RADIO TELESCOPE AS A TIME MACHINE

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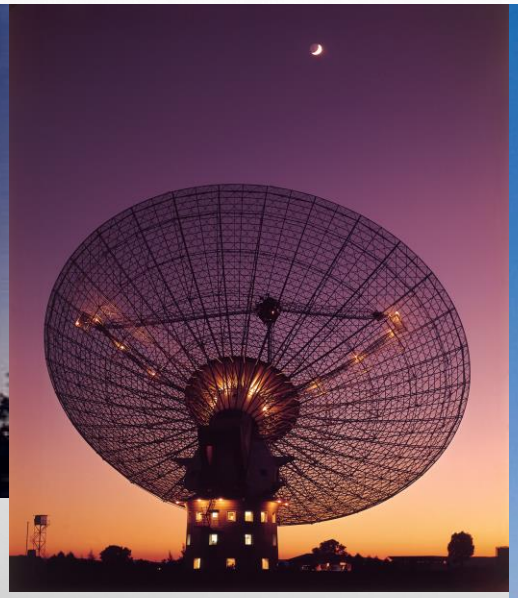
RADIO ASTRONOMY LAB, UC BERKELEY

GRCON 2018
Henderson, NV

RADIO TELESCOPES

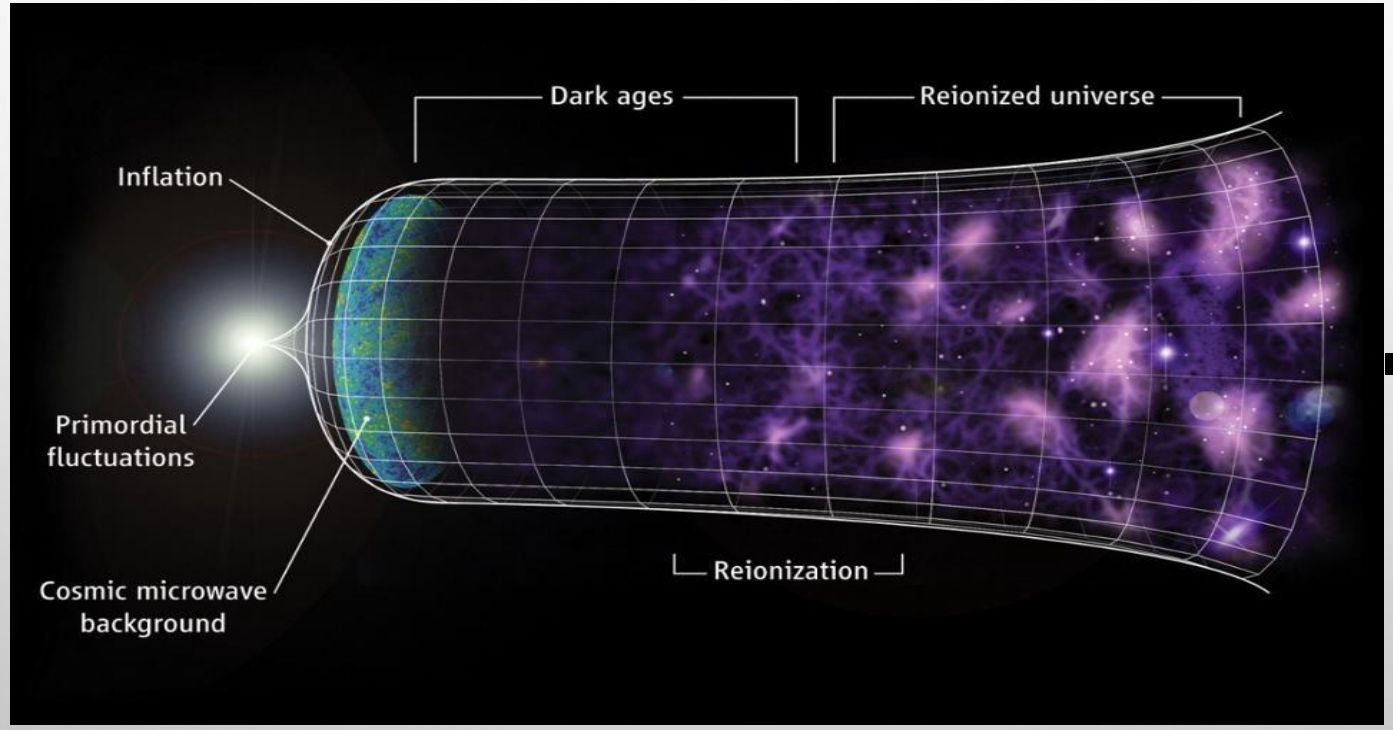


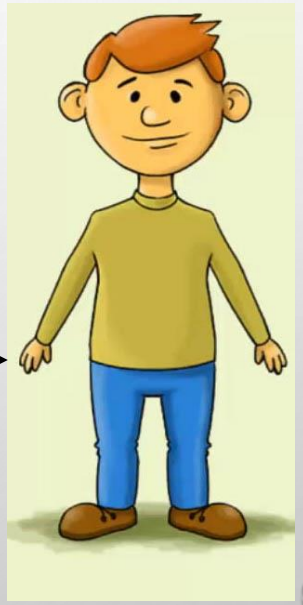
Some famous radio telescopes:
(l-r) VLA, Parkes, GBT, Arecibo

THIS ALSO…

LOOKING BACK IN TIME

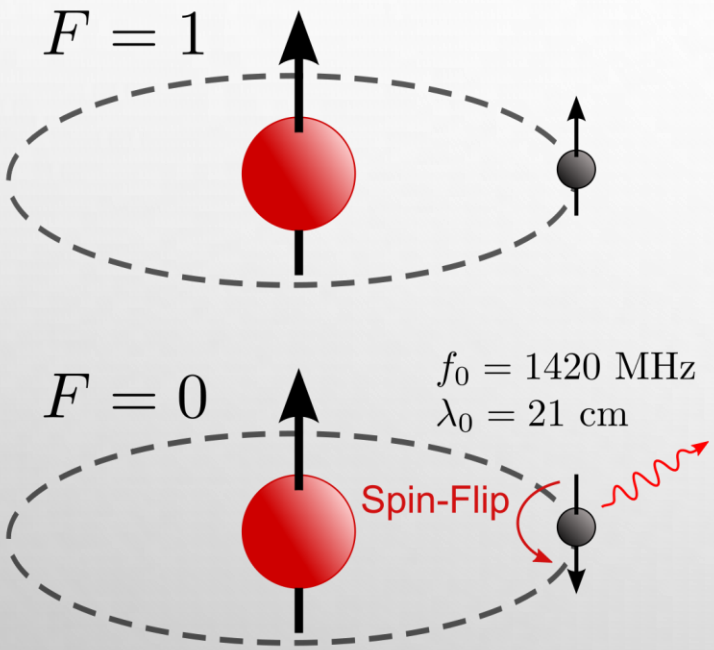
???





2018 AD

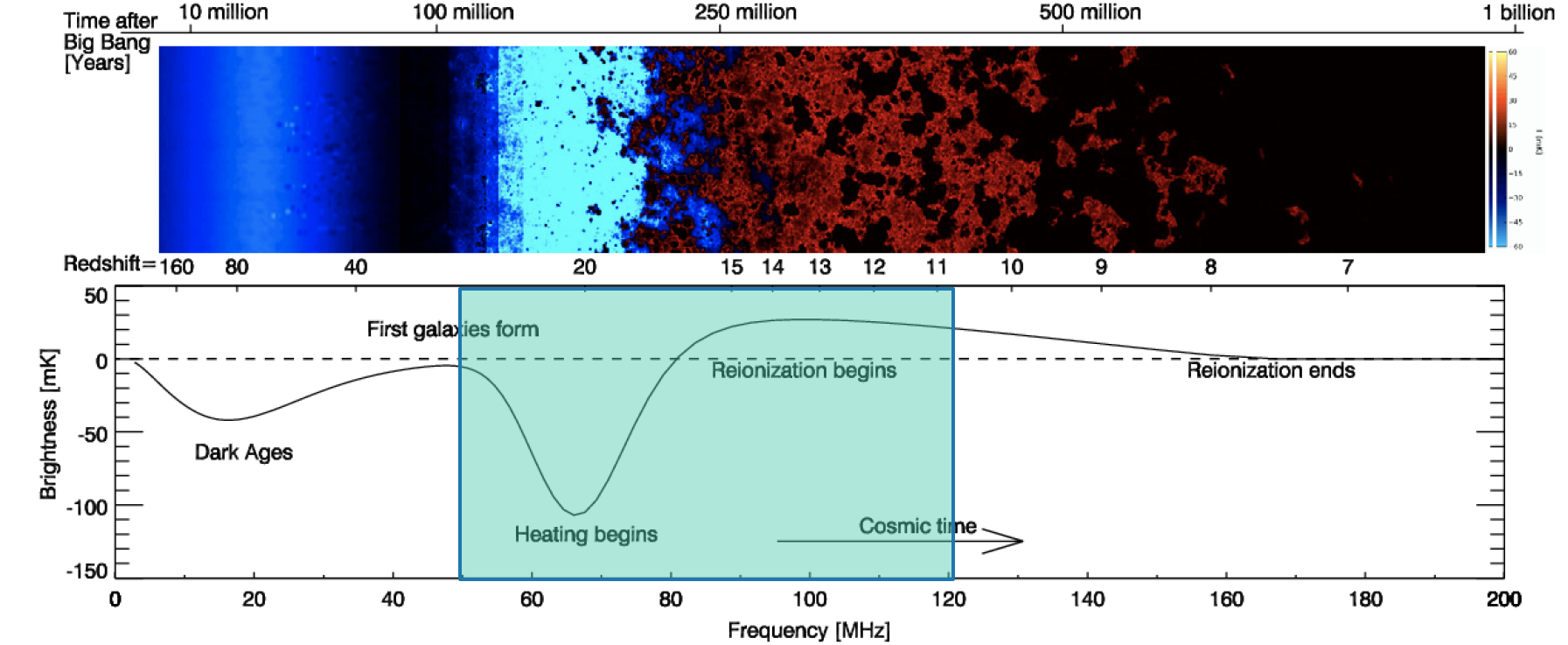
THE HYDROGEN STORY



21 cm emission line

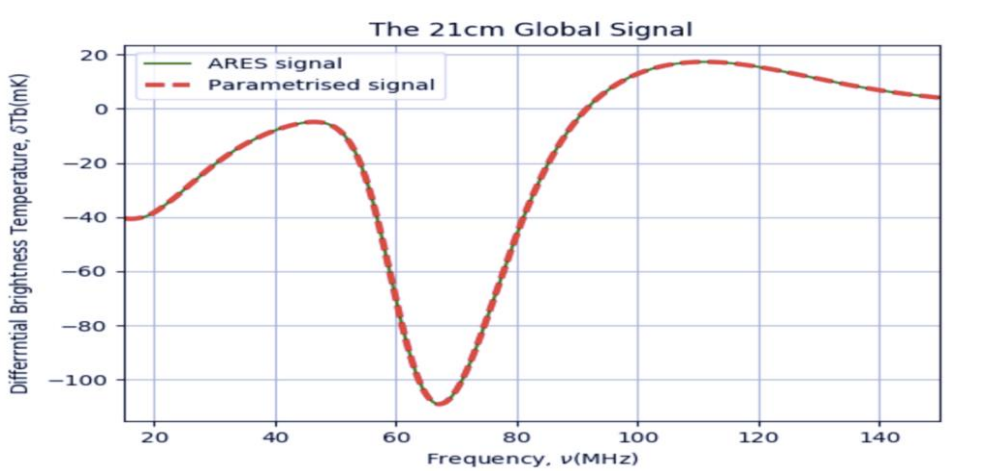
source: wikipedia.org

WHAT TO LOOK FOR ?

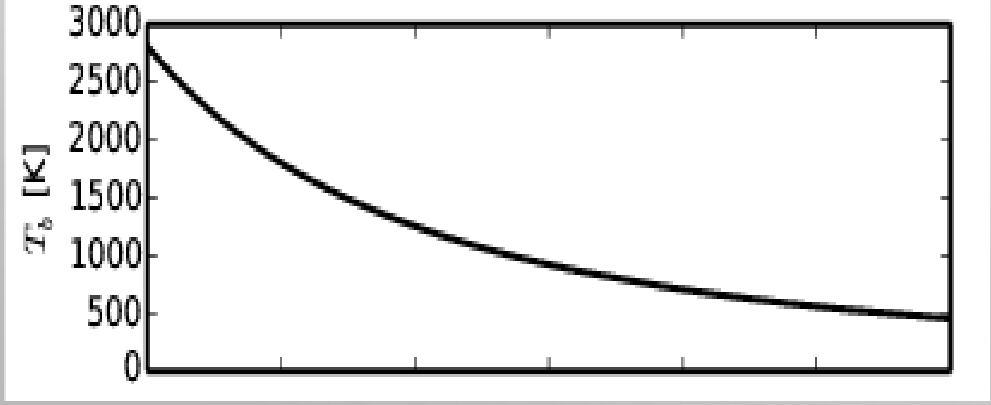


(Pritchard and Loeb,2012)

DIFFICULT?



Credits:
Abhirup dattta



Credits:
Switzer, Liu

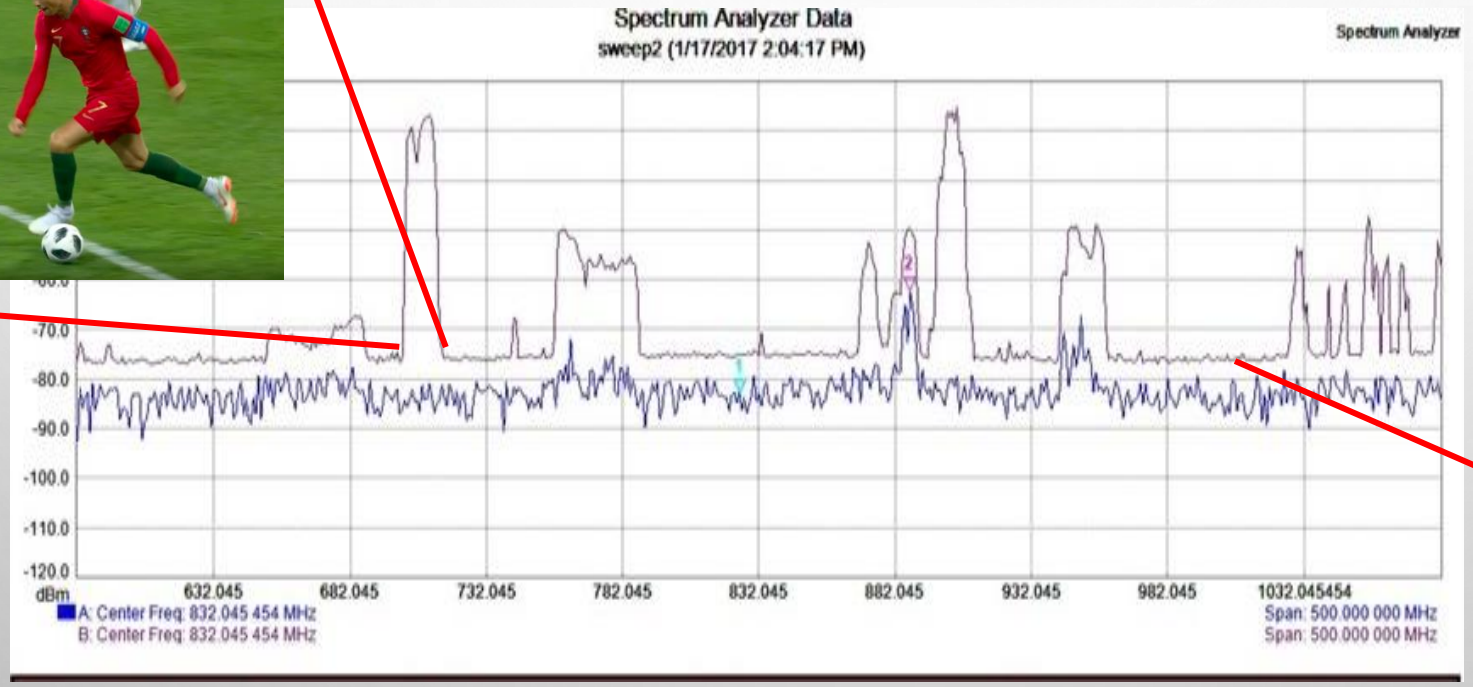
1” screw

Difference of 4th order

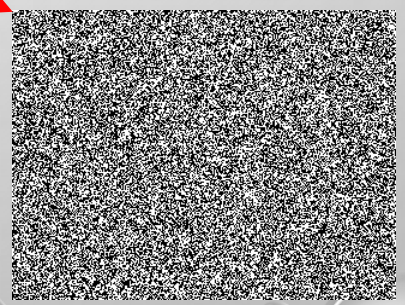
Eiffel Tower, elevation: 984’

WHAT MAKES IT WORSE?

Man-made



Astronomical



For representation purpose only

HYPERION

Aaron

Me

Cherie

Deployment at OVRO

Nipanjana

Sanah

Kara

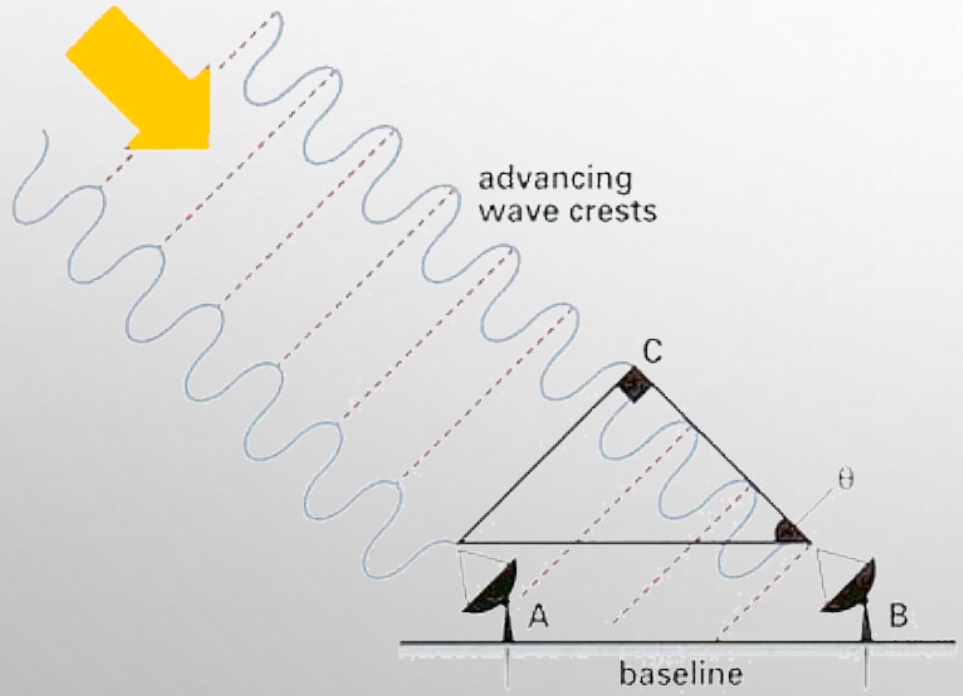
TRADITIONAL APPROACH

- Single antenna element
- Average over entire sky
- Entire system noise should be taken care of
- Requires very careful calibration

EDGES telescope

credits: Rogers and Bowman,2018

INTERFEROMETRY



Pros

- Cancellation of instrument noise of individual antenna path
- System calibration becomes easier

Cons

- Sky-average cancels out Fourier components
- Can't detect signal

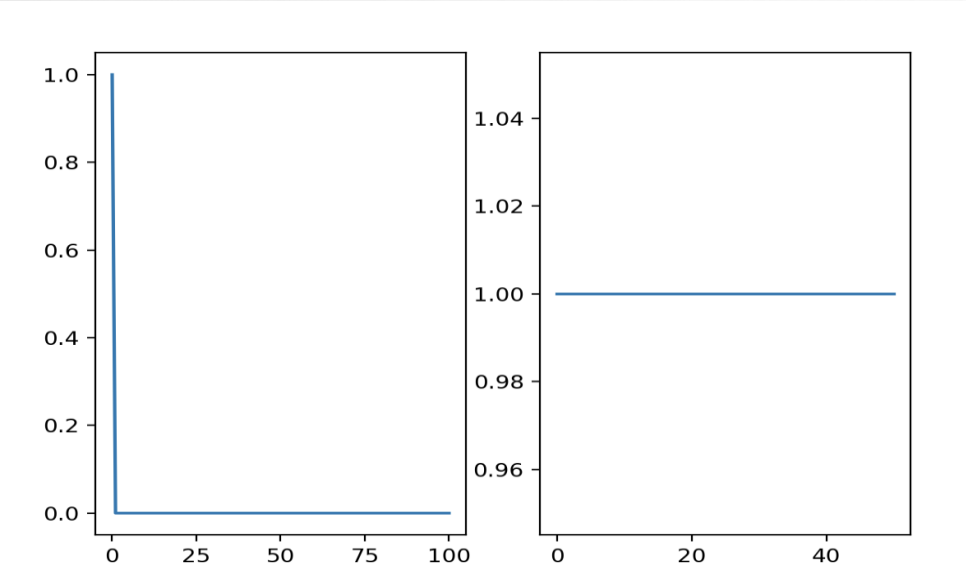
Correlation: $f(t) \star g(t) = \int \hat{f}(\omega)\hat{g}^*(\omega)e^{i\omega t}d\omega.$

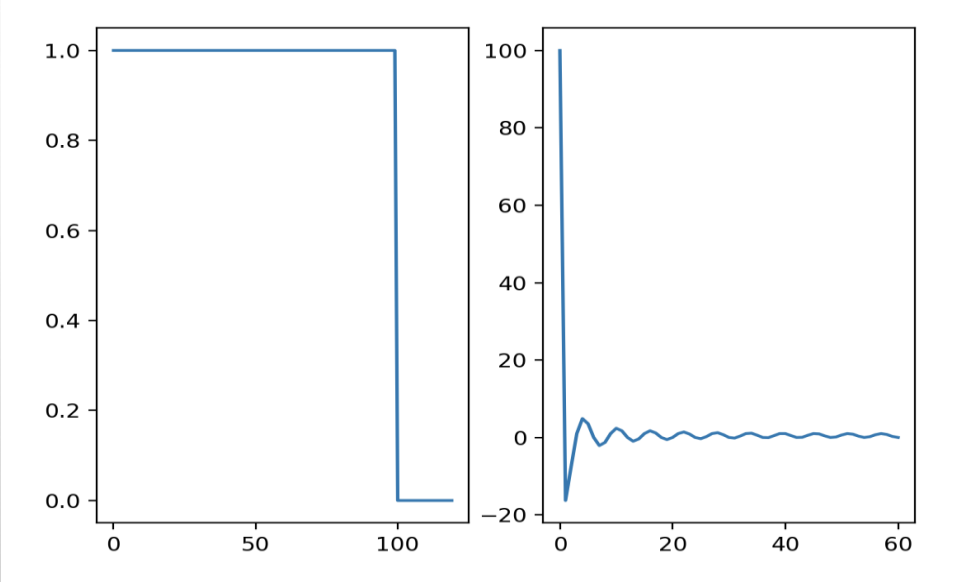
PRINCIPLE

Aperture Distribution
(What the Antenna receives)

FFT

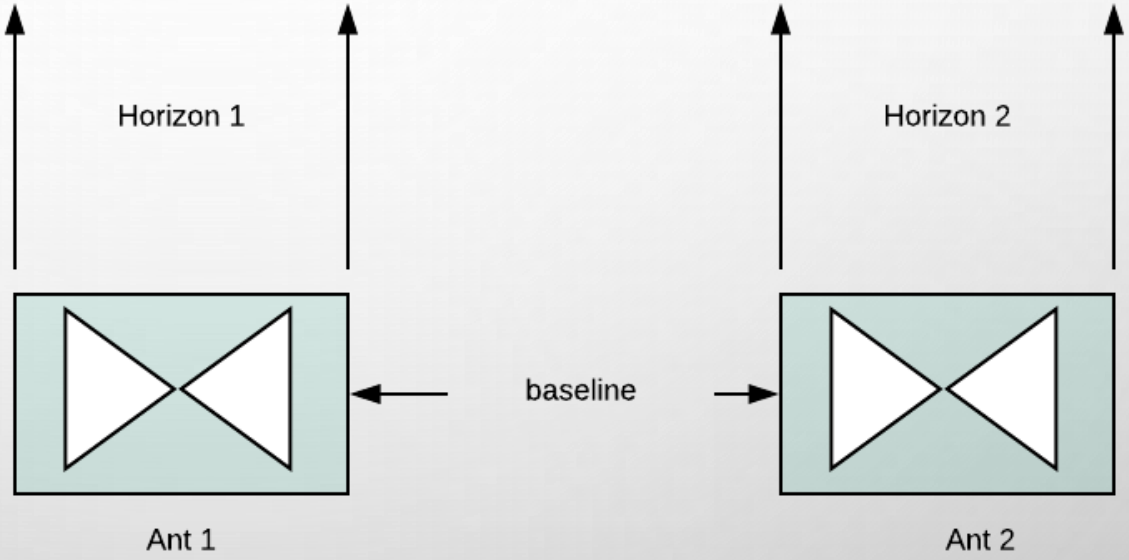
Sky brightness
(What comes from the sky)



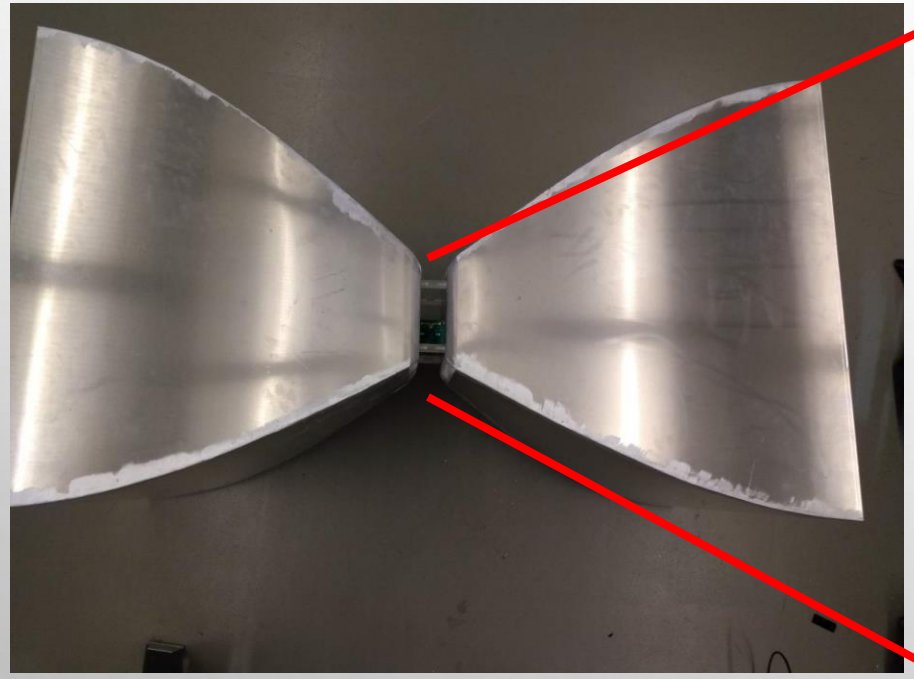


HYPERION STRATEGY

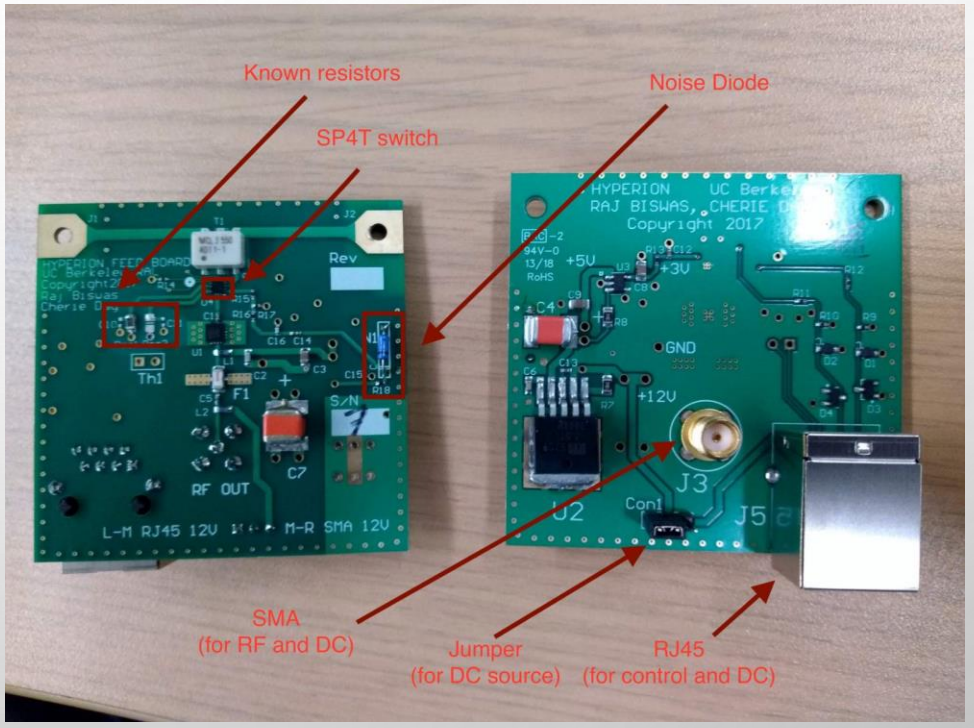
- Absorptive walls
- Affects antenna beam
- Creates individual horizon for different antenna
- Average over the horizon is non-zero



HYPERION FRONT-END

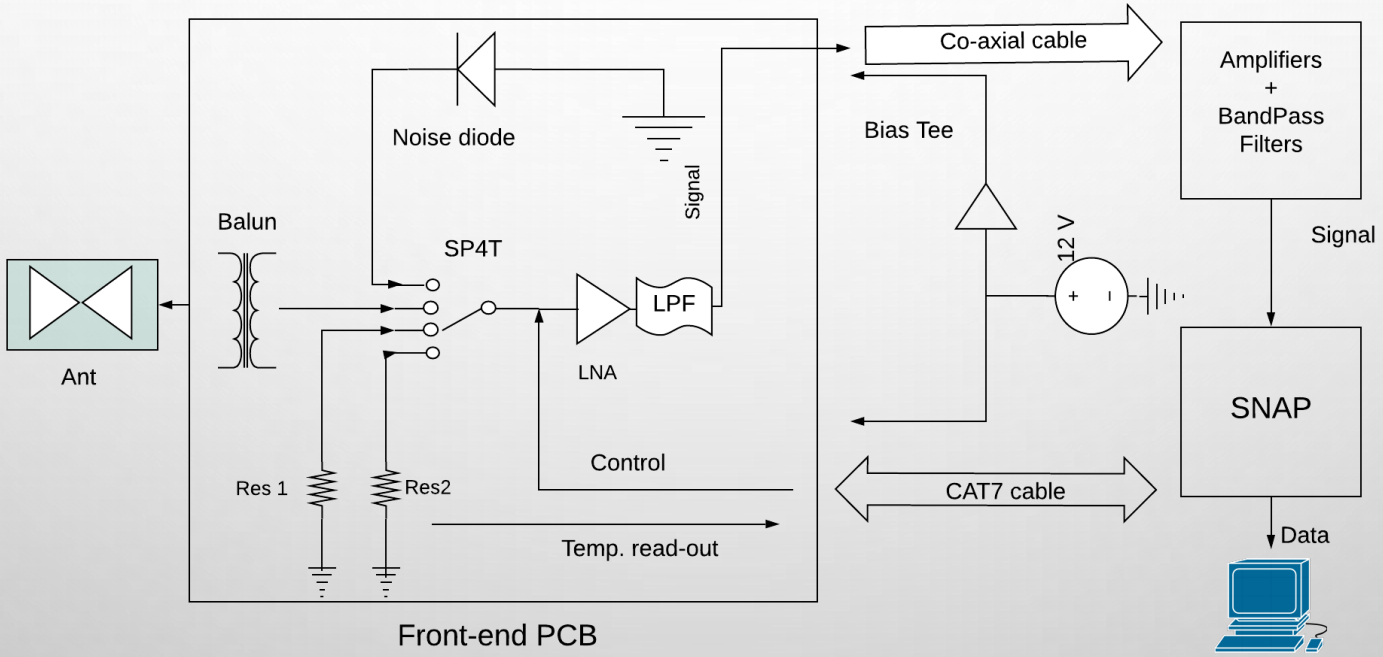


Fat Dipole

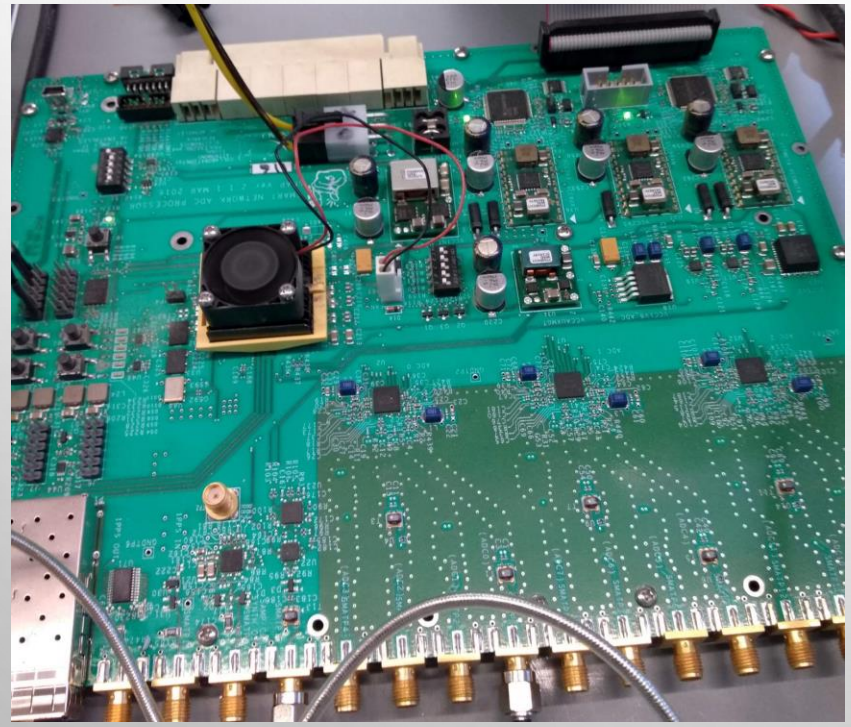


Front-end analog circuit

SYSTEM SCHEMATIC



BACK-END



SNAP Board

- Xilinx Kintex 7 series FPGA
- 250MHz FPGA clock-rate
- 3 on-board HMCAD1511 digitizers
- 8-bit ADC resolution
- Can use 12 inputs/6inputs/3inputs
- 3x1Gsps / 6x500 Msps / 12x250 Msps
- Approx. $3k per board

CASPER

Collaboration for Astronomy Signal Processing and Electronics Research

CASPER

Hardware:

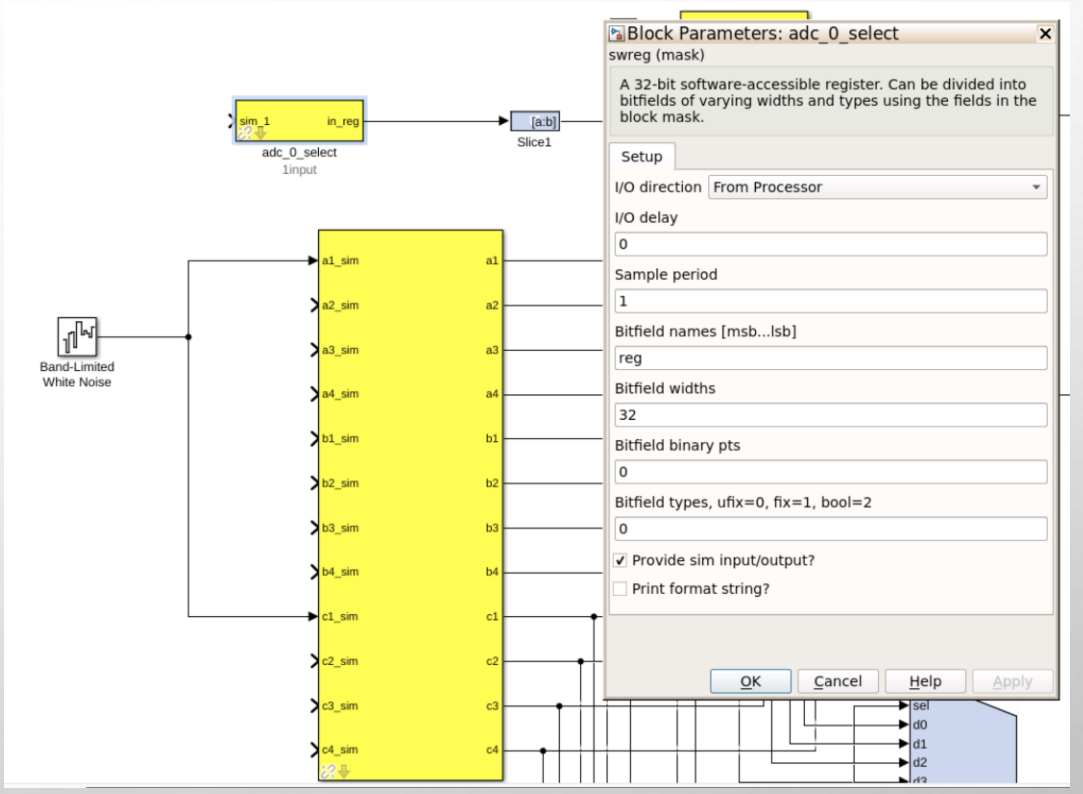
- ROACH
- ROACH2
- SNAP
- SNAP2
- SKARAB

SOFTWARE

- CASPER Toolflow

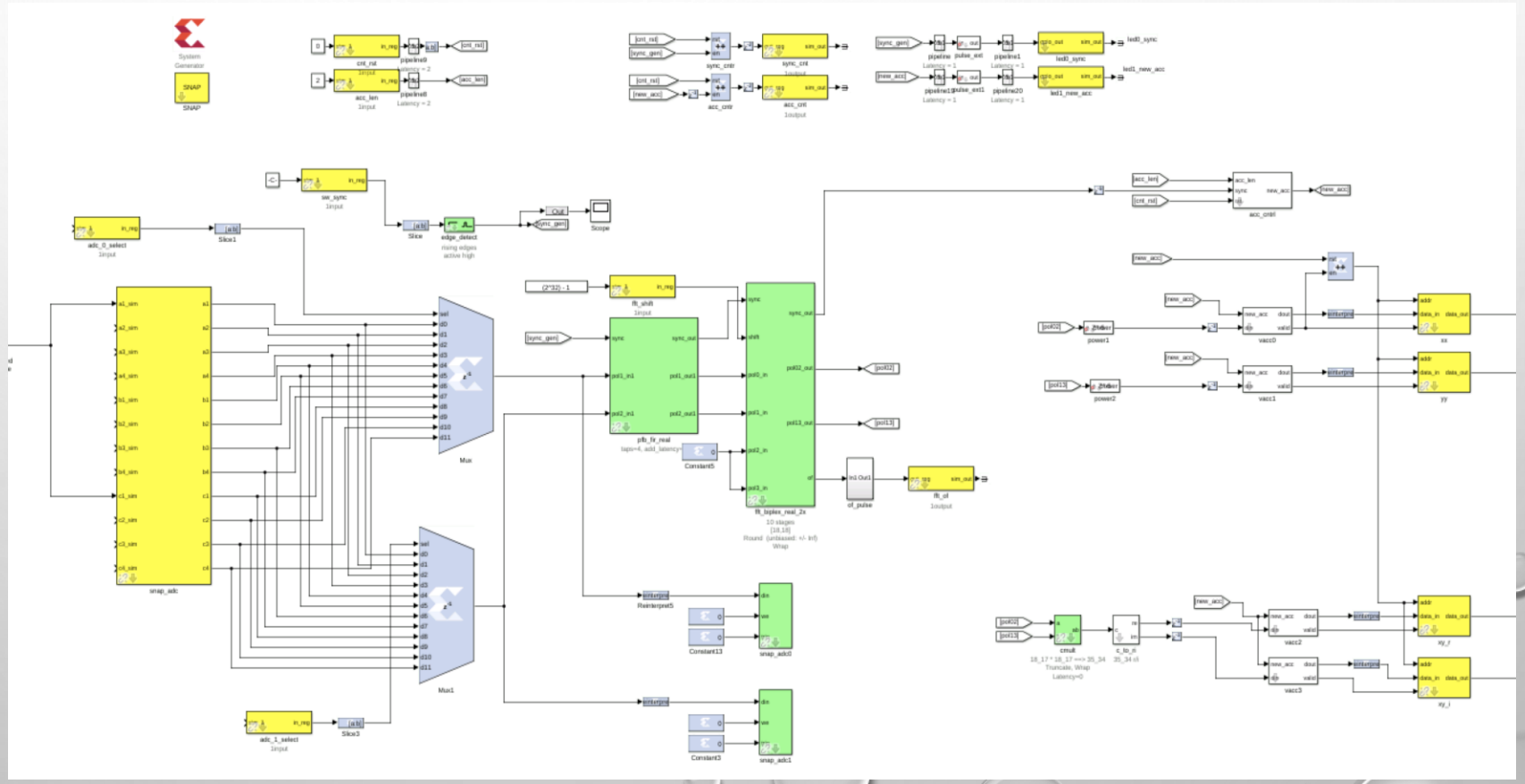
CASPER TOOLFLOW

- GNURadio of Radio Astronomy
- SIMULINK Front-end
- Drag-and-drop design
- Outputs .fpg/.bof files
- Presently Xilinx-based hardware supported
- Python support



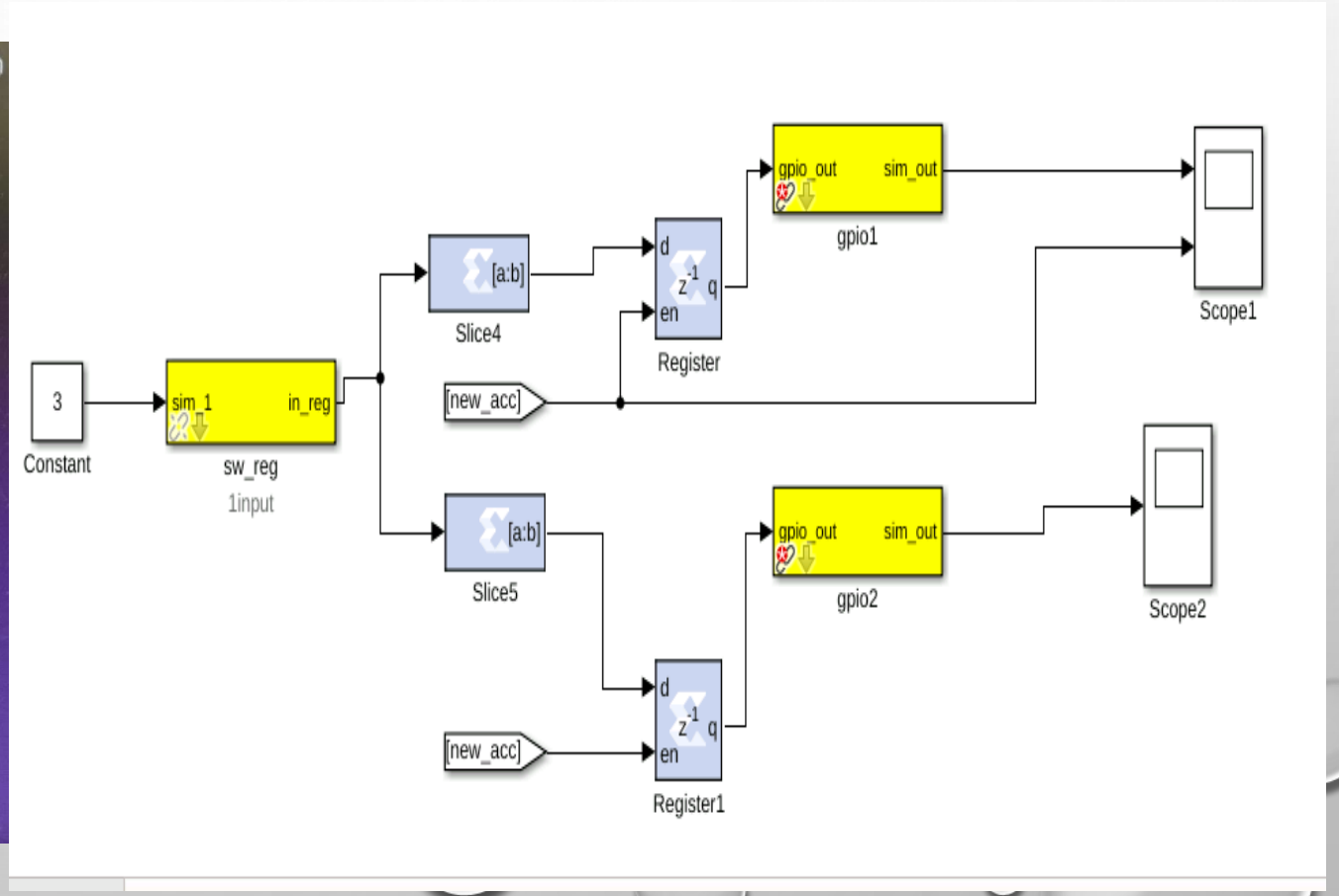
CORRELATOR DESIGN

- 80MHz across 512 channels
- 1024 pt FFT
- 64-bit data output
- Power in linear scale
- Data packets to RaspberryPi
- Format defined in Python (UV-miriad)

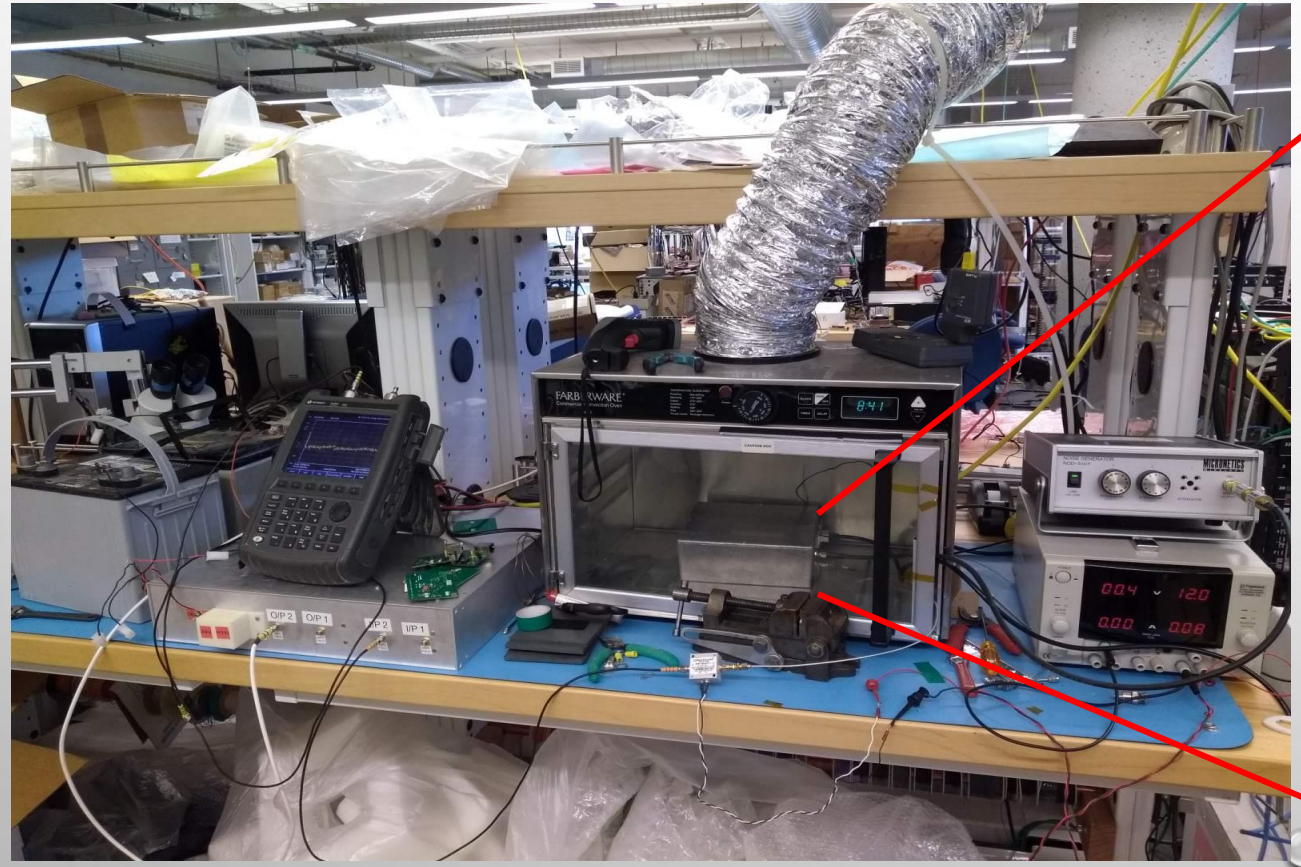


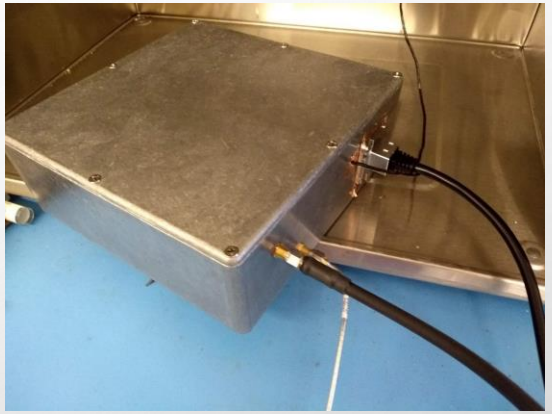
SWITCH CONTROL

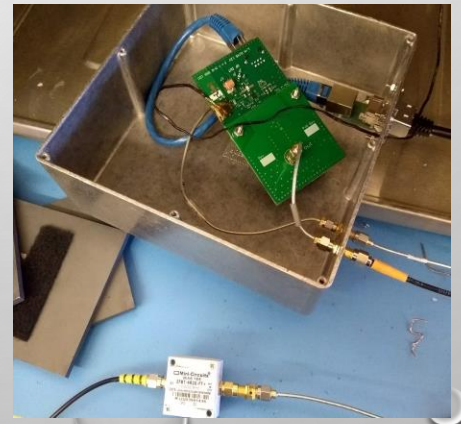
```
o@poco-ThinkPad-T410:~/Desktop/heat_test_Aug14$ python data_uv_capture_latest.py -h
ge: snap_init.py <ROACH_HOSTNAME_or_IP> [options]

ions:
h, --help            show this help message and exit
l ACC_LEN, --acc_len=ACC_LEN
                     Set the number of vectors to accumulate between dumps,
                     default is 2*(2^27)/512, or just under 4 seconds.
-s, --skip           Skip reprogramming the FPGA and configuring EQ.
-b FPGFILE, --fpg=FPGFILE
                     Specify the fpg file to load. Default:
                     dual_input_test_4.fpg
-f FFTSHIFT, --fftshift=FFTSHIFT
                     FFT shift schedule as an integer. Default:0xffff
-t FILETIME, --filetime=FILETIME
                     Time in seconds of each data file. Default:300
-n NNUMBER, --nnumber=NNUMBER
                     enter 1 for first nyquist zone,2 for second etc...
 -p INPUTS, --port_numbers=INPUTS
                     enter the input ports on the SNAP. Default: 1,9
 -d SD, --switchduration=SD
                     for how many integrations,the switch would be in a
                     position
 -q SP, --switchpos=SP
                     enter desired switch position: 0 for Antenna,1 for
                     Noise Diode,2 for Res1 or 3 for Res2
oco@poco-ThinkPad-T410:~/Desktop/heat_test_Aug14$
```



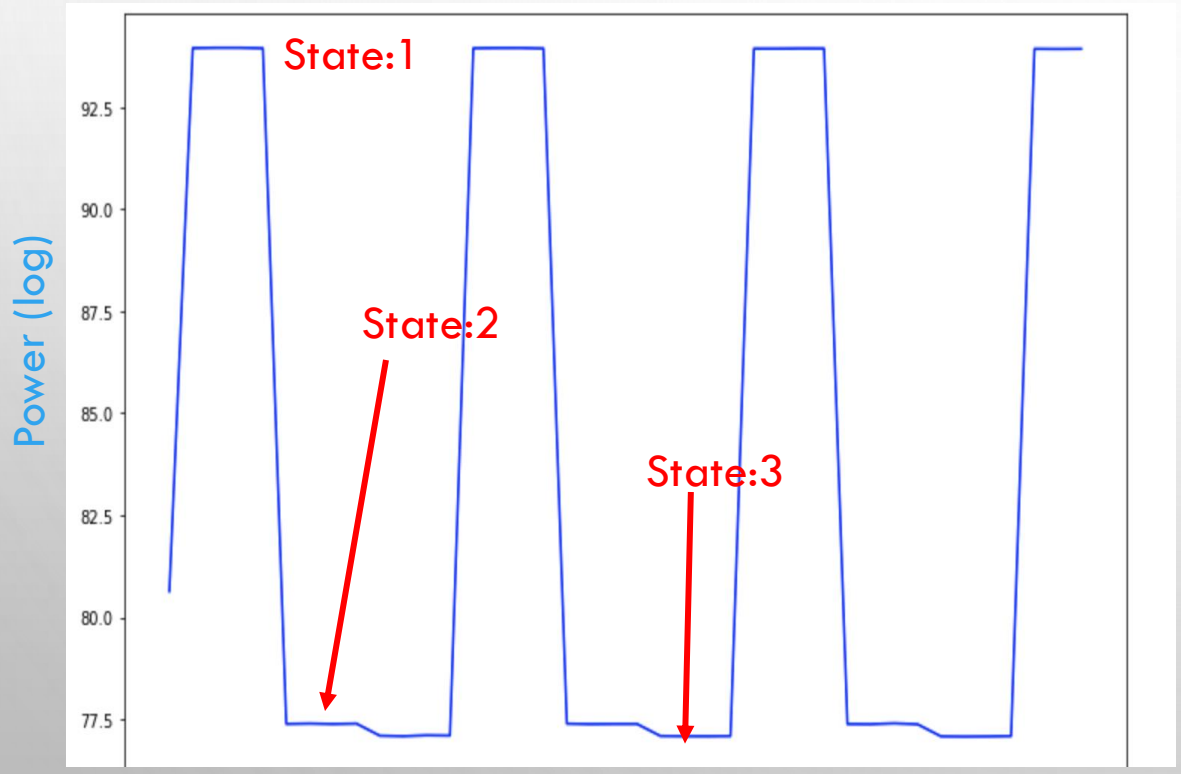
REALITY - NOT A PRETTY PICTURE



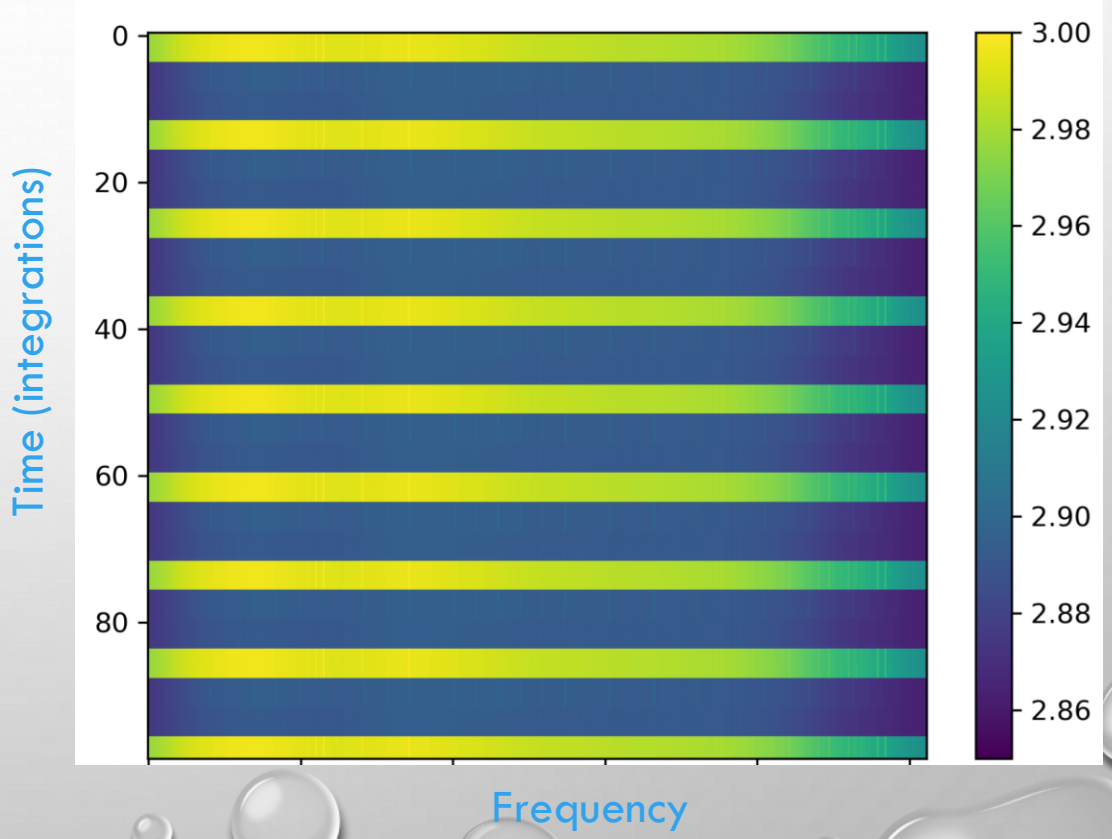




SWITCH DEMO

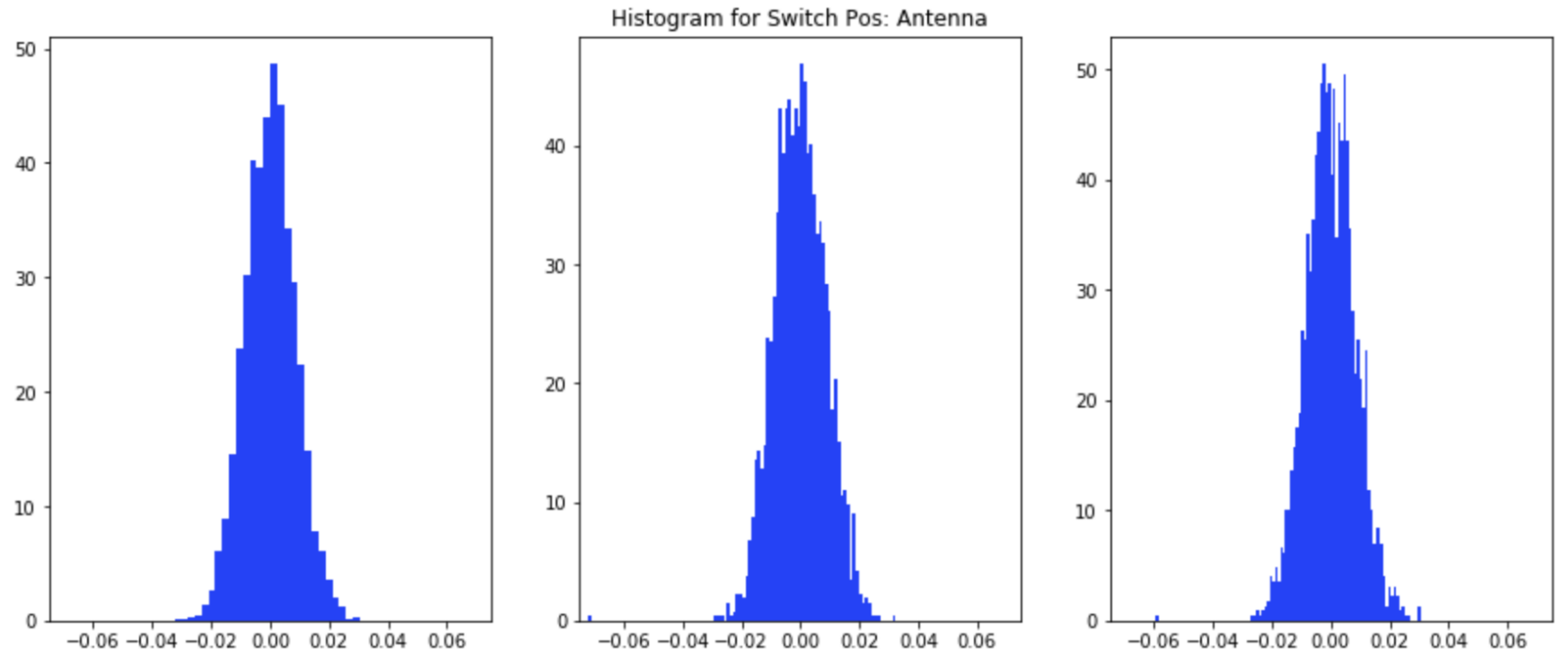


Median Channel data



Waterfall plot

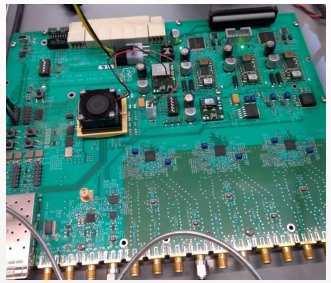
SWITCHING HISTOGRAM



CALIBRATION CIRCUIT

Amplifier + BPF

RF

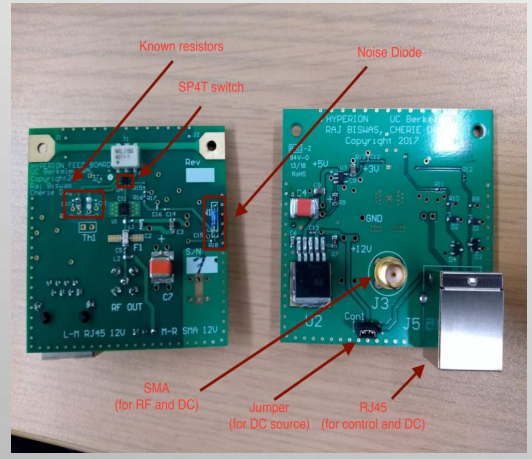


SNAP

Data

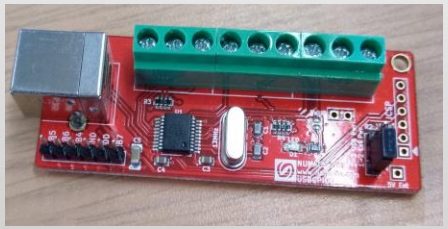
Data

RF



Front-end

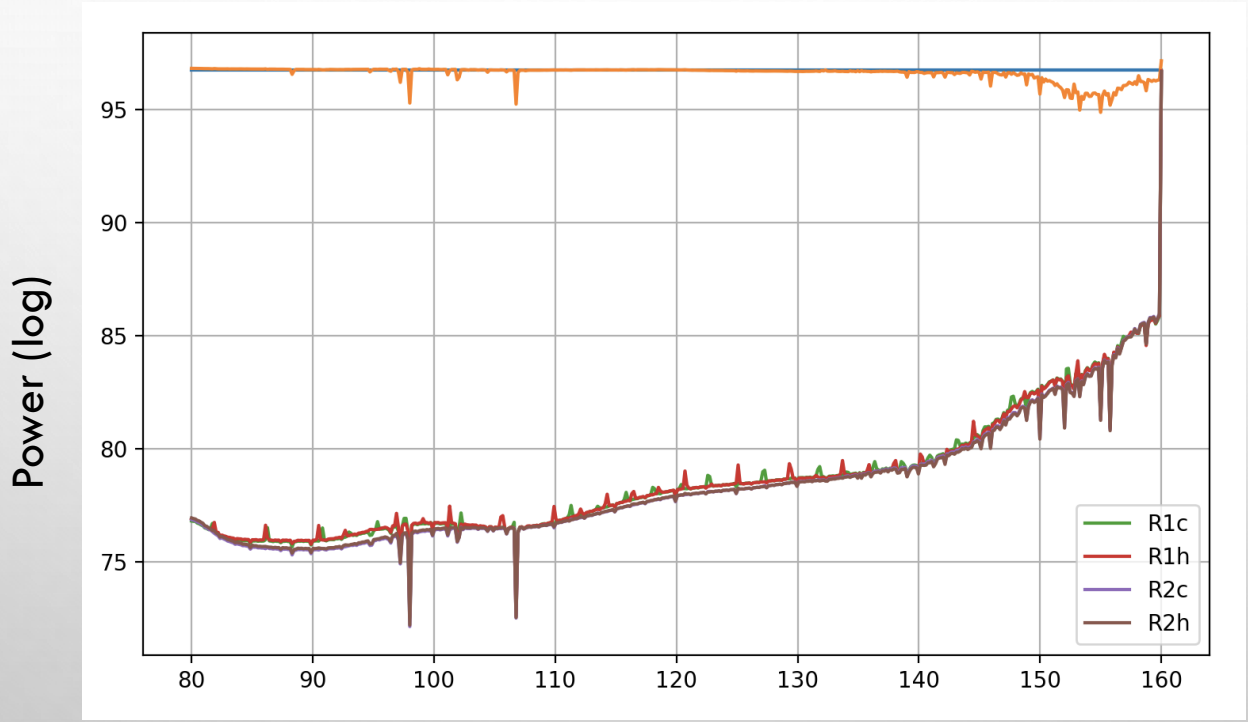
Temp. read



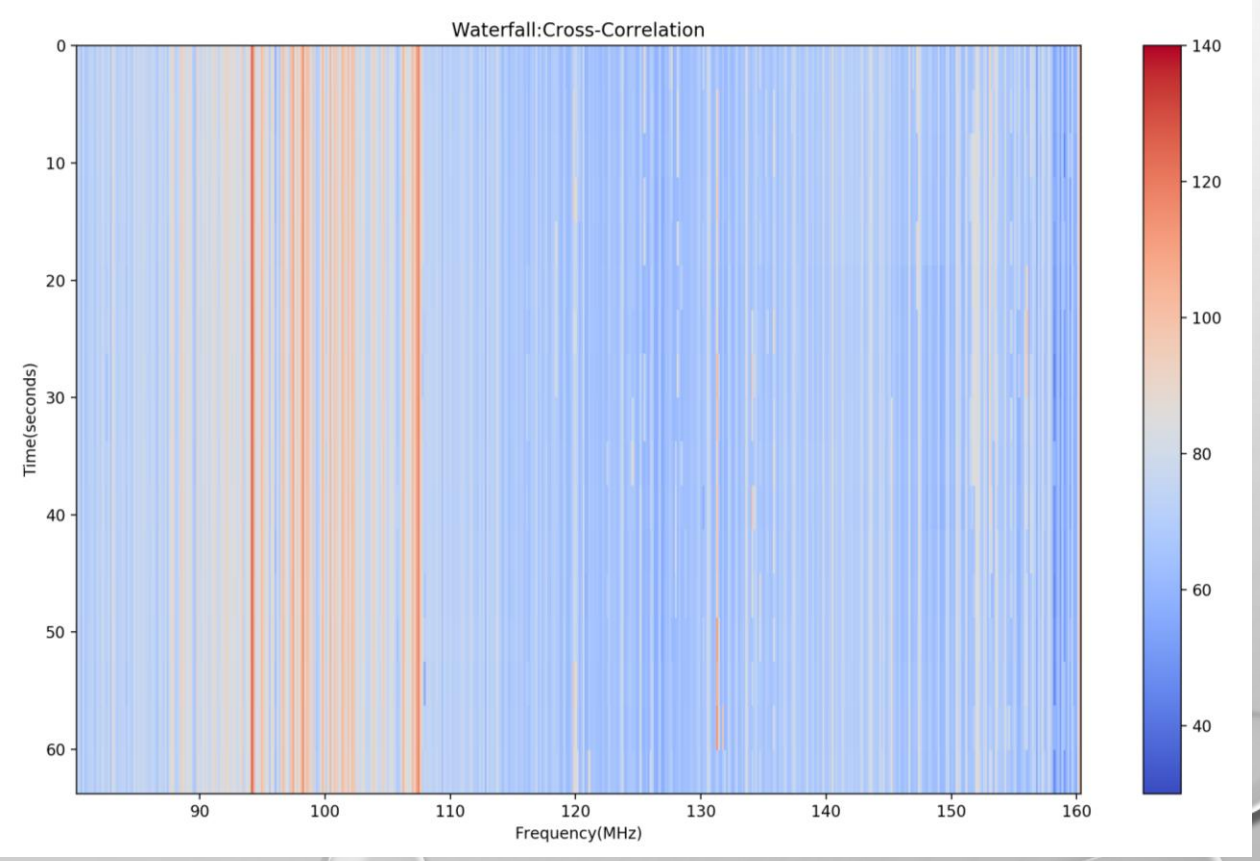
Numato ADC (~$20)

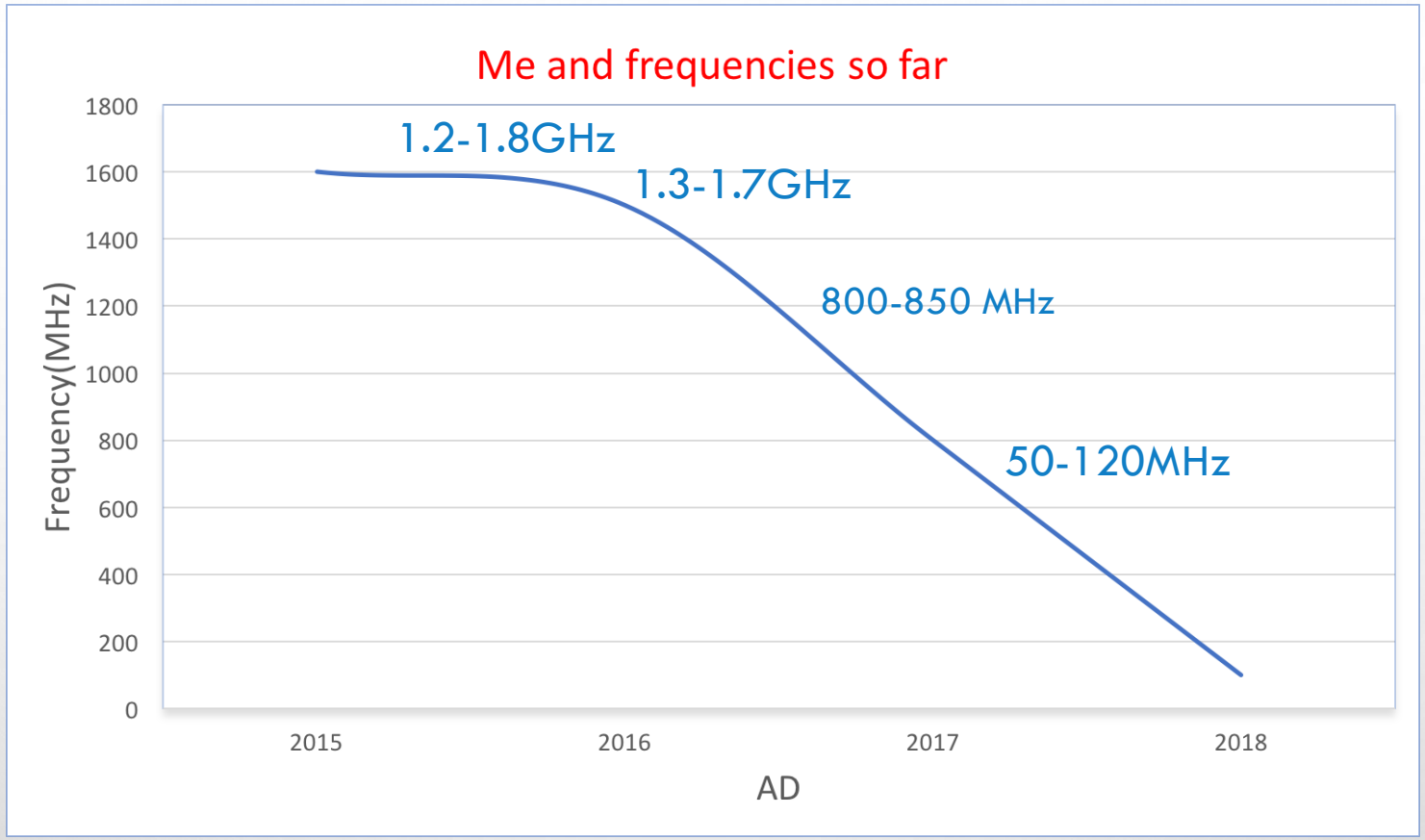
Data

BANDPASS CALIBRATION



WHAT ELSE?


Waterfall:Cross-Correlation
Time(seconds)
Frequency(MHz)
0
10
20
30
40
50
60
90
100
110
120
130
140
150
160
140
120
100
80
60
40



THANK YOU !!!

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- github.com/rajareanne