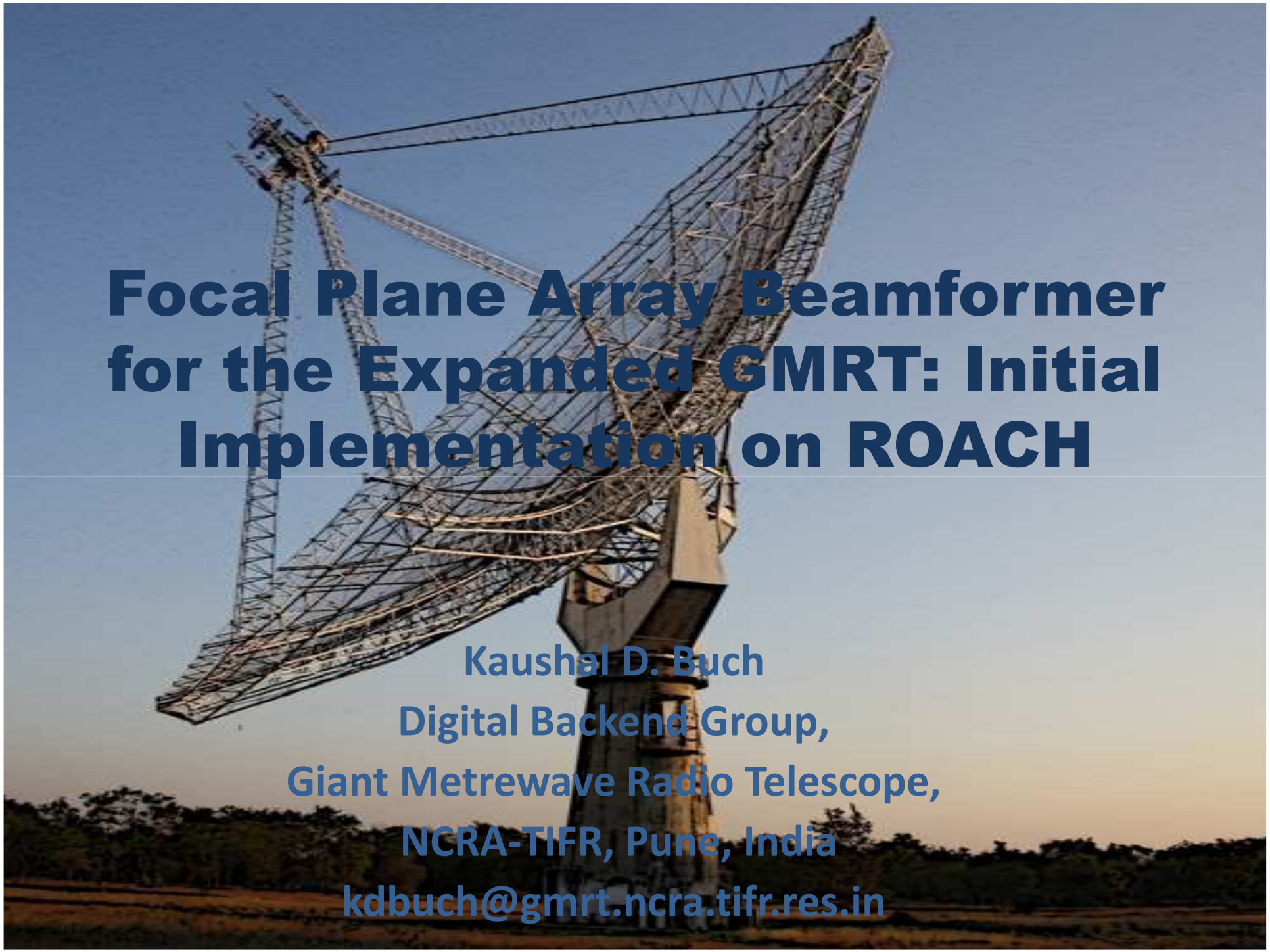

Focal Plane Array Beamformer for the Expanded GMRT: Initial Implementation on ROACH

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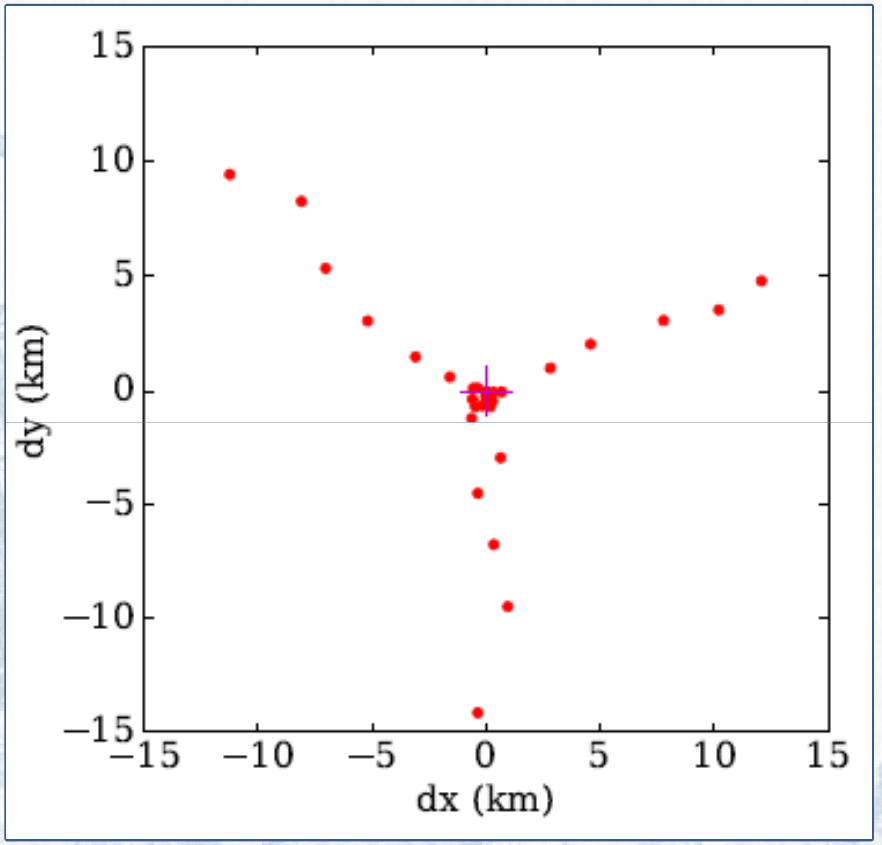
The GMRT

- Thirty 45-m dishes
- Max Baseline ~25km
- Min Baseline ~60m
- 14 antennas in a compact array
- 16 antennas in a Y-shaped array
- Freq: 150 MHz – 1450 MHz
- Bandwidth: 400 MHz, 16K spectral channels
- Single pixel feeds



Reference:
http://www.ncra.tifr.res.in/ncra/news-events/phiscc-2017-1/narendra_patra.pdf

The GMRT Central Square Antennas

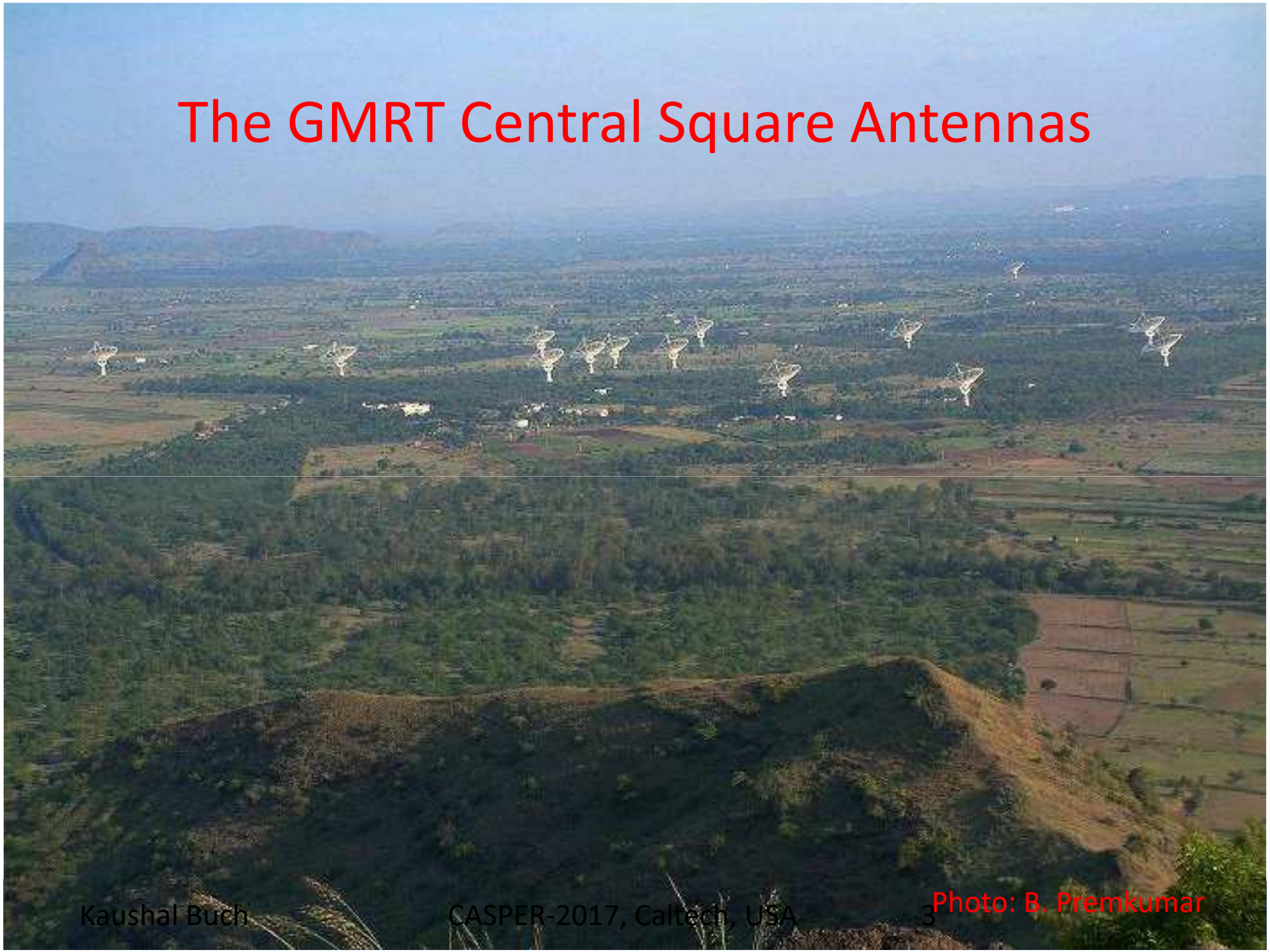


Photo: B. Premkumar

The Expanded GMRT (eGMRT)

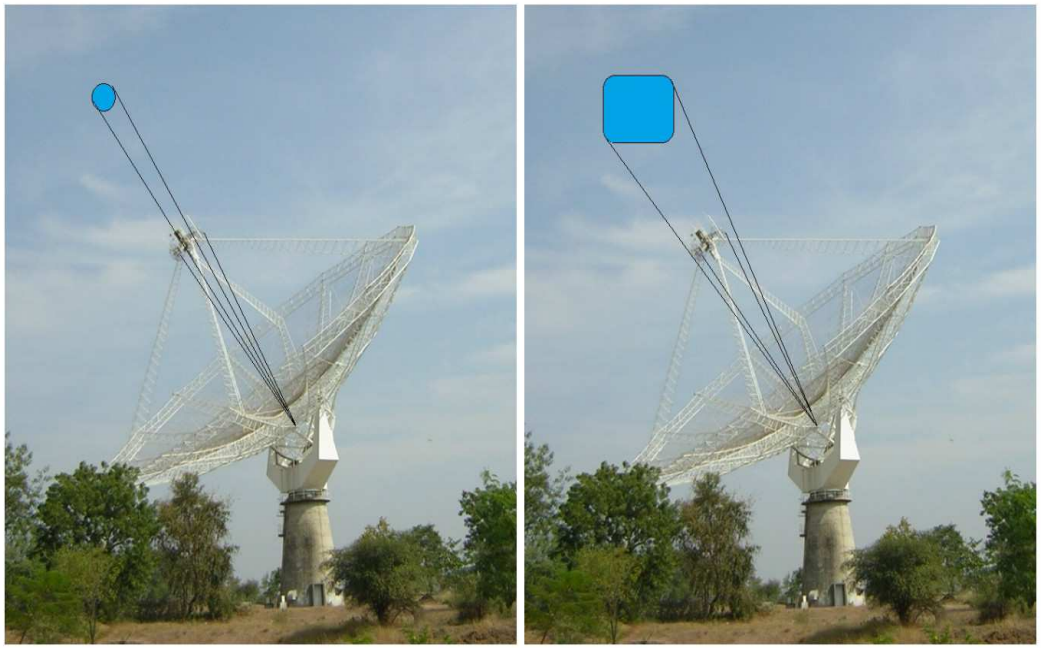
- 30 new antennas at baselines less than 5 km. : need correlator and beamformer for 30 antennas
- Focal Plane Array (FPA) feeds with 30 beams on the sky : need a multi-beam beamformer
- Bandwidth: 300 MHz, 16384 spectral channels
- Observing Frequencies
  - L-band (1000 – 1450 MHz)
  - 550 – 900 MHz
- Options being explored
  - GMRT + FPA
  - eGMRT
  - eGMRT + FPA

In prototype development stage

Reference:
http://www.ncra.tifr.res.in/ncra/news-events/phiscc-2017-1/narendra_patra.pdf

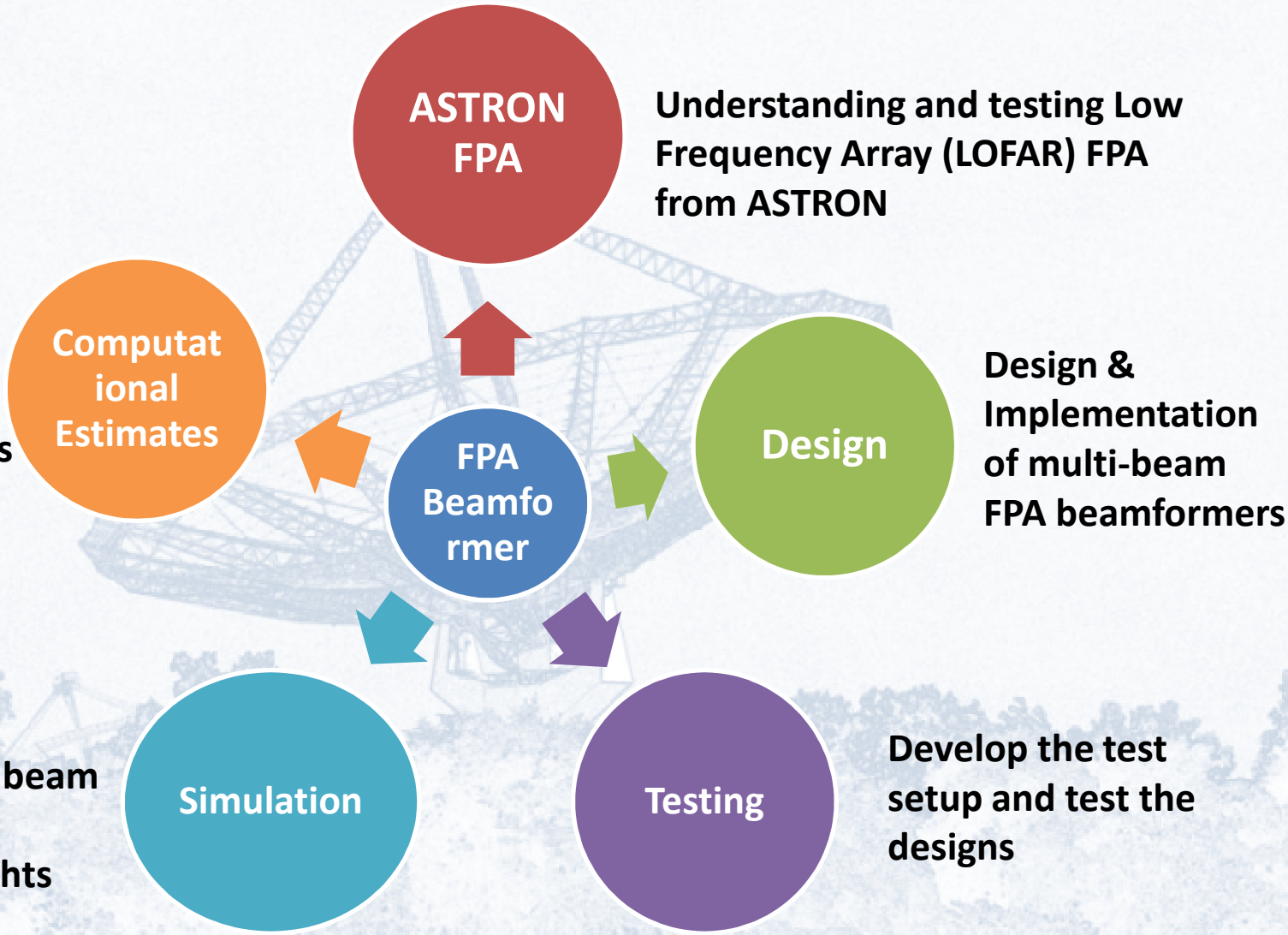
Requirements for eGMRT FPA prototype

- Signal Transport through optical links from FPA to Beamformer
- Multi-element, multi-beam prototype beamformer (300 MHz, 16k spectral channels, 30-beam, 144-element)
- Algorithms for calibration and optimal beamforming

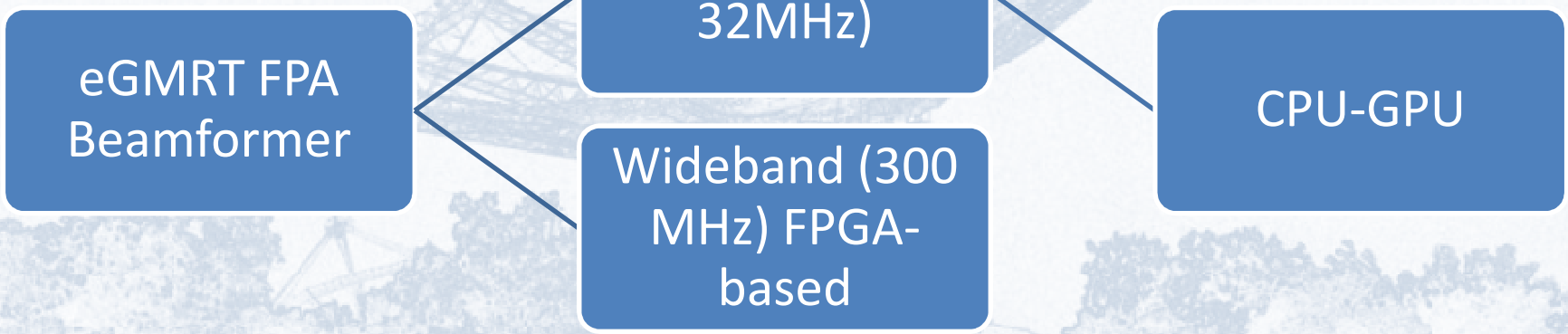


Artist's Impression: Increased Field-of-View with FPA at the focus

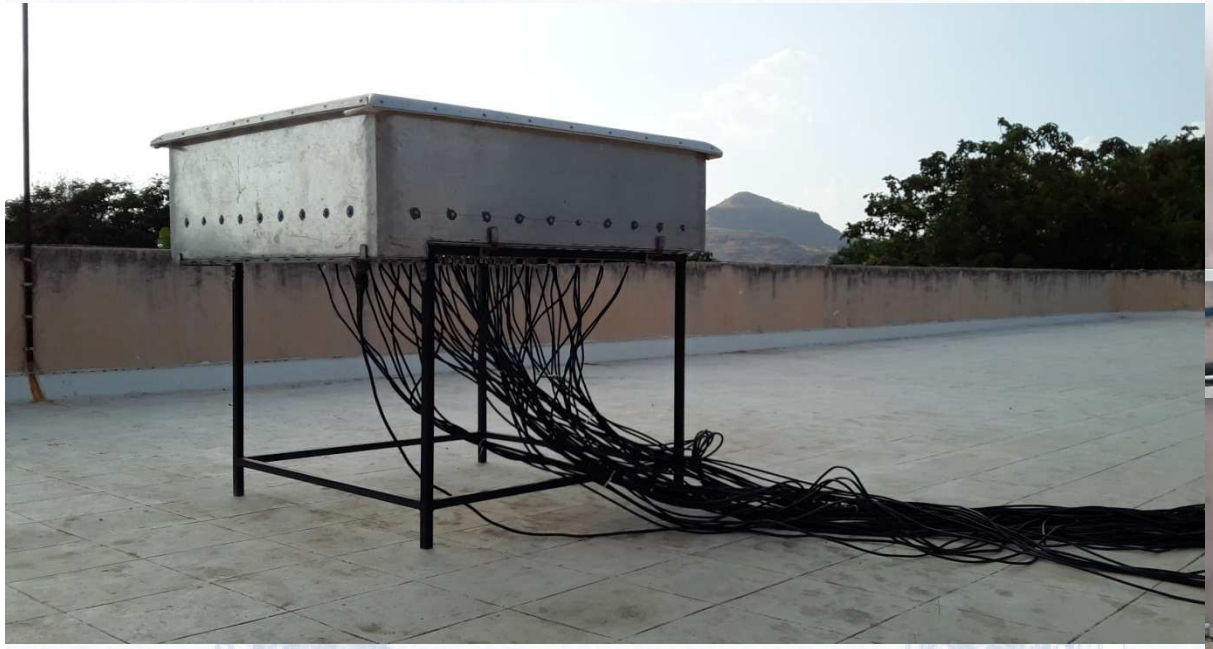
FPA Beamformer Development

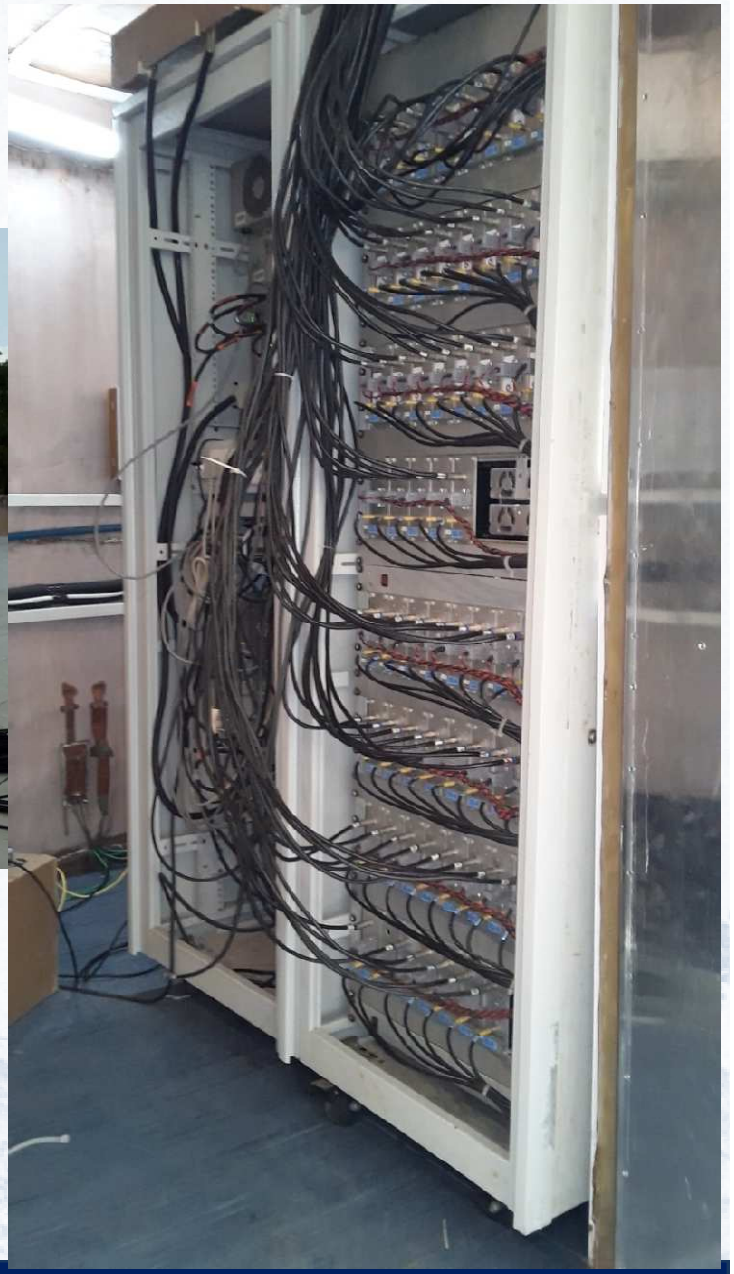


eGMRT Narrowband & Wideband beamformers



ASTRON Beamformer at GMRT



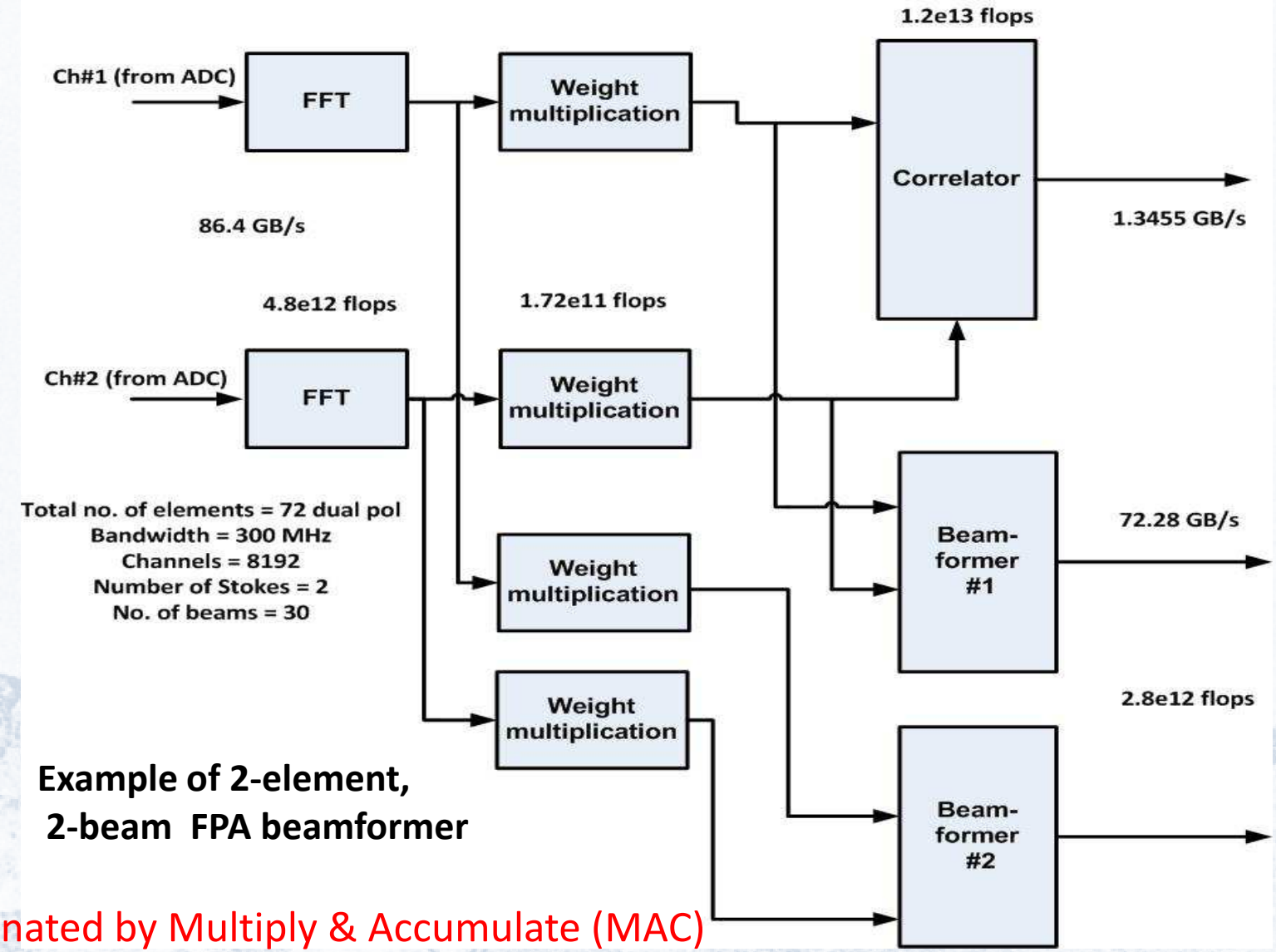


- 8*9 Vivaldi array (dual polarization) and beamformer– built by ASTRON Netherlands (DIGESTIF version)
- Used for understanding FPAs and capability building
- Currently installed at the GMRT site
- 1.1 – 1.7 GHz, 80 MHz bandwidth

Prototype FPA beamformer

- Multi-element (fixed) beamforming
- Multiple beams (complex weights)
- Correlator (required but not all the time)
- Real-time data acquisition and processing
- Optimal beamforming and calibration

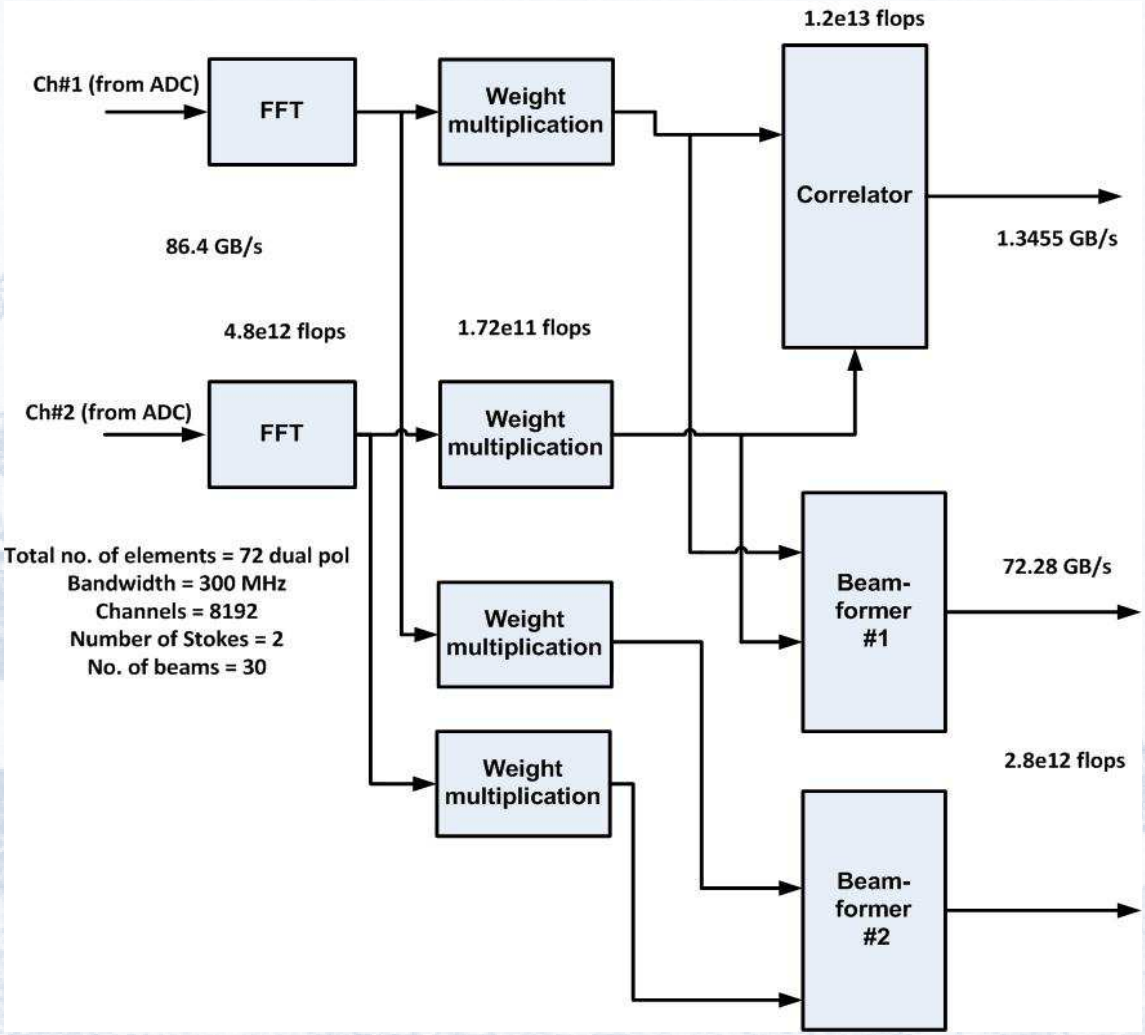
Compute & Data rate requirements



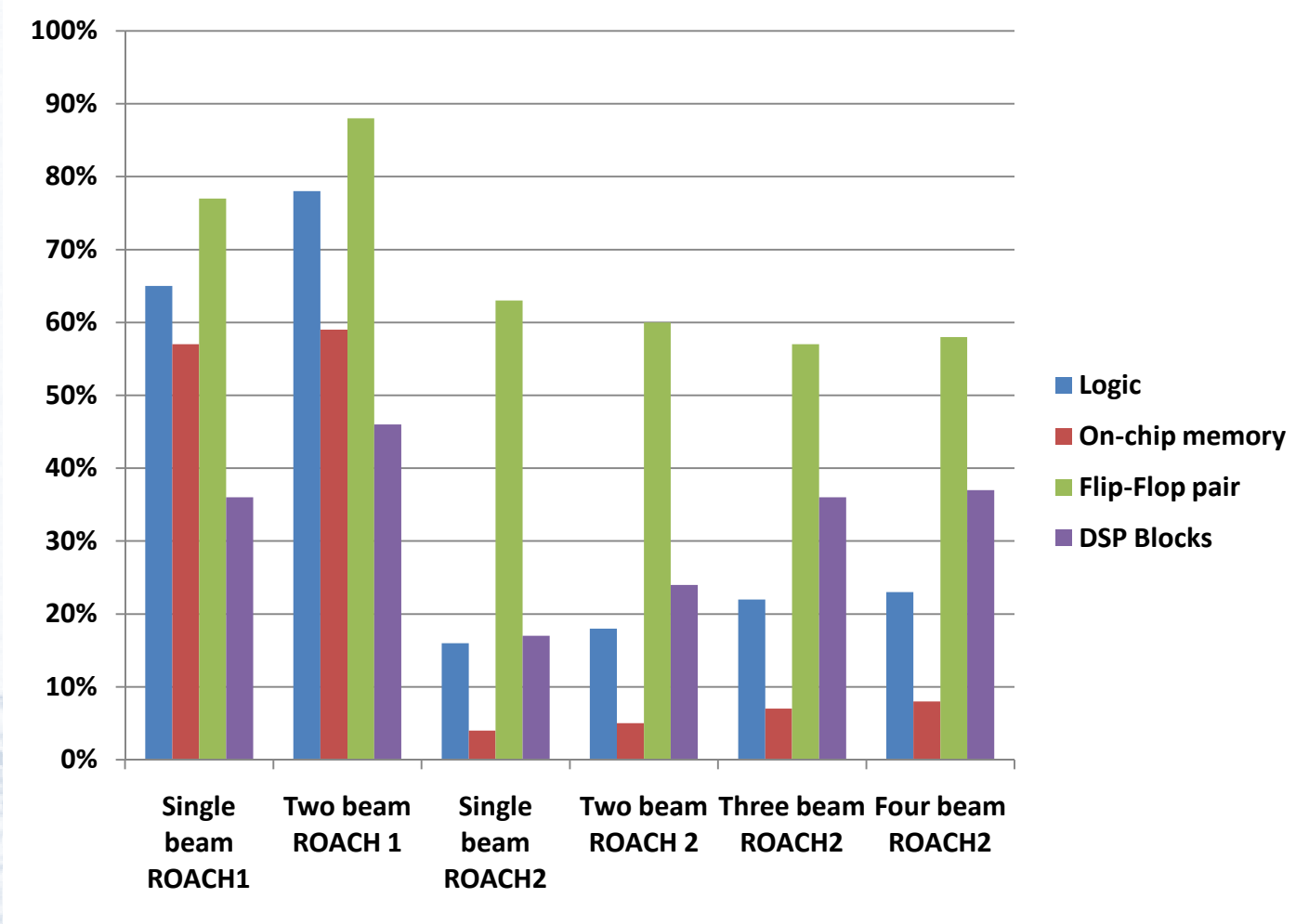
Dominated by Multiply & Accumulate (MAC)

Wideband FPA Beamformer: Single Board

- 4-input, 300 MHz bandwidth, 256-channel FPA beamformer and correlator, ROACH-1 + iADC
- No coarse delay correction
- 4-bit real, 4-bit imaginary correlation
- Phase multiplication (18-bit real, 18-bit imaginary)
- Phase resolution: ~0.1 degree
- Data output:
  - correlator (1 GbE)
  - beam (10 GbE) – coherent sum (8-bit)

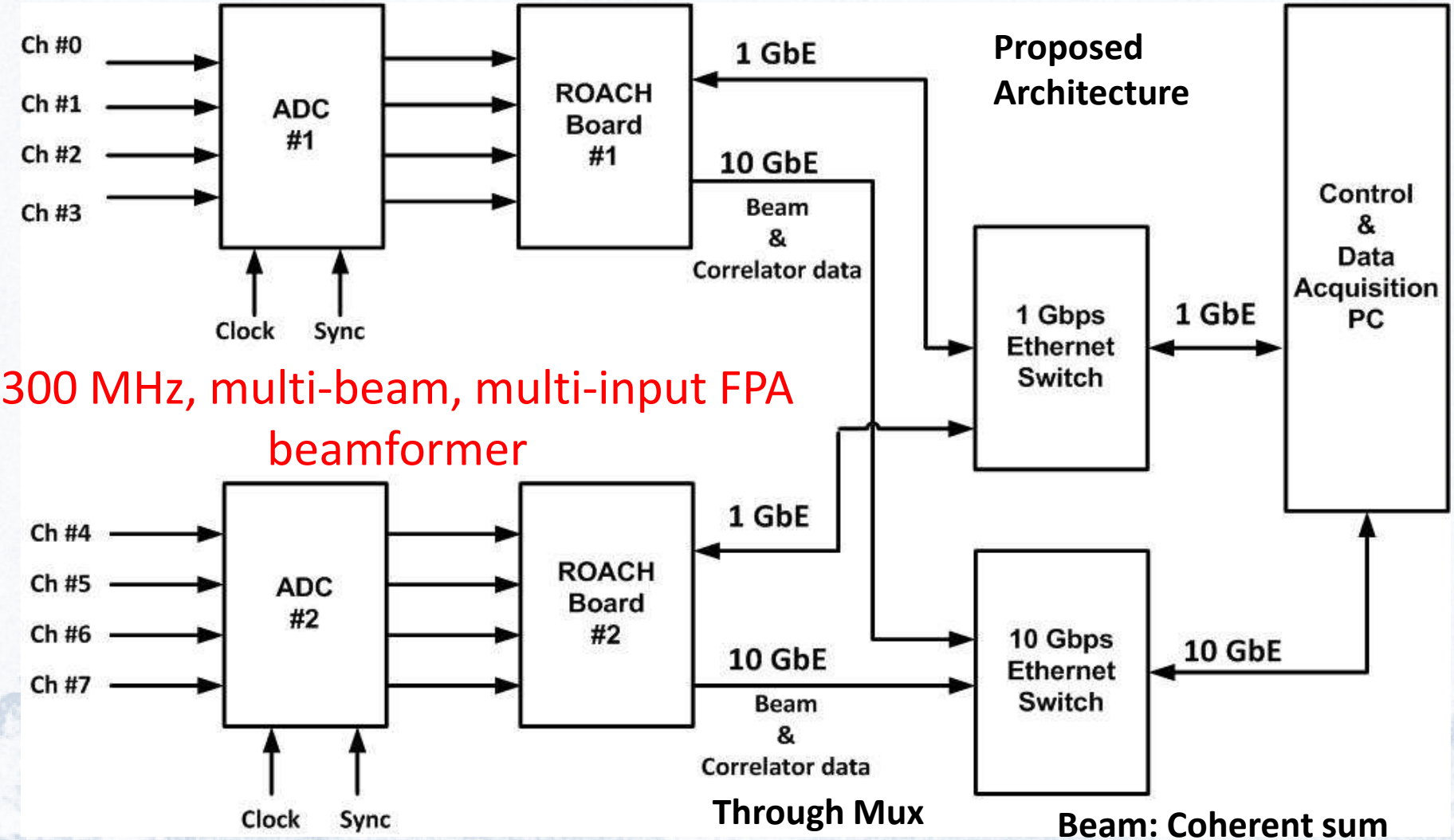


Resource Utilization



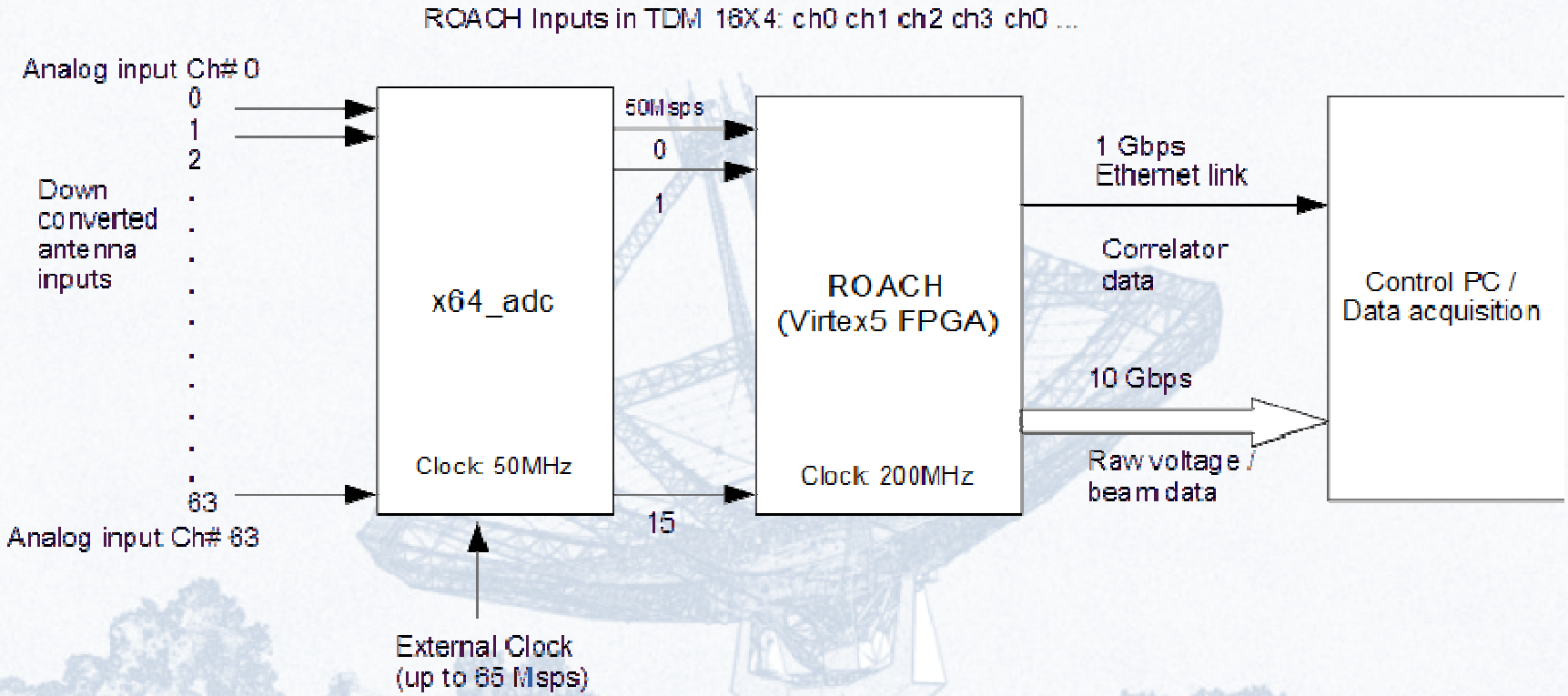
Comparison between ROACH-1 and ROACH-2 for 256-channel, 4-input, 300 MHz FPA beamformer

Wideband FPA Beamformer: Scalable



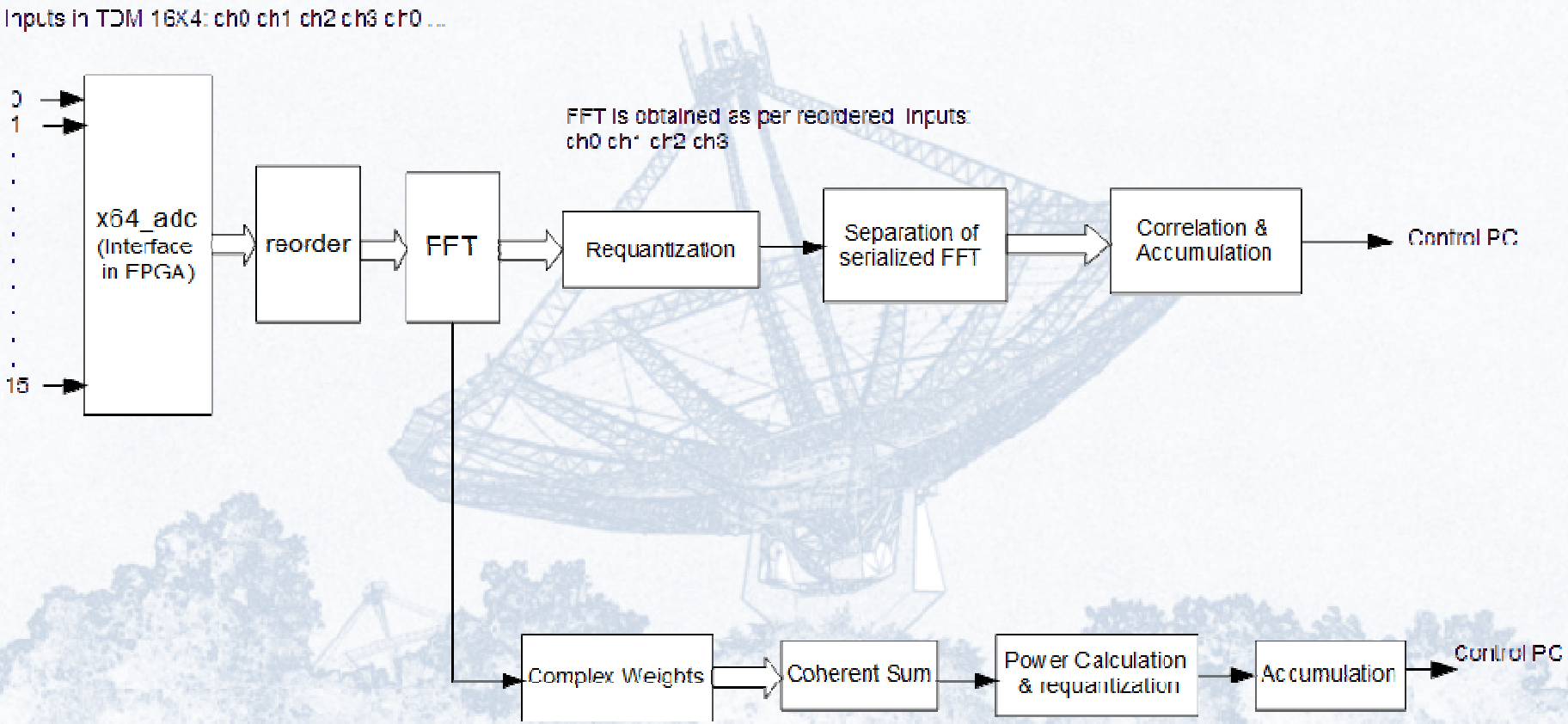
Final Beams are formed in the acquisition PC

Narrowband FPA Beamformer

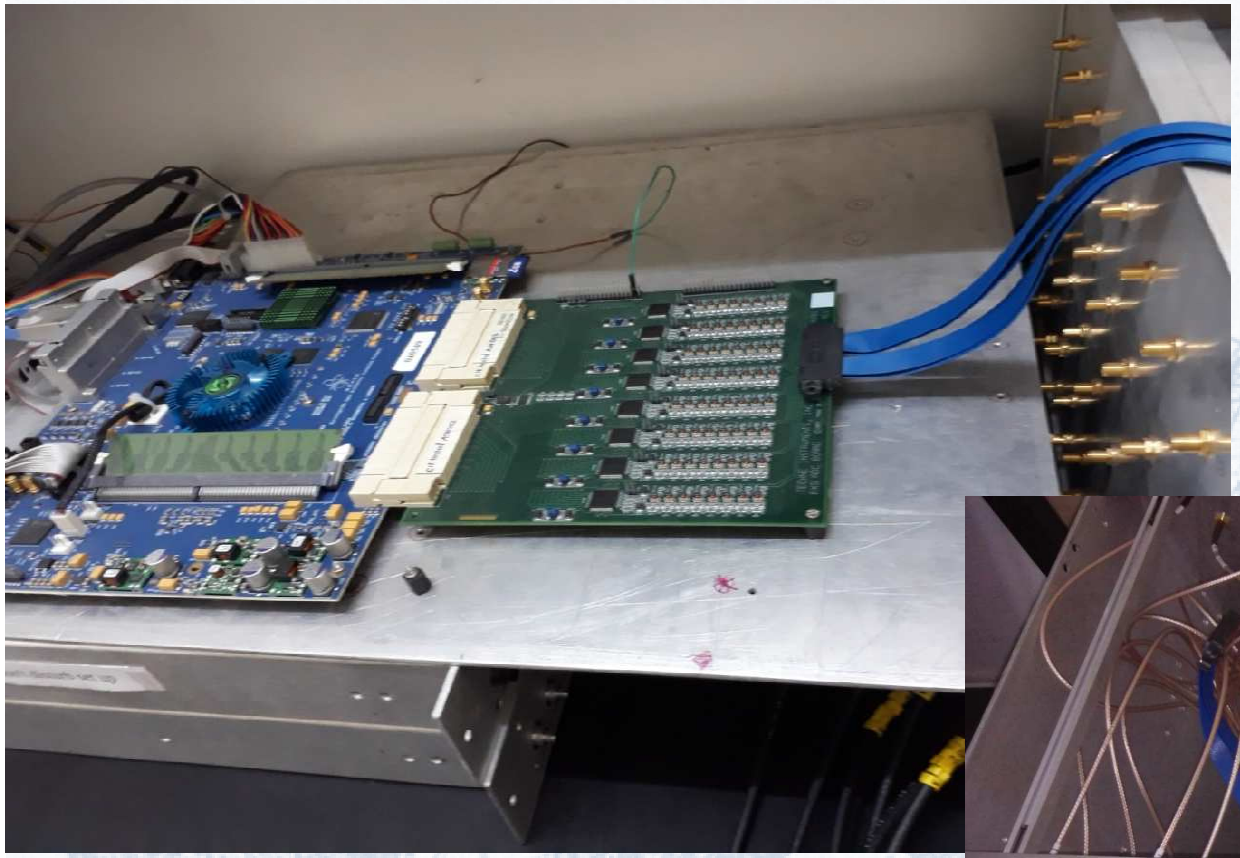


- Uses 64-input, 12-bit ADC from Techne Instruments Inc. connected to ROACH-1 board
- Processing in time division multiplexed fashion, FPGA clocked at 4x the ADC clock
- Narrowband multi-beam beamformer & correlator, 128-channel
- Raw voltage on 10 GbE port : processing in software

Narrowband FPA Beamformer Design

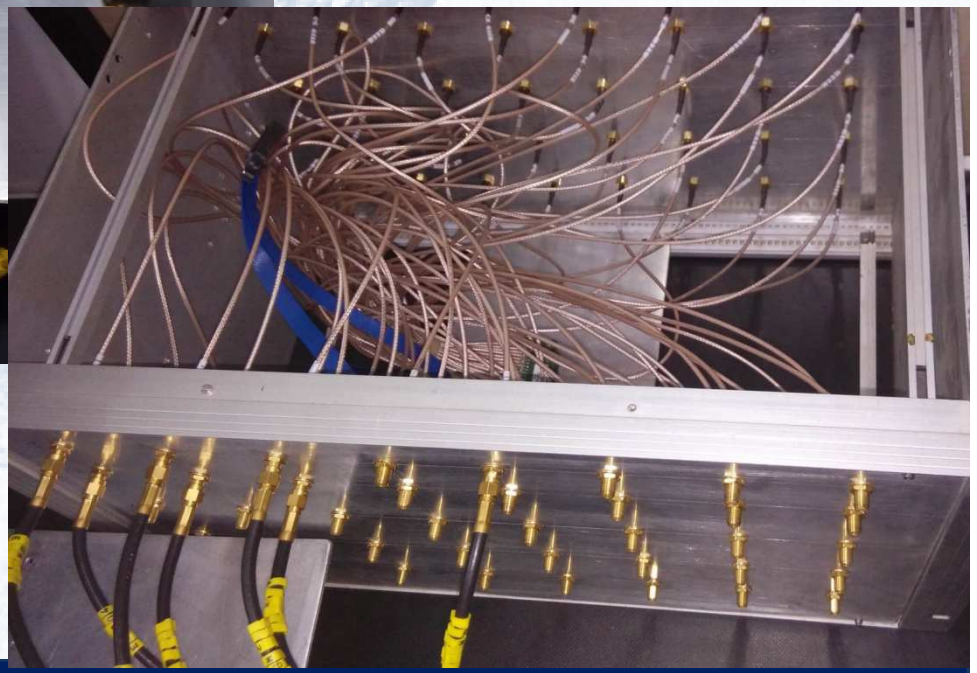


Narrowband Beamformer Setup

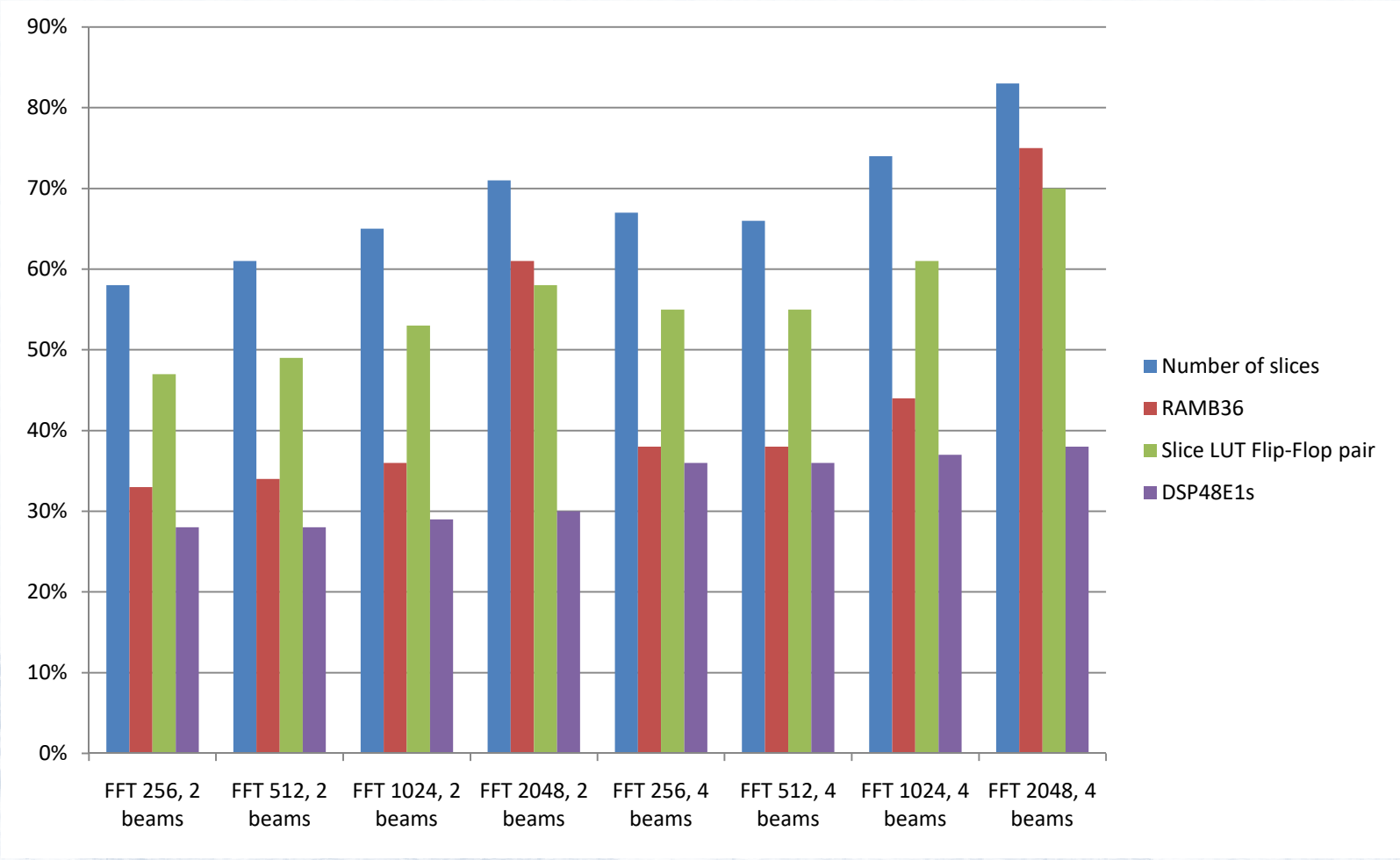


64-channel ADC
connected with the ROACH-1 board (above)

Connecting RF cables to the ADC (below)



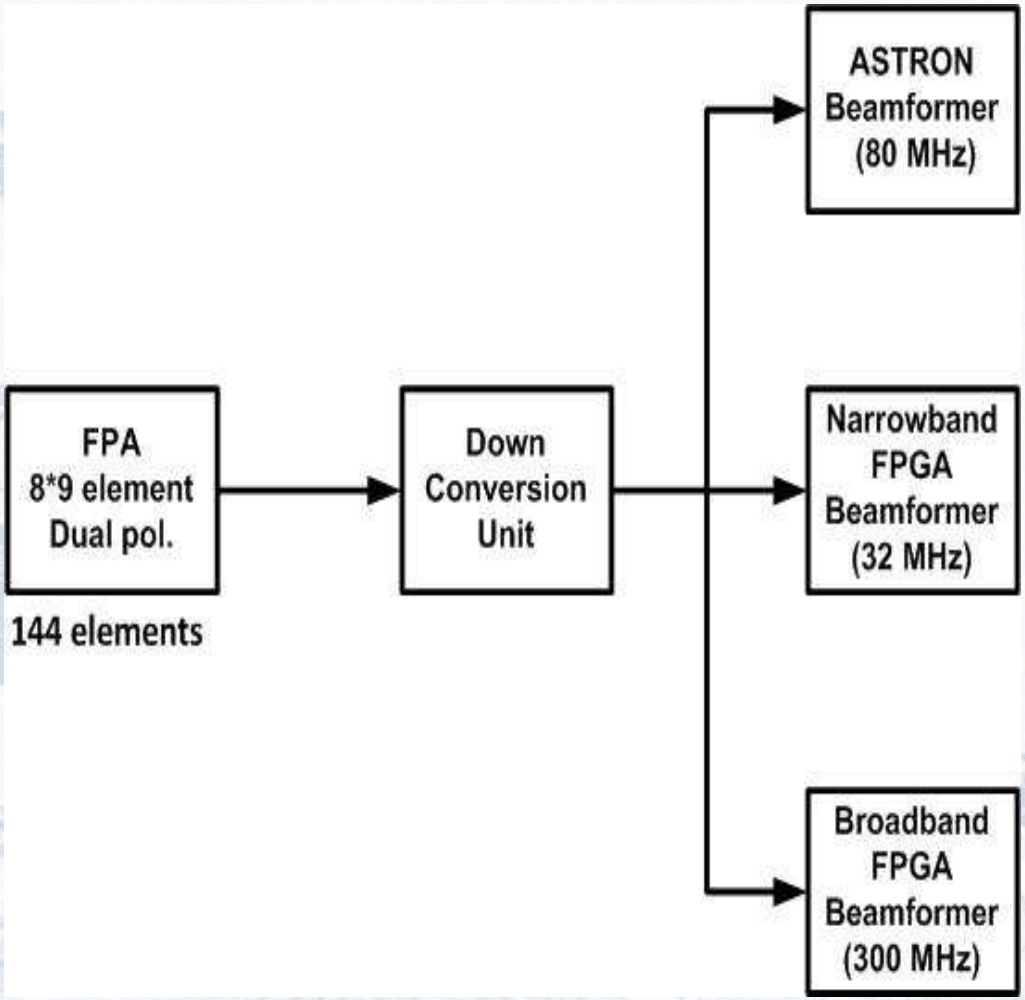
Resource Utilization



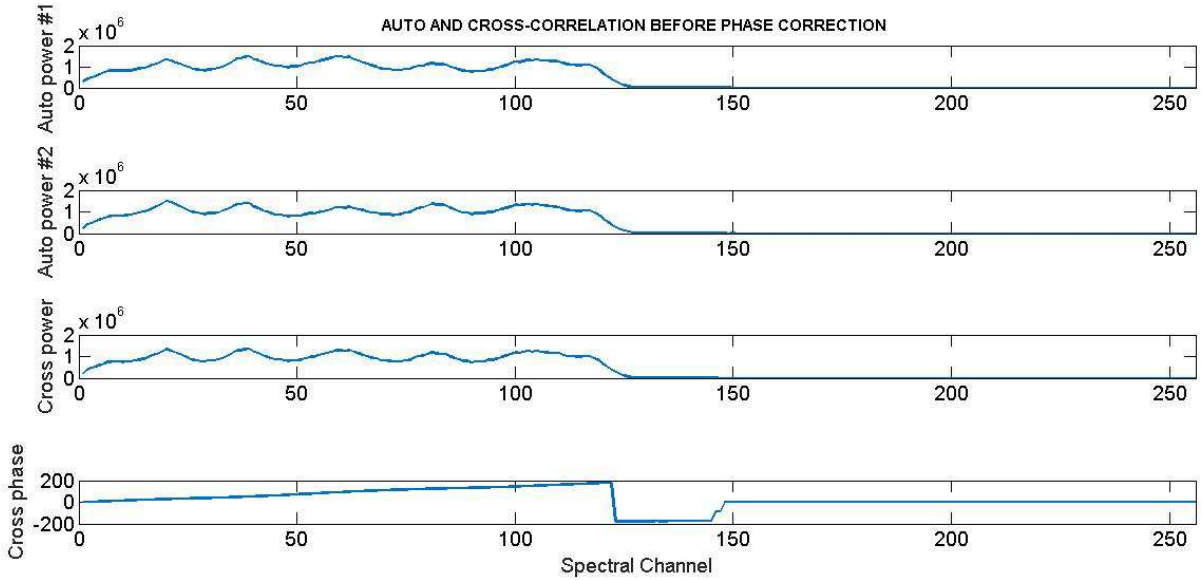
64-channel ADC+ROACH-1 based 16-input correlator and FPA beamformer (narrowband)

Testing beamformers with the FPA

- Initial tests with CW signal and noise
- Tests carried using directional antenna in free-space test range
- Operate the ASTRON FPA beamformer in parallel to compare the results

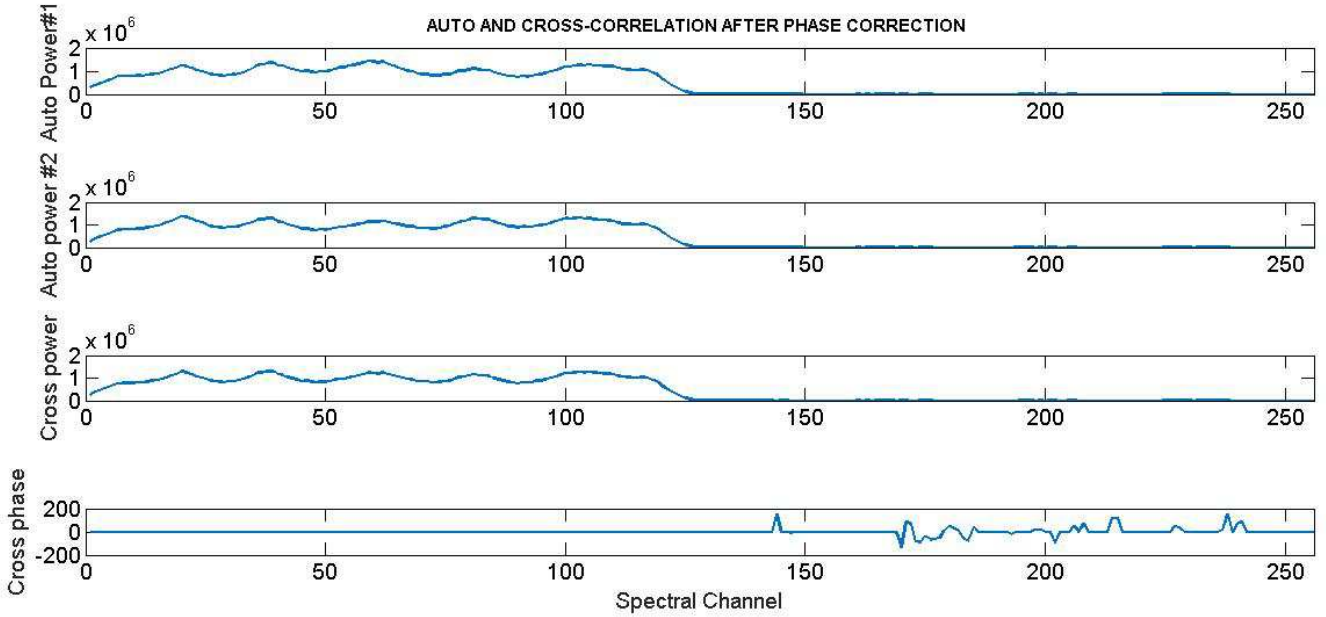


Basic tests: Phase Correction

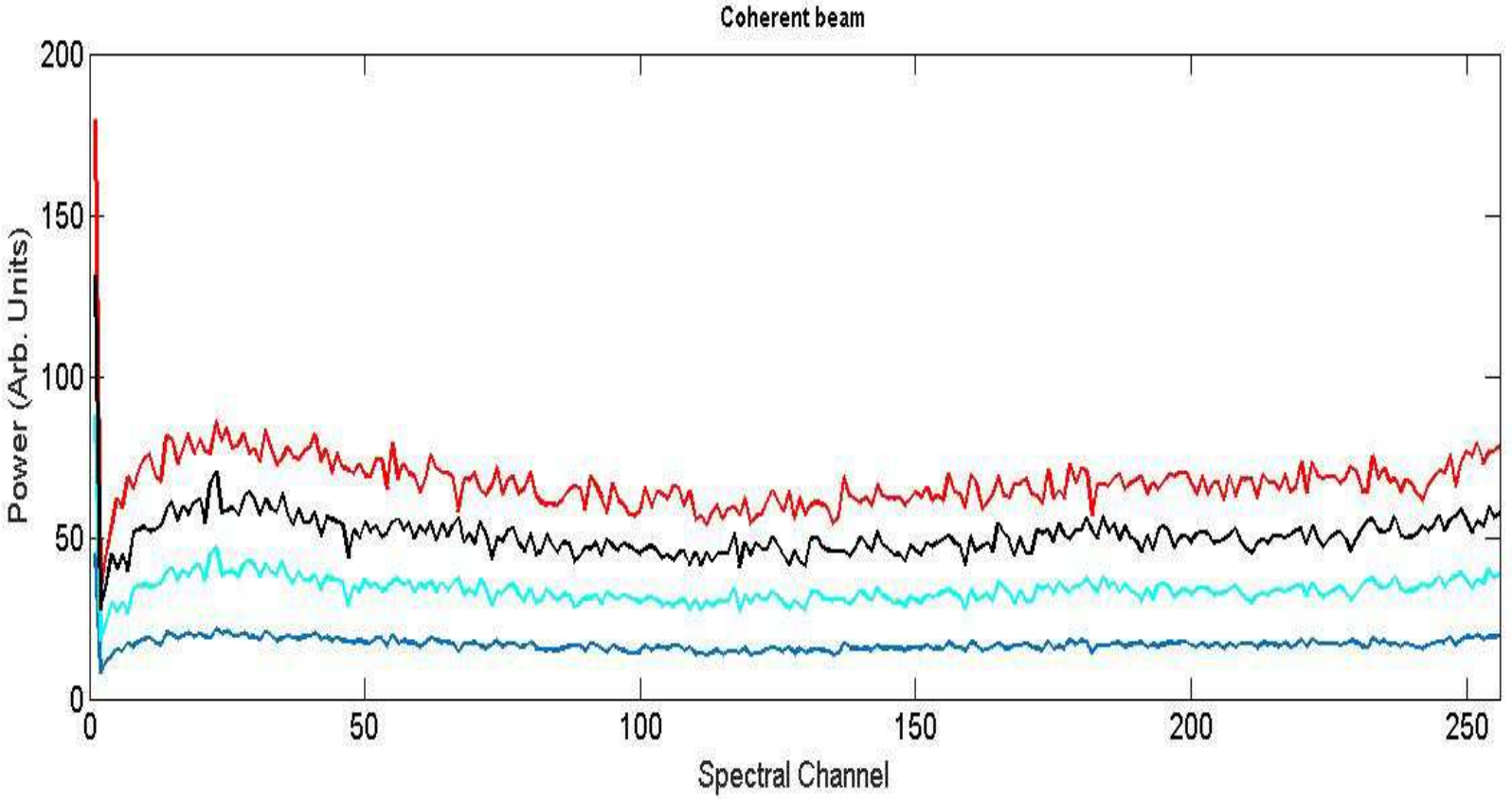


Before Phase correction (left)

After Phase correction (right)



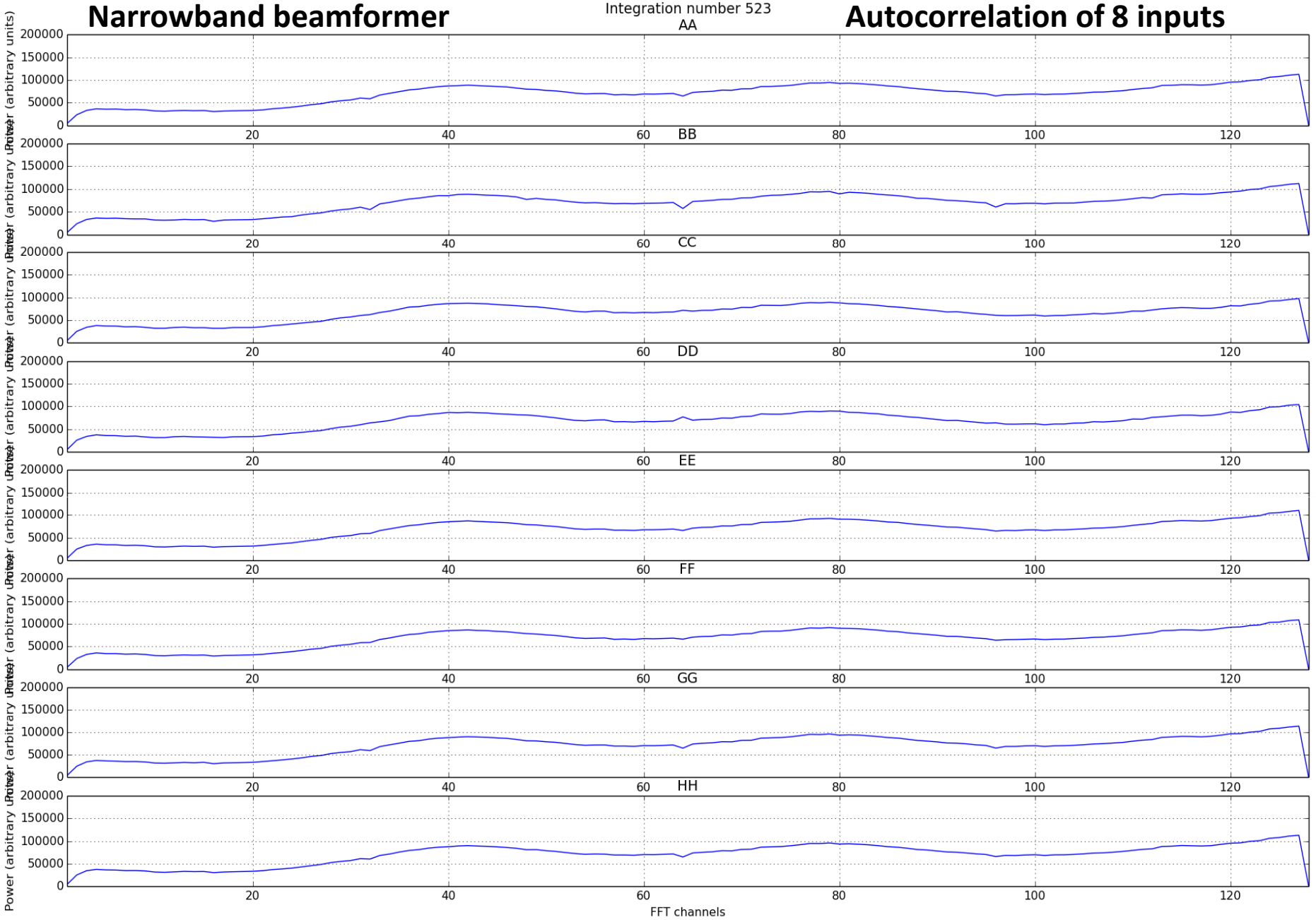
Basic tests: Addition of beams



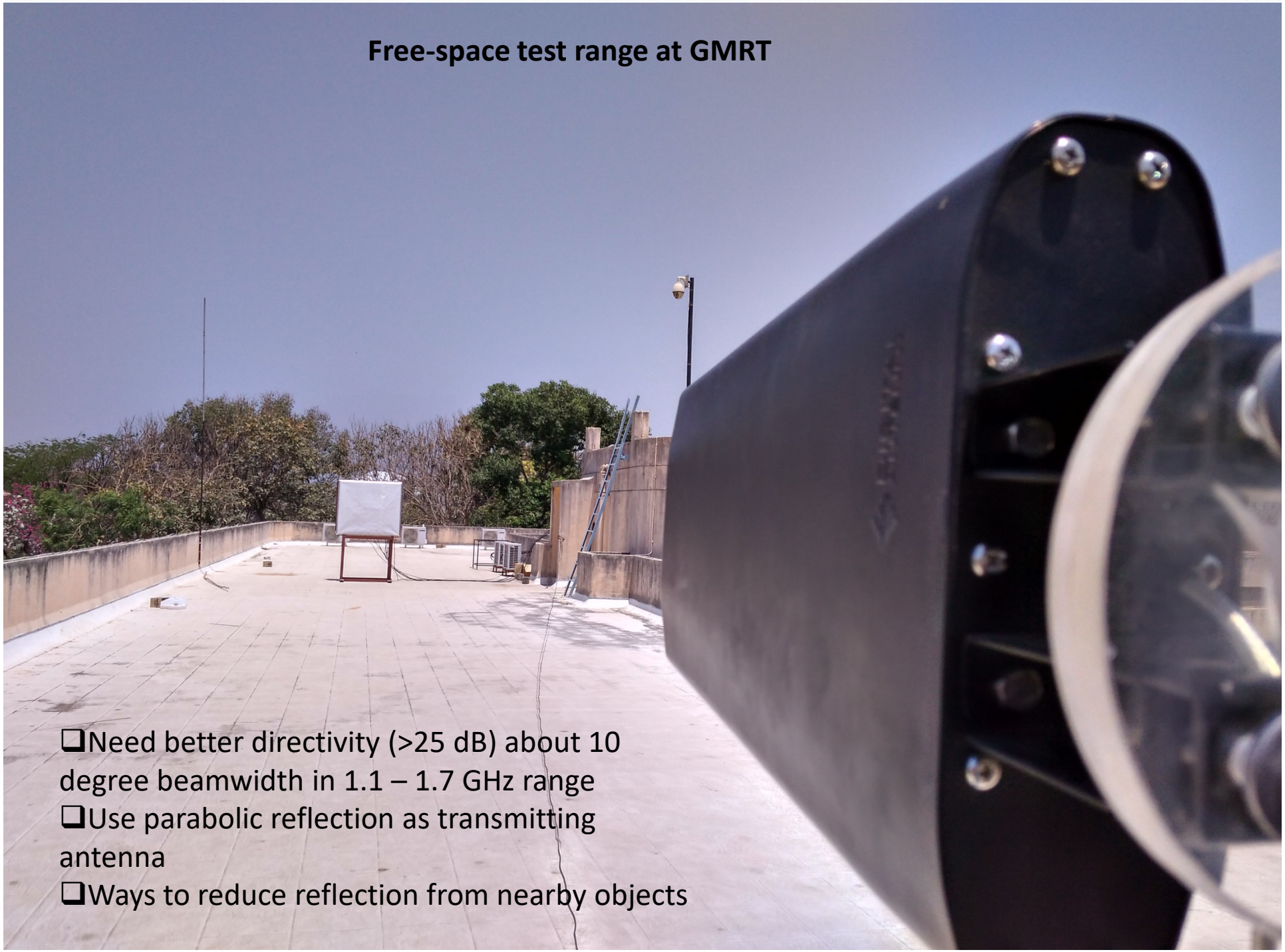
Coherent beamforming using four elements – single element (blue), two elements (cyan), three elements (black), four elements (red)

Narrowband beamformer

Autocorrelation of 8 inputs



Free-space test range at GMRT



- Need better directivity (>25 dB) about 10 degree beamwidth in 1.1 – 1.7 GHz range
- Use parabolic reflection as transmitting antenna
- Ways to reduce reflection from nearby objects

Summary

- Developing wide-band multi-beam multi-element FPA beamformer – basic design done on ROACH-1, testing in progress

- Scalable architecture with offline correlation (or through reconfiguration of FPGA) and beamforming being developed

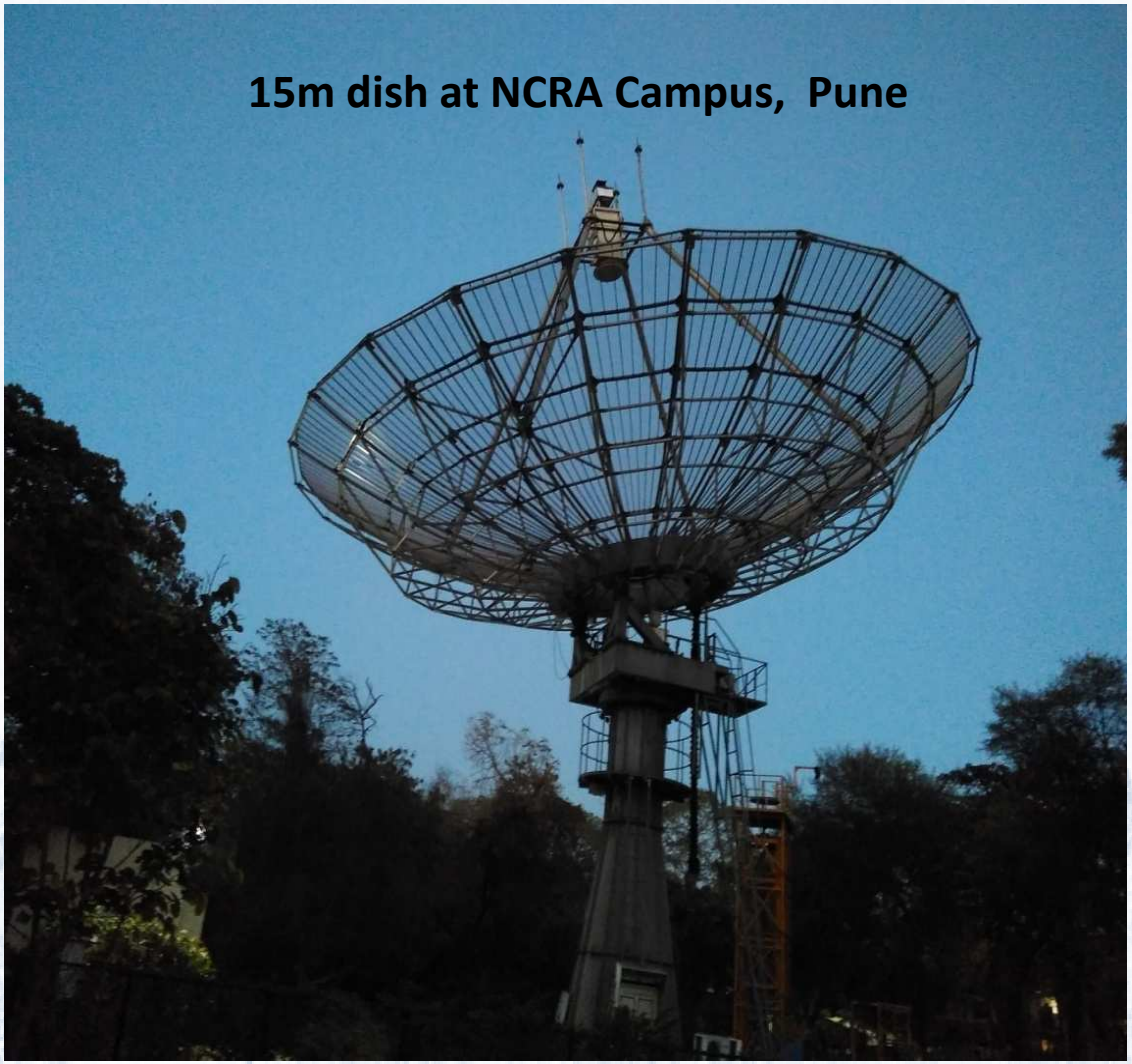
- Developing designs and testing narrowband FPA beamformer (in progress) – FPGA , software option (CPU/GPU) also being developed

- Characterizing and testing the FPGA-based beamformers with the ASTRON FPA

- Determining the best architecture, platform and cost estimates for the prototype 300 MHz FPA beamformer – ROACH-2, SNAP, SKARAB (?) (Inputs from the collaboration are welcome)

Future Plans

Mount the FPA on 15m dish at NCRA campus (Pune) for tests



Acknowledgements

Current team members

Atul Ghalame

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Ajithkumar B. (Co-I, eGMRT proposal)

Jayaram Chengalur (Co-PI, eGMRT proposal)

Yashwant Gupta (Co-PI, eGMRT proposal)

Nissim Kanekar (PI, eGMRT proposal)

Past team members

Bela Dixit

Priya Hande

GMRT groups

Backend Group

Computer Group

Frontend & OFC group

Mechanical, Electrical & Civil groups


Thank You!