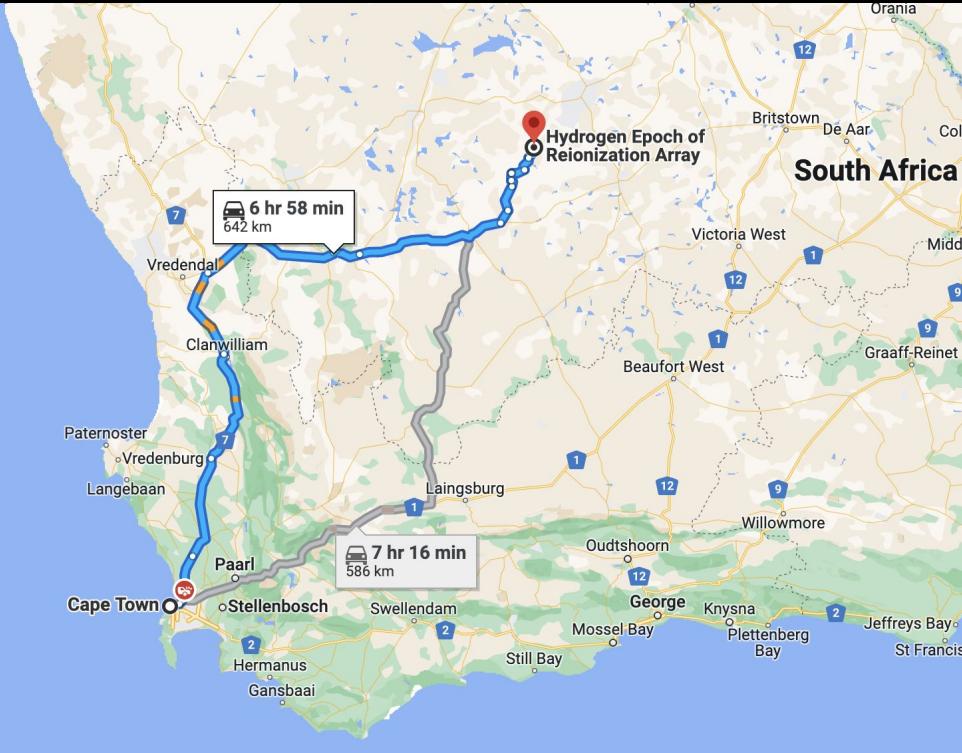


The background image shows the HERA radio telescope's antenna structure at sunset. The sky is filled with orange and yellow clouds, with the sun partially visible on the horizon. The dark silhouette of the antenna's support towers and cables stretches across the frame.

HERA System Overview

CHAMP Camp 6/08/22

Where



350 14-m dishes

Core and outriggers

Zenith pointing drift scan telescope

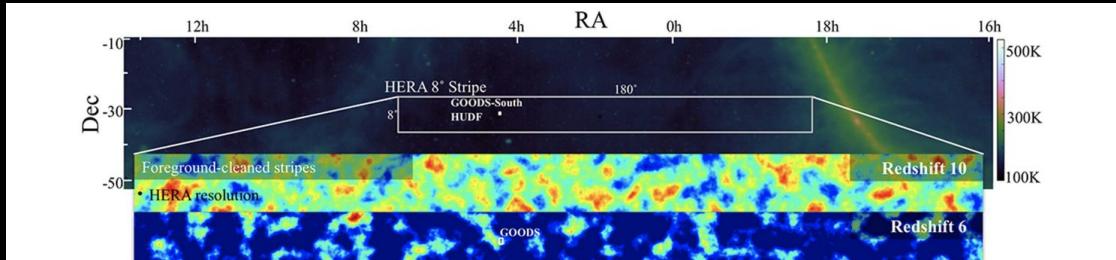
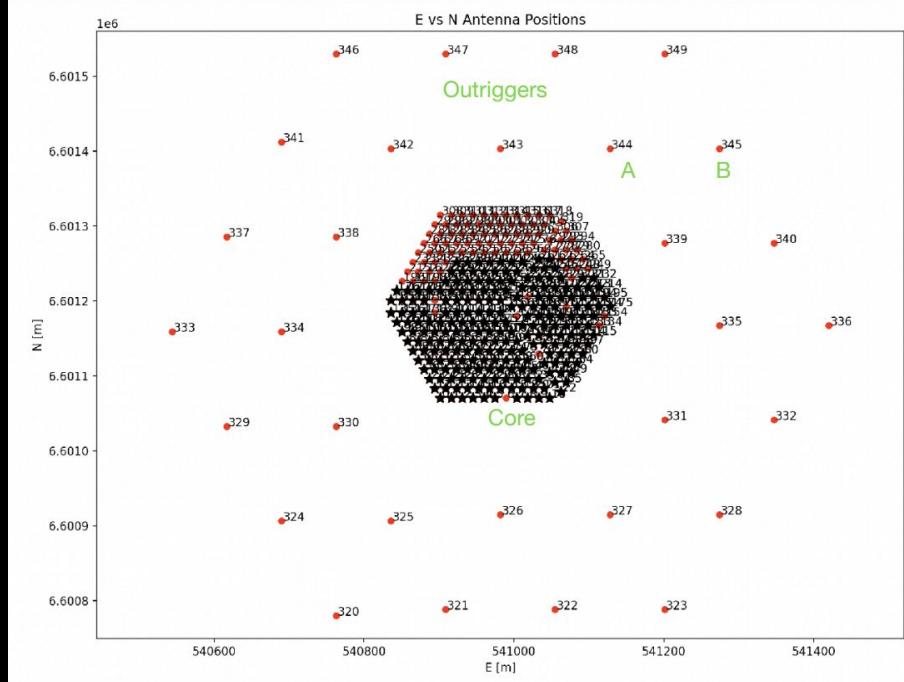


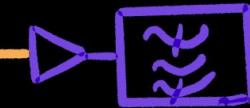
Figure 7. HERA will observe a 1440 deg^2 stripe centered near $\delta = -30^\circ$. HERA can measure the ionization state around galaxies in, e.g., the GOODS-South field that contains a third of all known $z > 8$ galaxies. HERA's primary imaging data product to the community will be deep cubes along the HERA stripe suitable for cross-correlation.

incoming
radiation

feed



RF
signal



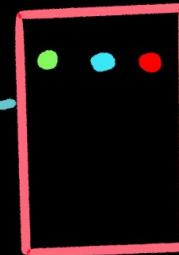
RF
signal

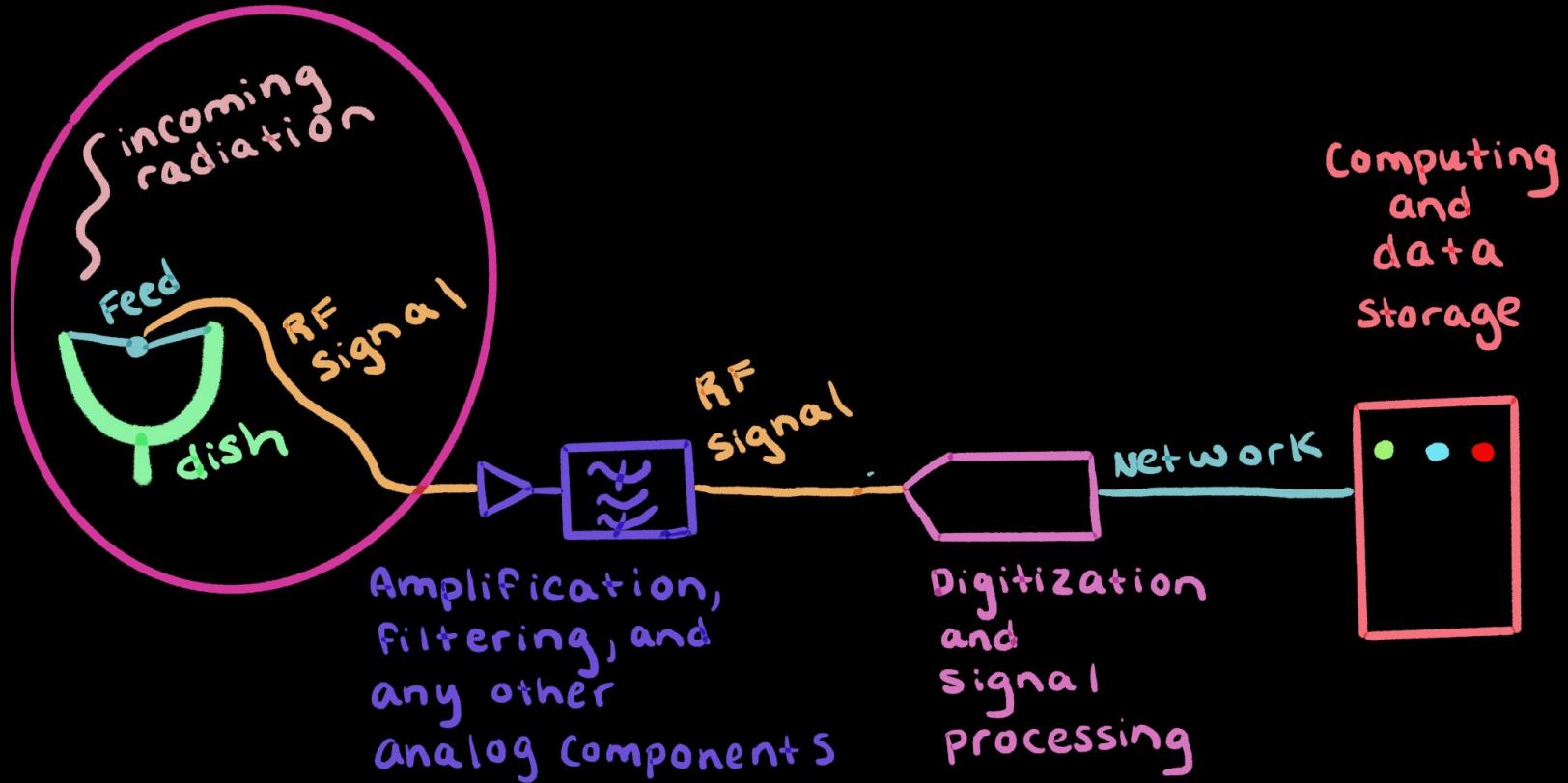
Amplification,
filtering, and
any other
analog components

Digitization
and
signal
processing

Network

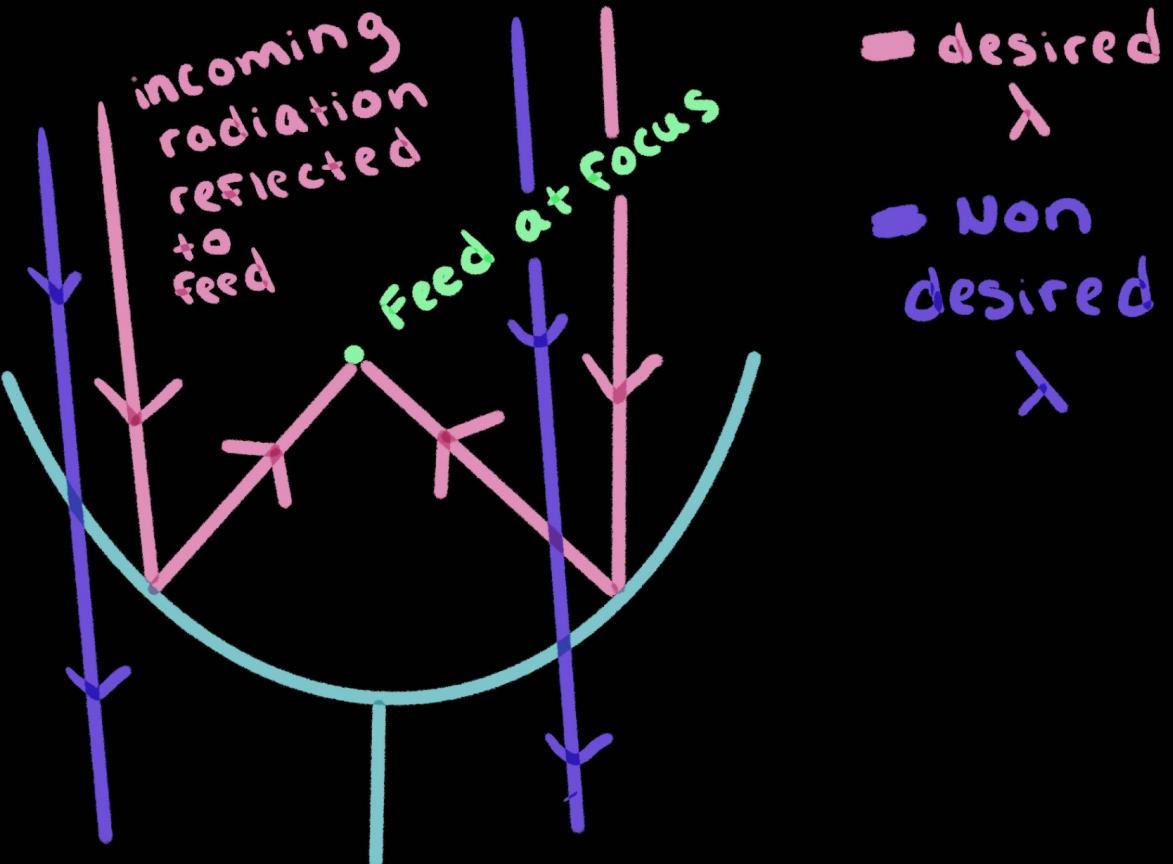
Computing
and
data
storage



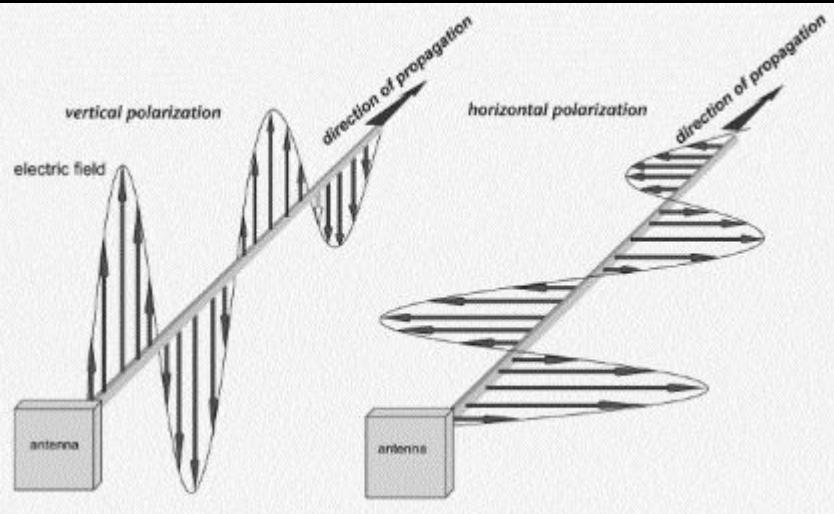


Vivaldi Feed





Feed and Antenna Polarization



HERA's feed is polarized into EE and NN polarizations, output data products reflect this.

Edges



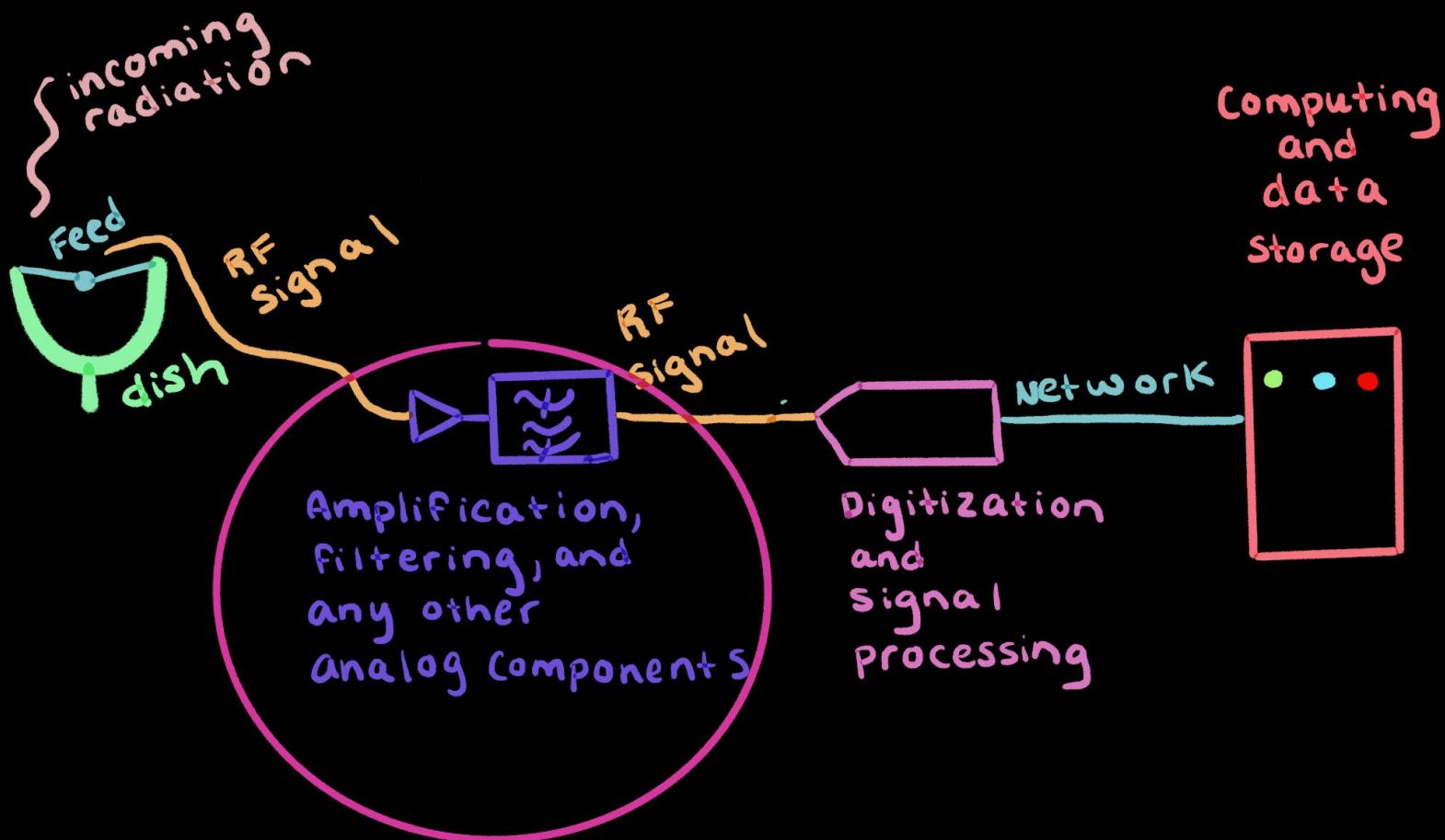
Local 21 cm exp



LWA

SKA Prototype





FEM

Front end module

RF IN -> FIBER OUT

Dual polarization

High pass filtering and amplification

Noise/Load/Sky switch



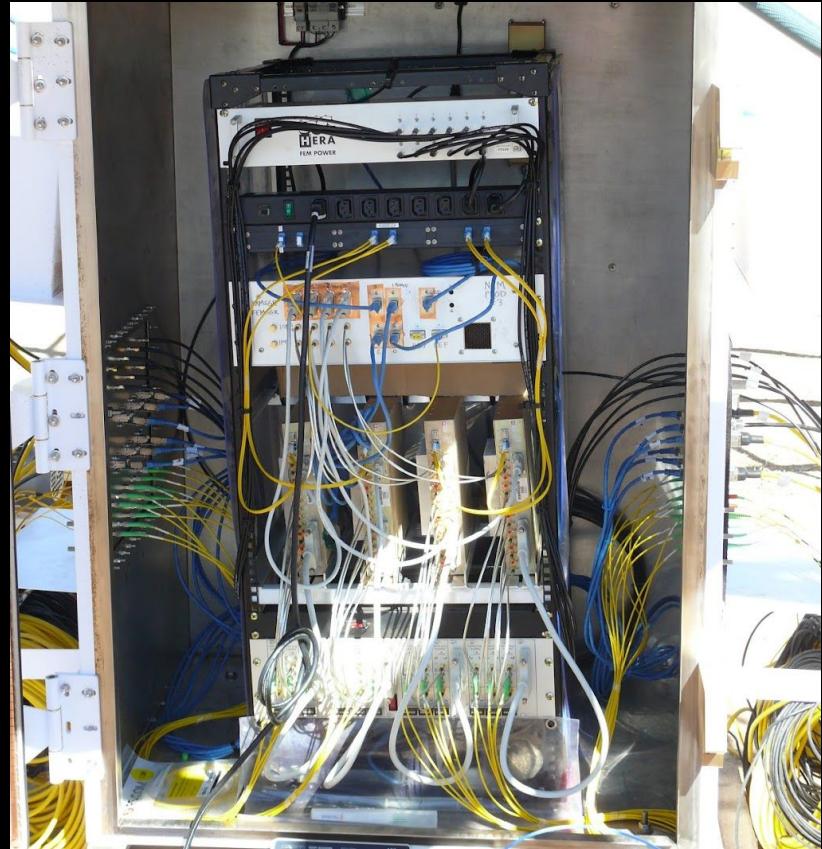
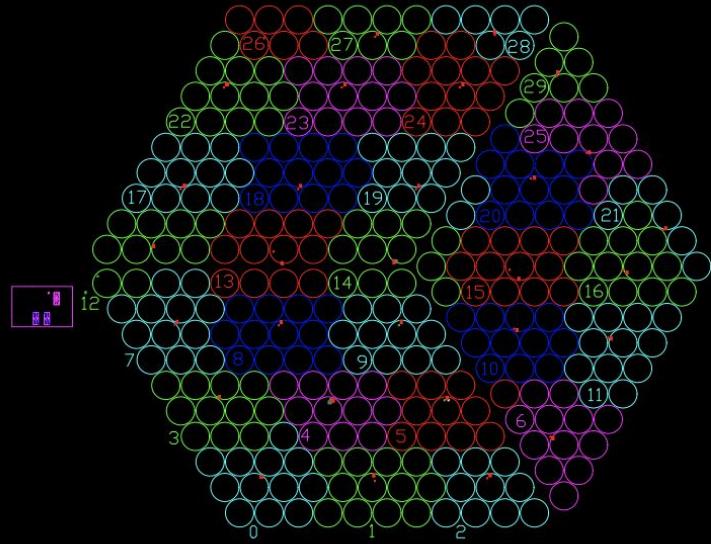
RF over Fiber
500m cable
length



Node organization

~12 antennas per node

30 total nodes



PAM

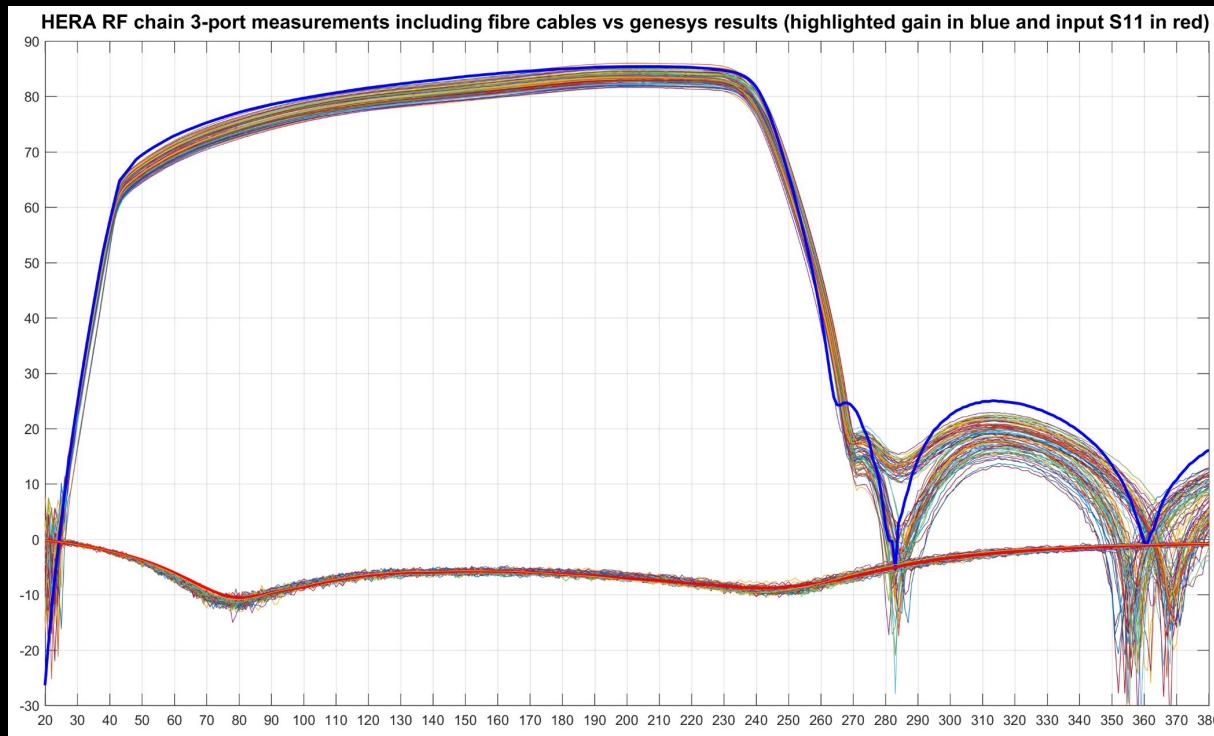
Post amplifier module

FIBER IN -> RF OUT

Attenuators, low pass filtering, amplification



HERA Bandpass

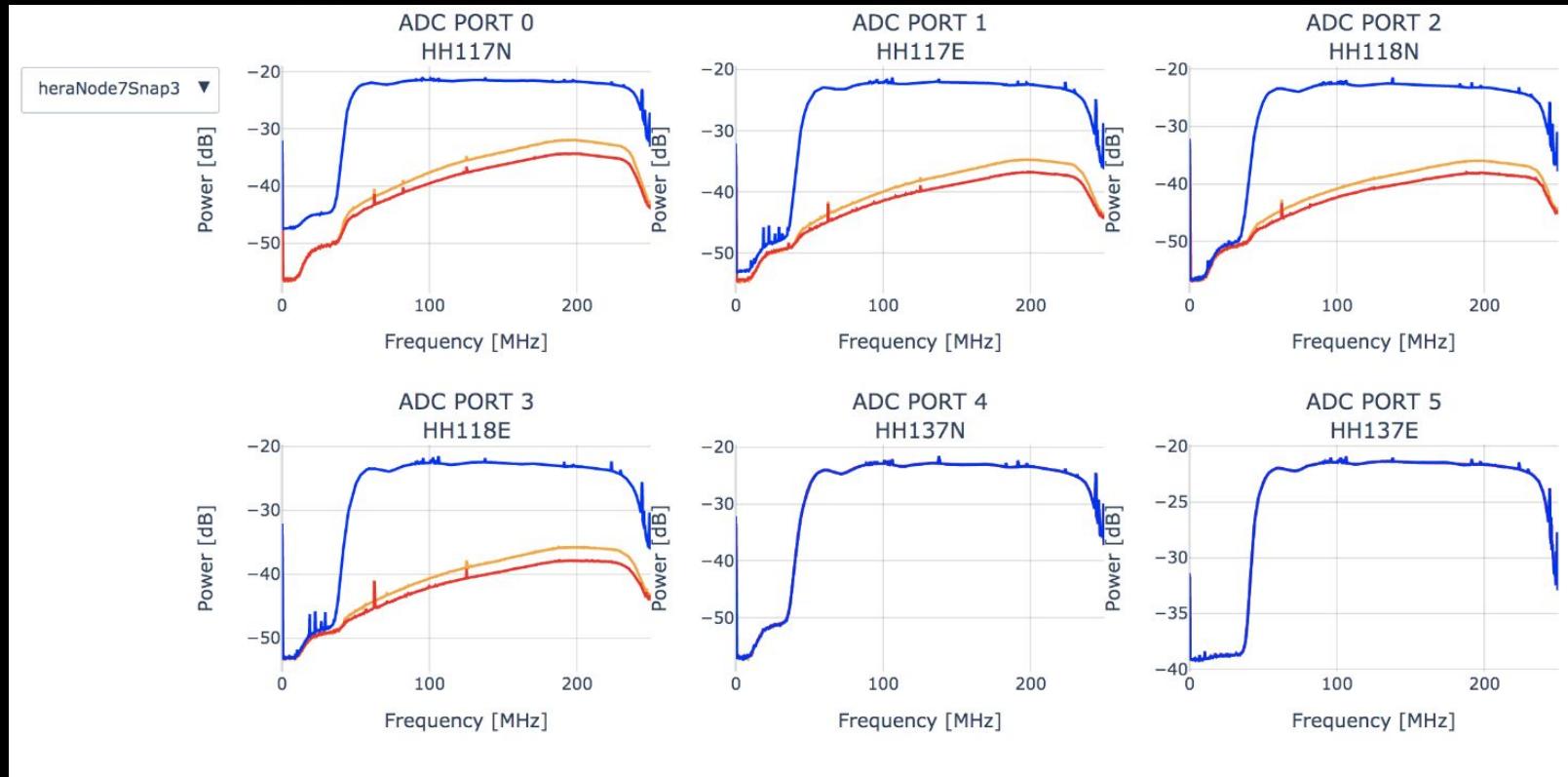


0-250 MHz

~80 db gain

~13db slope across
band

FEM Load/Noise



{ incoming
radiation

Feed

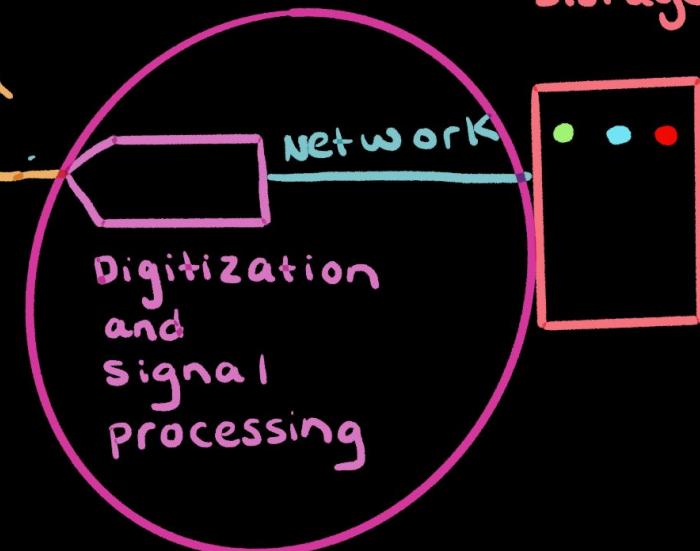
dish

RF
signal



RF
signal

Amplification,
filtering, and
any other
analog components



Computing
and
data
storage

SNAP

Smart network
ADC processor

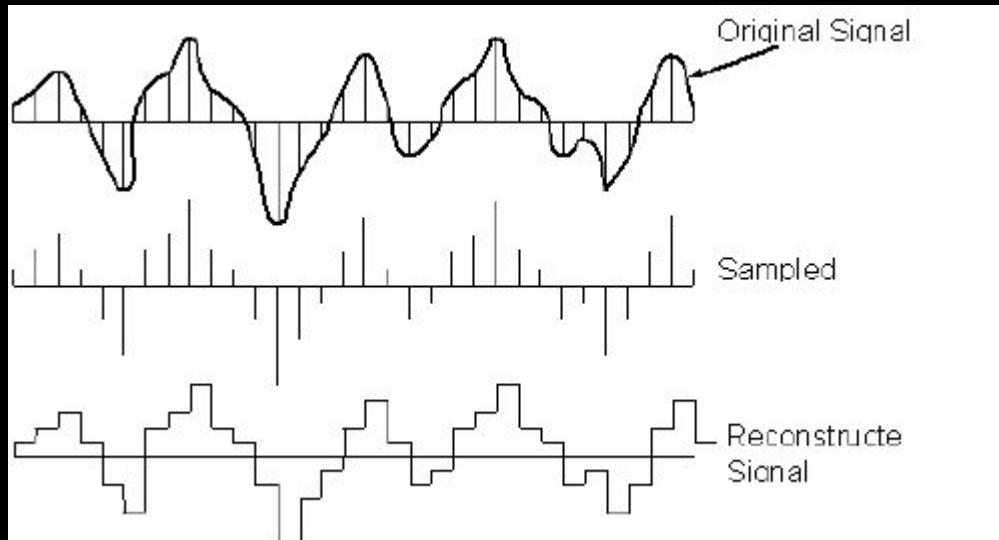
ADC + FPGA

Takes in 3 dual
polarization
antennas (6
inputs), digitizes
and does the DSP

Clocked at 10
MHz/1pps



ADC



Analog to digital converter

Analog input in is compared to a reference voltage and digitized into a range of numbers dependent on ADC bit spec

HERA has 3 8-bit ADCs and samples at 500 Msps, giving 250 MHz of bandwidth

<http://www.azimadli.com/vibman/analogtodigitalconversion.htm>

FPGA

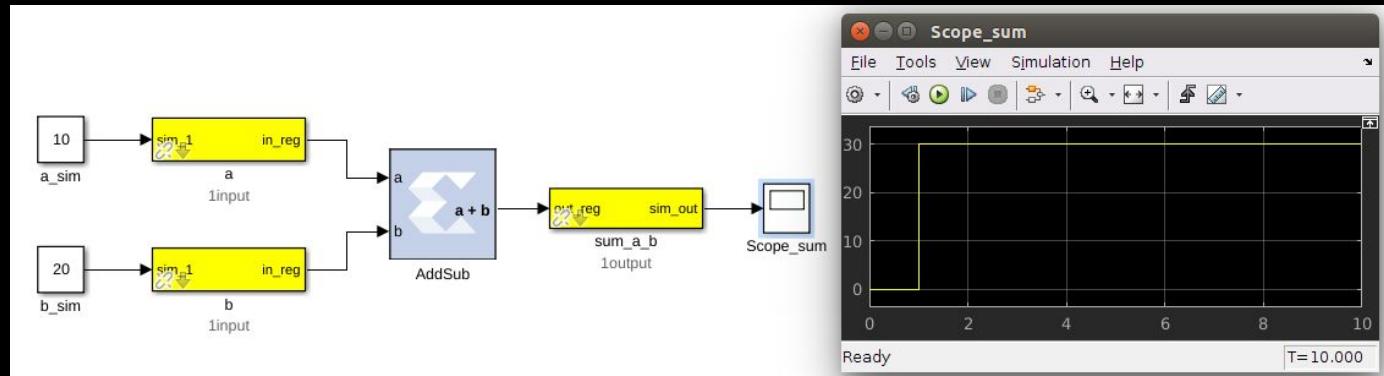
Field Programmable Gate Array

Reconfigurable integrated circuit

SNAP has a Xilinx Kintex7

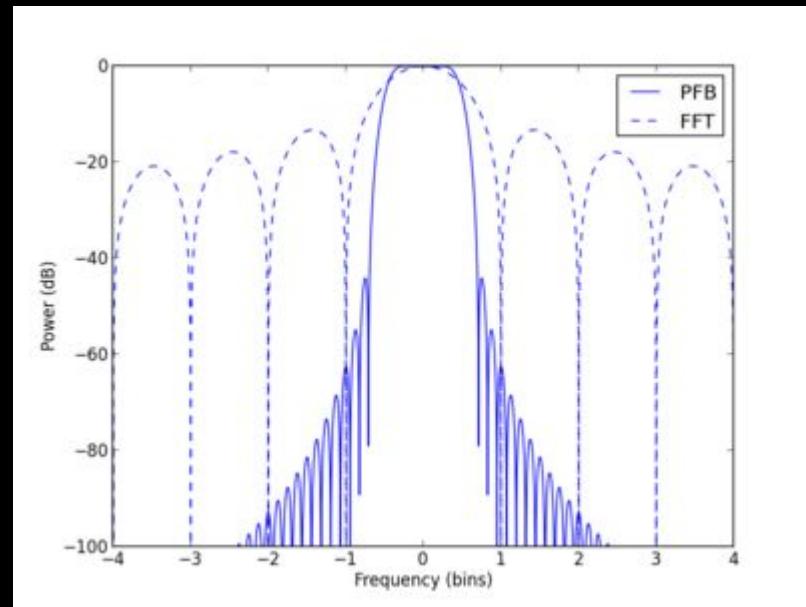
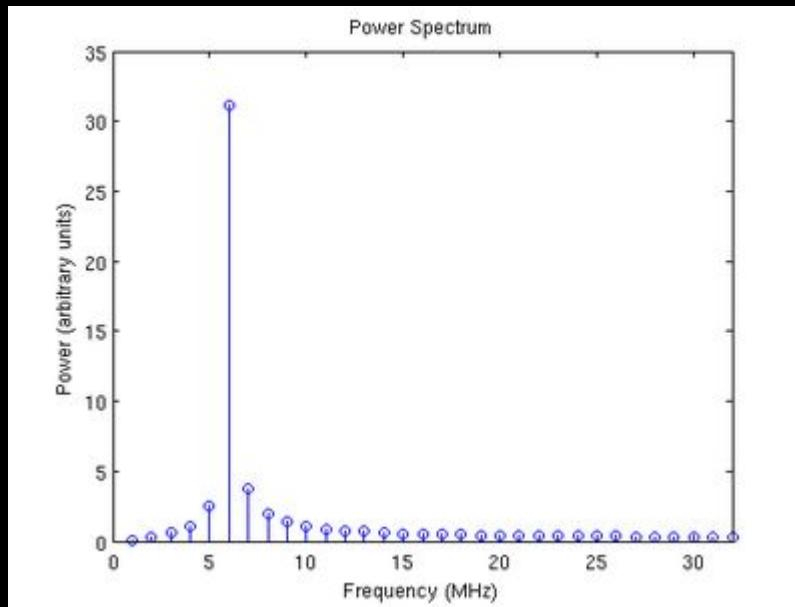
Handles the Fengine part of the

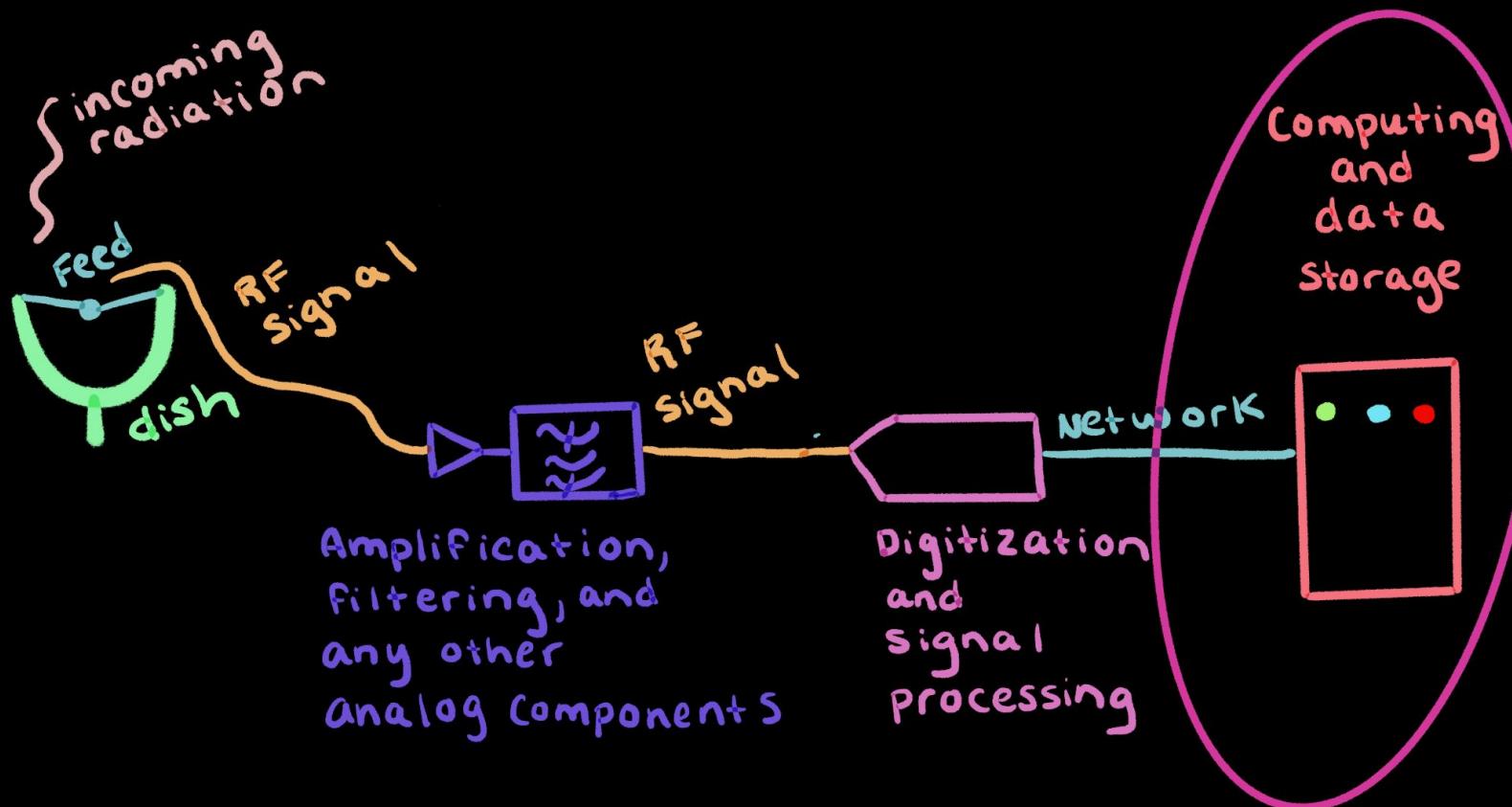
FX correlator.



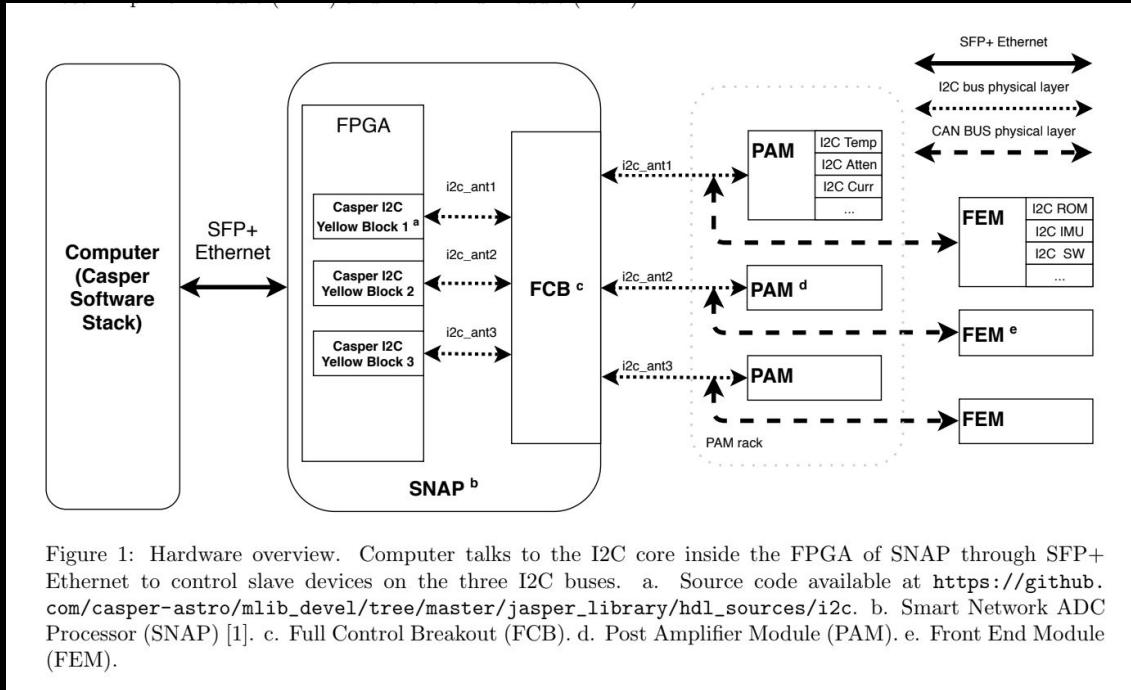
PFB and FFT

HERA uses an 8192 channel FFT with a PFB in front
reduces channel # to 6144



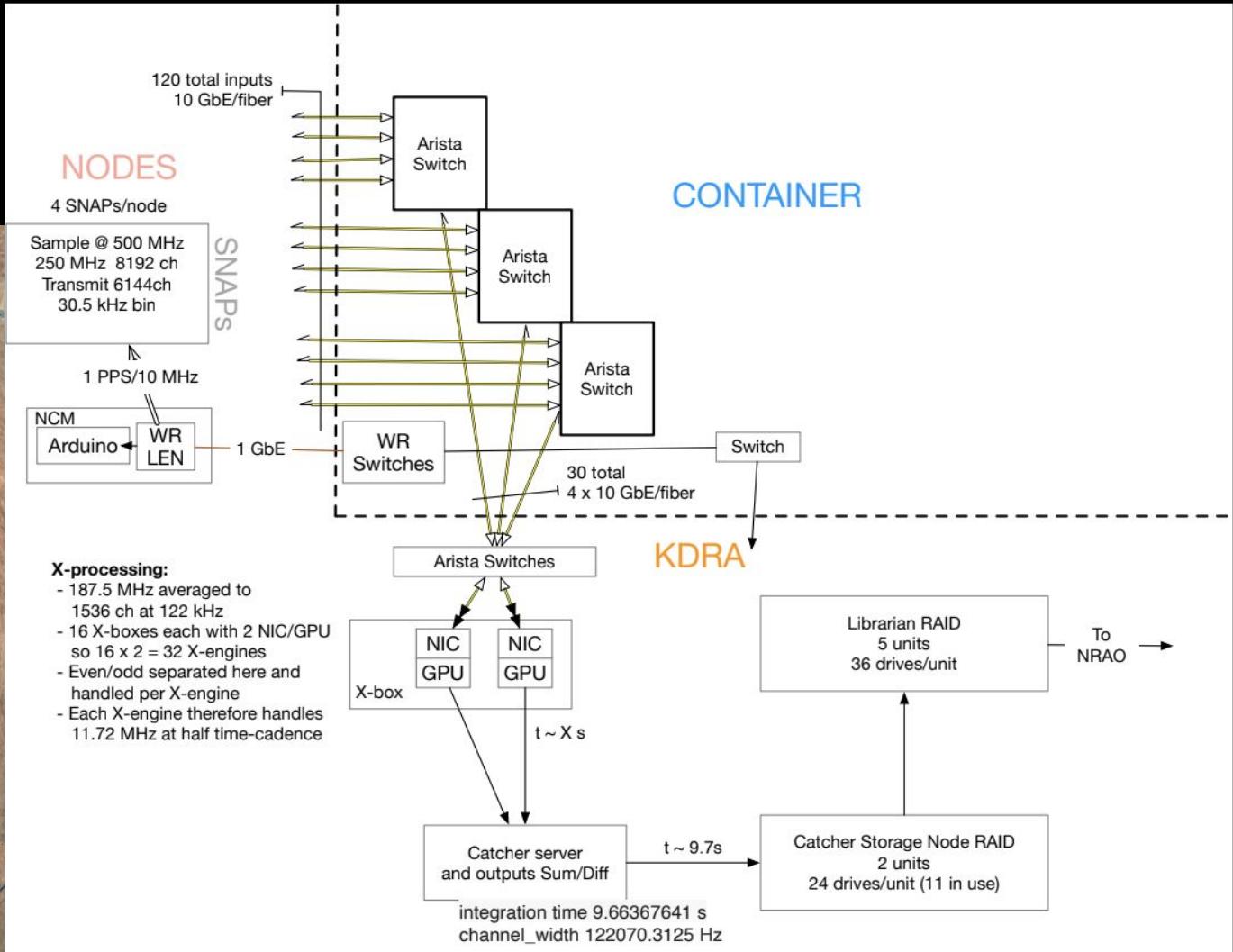


An aside on digital control

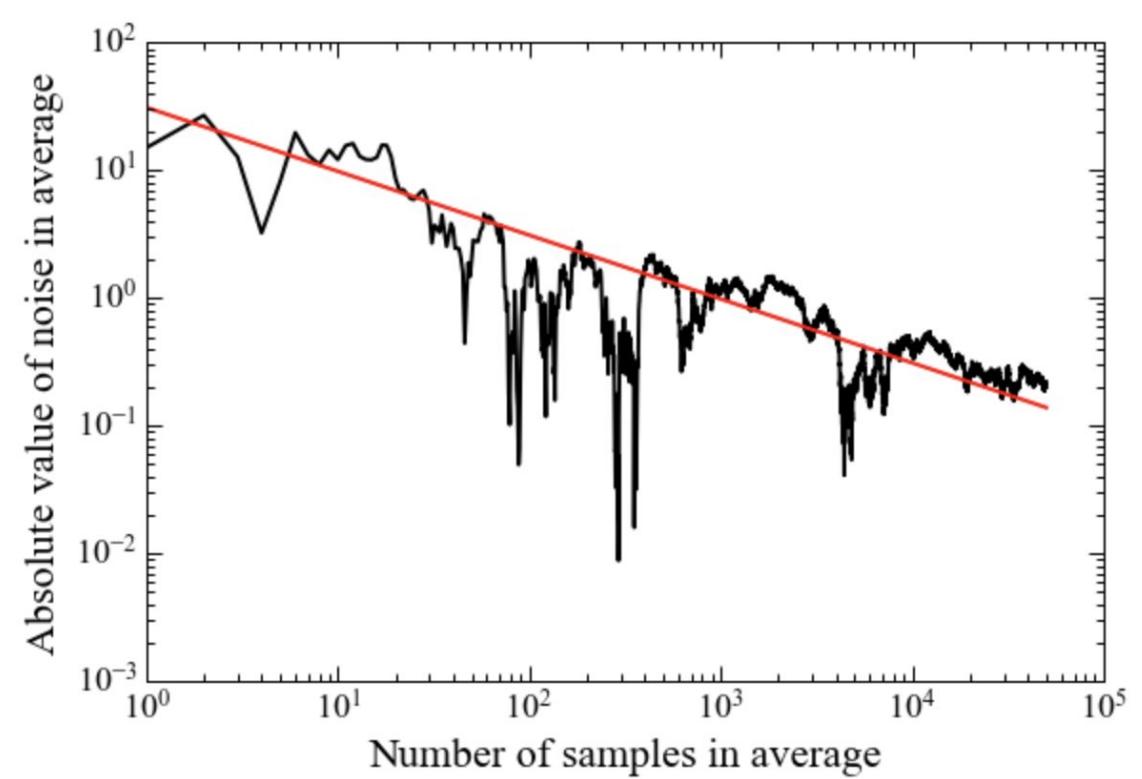


In addition to RF coming from FEM -> SNAP, there is also ethernet control communication going from SNAP -> FEM

Xengines



Integration



Noise goes down as $1/\sqrt{t}$
Don't want to integrate longer than you expect your signal to remain constant

Disk/RTP/Librarian

Table 3: Per-Node, Per-Night Flagging

This table summarizes flagging by node, showing how many antennas are in the data from each node, how many antenna-days were flagged for the whole season and the last 7 nights).

Node	Number of Ants	Total Antenna-Days This Season	Unflagged Antenna-Days This Season	Flag % This Season	Total Antenna-Days This Week	Unflagged Antenna-Days This Week	Flag % This Week	2459722	2459720	2459719	2459718	2459717	2
0	12	1976	17.6	99%	84	0.0	100%	100%	100%	100%	100%	100%	100%
1	11	1955	565.0	71%	77	11.0	86%	45%	100%	100%	100%	100%	100%
2	12	1658	203.9	88%	84	6.6	92%	68%	100%	100%	100%	100%	100%
3	12	1821	160.4	91%	84	1.0	99%	92%	100%	100%	100%	100%	100%
4	12	1812	403.5	78%	84	12.0	86%	58%	100%	100%	100%	100%	100%
5	3	534	139.2	74%	21	2.0	90%	67%	100%	100%	100%	100%	100%
7	9	1599	377.3	76%	63	2.0	97%	89%	100%	100%	100%	100%	100%
8	12	2073	450.7	78%	84	0.0	100%	100%	100%	100%	100%	100%	100%
9	12	1966	287.9	85%	84	0.0	100%	100%	100%	100%	100%	100%	100%
10	11	1958	738.3	62%	77	8.0	90%	64%	100%	100%	100%	100%	100%
12	12	1788	455.5	75%	78	5.0	94%	75%	100%	100%	100%	100%	100%
13	10	1650	497.7	70%	70	8.0	89%	60%	100%	100%	100%	100%	100%
14	11	1958	732.5	63%	77	10.0	87%	55%	100%	100%	100%	100%	100%
15	11	1323	124.9	91%	56	2.0	96%	88%	100%	100%	100%	100%	100%
18	3	438	5.0	99%	21	0.0	100%	100%	100%	100%	100%	100%	100%

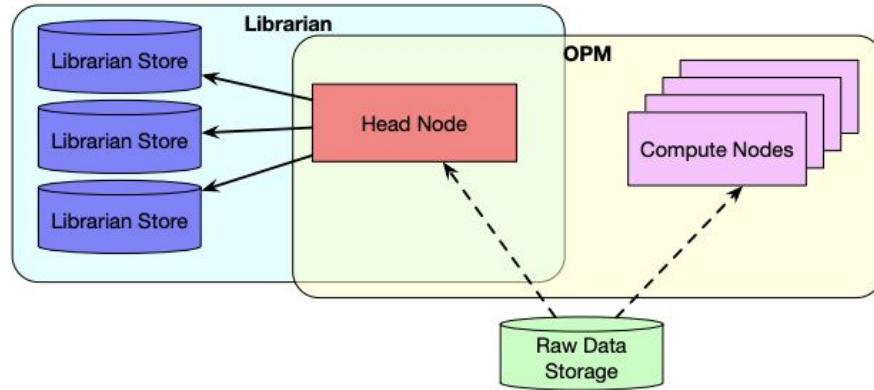


Figure 1: A schematic of how the RTP system operates on-site as part of the HERA processing cluster. Both the `librarian` and `hera_opm` systems make use of the head node, as well as auxiliary machines. See Sec. 4 for additional discussion of how the systems interact.

NRAO

National Radio Astronomy
Observatory

Librarian instance to stage
data

Post processing for HERA



