SARSAT
Beacon Manufacturers Workshop
May 1, 2014

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Second Generation Beacons Background

- Cospas-Sarsat (C/S) documents concerning second generation beacons
  - Operational Requirements for Cospas-Sarsat Second Generation 406 MHz Beacons, C/S G.008
  - Second Generation Beacon Implementation Plan (BIP), C/S R.017
  - Second Generation Beacon Specification, T.X01
- Experts Working Groups held yearly on Second Generation Beacon Development since 2010
- Currently, two approaches to meet the requirements in G.008 are being pursued

Spread Spectrum Approach

- Several participants, including NASA and CNES, worked together on the application of Direct Sequence Spread Spectrum techniques
- Design Goals
  - Improve system performance to meet or exceed C/S requirements, including
    - detection probability, location accuracy and system capacity
  - Modernize beacon signal for MEOSAR system
  - Relax beacon requirements to reduce cost and complexity
  - Collaborate with manufacturers to obtain the most competitive end product

Fully realize ability of Cospas-Sarsat to provide the gold standard of emergency distress location

Message Format

- Simple and efficient
  - Single message structure – fixed and rotating sections
  - Use of a modified Type Approval Certification (TAC) data base to provide some required data
  - Message length to meet all requirements with some margin
  - Protected with a single BCH Forward Error Correction code to exceed Bit Error Rate requirement with minimal cost to beacon

RF Modulation

- Offset Quadrature Phase Shift Keying (OQPSK)
  - Industry standard
  - Many commercially available chip sets available
  - Relaxes requirements on amplifier
  - Increases system performance and efficiency of data transmission

Direct Sequence Spread Spectrum Code Division Multiple Access

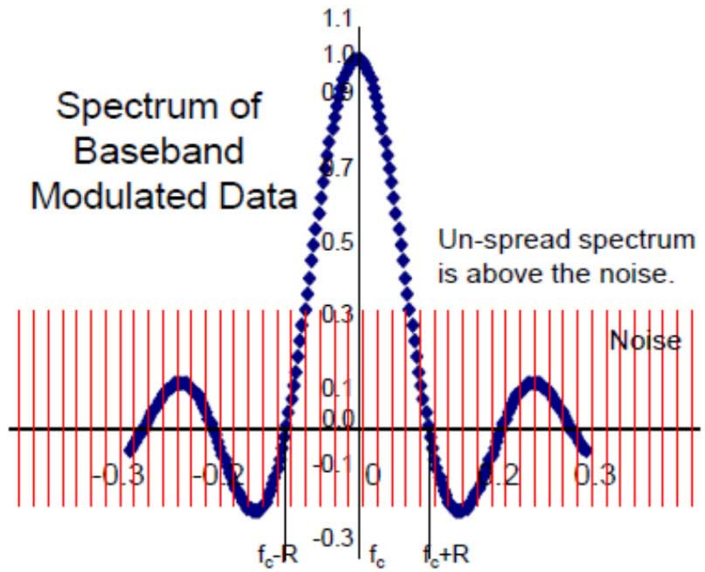
- Industry standard basis for major performance improvements in detection, location and capacity
- Easy to implement – code applied to digital data in software
- Relaxes beacon requirements
  - Oscillator frequency stability of 5-10 ppmillion – orders of magnitude improvement over current 1-2 pp*billion*
  - All beacons transmit at same center frequency
    - never have to change oscillator
    - different codes applied in software.

Direct Sequence Spread Spectrum
Code Division Multiple Access

With the same PA output power, area under the Power spectrum curve is the same for spread and un-spread transmission. Since Null to Null spacing is a function of the data rate, for spread data the spectrum is much wider, at least 10 times as wide for this specification.

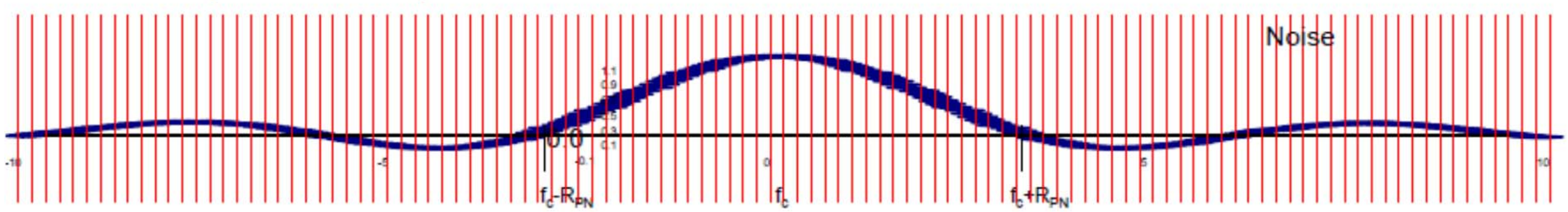
Amplitude of power spectrum of spread signal is thus less than 1/10th the level of un-spread spectrum and will often be below the noise floor.

f_c = carrier center frequency
R = data rate of original data
R_{PN} = data rate of the PN chips



Spectrum of Spread Modulated Data

Spread spectrum signal shown below the noise.



(Curves shown are linear Voltage spectrum and need to be squared for power spectrum)

NASA Proof of Concept system

- NASA has developed a proof of concept system, including a programmable beacon and real time receiver.
- Preliminary testing used waveform representative of a fully compliant waveform.
- NASA is currently working on testing fully compliant waveform.
- CNES is performing independent testing as well.

Prototype and Test Beacons

Programmable beacon developed to aid field testing of candidate signal structures

- Programmable beacon for early field testing
- Laboratory equipment for easily configurable test beacon signal
- Prototype using simple components to produce required beacon signal

4 Channel Software Defined Receiver

Real Time Receiver

- Processes beacon signal relayed by GNSS satellites.
- Measurements made on each beacon burst fed into NASA MEOLUT for location processing.

NASA MEOLUT

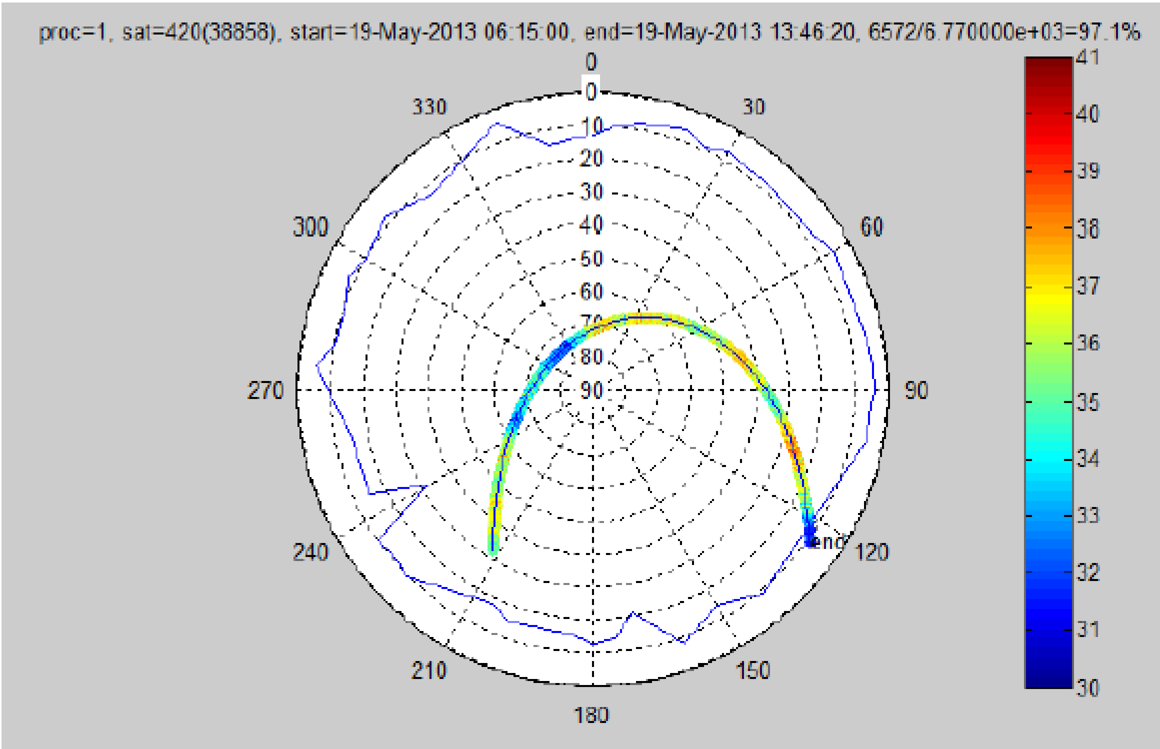
Preliminary Location Performance Test Results

G.008 Requirement			Independent Location Results
3.1	Independent Location Accuracy	The operational performance requirement is for first burst 2D independent location accuracy within 5 km, 90% of the time.	Single burst independent locations within 5 km 100% of the time
			Single burst independent locations within 2.8 km 100% of the time
		5 km, 95% of the time, within 30 seconds after beacon activation;	Same as above
		1 km, 95% of the time, within 5 minutes after beacon activation;	Less than 1km, 99.6% of the time, within 5 minutes after beacon activation
		100 m, 95% of the time, within 30 minutes after beacon activation.	Less than 100 m, 58.3% of the time, within 30 minutes after beacon activation
			Less than 247 m, 95% of the time, within 30 minutes after beacon activation

- Preliminary location accuracy test results meet or exceed nearly all G.008 requirements
- Additional refinements being pursued to minimize remaining causes of error.

Detection Test Results

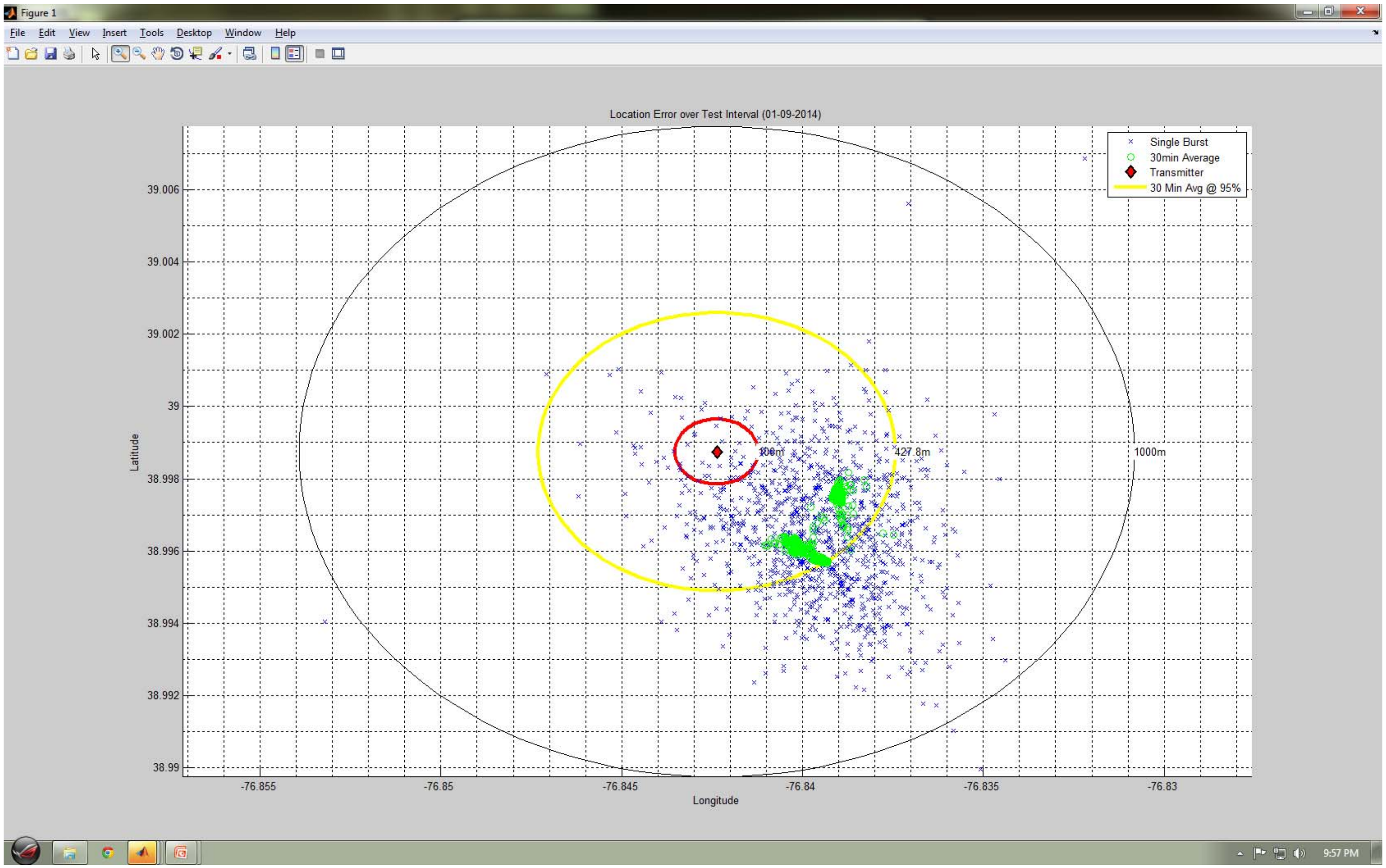
On two Galileo passes, the detection probability was 97.1 and 99.1%



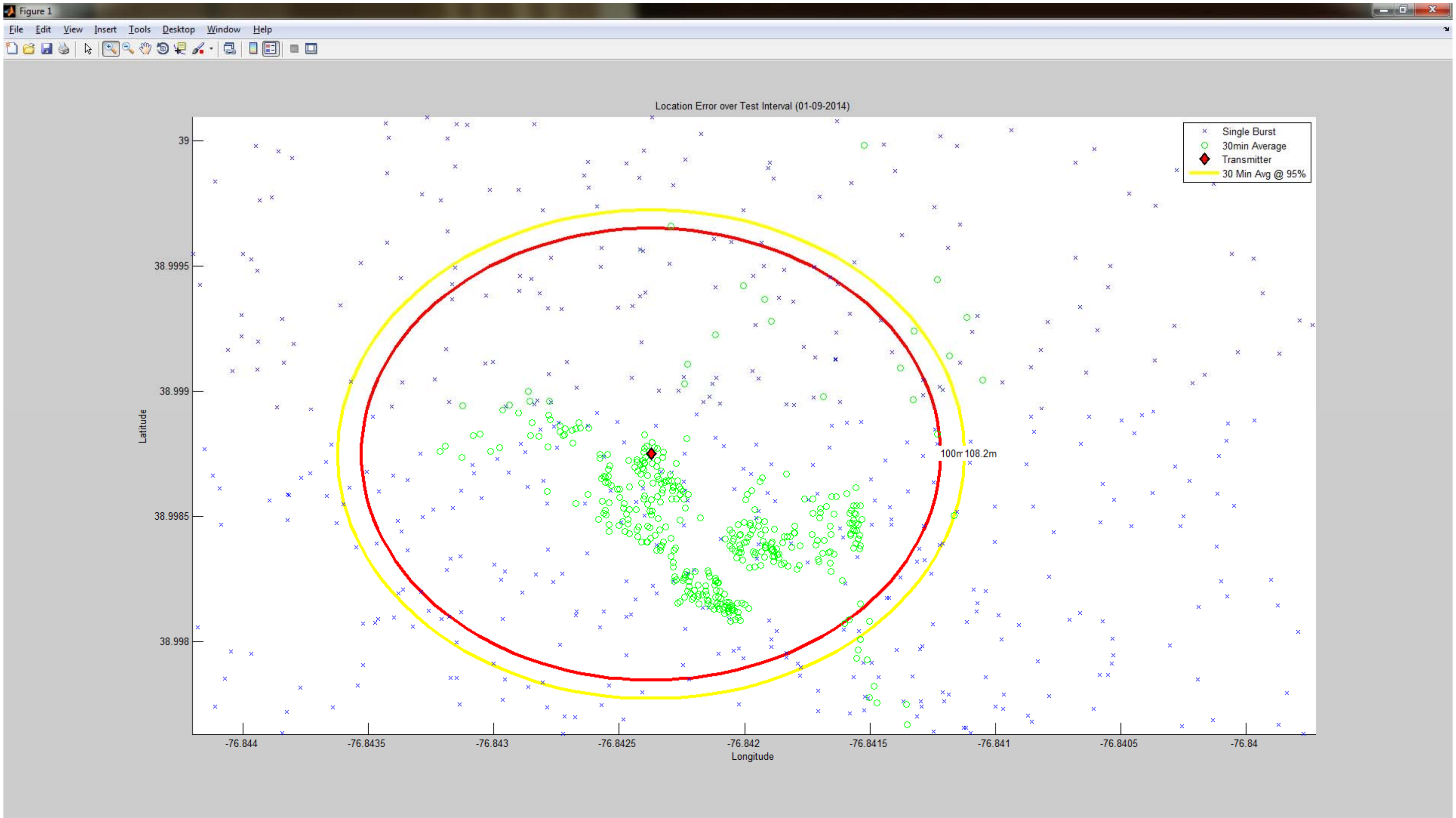
Causes of Error Being Investigated

- Satellite Group Delay
- Ground Segment Calibration Delays
  - Antenna to receiver, distance and electronics
  - Initial calibration has been performed
- Ionosphere
  - To a lesser extent, but a necessary refinement for location accuracy

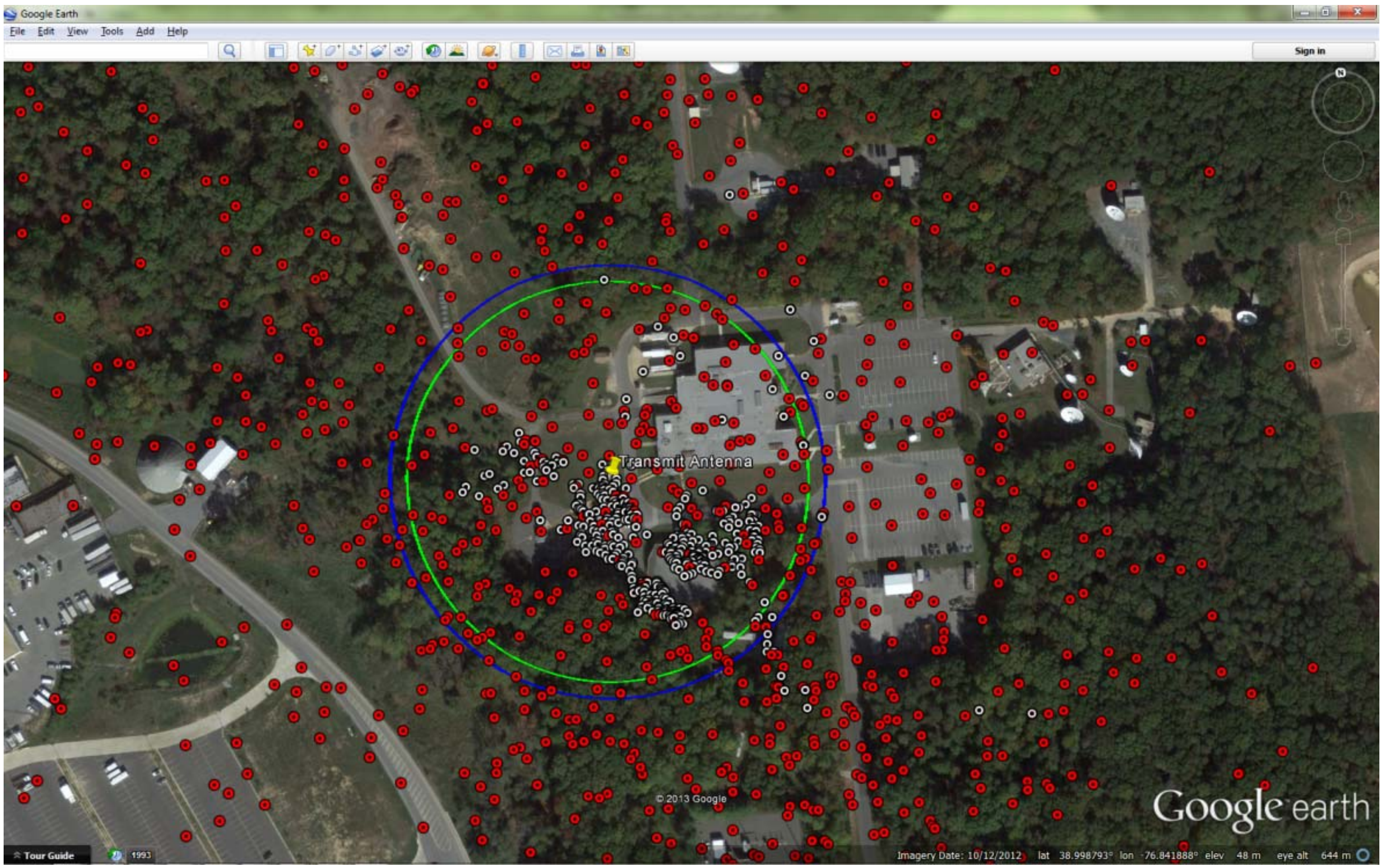
Location Results with Biases Present



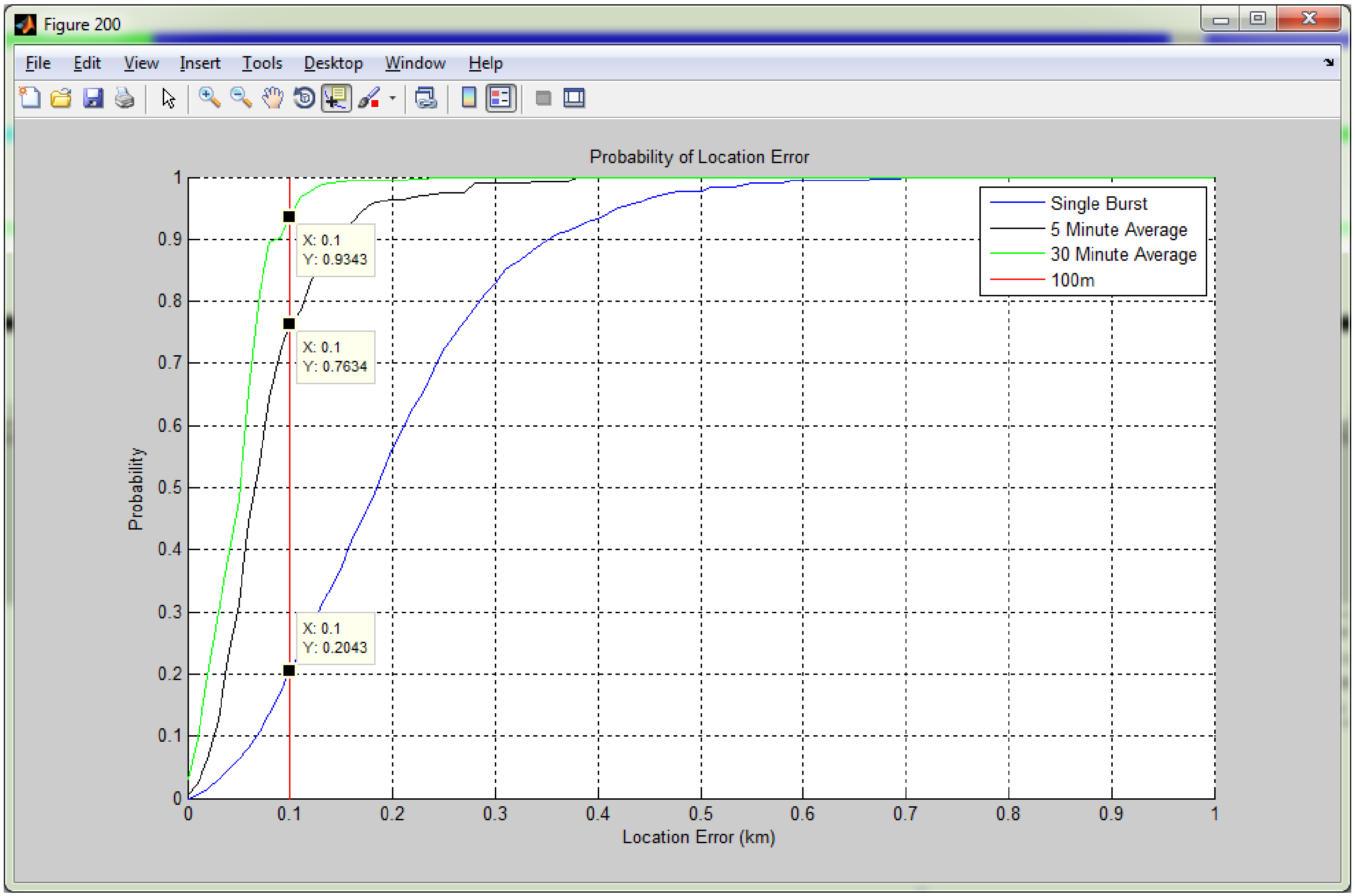
Location Results Biases Removed



Location Map



Cumulative Distribution of Location Error with Biases Removed



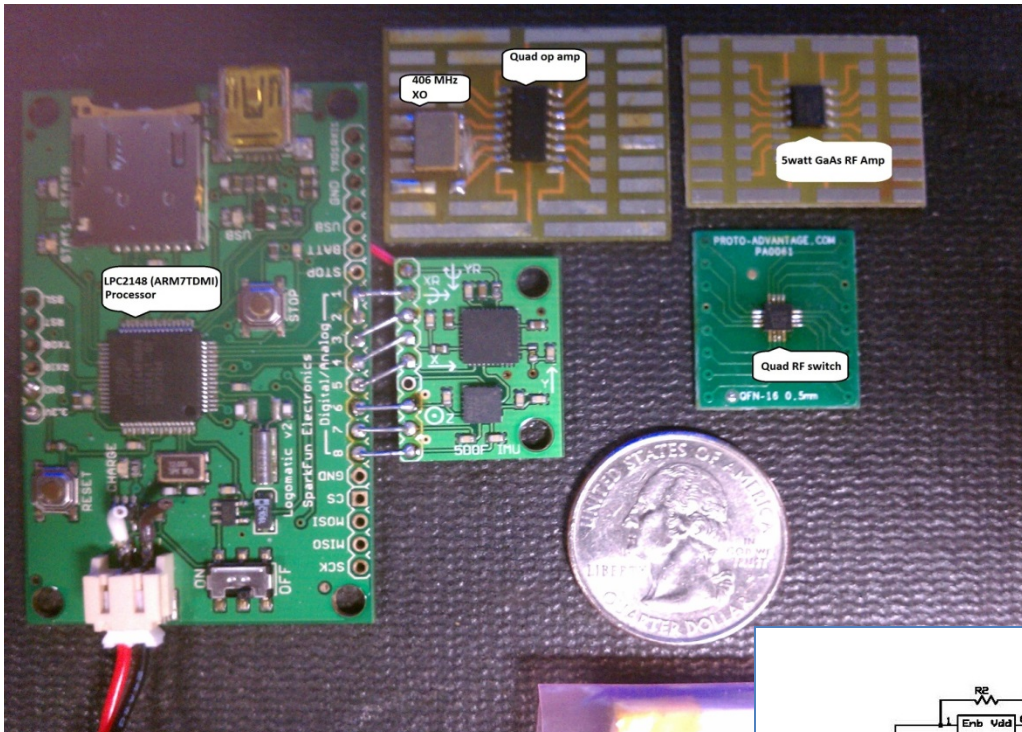
Goals of Current Work

- Determine Satellite Group Delays
  - Additional tests to get more samples on each satellite
  - Track same sat using multiple antennas
- Update Ground Segment Calibration Biases
- Experiment with Ionospheric Corrections to verify repeatability
- Verify MEOLUT performance with corrected data

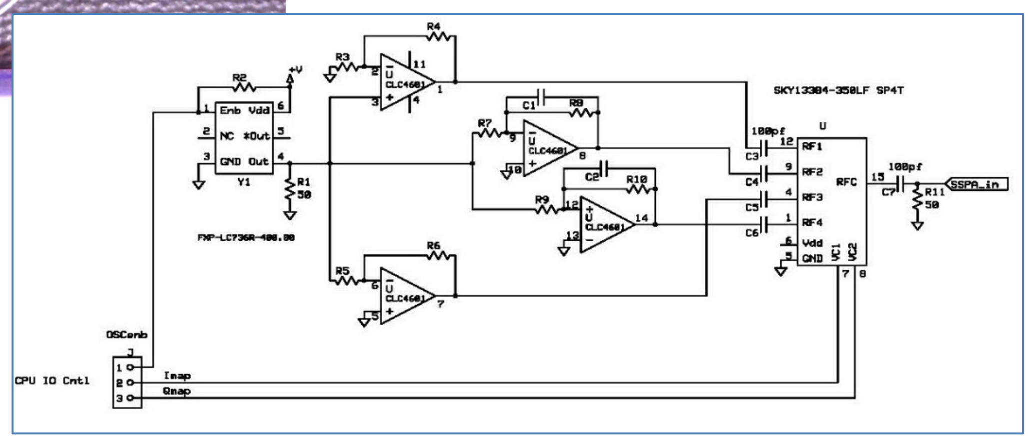
Related Areas of Investigation

- Prototype Beacon
- 406 MHz Signal for Local Detection and Homing
- ELT Crash Survivability
- Location processing for Moving Beacons
  - Necessary for in flight beacon activation

Prototype Beacon



- Basic development boards employed to demonstrate QPSK modulator. Note the overwhelming size of the quarter. The prototype has many options but was especially well-suited to rapid development. (QPSK modulator and final RF amp are shown without passive components.)



Local Detection and Homing Signal

- Pursuing development of a 406 MHz signal specifically designed for local detection and homing
  - Possible replacement for 121.5 MHz homing signal – allows for simpler, single frequency beacon design
  - Collaborating with DF equipment manufacturers on signal design
  - Purpose built design will improve performance over current systems
  - Software configurable so beacon utilizes existing 406 MHz transmit chain

ELT Crash Survivability Working Group

Issue - ELT Failures

- There is a history of SAR Emergency Locator Transmitters (ELTs) failing in general aviation incidents.
- These failures have been studied to some degree by various agencies around the world, but a comprehensive study needs to be done.
- Focus on ELT system as a whole, including ELT, transmit antenna, and interconnecting cabling.

Supporting Organizations

- NASA LaRC has a strong history of research in aviation accidents, and doing studies/testing of crash scenarios.
- NASA GSFC SAR Mission Office leads on SAR-related items, including beacon research and national and international outreach.
- The FAA, NTSB and Air Force provide guidance, data, and procedures for improving deployment of ELTs in aircraft

ELT Survivability WG Goals and Objectives

- Goal 1: To deliver recommendations to the FAA, beacon manufacturers, and airframe manufacturers on ways to increase ELT survivability.
  - Objective 1: Research historical ELT failures in general aviation (light aircraft) accidents, and gather data to determine reasons for low survivability.
  - Objective 2: Study data, perform failure modes analysis, and develop new procedures/processes for beacon design, installation, etc. as findings dictate.
  - Objective 3: Test these procedures on a system level, including use of the LaRC test crash site to crash a plane and analyze results.
  - Objective 4: Develop recommendations based on comprehensive test results.

- Goal 2: To improve ELT survivability on a global level through coordination and information transfer with COSPAS-SARSAT.

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