APPLICATION OF ARRAY RADAR CONCEPT TO ORBITAL DEBRIS (OD) AND NEAR-EARTH OBJECT (NEO) CHARACTERIZATION

V. Vilnrotter, P. Tsao

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Authors are with the Jet Propulsion Laboratory, California Institute of Technology

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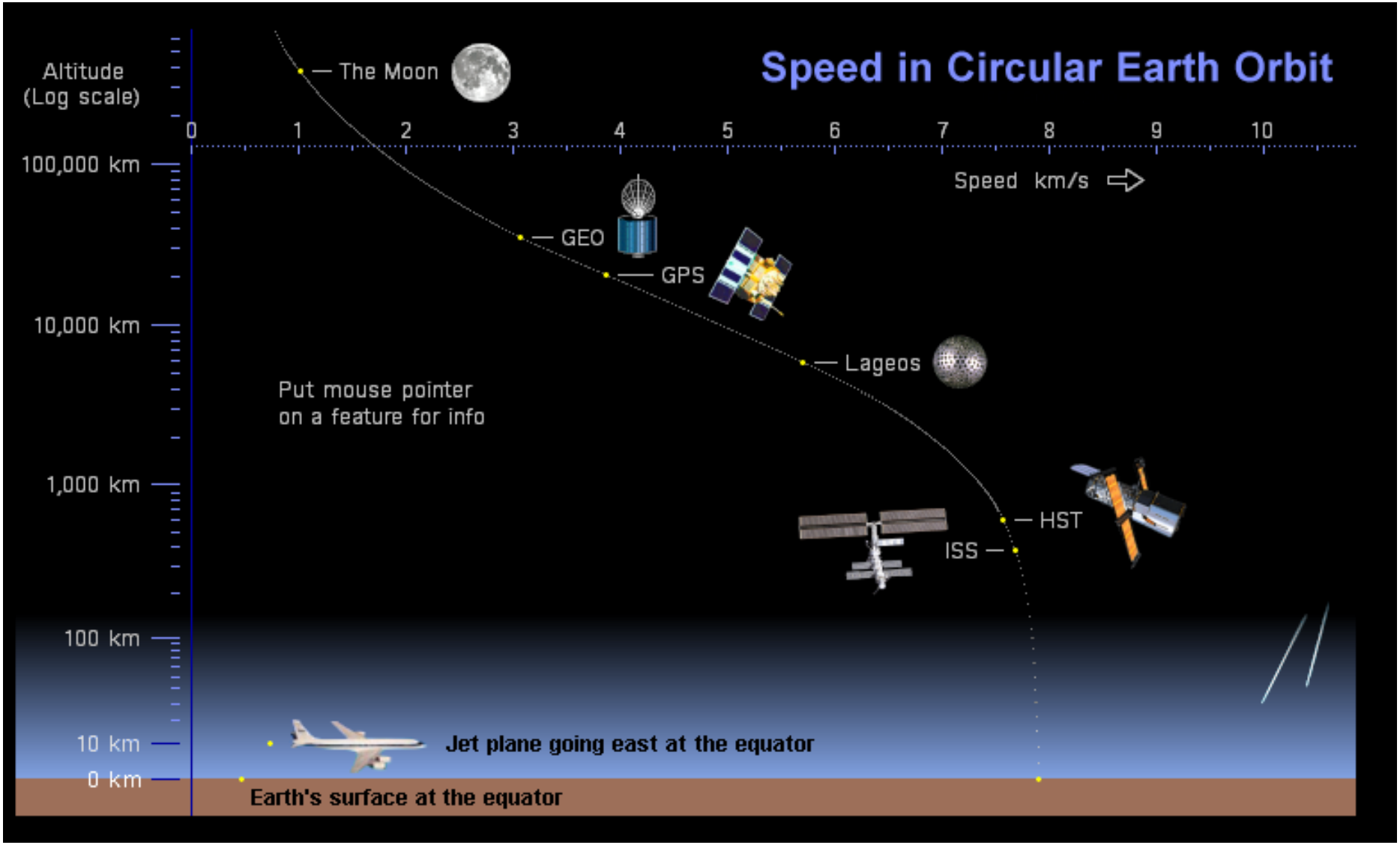

Speed in Circular Earth Orbit
Altitude
(Log scale)
100,000 km
10,000 km
1,000 km
100 km
10 km
0 km
0
1
2
3
4
5
6
7
8
9
10
Speed km/s
The Moon
GEO
GPS
Lageos
HST
ISS
Put mouse pointer
on a feature for info
Jet plane going east at the equator
Earth's surface at the equator

APPLICATION OF **ARRAY RADAR** TO NEO AND OD OBJECTS

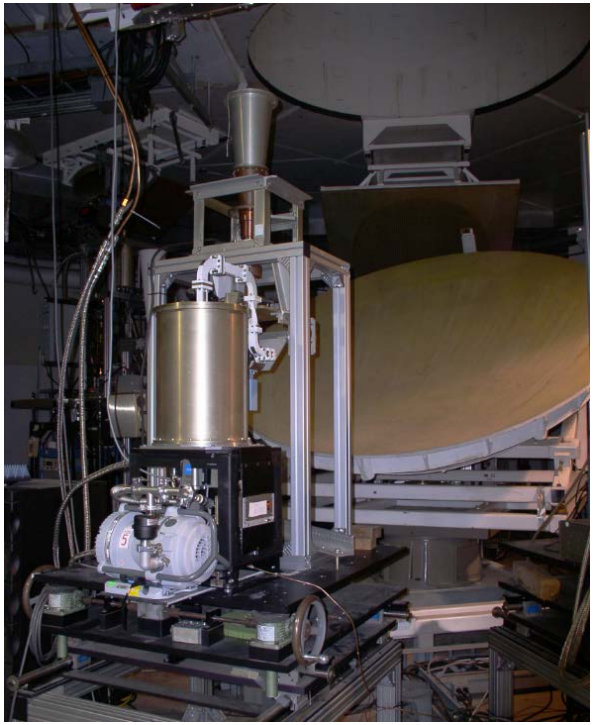
- Precise calibration of Array Radar antenna phase required
  - Array Radar phase calibration can be accomplished via “Moon-Bounce”
- Closed-loop phase control is required to maintain phase cal
  - Temperature variations and equipment instabilities degrade coherence
- The proposed Array Radar approach provides simultaneous projection of OD **velocity vectors** onto **three independent baselines,** thus enabling trajectory determination from a single Array Radar observation!

Picture of Apollo cluster, forming transmitter part of Array Radar (DSS-24, DSS-25, DSS-26)

- Three 34m BWG antennas, 20 KW transmitters
- Array spans ~ 500 meters
    - Antenna null-to-null beamwidth ~ 170 mdegs
    - DSS-24 – DSS-25 baseline ~ 23 mdegs
    - DSS-24 – DSS-26 baseline ~ 15 mdegs

7.18 GHz Array Radar receiver in the DSS-13 pedestal room

- Upgraded to cryogenic LNA
- X-band output to MMS
- 300 MHz IF to VSR (DSS-13)



Array radar transmitter characteristics

- DSS-24/25/26, 20 kW transmitters, ~7.18 GHz
  - Single antenna: EIRP of 34m antenna, 20 kW transmitter
  - Two antenna array: peak EIRP of 34m antenna, 80 kW transmitter
  - Three antenna array: peak EIRP of 34m antenna, 180 kW transmitter
- Simultaneous multi-frequency/multi-baseline operation remains to be shown
  - Enables processing of simultaneous echoes from different baselines

Array radar receiver characteristics

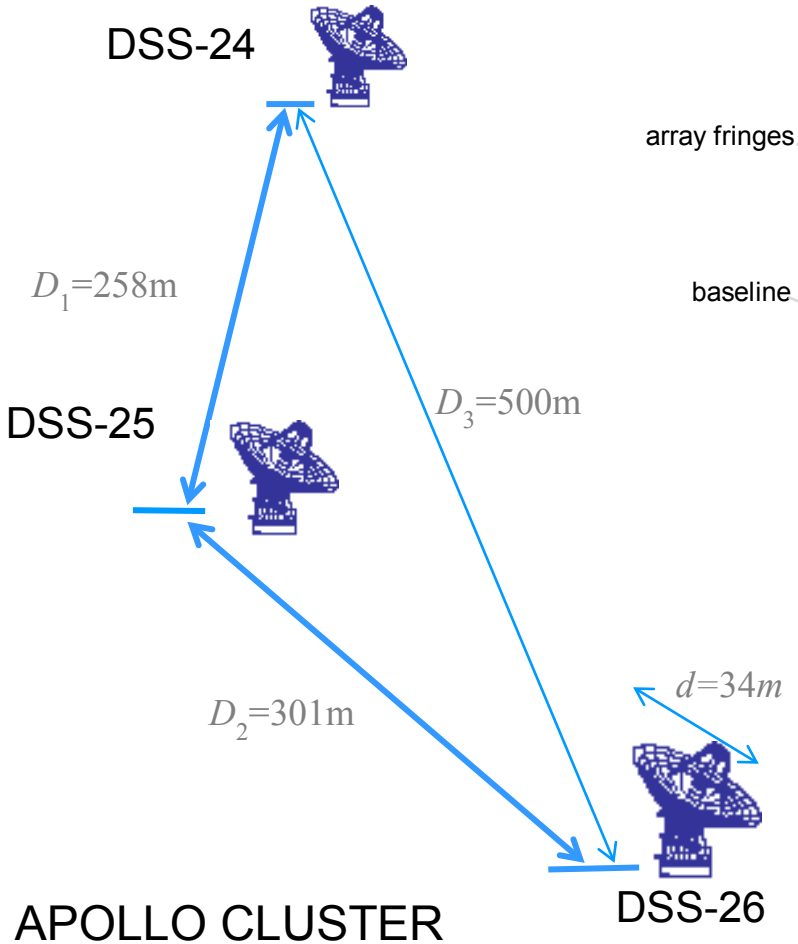
- GSSR cryogenic-LNA at DSS-13 receives array radar echoes
- VSR at DSS-13 used to record complex baseband samples
  - 1 MSPS complex samples, 8 bits quantization

Array radar signal processing

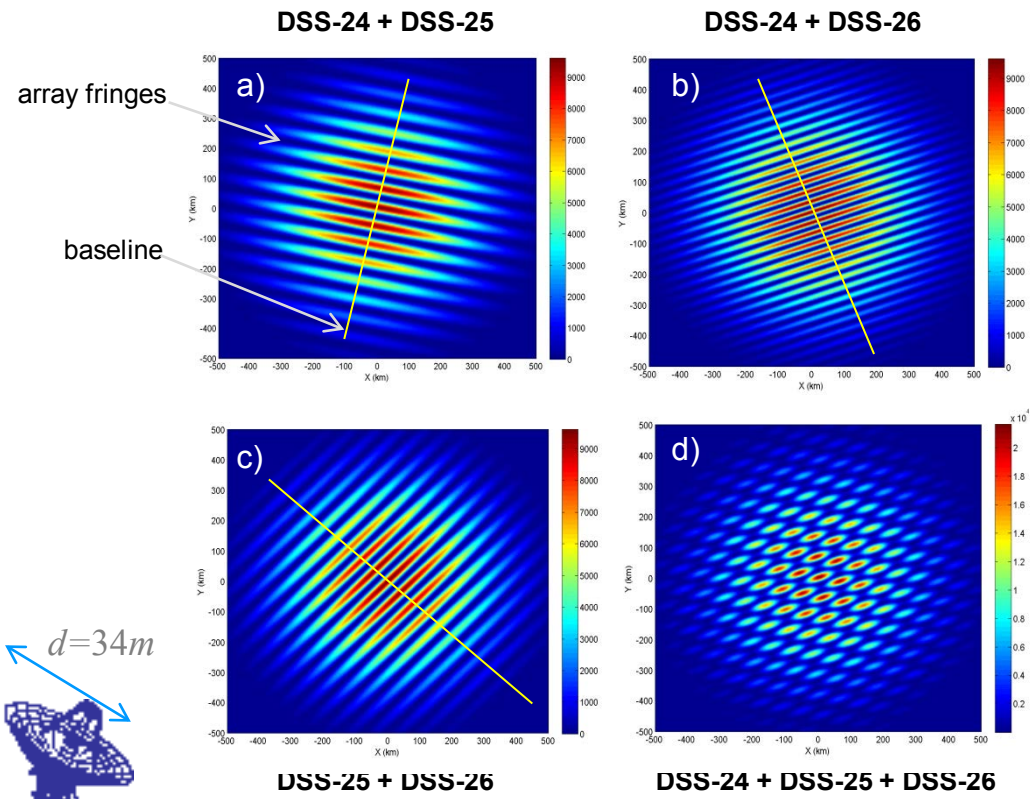
- Developed algorithms to process received samples, display data
  - Event frequency and amplitude, spectrograph displays were generated

SIMULATED FAR-FIELD PATTERNS, APOLLO CLUSTER

Cartesian coordinates, antennas pointed at zenith



APOLLO CLUSTER
OF 34M ANTENNAS

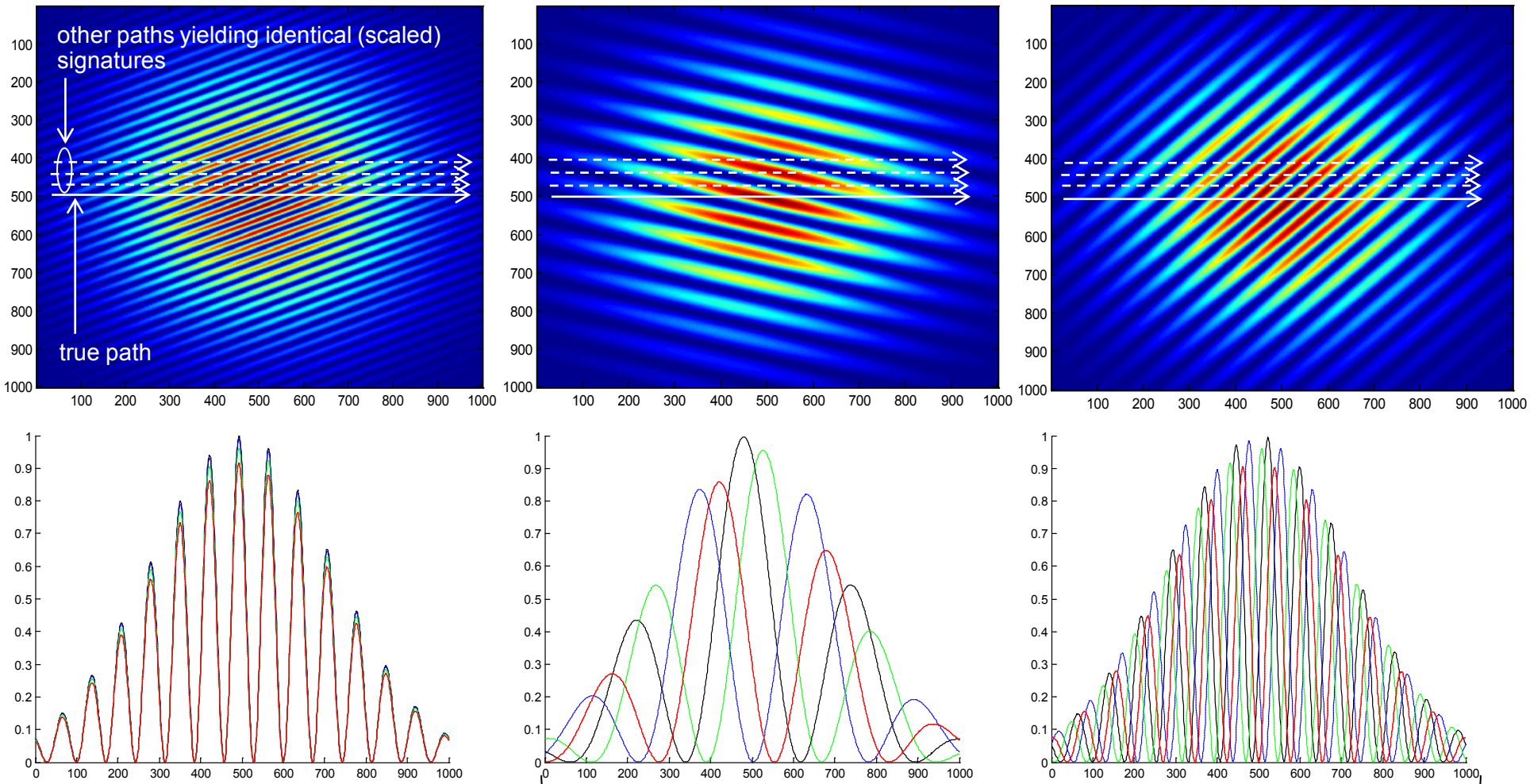


Simulated far-field patterns of various two-antenna and three-antenna Array Radar baselines (Apollo cluster)

Example 1: OD passing through zenith-pointed Array Radar fringes

- High-precision OD trajectory determination, with ambiguity resolution
- In this example, all three Array Radar antennas are pointing at zenith
- Velocity-projections onto all three baselines determine trajectory uniquely

DSS-24/26 baseline $f_{24/26}$ DSS-24/25 baseline $f_{24/25}$ DSS-25/26 baseline $f_{25/26}$

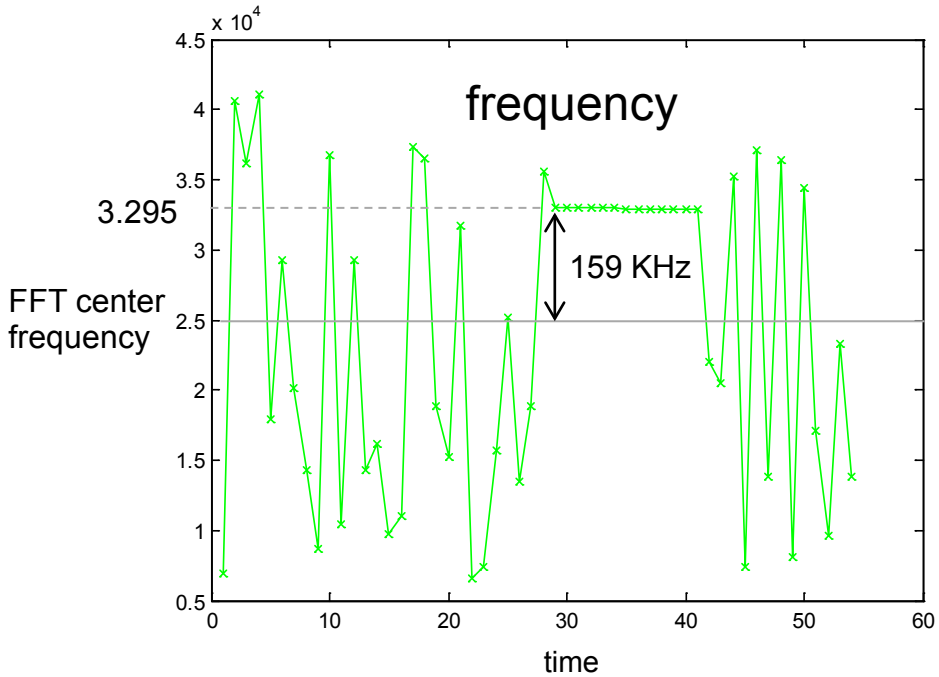


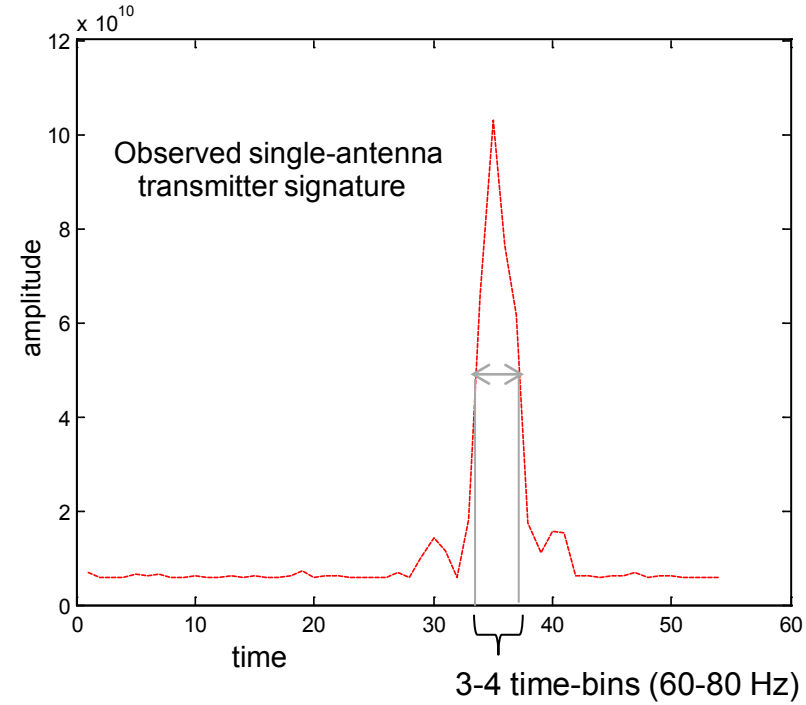
Ambiguous signatures, but with ~mdeg pointing accuracy

Trajectory ambiguities resolved by matching observed signatures over the other baselines

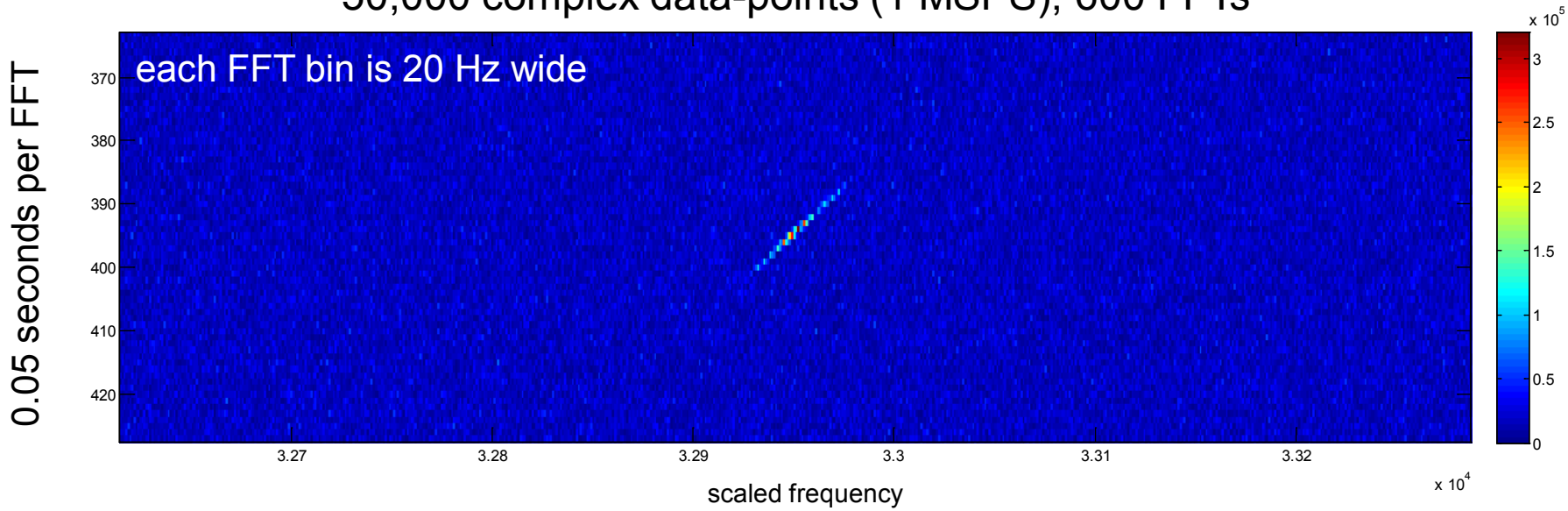
PRELIMINARY EXPERIMENTAL RESULTS

Single-antenna radar signature: DSS-25 transmitting, DSS-13 receiving



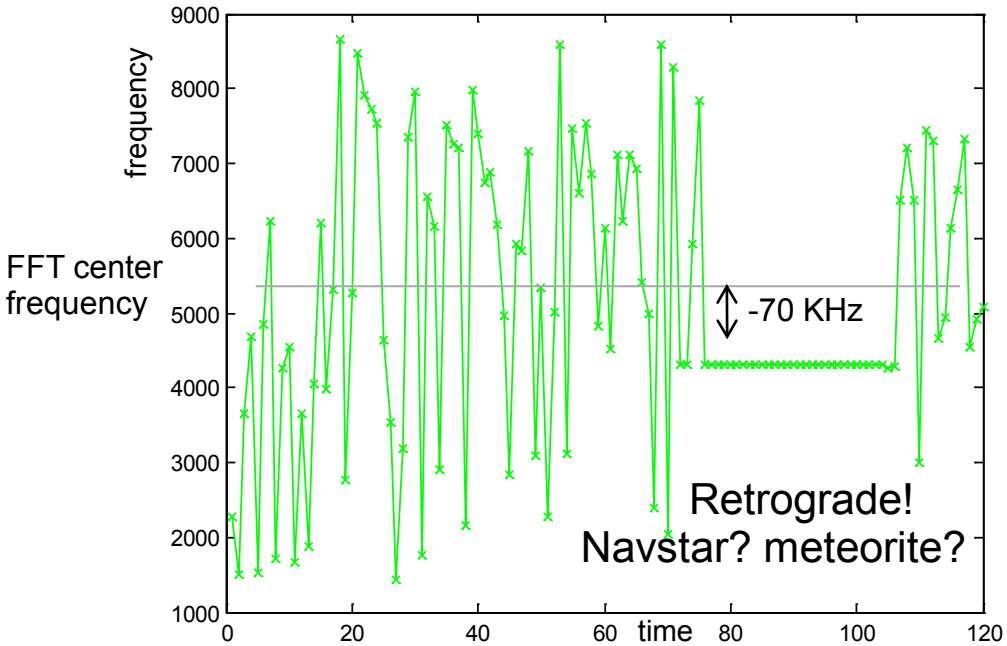


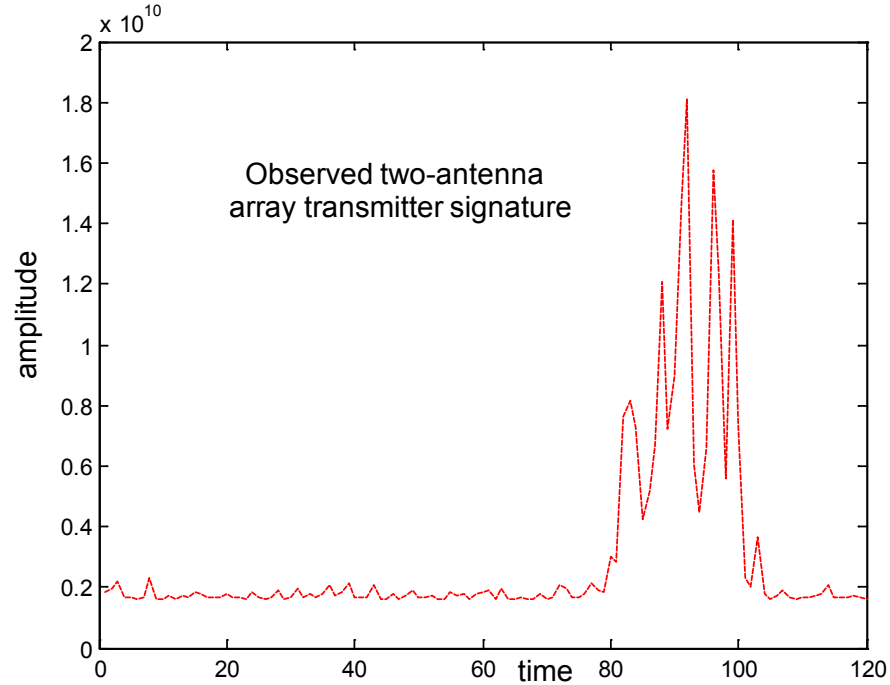
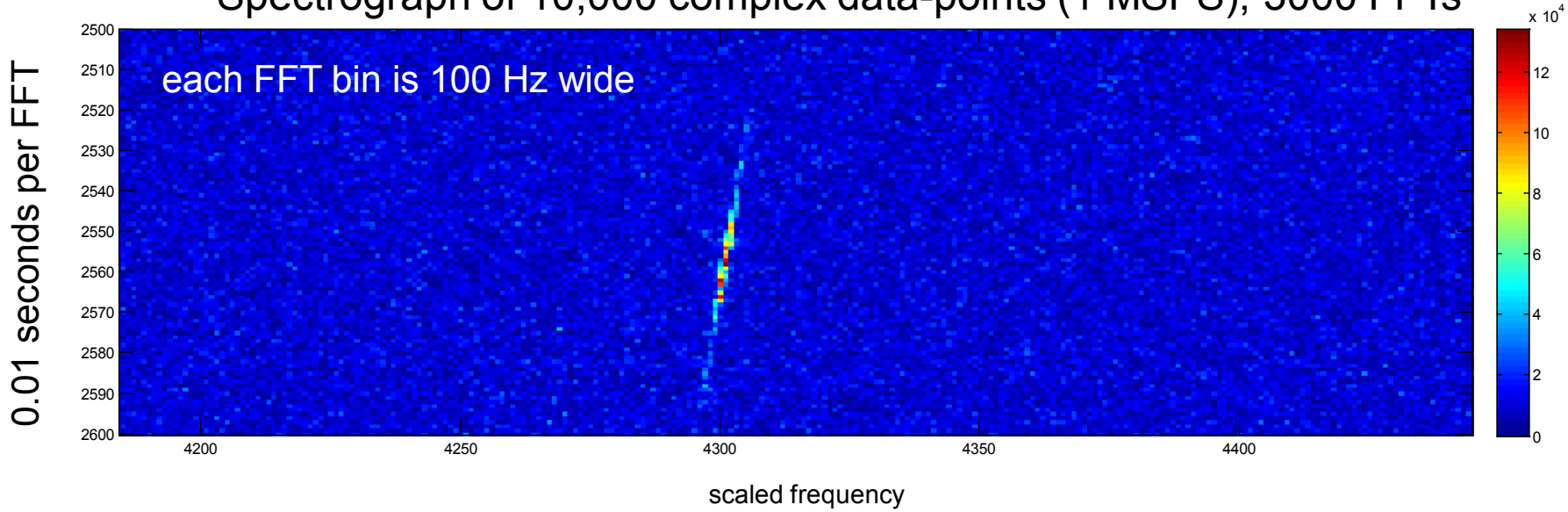
50,000 complex data-points (1 MSPS); 600 FFTs



PRELIMINARY EXPERIMENTAL RESULTS

two-antenna array radar signature: DSS-24/25 transmitting, DSS-13 receiving





Spectrograph of 10,000 complex data-points (1 MSPS); 3000 FFTs