Spectrum Sensing as a tool to analyze Wideband HF channel availability

W. Furman, C. Henry, E. Koski, J. Nieto
Harris Corporation

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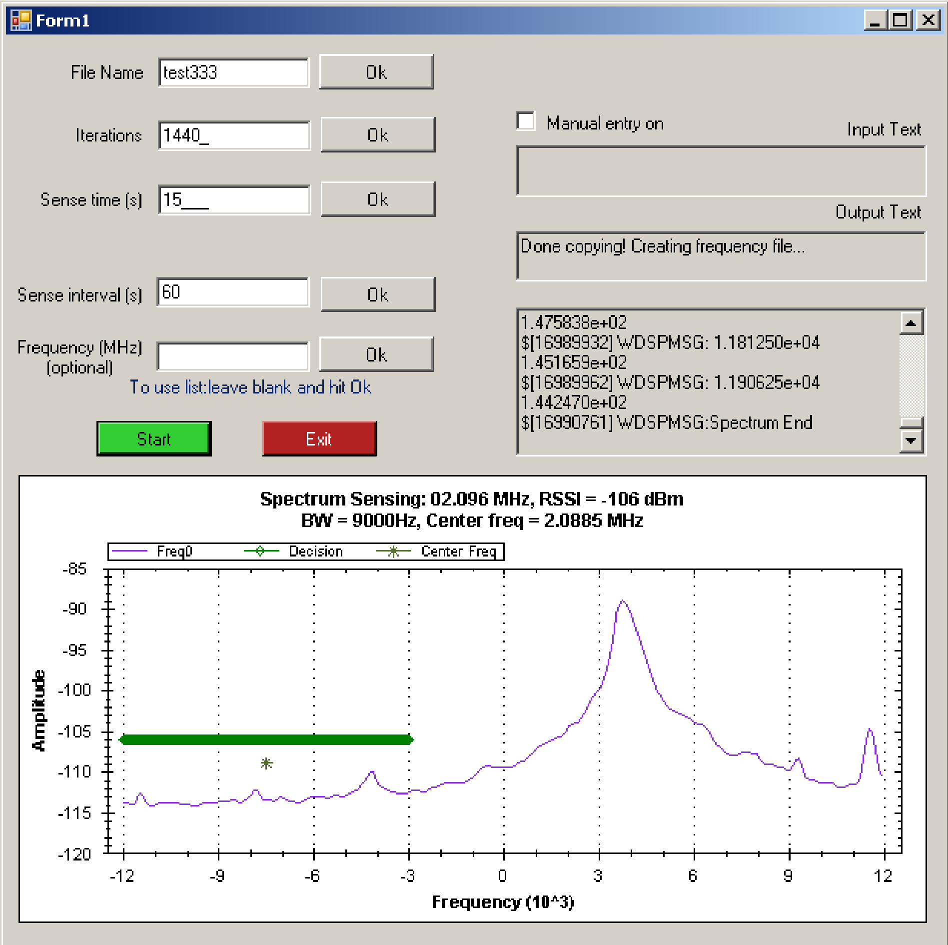
Overview

- Role of Spectrum Sensing
- Automated Spectrum Sensing Tool
- Wideband Availability Experiment #1
- Wideband Availability Experiment #2
- Summary
- Way Forward

Role of Spectrum Sensing

- Spectral Evaluation of Carrier Frequency +/- 12 kHz
- Harris is exploring this as a component of a new Adaptive Wideband ALE system which would:
  - Use spectrum sensing to evaluate interference
  - Use traditional 3kHz bandwidth ALE signaling (2G/3G) to probe and evaluate a sub-band of the allocated wideband channel
  - Combine these techniques to adaptively select the available bandwidth and offset within the allocated wideband channel
  - Convey this information and link radios

Automated Spectrum Sensing Tool

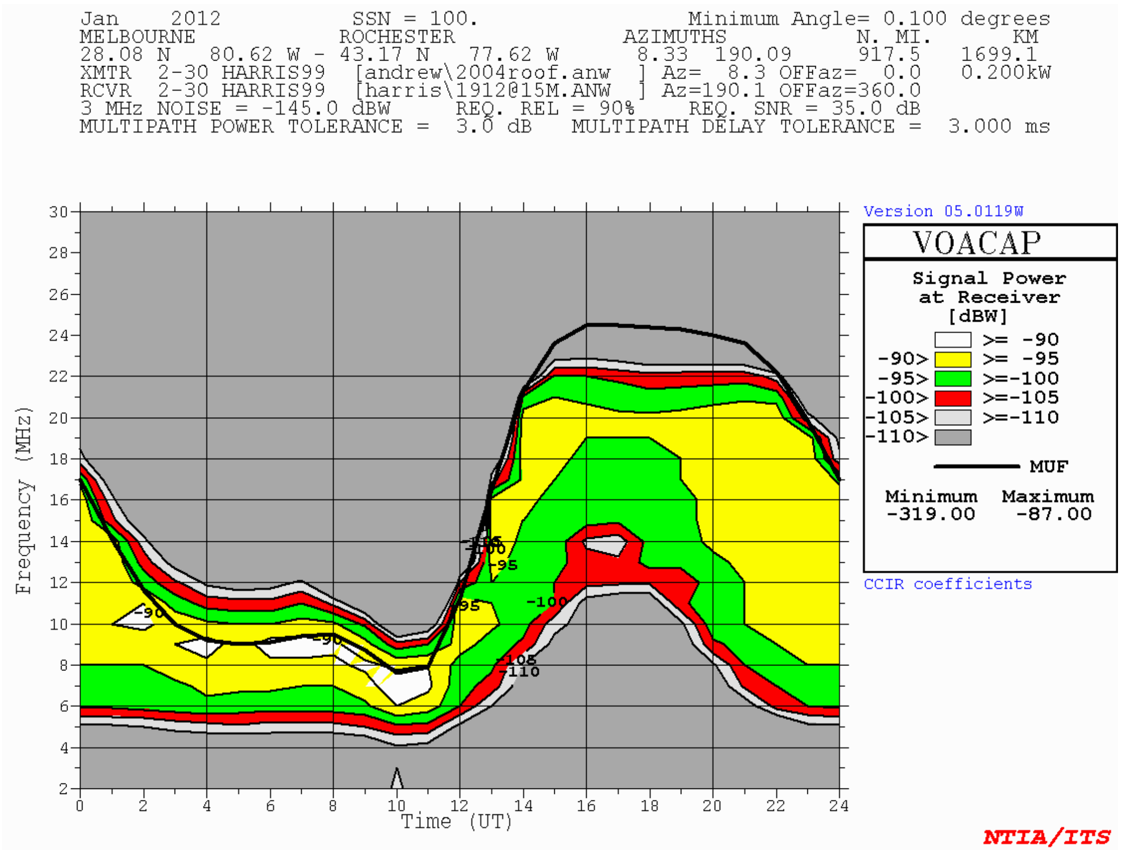


- PC based application which interfaces with a prototype wideband receiver
- User inputs file name, number of senses, duration of sense, and interval time
- User can specify single frequency or run from a list of frequencies
- All data logged to PC
- For each Spectrum Sense a plot of received signal density (dBm/Hz) versus frequency is calculated, displayed, logged

Wideband Availability Experiment #1

- The spectrum sensing tool was used to perform an experiment examining wideband HF channel availability and achievable performance gains
- This was accomplished by using VOACAP to predict the usable frequency range and received signal levels on specific links at various times of day
- By performing spectrum sensing at the receive site and constraining the observation frequencies based on the VOACAP predictions, we can predict overall system throughput and wideband channel utilization

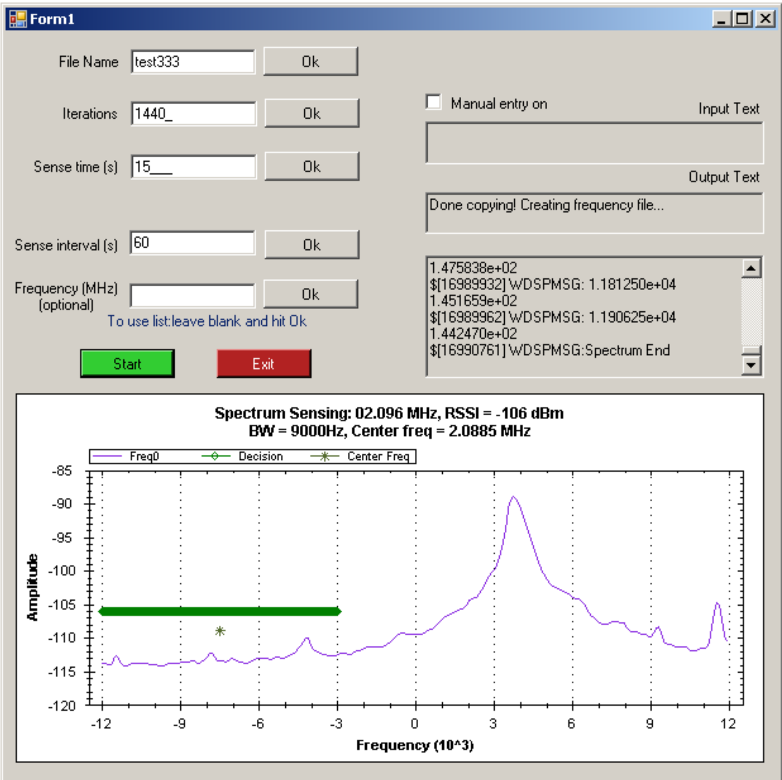
Wideband Availability Experiment #1

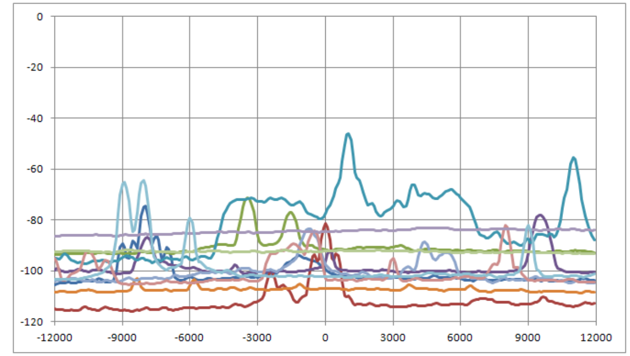


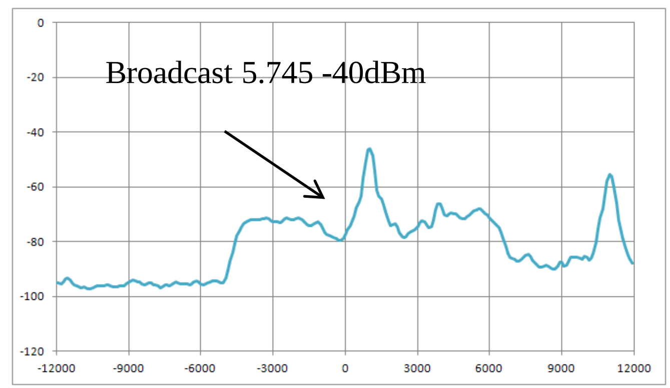
UTC	Min	Max	dBM
0	9	17	-60
1	9	14	-60
2	9	11	-60
3	8	10	-60
4	8	10	-60
5	8	10	-60
6	8	10	-60
7	8	10	-60
8	8	10	-60
9	7	9	-60
10	7	9	-60
11	7	9	-65
12	9	13	-65
13	10	16	-65
14	12	22	-65
15	14	22	-65
16	14	22	-65
17	14	22	-65
18	14	22	-65
19	14	22	-60
20	14	22	-60
21	9	22	-60
22	9	20	-60
23	9	18	-60

- Step 1 – VOACAP used to estimate usable frequency range and received signal strength in dBm

Wideband Availability Experiment #1



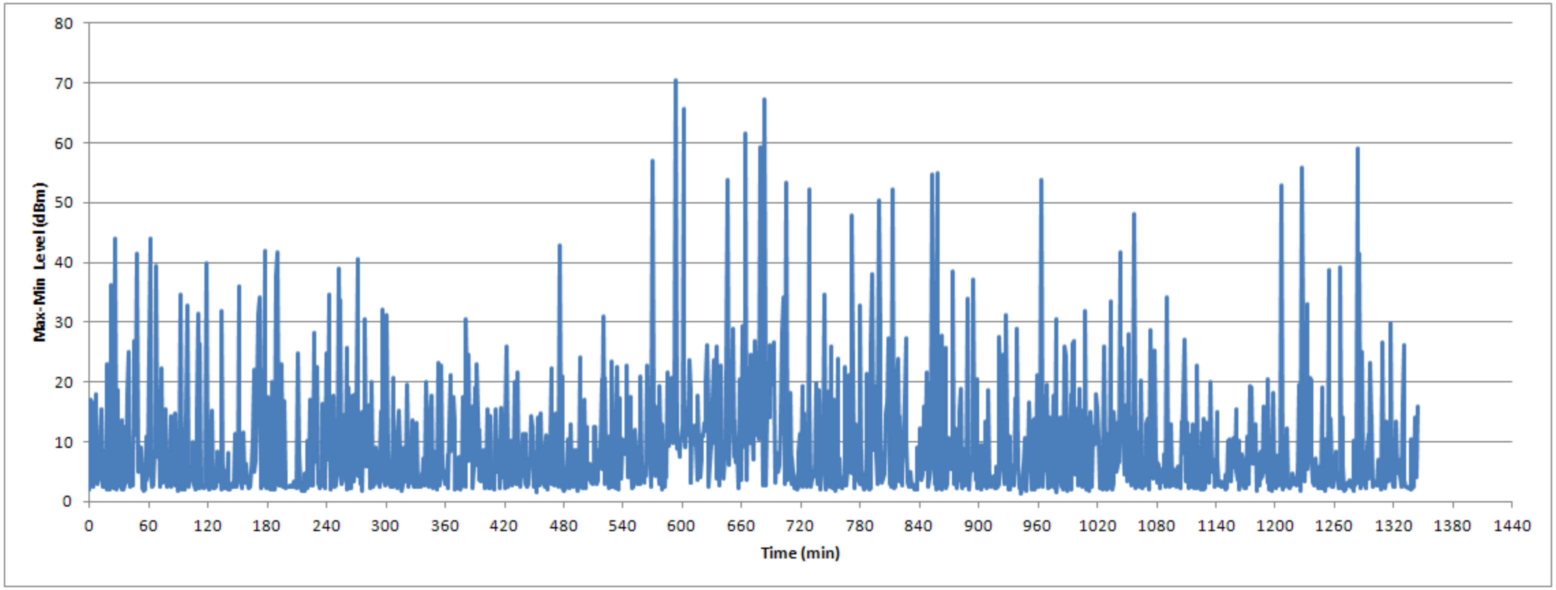




- Step 2 – Program the Spectrum Sense application to collect 24 kHz channel spectra once per minute, on randomly-selected frequencies between the estimated min and max. Frequency limits are changed each hour based on VOACAP predictions

Wideband Availability Experiment #1 -Results

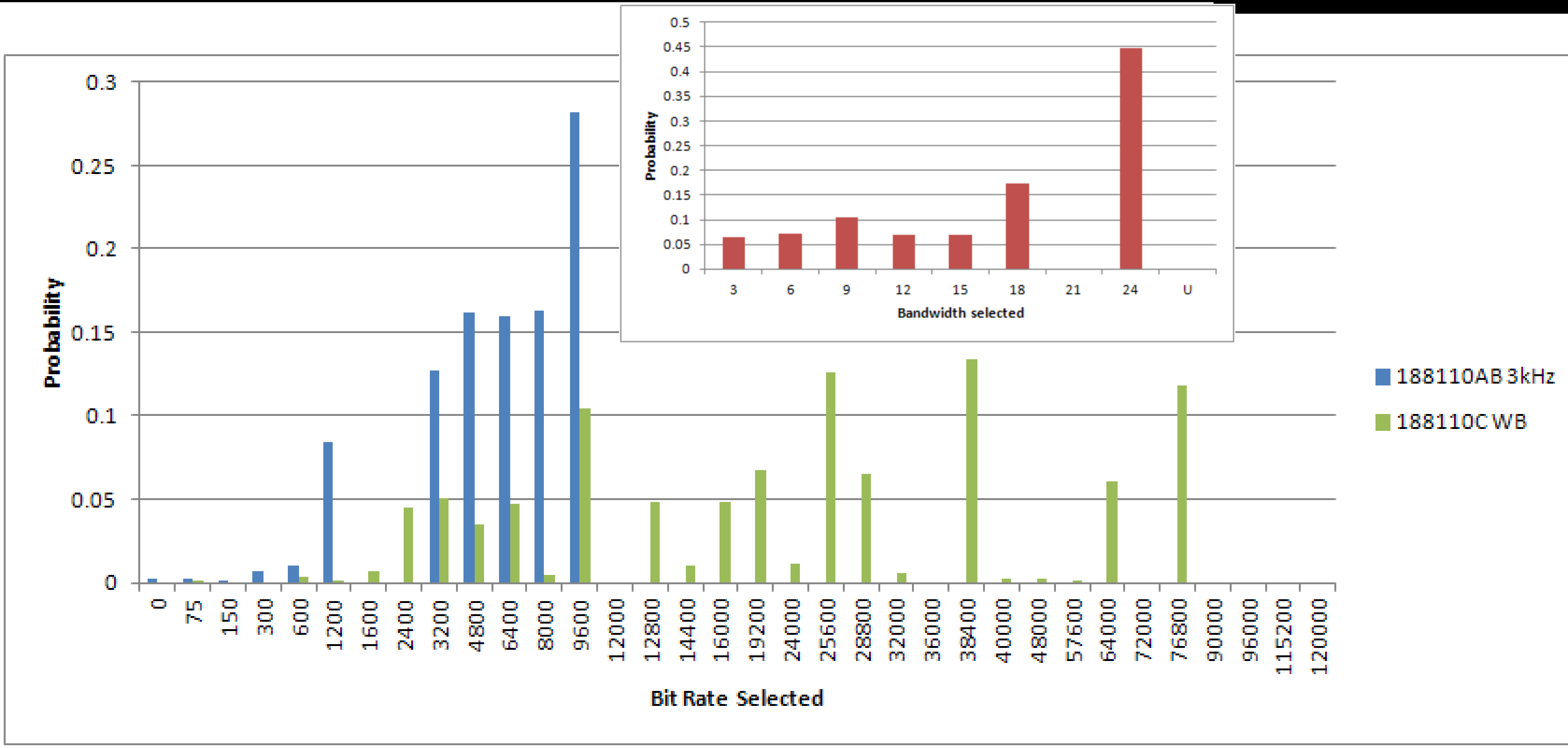
- 24 Hour Experiment – Strategic 1 hop
- Transmitter - Melbourne Fl, 200 Watts – Log Periodic Antenna
- Receiver – Rochester NY – Broadband Dipole



Wideband Availability Experiment #1- Results

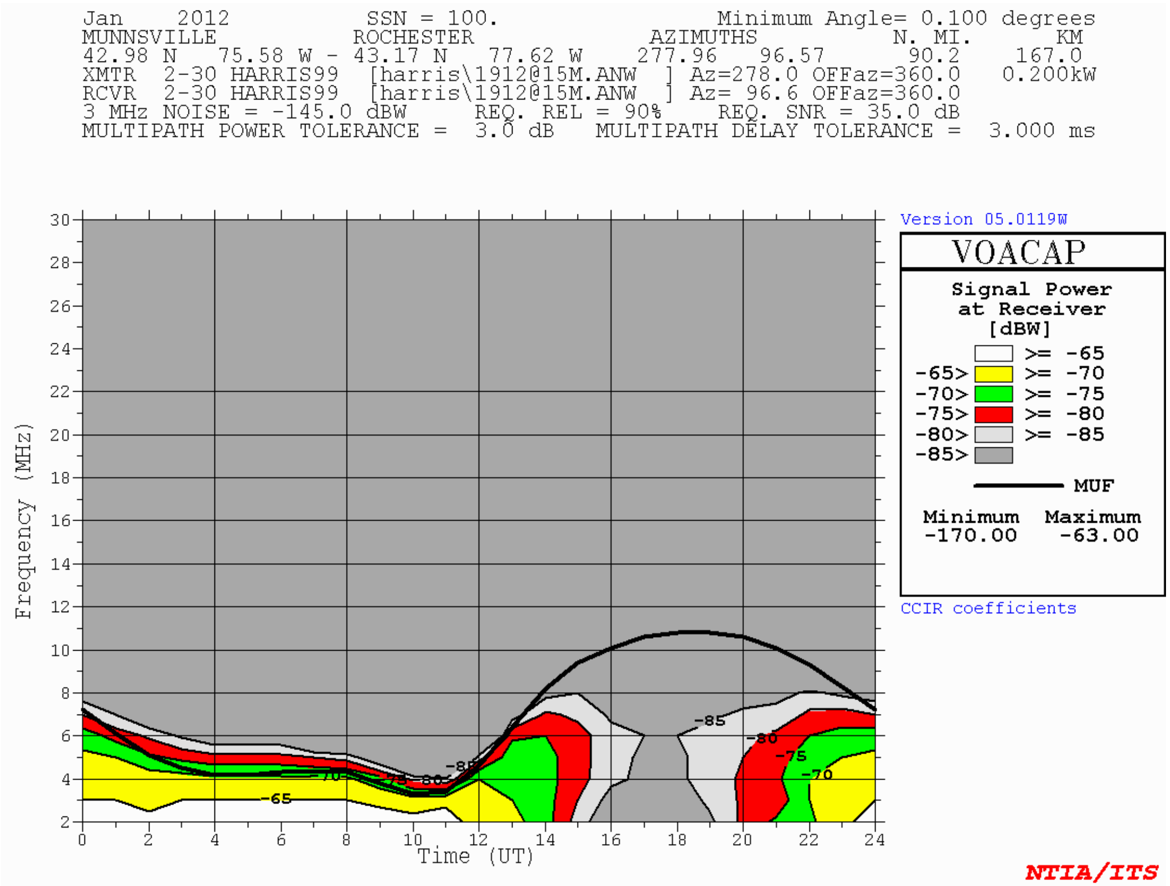
- Step 3 Data Analysis
  - Data are post-processed. Based on predicted Rx signal power and measured interference power a received SNR is estimated, accounting for constant Rx power and varying noise+interference bandwidth
  - Received SNR is compared against AWGN and POOR channel SNR thresholds for a 10^{-5} BER at each bit rate, to determine maximum bit rate supported using:
    - 188-110A/B 3 kHz signaling, fixed alignment
    - 188-110C Wideband: combination of bandwidth and alignment is chosen so as to maximize achievable data rate (with BER no worse than 10^{-5}).
  - Total throughput is calculated by integrating bit rate selected for each minute over the 24 hour test duration

Wideband Availability Experiment #1- Results



- Total Throughput
  - AWGN: 85MB (3kHz), 505MB (Adaptive Wideband)
  - POOR: 65MB (3kHz), 294MB (Adaptive Wideband)

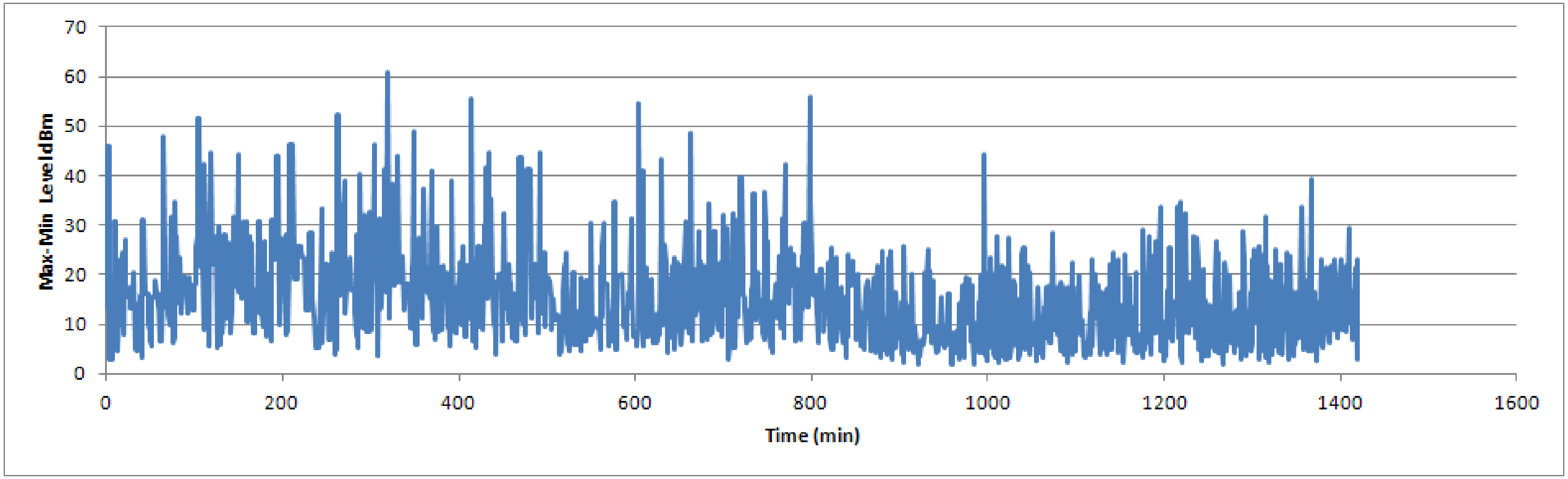
Wideband Availability Experiment #2



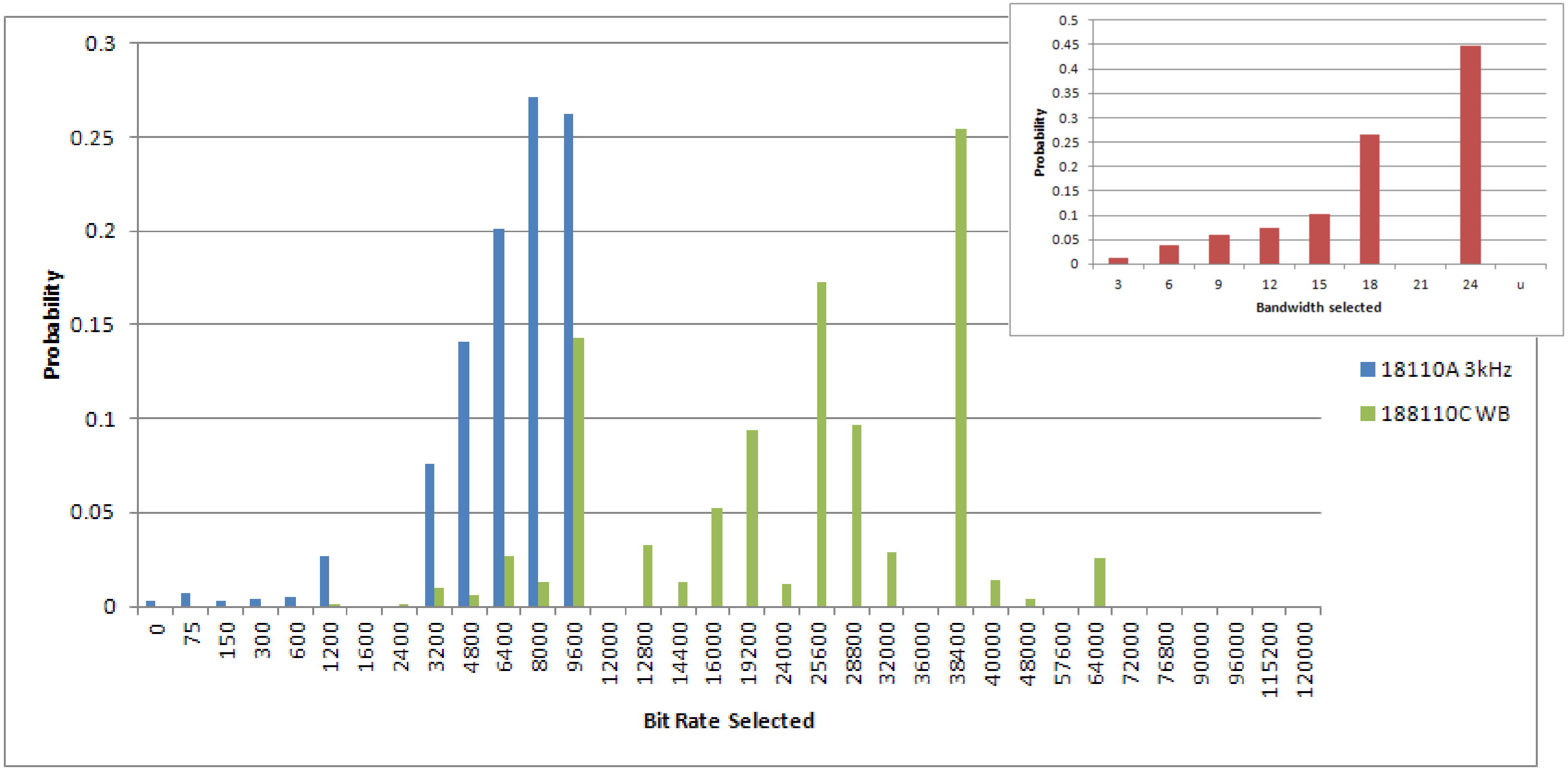
UTC	Min	Max	dBM
0	3	5	-35
1	3	5	-35
2	3	4	-35
3	3	4	-35
4	3	4	-35
5	3	4	-35
6	3	4	-35
7	3	4	-35
8	3	4	-35
9	3	4	-35
10	3	4	-35
11	3	5	-35
12	3	5	-35
13	3	6	-40
14	3	6	-40
15	4	8	-40
16	4	8	-50
17	4	8	-50
18	4	8	-50
19	4	8	-50
20	4	6	-45
21	4	6	-45
22	3	5	-35
23	3	5	-35

Wideband Availability Experiment #2- Results

- 24 Hour Experiment (Tactical NVIS Link)
- Transmitter – Stockbridge NY, 10 Watts – RF-1912
- Receiver – Rochester NY – Broadband Dipole



Wideband Availability Experiment #2- Results



- Total Throughput
  - AWGN: 91MB (3kHz), 493MB (Adaptive Wideband)
  - POOR: 71MB (3kHz), 262MB (Adaptive Wideband)

Summary

- Spectrum sensing is a valuable tool for characterizing the potential utility and performance of wideband HF systems
- Spectrum sensing will be a key component in ALE and data protocol implementations which adapt the wideband HF data waveform parameters to maximize performance
- Our observations, although limited, strongly suggest that sufficient interference-free bandwidth is available to support effective use of the wideband waveforms
- Analysis of a 1700 km link from Melbourne, Florida to Rochester, NY and of a 167 km link from Stockbridge, NY to Rochester, NY show how a wideband system can achieve significantly higher throughput than a current 3 kHz system using the ***same transmit power***, resulting in superior capacity and power efficiency

Way Forward

- Plans include further tests:
  - Simultaneous spectrum sensing at different Rx locations
  - Various link types: NVIS, etc.
- Incorporation of spectrum sensing into a wideband ALE system