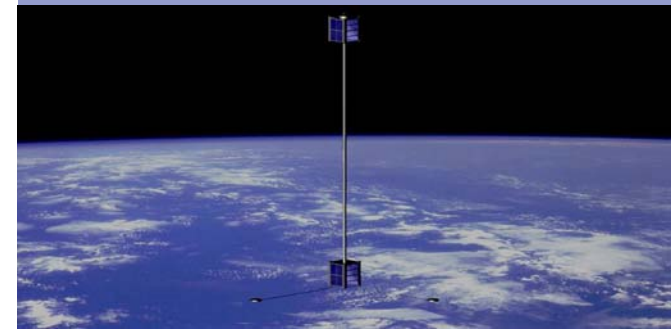
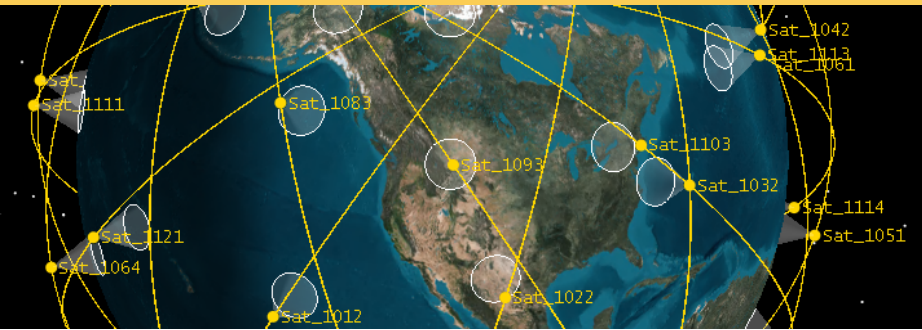


SRI International



Using The Allen Telescope Array (ATA) for CubeSat Communications

10th Annual CubeSat Developers' Workshop

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Outline

- ATA Overview
- Tracking CubeSat Transmissions Immediately After a Launch
- Matching CubeSats with TLE objects
- Capturing and decoding telemetry data
- Summary

Overview of the Allen Telescope Array (ATA)

- 42 dishes located in northern California at the Hat Creek Radio Observatory
- Designed for 500 MHz to 10 GHz
- Receive only, no transmitter



Aerial View #1



Aerial View #2



ATA Specifications

- Array of 42 Antennas
- Each antenna 6.1m diameter
- Slew rate 2° /sec
- Frequencies 500 MHz to 10 GHz
 - However, successful observations at 437 MHz and 12 GHz
- Max Effective Gains:
 - UHF (437 MHz) 43 dB
 - L-Band (1.5 GHz) 53 dB
 - S-Band (3 GHz) 59 dB
 - C-Band (6 GHz) 65 dB
- Instantaneous bandwidth: 104 MHz
- System Noise Temperature: 70K (at 2 GHz)
- Location: 40.817N Lat, 121.470W Lon, 1008 m Alt
 - North East of Redding California

Experiment #1: Identify and Capture Beacons

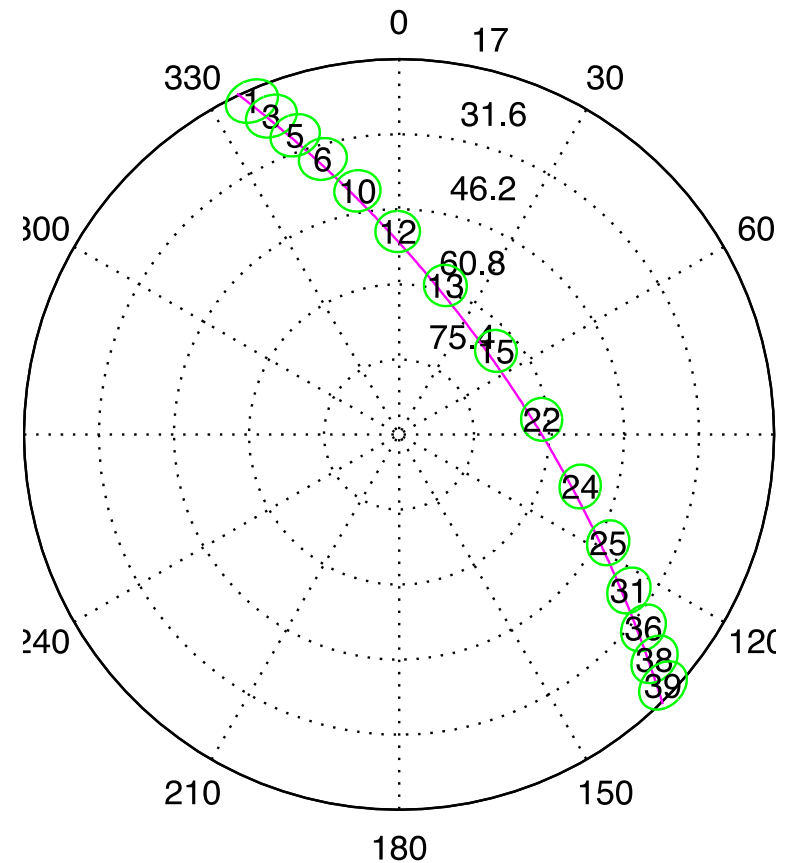
Overview

- OUTSat launch on September 13th, 2012 included 11 CubeSats
 - 4 of the CubeSats had beacons on 437 MHz band
 - ANEAS, CP5, CSSWE, and CXBN
- Goal of the experiment
 - To positively identify all CubeSats in a single frequency band with autonomous beacons in a single pass
- Experiment with ATA conducted on October 1st, 2012

Experiment #1: Identify and Capture Beacons

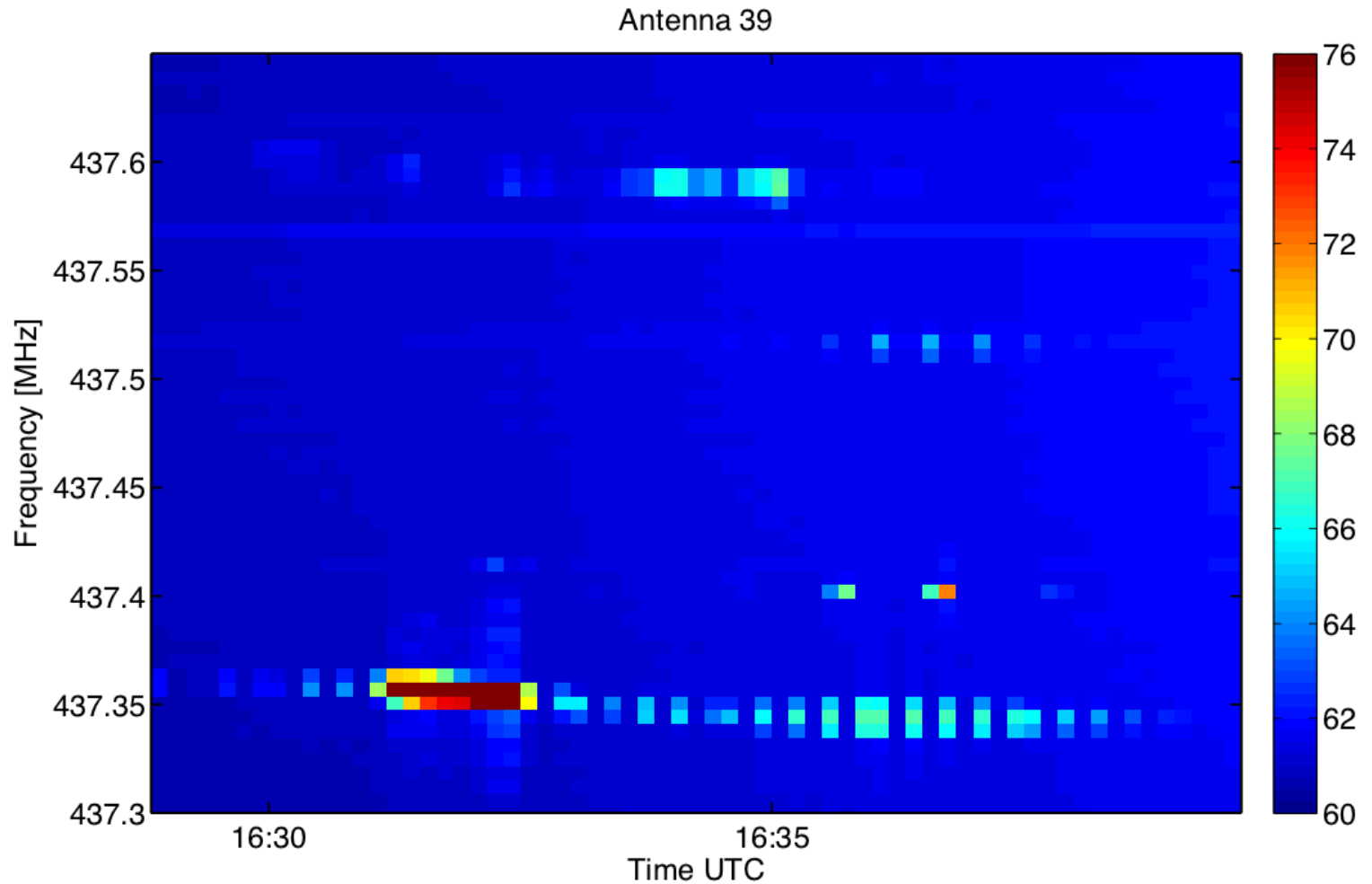
ATA Setup

- Goal: Try to capture beacons from all CubeSats during first pass after a launch
- Utilized 15 dishes
- Fan beam format: *statically* point the dishes along the predicted orbital ground path
- Start gathering data from all dishes a couple minutes before and a couple minutes after predicted pass



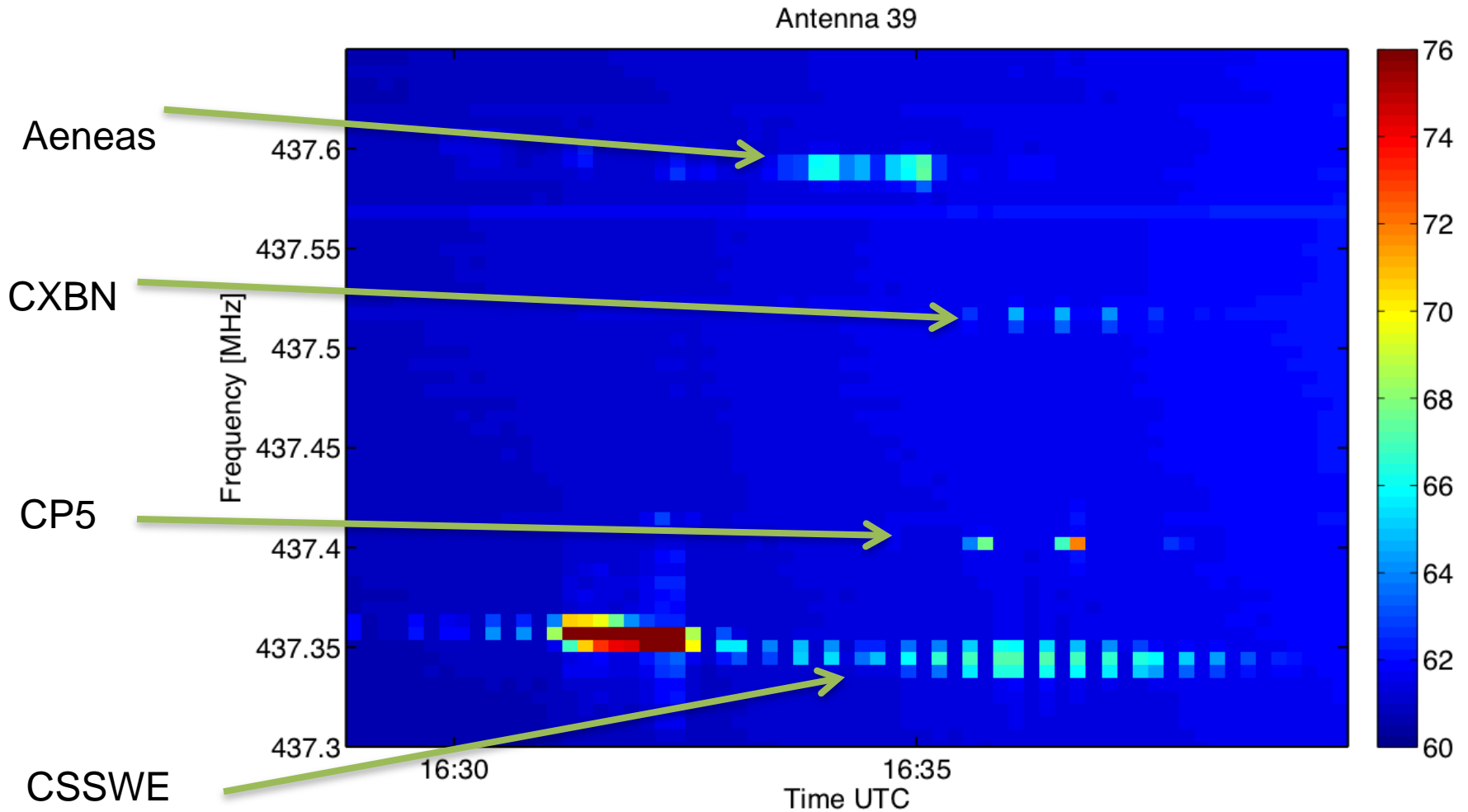
Experiment #1: Identify and Capture Beacons

Results



Experiment #1: Identify and Capture Beacons

Results



Experiment #2a-c: Matching CubeSats with TLEs

Overview

- In the first days and weeks following a launch with multiple CubeSats, the CubeSats must be identified and matched to TLE object numbers
- The ATA can operate in an “imaging” mode:
 - 1) A group of dishes are pointed in the same direction
 - 2) A snapshot image of signal intensity and frequency can then be created
- The unmatched TLEs can then be plotted onto the images and CubeSats can be matched to the closest TLE.
- Sets of images can also be combined to create “movies”

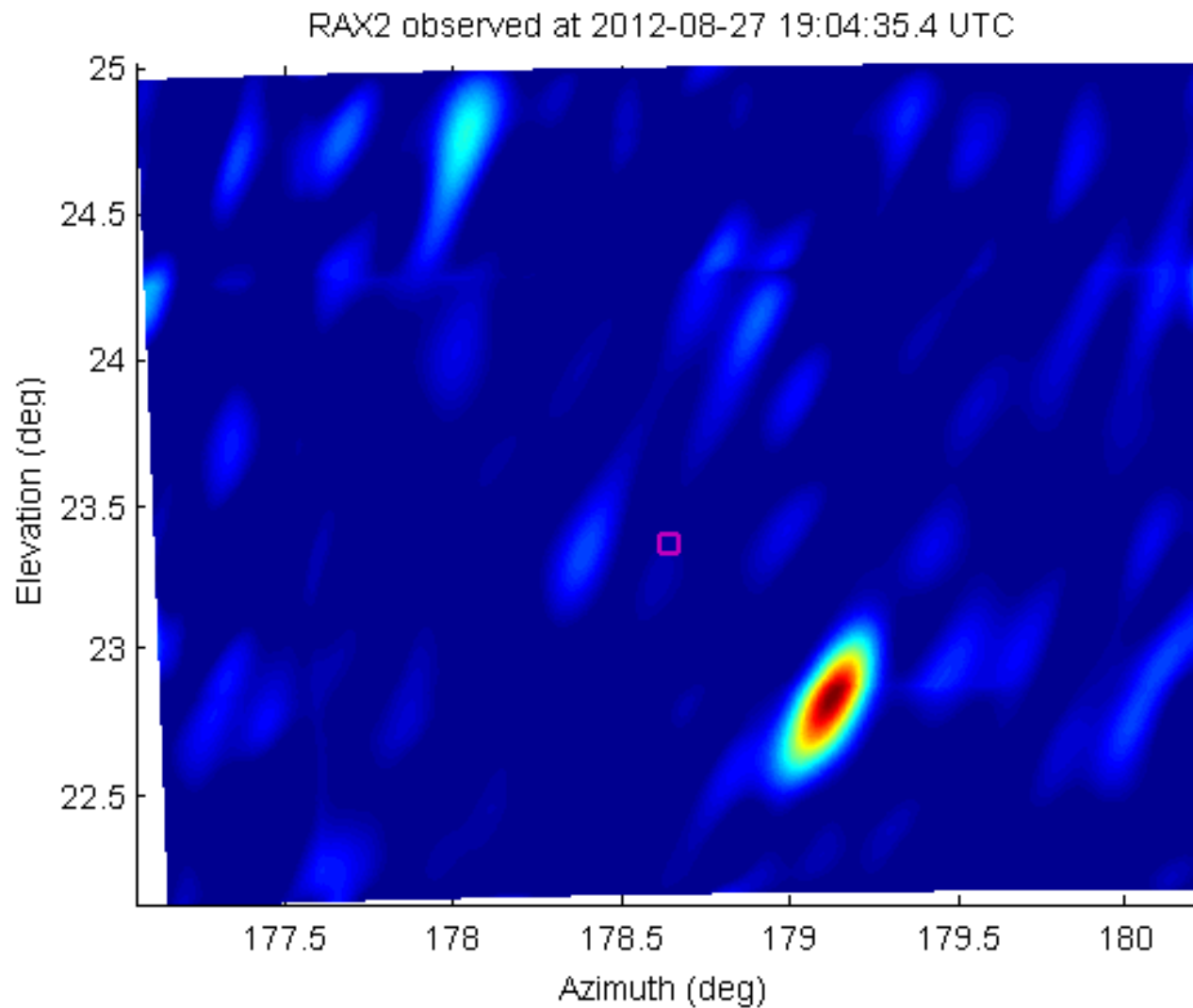
Experiment #2a: Matching CubeSats With TLEs

ATA Setup

- Date: August 27, 2012
- Number of Dishes: 18
- Objective: To take in image of RAX2 during a scheduled data downlink over California

Experiment #2a: Matching CubeSats With TLEs

Results



Experiment #2b: Matching CubeSats With TLEs

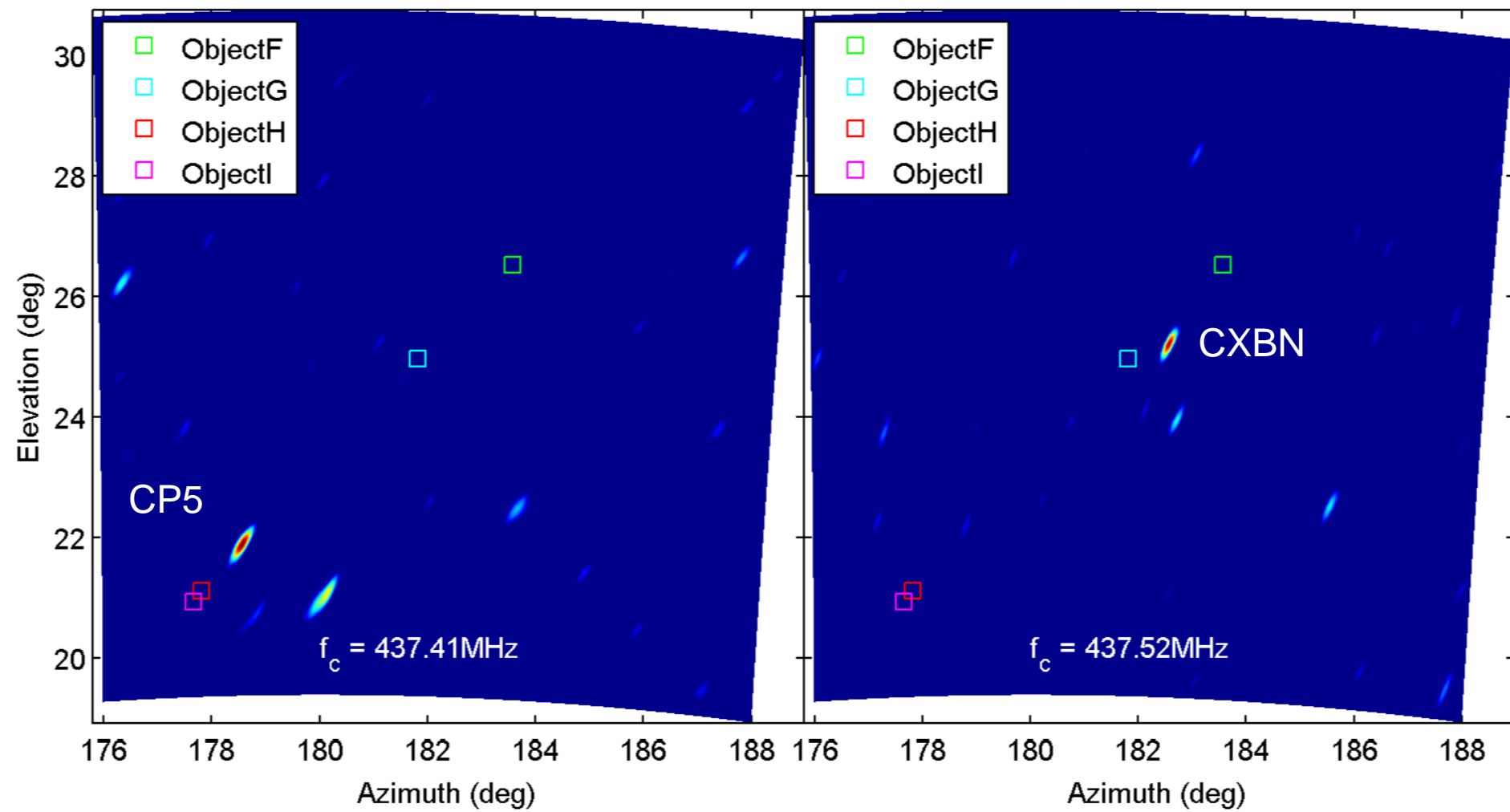
ATA Setup

- Date: October 5, 2012
- Number of Dishes: 18
- Objective: To take in image of the CubeSats deployed from OutSat and match different CubeSats to TLEs
 - Aeneas
 - CP5
 - CSSWE
 - CXBN

Experiment #2b: Matching CubeSats With TLEs

Results

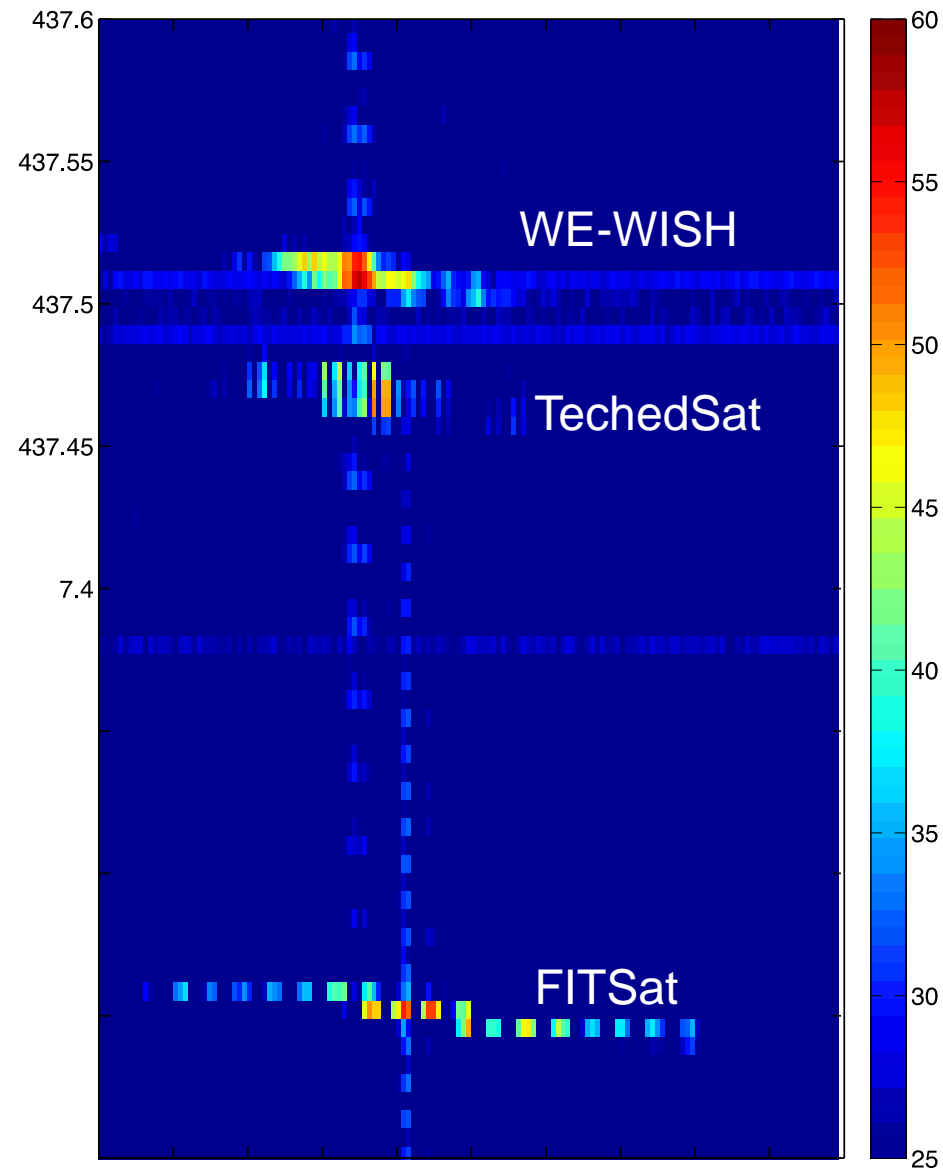
05-Oct-2012 16:20:58 UTC



Experiment #2c: Matching CubeSats With TLEs

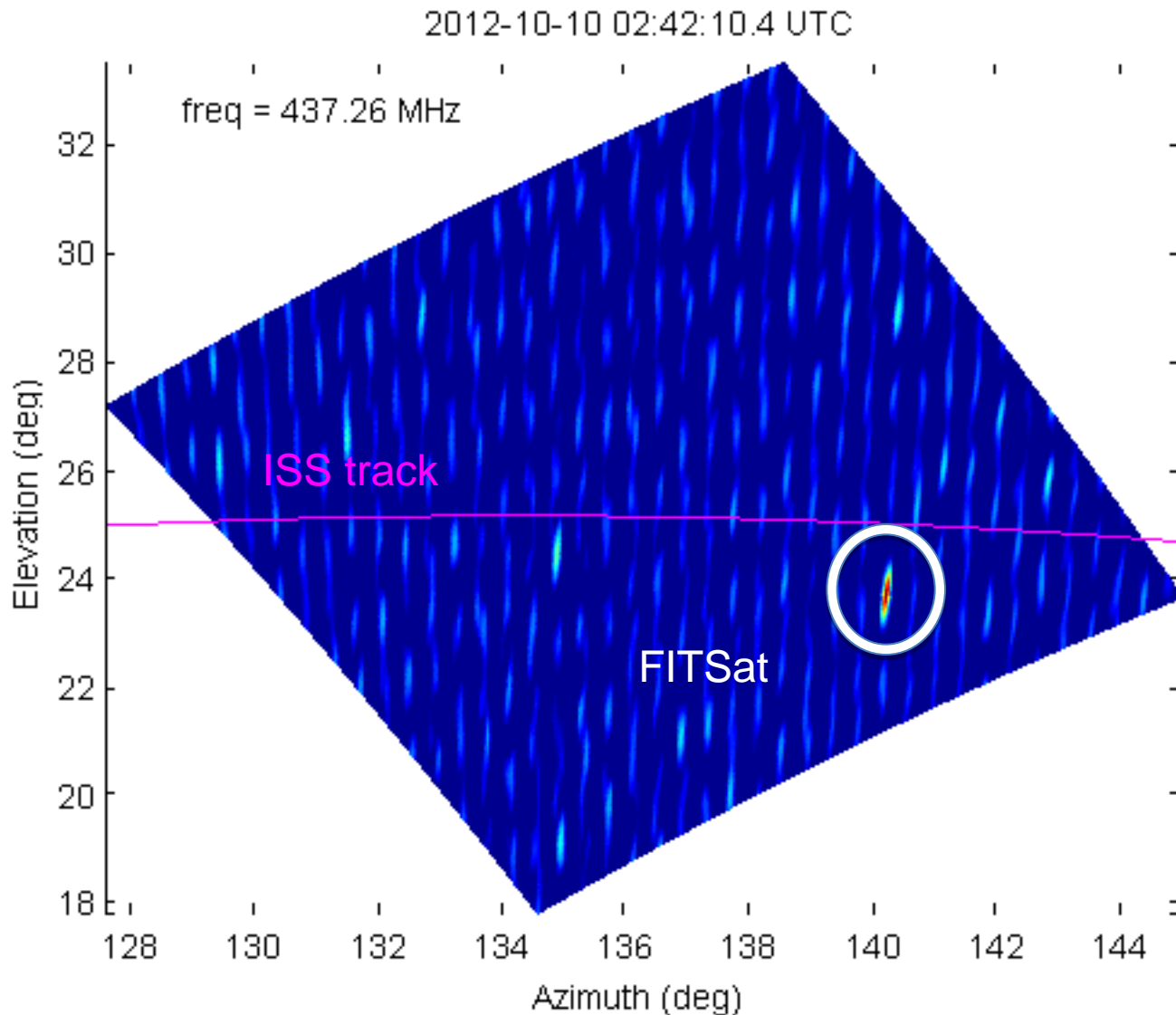
ATA Setup

- Date: October 9, 2012
- Number of Dishes: 17
- Objective: To take in image of the CubeSats deployed from the ISS prior to access to TLEs



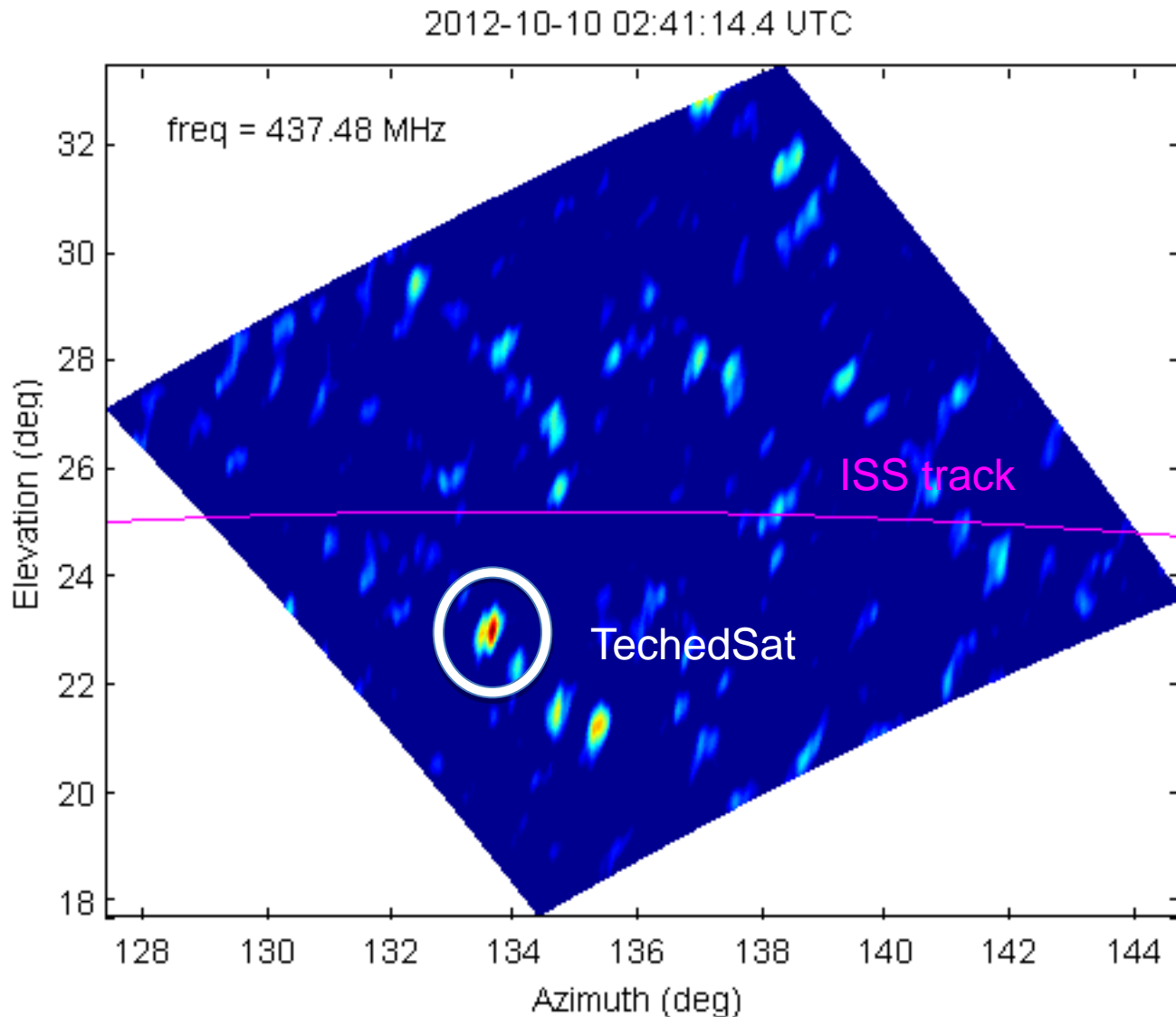
Experiment #2c: Matching CubeSats With TLEs

Results



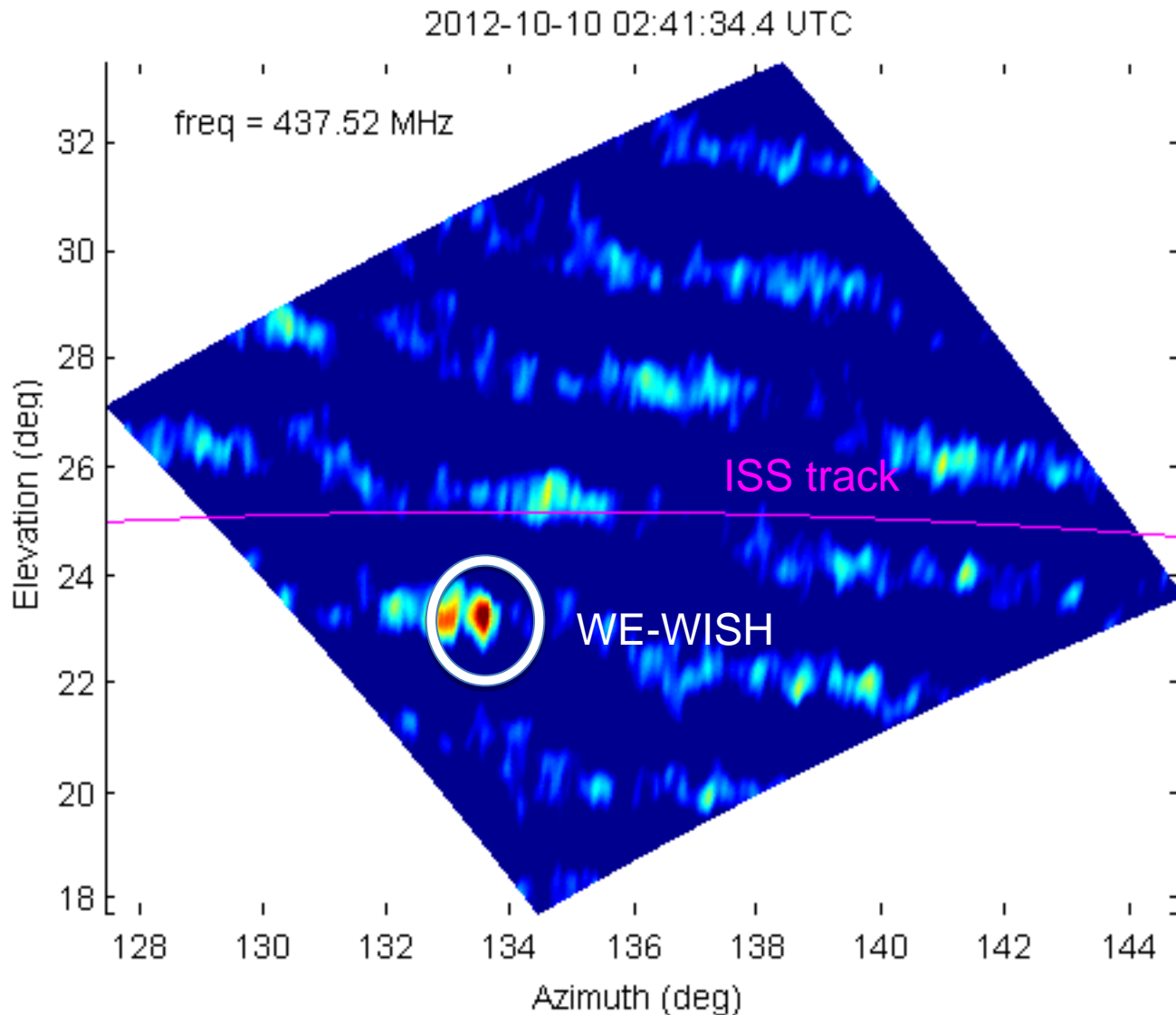
Experiment #2c: Matching CubeSats With TLEs

Results



Experiment #2c: Matching CubeSats With TLEs

Results



Experiment #3: Capturing and Decoding Data

Overview

- The ATA facility could also be utilized for high speed data downlinks from CubeSats
- By utilizing a “direct-to-disk” mode raw IQ samples are stored during a pass. After the pass these samples can be processed to extract data packets.
- In this mode the ATA is functioning like a non-realtime Software Defined Receiver
 - A computer cluster at the site will support real-time operations, after some software development

Experiment #3: Capturing and Decoding Data

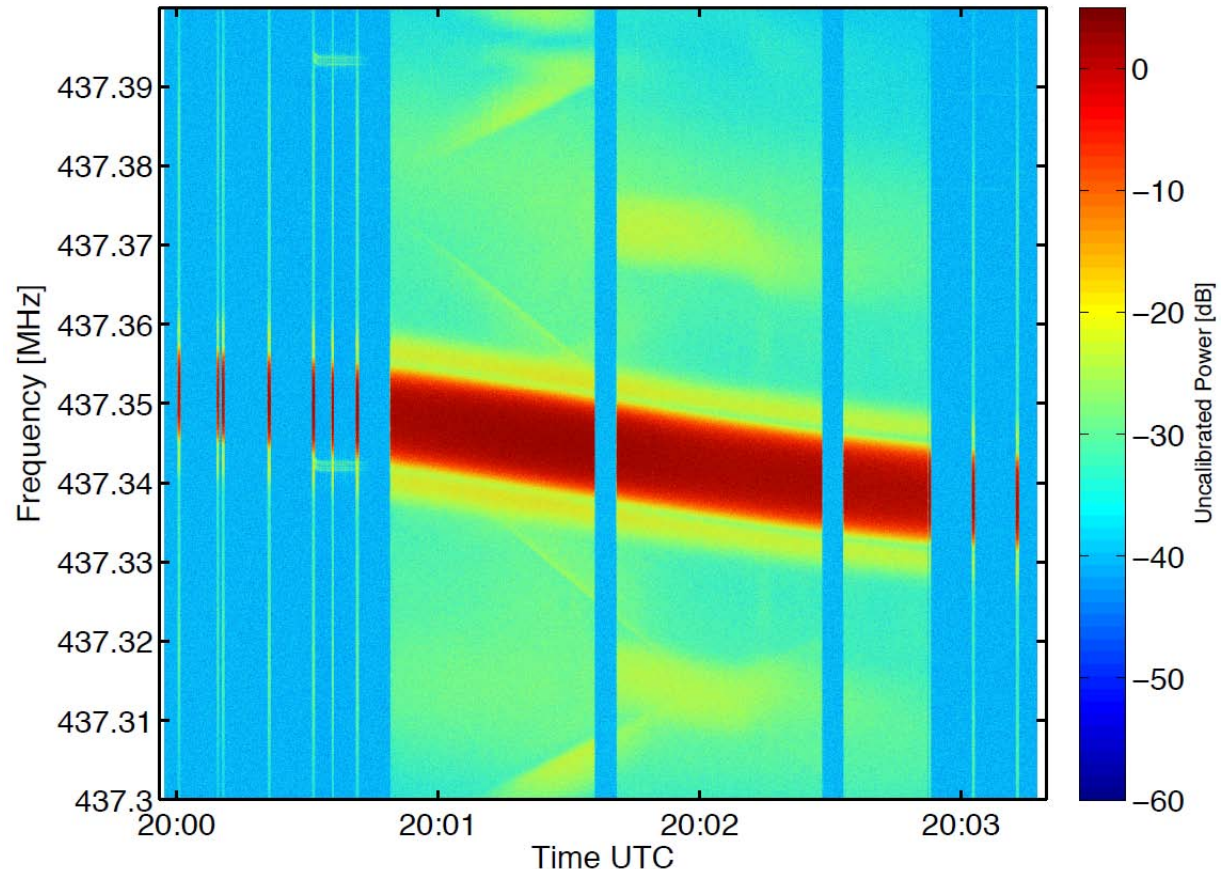
ATA Setup

- Date: August 30, 2012
- Number of Dishes: 1
- Objective: To capture data from RAX2 at the ATA during a standard downlink to the SRI Yagi station in Menlo Park

Experiment #3: Capturing and Decoding Data

Results

- Plenty of signal to decode the packets
- After some pre-processing IQ samples were sent to University of Michigan
- University of Michigan students were able to decode packets utilizing their GNU Radio framework



Summary

- A series of experiments were conducted by SRI in the fall of 2012 to evaluate the utility of the Allen Telescope Array to address CubeSat communication issues
- The experiments were highly successful even operating in a frequency region for which the ATA was not designed
- The following modes were successfully demonstrated:
 - Multiple CubeSats identified in a single pass
 - TLE to CubeSat matching
 - CubeSat downlink capture and decoding

Thank You – Questions?



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