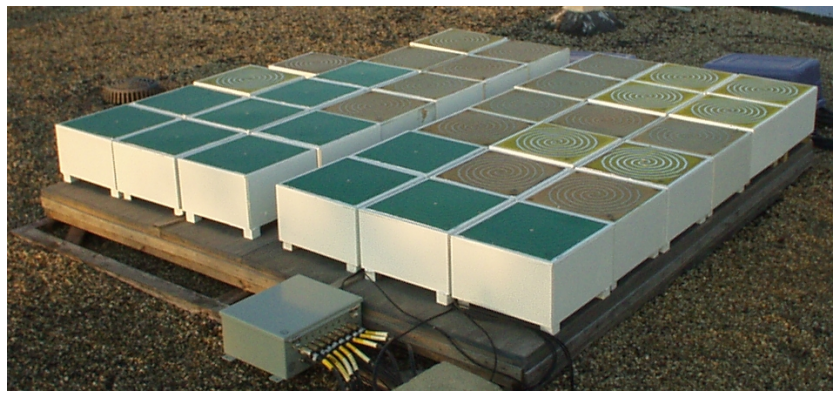
ARGUS

An L-Band Array for Detection of Astronomical Transients



S.W. Ellingson and G.A. Hampson

ElectroScience Laboratory

The Ohio State University

ellingson.1@osu.edu

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Background

- **Traditional radio astronomy uses large, filled-aperture antennas to achieve high sensitivity and spatial resolution.**

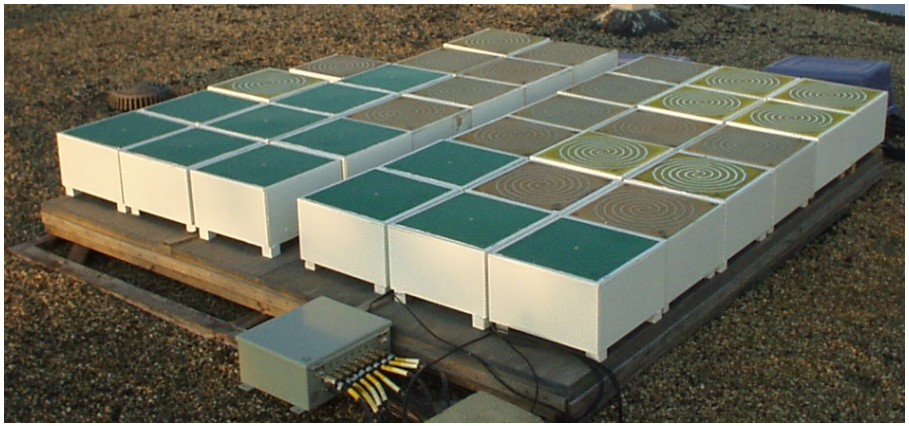
- **The resulting field of view (FOV) is extremely narrow, which limits sensitivity to transient astronomical sources; e.g.,**
  - **Radio component of gamma ray bursts (GRB)**
  - **"Giant pulses" associated with some pulsars**
  - **Other undiscovered natural transients?**
  - **ETI?**

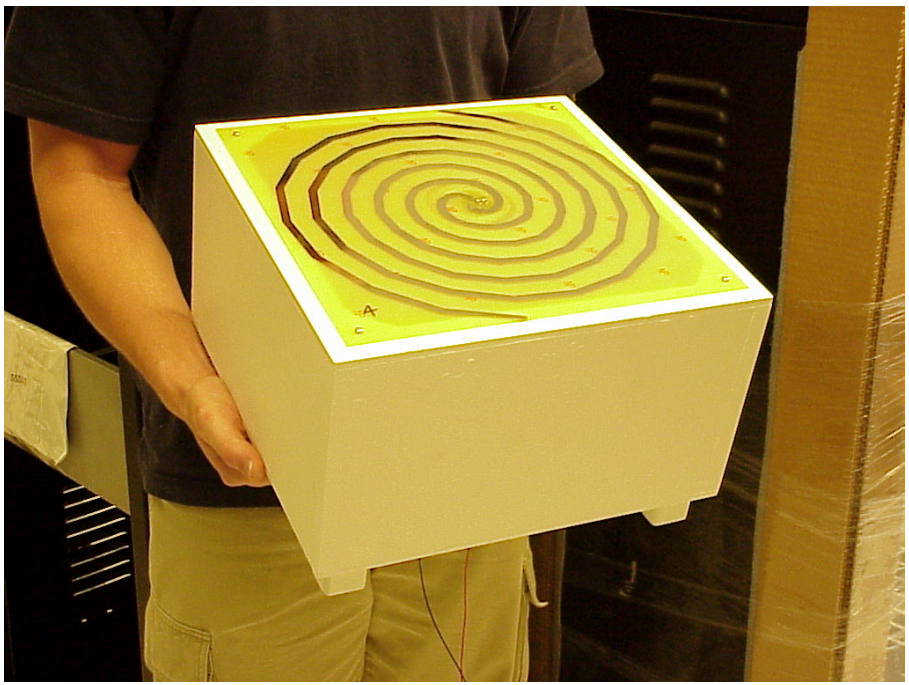
  Pulses

  Tones

- **<u>Argus concept:</u> Use instead large numbers of low gain (broadbeam) elements to achieve sensitivity over the entire sky. Three general strategies:**
  - **Monitor a "basis set" of beams, search independently in each beam**
  - **Compare sky images over time**
  - **Monitor the spatial covariance ("visibilities") directly**

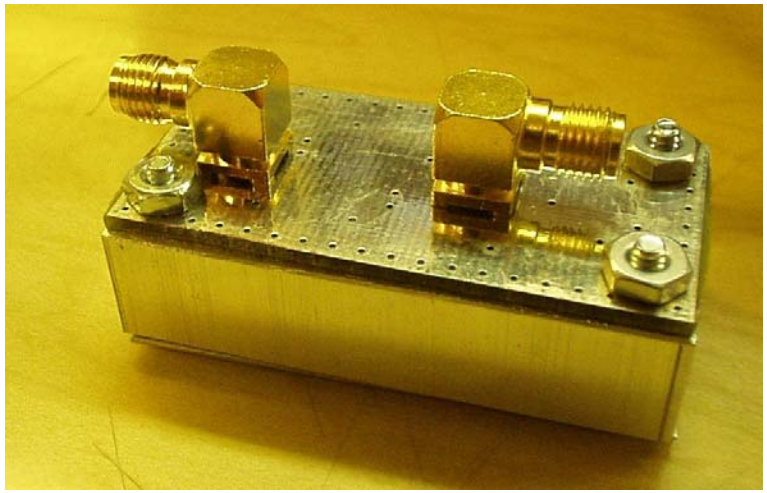
Antenna Array

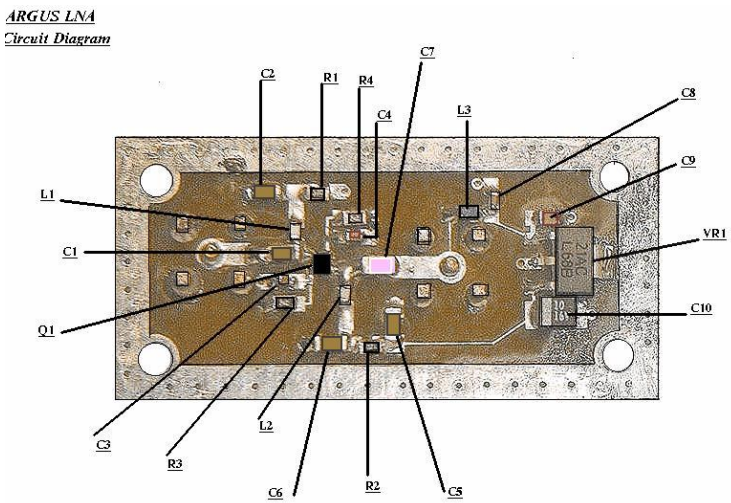




- Currently 34 antenna units in array (not necessarily always arranged as shown)
- Element is planar RHCP spiral on FR4 with tiered ground plane
- VSWR better than 2.5:1 in 900-1700 MHz
- A_e ~ 60 cm^2 per antenna @ 1420 MHz, zenith
- Integrated LNA powered through RF cable (i.e., just one connection)

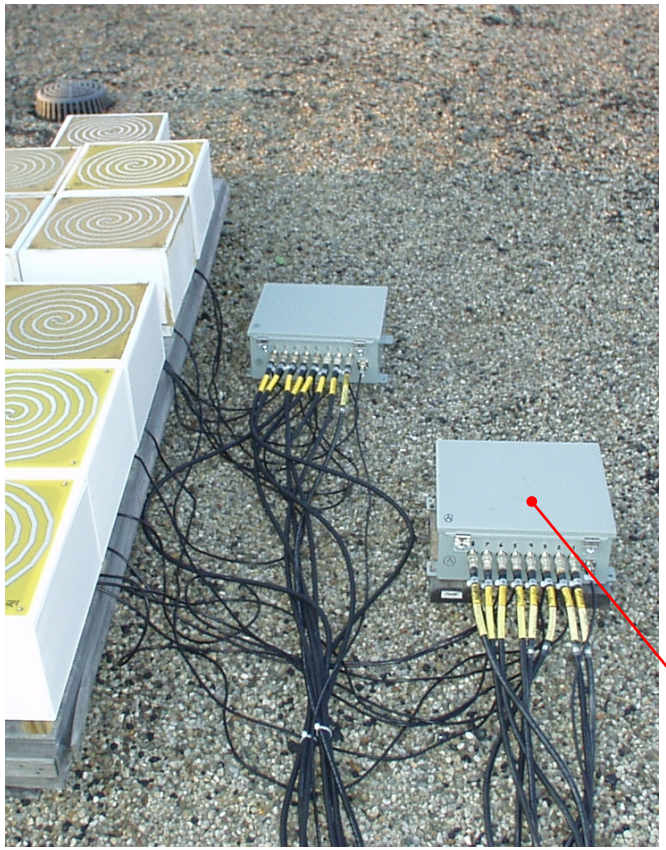
Low Noise Amplifier (LNA)



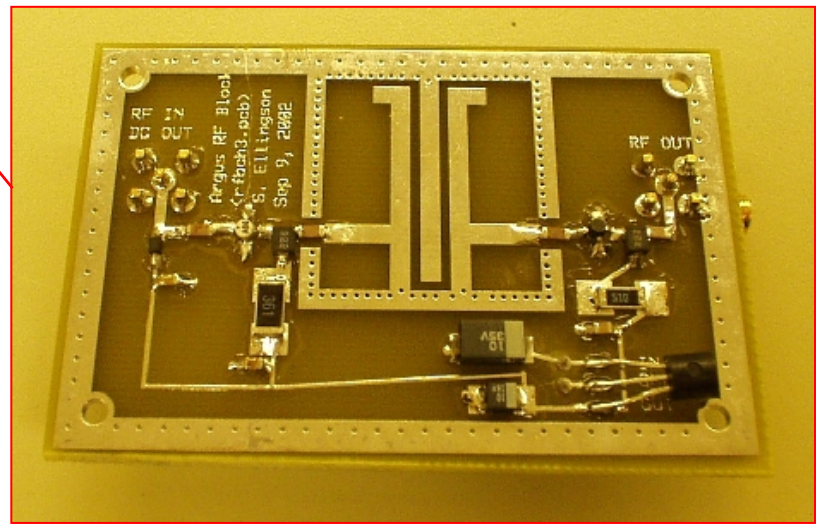


- **Embedded in antenna unit**
- **Simple pHEMT design**
- **~ 170°K**
- **~ +15 dB gain**
- **P_{1dB} ~ -5 dBm in band**
- **1 GHz highpass**

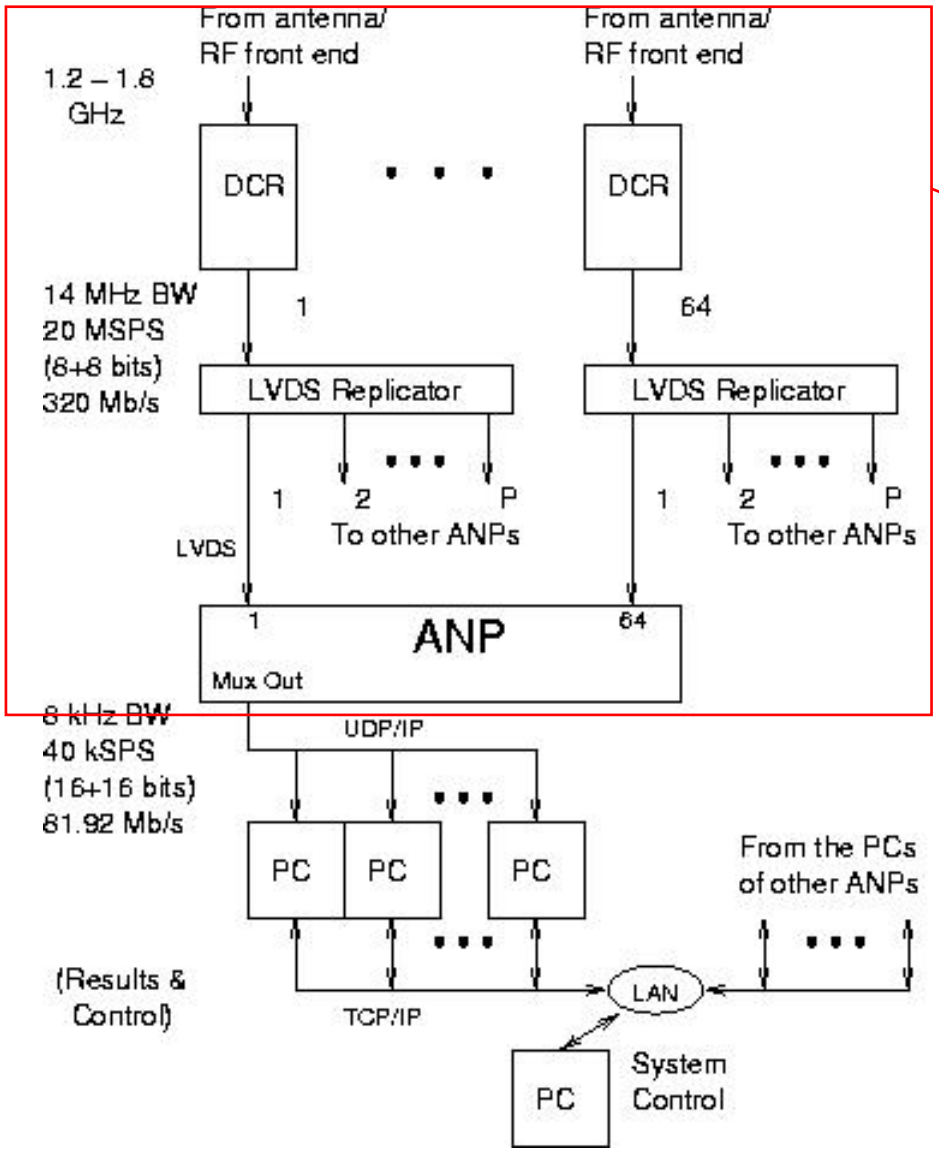
Line Amp Array

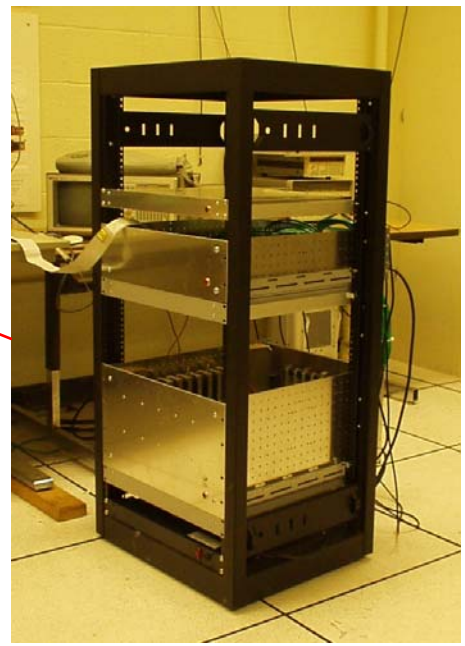


- 1 line amp array per 8 antenna units
- Provides filtering to 1200-1800 MHz and ~ +20 dB gain to drive cable
- Distributes power to LNAs in antenna modules through bias tee arrangement



"Downstairs" Electronics

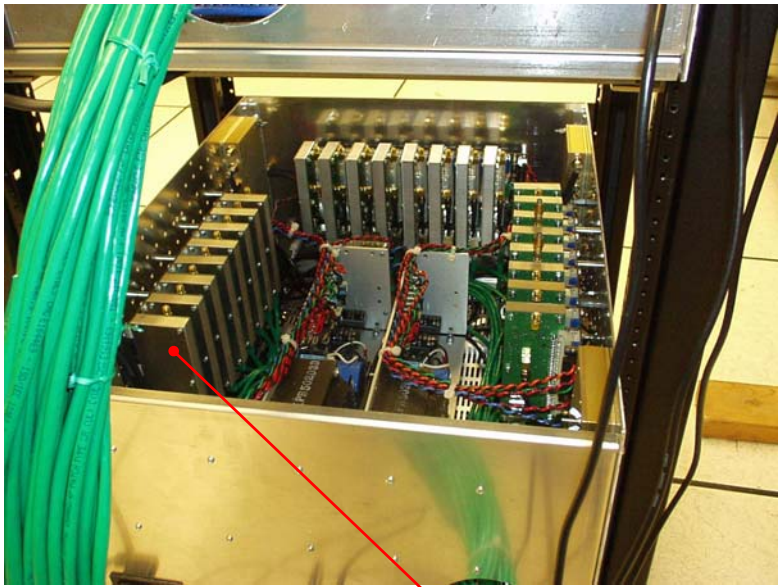




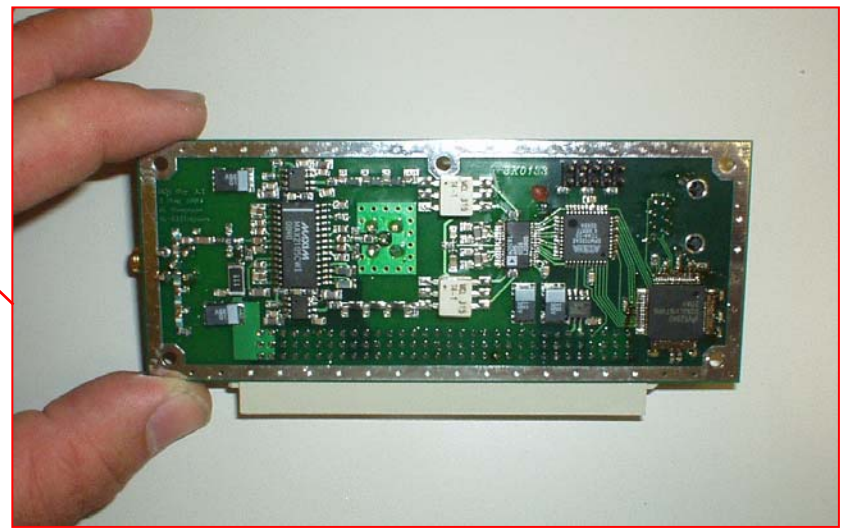
Current Implementation
N=32 (24 populated)
60 kHz BW
78.125 kSPS

THE OHIO STATE UNIVERSITY

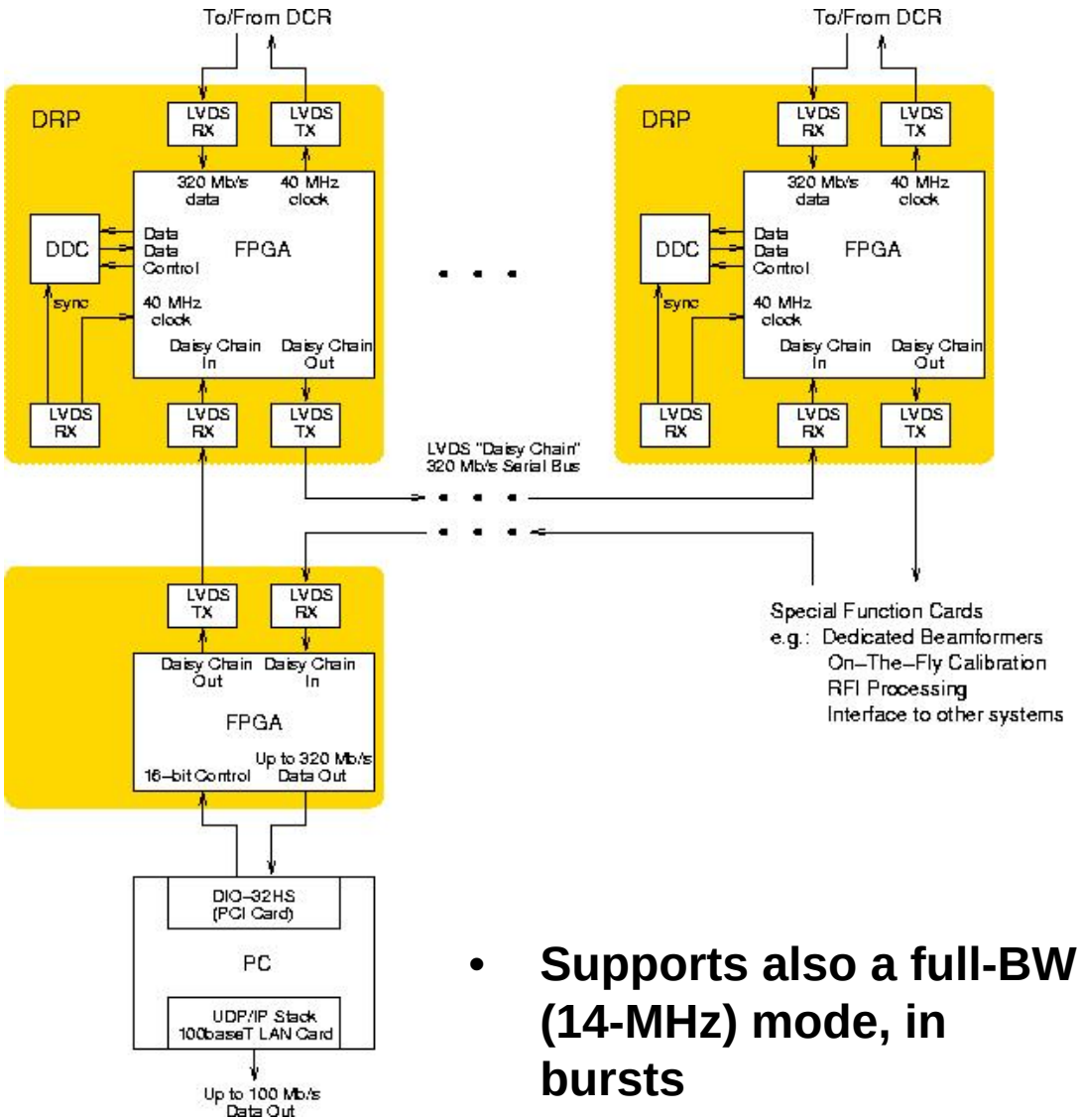
Direct Conversion Receiver (DCR)



- Moves 14 MHz spectrum from L-band to baseband (I/Q)
- 20 MSPS, 8-bit “I” + 8b “Q”
- Output at 320 Mb/s using LVDS on CAT-5 cable

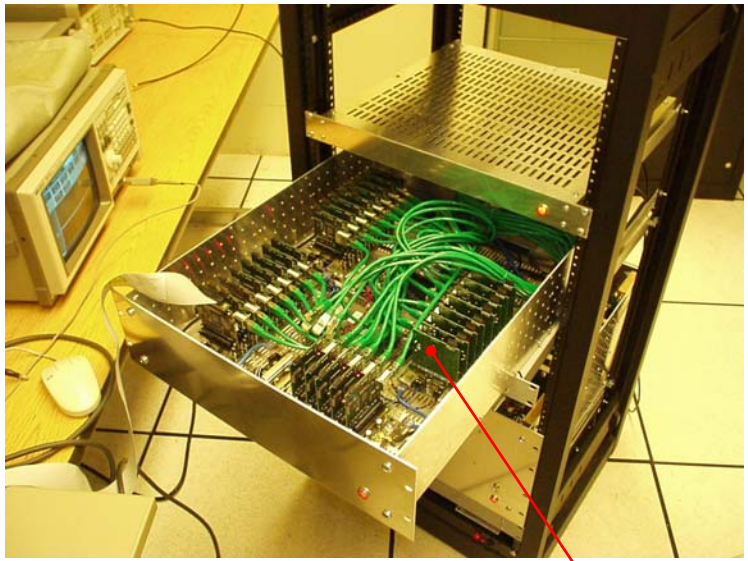


Argus Narrowband Processor (ANP)

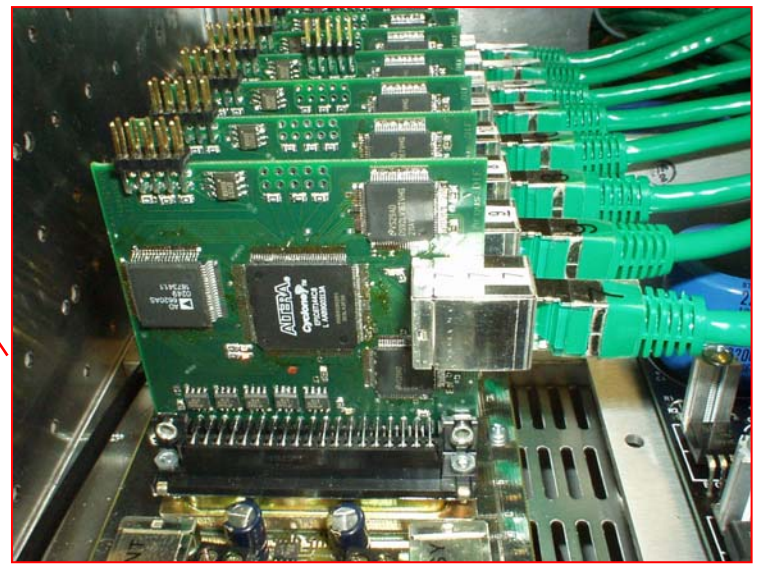


- **Arranges samples into snapshots using serial bus “daisy chain” architecture**
- **Same architecture enables additional processing & interfaces to other systems**
- **Snapshots exit to PC at 40 kSPS (N=64) or 78.125 kSPS for N=32)**
- **Supports also a full-BW (14-MHz) mode, in bursts**
- **Data is broadcast over a LAN using UDP/IP (81.92 Mb/s)**

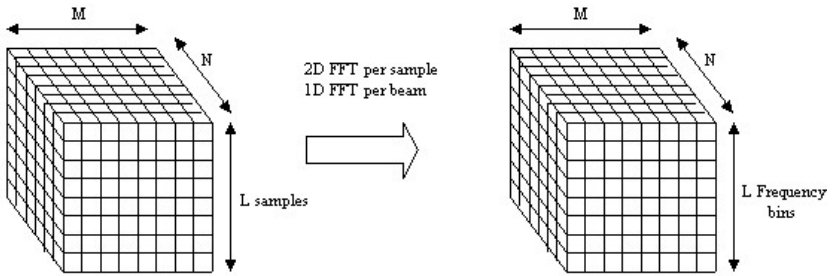
Digital Receiver/Processor (DRP)



- **“Tune and Zoom” within 14 MHz digital passband using AD6620 Digital Downconverter**
- **N=64: 34 kHz BW @ 40.000 kSPS**
  N=32: 60 kHz BW @ 78.125 kSPS
- **Corrects (small) I/Q imbalance from DCR**



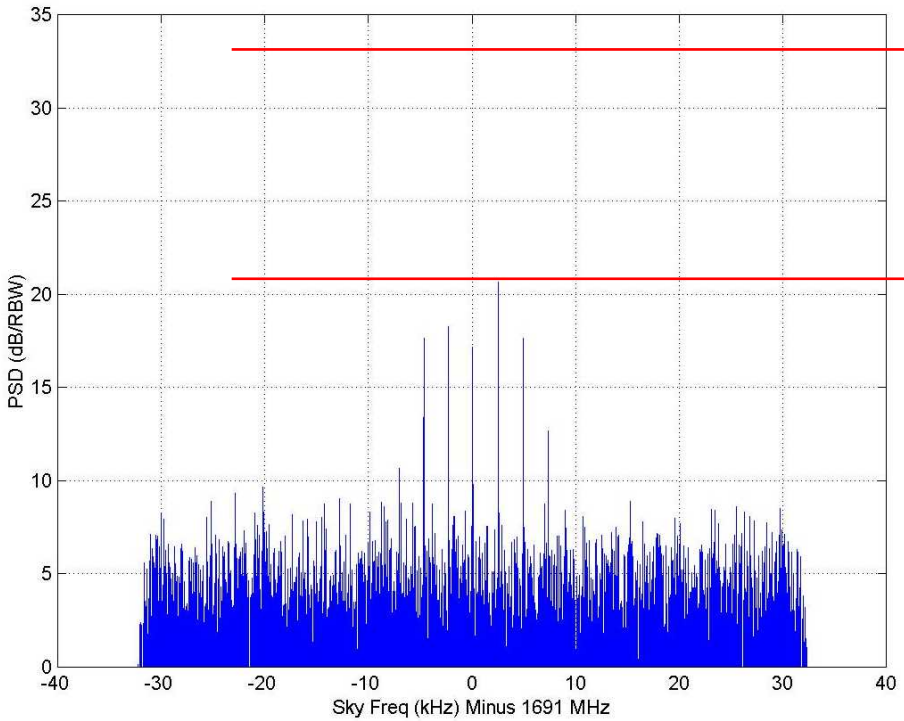
Signal Detection & Analysis



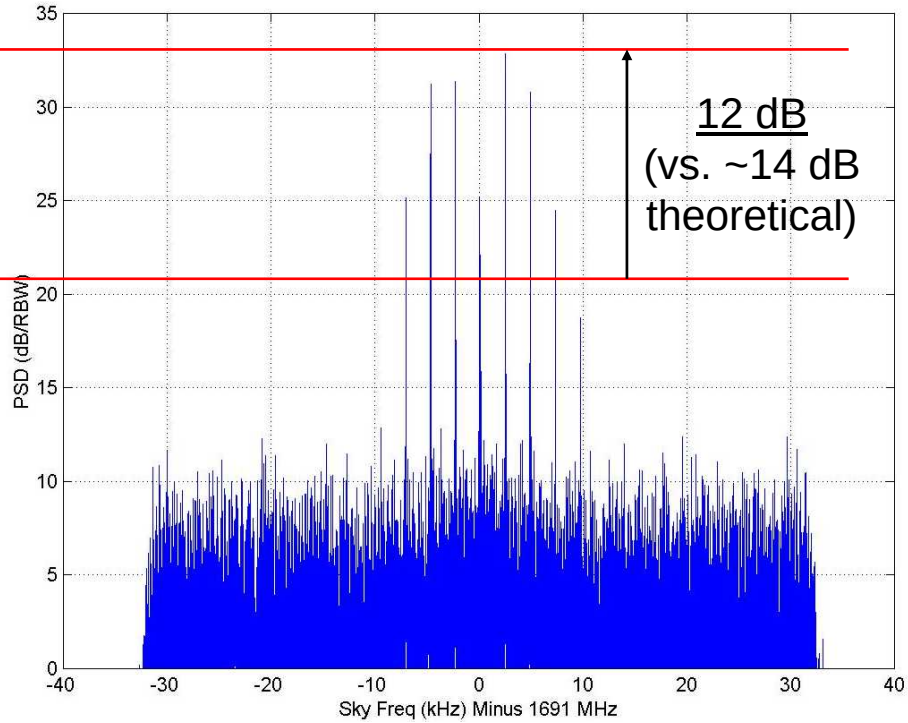
- **Implemented in C on Linux PCs**
- **Each PC recieves the full array output via LAN broadcast**
  - **Unlimited number of processing nodes**
  - **Unlimited number of simultaneous users**
- **Examples of processing software:**
  - **Beamform-FFT to detect tones**
  - **Beamform-Matched Filter to detect pulses**
  - **Tones from subband visibilities**
  - **Pules from full-band visibities**
  - **RFI characterization & mitigation**
  - **Anything you can write in C!**

Adaptive Beamforming Example

- 1691 MHz (WEFAX) emission from geostationary satellite GOES-EAST
- Relatively weak signal (normally requires 1-m dish and good LNA)



Signal from single element



Signal after beamforming with 24 elements, using adaptively estimated weights

Summary & Current Status

- **T_{sys} ~ 215 °K per element**
- **N=64 (Goal System)**
  - **Sensitivity ~ (10^{-20} W m^{-2} Hz^{-1}) (cos θ) ($B\tau$) $^{-1/2}$**
  - **B = 34 kHz instantaneous bandwidth**
  - **Strongest astrophysical sources (~1 kJy) detectable in τ ~ 30 s**
  - **~US$64K ($1K/channel) for complete system**
- **Cost scales linearly with B in this design, up to B=14 MHz**
- **Currently, one N=24 (recently completed) expandable to 32, plus one N=8 (pilot) system**
- **No transients detected, yet...**
- **Thanks: SETI Institute, NAAPO, OSU**