Updates on RFSoC / Attemplifier interface

- "Spectrometer" (total power) mode compiled for 4x2 inputs
  + UDP streaming mode

- Packets are flowing through network.

- Tweaks to firmware are needed to:
  - Make sure UPD destination port is configurable for every output pair
  - Interface to control RFSoC boards as similar to SNAPs as possible

- Current backend receiver codes ingest data

- Connect new antennas to board

- attemplifiers <-> rfsoc <-> recorders mapping established.
  + get-ing and set-ing attenuation values

- IF-balancing logic to deal with RFSoC + SNAP boards at the same time (testing changes to configuration files, + python modules, etc…)

- <u>What's still needed:</u>

- Tests listed in Jack's document underway:
  Input panel <-> ADC <-> pipeline number mapping
  + cross-talk measurement

- Collect data with backend:
  - perform on/off measurement
  - perform pulsar observation

Update on high-speed data capture

- Current voltage-streaming mode can ingest **4 GB/s** on each NIC
  Would like to push it up to at least
  <u>**8 GB/s**</u> (64 gbits/s)

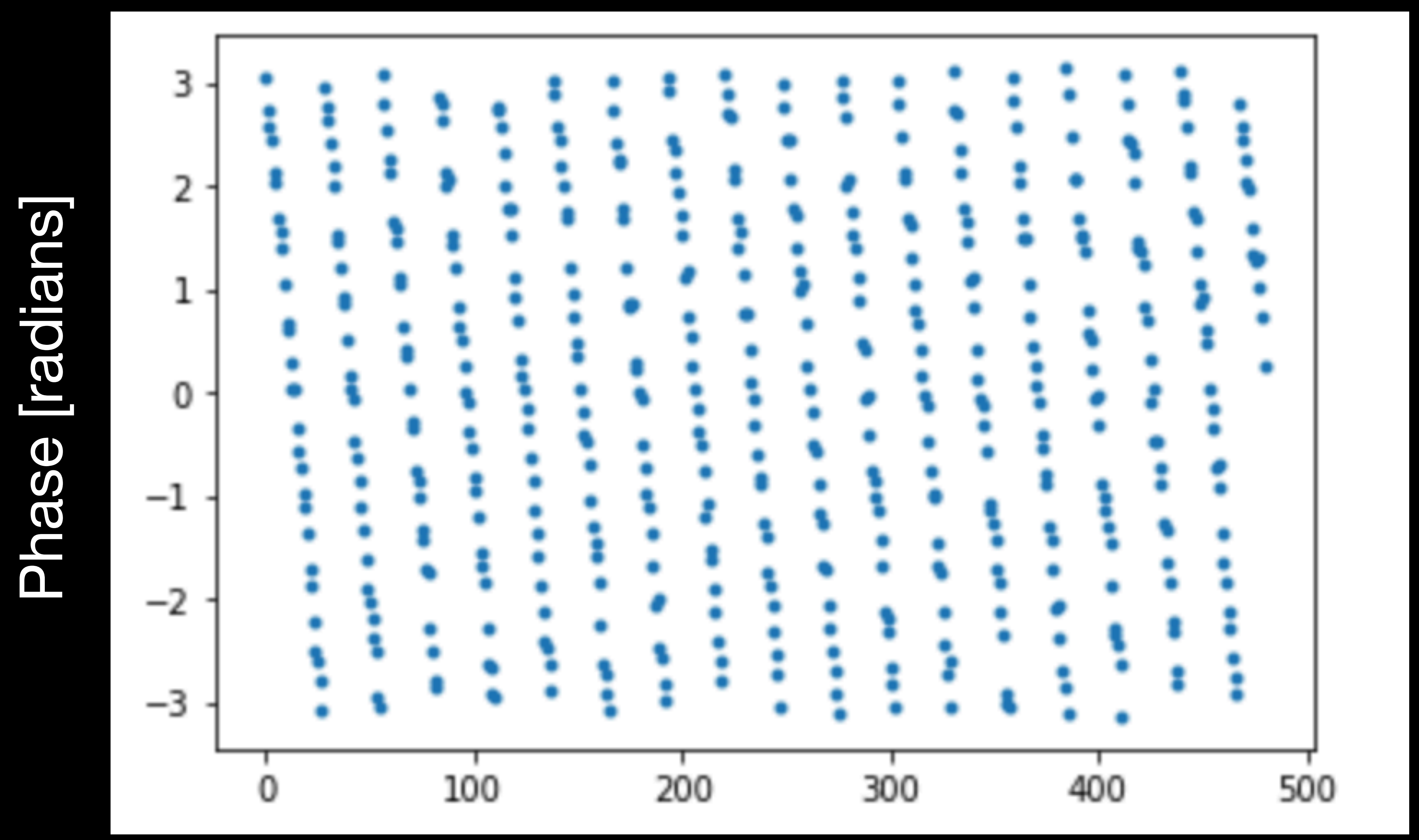
- Kernel-bypassing on Connect X5 NICs.
  libvma + libibverbs

- <u>Current status:</u>
  - ping-pong between IBV builtin server and client
  - Flow creation within voltage recorder
  - "Work completion" (i.e. packet reception) errors out

Updates on Correlator

- Written “toy” python correlator.
- Collected “golden” data on bright quasar (3c84)
- xGPU + hashpipe:
  - Correlator compiled for 4-bit mode
  - Can run in “live” mode
- Testing 4-bit correlator:
  - Writing: disk <-> RAM hashpipe threads to load and offload data easily
  - Investigate source of packet drops (turns out package was compiled with debug flag)
- Imaging software for faster display of data
- Live data flow + correlator
- GPU Complex multiplier for delay and phase compensation (currently happening offline post-correlation)

1a <-> 2b baseline



Frequency channel [number]

Prototype beam-former

- Written prototype python beam-former.

- Collected golden data on bright quasar (3c84) + Pulsar J0332+5434 in voltage mode:

- Observation:
  - 11 antennas (SNAP boards)
  - 64 MHz x 2 of bandwidth (256x2 channels)
  - 1.5 GHz sky frequency
  - 5 mins on each source
  - 1 + 1 TB of data

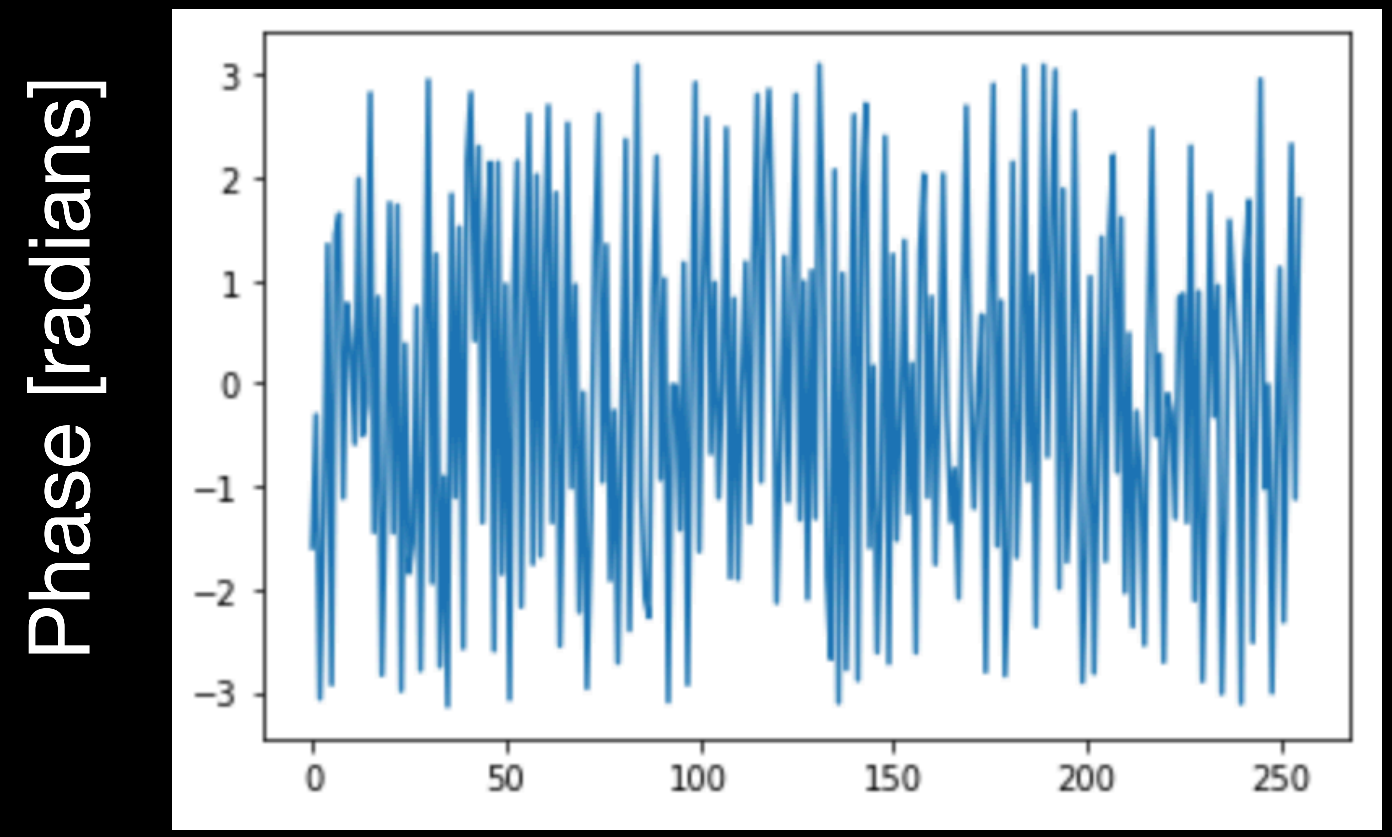
- Calibrate on bright quasar

- beam-form on pulsar

Calibration (delay+ phase) scheme

1. Cross-correlate antennas,
 display data + sanity checks

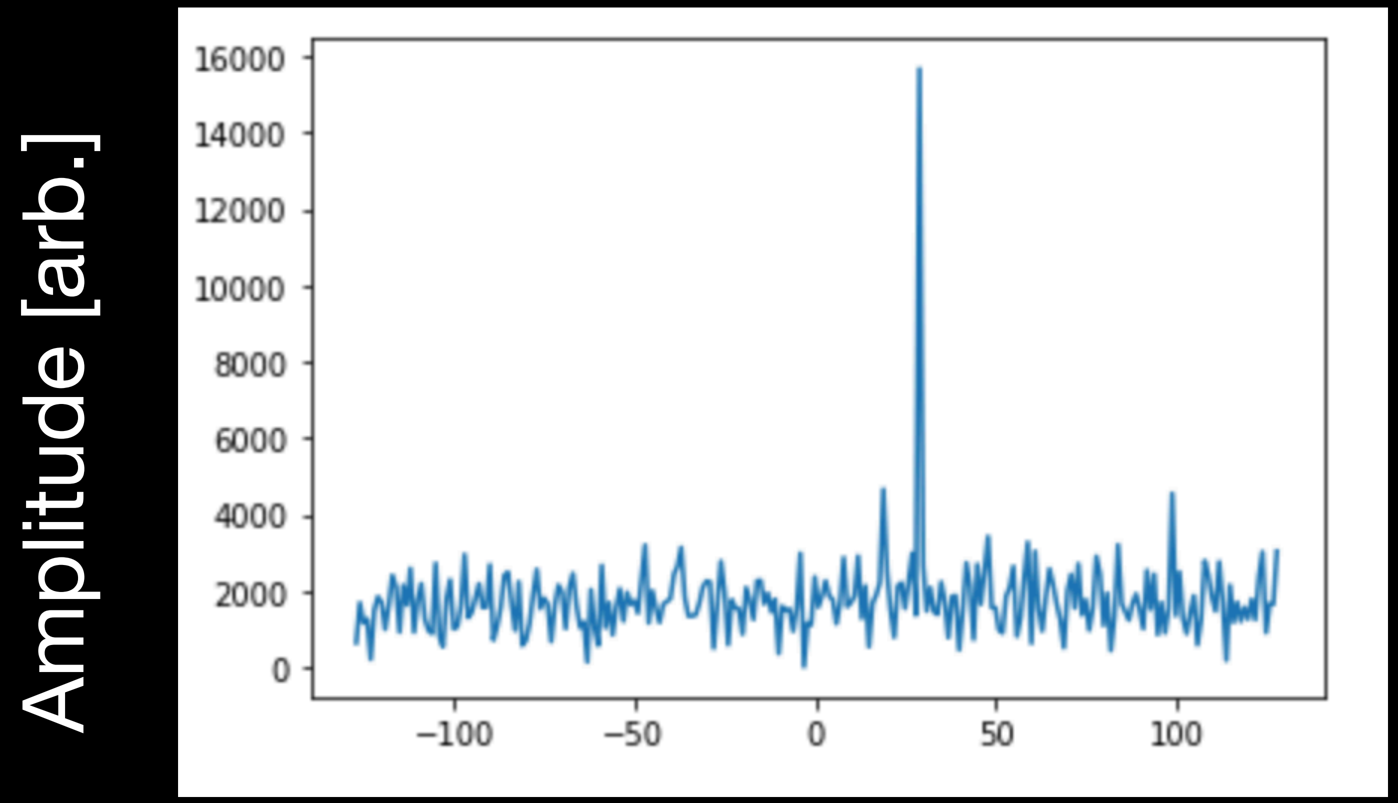
1c <-> 5c baseline (x pol)



Frequency channel [number]

iFFT

Lag spectrum

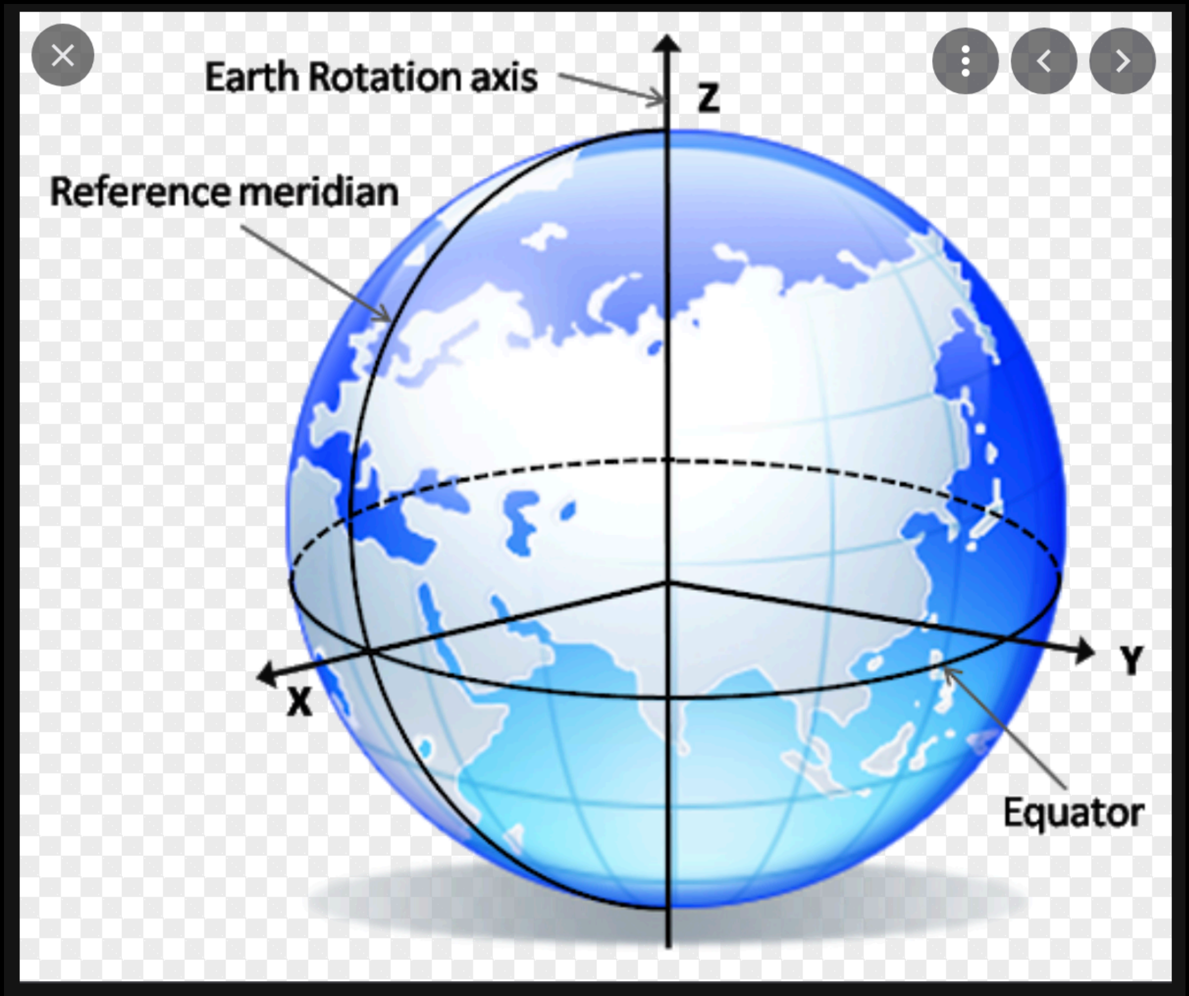


Samples [1/64MHz = 15.625 ns]

Calibration (delay+ phase) scheme

1. Cross-correlate antennas, display data + sanity checks

2. Calculate **geometric delays** given the position of antennas + position of source (and a reference antenna position)



ITRF (ECEF; earth centered earth fixed)
antenna positions XYZ

	x	y	z
1A	-2.524136e+06	-4.123448e+06	4.147709e+06
1F	-2.524193e+06	-4.123464e+06	4.147658e+06
1C	-2.524141e+06	-4.123508e+06	4.147649e+06
2A	-2.524086e+06	-4.123417e+06	4.147769e+06
4J	-2.523998e+06	-4.123376e+06	4.147863e+06
2H	-2.524174e+06	-4.123388e+06	4.147745e+06
3D	-2.524045e+06	-4.123400e+06	4.147811e+06
5B	-2.523924e+06	-4.123448e+06	4.147837e+06
1K	-2.524156e+06	-4.123435e+06	4.147709e+06
5C	-2.523925e+06	-4.123461e+06	4.147824e+06
1H	-2.524203e+06	-4.123431e+06	4.147685e+06
2B	-2.524070e+06	-4.123435e+06	4.147761e+06

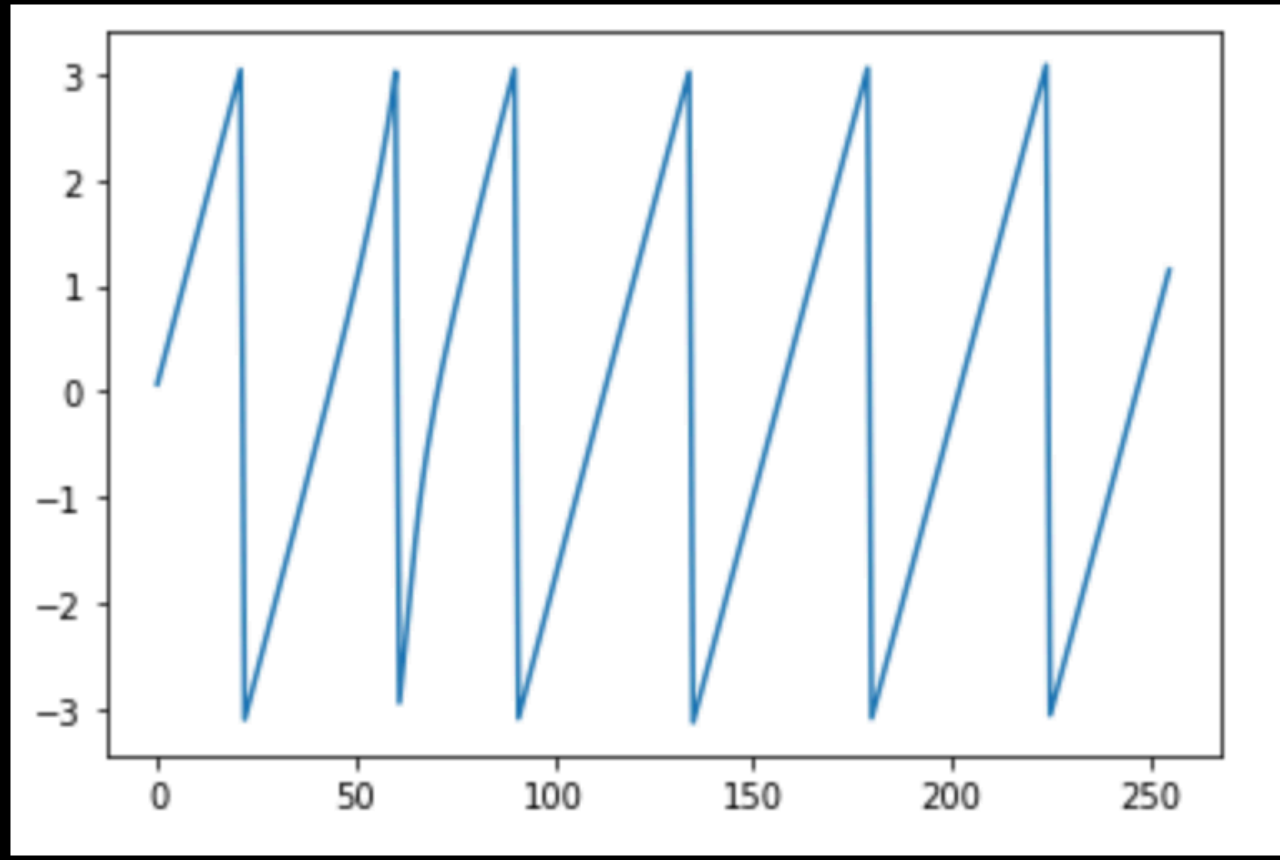
Calibration (delay+ phase) scheme

1. Cross-correlate antennas, display data + sanity checks

2. Calculate **geometric delays** given the position of antennas + position of source (and a reference antenna position)

3. Apply geometric delays:

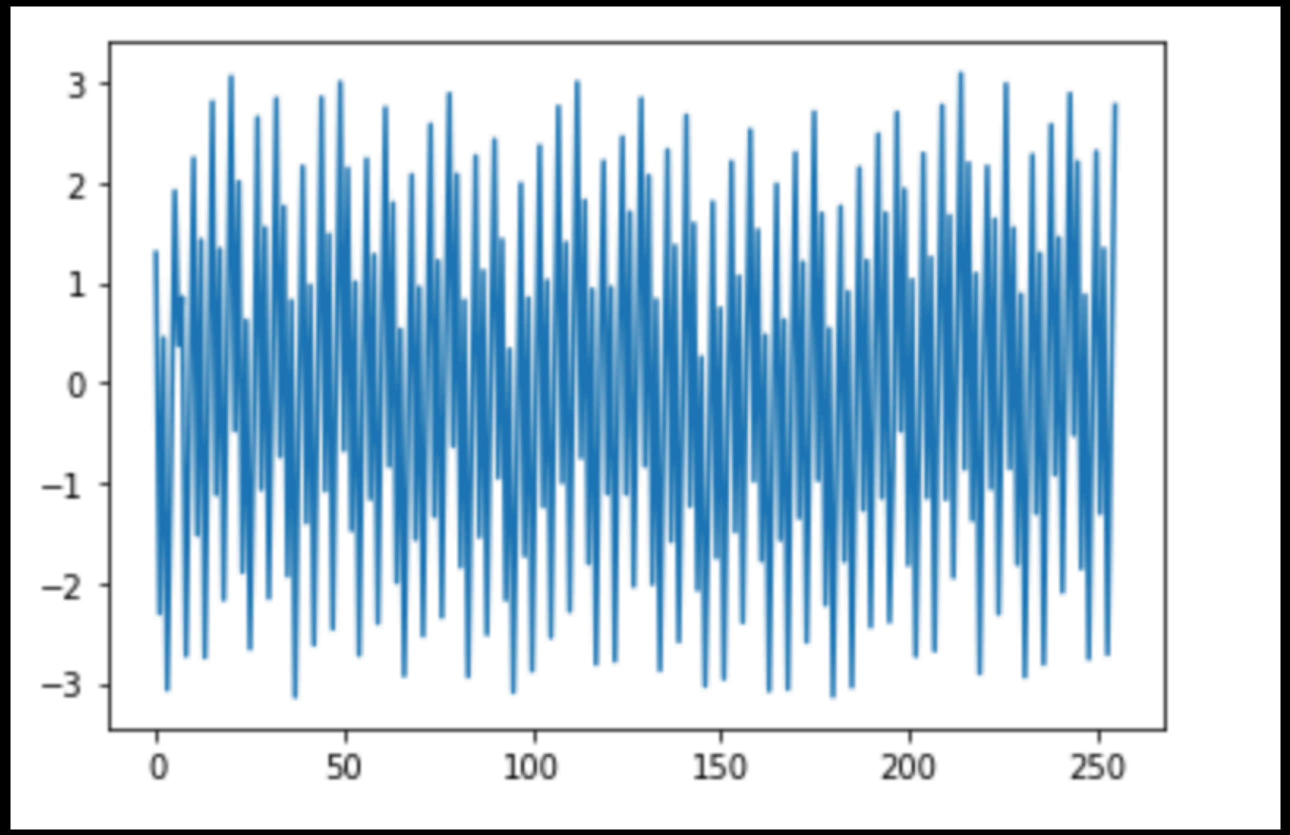
Phase [radians]



Frequency channel [number]

1c <-> 5c baseline

Phase [radians]

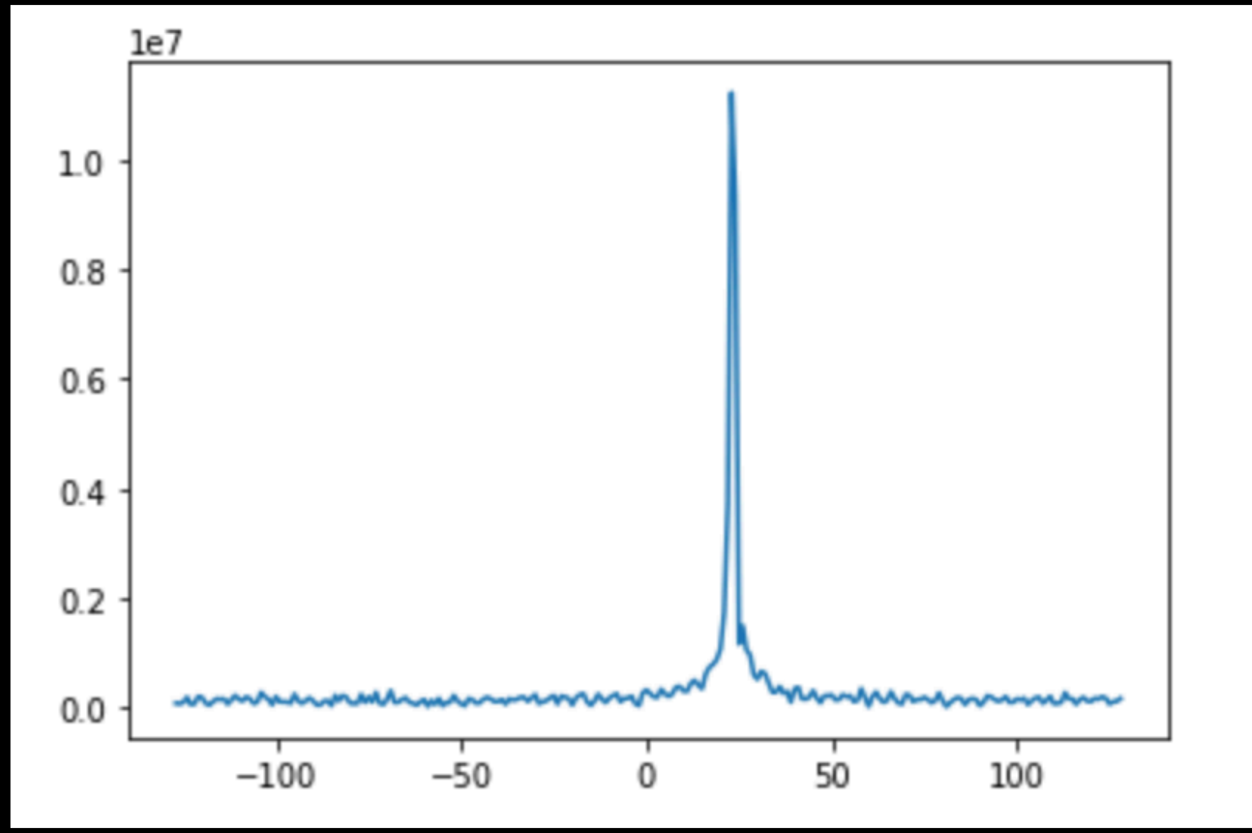


Frequency channel [number]

iFFT

Lag spectrum

Amplitude [arb.]



Samples [1/64MHz = 15.625 ns]

Calibration (delay+ phase) scheme

1. Cross-correlate antennas, display data + sanity checks

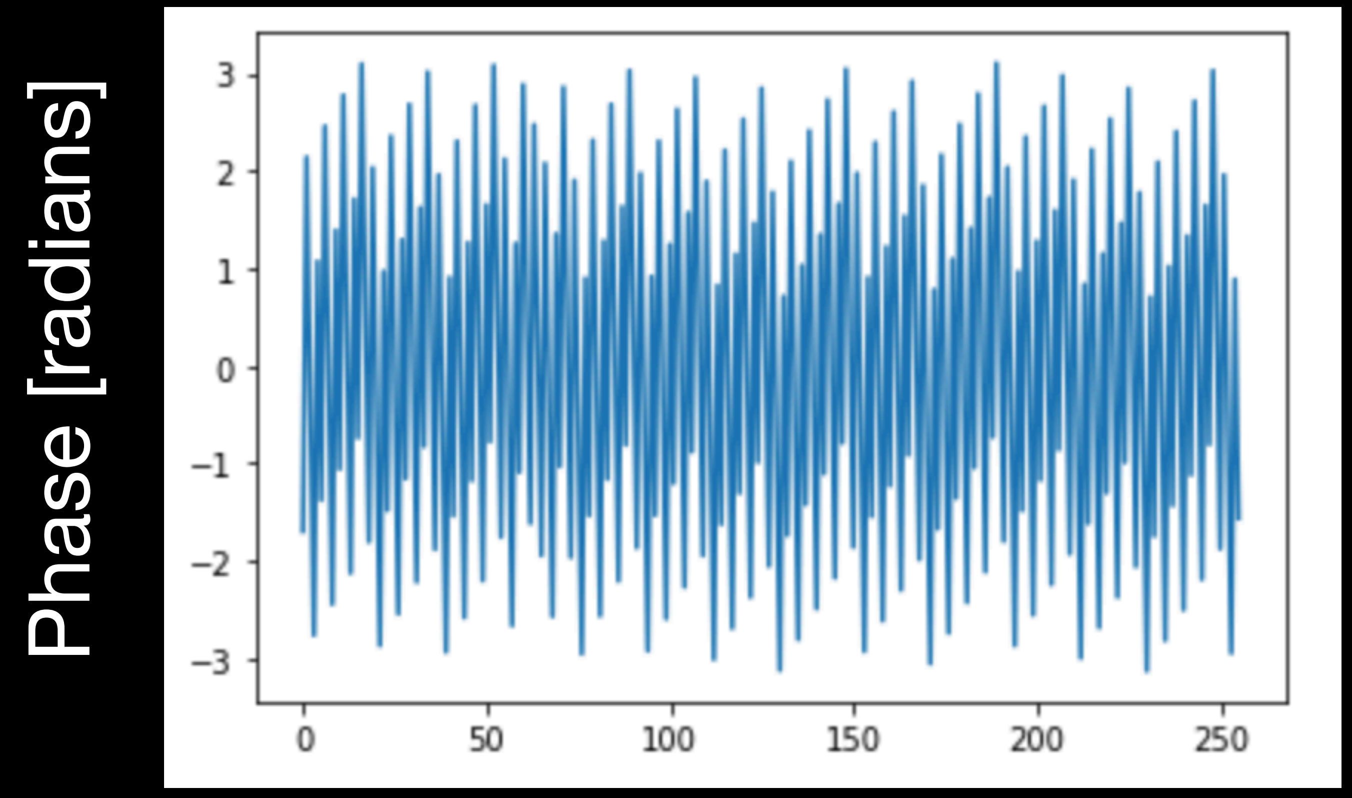
2. Calculate **geometric delays** given the position of antennas + position of source (and a reference antenna position)

3. Apply geometric delays

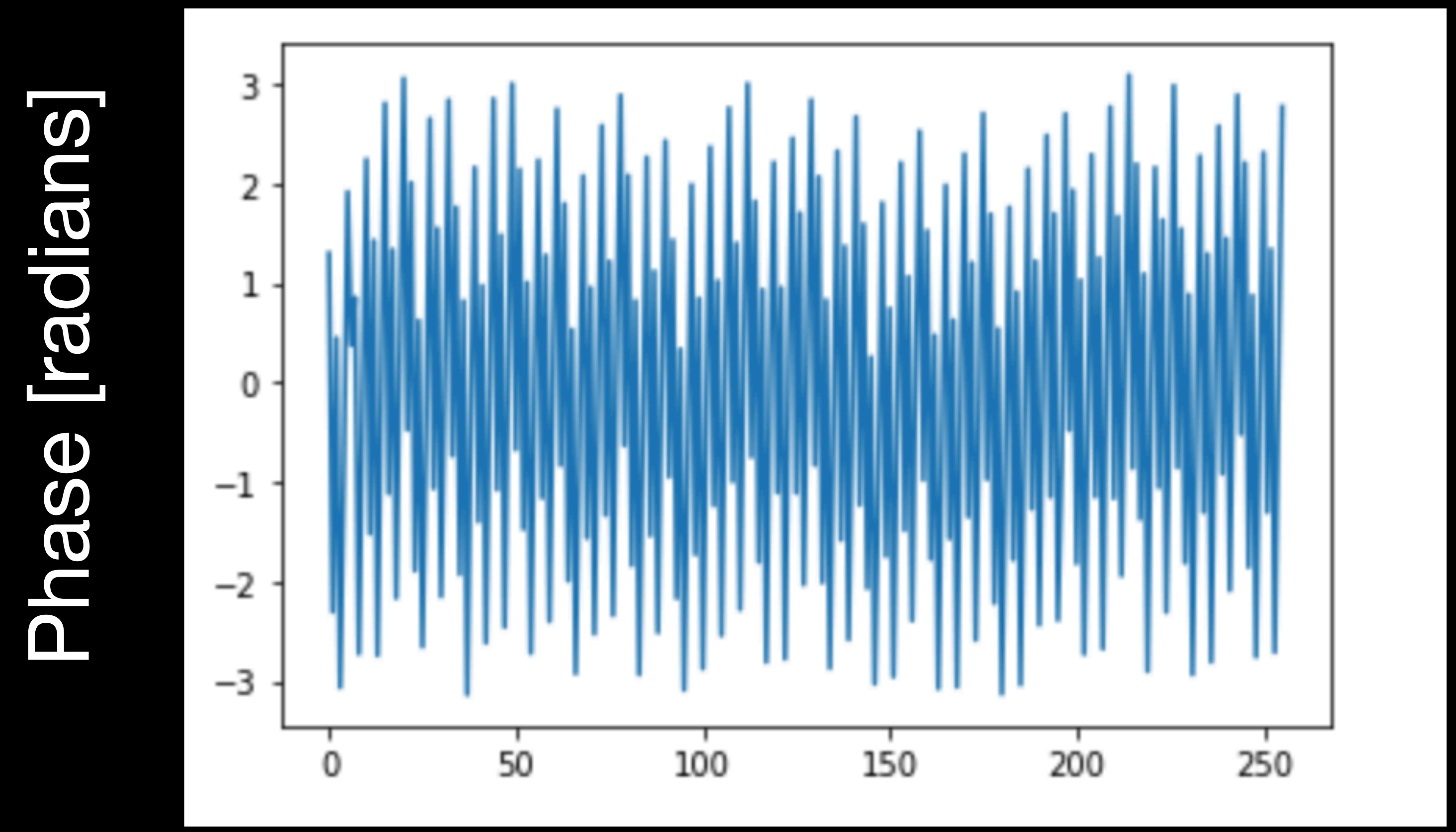
4. Measure integer-sample **fixed delays** from lag spectrum.

22 samples = 343.75ns

Fixed delay phasor:

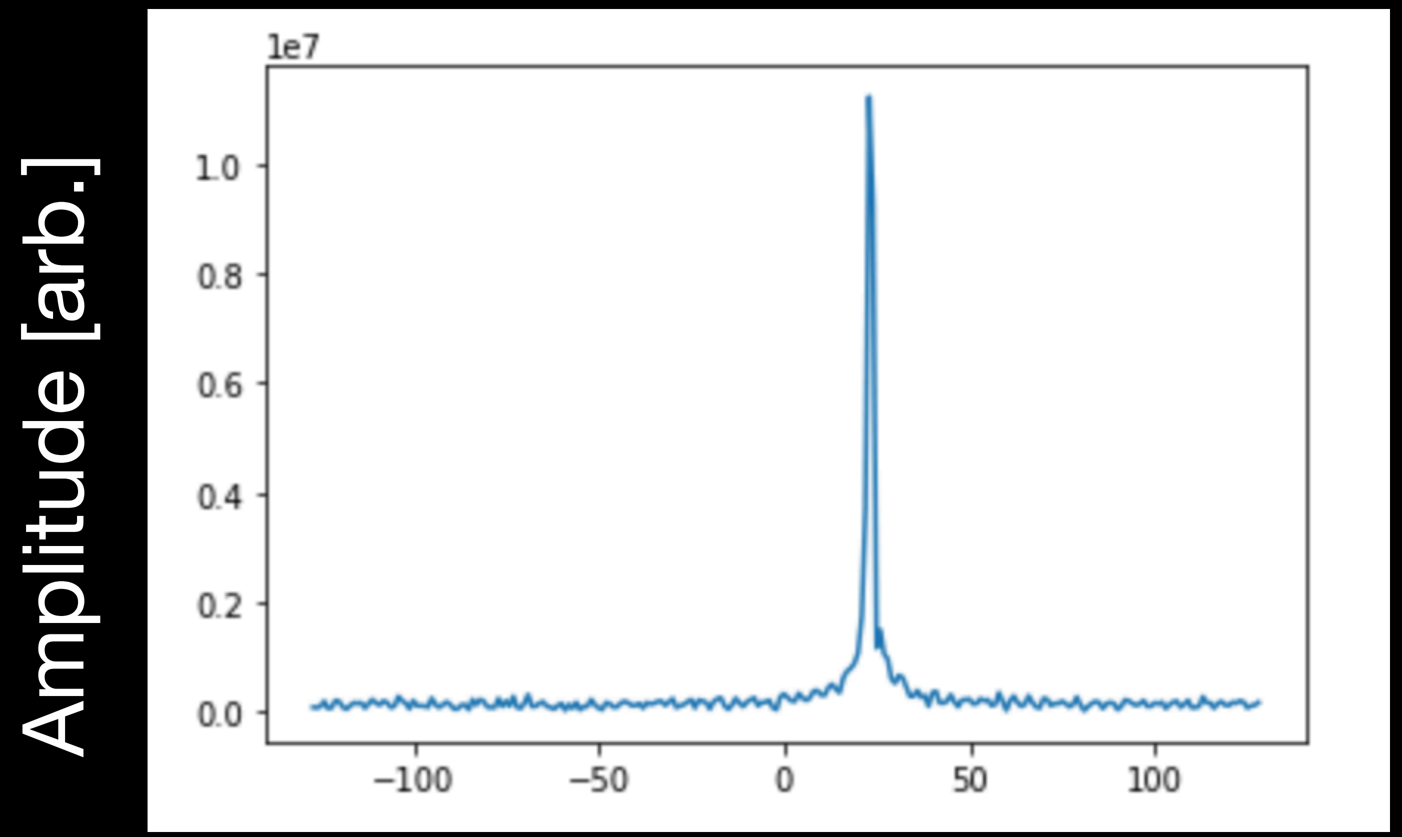


1c <-> 5c baseline



iFFT

Lag spectrum



Calibration (delay+ phase) scheme

1. Cross-correlate antennas, display data + sanity checks

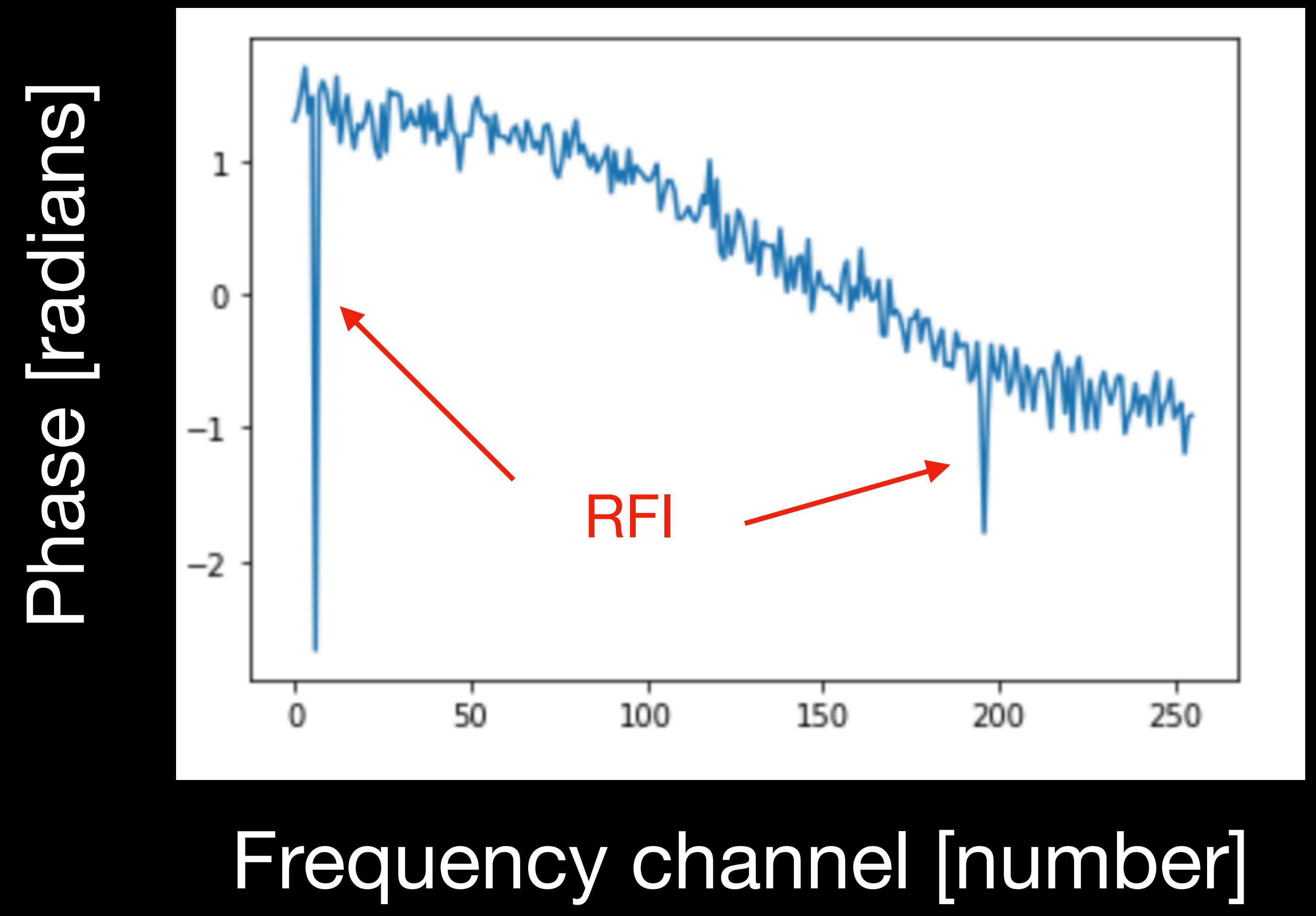
2. Calculate **<u>geometric delays</u>** given the position of antennas + position of source (and a reference antenna position)

3. Apply geometric delays

4. Measure integer-sample **<u>fixed delays</u>** from lag spectrum.

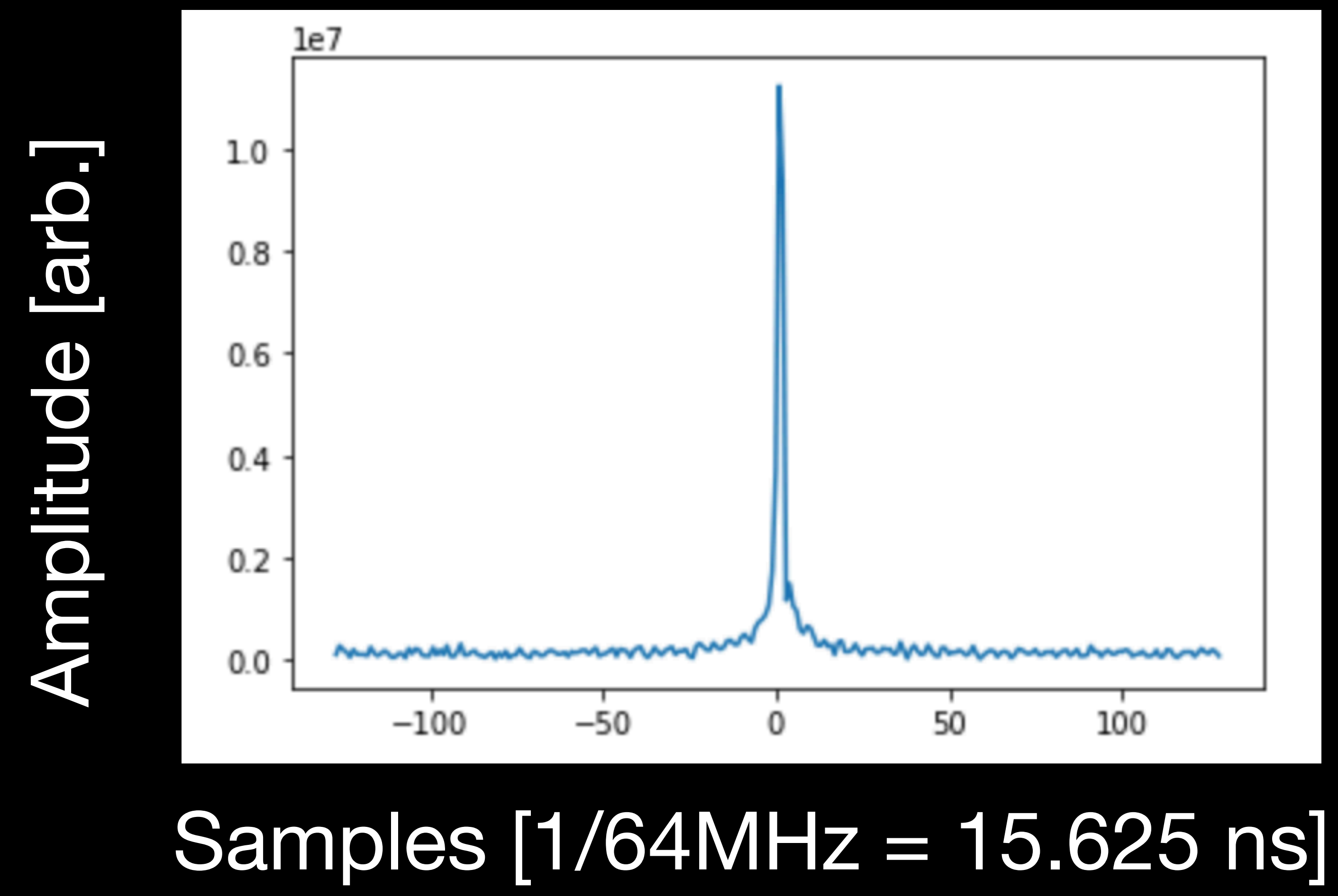
5. Apply <u>fixed sample delays:</u>

1c <-> 5c baseline



iFFT

Lag spectrum



Calibration (delay+ phase) scheme

1. Cross-correlate antennas, display data
 + sanity checks

2. Calculate **<u>geometric delays</u>** given the
 position of antennas + position of source
 (and a reference antenna position)

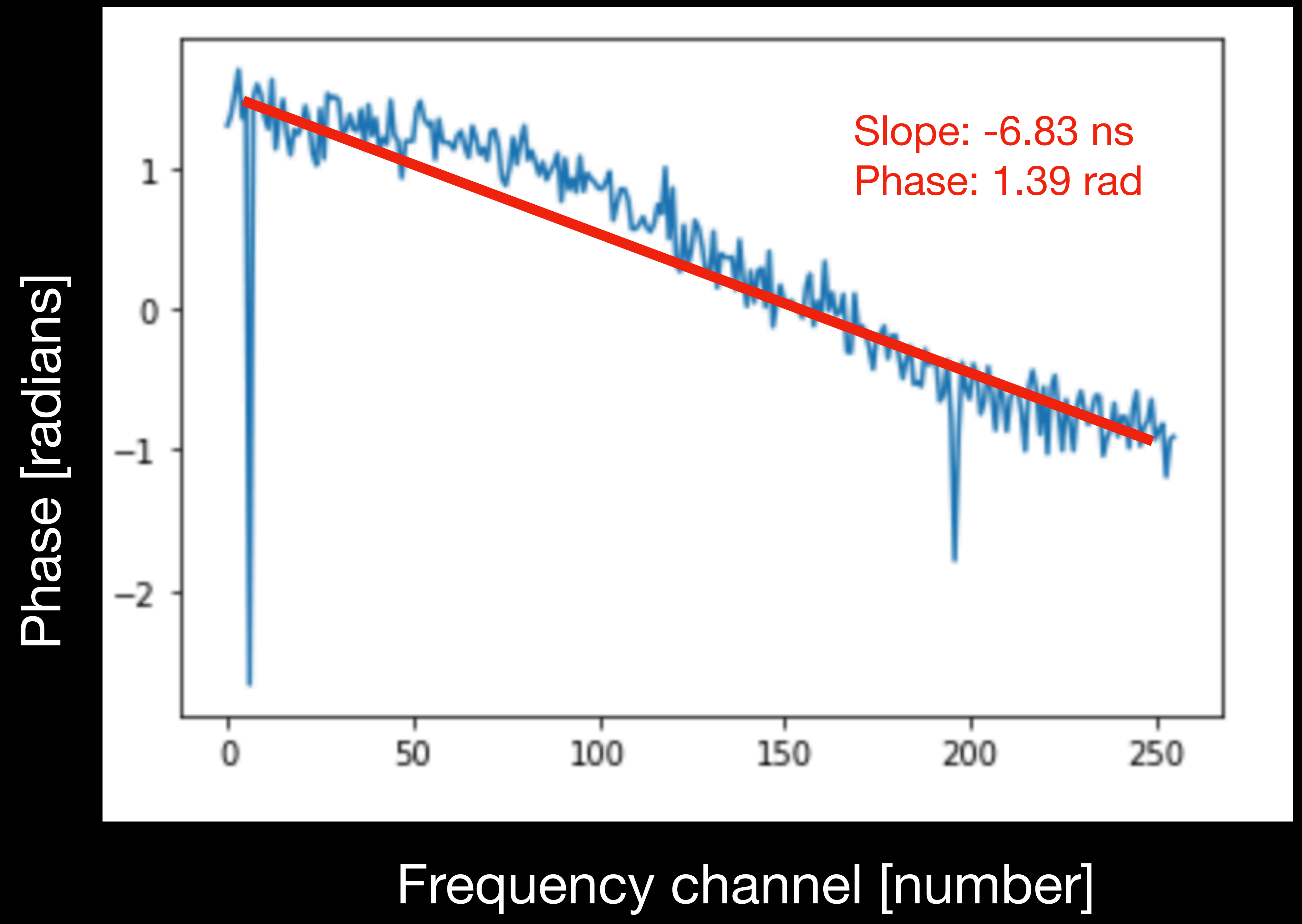
3. Apply geometric delays

4. Measure integer-sample **<u>fixed delays</u>**
 from lag spectrum.

5. Apply <u>fixed sample delays</u>

6. Measure <u>sub-sample delay</u> (slope)
 and
 measure <u>phase</u> (intercept)

1c <-> 5c baseline



Calibration (delay+ phase) scheme

1. Cross-correlate antennas, display data + sanity checks

2. Calculate **<u>geometric delays</u>** given the position of antennas + position of source (and a reference antenna position)

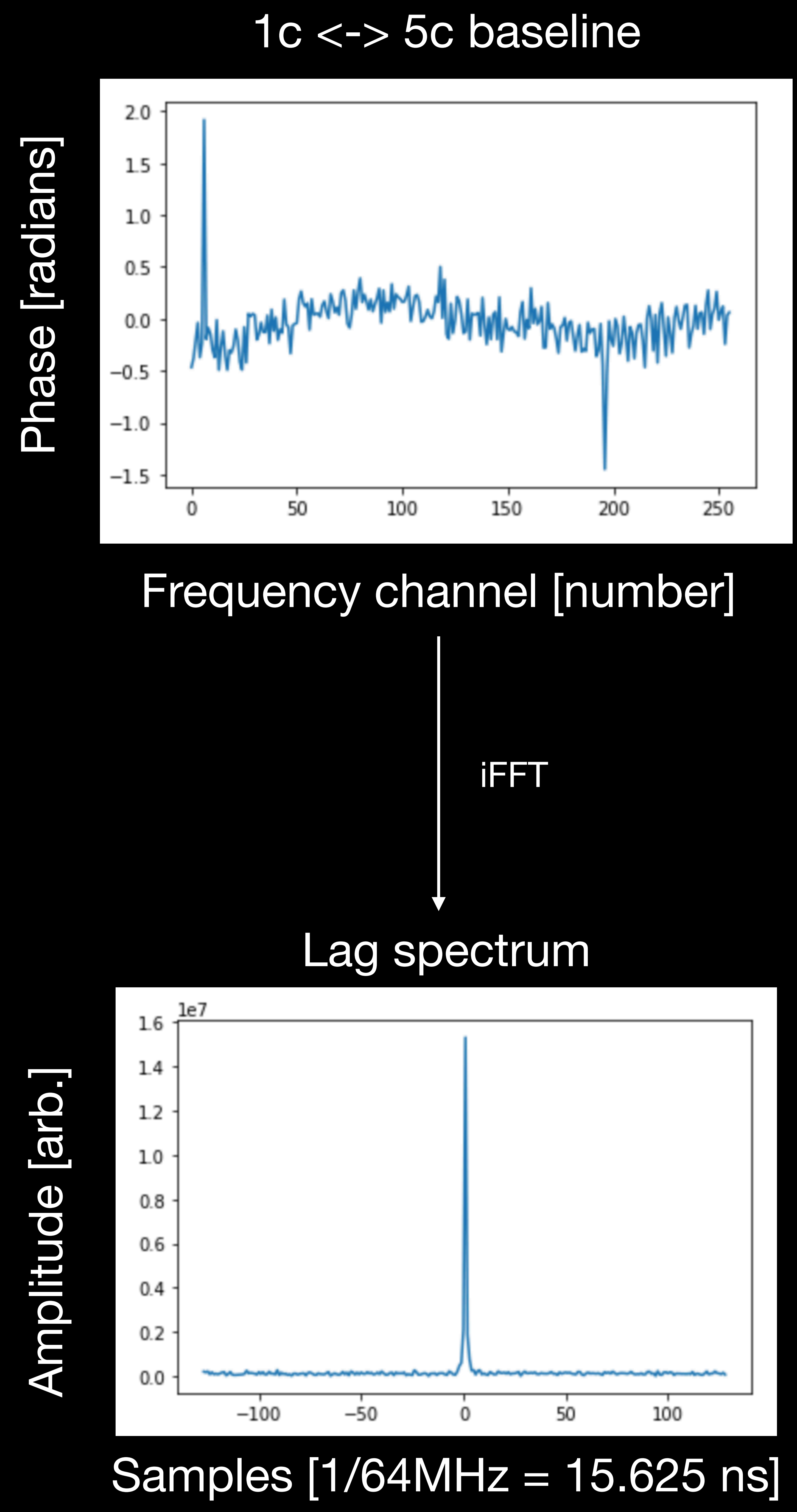
3. Apply geometric delays

4. Measure integer-sample **<u>fixed delays</u>** from lag spectrum.

5. Apply <u>fixed sample delays</u>

6. Measure <u>sub-sample delay</u> (slope)
   and
   measure <u>phase</u> (intercept)

7. Apply <u>sub-sample delay</u> + <u>phase</u>



Beamform on sky source

1. Apply geometric + fixed delays + phase offset

   (no gain, nor bandpass calibration applied)

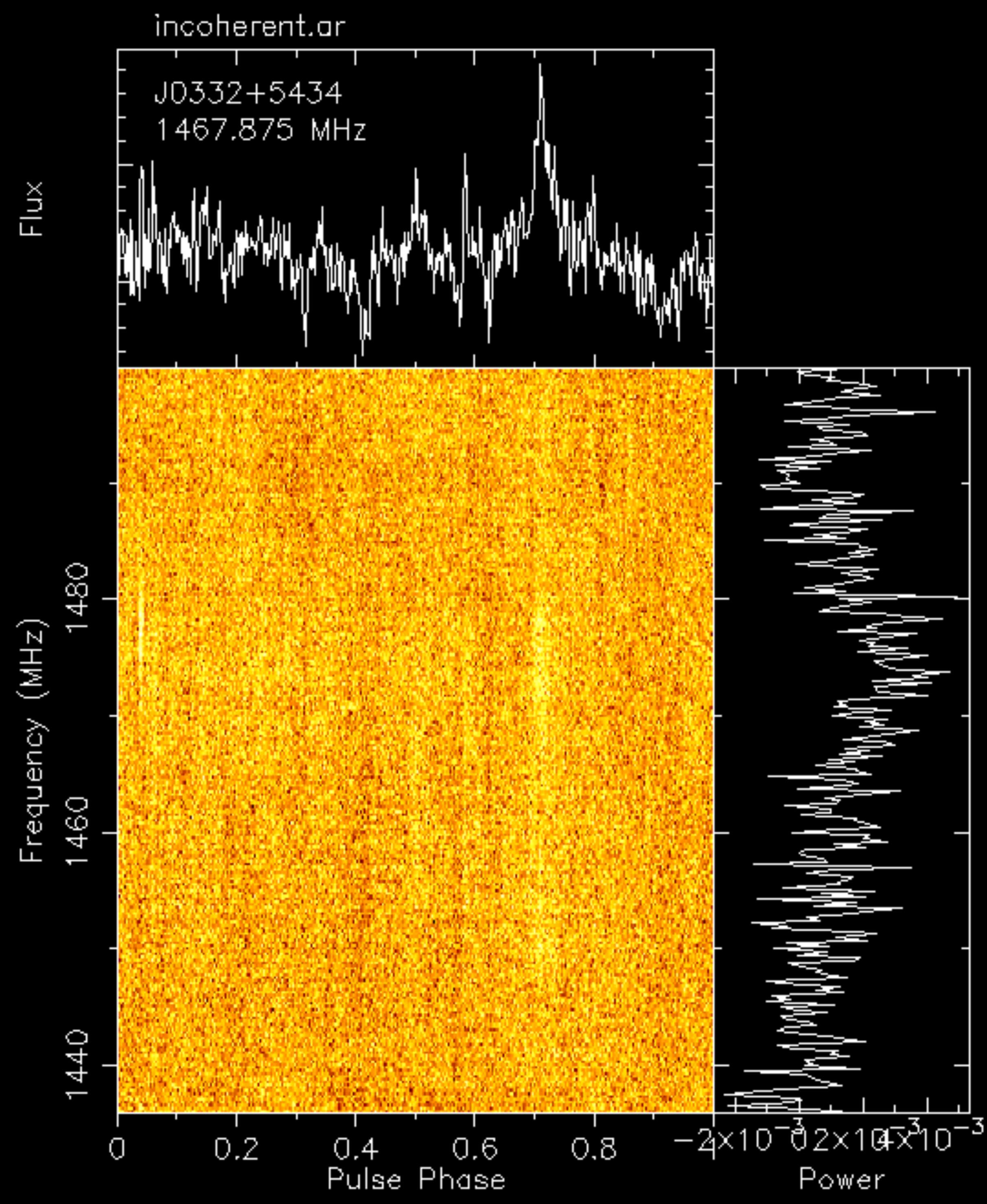
2. Coherent summation (in phase)

3. Incoherent sum (for comparison)

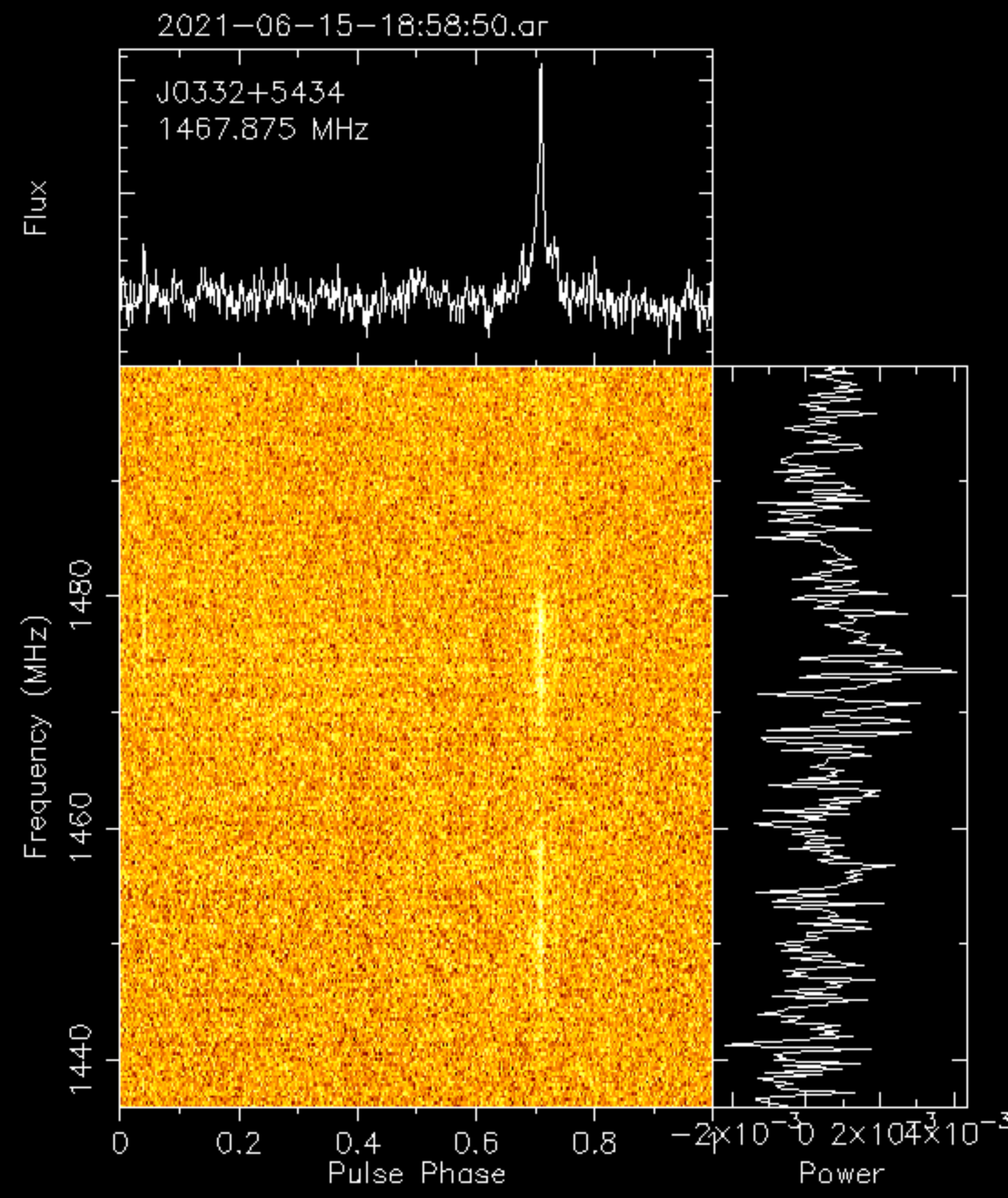
4. Pulsar processing

5. ~ factor of 2 improvement in S/N (Theoretical improvement is sqrt(Nants) = sqrt(11) = 3.3, with perfect beam forming efficiency)

Incoherent sum



coherent sum



Beamform on sky source

1. Apply geometric + fixed delays + phase offset

   (no gain, nor bandpass calibration applied)

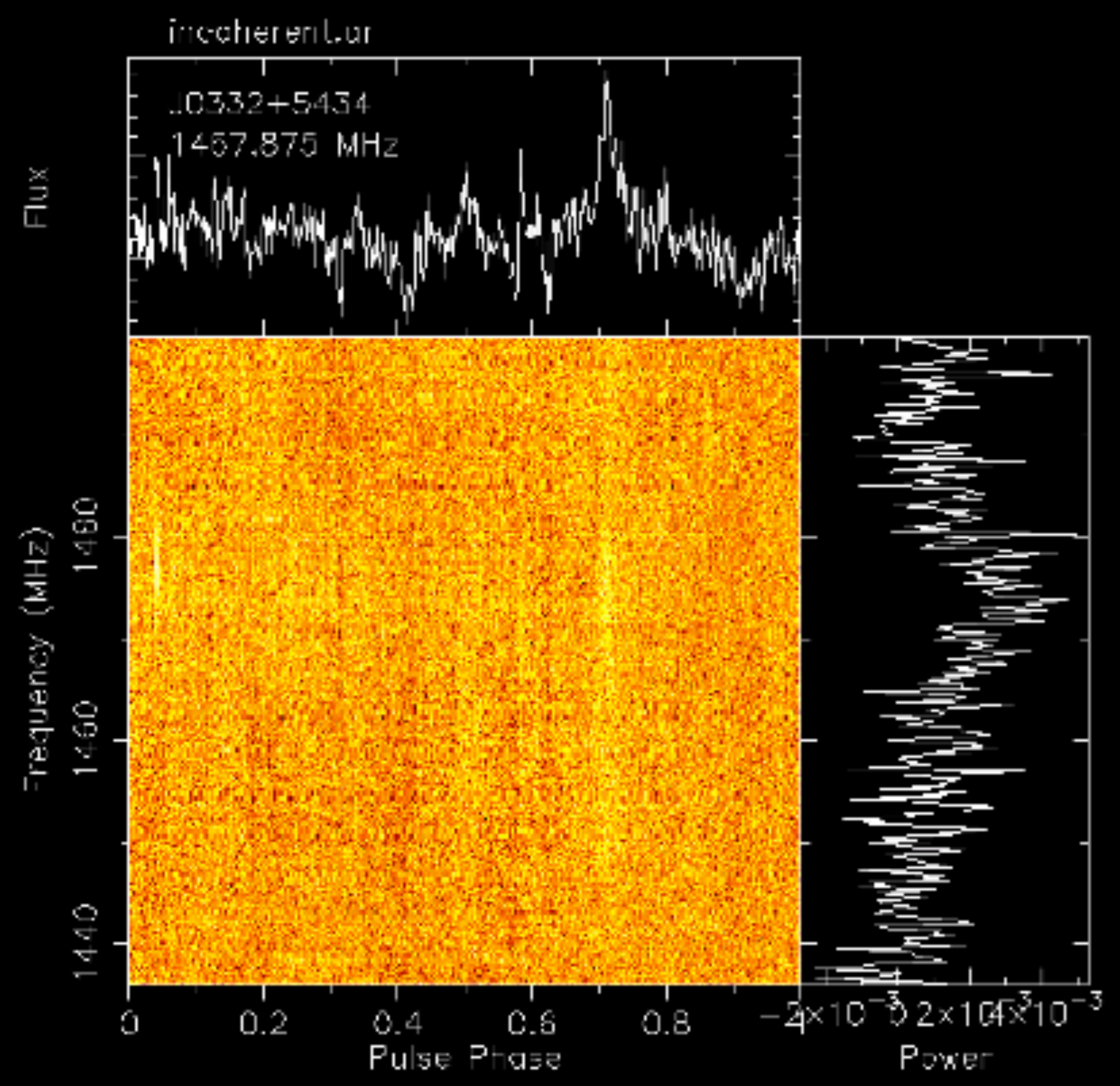
2. Coherent summation (in phase)

3. Incoherent sum (for comparison)

4. Pulsar processing

5. Using polarisation-dependent phase solution. S/N scales correctly with number of antennas

Incoherent sum



coherent sum