Dublin Ireland
Spectrum Occupancy Measurements
Collected On April 16-18, 2007

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Table of Contents

List of Tables

List of Figures

1. Introduction

1.1 Summary

This document describes spectrum occupancy measurements performed by Shared Spectrum Company at the top of Commission for Communications Regulation Building in Dublin, Ireland from April 16 through April 18, 2007. Figure 1 shows a view from the measurement site.

Figure 1. View from the Measurement Site

1.2 Report Organization

This report is organized into four sections, as follows:

Section 1 Introduction
Section 2 Description of measurement equipment
Section 3 Plots showing measured spectrum occupancy for each band
Section 4 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 for spectrum from both public and private sectors is increasing very rapidly, if not exponentially. Increasingly, there is recognition that most of the spectrum is actually unused and that real root of the problem is that 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.

This document summarizes the results of the spectrum occupancy measurements taken in Dublin, Ireland. Shared Spectrum Company has taken spectrum occupancy measurements in different cities in USA before, but no measurements were taken in different countries up to now. The results in this document are of special interest since they provide a better understanding of the actual utilization of spectrum in a dense urban environment in a different country.

Occupancy was quantified as the amount of spectrum detected above a certain received signal power threshold. This metric doesn't capture all of the factors involved in spectrum use. But when applied consistently between different locations and between different bands, it provides a useful comparative metric.

2. Measurement Equipment

This section describes the spectrum occupancy measurement equipment.

2.1 Equipment Description

The equipment used for measurement in this study consisted of a spectrum analyzer, preselector, a low frequency discone antenna (Diamond D-130J), a high frequency discone antenna, and a laptop computer. The low frequency discone antenna was used to measure signals between 100 MHz and 1 GHz and the high frequency one to measure signals between 1 GHz and 3 GHz. An RG-8 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. A block diagram is shown in Figure 2.

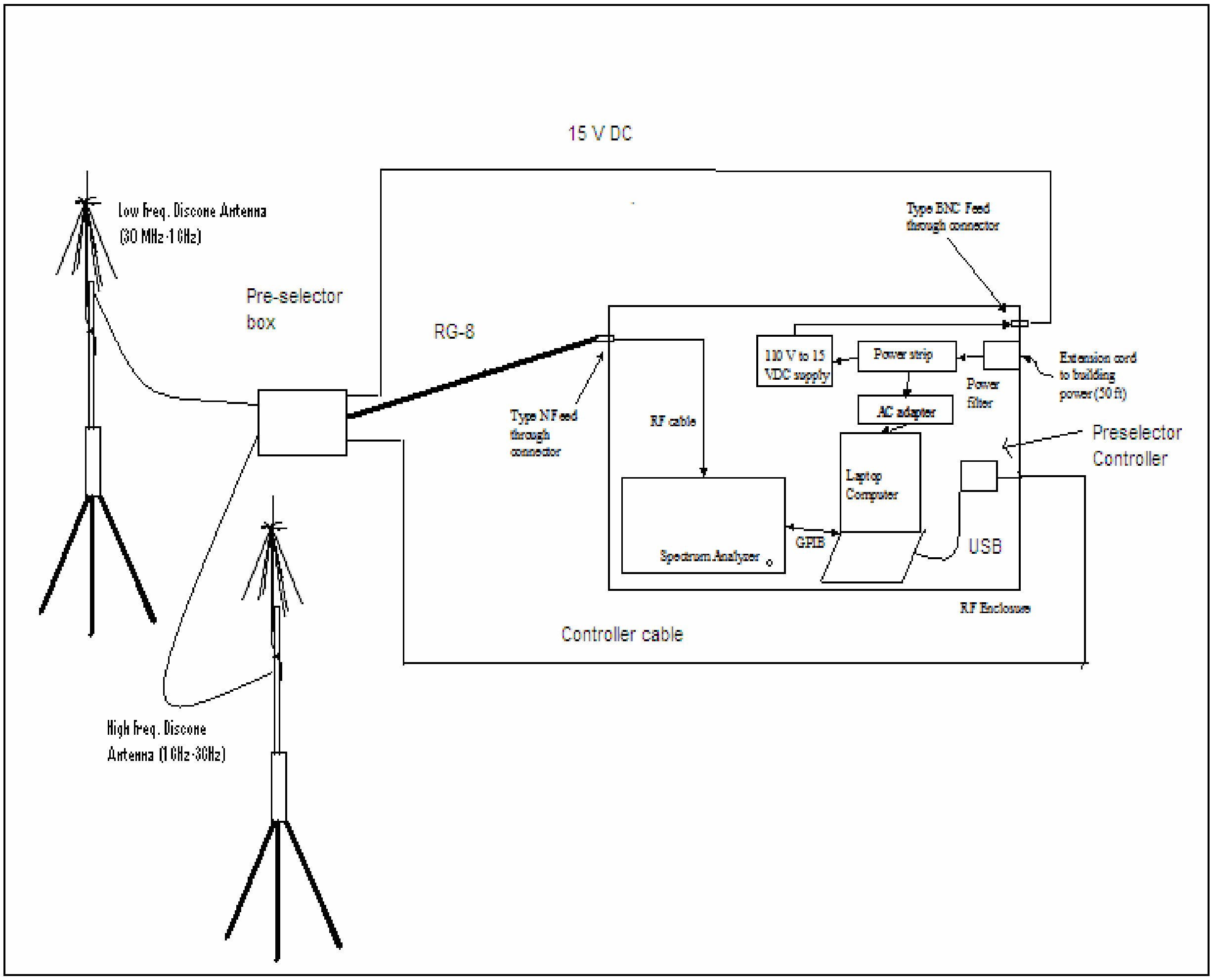

Figure 2. Spectrum Measurement Equipment Configuration

A photograph of the discone antennas used for the measurements is in Figure 3.

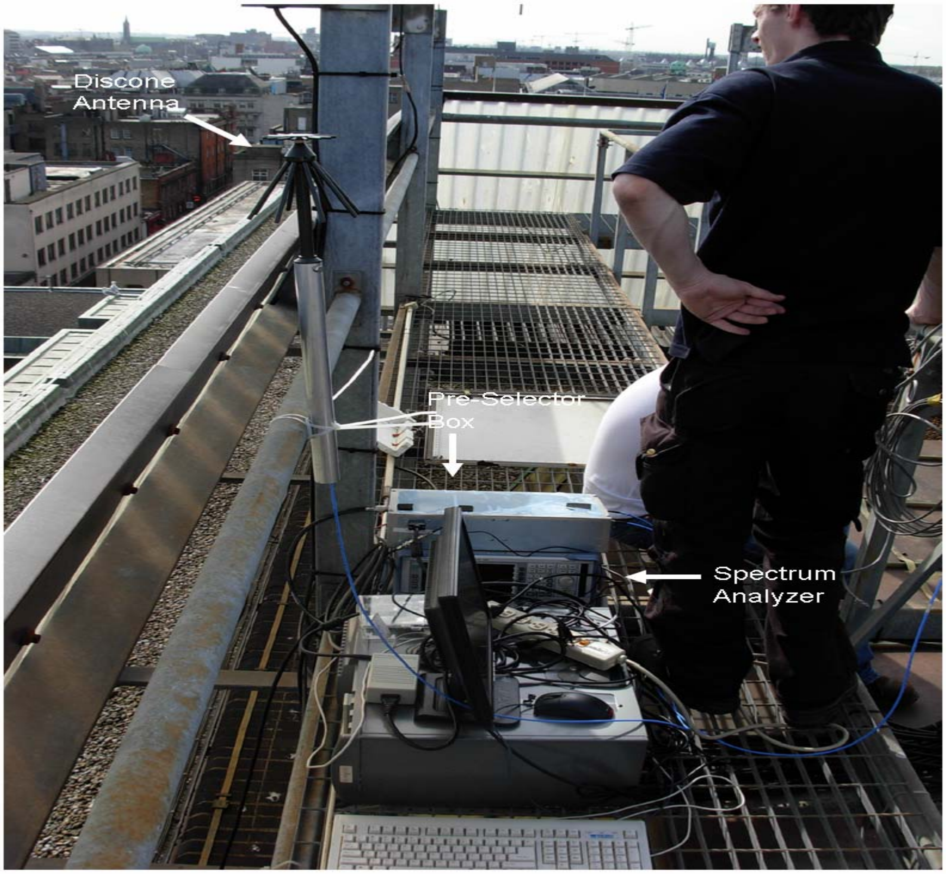

Figure 3. Low Frequency Discone Antenna Used for the Measurements

Figure 4 shows the high frequency antenna used for the measurements. The LPA antennas shown in the figure are not part of our test equipment and they did not affect the results of the measurements.

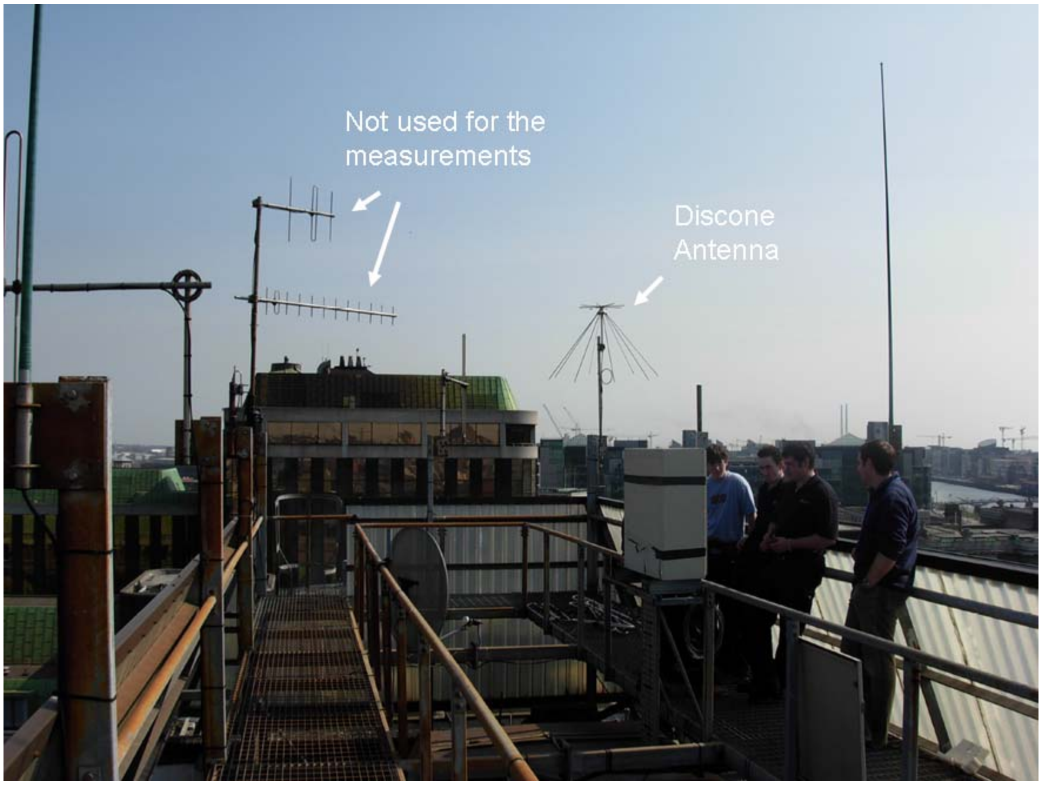

Figure 4. High Frequency Discone Antenna for the Measurements

Before each measurement was taken at the site, test data was collected. 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. Then the spectrum analyzer reference level, the spectrum analyzer RF attenuation and the spectrum analyzer pre-selection (on or off) were varied in each band to optimize sensitivity.

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.

Long duration measurements began on April 16, 2007 and ended on April 18, 2007. Day 1 of the study took place over a 24-hour data-collection period from April 16 through April 17. Day 2 took place over a second 18-hour collection period from April 17 through April 18.

2.2 Pre-Selector Description

The Pre-selector configuration is illustrated in the block diagram shown in Figure 5 below.

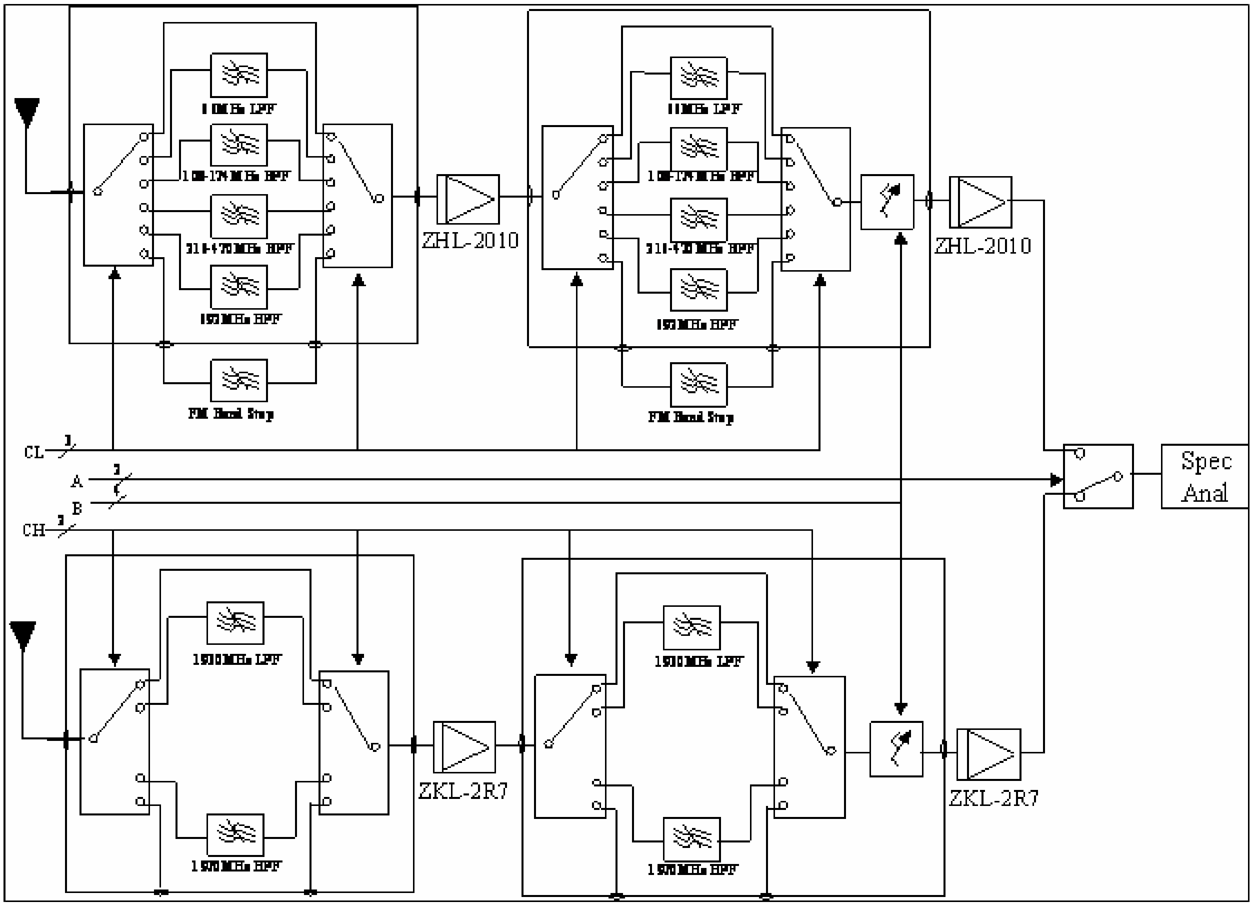

Figure 5. Pre-Selector Block Diagram

As illustrated in

Figure 5, 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

Start Frequency (MHz)	Stop Frequency (MHz)	Spectrum Analyzer				
		RBW (kHz)	VBW (kHz)	Attenuation (dB)	Ref Level (dBm)	Pre-selector (on/off)
30	54	10000	10000	10	-10	1
54	88	10000	10000	30	10	1
108	138	10000	10000	20	5	1
138	174	10000	10000	30	10	1
174	216	10000	10000	30	10	1
216	225	10000	10000	20	5	1
225	406	10000	10000	30	10	1
406	470	10000	10000	30	10	1
470	512	10000	10000	20	5	1
512	608	10000	10000	20	0	1
608	698	10000	10000	20	-10	1
698	806	10000	10000	20	-10	1
806	902	10000	10000	30	10	1
902	928	10000	10000	30	10	1
928	1000	10000	10000	30	10	1
1000	1240	10000	10000	10	-20	0
1240	1300	10000	10000	10	-20	0
1300	1400	10000	10000	10	-20	0
1400	1525	10000	10000	10	-20	0
1525	1710	10000	10000	10	-10	0
1710	1850	10000	10000	20	5	0
1850	1990	10000	10000	20	5	0
1990	2110	10000	10000	10	0	0
2110	2200	10000	10000	10	0	0
2200	2300	10000	10000	10	-20	0
2300	2360	10000	10000	10	-20	0
2360	2390	10000	10000	10	-20	0
2390	2500	10000	10000	10	-20	0
2500	2686	10000	10000	10	-20	0
2686	2900	10000	10000	10	-20	0
2900	3000	10000	10000	10	-20	0

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. Spectrum Occupancy Measurements

This section contains plots of the spectrum occupancy measurements.

3.1 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 and stop times.

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.

3.2 Measurements Made Below 1,000 MHz

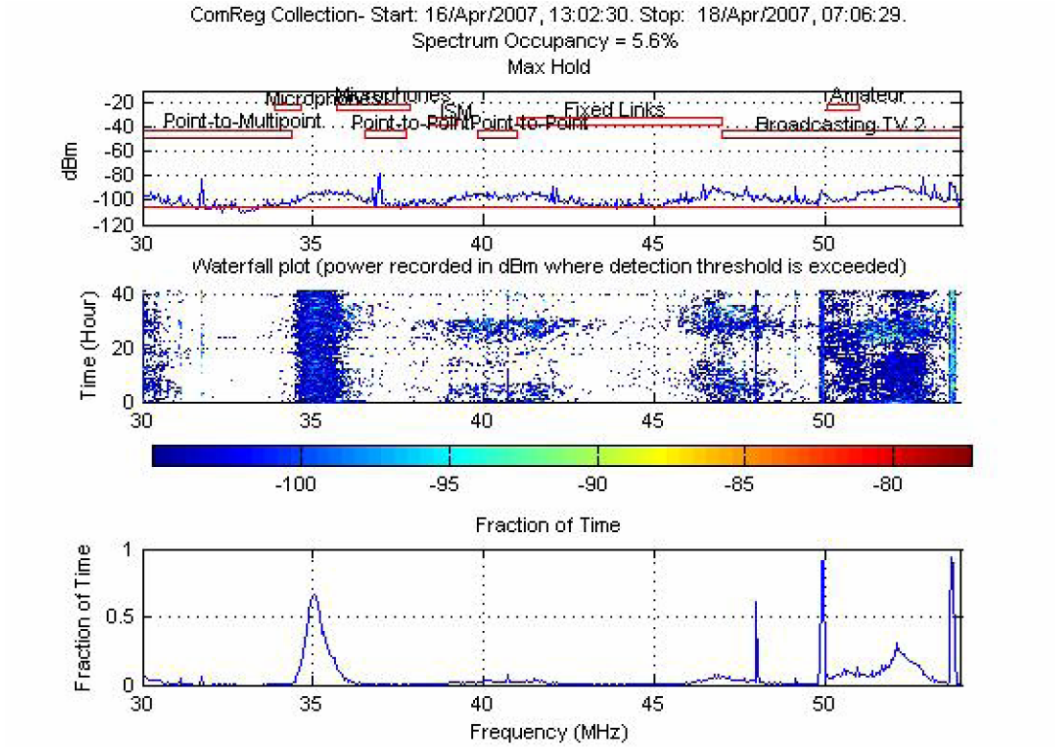

Figure 6. 30 MHz to 54 MHz

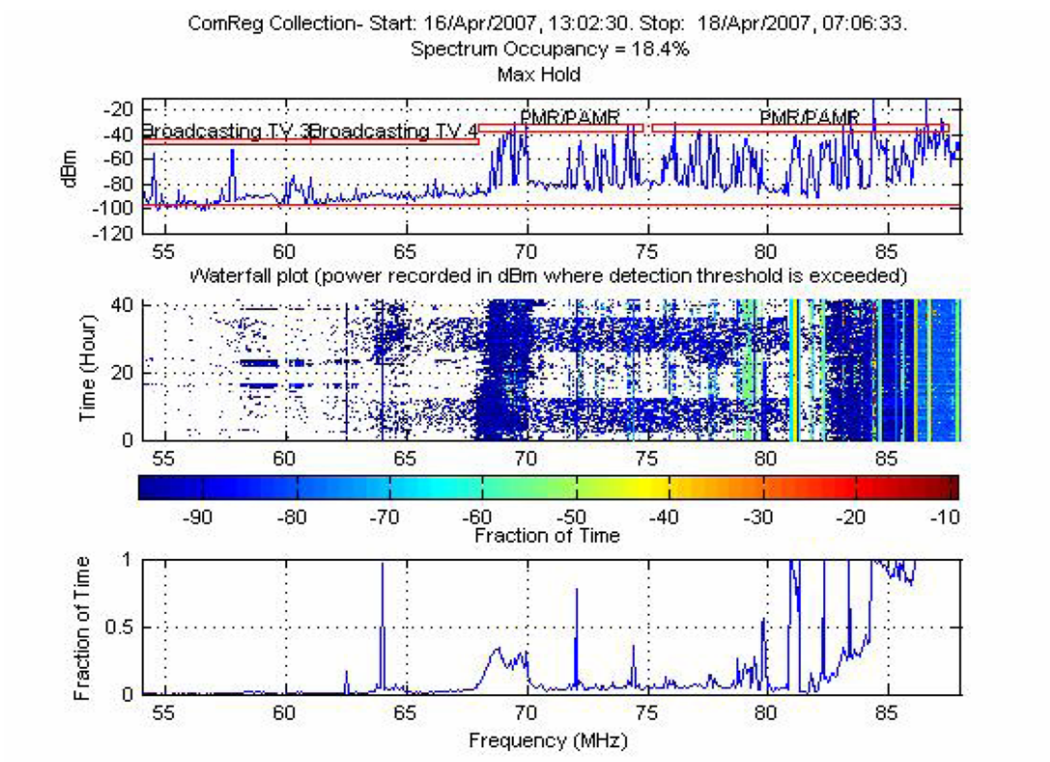

Figure 7. 54 MHz to 88 MHz

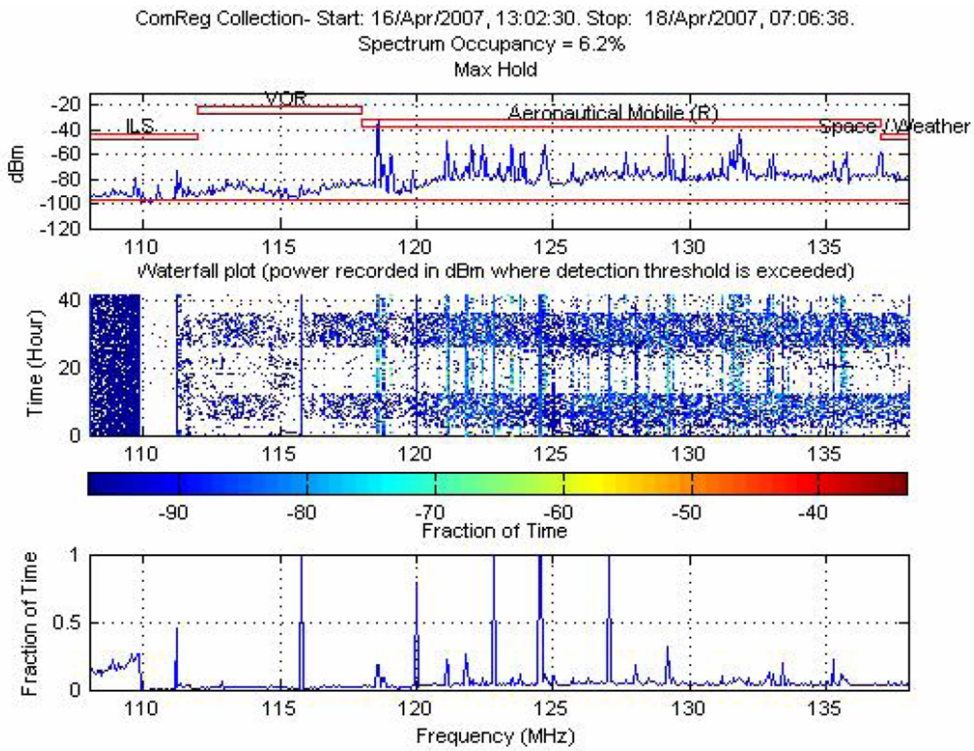

Figure 8. 108 MHz to 138 MHz

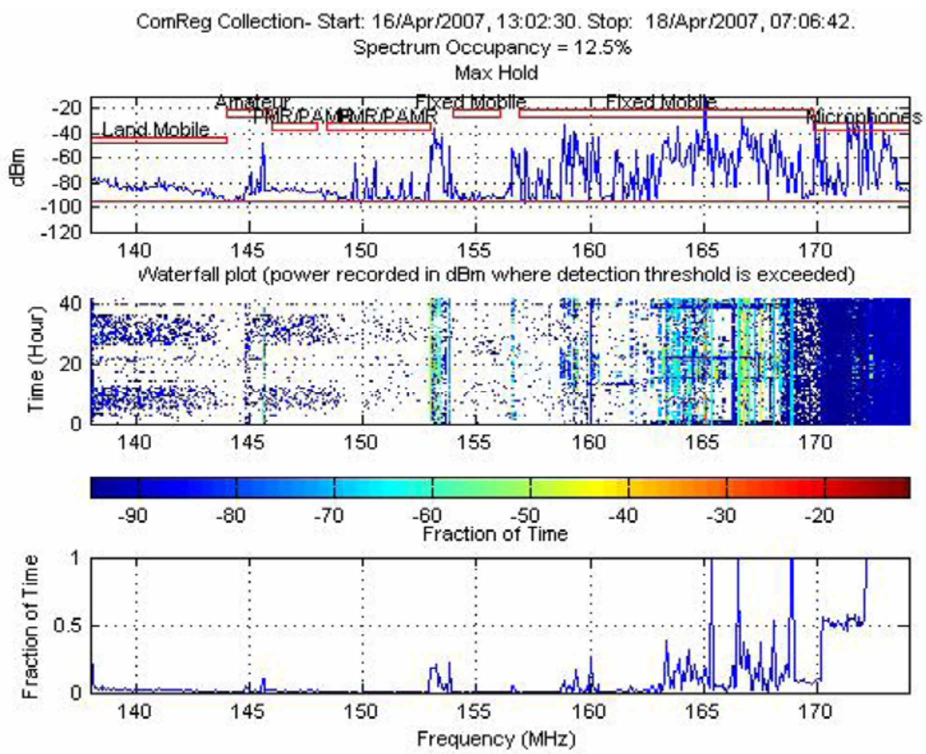

Figure 9. 138 MHz to 174 MHz

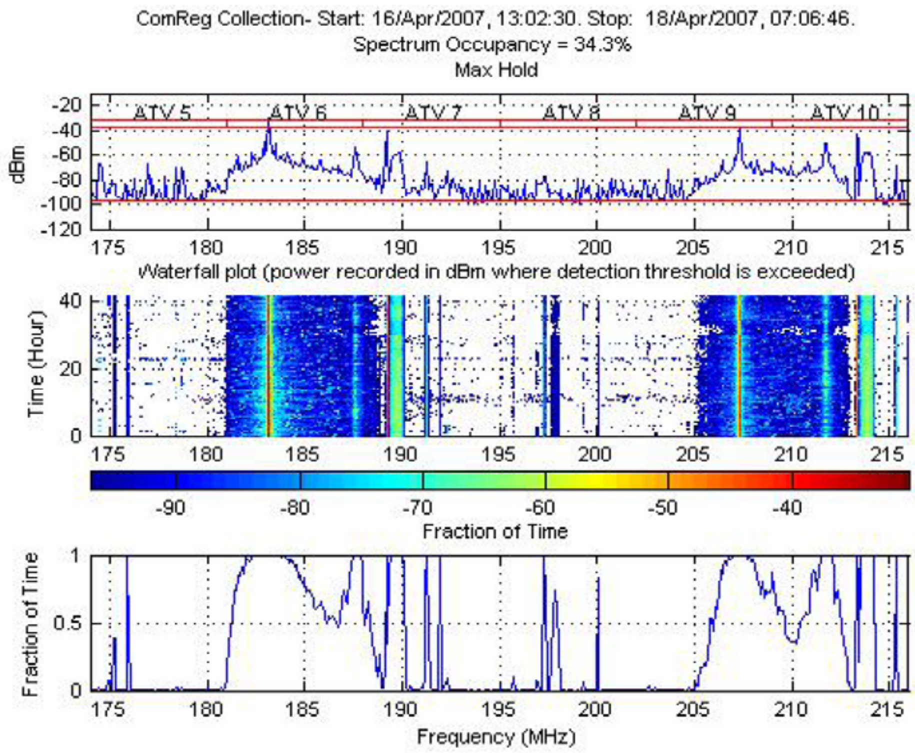

Figure 10. 174 MHz to 216 MHz

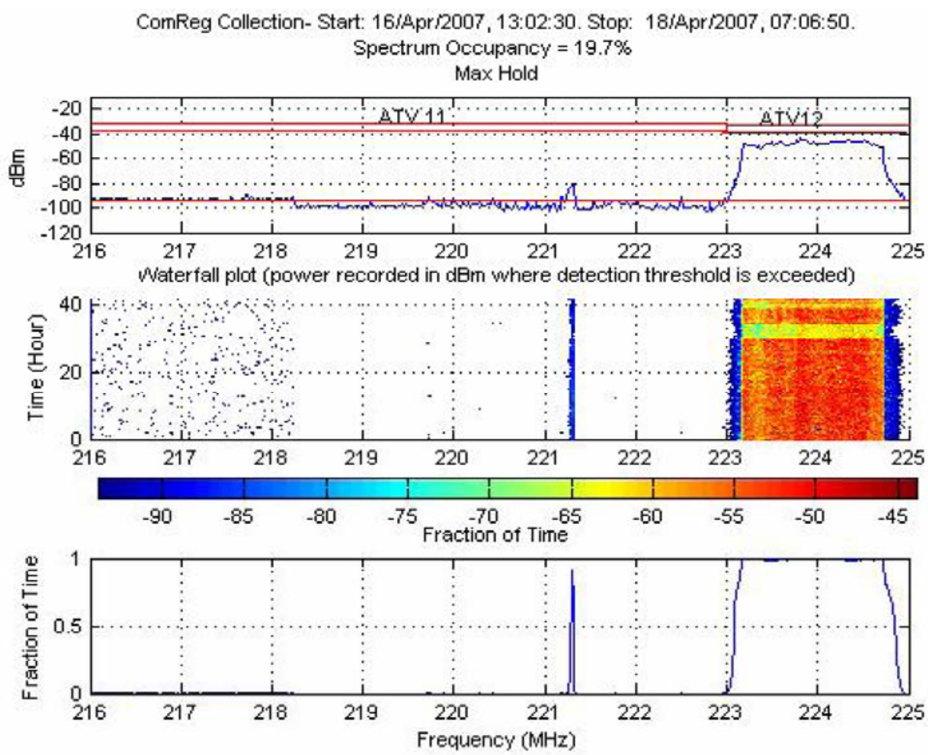

Figure 11. 216 MHz to 225 MHz

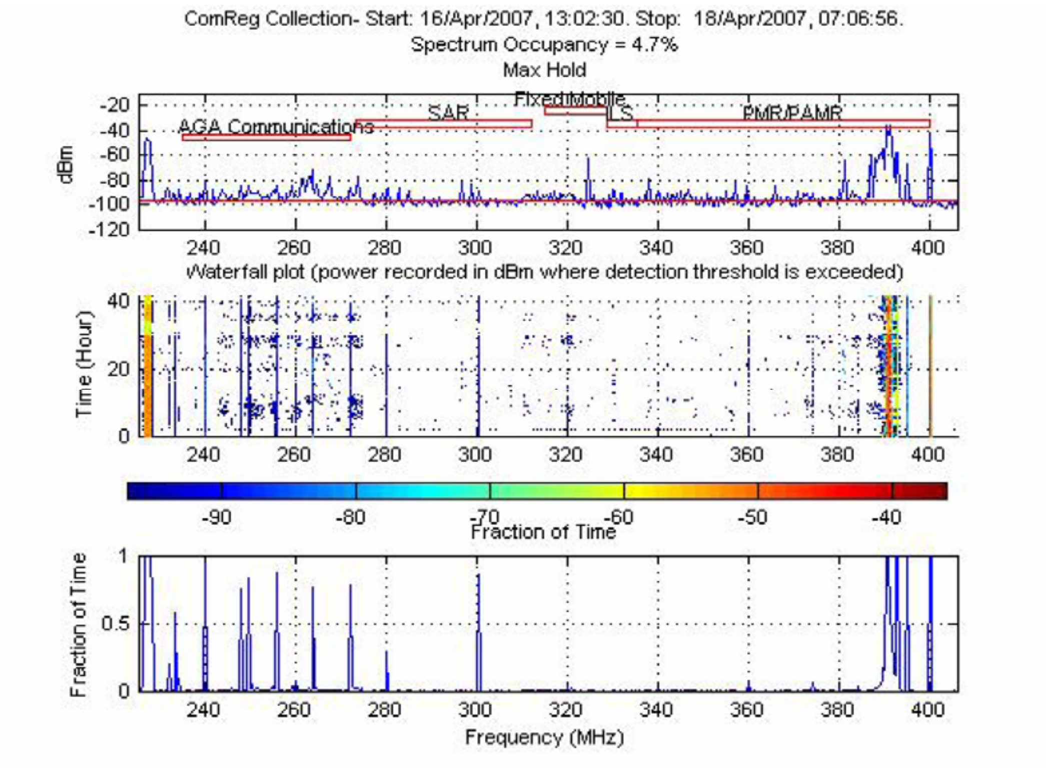

Figure 12. 225 MHz to 406 MHz

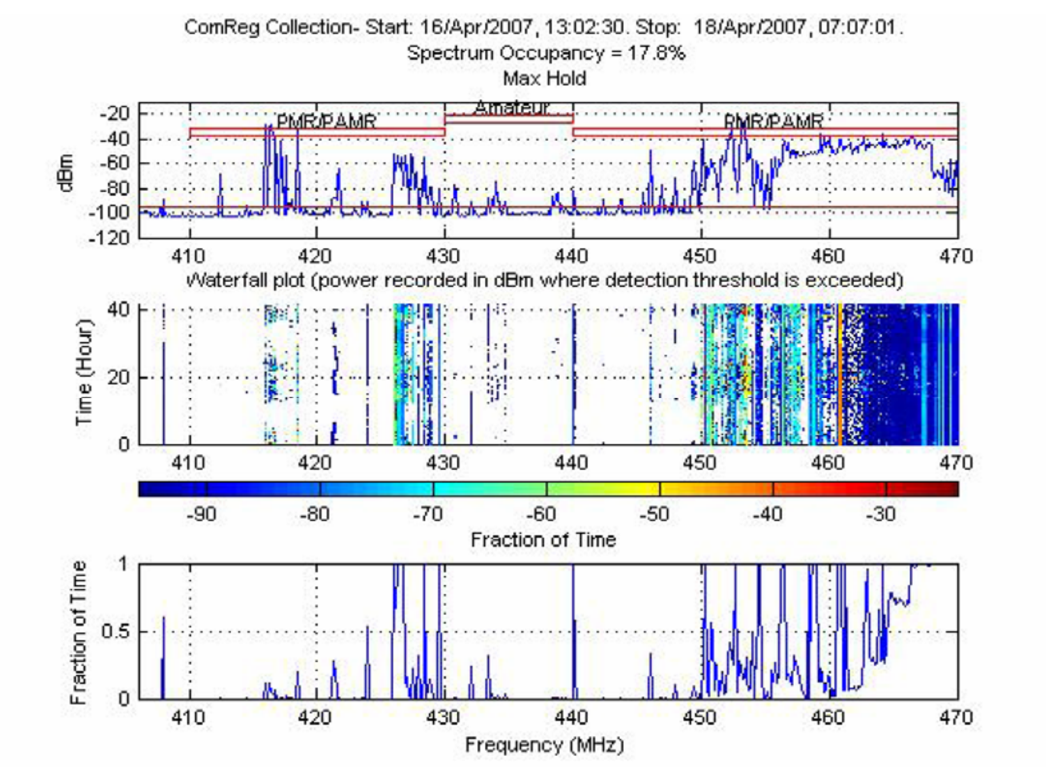

Figure 13. 406 MHz to 470 MHz

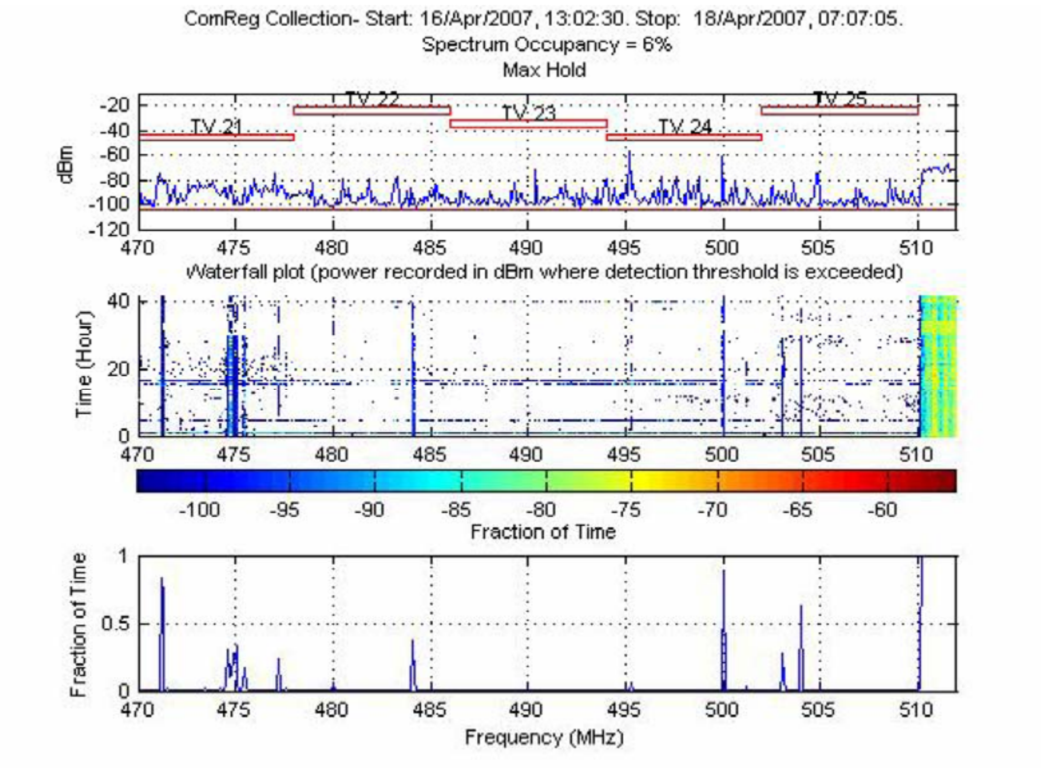

Figure 14. 470 MHz to 512 MHz

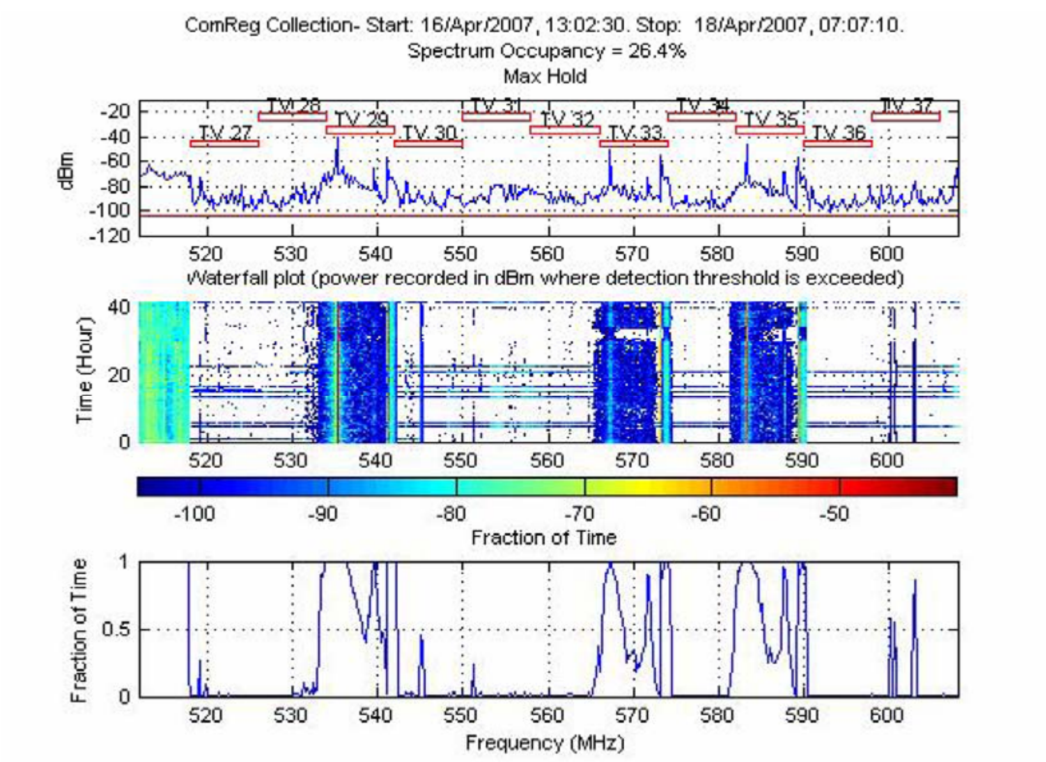

Figure 15. 512 MHz to 608 MHz

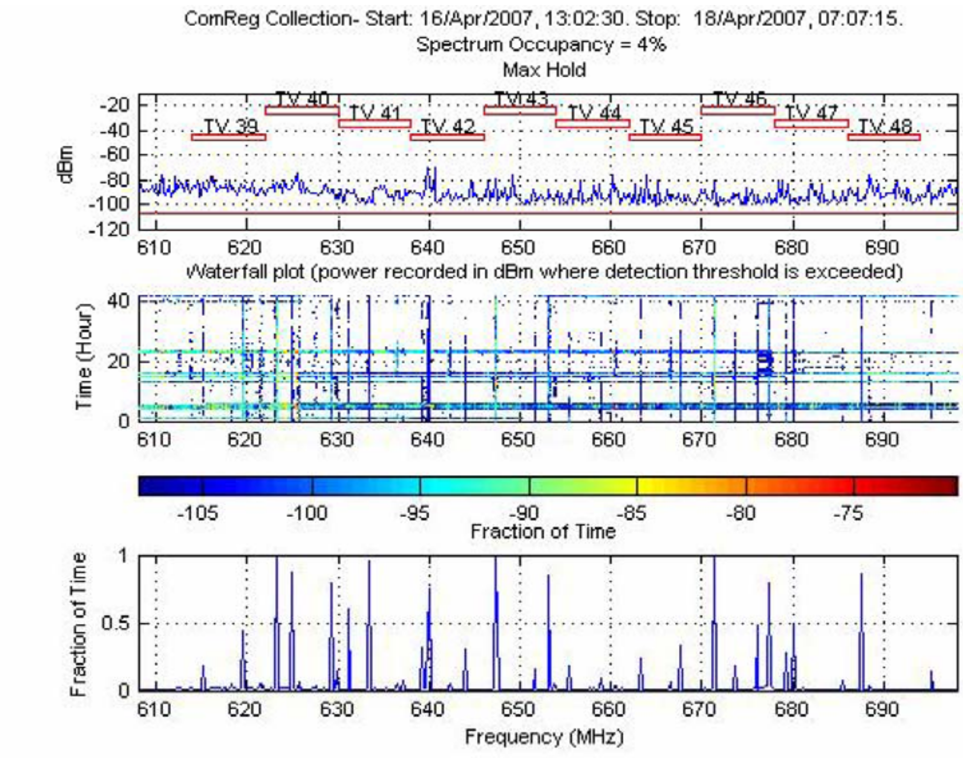

Figure 16. 608 MHz to 698 MHz

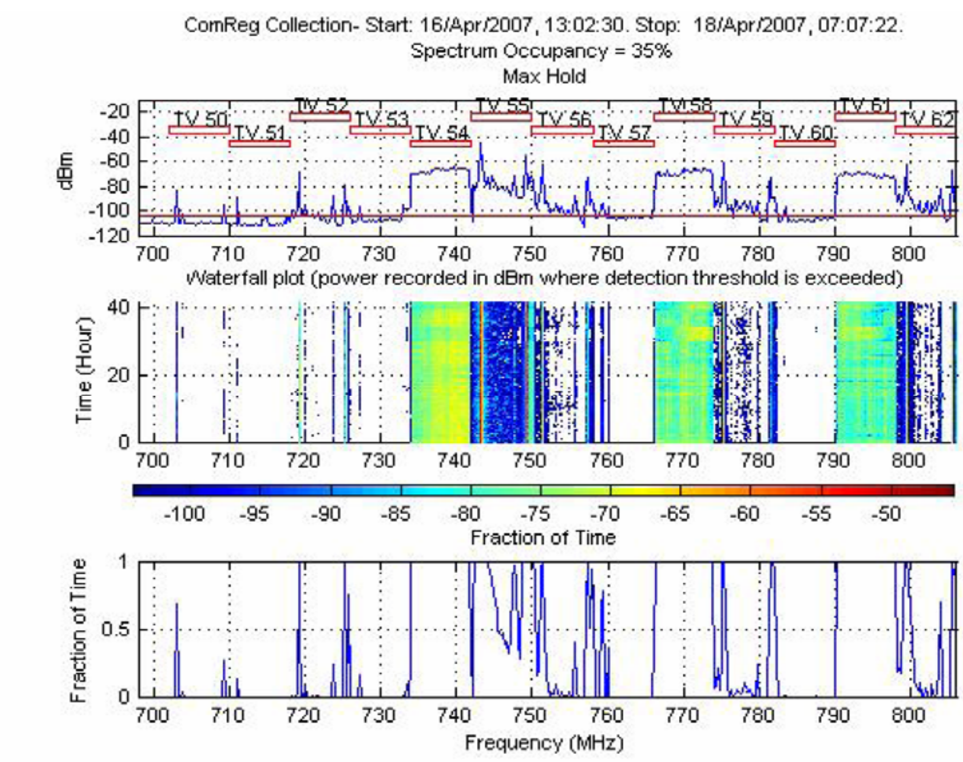

Figure 17. 698 MHz to 806 MHz

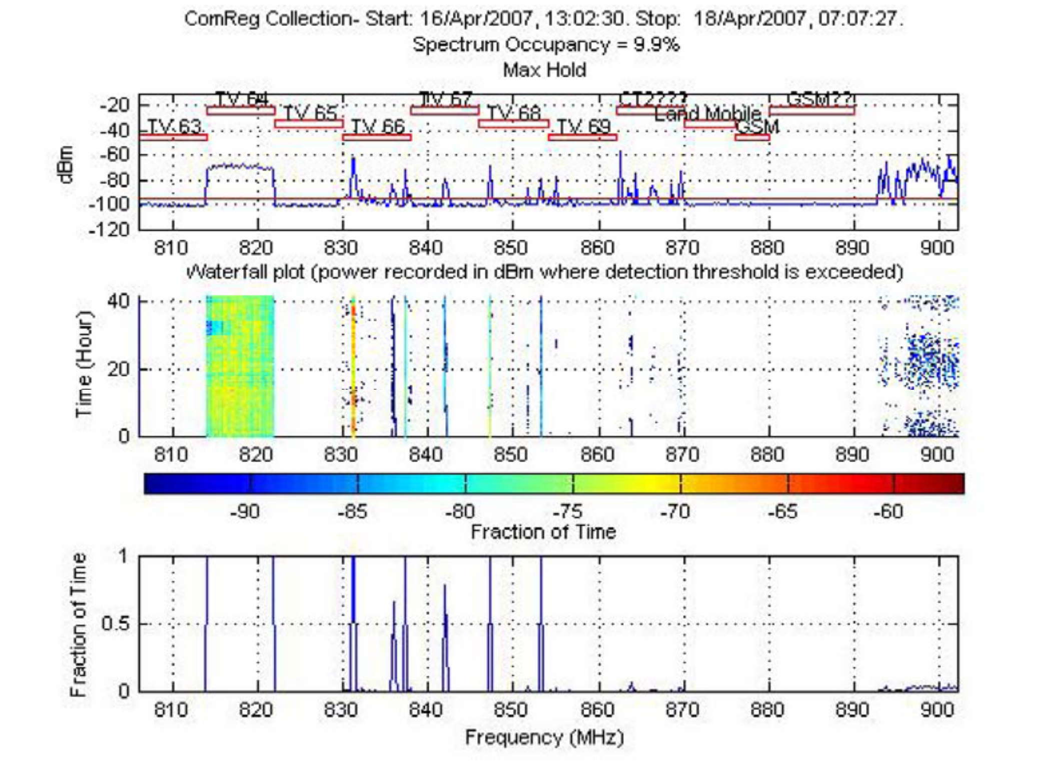

Figure 18. 806 MHz to 902 MHz

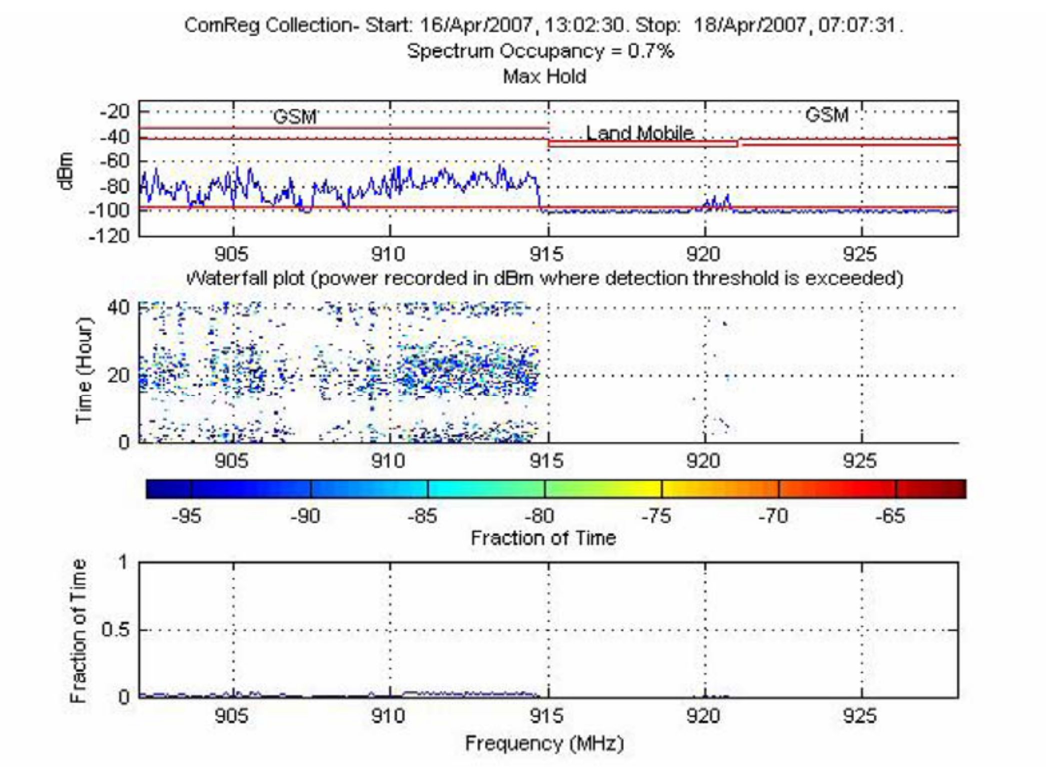

Figure 19. 902 MHz to 928 MHz

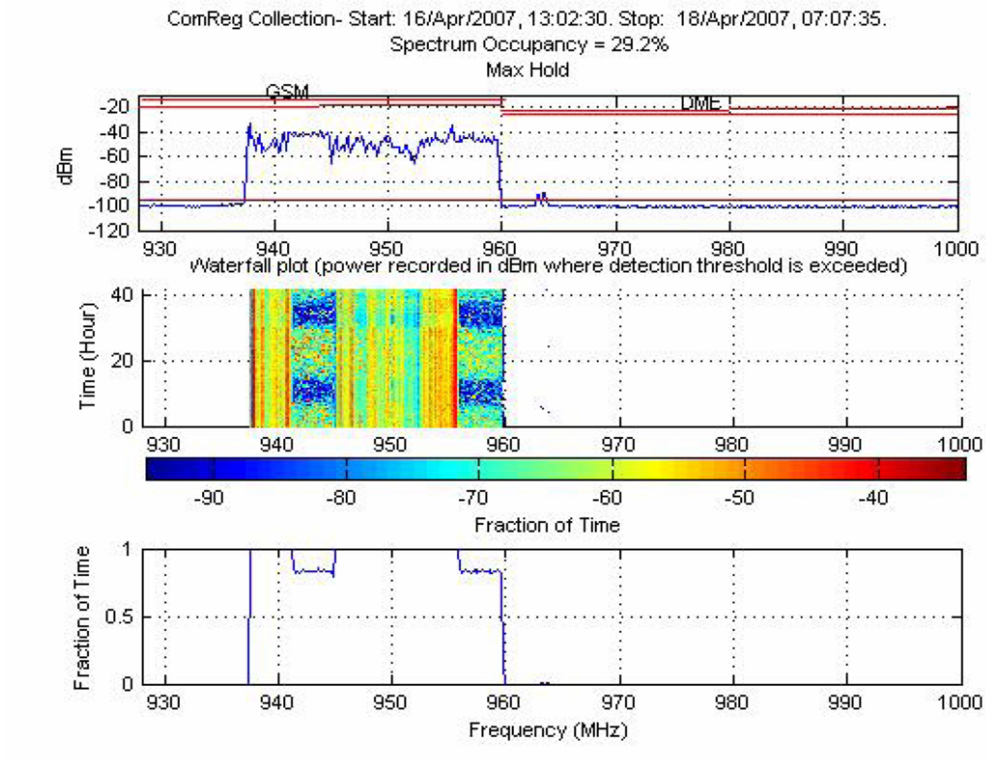

Figure 20. 928 MHz to 1000 MHz

3.3 Measurements Made Above 1,000 MHz

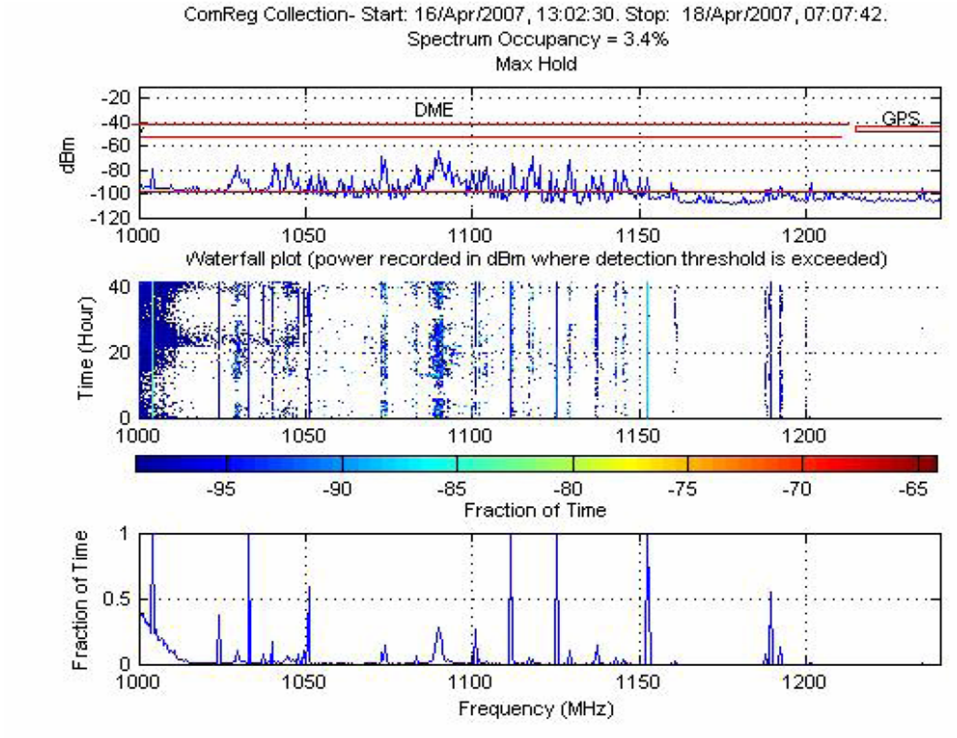

Figure 21. 1000 MHz to 1240 MHz

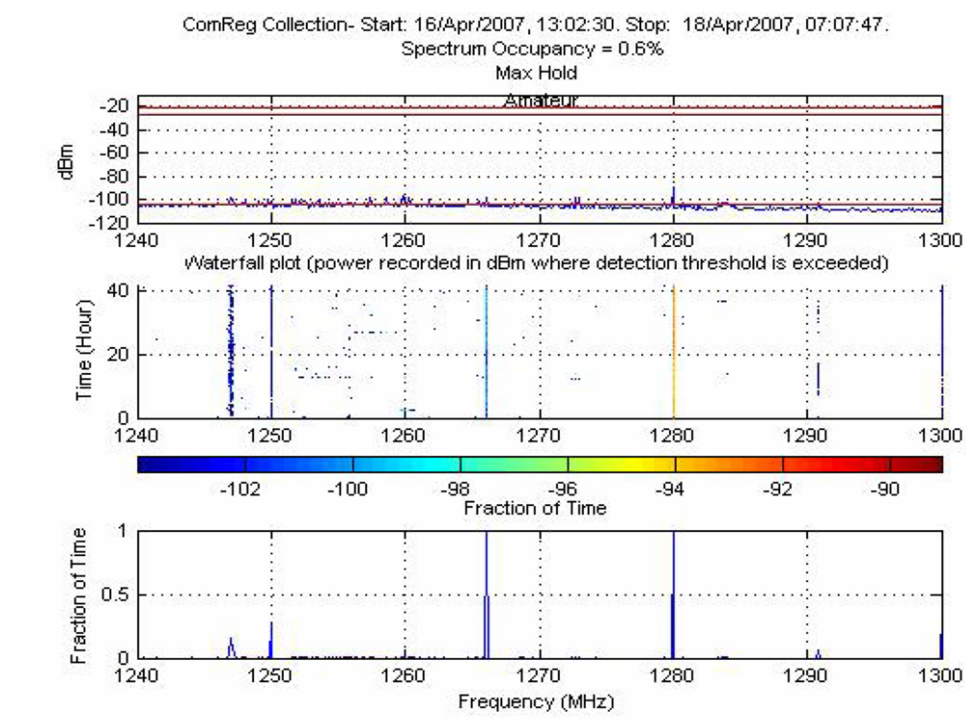

Figure 22. 1240 MHz to 1300 MHz

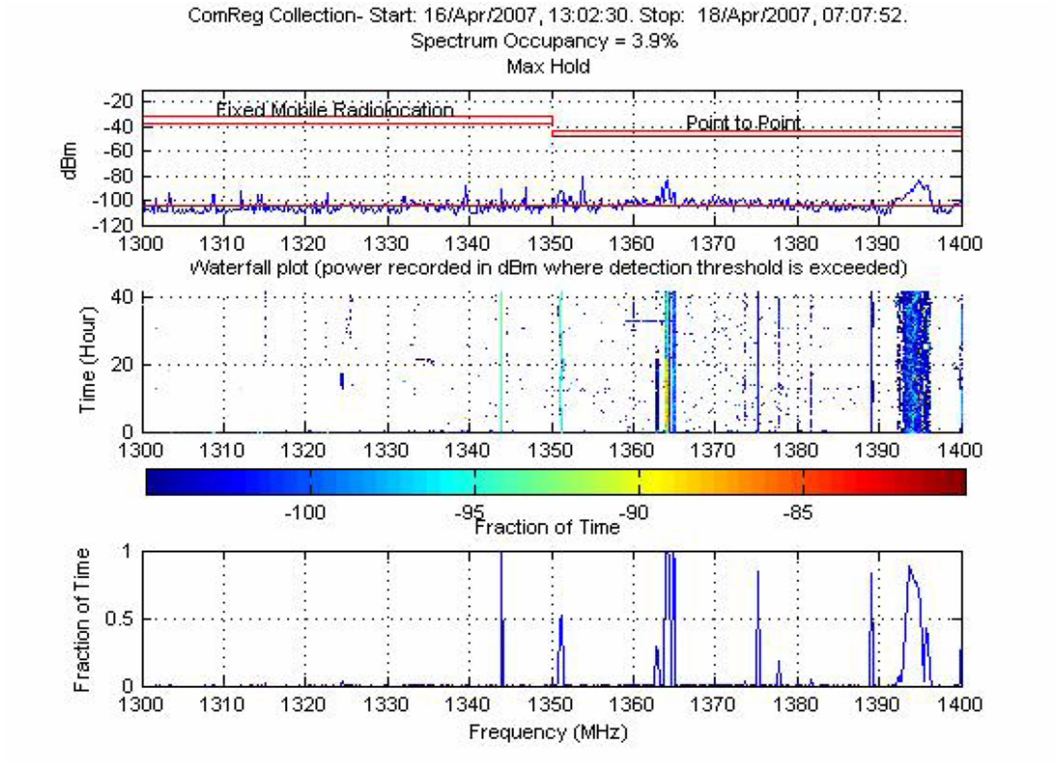

Figure 23. 1300 MHz to 1400 MHz

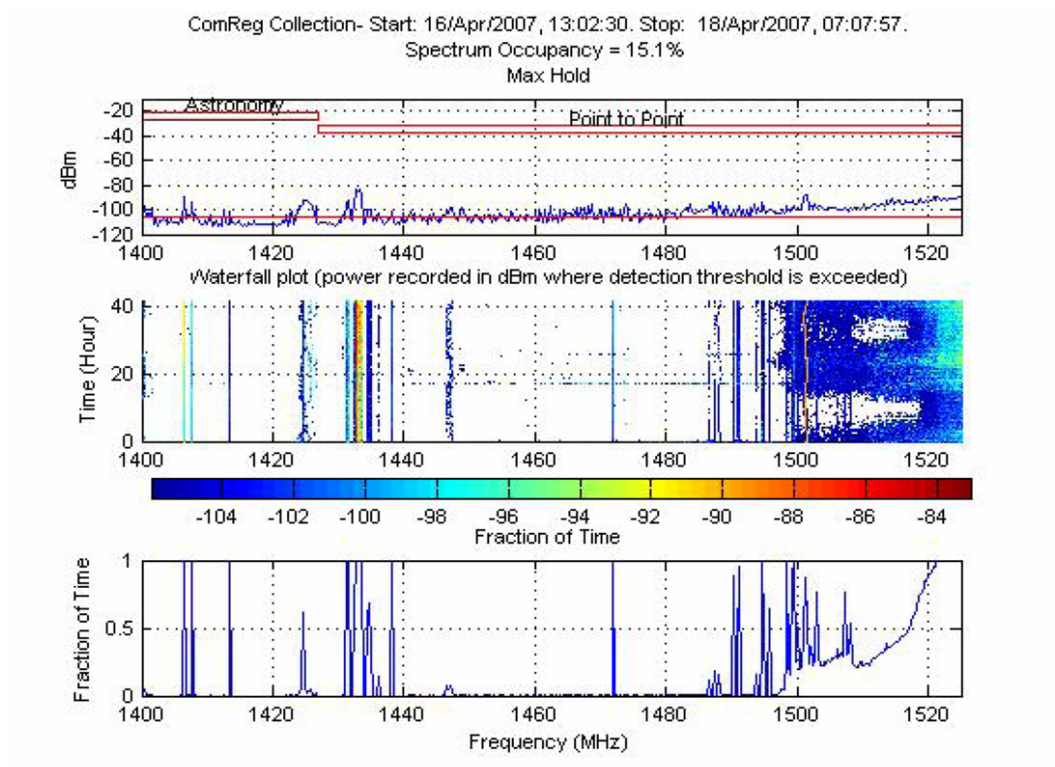

Figure 24. 1400 MHz to 1525 MHz

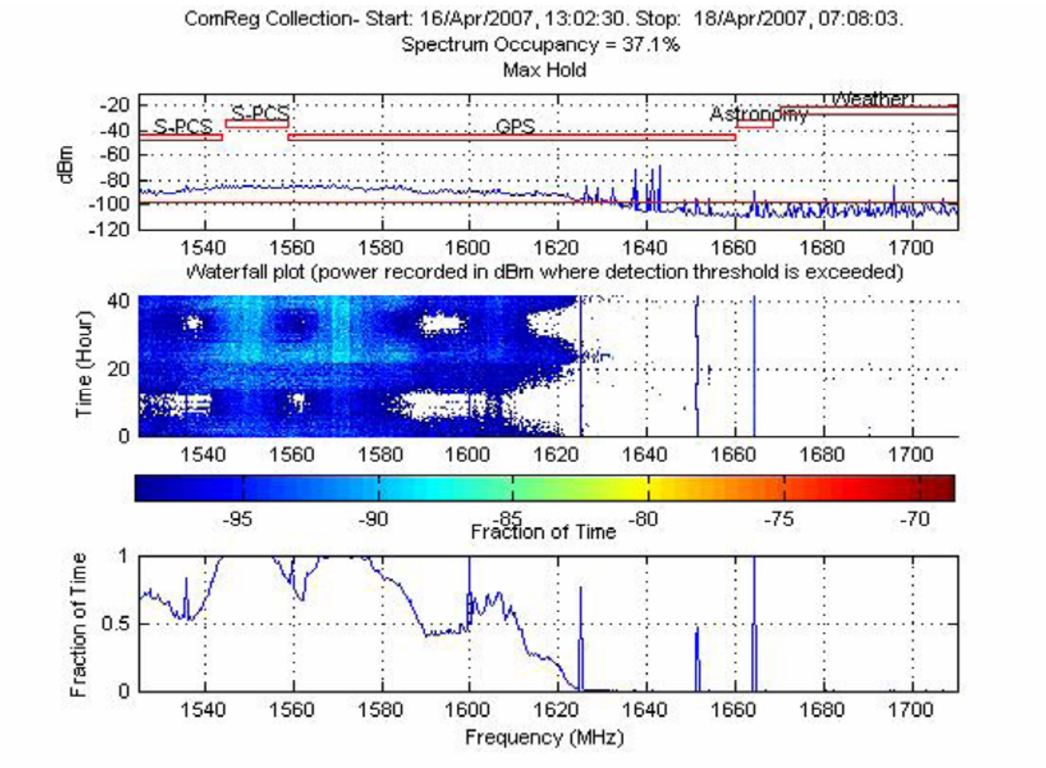

Figure 25. 1525 MHz to 1710 MHz

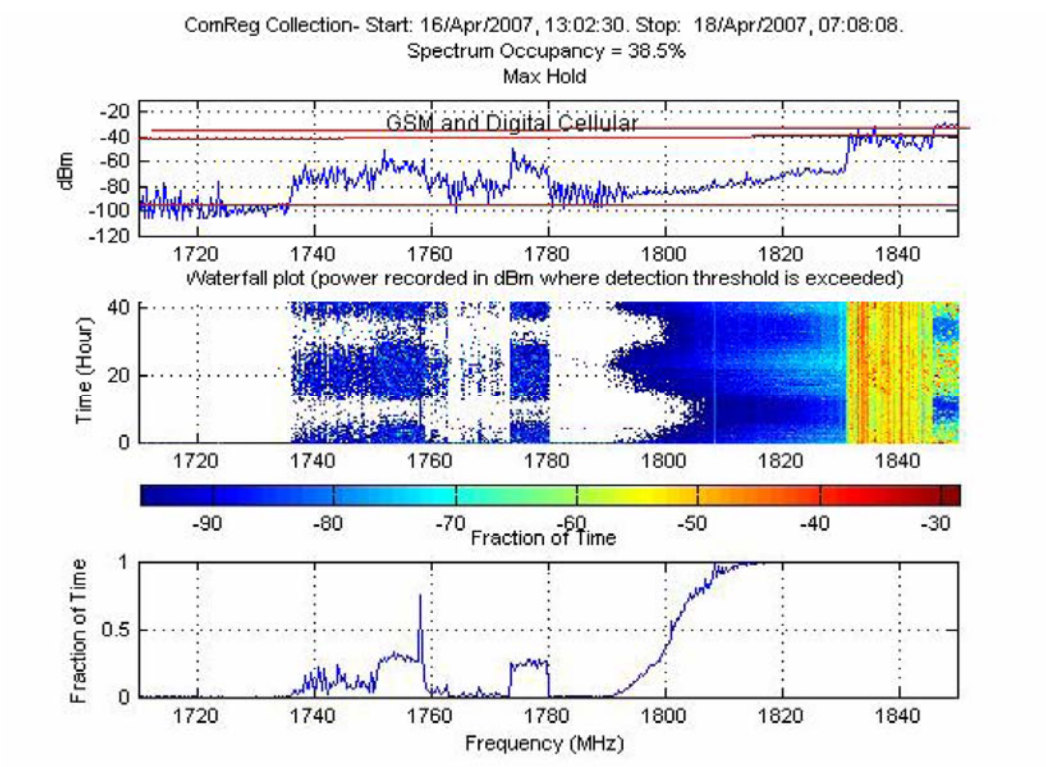

Figure 26. 1710 MHz to 1850 MHz

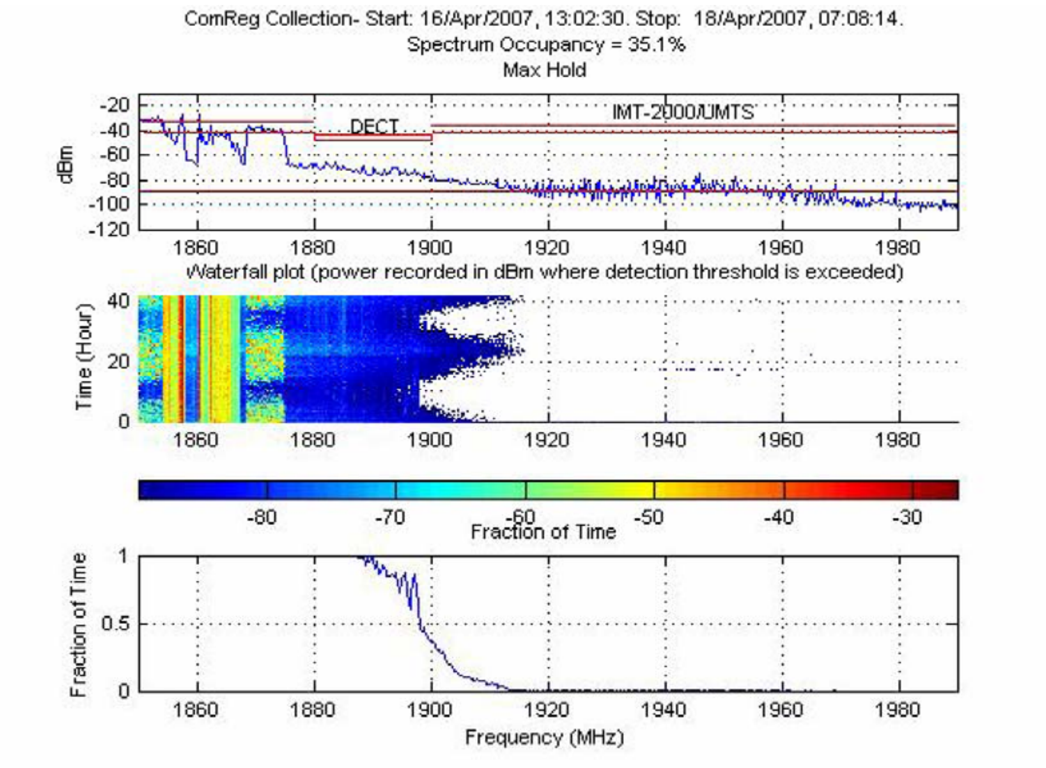

Figure 27. 1850 MHz to 1990 MHz

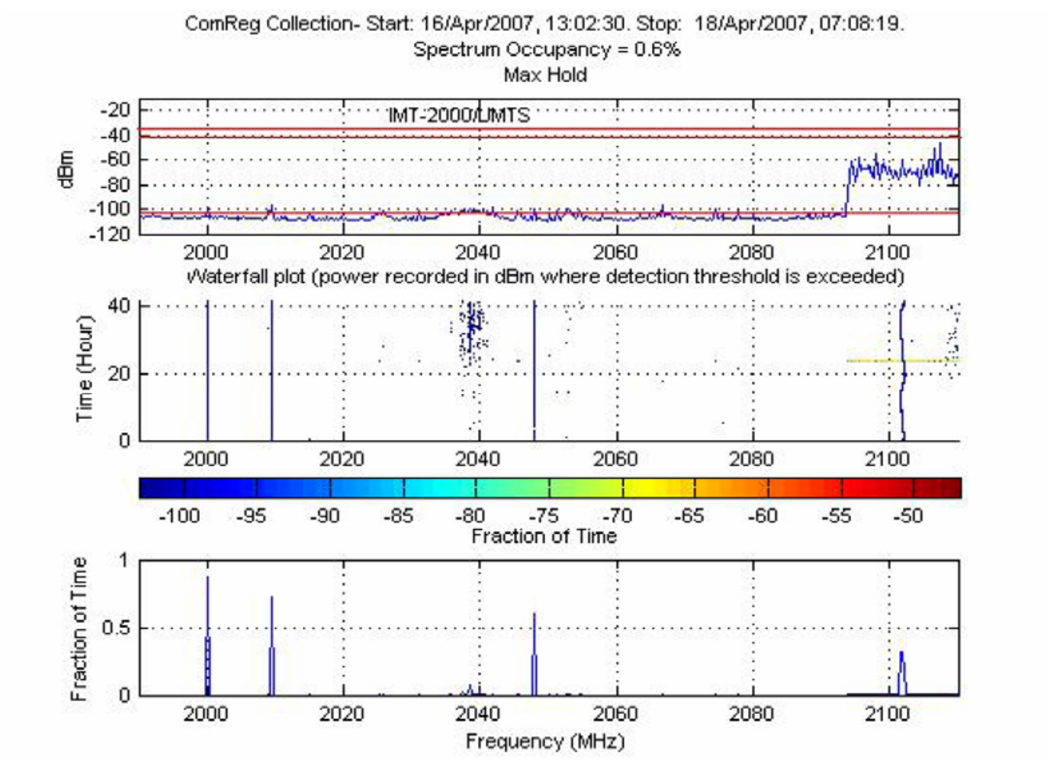

Figure 28. 1990 MHz to 2110 MHz

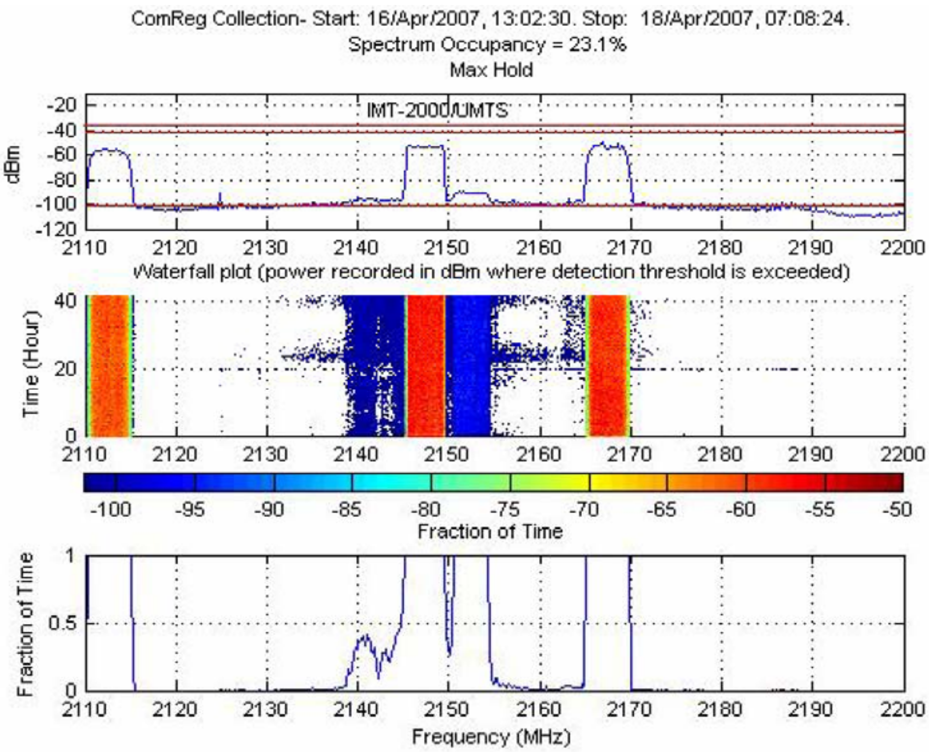

Figure 29. 2110 MHz to 2200 MHz

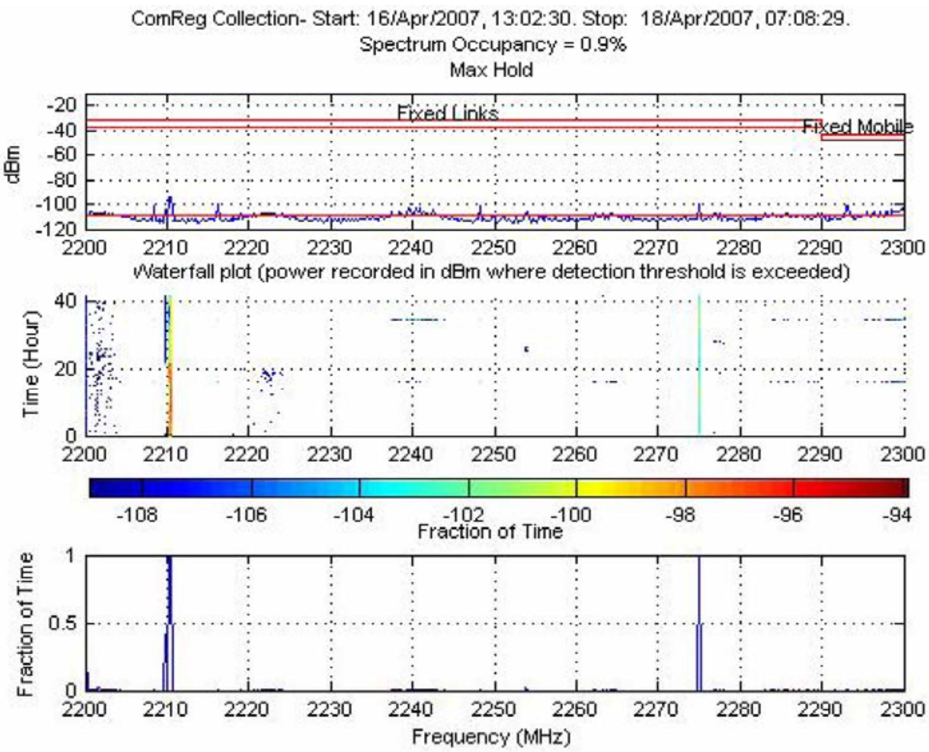

Figure 30. 2200 MHz to 2300 MHz

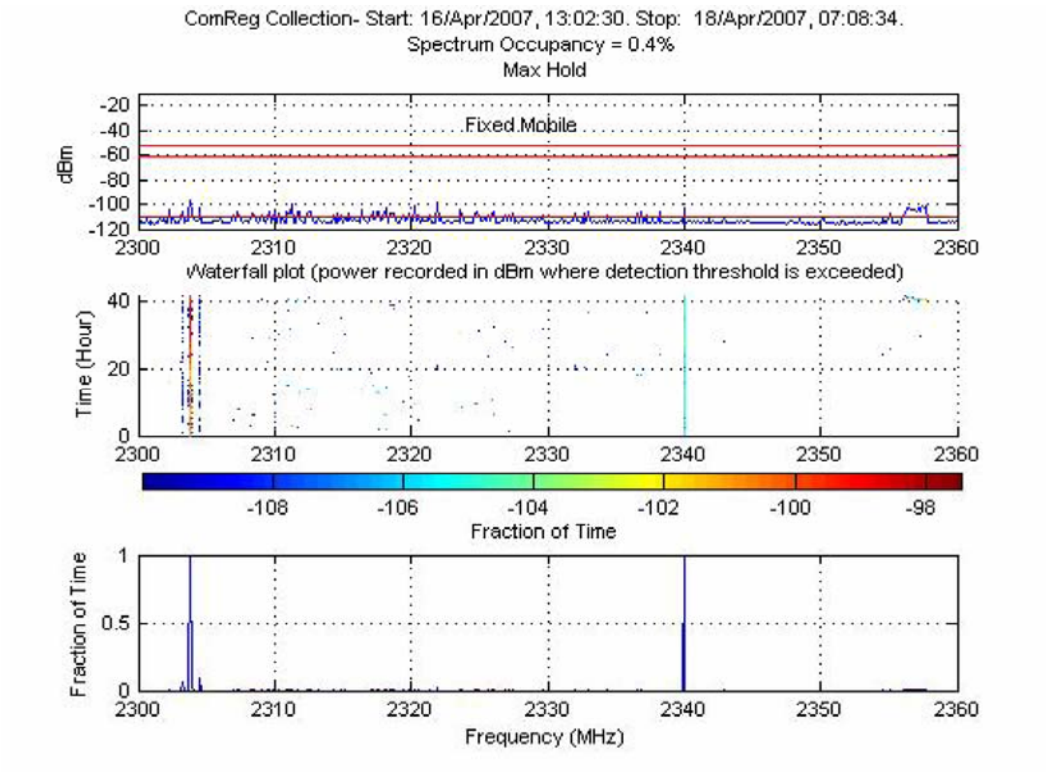

Figure 31. 2300 MHz to 2360 MHz

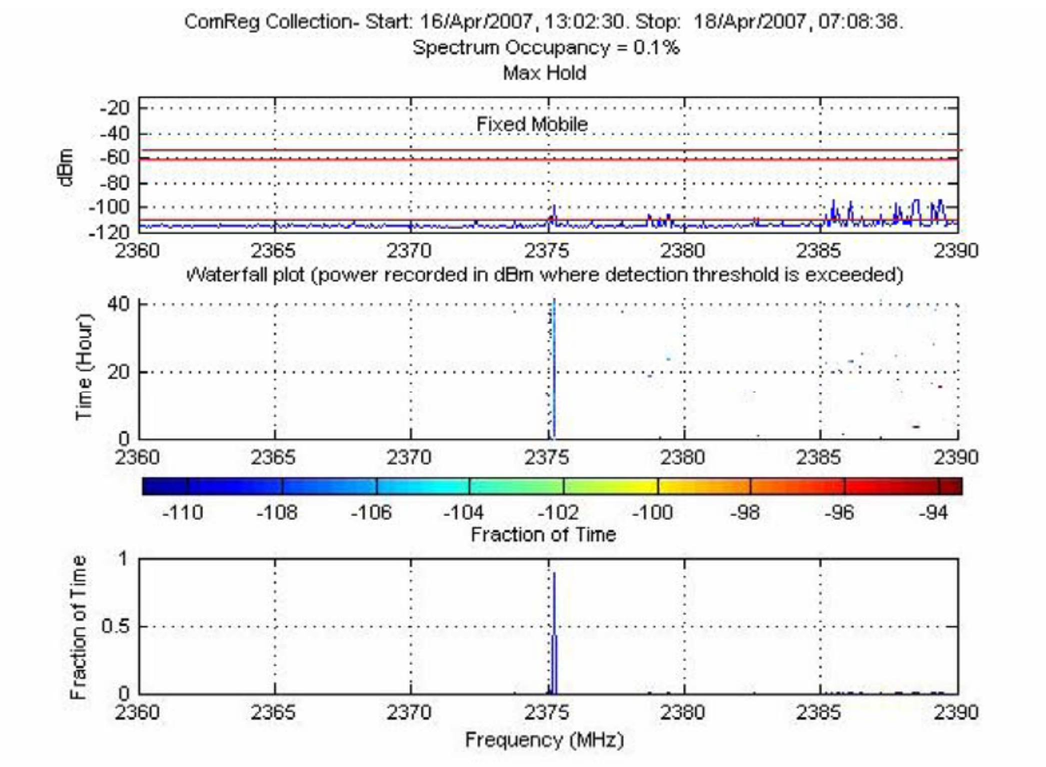

Figure 32. 2360 MHz to 2390 MHz

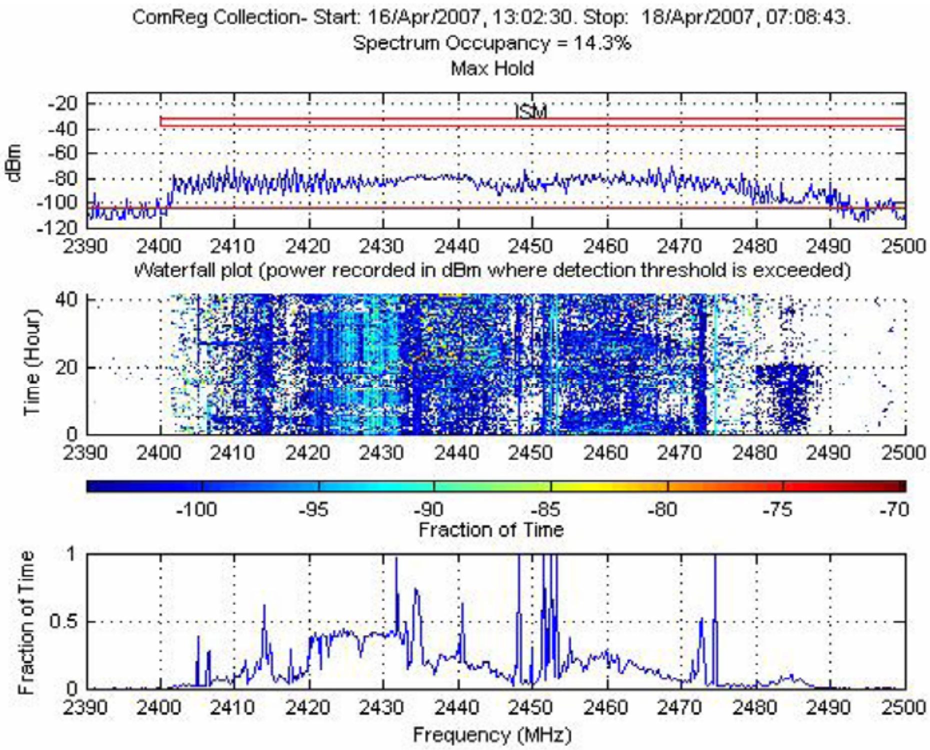

Figure 33. 2390 MHz to 2500 MHz

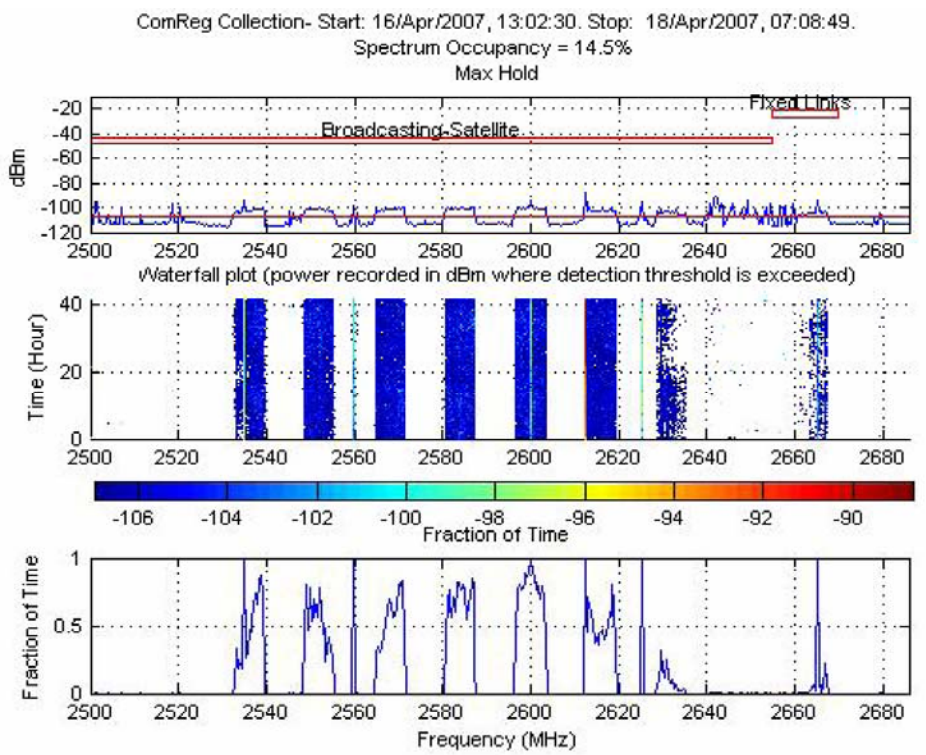

Figure 34. 2500 MHz to 2686 MHz

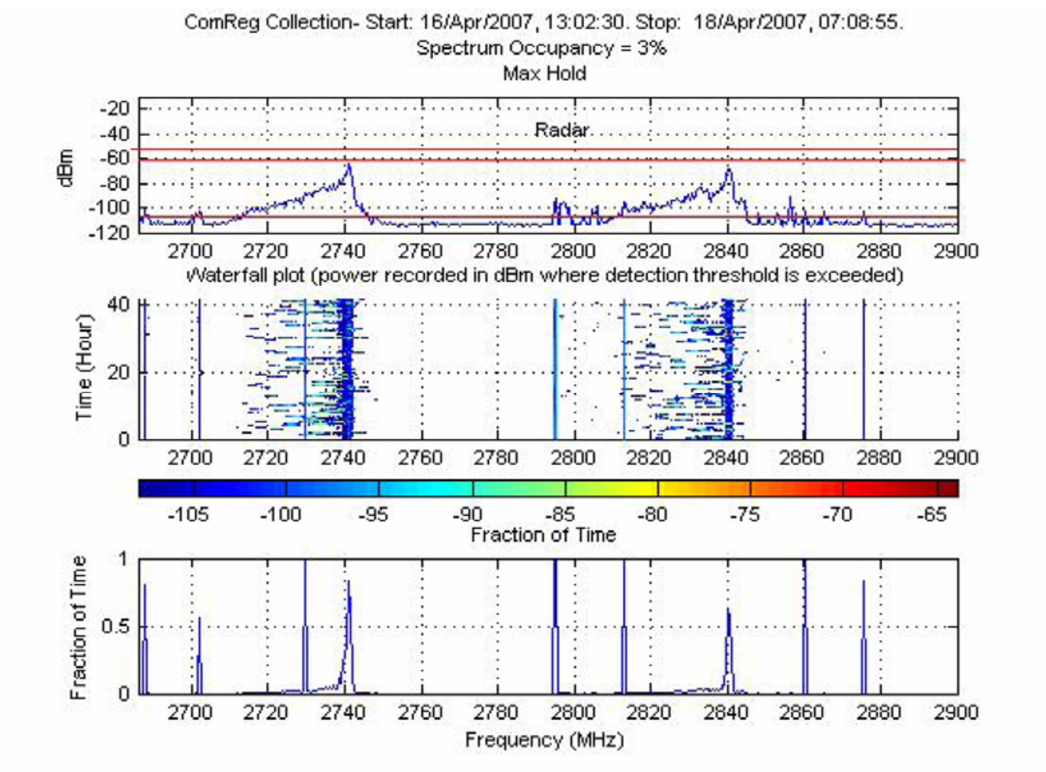

Figure 35. 2686 MHz to 2900 MHz

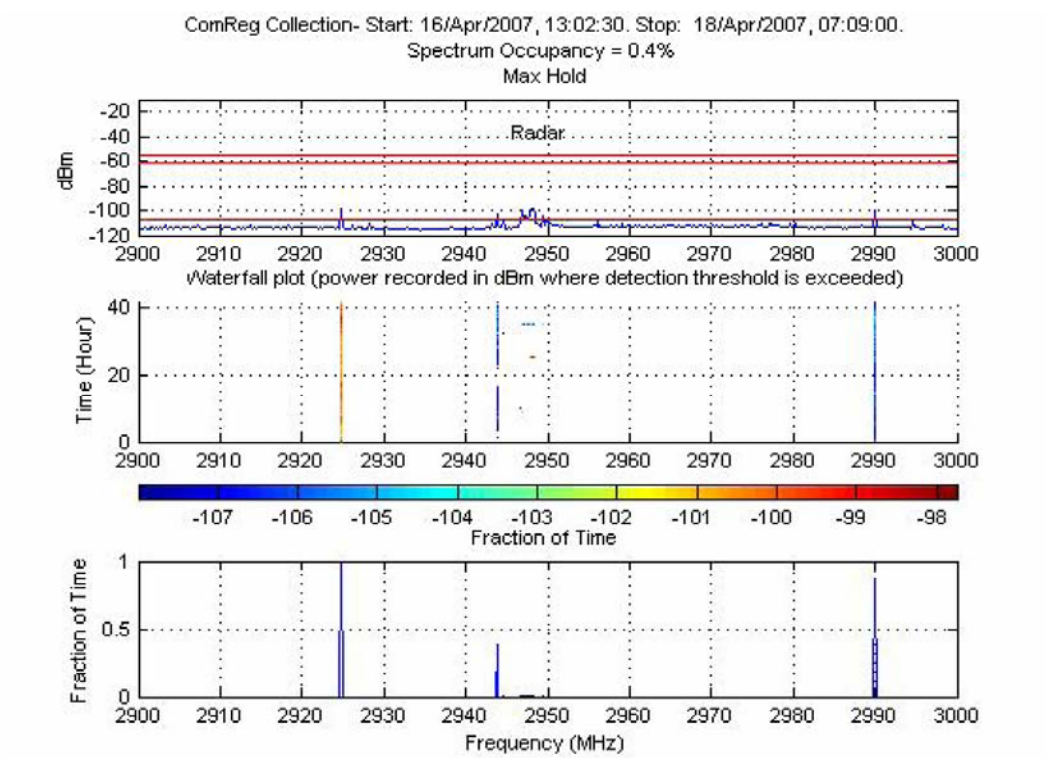

Figure 36. 2900 MHz to 3000 MHz

4. Conclusions

4.1 Introduction

This report documents spectrum occupancy measurements made by Shared Spectrum Company at the Commission for Communications Regulation Building, Dublin, Ireland. Measurements were made in all bands in the 30 MHz to 3000 MHz range. The measurements were made during a normal work week (Monday through Wednesday) which is believed to be a high usage period.

4.2 Potential Overload and/or Inter-modulation Effects

There is evidence of signal overload and/or inter-modulation effects in the data that would tend to increase the measured occupancy compared to the real occupancy. In Figures 24 and 25, from 1510-1620 MHz the measured signal bandwidth is extremely large. The signal has a very low received signal level. We have not measured a signal like this before. We suspect that this weak signal is related to overload of the measurement equipment that is occurring in another band. This overload is creating the weak signals seen at this band.

In Figures 26-27, from 1790-1830 MHz and 1880-1910 MHz the measured signal appears to be the sidelobes from the strong cell phone signal at 1830-1880 MHz.

In both of these cases, the actual spectrum occupancy is equal or less than what is shown in the figures. Our analysis thus is an upper bound of the actual occupancy.

4.3 Spectrum Occupancy Upper Bounds

Based on the results of the study, we conclude that the average spectrum usage during the measurement period was 13.6%. Occupancy[1] varied from less than 1% to 38.5% (1710 MHz – 1850 MHz) in the measurement area as shown in Table 2.

[1] Occupancy is defined as the average duty cycle based on the time-frequency product.

4.4 Table 2. Spectrum Occupancy in Each Band

Start Freq (MHz)	Stop Freq (MHz)	Span (MHz)	Spectrum Band Allocation	Spectrum Fraction Used	Occupied Spectrum (MHz)	Average Percent Occupied
30	54	24	Fixed Mobile	0.056309	1.351416	5.6
54	88	34	Fixed Mobile	0.18486	6.28524	18.5
108	138	30	Aeronautical	0.062866	1.88598	6.3
138	174	36	Aeronautical	0.12546	4.51656	12.5
174	216	42	Broadcasting	0.34356	14.42952	34.4
216	225	9	Broadcasting	0.19751	1.77759	19.8
225	406	181	Satellite Space	0.047869	8.664289	4.8
406	470	64	Amateur	0.17873	11.43872	17.9
470	512	42	Broadcasting	0.060675	2.54835	6.1
512	608	96	Broadcasting	0.26453	25.39488	26.5
608	698	90	Broadcasting	0.040389	3.63501	4.0
698	806	108	Broadcasting	0.35093	37.90044	35.1
806	902	96	Broadcasting	0.09924	9.52704	9.9
902	928	26	GSM, Land Mobile	0.0072915	0.189579	0.7
928	1000	72	Broadcasting	0.29214	21.03408	29.2
1000	1240	240	Broadcasting, Satellite	0.034669	8.32056	3.5
1240	1300	60	Amateur	0.0061554	0.369324	0.6
1300	1400	100	Satellite	0.0395	3.95	4.0
1400	1525	125	Fixed Mobile	0.15158	18.9475	15.2
1525	1710	185	Satellite	0.37198	68.8163	37.2
1710	1850	140	Fixed Mobile	0.38536	53.9504	38.5
1850	1990	140	Fixed Mobile	0.35121	49.1694	35.1
1990	2110	120	Fixed Mobile	0.0066952	0.803424	0.7
2110	2200	90	Fixed Mobile	0.2319	20.871	23.2
2200	2300	100	Fixed Mobile	0.0091076	0.91076	0.9
2300	2360	60	Fixed Mobile	0.004666	0.27996	0.5
2360	2390	30	Fixed Mobile	0.001883	0.05649	0.2
2390	2500	110	ISM	0.14357	15.7927	14.4
2500	2686	186	Broadcasting	0.14514	26.99604	14.5
2686	2900	214	Astronomy, Radar	0.03031	6.486982	3.0
2900	3000	100	Astronomy, Radar	0.00452	0.4519	0.5
Total		2950		4.2306077	426.75143	
Total Available Spectrum				2950		
Average Spectrum Use (%)				13.60%		

Figure 37 shows the percentage occupancy across all frequency bands graphically.

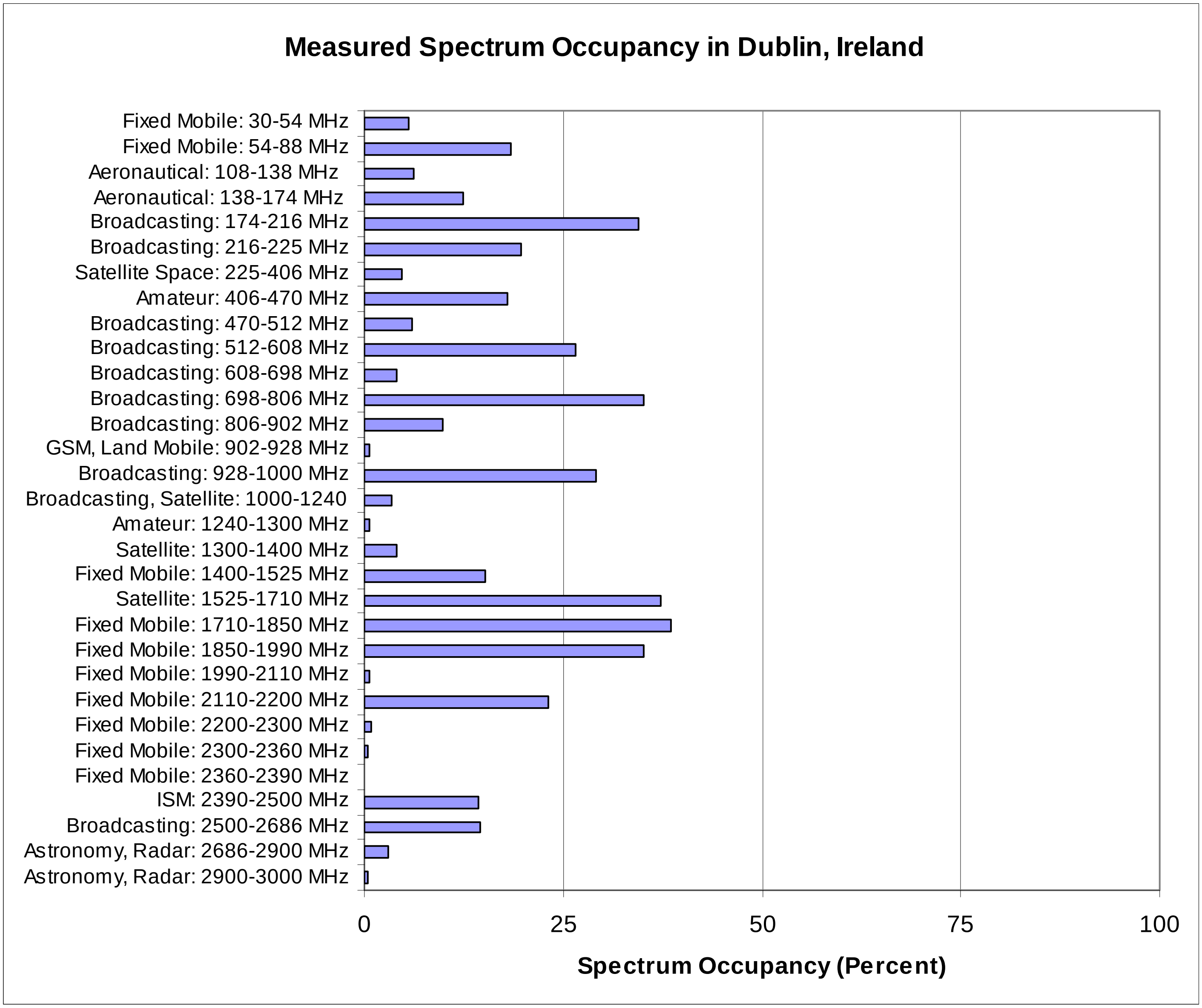

Figure 37. Spectrum Occupancy Measured in Each Band at Commission for Communications Regulation Building, Dublin, Ireland

4.5 Comparison to Other Locations

The spectrum occupancy in Dublin is comparable to the other dense urban environments in USA such as New York and Chicago. Figure 38 shows the spectrum occupancy with the measurements taken in New York City[2] and Chicago[3]. Although the allocation of frequency

[2] "Spectrum Occupancy Measurements, Location 4 of 6: Republican National Convention, New York City, New York, August 30, 2004 - September 3, 2004, Revision 2", Mark A. McHenry, Dan McCloskey, George Lane-Roberts, Shared Spectrum Company Report, August, 2005 (www.sharedspectrum.com).
[3] "Spectrum Occupancy Measurements, Chicago, Illinois, November 16-18, 2005", Mark A. McHenry, Dan McCloskey, Dennis Roberson and John T. MacDonald, (www.sharedspectrum.com).

spectrum in Ireland is different from the one in USA, the spectrum occupancy is similar for the same frequency bands in Dublin, New York city and Chicago.

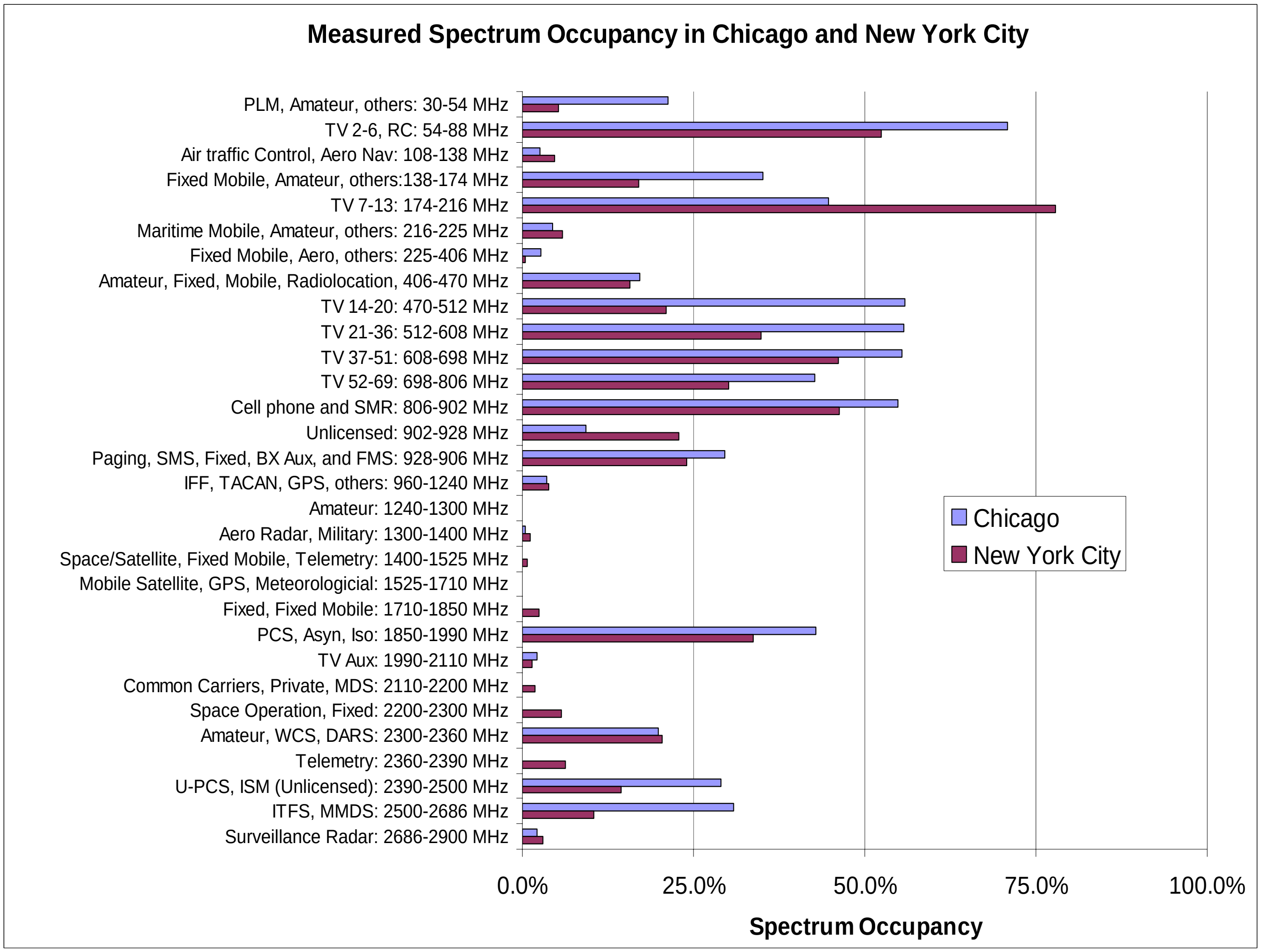

Figure 38. Bar Graph of the Spectrum Occupancy in Each Band in New York City, and Chicago, USA

4.6 Summary

Dublin is the most densely populated city in Ireland and in this report; it is shown that the spectrum occupancy during a high usage period in a normal work week is only 13.6% in this city. Thus, no more than 13.6% of the spectrum opportunities (in frequency and in time) are utilized in Dublin during a high use period when measured from an elevated location.

The spectrum occupancy in Dublin, Ireland is similar to the ones in Chicago and New York. This proves that the inefficient usage of frequency spectrum is a problem not only in USA, but also in other European countries. Shared Spectrum Company believes that Dynamic Spectrum Access technology can be used to harvest the large amount of unoccupied channels worldwide.

Acknowledgement

We would like to thank Dr. Keith Nolan from Centre for Telecommunications Value-Chain Research, and Brian Whelan and Ivan Kiely from Commission for Communications Regulation for all their help for the measurements.