Electrical Engineering
Capstone Design II
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Direction Finding Spread Spectrum Signals

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Outline

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- Needs and Objectives
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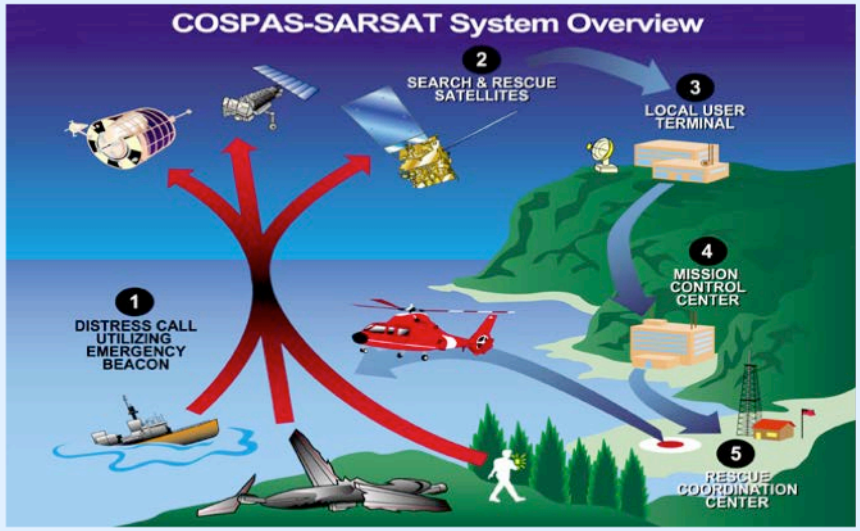
Introduction

- U.S. Coast Guard is a multi-mission service
- Search and Rescue (SAR) is a primary mission
- SAR leverages technology to reduce searching
- Mariners in distress use EPIRBs

Background

- **E**mergency **P**osition **I**ndicating **R**adio **B**eacon
- EPIRBs responsible for 39,000+ people rescued since 1982
- Current EPIRB
  - Narrow band signals
  - Broadcasts signal to satellite on 406 MHz
  - Homing signal operates on 121.5 MHz



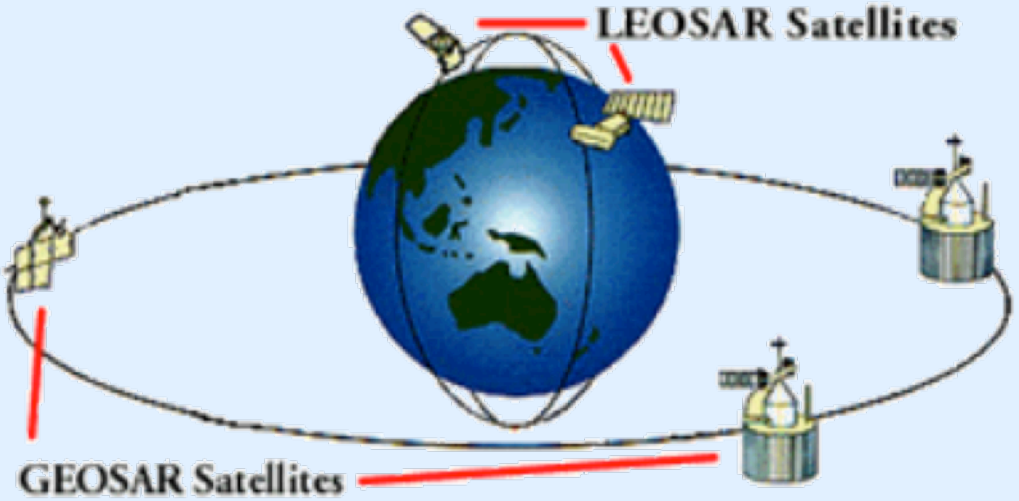
COSPAS-SARSAT Update

Current system:

- LEOSAR – Low Earth Orbiting SAR
- GEOSAR – Geostationary Earth Orbiting SAR

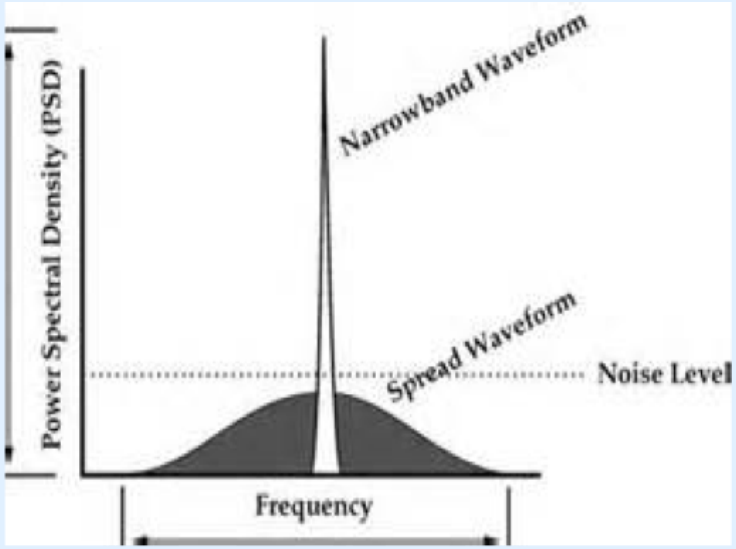
New addition:

- MEOSAR – Medium Earth Orbiting SAR



EPIRB System Upgrade

- Direct Sequence Spread Spectrum (DSSS)
- Greater immunity to interference/jamming
- Potential for greater quantity of beacons (different spreading codes)
- Smaller and lower cost



Needs and Objectives

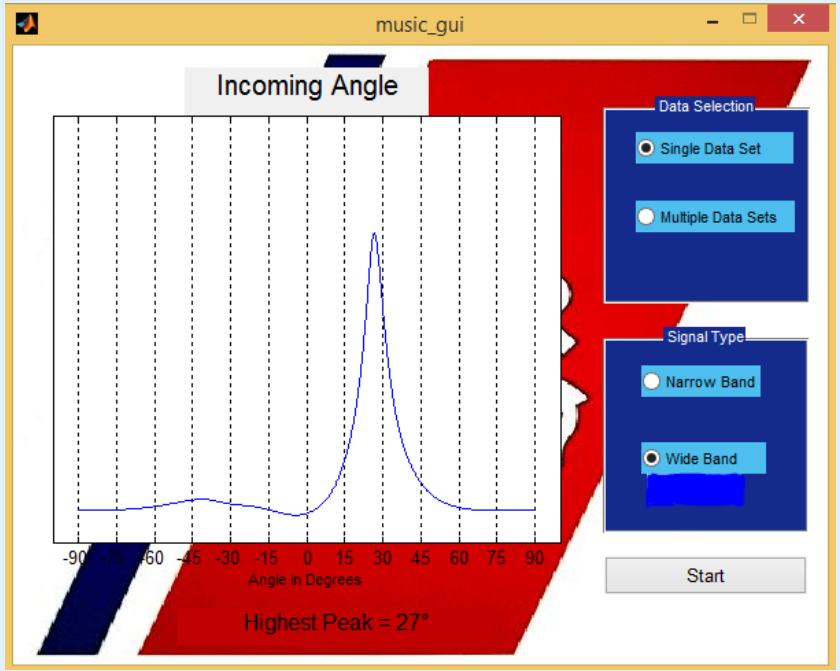
- Problem: Search and Rescue assets will lose the capability to home in on EPIRB satellite signals.
- Goal: Develop proof of concept architecture for direction finding on DSSS signals.

System Requirements

- User friendly GUI
- DF a wide band (WB) and narrow band (NB) signals within ± 5°
- Test under realistic conditions set by the Second Generation Beacon (SGB) systems

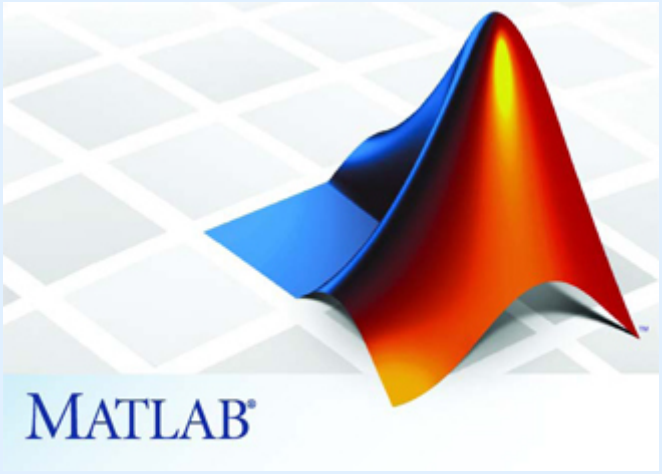
Results to Date

- Began with two element phased array antenna
- Incorporated and successfully built 4 element antenna/4 USRP system
- Successful DF on WB signals



System Overview

- Host computer OS: Ubuntu 14.04 LTS
- GnuRadio Companion (GRC) and MATLAB
- USRP: specific Software-Defined Radio
- Phased array antenna

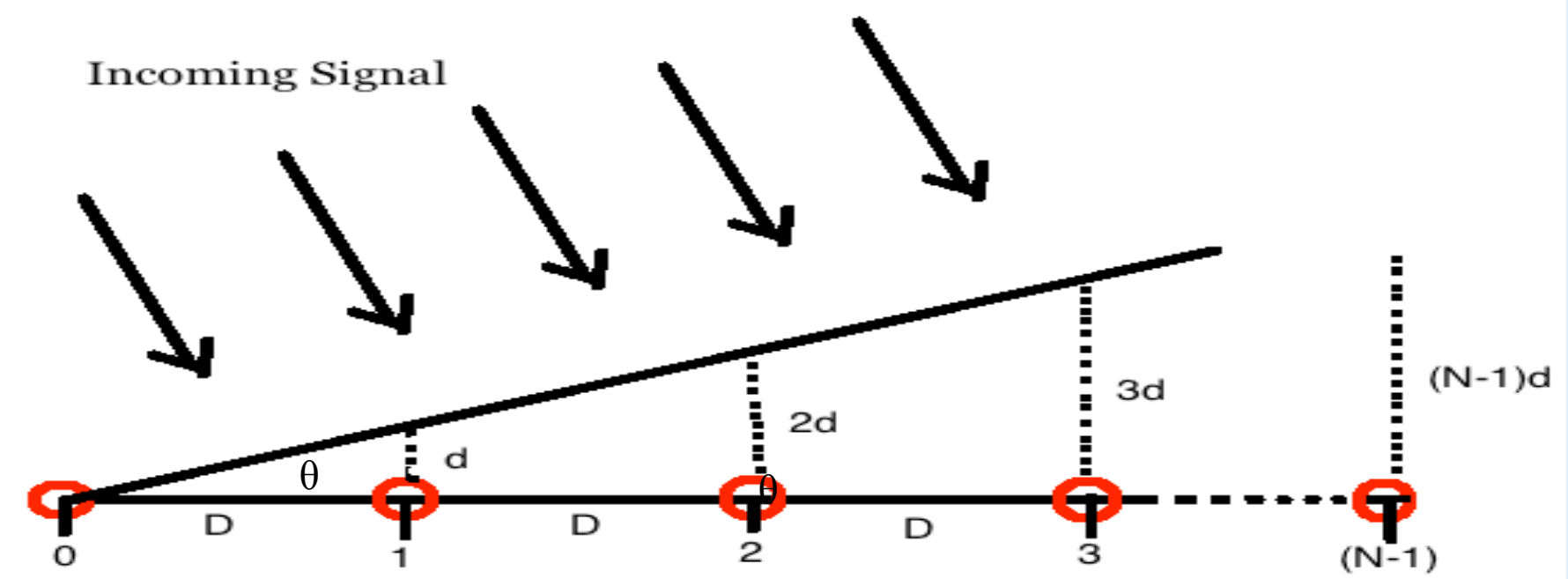


MUSIC Algorithm

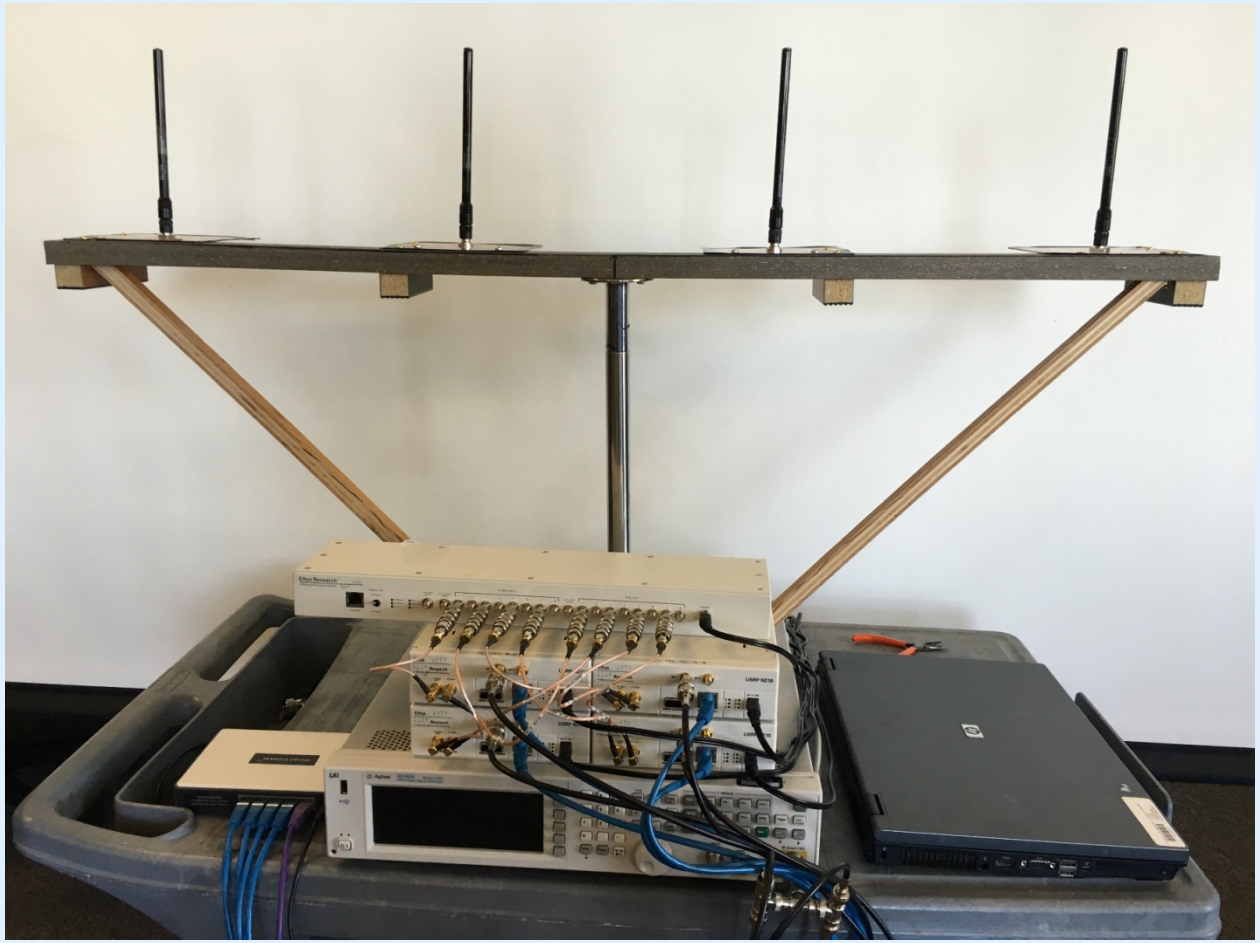
- Greatest strength of the system
- Uses differences in phase to locate signal
- Based on Eigen vectors and values of covariance matrix
- Implemented in MATLAB

MUSIC Algorithm

- $R = ASA^H + Q$, Eigen Decomposition of inputted data
- $J(\theta) = (\sum_{m=M+1}^{N} |\bar{a}^H(\theta) \cdot \bar{u}_m|)^{-1}$, Peak estimator function

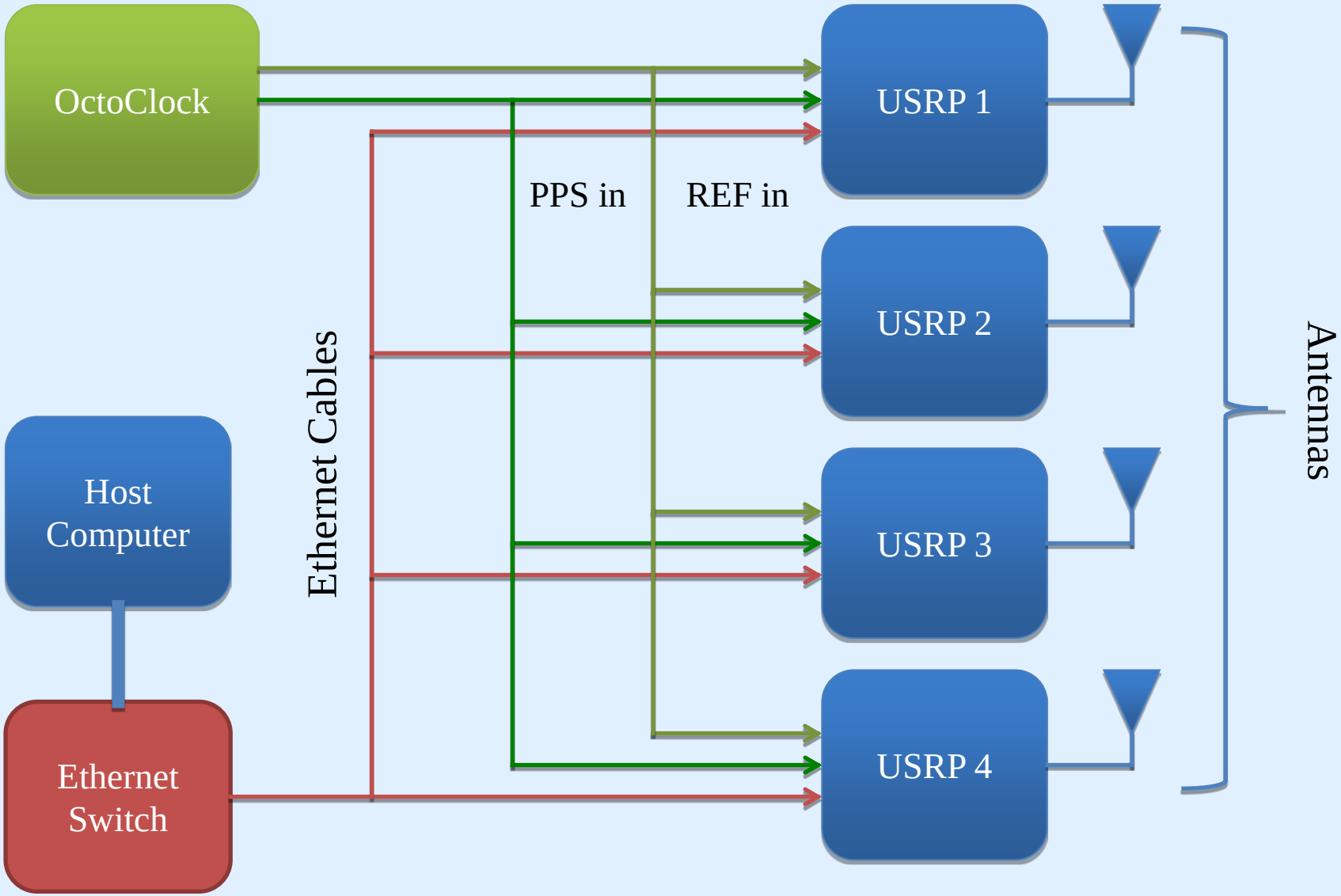


4x4 Direction Finding System



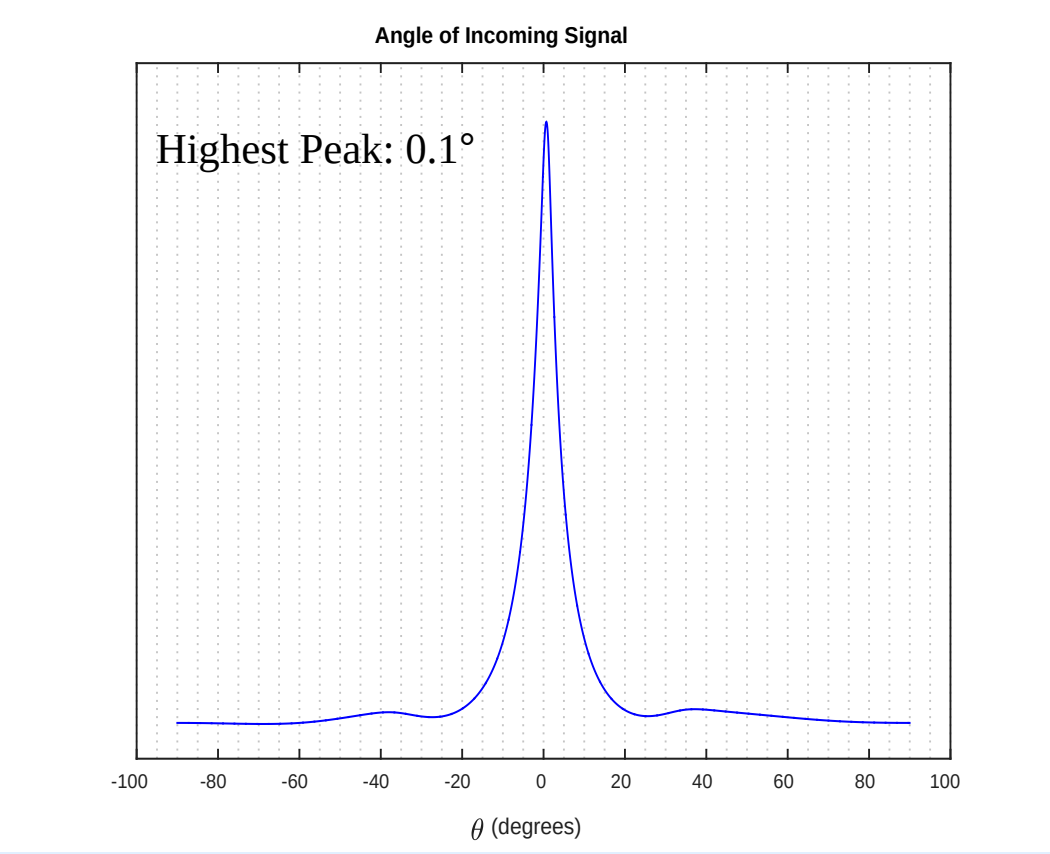
4x4 = 4 antennas + 4 USRPs

Function Design Overview



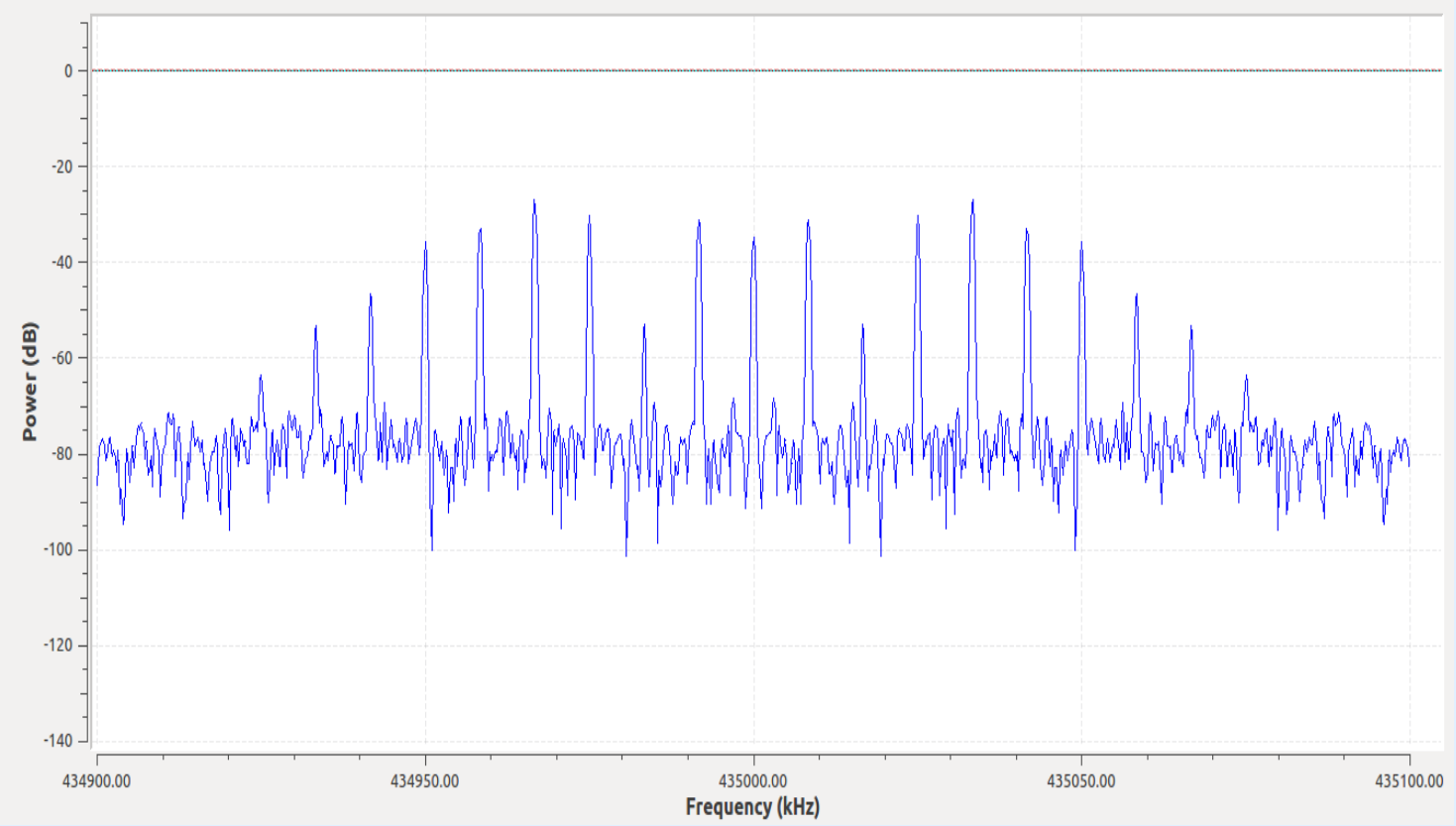
4x4 System Field Tests

- First tested with NB transmitted source
- Successful tests with repeatable, reliable results
- Next step: WB signal



4x4 System Field Tests

- Test with wide band signal
- Bandwidth = 100 kHz

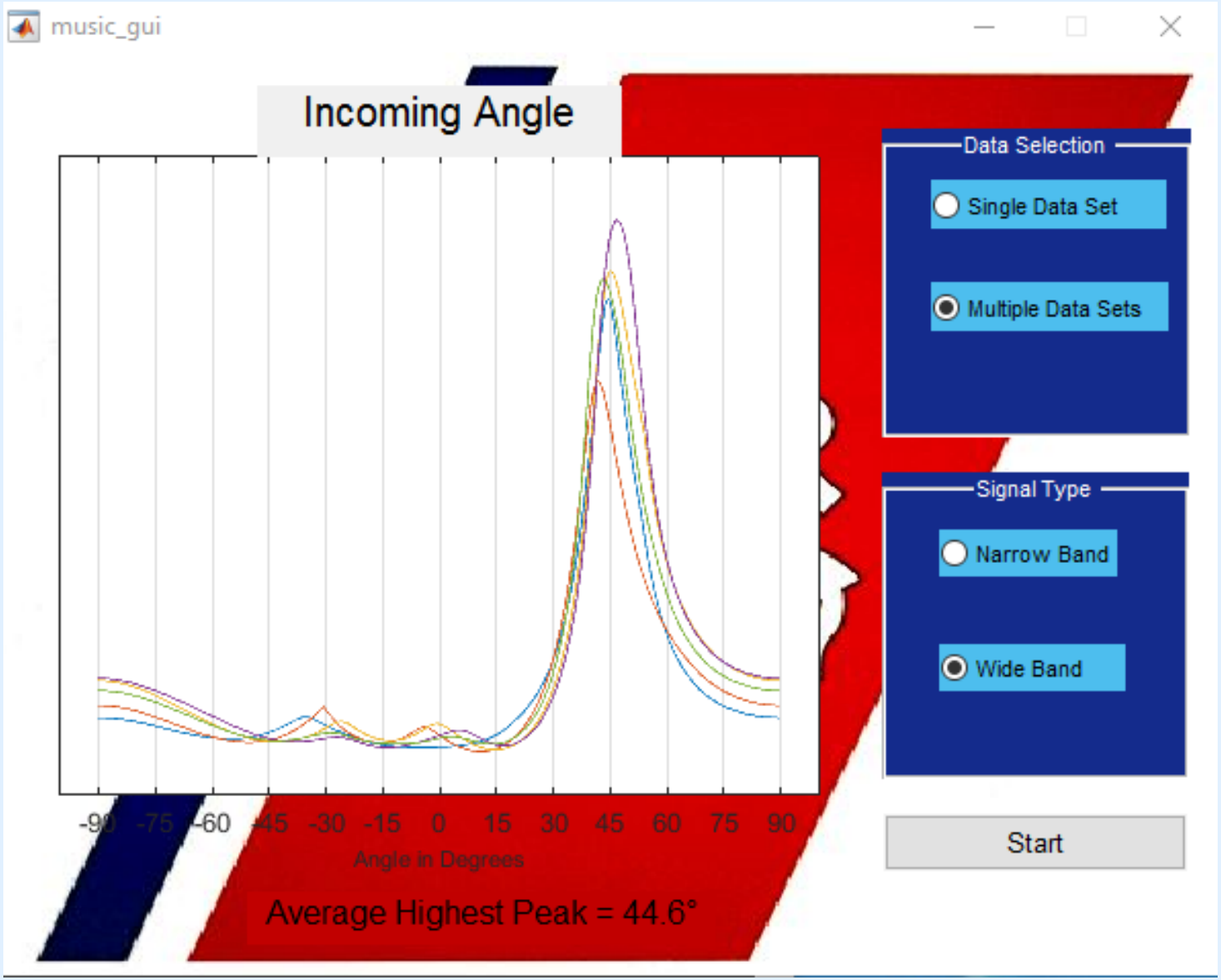


4x4 System Field Tests

- Successful DF on wide band signal
- Tested at 30°, 45°, and 60°

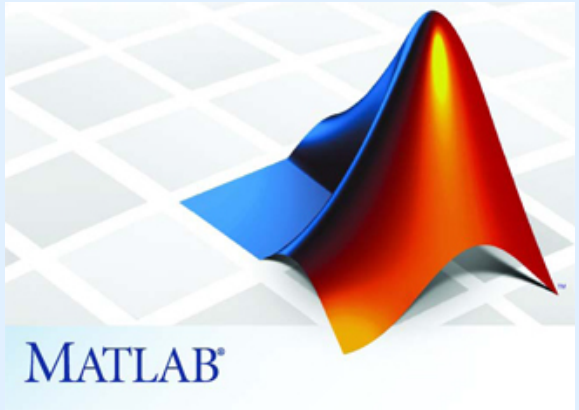
Expected Angle	Mean Bearing	Standard Deviation
30.0°	35.7°	1.2°
45.0°	44.3°	1.9°
60.0°	51.9°	3°

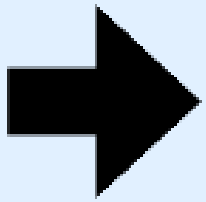
Repeatability Illustration



Software Challenges

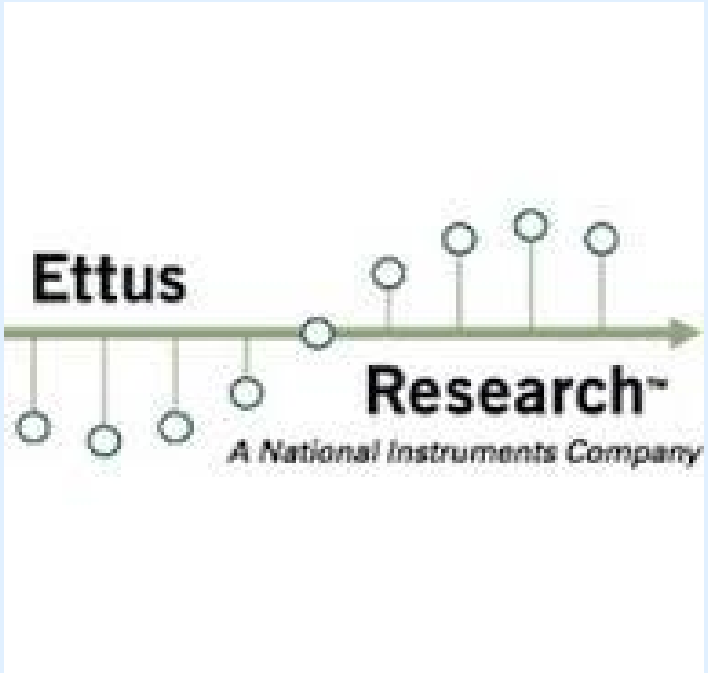
- Difficult to acclimate to Linux
- GRC easy to learn, hard to master
- User block creation
- Misleading block (e.g. ‘valve’ block)





Hardware Challenges

- Familiarization with USRPs
- Hardware malfunctions
- Receiver synchronization
- Undocumented functionality



Field Test Challenges

- Testing 4x4 DF system
- Battery failure
- GRC crashing
- Antenna sensitivity to nearby objects

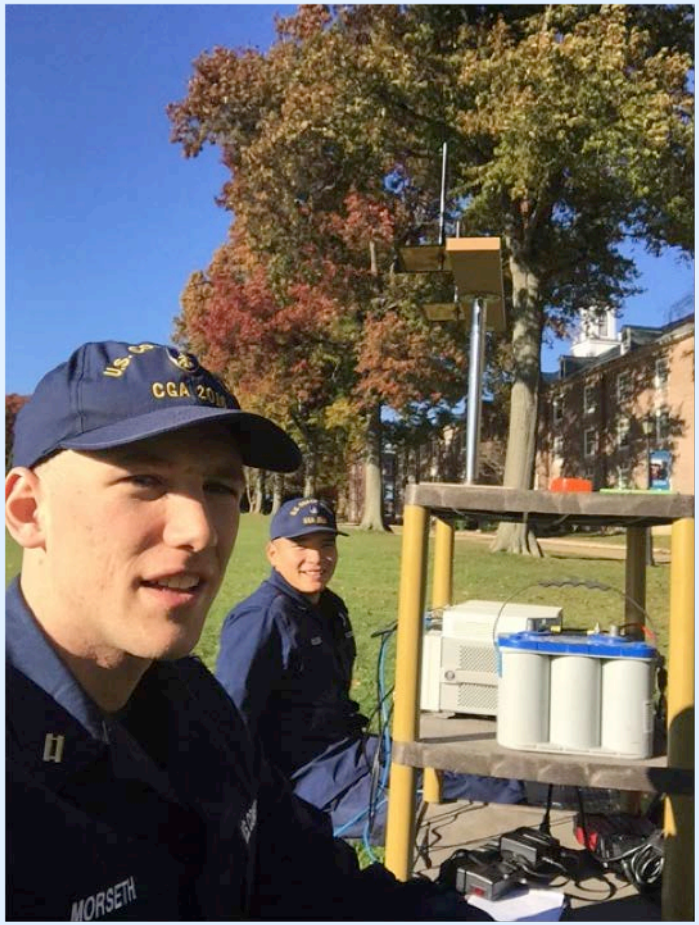
Future Direction

- Shift from GRC to National Instruments LabVIEW
- DF on actual SGB prototype
- Real time data acquisition
- DF on cell phone and Wi-Fi signals

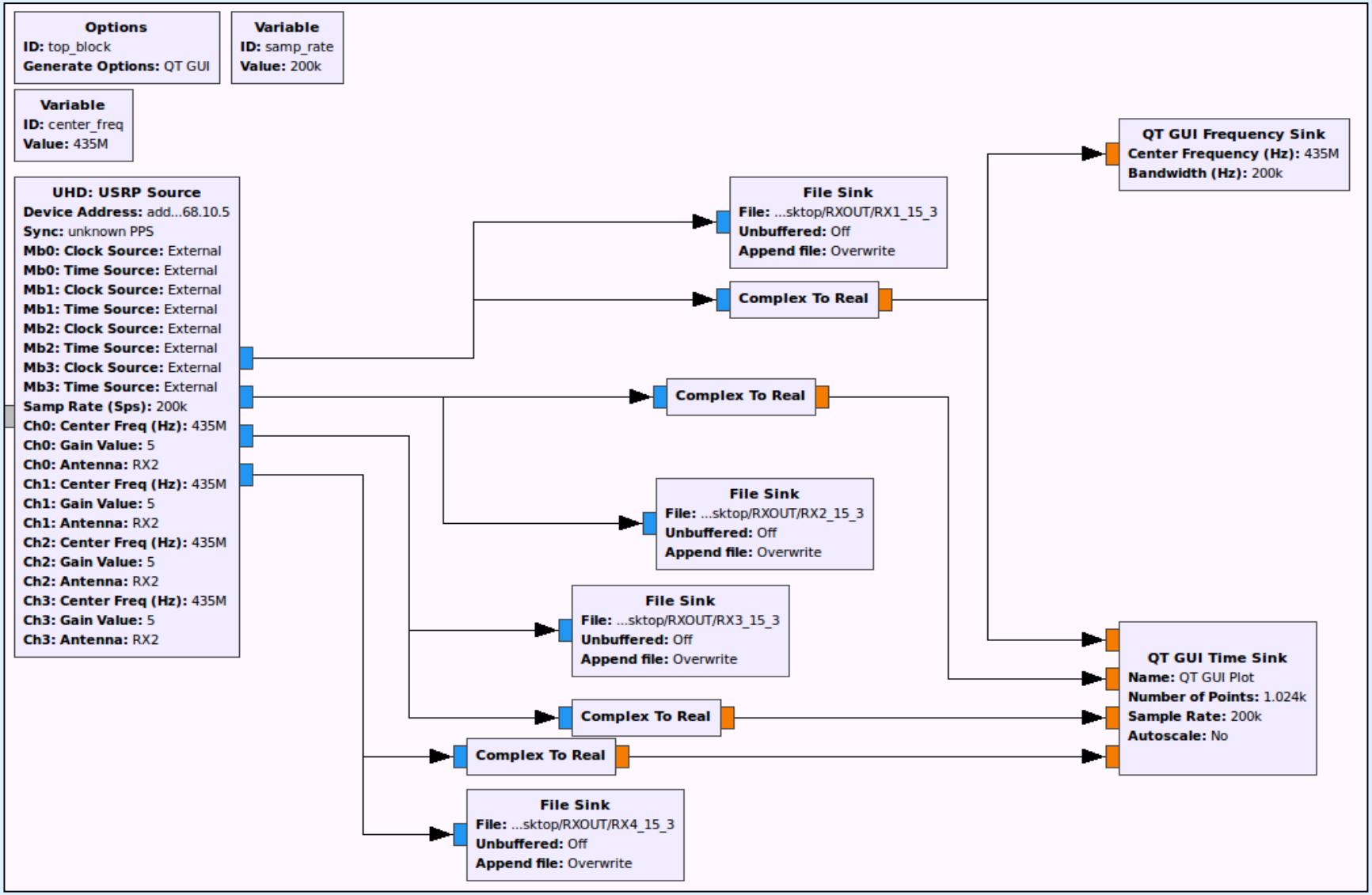
Conclusions

- Demonstrated capability to DF on both traditional narrow and new wide band beacon signals
- Results are accurate and repeatable
- Technology exists to bring wide band DF to SAR Response Units

Questions?



4x4 GnuRadio Model



4x4 GnuRadio Model