



Mobile-to-Mobile Wireless Propagation Measurement Systems

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Overview

- Project Background/Overview
- Measurement System Description
- Measurement Locations
- Selected Measurement Results
- Alternative Measurement Approaches
- Summary and Conclusions



Short Range (Mobile-to-Mobile) Project Background

- Measure Radio Propagation Between (Mobile) Terminals Immersed in Clutter at Short Range
- $d \leq 2\text{-}3 \text{ km}$
- Low Terminal Heights (Typically $h_{t,r} \leq 3 \text{ m}$)
- Frequency Range: $\sim 150 \text{ MHz} - 6000 \text{ MHz}$
- Although All Land-Use/Land-Clutter Categories are of Interest, Urban Category has Highest Priority



Short Range (Mobile-to-Mobile) Project Background

- Pseudo Mobile Realization (Fixed Tx, Mobile Rx)

Locations so far

- Downtown Denver High-Rise Environment—deep urban canyon
- Large Parking Lot, Empty & Full, Downtown Denver, CO
- Low-Rise Urban Downtown Boulder, CO
- Rural—Country road NW of Boulder, CO
- Mixed—Residential & open Boulder, CO



The System

- Transmitter Truck-stationary
- Receiver Van-driven in prescribed patterns



Transmitter Truck



Receiver Truck



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General Features

- Measure over large frequency range: 183-5750 MHz
- Seven Channels: 183, 430, 915, 1360, 1602, 2260, and 5750 MHz
- 511 bit PN codes transmitted into the environment via binary PSK
- Transmitter/Receiver Phase synchronization maintained using Rubidium clocks
- Variable chip rates: 2, 5, 10 Mb/sec—avoid interference with other services
- Transmitted power levels 1-8 W



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Measurement Frequencies and Bandwidths

Configuration	Channel Number	Frequency (MHz)	Bit Rate (MHz)	Processing Bandwidth's		
				Max (MHz)	3dB (MHz)	Min (kHz)
Tx/Rx 1	1	430	10	20	10	19.6
	2	1350	10	20	10	19.6
	3	2260	10	20	10	19.6
	4	5750	10	20	10	19.6
Tx/Rx 2	1	183	2	4	2	3.9
	2	915	10	20	10	19.6
	3	1602.5	5	10	5	9.8
	4	5750	10	20	10	19.6



General Features cont'd

- Power-delay profiles generated using cross-correlation of transmitted and received P/N sequences
- High-fidelity time-domain information
- RMS delay spread, range, multipath effects
- We obtain frequency-domain information as well
- excess path loss, basic path loss, fading
- We can examine both broadband and narrowband fading

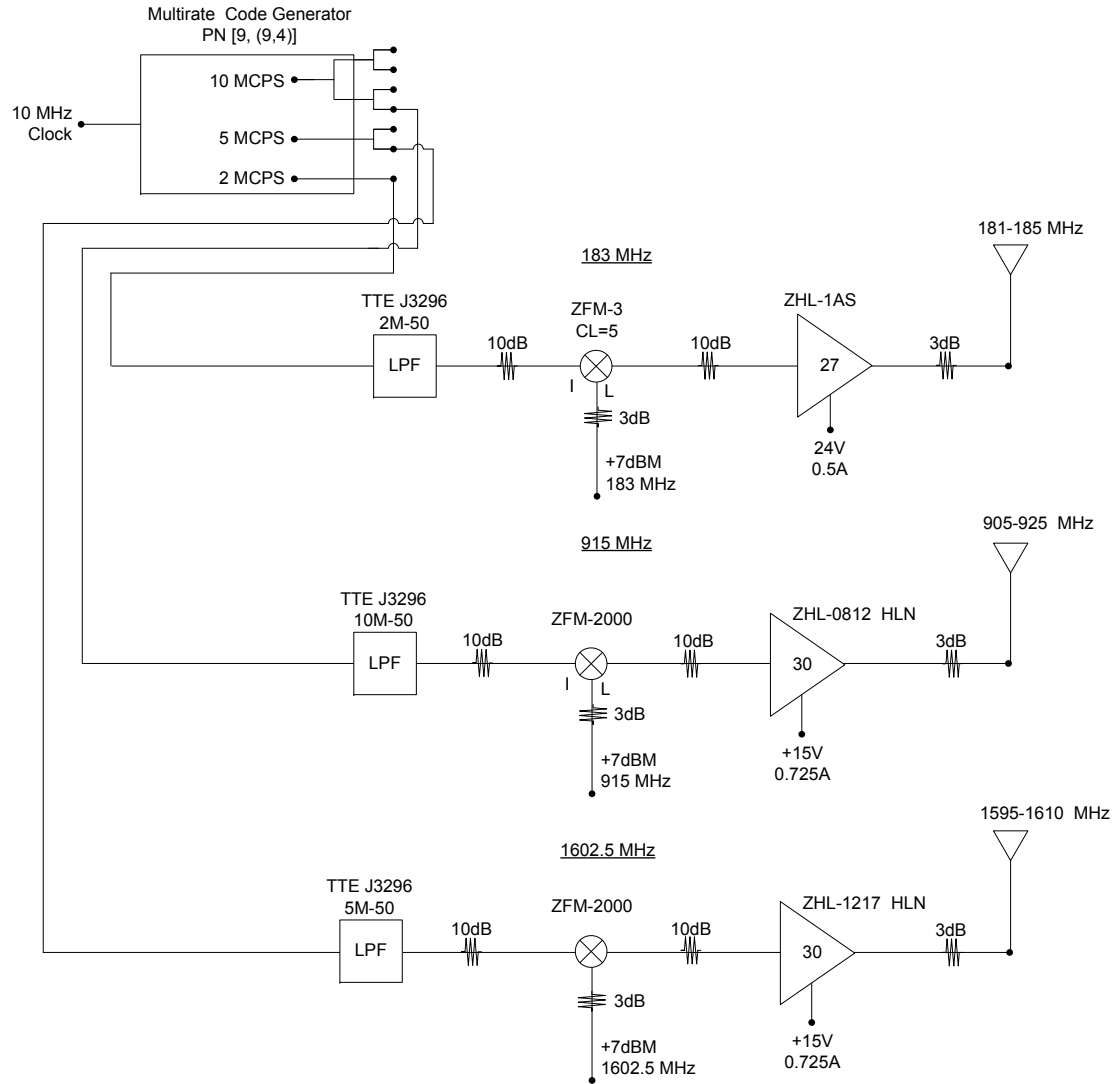


System Architecture-Transmitter

- Baseband variable chip rate codes generated by programmable COTS generator
- RF signals generated using commercial signal generators and ITS designed & fabricated boxes
- High-quality hardware used to achieve precise spectral control
- Two transmit setups, 4 channels each (5750 MHz covered twice)
- High- & low-power modes available



OSM Transmitter 2



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Transmitter Truck Interior



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Transmit Antenna Configuration-2

183, 915, 1602.5, 5750 MHz



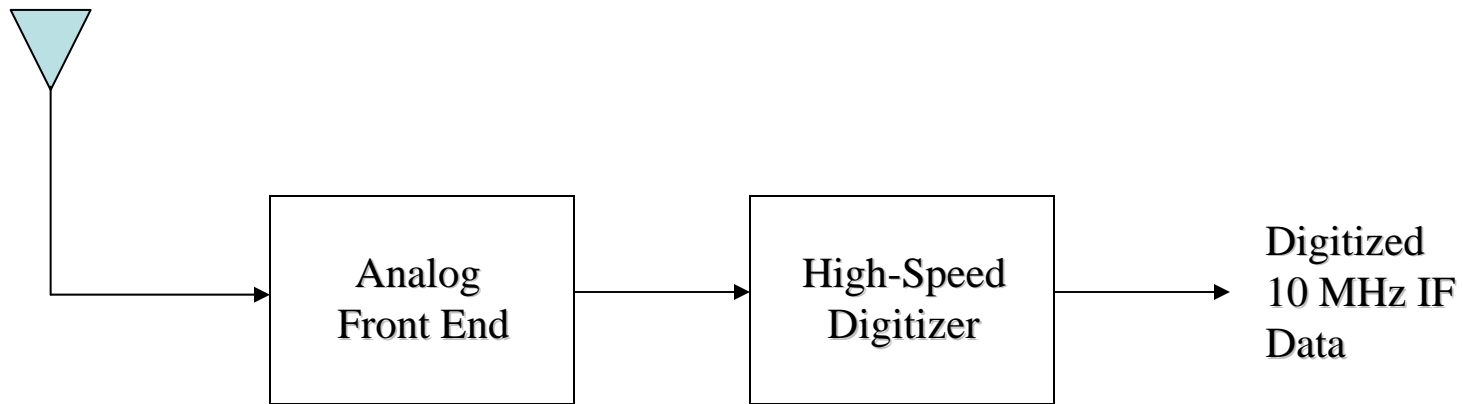


Receiver Architecture

- Dual-Conversion—150 MHz & 10 MHz IF frequencies
- Analog front end custom-built and fabricated by ITS engineers
- High-quality components (mixers, filters, amplifiers, cables)
- Designed to maximize linearity & dynamic range
- Fixed gain design to capture rapidly-changing propagation effects encountered in complex propagation environments
- High-speed 40 Ms/sec digitizer to capture 4 channels simultaneously



Receiver Architecture

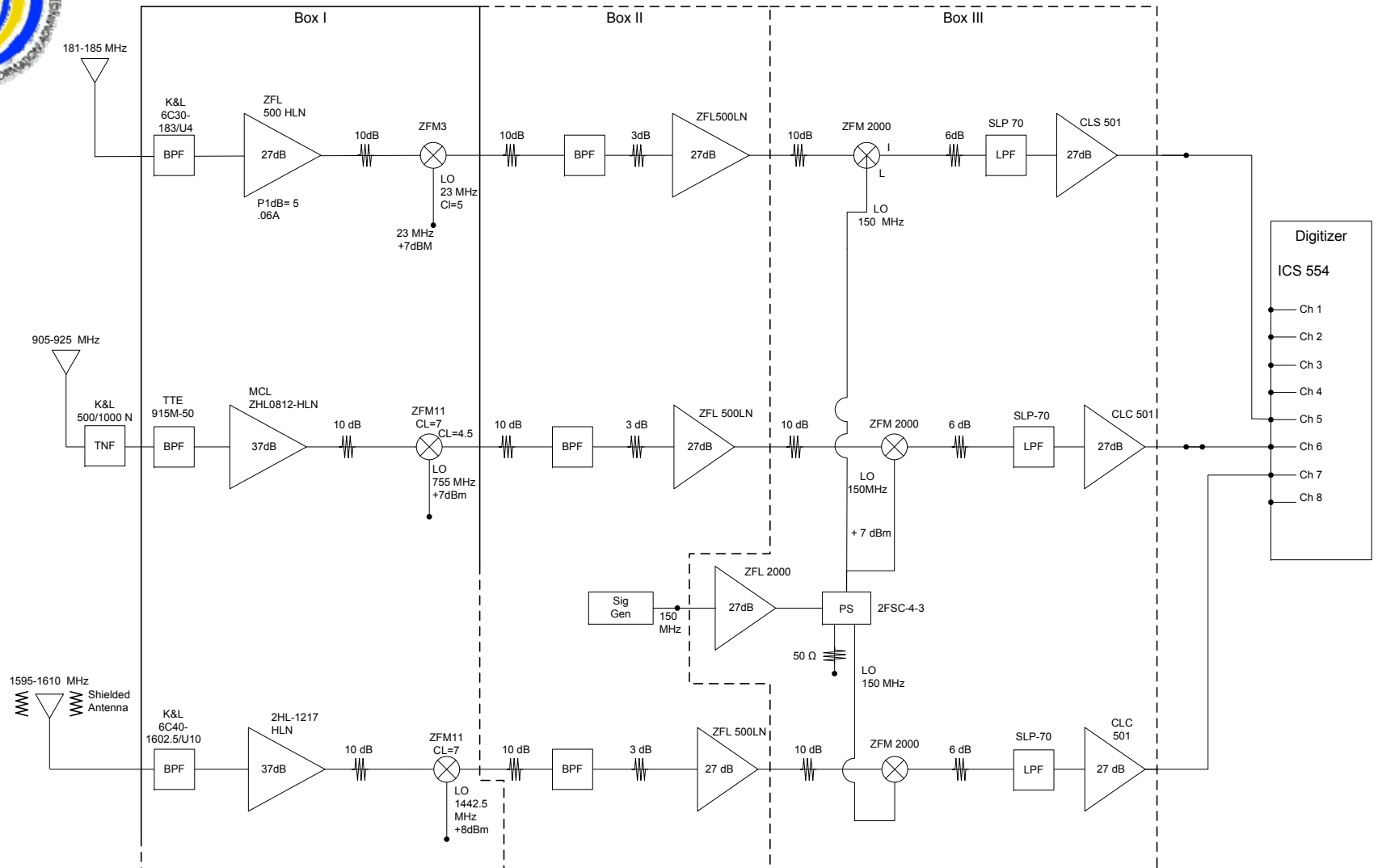


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OSM Receiver 2



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Receiver Truck Interior



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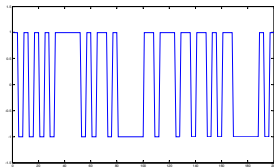


Digitizer

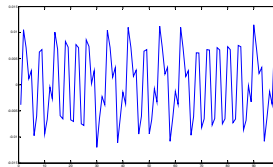
- High-speed 14-bit ADC
- ITS designed & fabricated FPGA timing board
- Windows-controlled PC & 300 GB raid array
- Custom Labview program for data acquisition
- Acquires data on the fly
- 4 channels



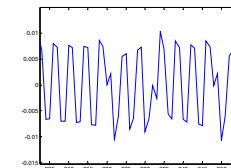
The Process



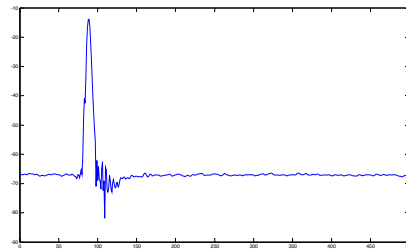
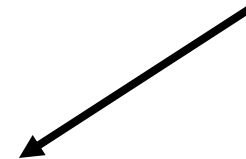
PN sequence input



Digitized 10MHz IF



Baseband PN Sequence



Channel Impulse Response



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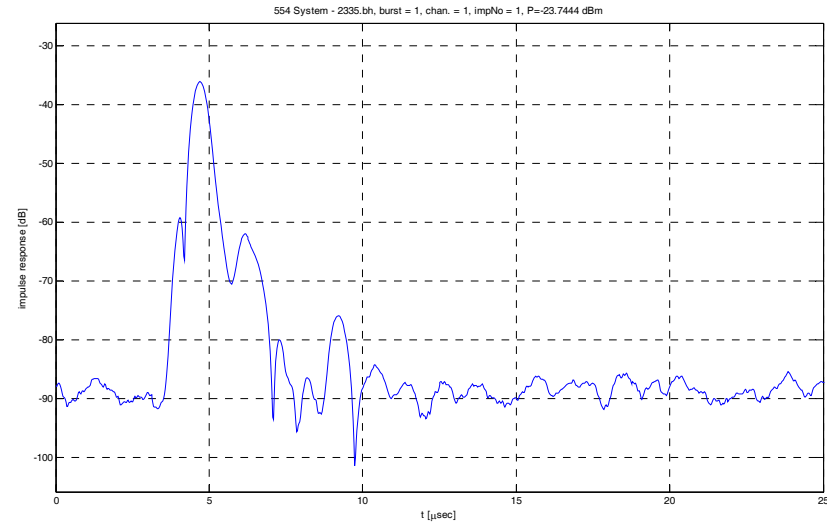
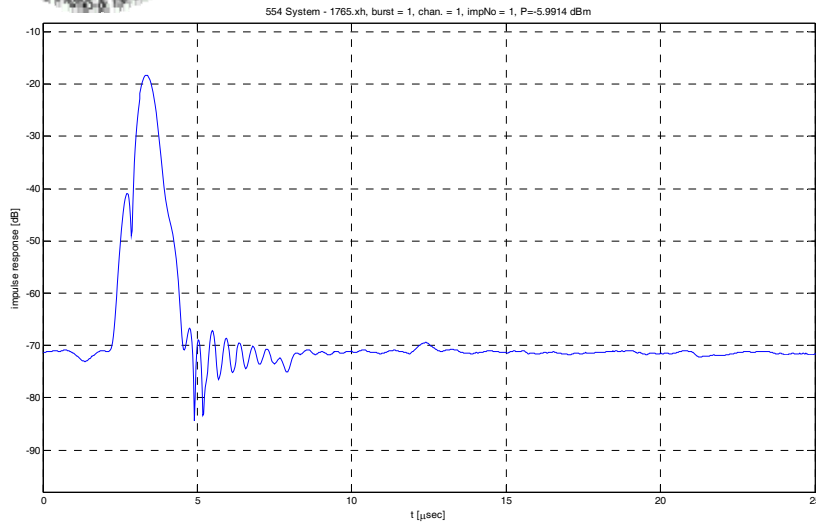
Boulder, Colorado



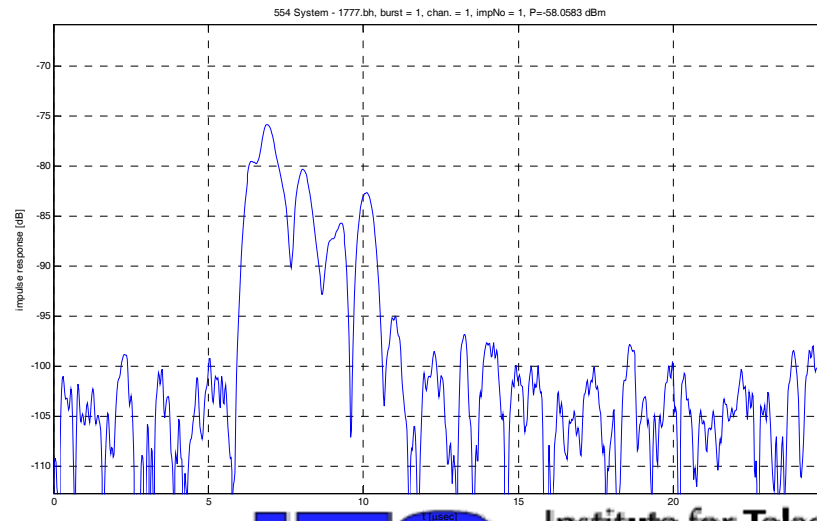
Sample Waveforms—Time Domain

Thru Calibration-183 MHz

Rural-183 MHz



**Downtown
Denver-183 MHz**

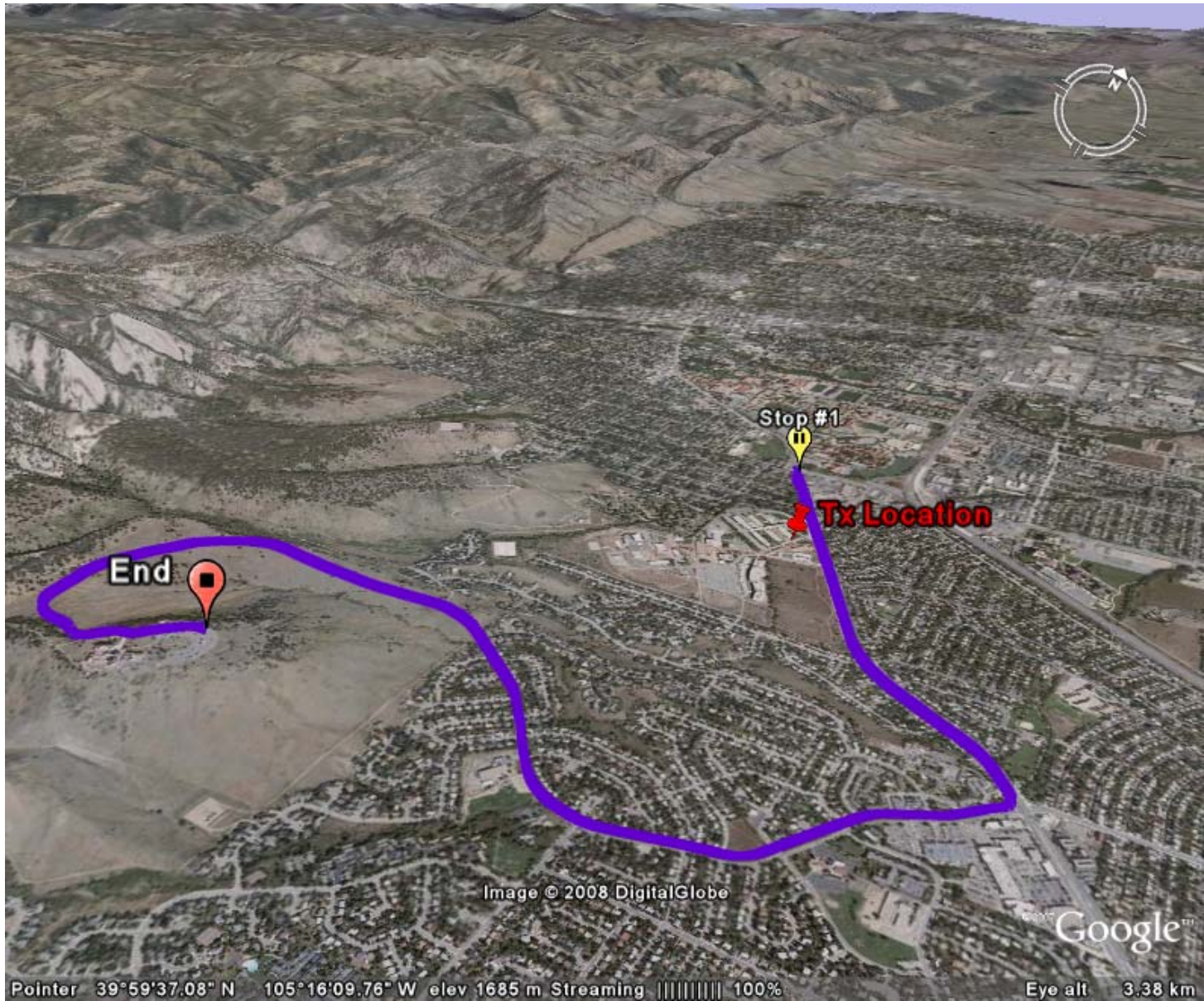


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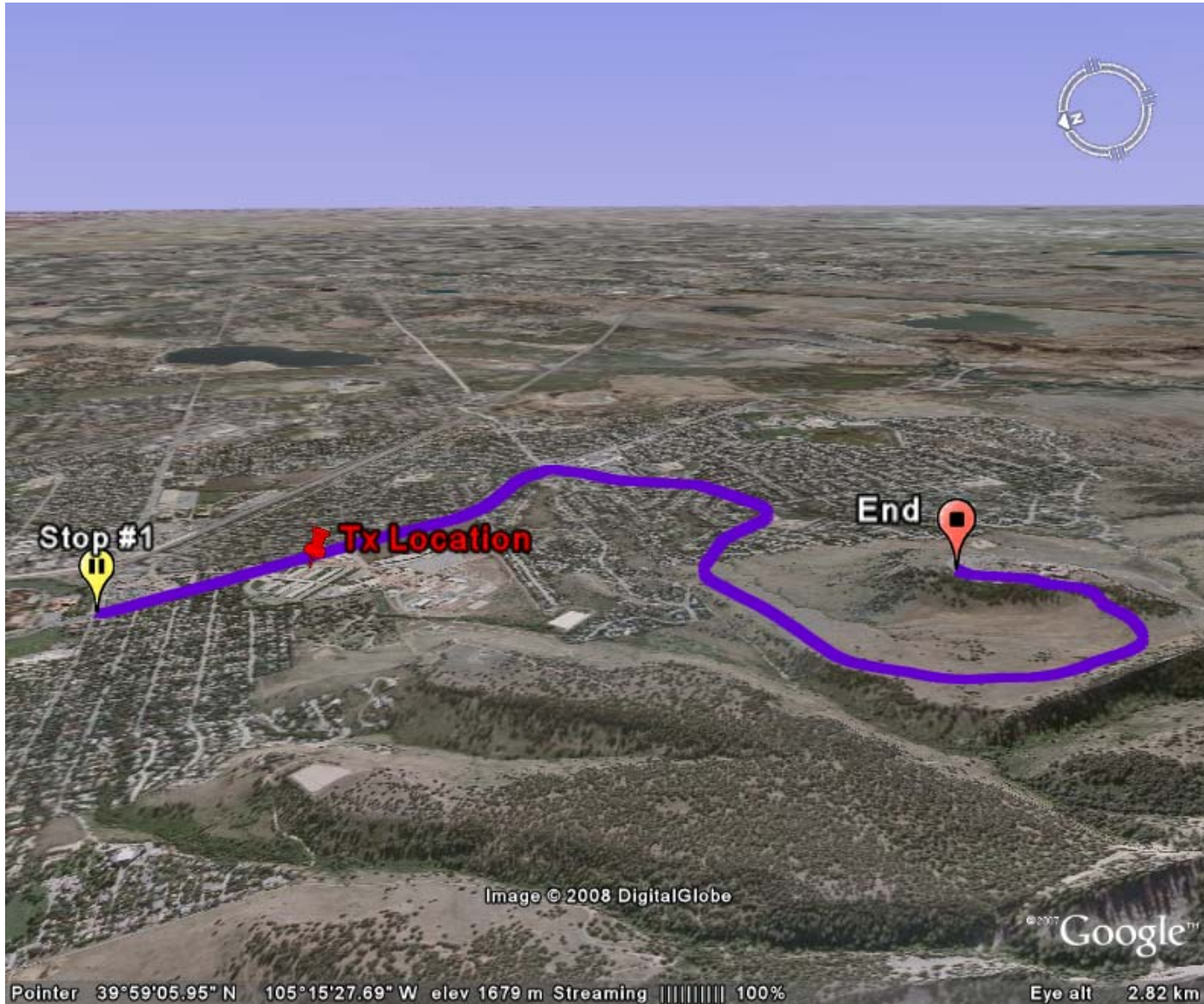
Boulder, Colorado



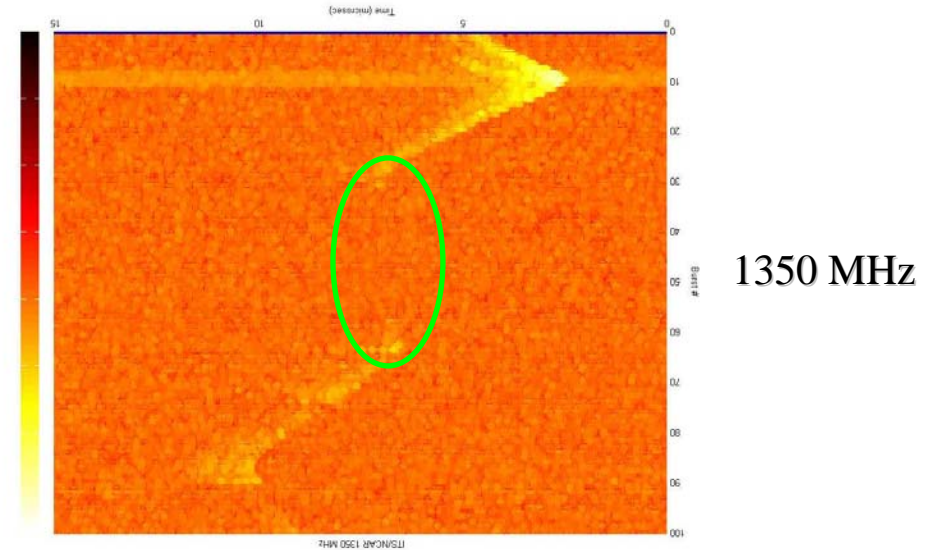
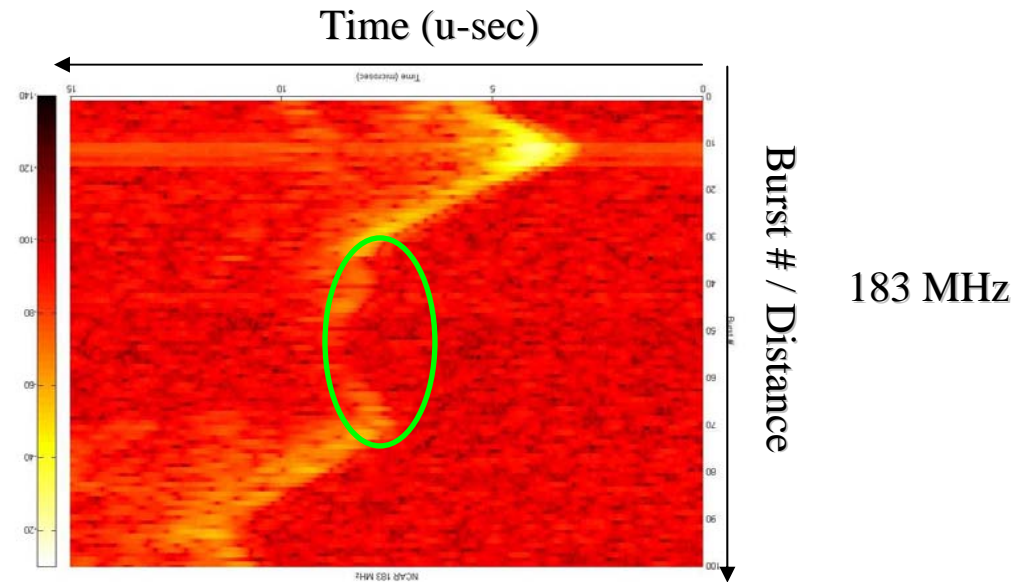
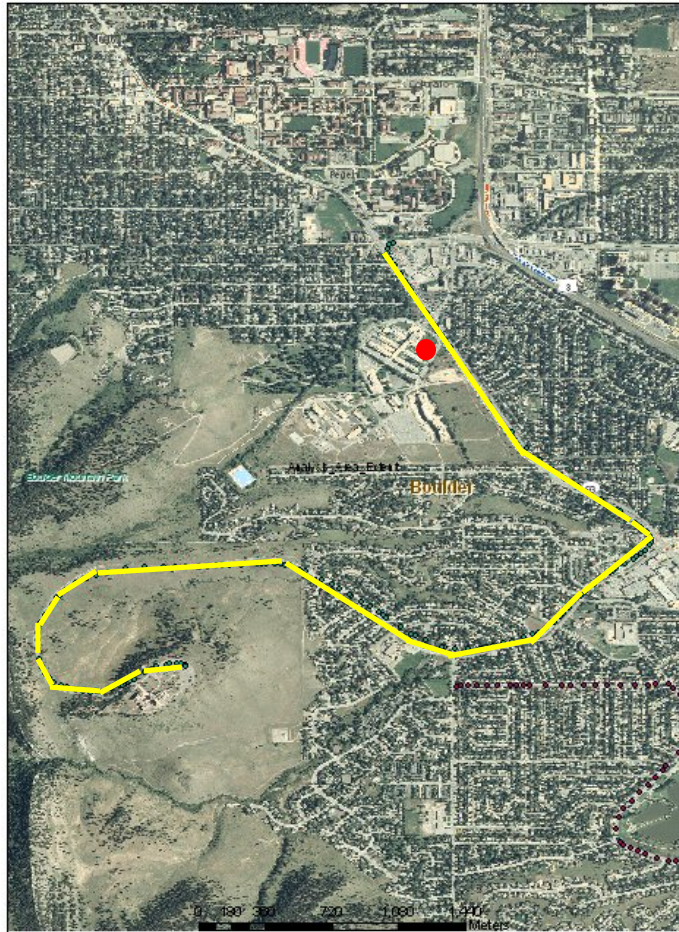
A Drive to NCAR



Boulder, Colorado

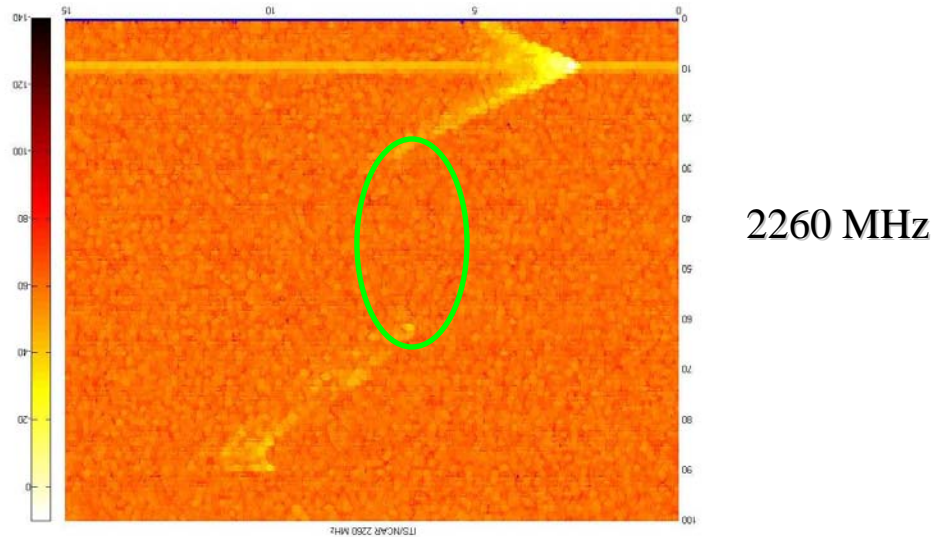
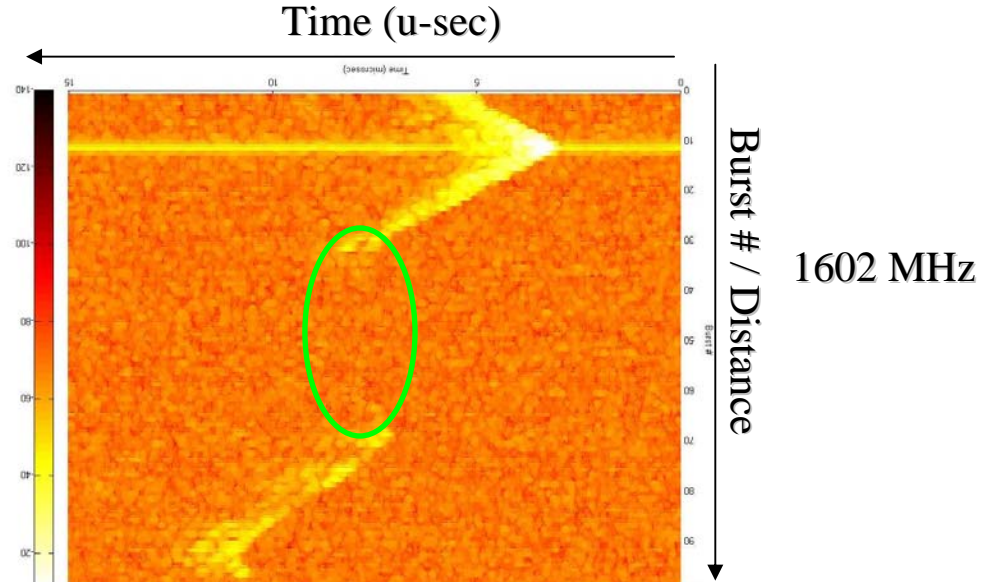
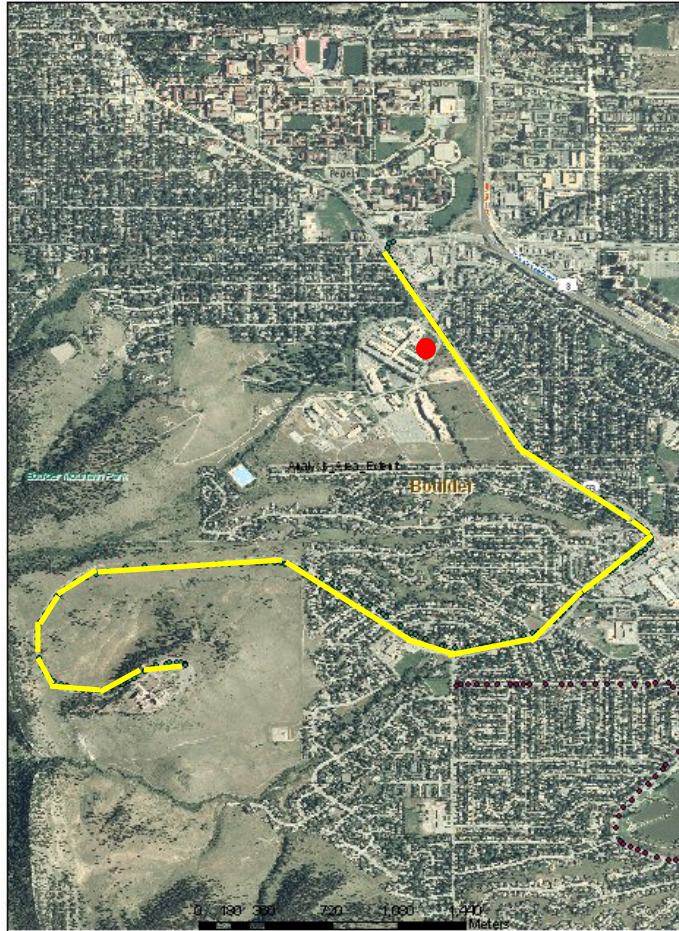


A drive to NCAR—Impulse Signal Levels





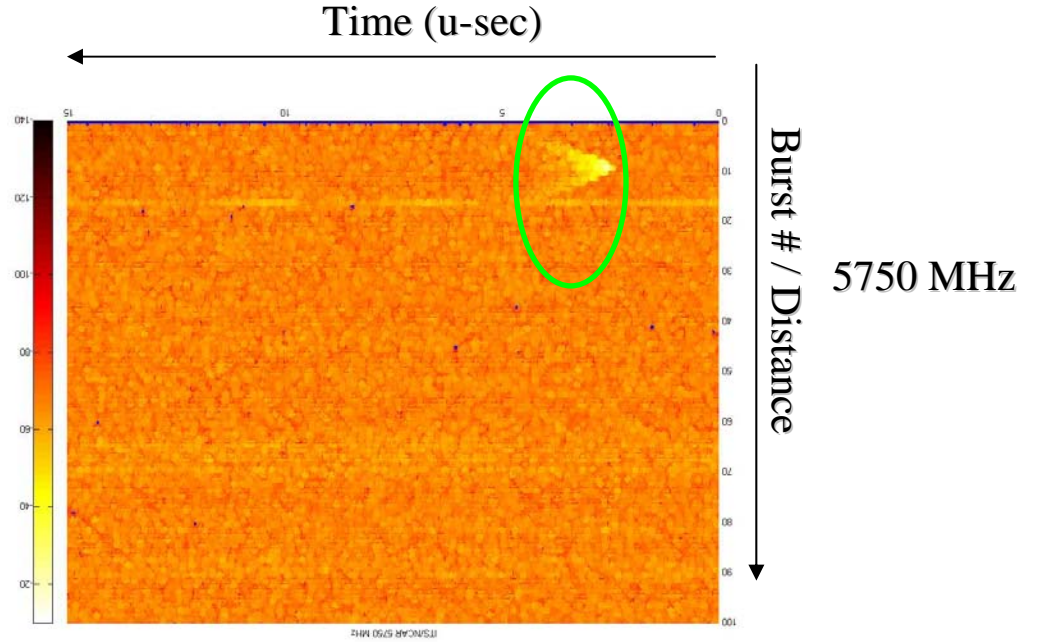
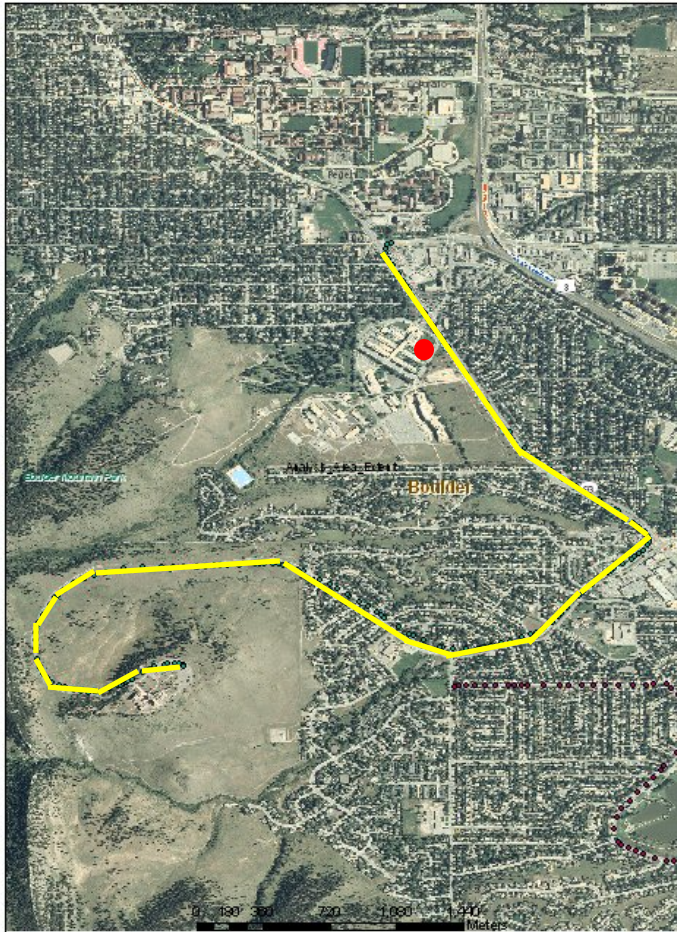
A drive to NCAR—Impulse Signal Levels—cont'd



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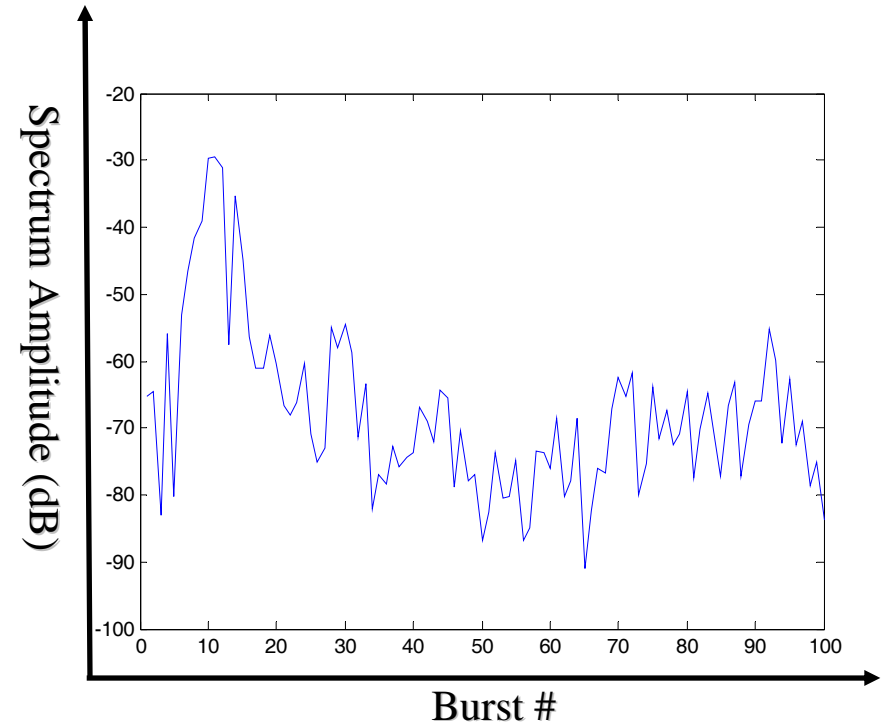
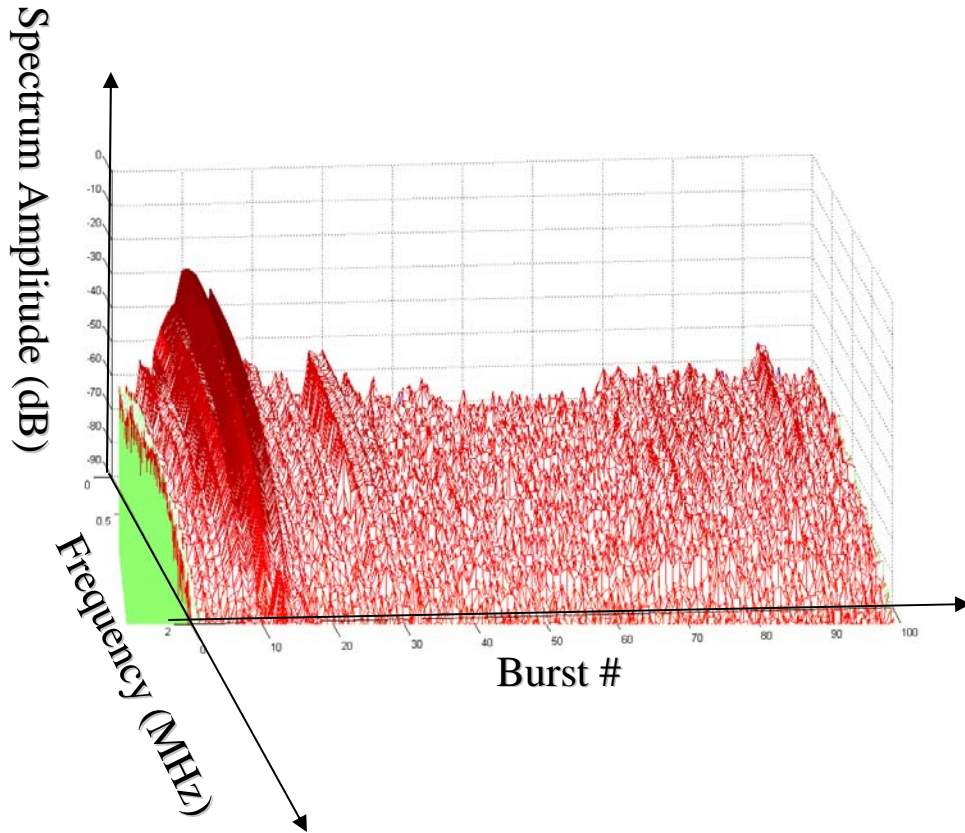
Boulder, Colorado

A drive to NCAR—Impulse Signal Levels—cont'd





NCAR Run 183 MHz—Narrowband Response





Downtown Denver



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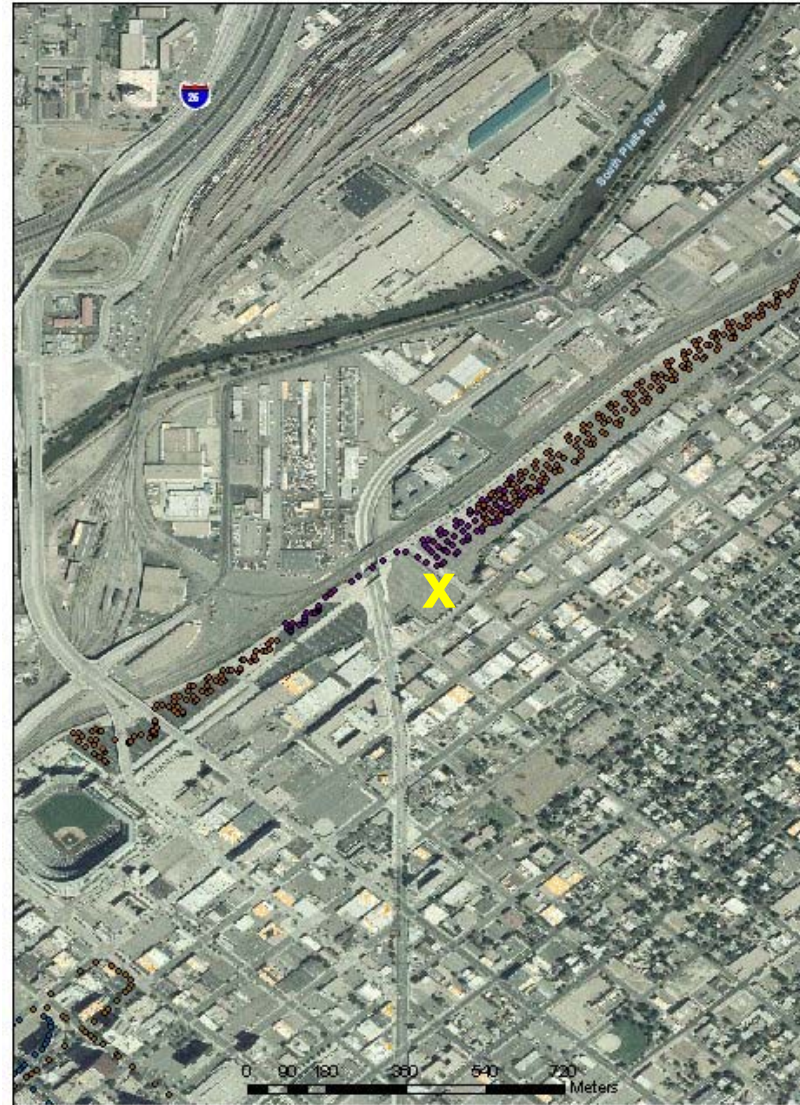


Downtown Denver Measurement Locations



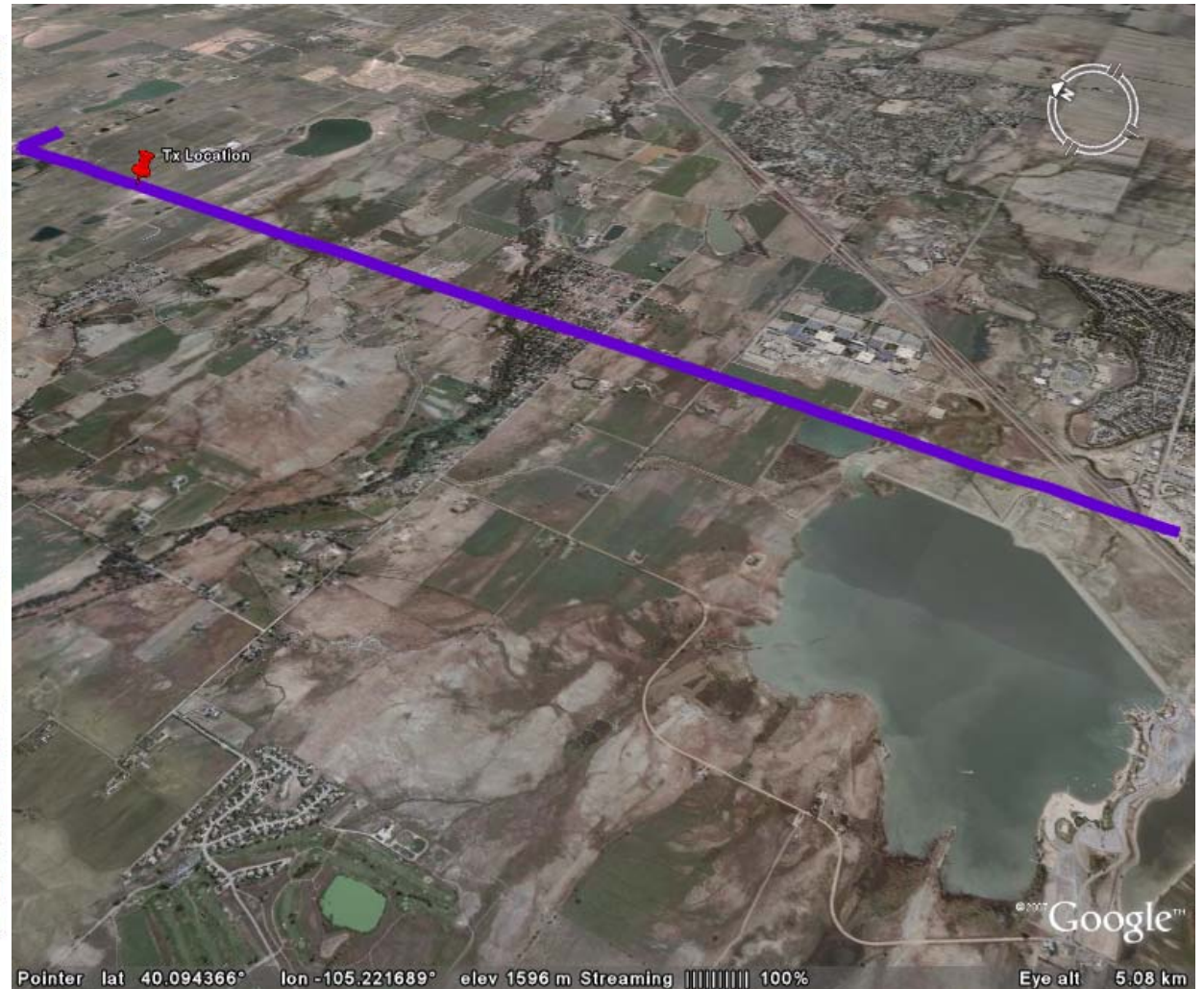
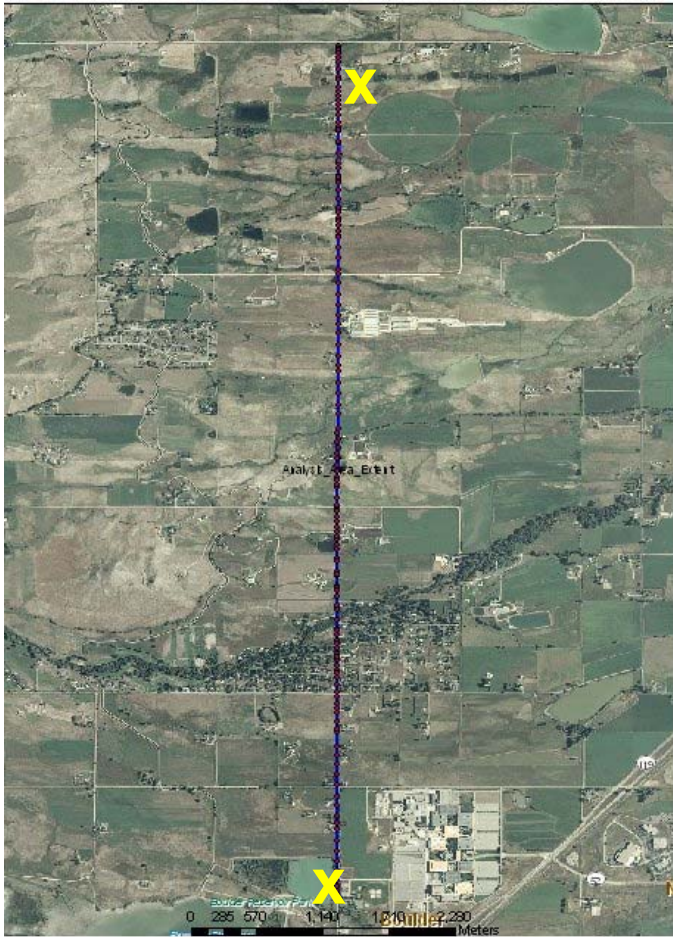


Parking Lot Measurement Locations Coors Field Downtown Denver





Rural Country Road Boulder County

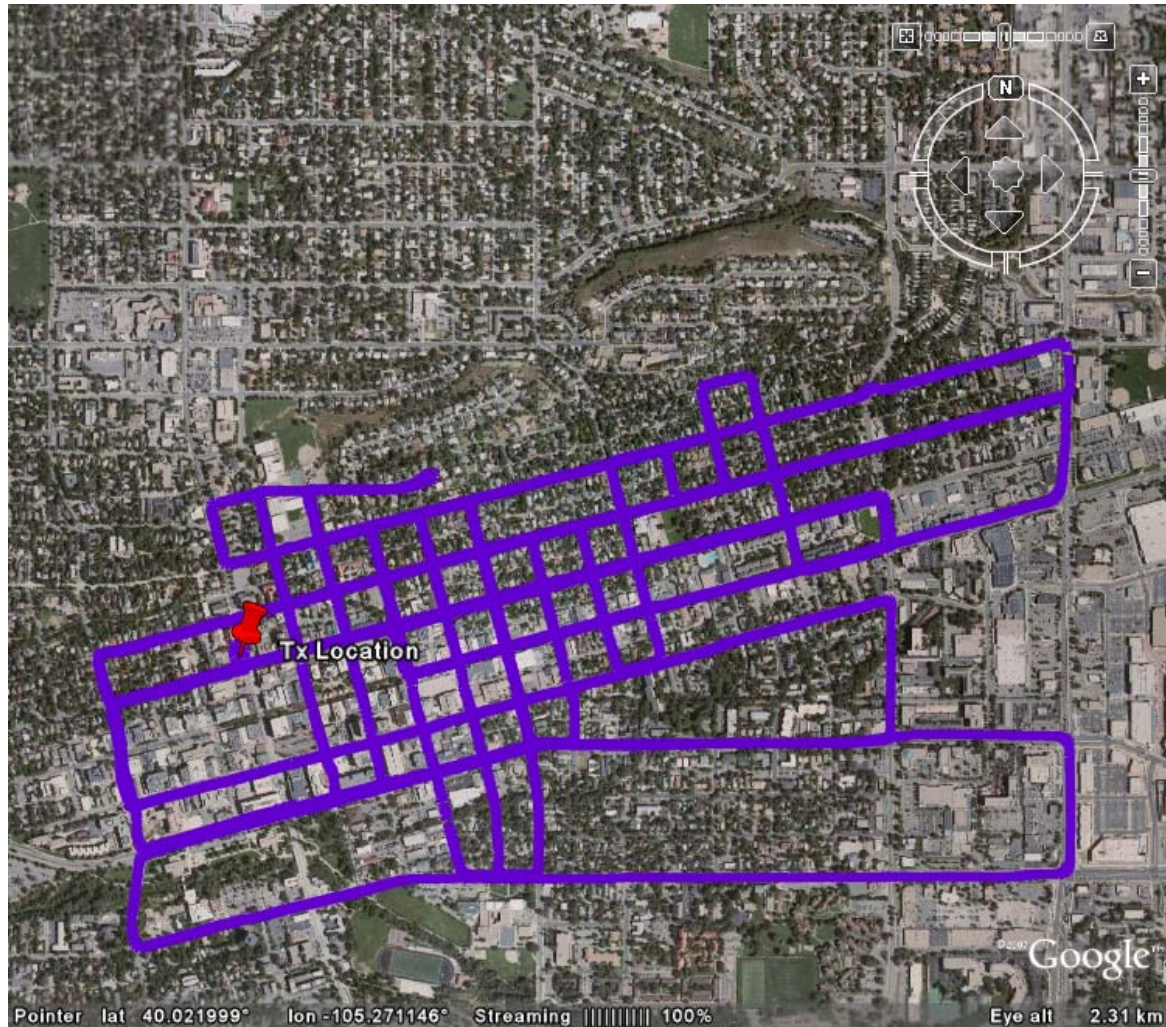


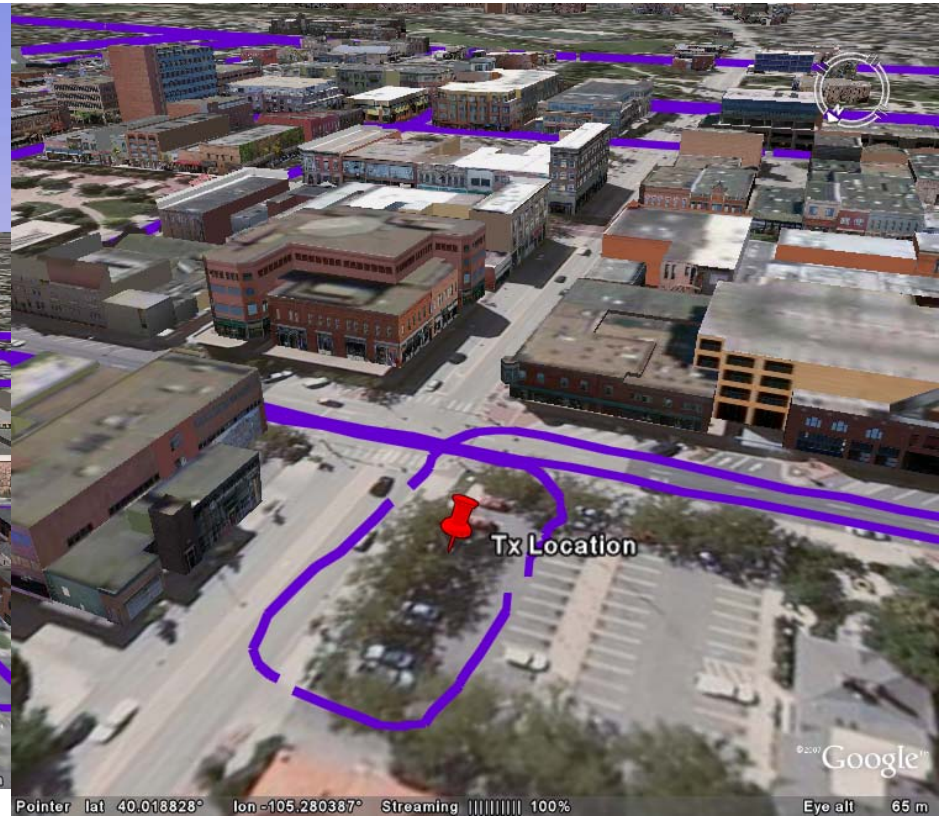
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Low-Rise Urban Downtown Boulder, CO







Broadway and Spruce Streets--Boulder





Wells Fargo Bank Downtown Boulder Transmitter Location With 2-3 Story Urban Corridor





Ryssby Church 63rd Street Transmitter Location With Rural Environment Showing Measurement Path





Measurement Vans at Ryssby Church 63rd Street Transmitter Location With Rural Environment





Measurement Vans at Coors Field Parking Lot





Auraria Campus Transmitter Site Next to Downtown Denver Medium-Rise Urban Environment



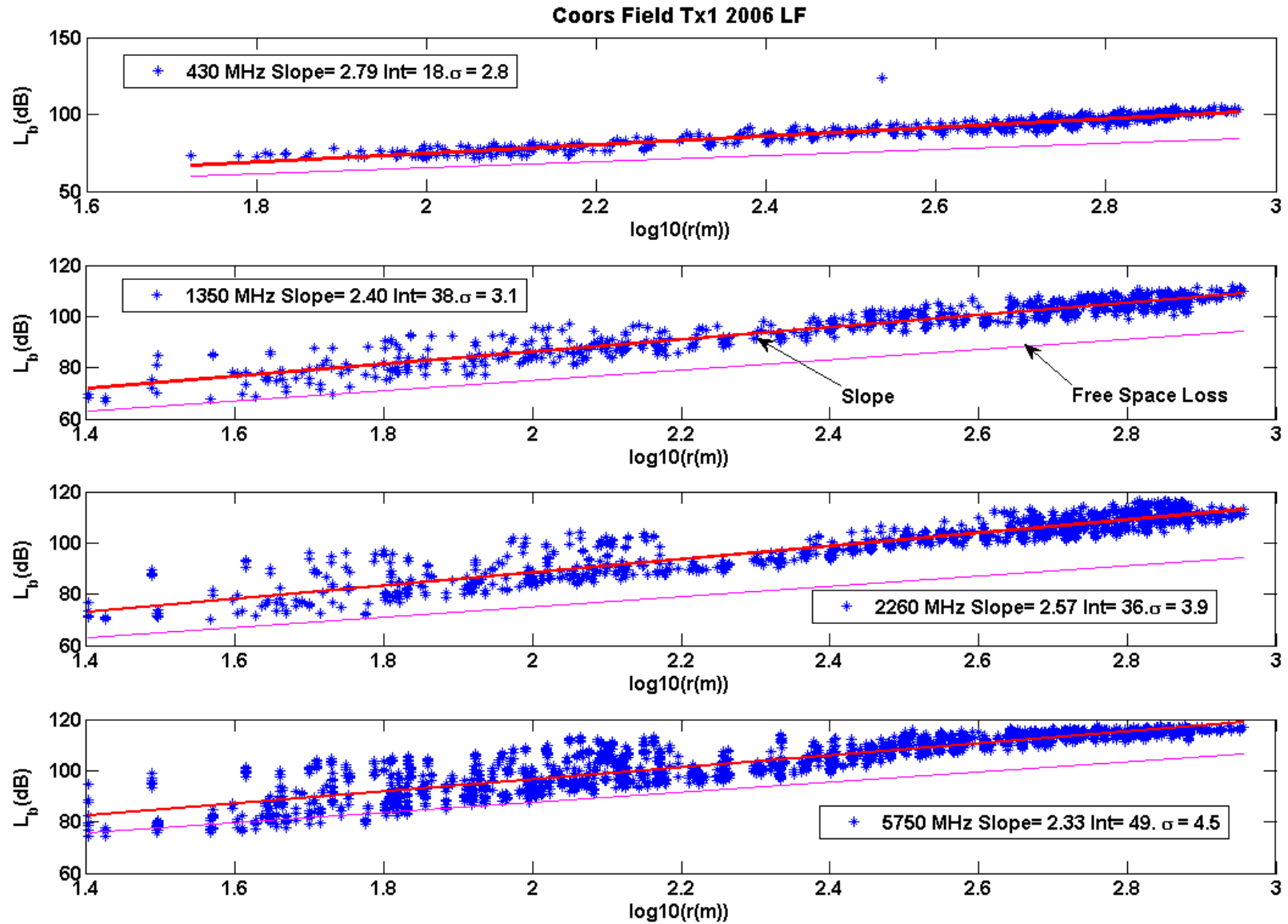


Sample Data Run – Coors Field, Transmitter 1



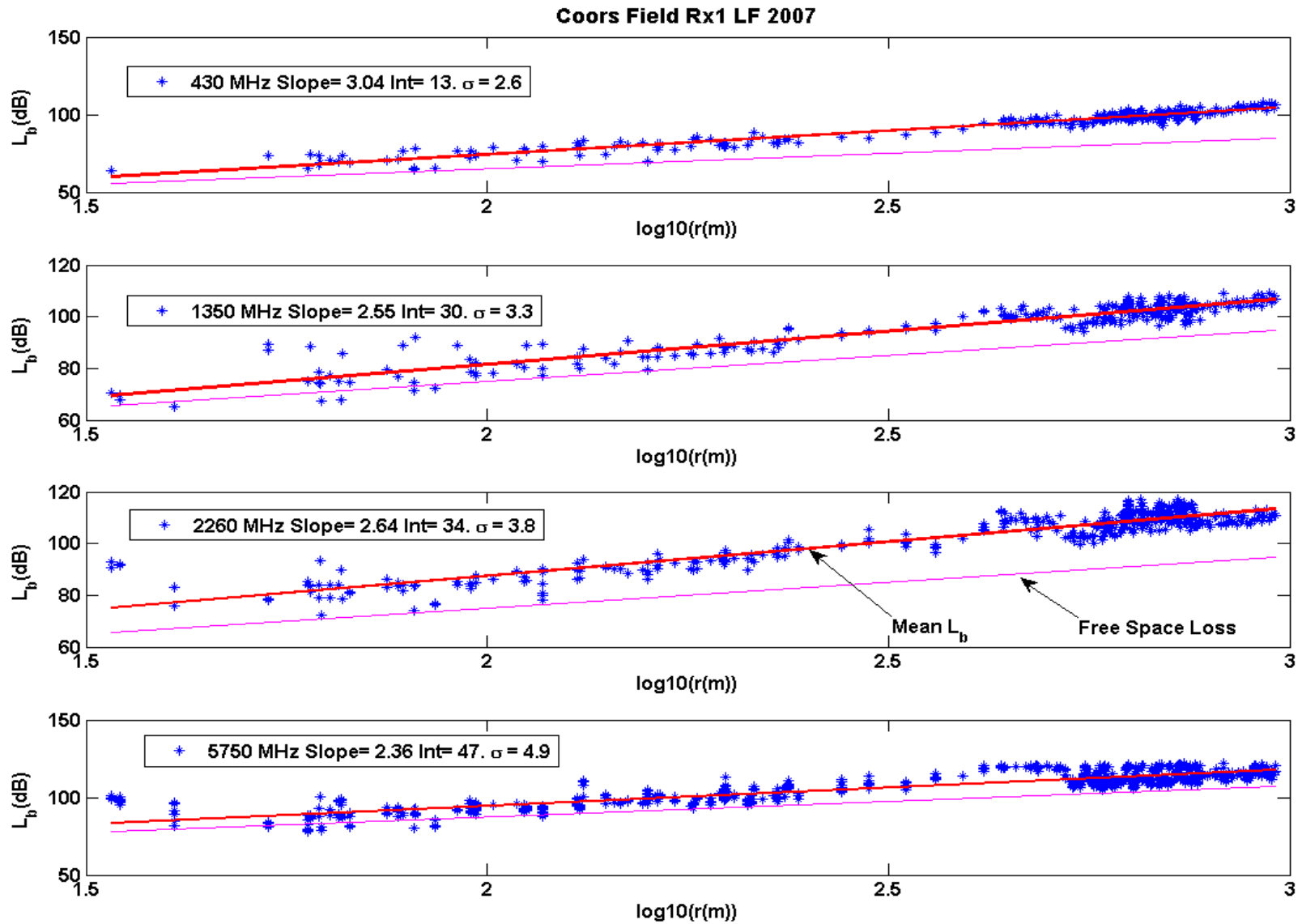


Basic Transmission Loss Coors Field Lot Full 2006





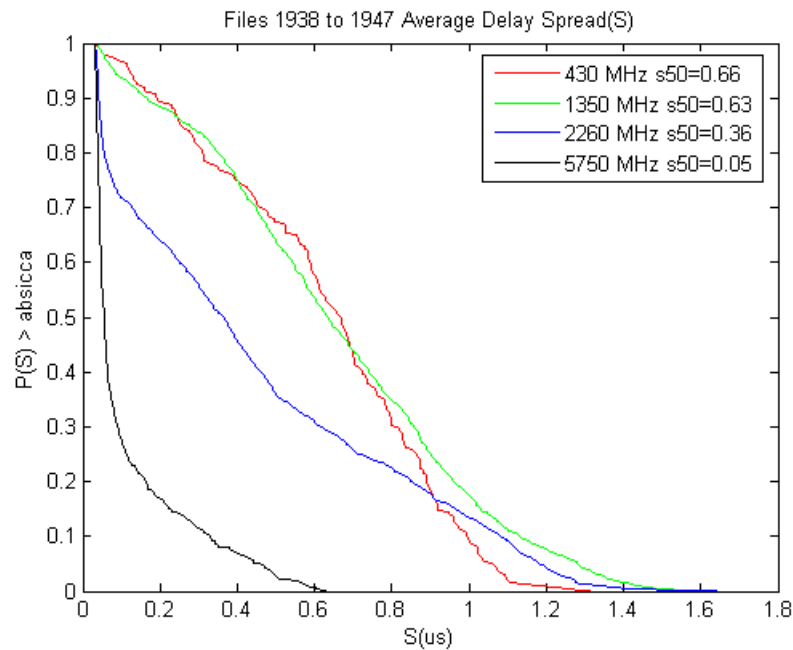
Basic Transmission Loss, Coors Field, Lot Full 2007



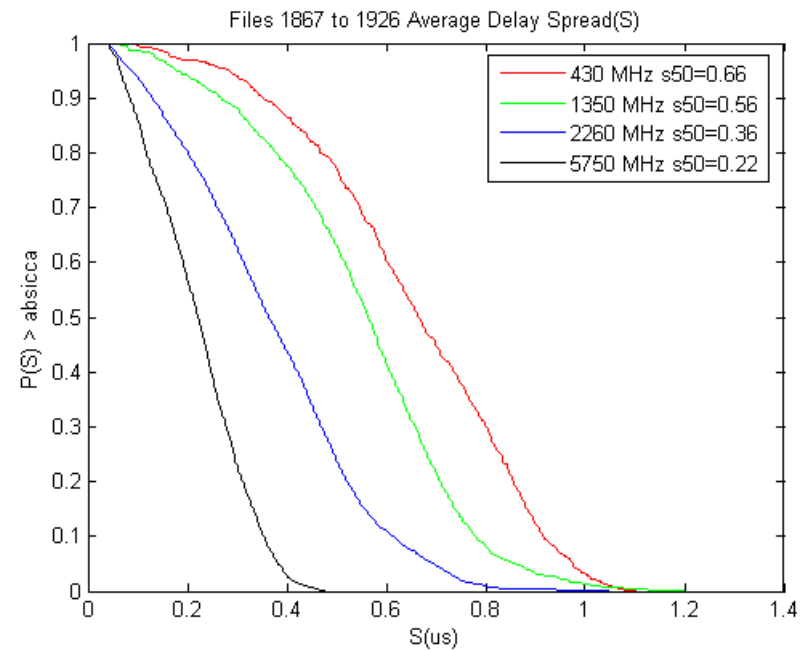


Downtown Denver: Auraria Campus (Tx Site), Speer Blvd. and High Rise Routes, Delay Spreads

Speer Blvd.



High Rise



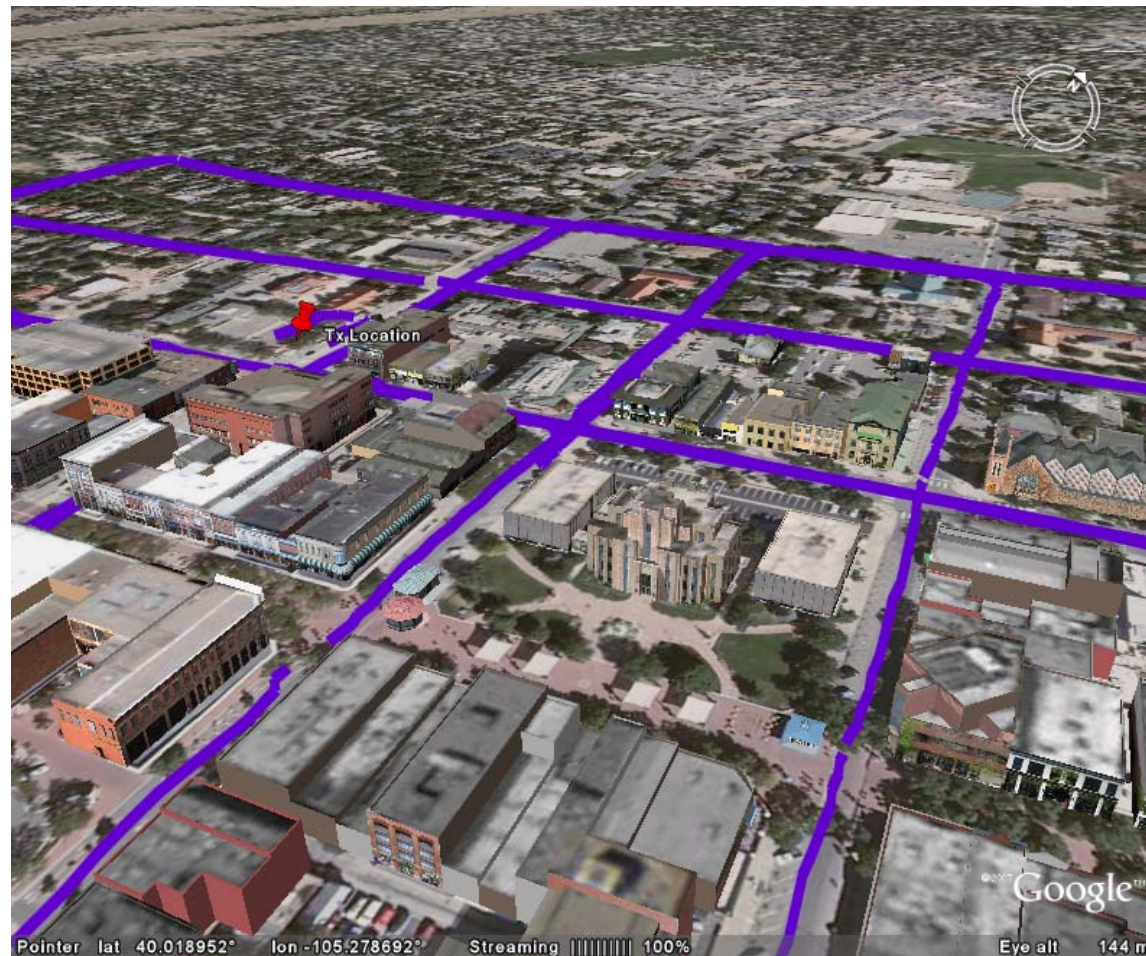


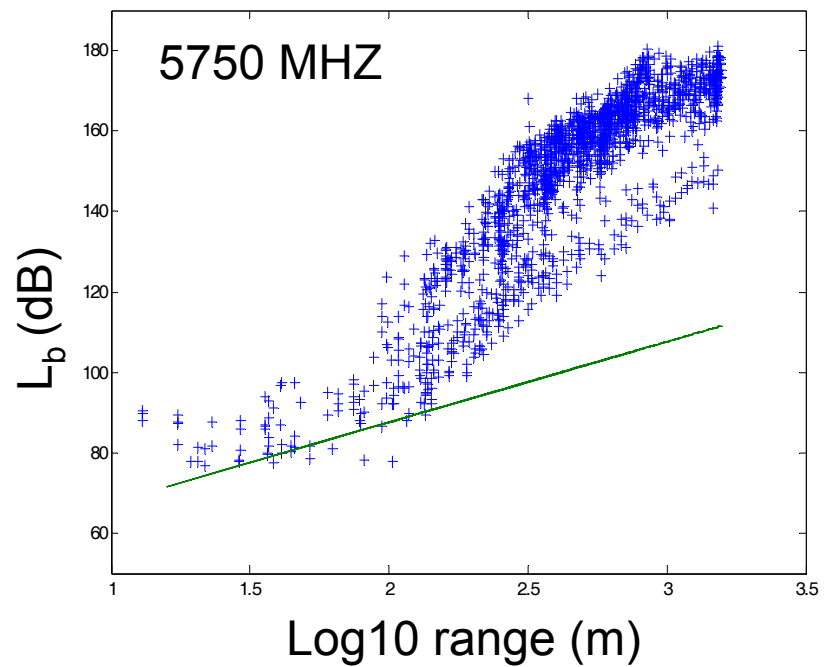
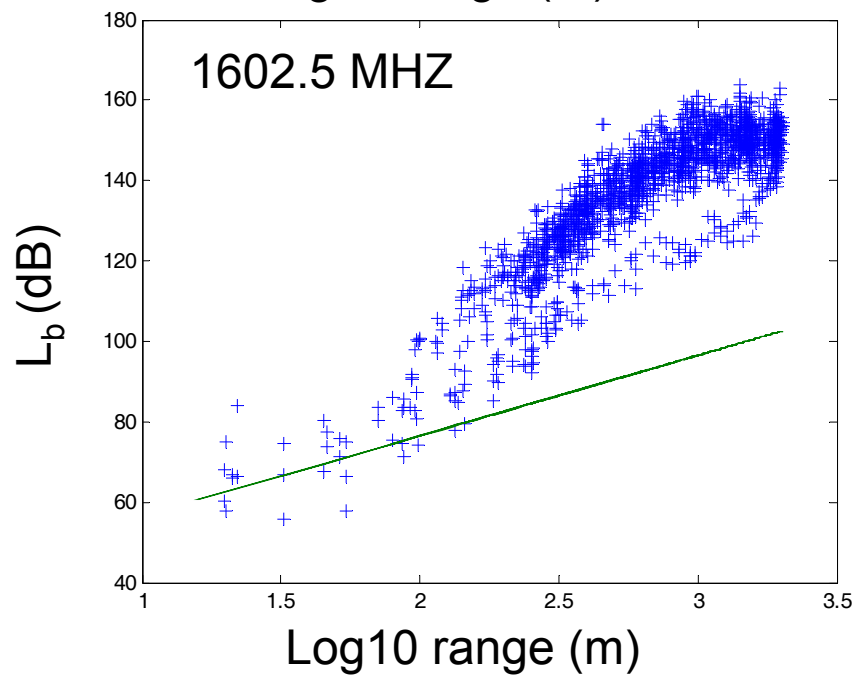
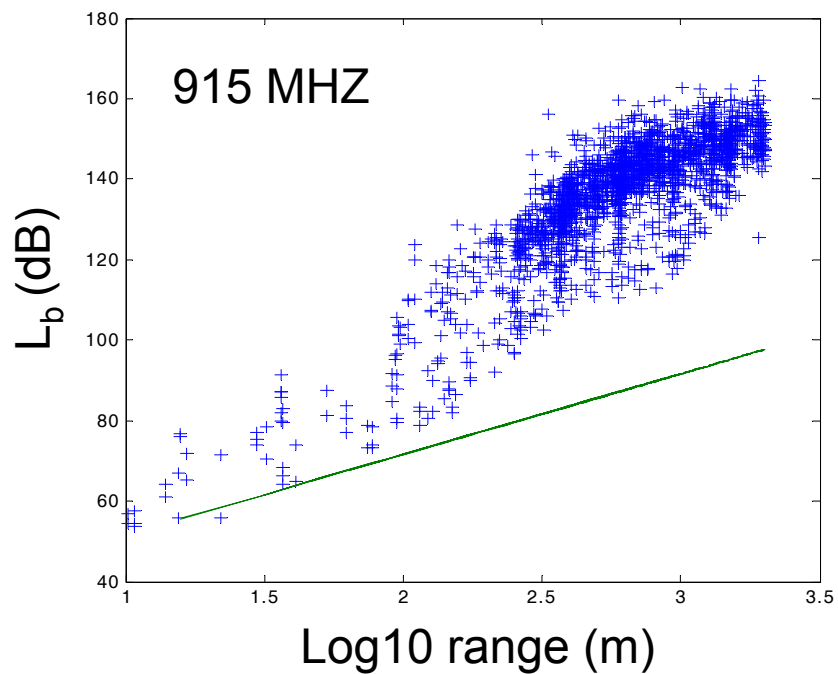
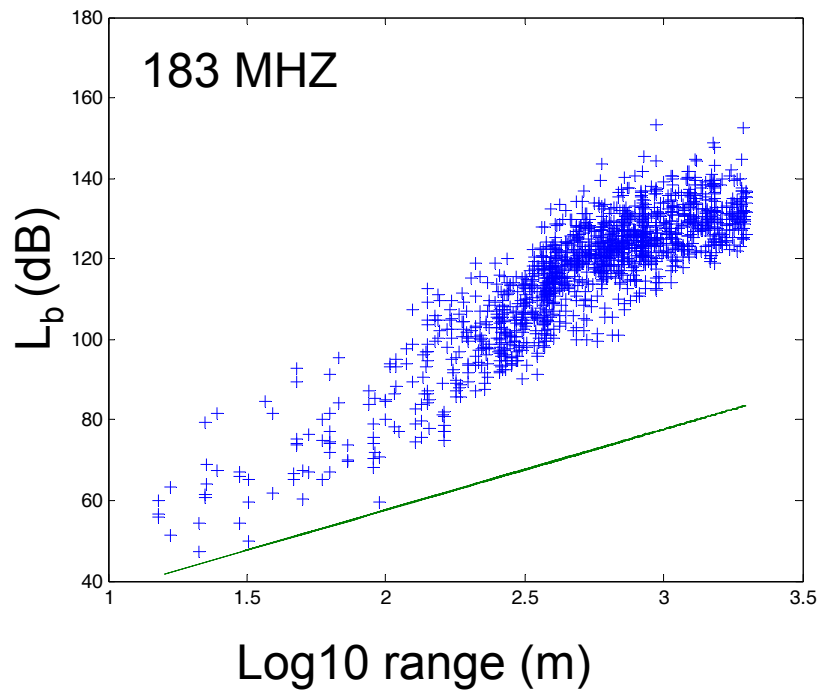
Alternative Measurement Methods

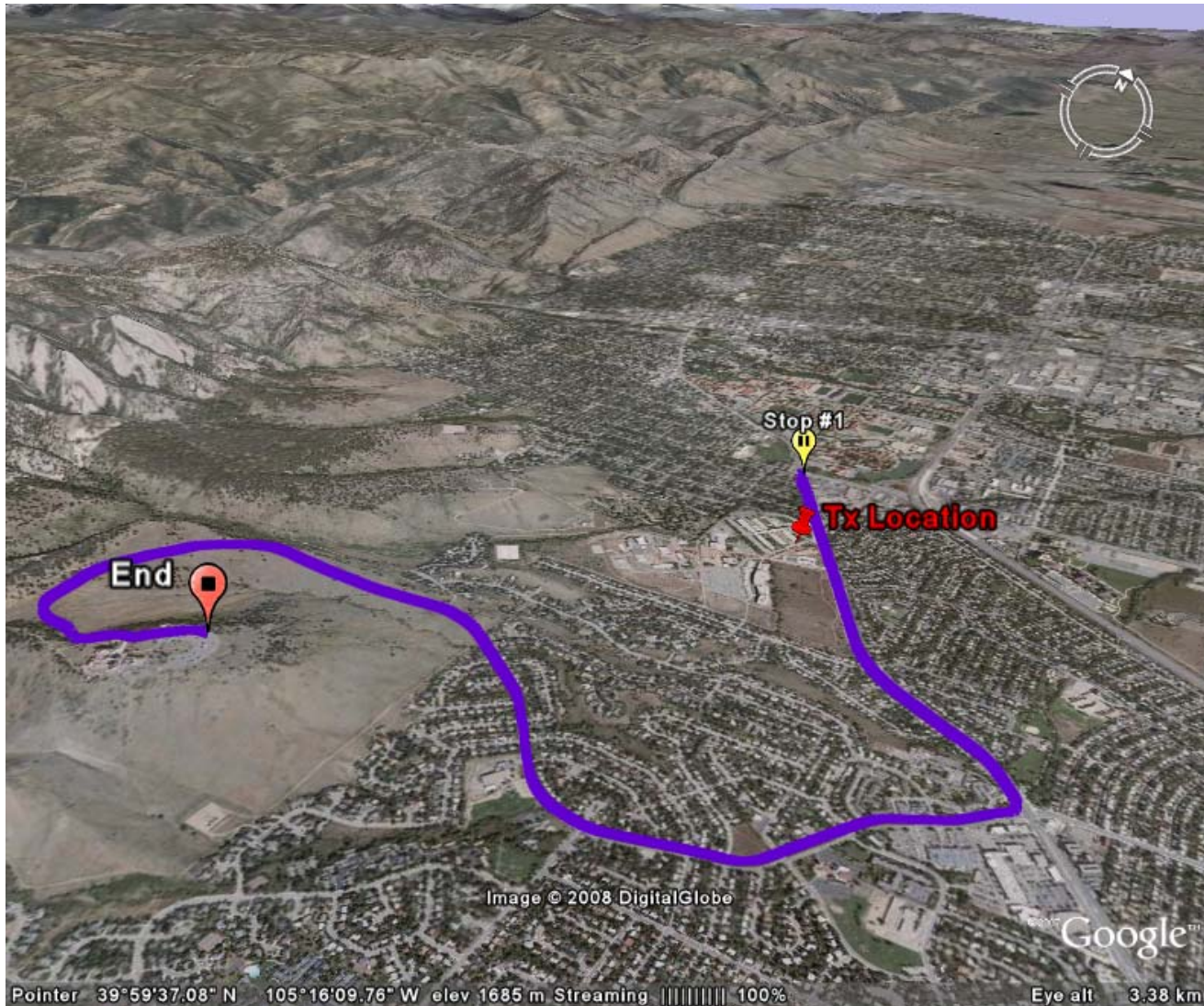
- Interference Immunity—problems with the wideband system at certain frequencies
 - Improved Sensitivity/Dynamic Range
 - Fast Fading & Doppler Spreading
 - Provide Traceable Measurement
-
- Spectrum Analyzer & GPS logger
 - Sound Card/Receiver Method

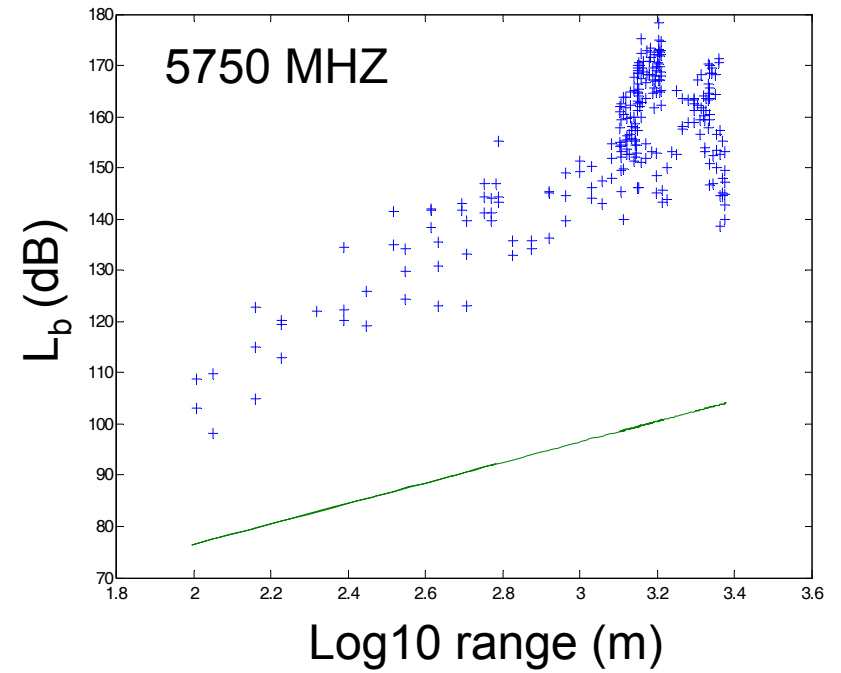
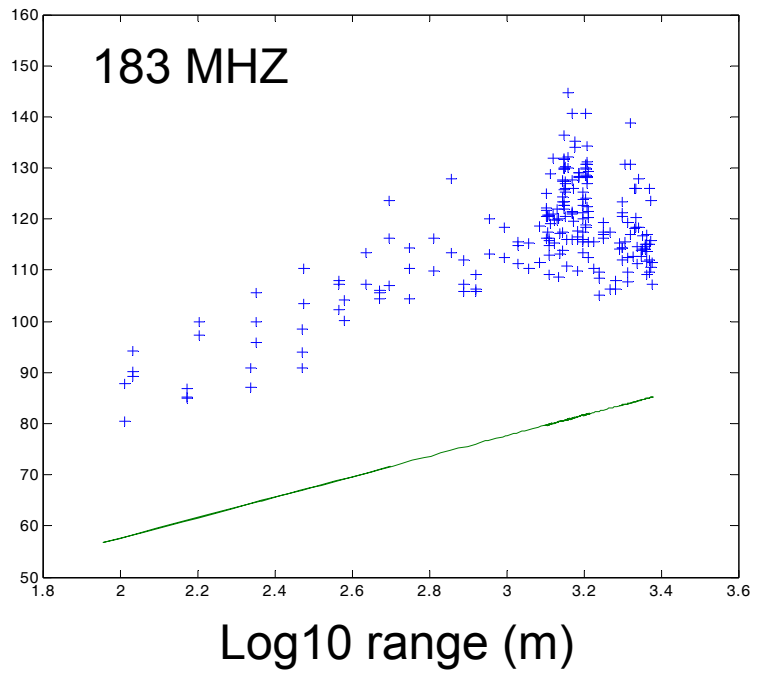


Spectrum Analyzer Results Downtown Boulder





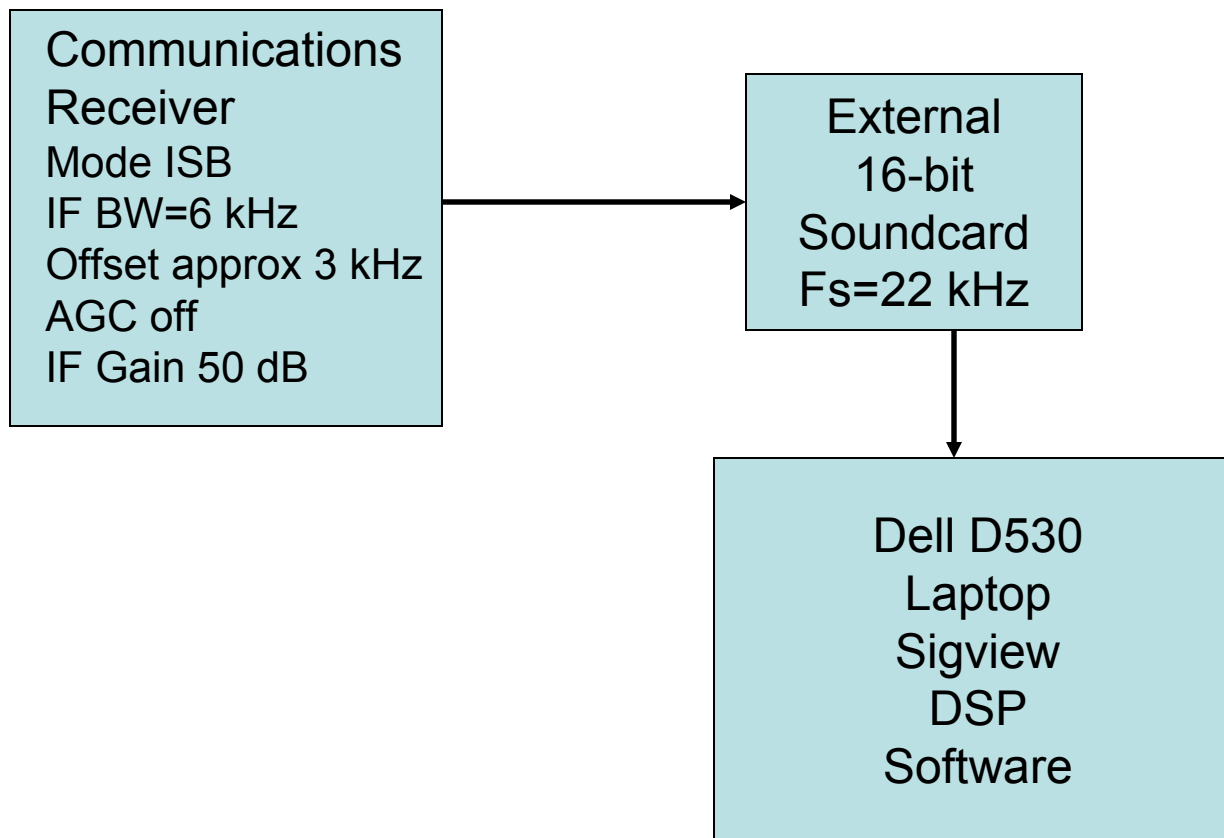






Soundcard/Receiver Method

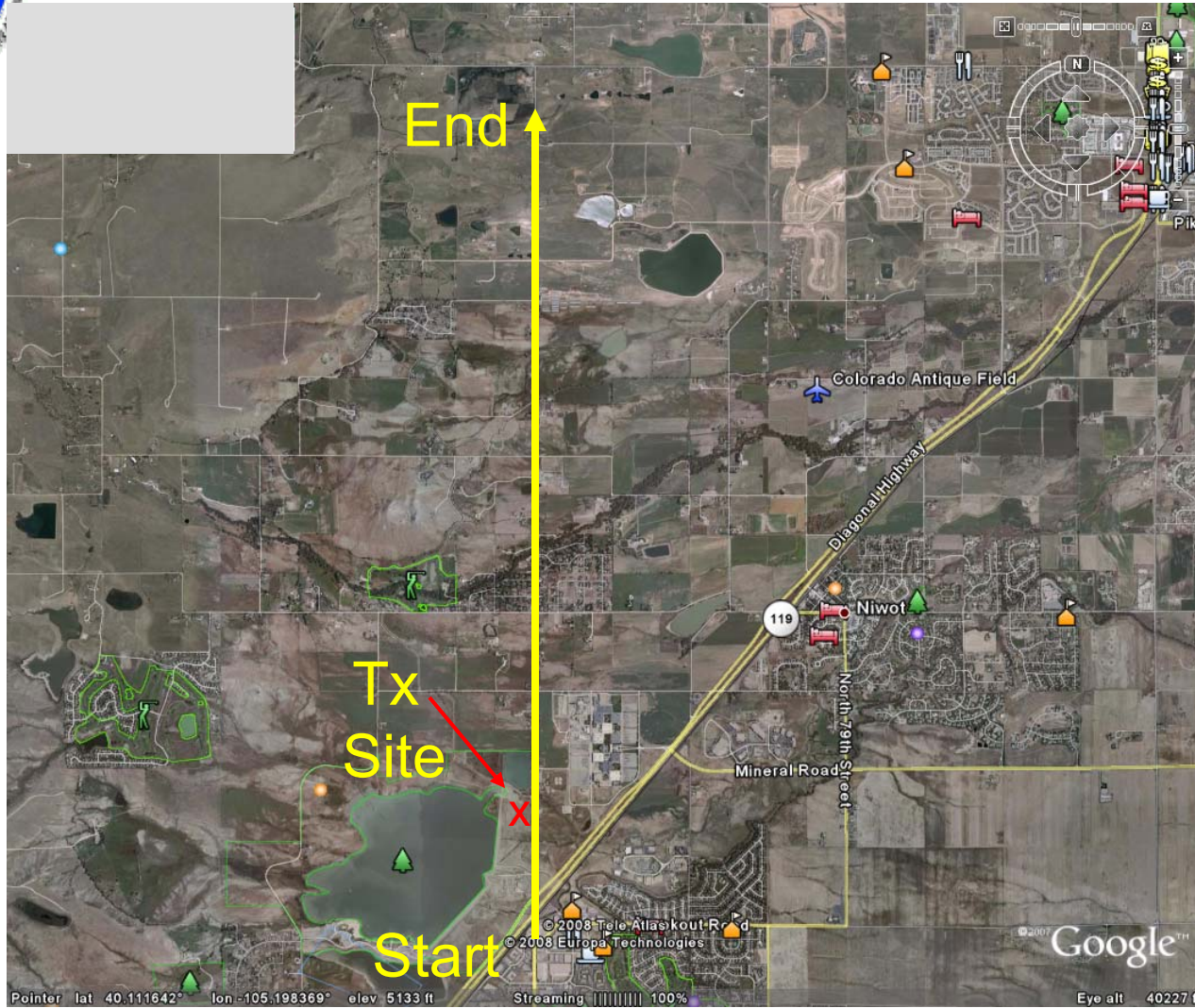
Rx Frequency @ 1602.5 MHz
 $P_t = 1W$





Coot Lake N. 63rd St., Boulder County

Length of run approx. 4.5 mi



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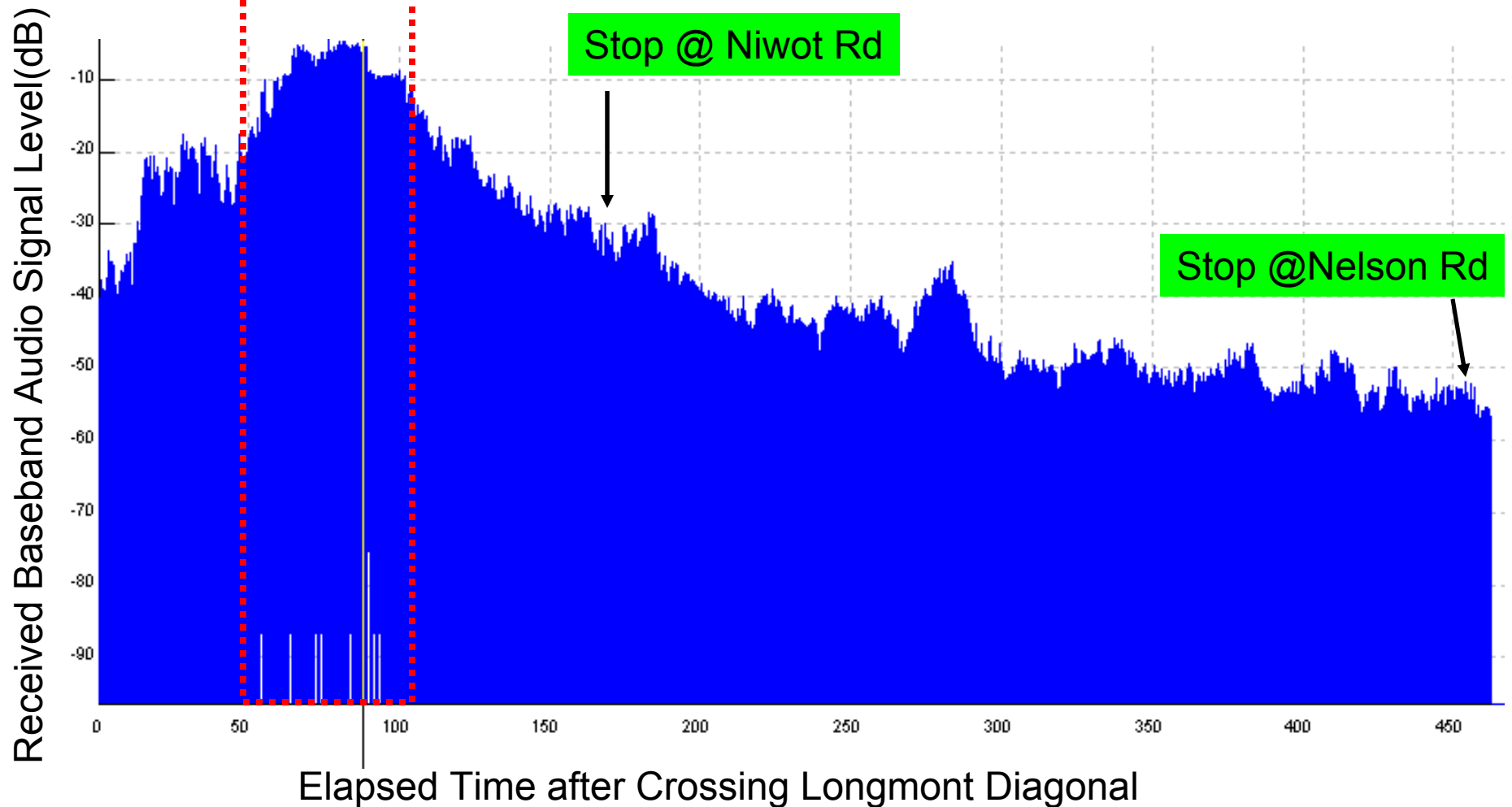
Coot Lake Signal Profile

$20 \cdot \log_{10}(|V_r|)$ (dB)



Longmont
Diagonal

Receiver Saturation
Tx Site too close!



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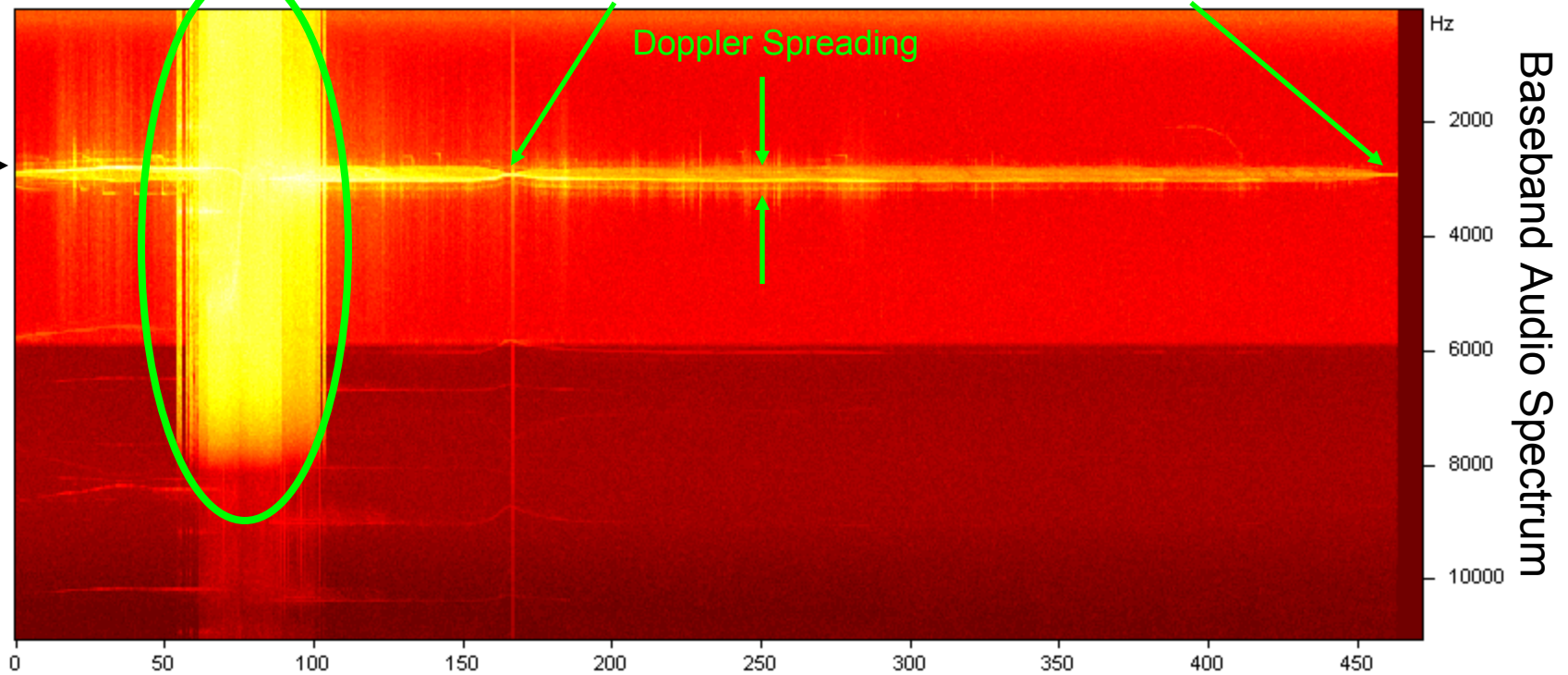
Coot Lake Spectrogram 11,000+ FFT's 2048 Pts

Receiver Saturation
Tx Site too close!

Stop @ Niwot Rd

Stop @ Nelson Rd

Longmont
Diagonal



Elapsed Time after Crossing Longmont Diagonal



Future Directions

- More measurements in selected environments
- Model Development
- Enhanced signal processing
- Doppler spreading measurements
- Additional Narrowband Propagation measurements
- Final Report