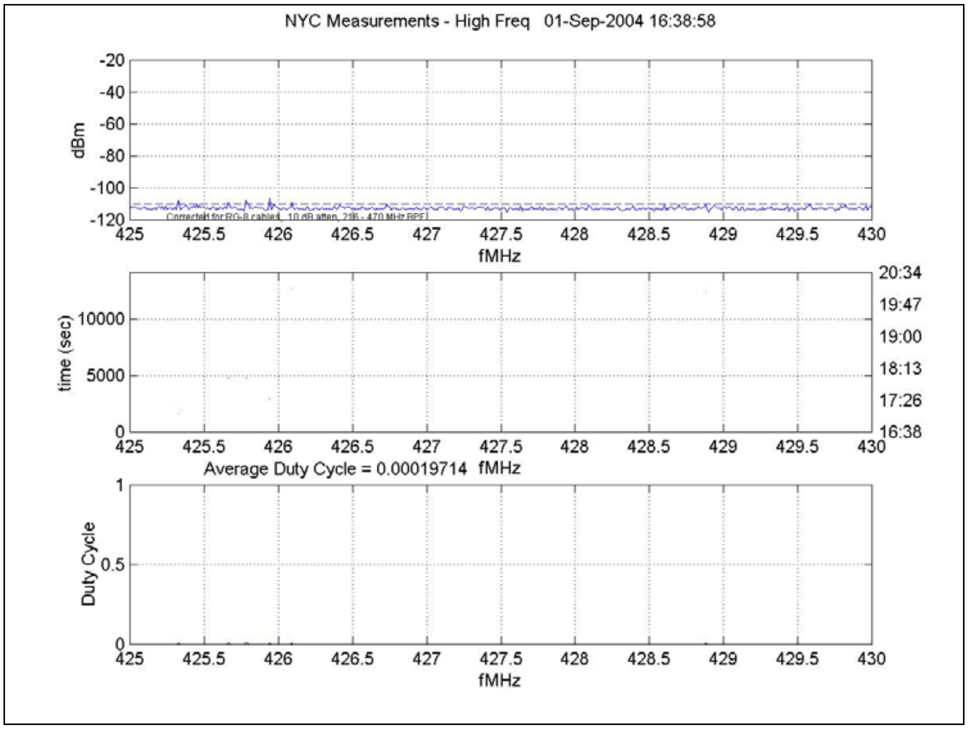

Figure 134: Small Frequency Resolution, 425 MHz – 430 MHz

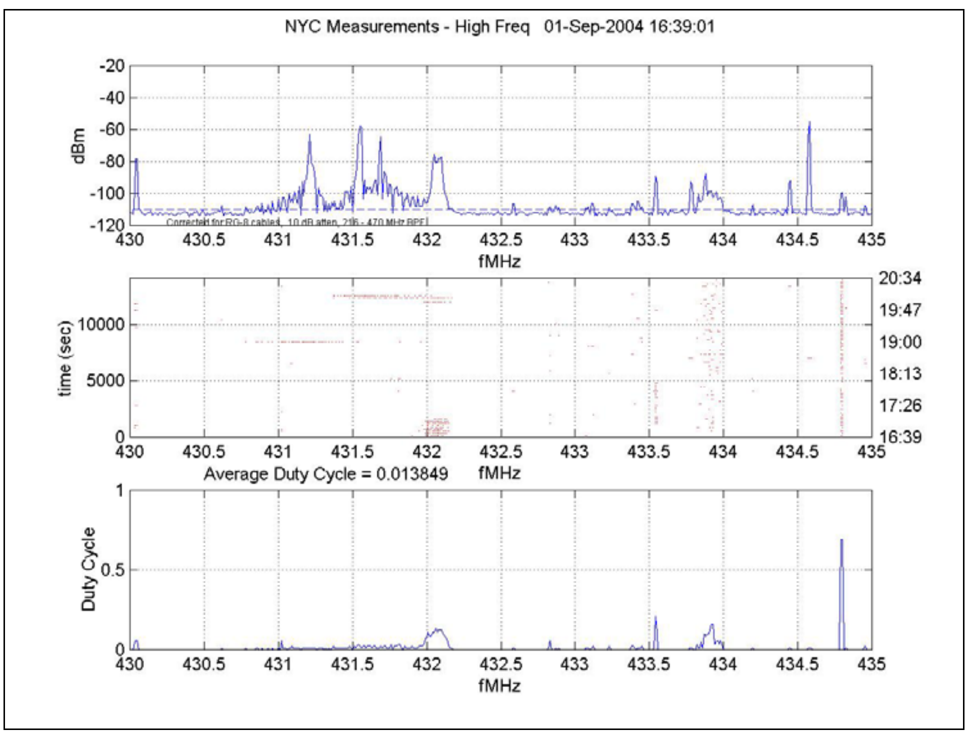

Figure 135: Small Frequency Resolution, 430 MHz – 435 MHz

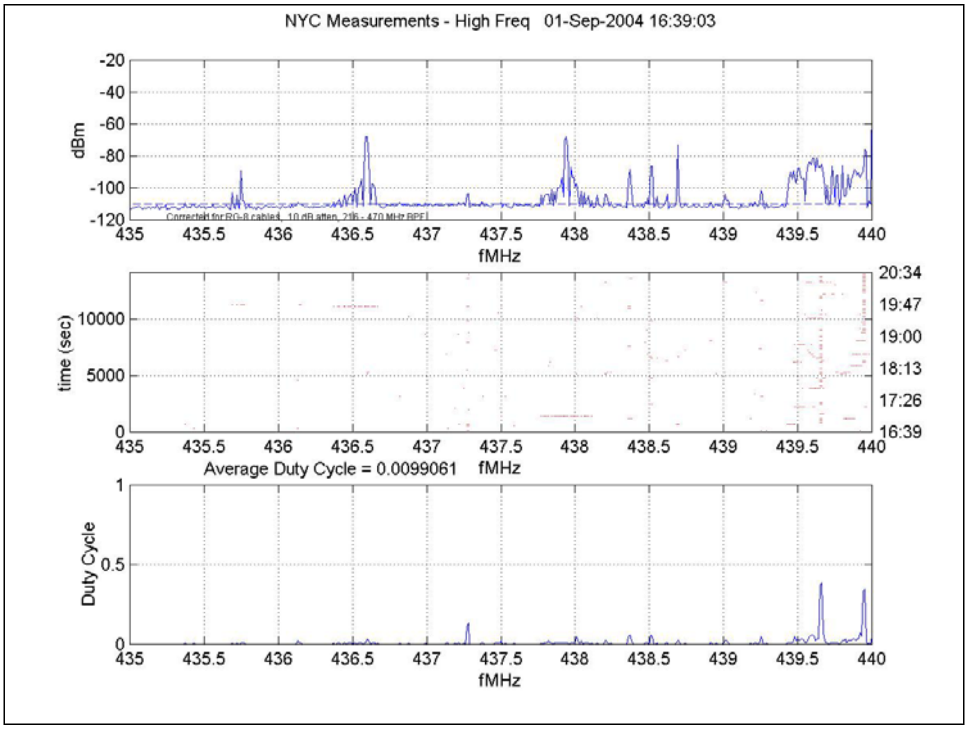

Figure 136: Small Frequency Resolution, 435 MHz – 440 MHz

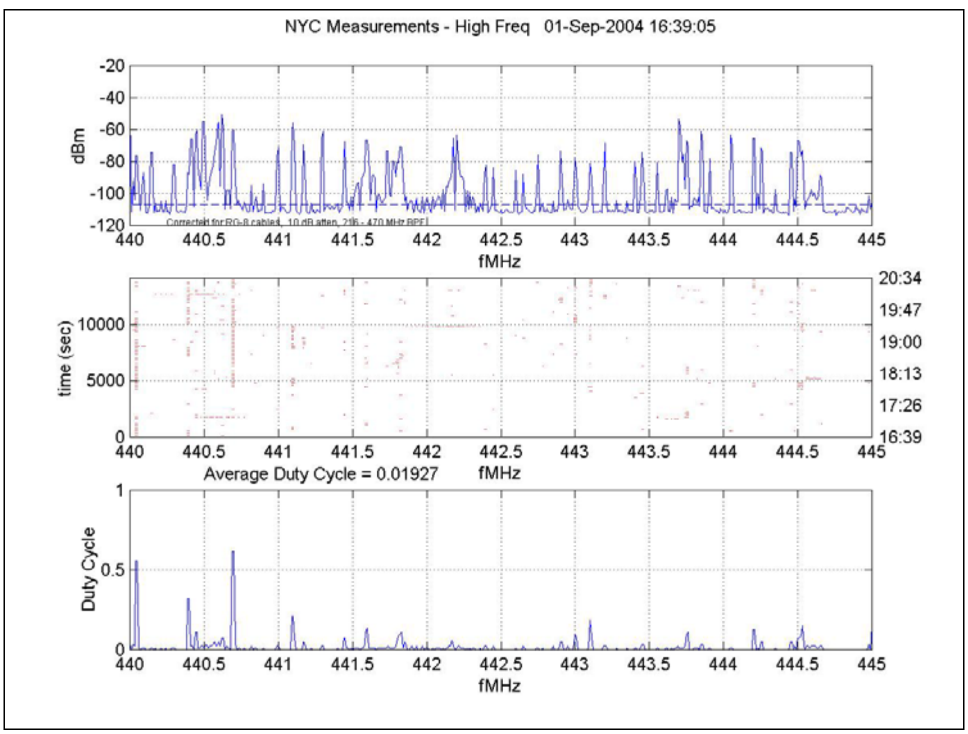

Figure 137: Small Frequency Resolution, 440 MHz – 445 MHz

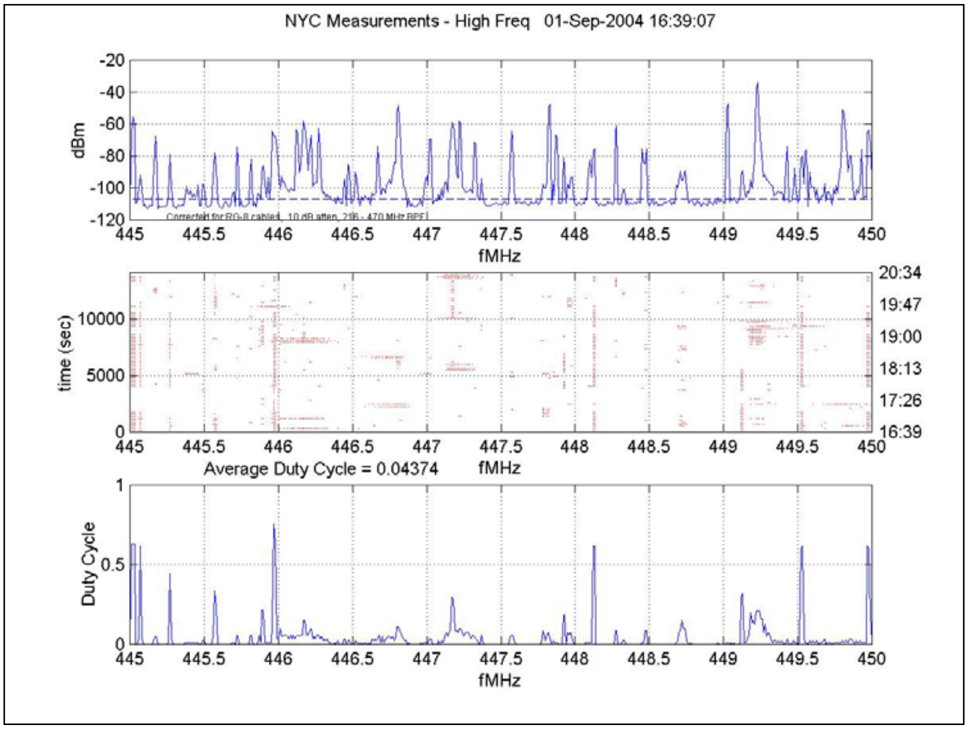

Figure 138: Small Frequency Resolution, 445 MHz – 450 MHz

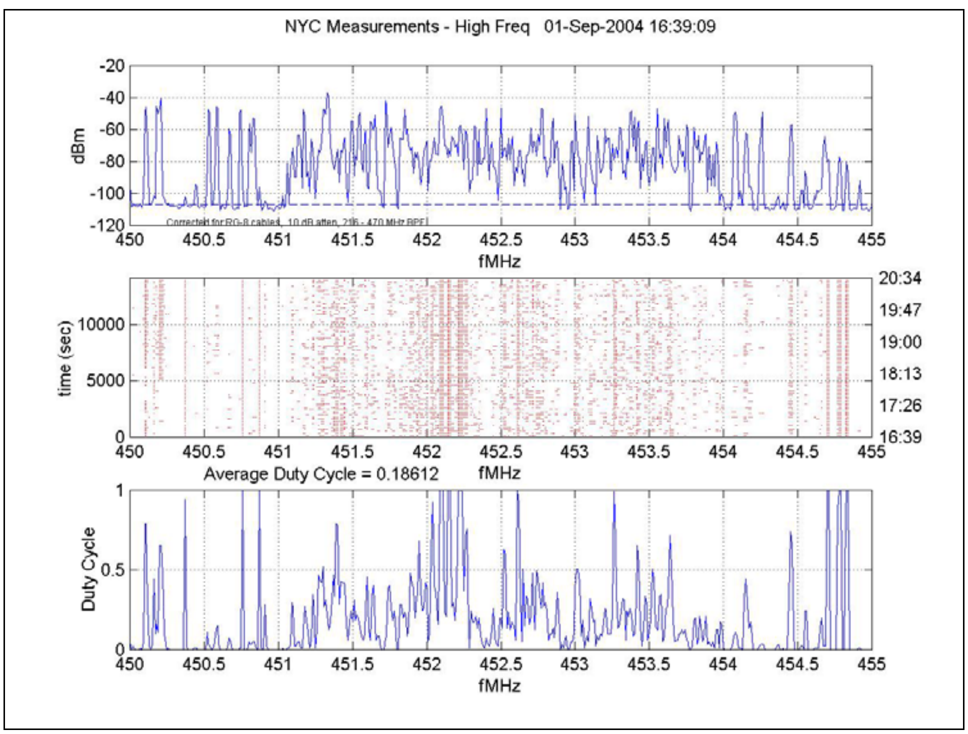

Figure 139: Small Frequency Resolution, 450 MHz – 455 MHz

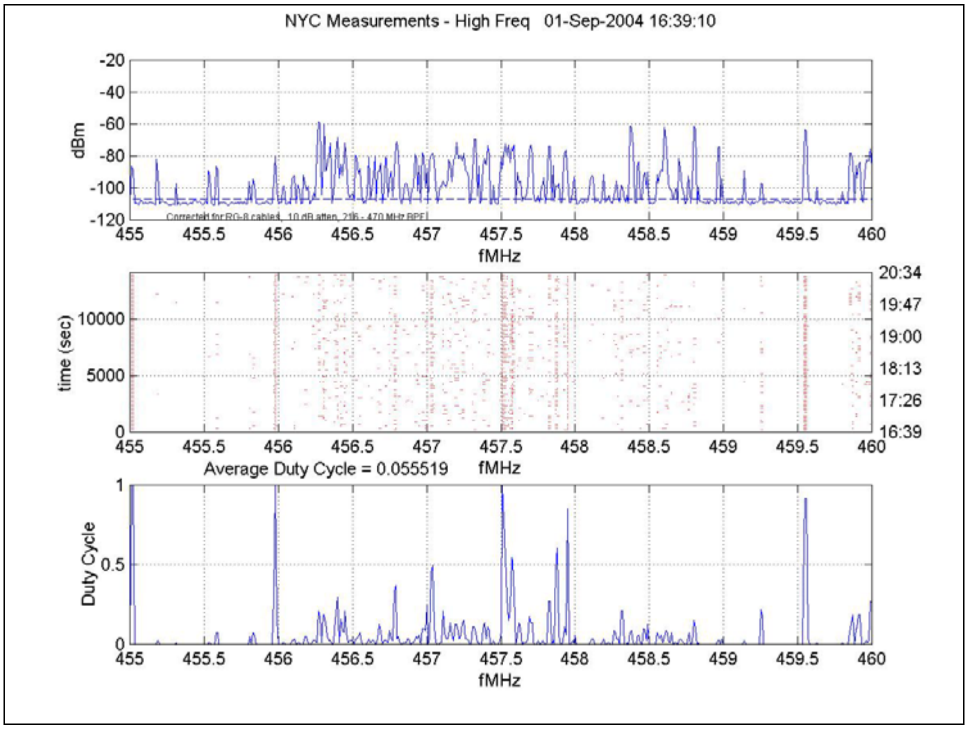

Figure 140: Small Frequency Resolution, 455 MHz – 460 MHz

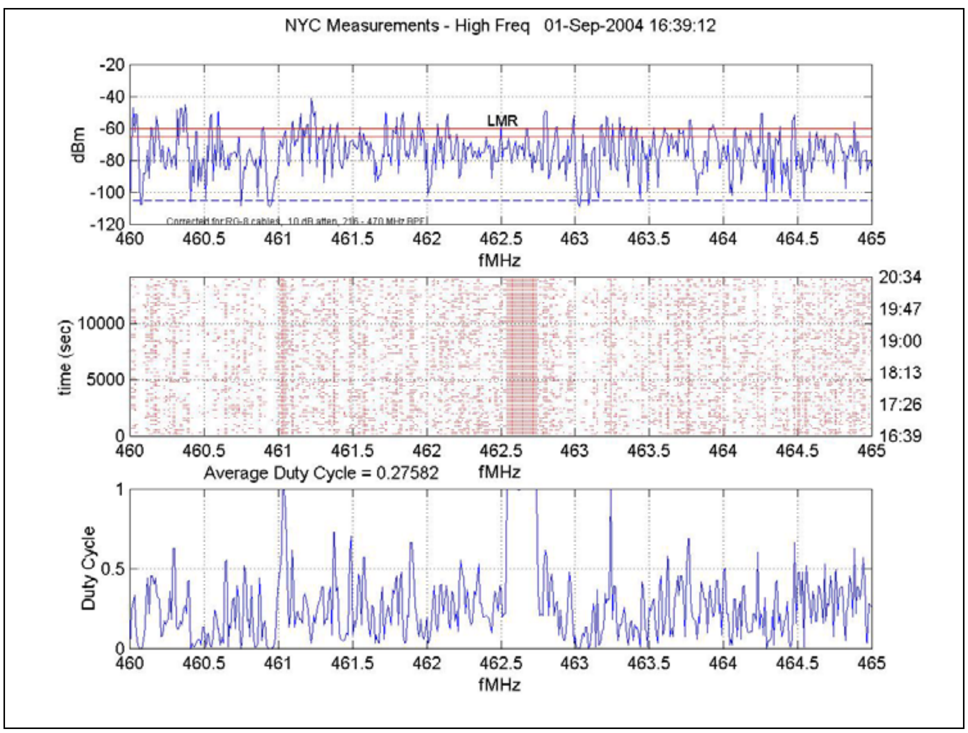

Figure 141: Small Frequency Resolution, 460 MHz – 465 MHz

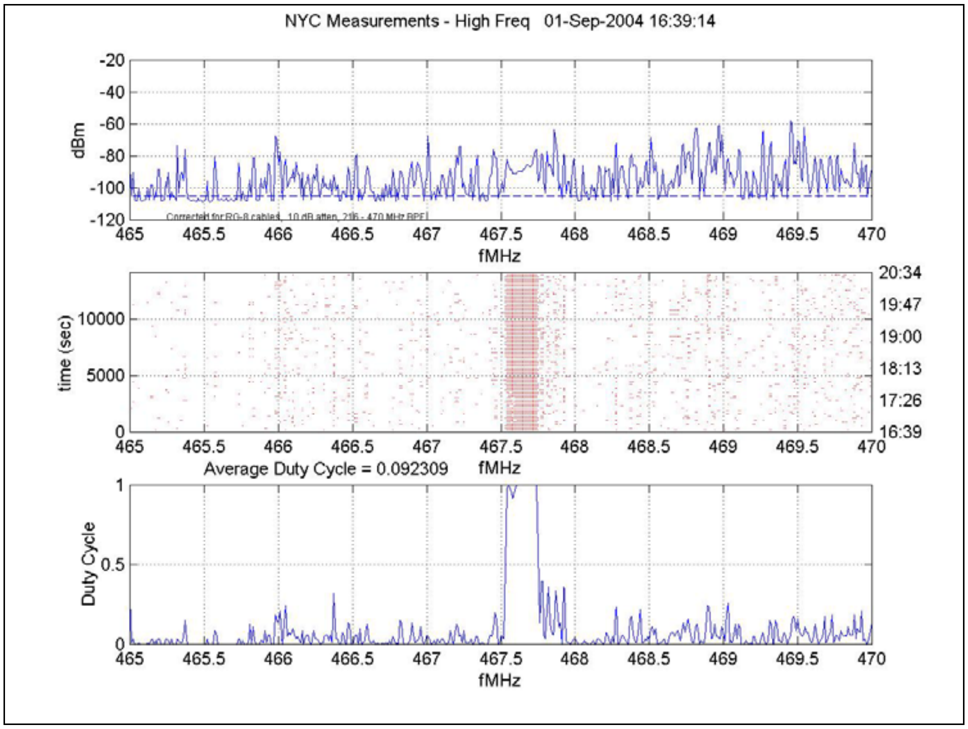

Figure 142: Small Frequency Resolution, 465 MHz – 470 MHz

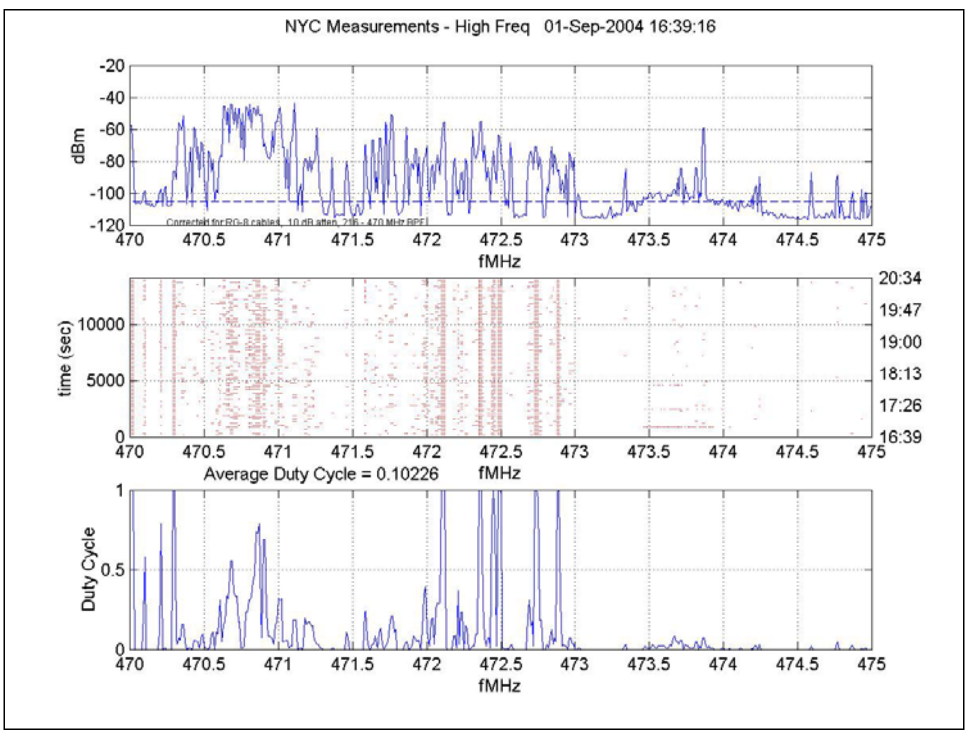

Figure 143: Small Frequency Resolution, 470 MHz – 475 MHz

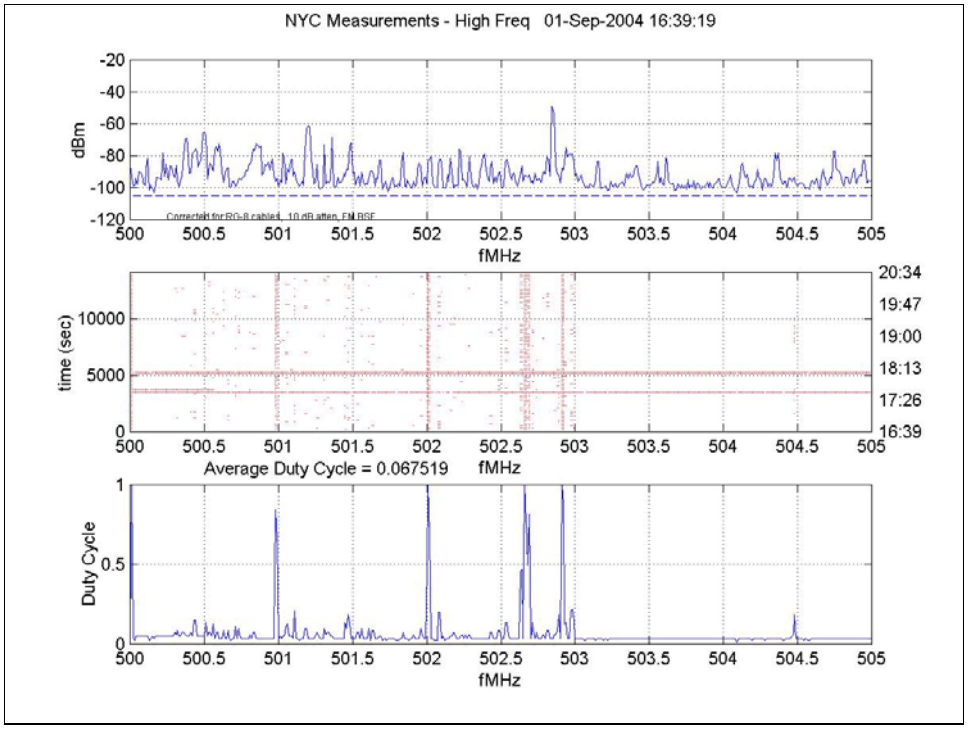

Figure 144 : Small Frequency Resolution, 500 MHz – 505 MHz

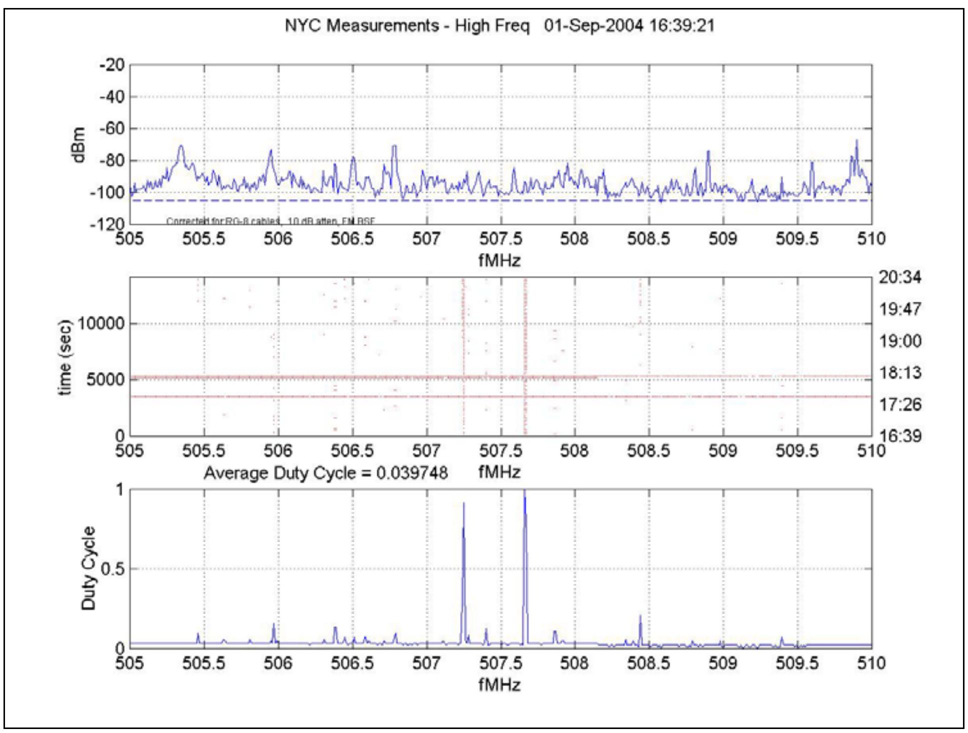

Figure 145: Small Frequency Resolution, 505 MHz – 510 MHz

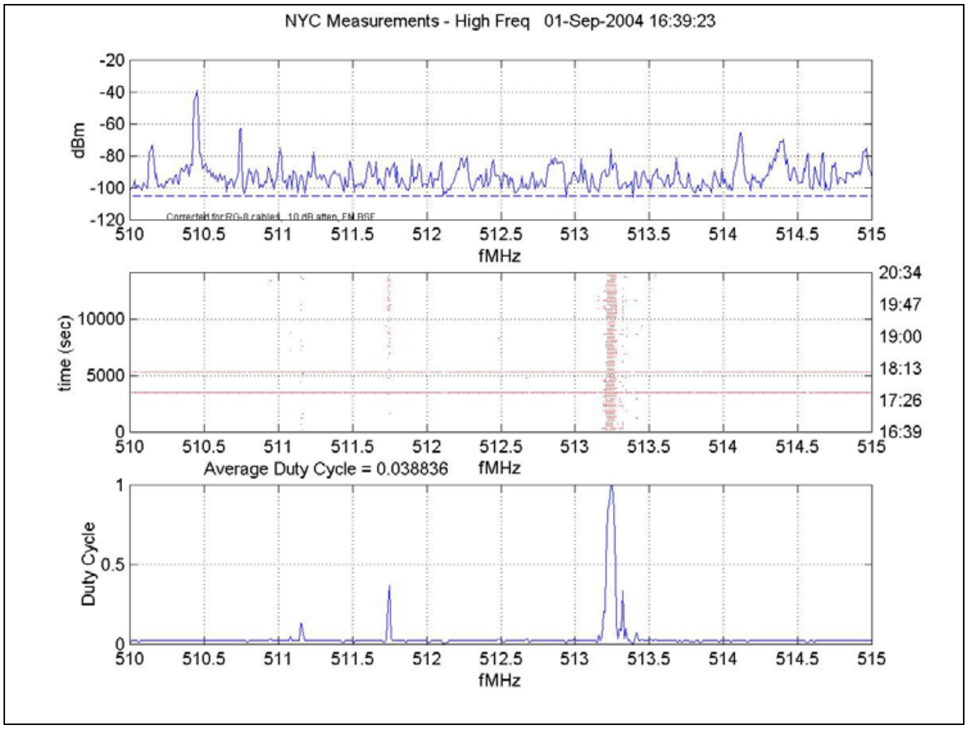

Figure 146: Small Frequency Resolution, 510 MHz – 515 MHz

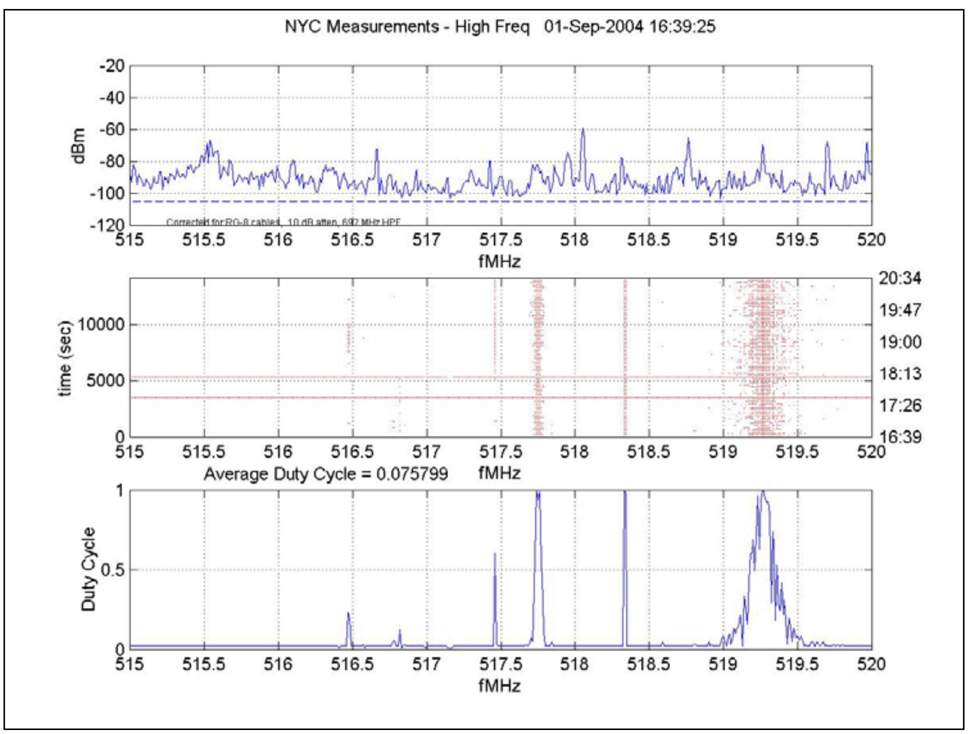

Figure 147: Small Frequency Resolution, 515 MHz – 520 MHz

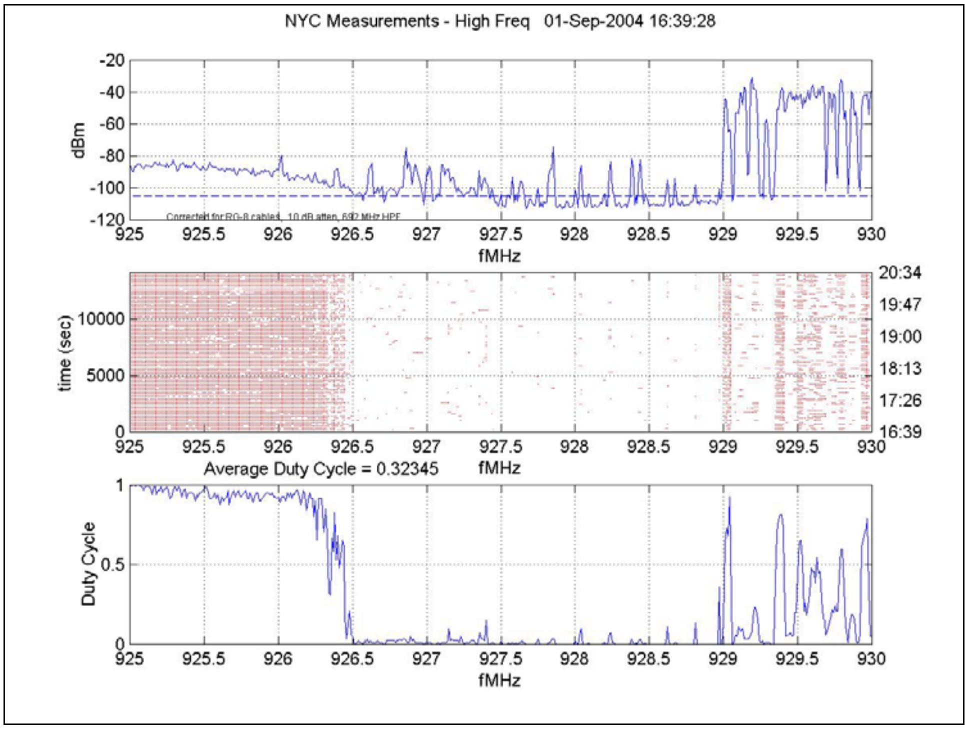

Figure 148: Small Frequency Resolution, 925 MHz – 930 MHz

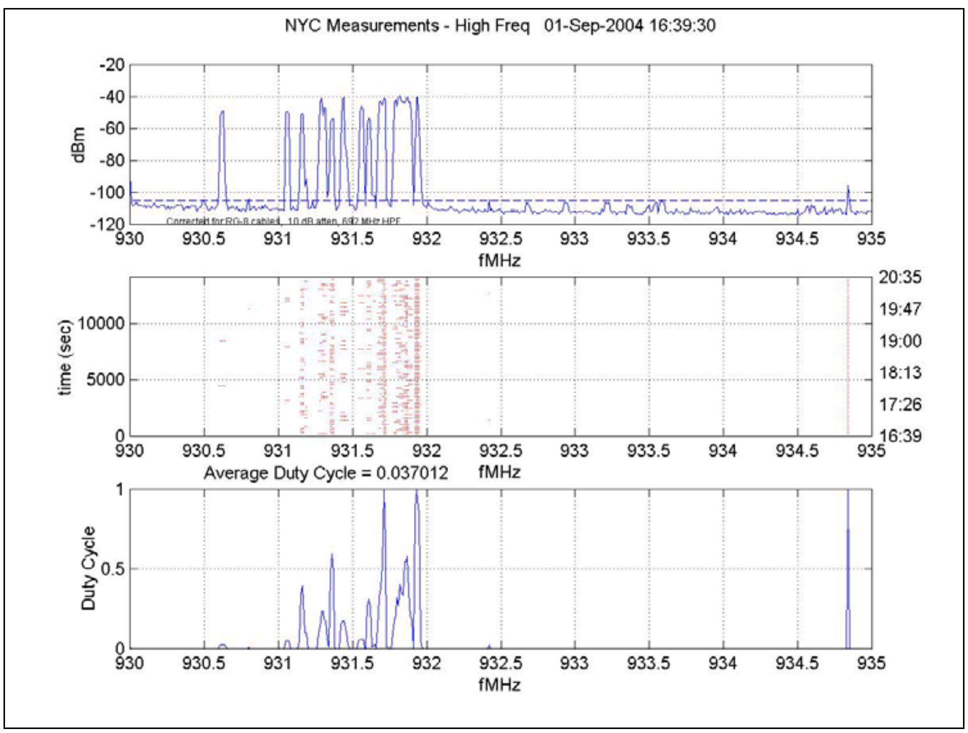

Figure 149: Small Frequency Resolution, 930 MHz – 935 MHz

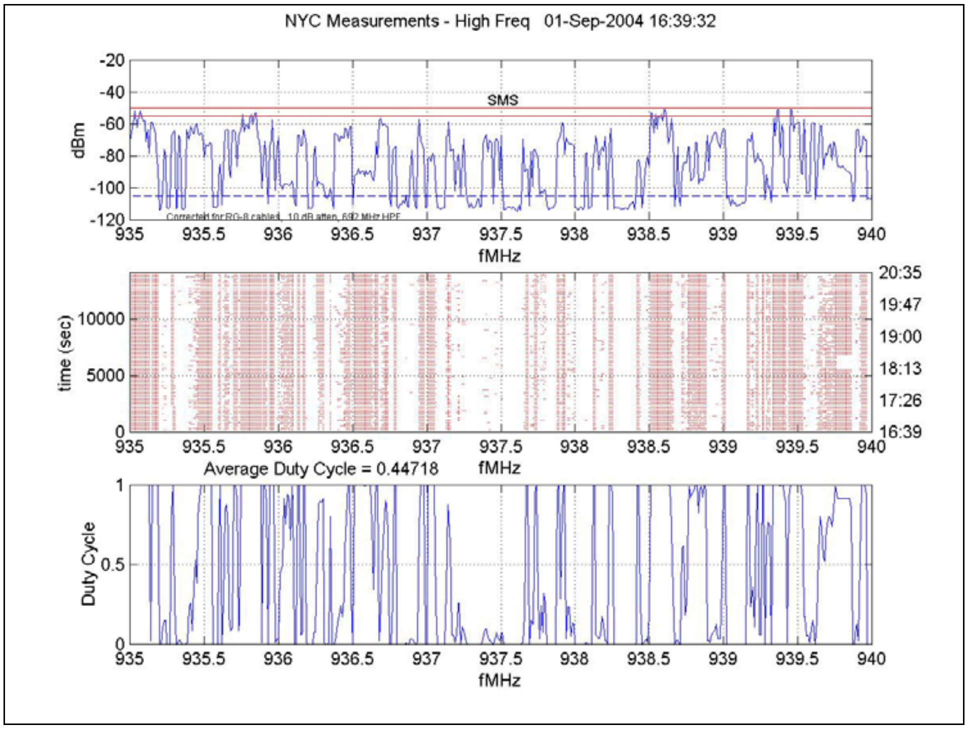

Figure 150: Small Frequency Resolution, 935 MHz – 940 MHz

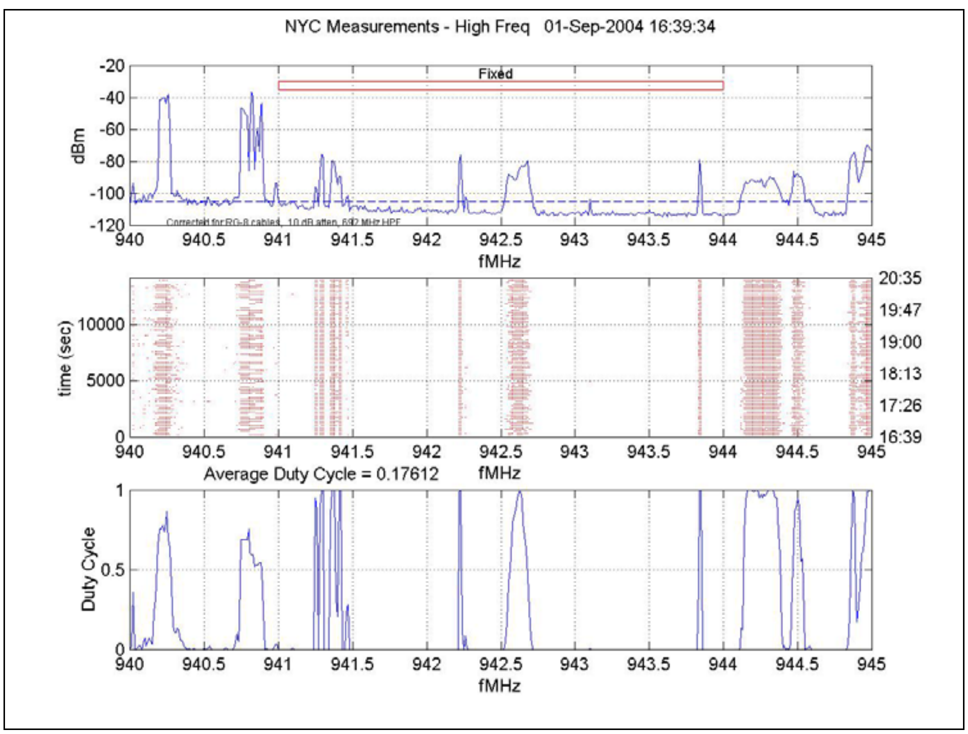

Figure 151: Small Frequency Resolution, 940 MHz – 945 MHz

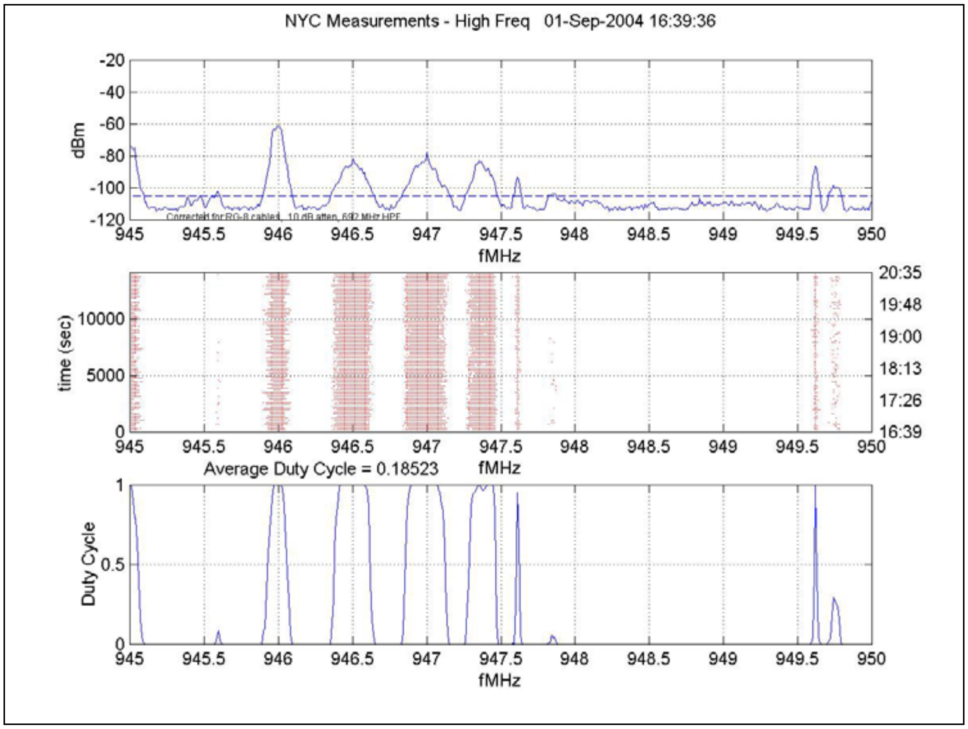

Figure 152: Small Frequency Resolution, 945 MHz – 950 MHz

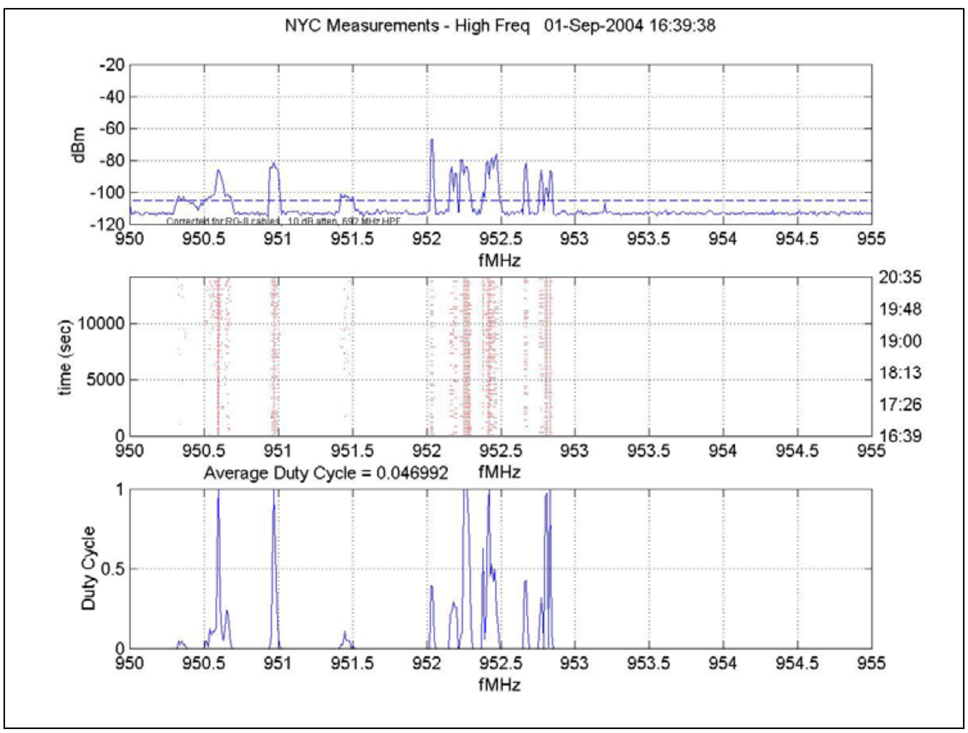

Figure 153: Small Frequency Resolution, 950 MHz – 955 MHz

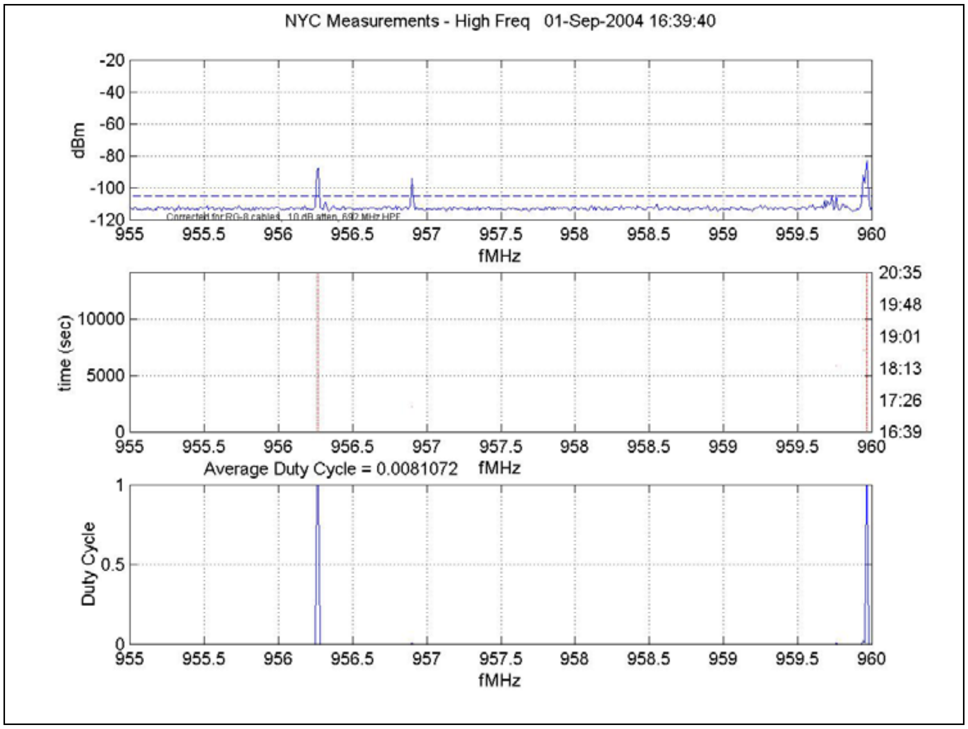

Figure 154: Small Frequency Resolution, 955 MHz – 960 MHz

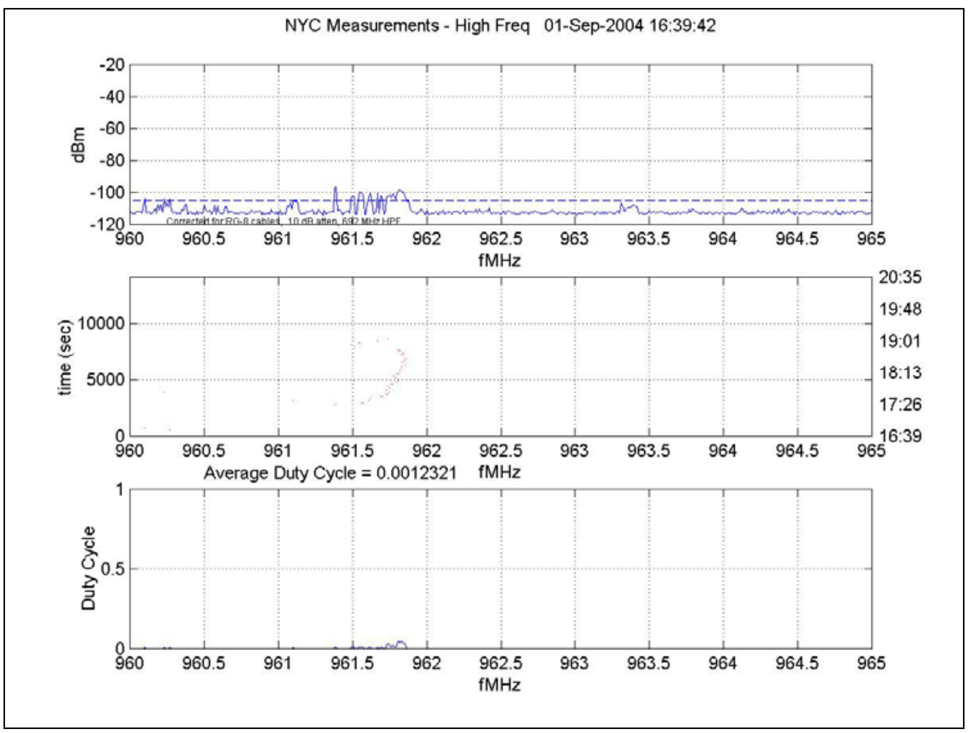

Figure 155: Small Frequency Resolution, 960 MHz – 965 MHz

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 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.

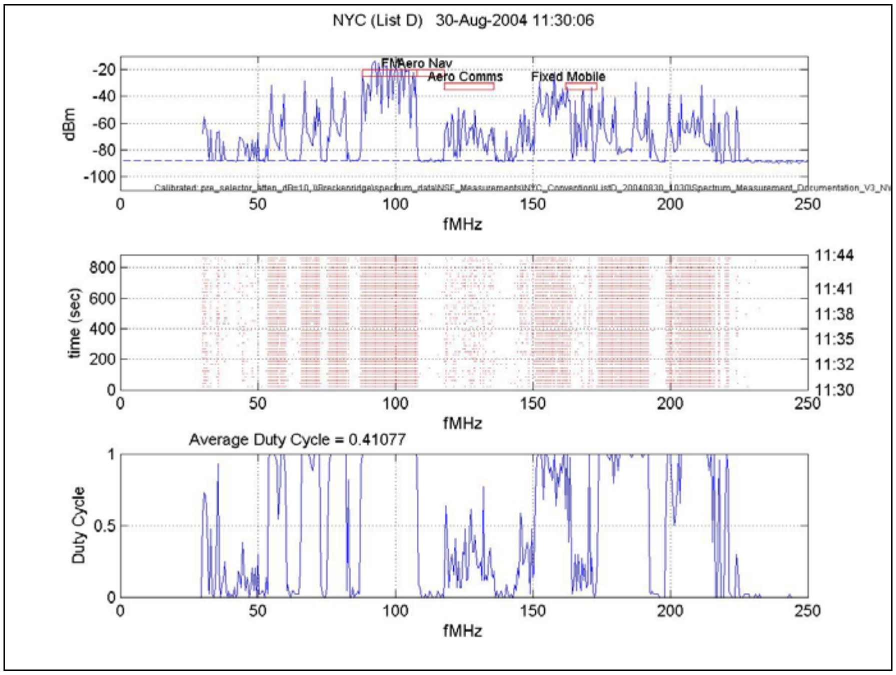

Figure 156: Large Signal Data, 0 – 250 MHz

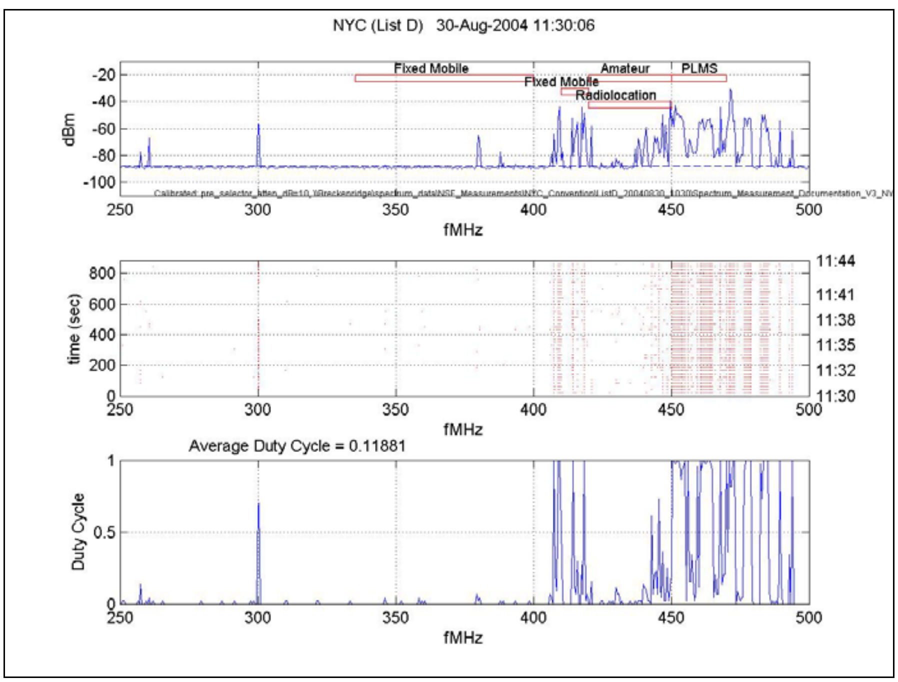

Figure 157: Large Signal Data, 250 MHz – 500 MHz

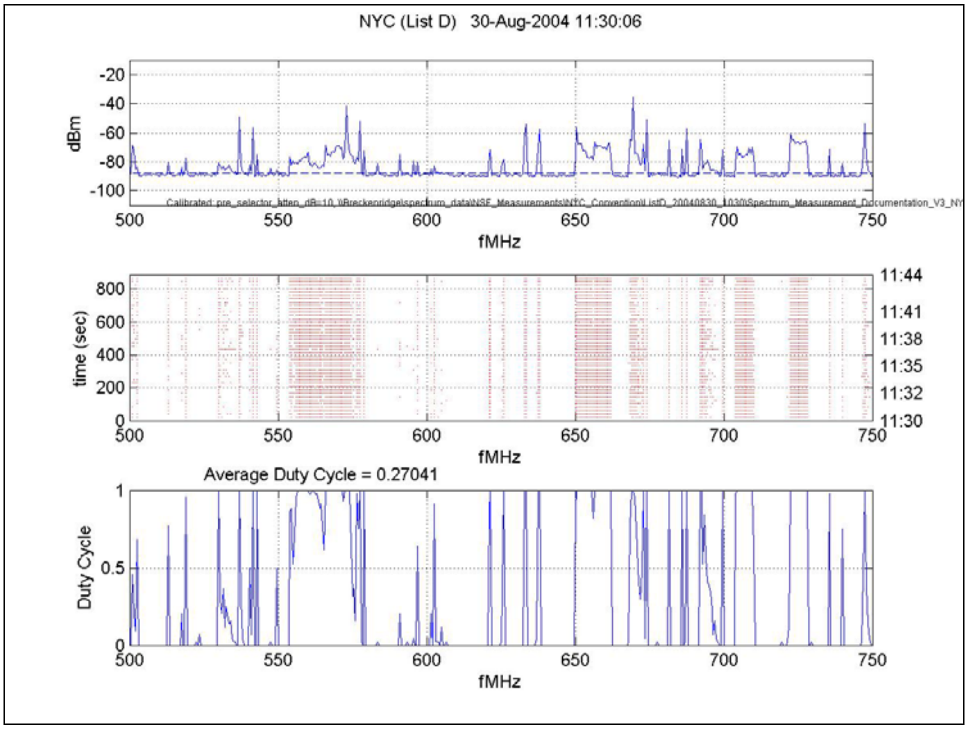

Figure 158: Large Signal Data, 500 MHz – 750 MHz

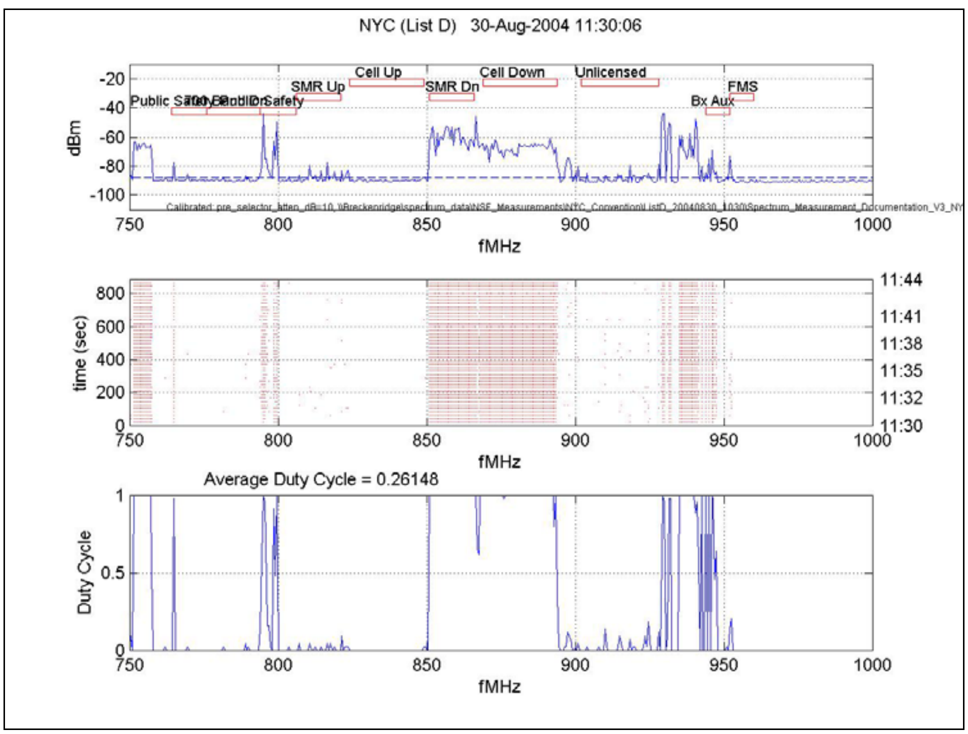

Figure 159: Large Signal Data, 750 MHz – 1000 MHz

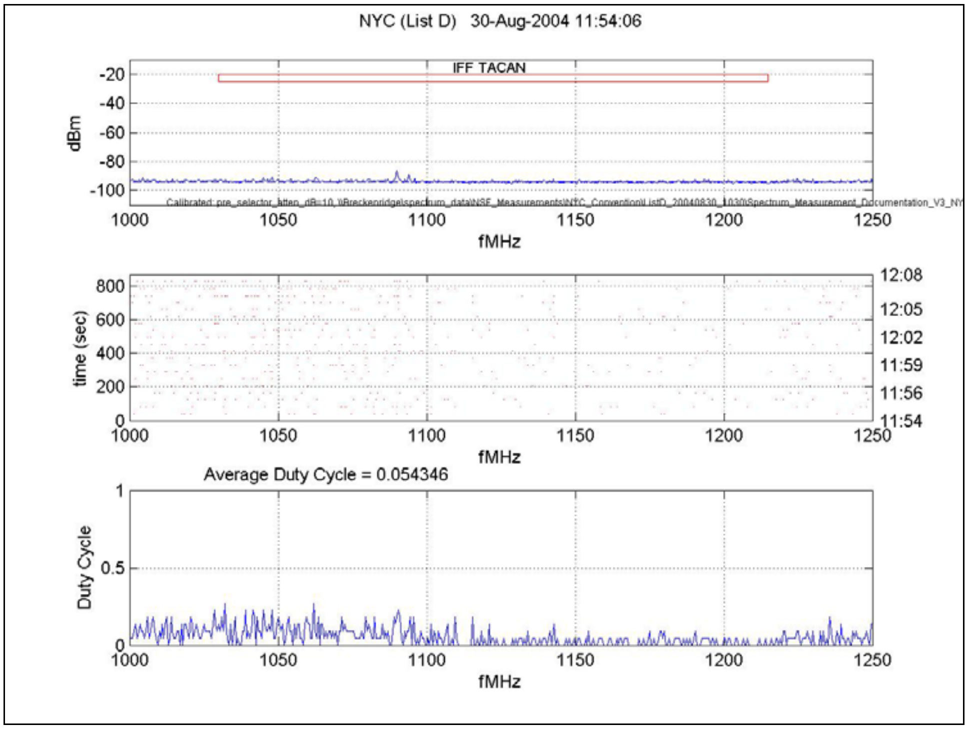

Figure 160: Large Signal Data, 1000 MHz – 1250 MHz

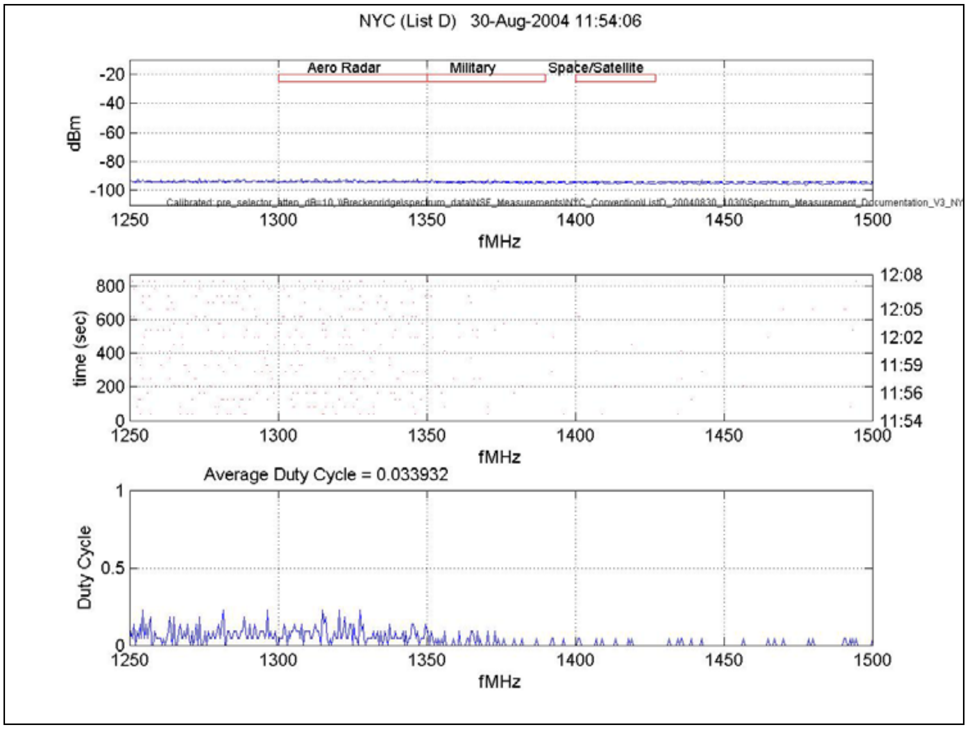

Figure 161: Large Signal Data, 1250 MHz – 1500 MHz

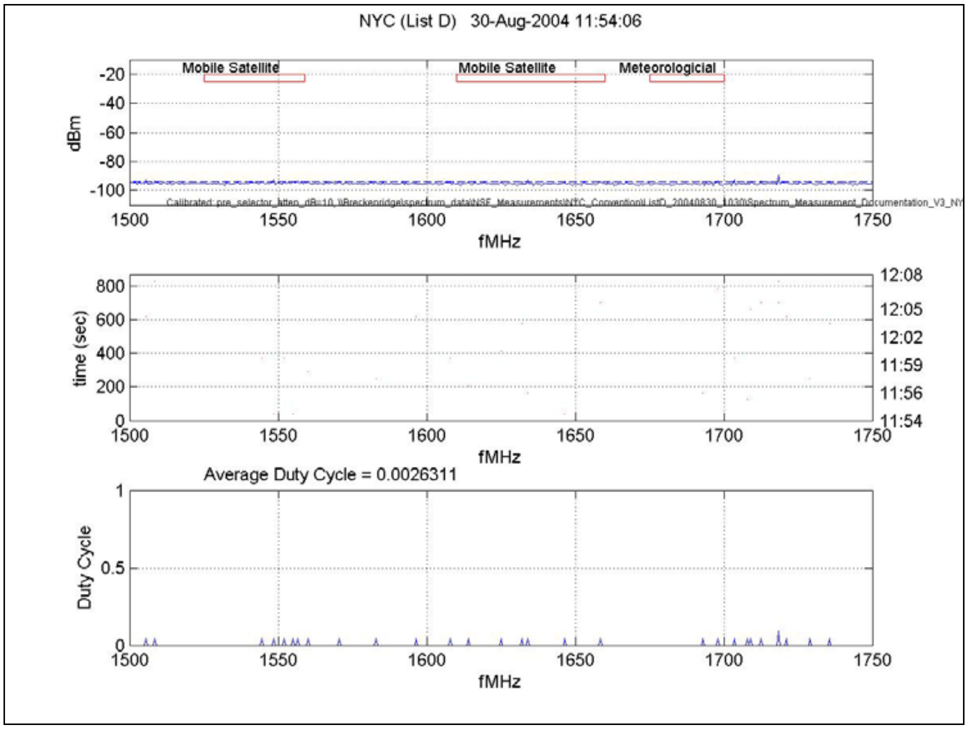

Figure 162: Large Signal Data, 1500 MHz – 1750 MHz

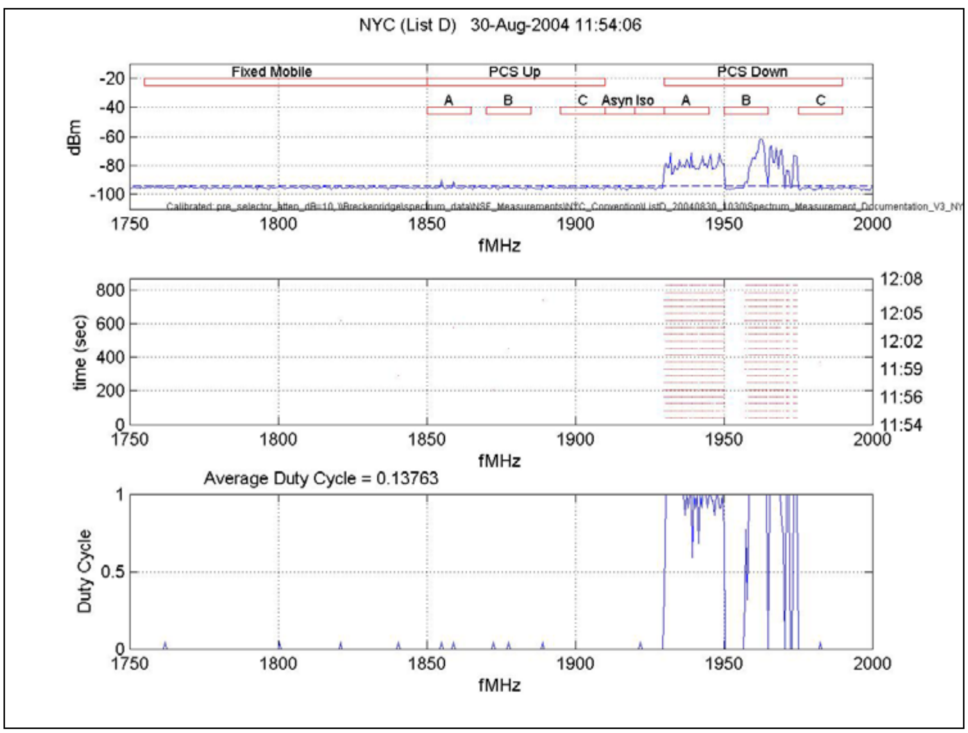

Figure 163: Large Signal Data, 1750 MHz – 2000 MHz

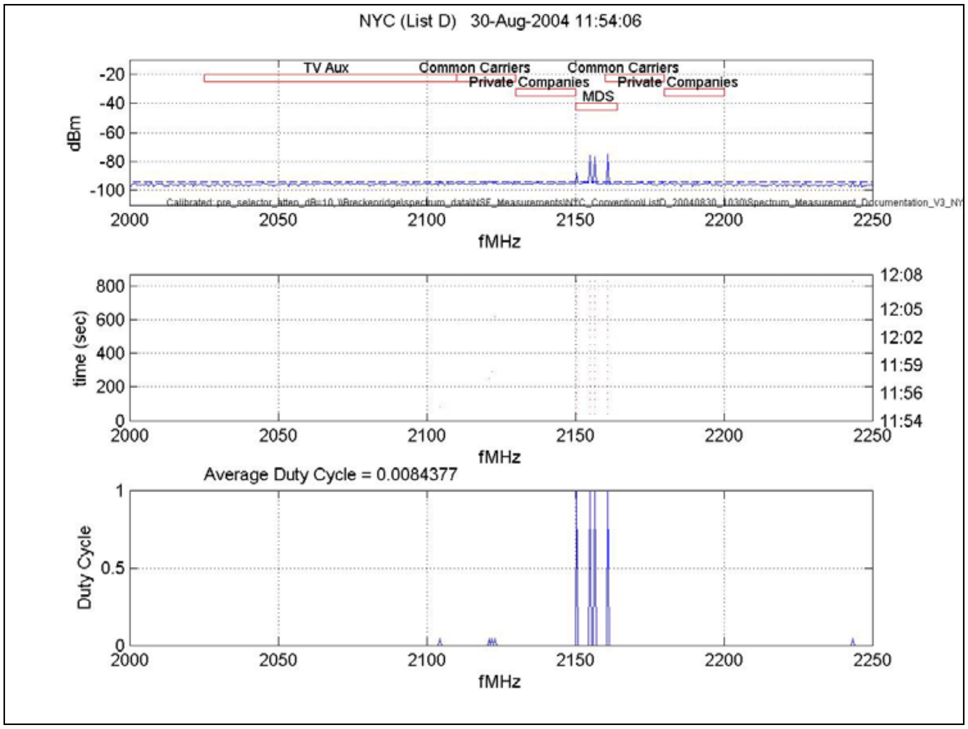

Figure 164: Large Signal Data, 2000 MHz – 2250 MHz

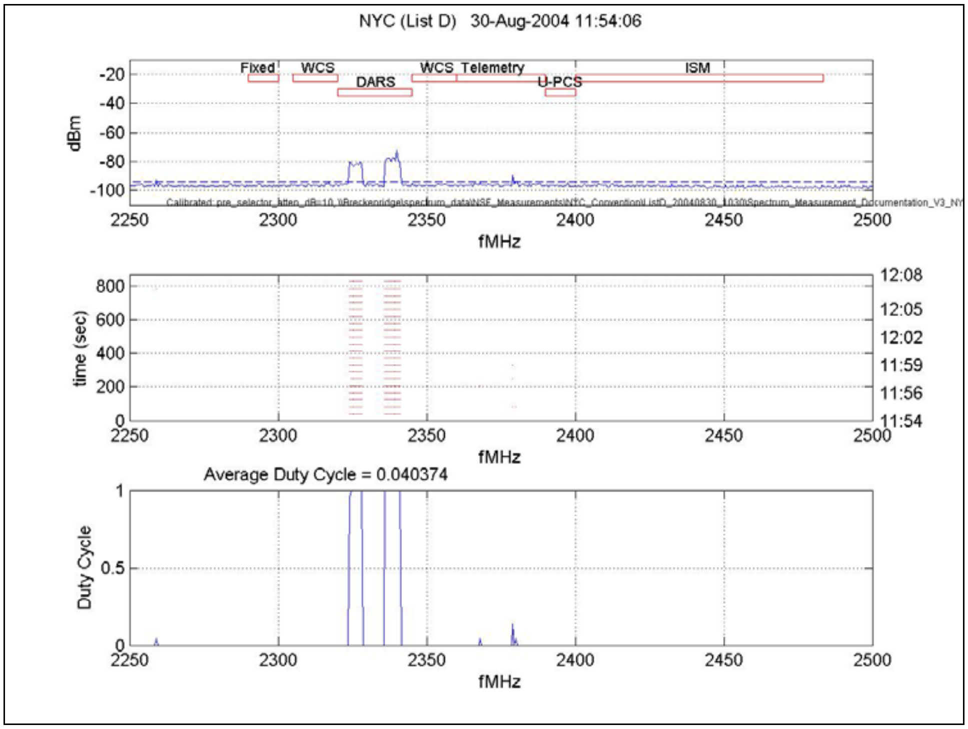

Figure 165: Large Signal Data, 2250 MHz – 2500 MHz

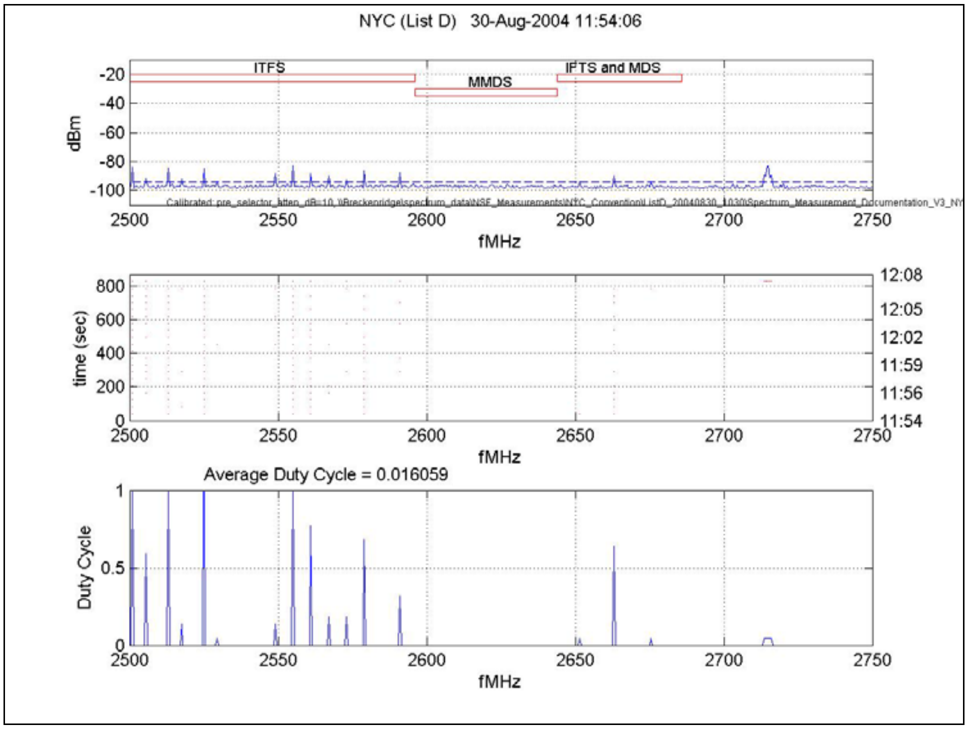

Figure 166: Large Signal Data, 2500 MHz – 2750MHz

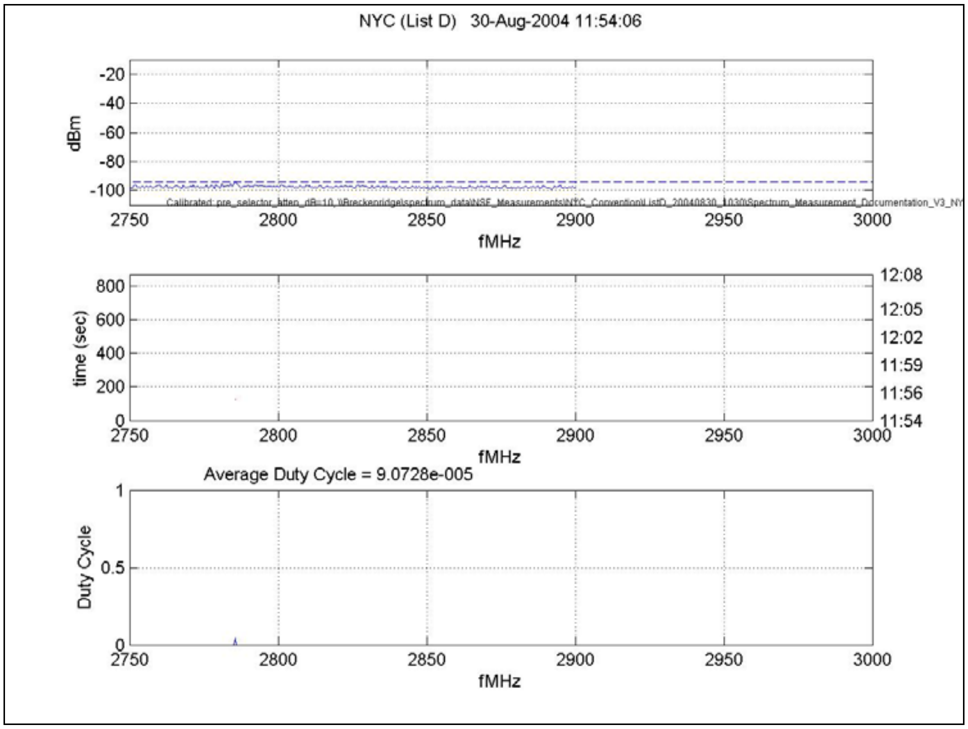

Figure 167: Large Signal Data, 2750 MHz – 3000 MHz

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

Start Freq (MHz)	Stop Freq (MHz)	Bandwidth (MHz)	Spectrum Band Allocation	NYC Day 1	NYC Day 2	NYC Average	NYC Occupied Spectrum (MHz)	Percent Occupied
30	54	24	PLM, Amateur, others	0.04300	0.06250	0.05275	1.27	5.3%
54	88	34	TV 2 -6, RC	0.52830	0.52080	0.52455	17.83	52.5%
108	138	30	Air traffic Control, Aero Nav	0.05270	0.04030	0.04650	1.40	4.7%
138	174	36	Fixed Mobile, amateur, others	0.17080	0.16980	0.17030	6.13	17.0%
174	216	42	TV 7-13	0.77730	0.77950	0.77840	32.69	77.8%
216	225	9	Maritime Mobile, Amateur, others	0.05860	0.05950	0.05905	0.53	5.9%
225	406	181	Fixed Mobile, Aero, others	0.00530	0.00370	0.00450	0.81	0.5%
406	470	64	Amateur, Radio Geolocation, Fixed, Mobile, Radiolocation	0.16610	0.14750	0.15680	10.04	15.7%
470	512	42	TV 14-20	0.21140	0.21000	0.21070	8.85	21.1%
512	608	96	TV 21-36	0.35520	0.34270	0.34895	33.50	34.9%
608	698	90	TV 37-51	0.46160	0.46090	0.46125	41.51	46.1%
698	806	108	TV 52-69	0.29580	0.30790	0.30185	32.60	30.2%
806	902	96	Cell phone and SMR	0.46190	0.46450	0.46320	44.47	46.3%
902	928	26	Unlicensed	0.22270	0.23460	0.22865	5.94	22.9%
928	960	32	Paging, SMS, Fixed, BX Aux, and FMS	0.23640	0.24370	0.24005	7.68	24.0%
960	1240	280	IFF, TACAN, GPS, others	0.03560	0.04080	0.03820	10.70	3.8%
1240	1300	60	Amateur	0.00030	0.00010	0.00020	0.01	0.0%
1300	1400	100	Aero Radar, military	0.02160	0.00130	0.01145	1.15	1.1%
1400	1525	125	Space/Satellite, Fixed Mobile, Telemetry	0.01520	0.00050	0.00785	0.98	0.8%
1525	1710	185	Mobile Satellite, GPS L1, Mobile Satellite, Meteorologicial	0.00240	0.00130	0.00185	0.34	0.2%
1710	1850	140	Fixed, Fixed Mobile	0.02350	0.02540	0.02445	3.42	2.4%
1850	1990	140	PCS, Asyn, Iso	0.33090	0.34430	0.33760	47.26	33.8%
1990	2110	120	TV Aux	0.01910	0.00820	0.01365	1.64	1.4%
2110	2200	90	Common Carriers, Private Companies, MDS	0.01820	0.01900	0.01860	1.67	1.9%
2200	2300	100	Space Operation, Fixed	0.05270	0.06180	0.05725	5.73	5.7%
2300	2360	60	Amateur, WCS, DARS	0.20220	0.20530	0.20375	12.23	20.4%
2360	2390	30	Telemetry	0.06200	0.06420	0.06310	1.89	6.3%
2390	2500	110	U-PCS, ISM (Unlicensed)	0.13470	0.15510	0.14490	15.94	14.5%
2500	2686	186	ITFS, MMDS	0.10430	0.10420	0.10425	19.39	10.4%
2686	2900	214	Surveillance Radar	0.02860	0.03090	0.02975	6.37	3.0%
Total		2850		0.0000	0.0000	0.0000	373.97	
Total Available Spectrum							2850	
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 over estimates the occupancy. Smaller frequency bins were not used in most of the measurements because of the greatly increased measurement time required.

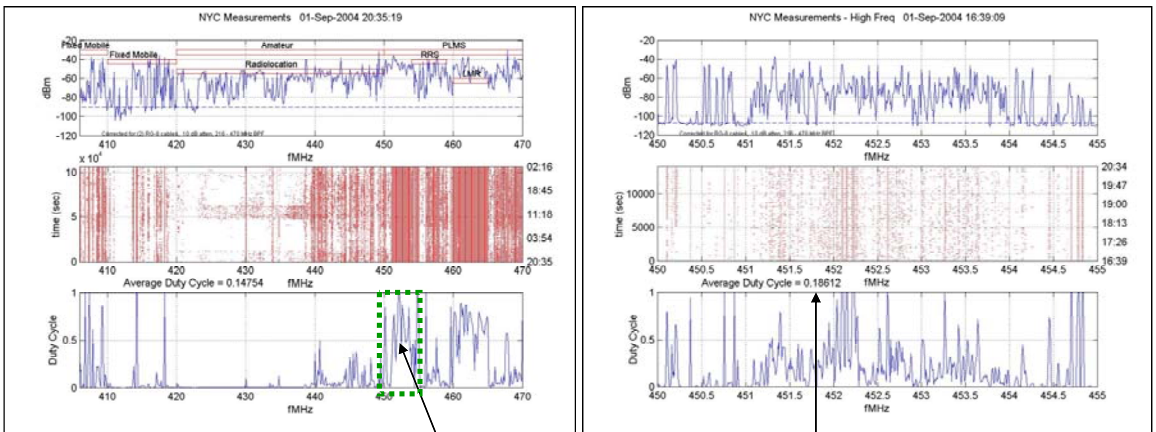

Figure 25: September 1 to September 3, 406 MHz – 470 MHz

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

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)

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.