How to Observe with LWA-1

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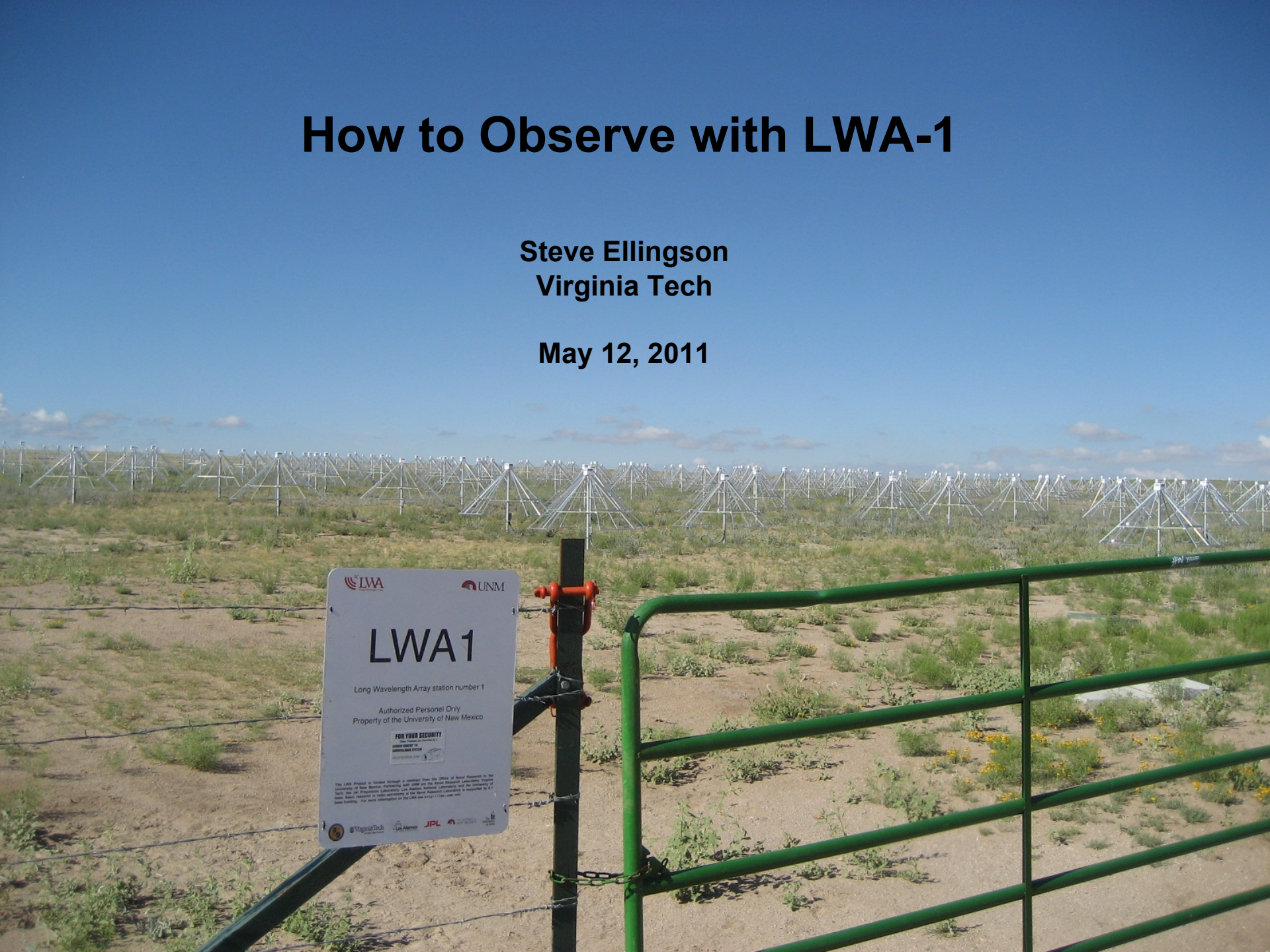
May 12, 2011



LWA-1

- 10-88 MHz usable; Galactic noise-dominated (>4:1) 24-87 MHz
- 4 independent beams x 2 pol. x 2 center frequencies x up to at least 13 MHz
- SEFD ~ 3 kJy (zenith) (~ frequency independent)
  - S_{min} ~ 5 Jy (5σ, 1 s, 13 MHz, zenith)
- "All sky" (all dipoles) modes:
  - "TBN": 67 kHz-bandwidth, continuous for up to 10 (20) hours
  - "TBW": 78 MHz-bandwidth, 61 (12b) or 183 ms (4b) burst, 0.1% duty cycle
- One "outrigger" antenna pair ~300 m to E
- LWA-1 science emphasis: transients, pulsars, Sun, Jupiter, & ionosphere

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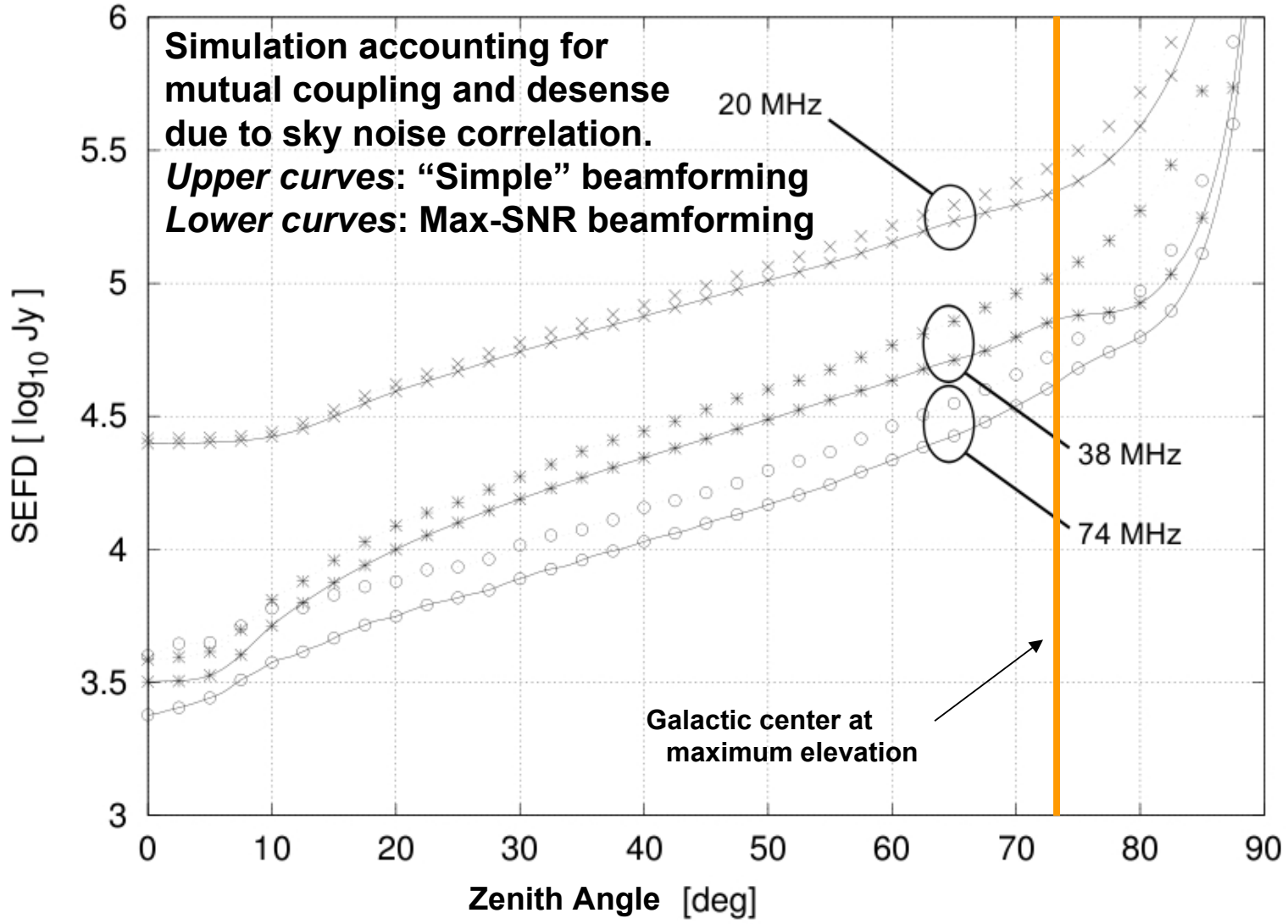
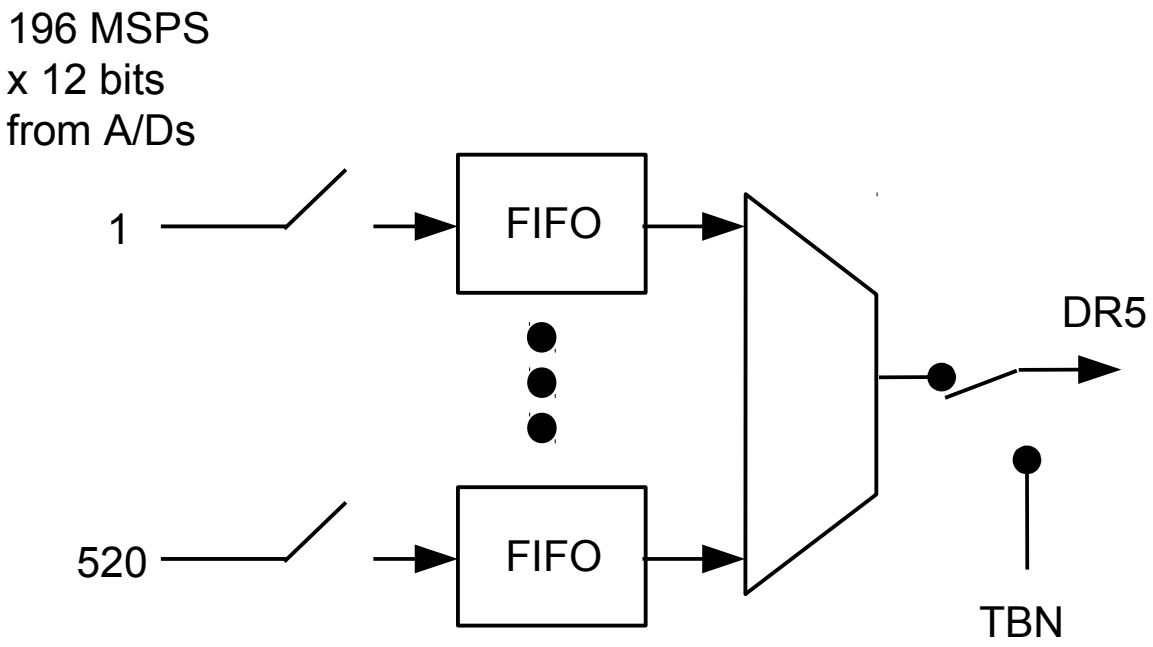
LWA-1 Estimated Beam SEFD



astro-ph/1005.4232 (LWA Memo 166)

TBW ("Transient Buffer Wideband")



Engineering Uses
Diagnostics/Status
Station Level Cal
Panoramic RFI assessment
Impulsive RFI assessment
Directional RFI localization

Science Uses
Long duration "total power" transients
Solar *
Riometry *

* Could also be done with beams, but doing it with TBW frees up beams for other uses.

Per Trigger:
12,000,000 12-bit samples (61.2 ms) → $\Delta\nu$ ~16 Hz
OR
36,000,000 4-bit samples (183.7 ms) → $\Delta\nu$ ~ 5 Hz

~60 s between triggers (~0.1% duty cycle)

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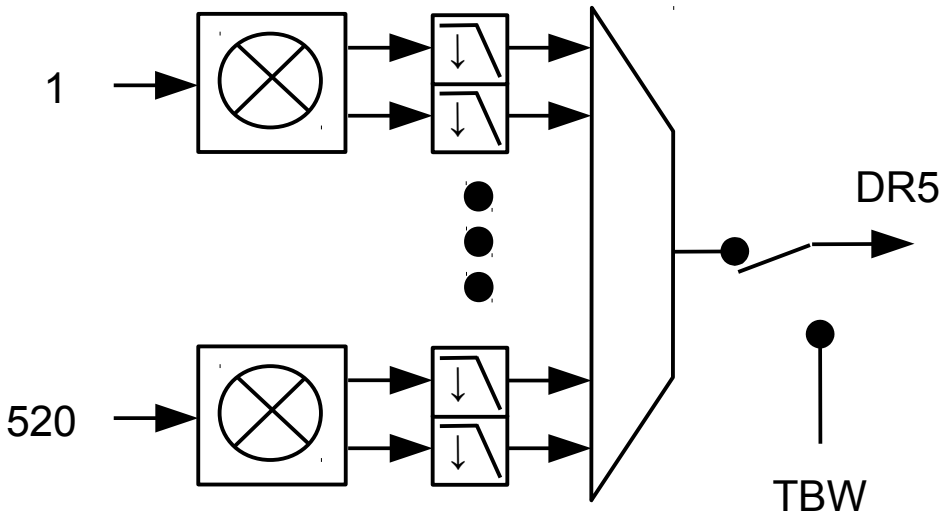
TBN ("Transient Buffer Narrowband")



Engineering Uses
Station-Level Cal
Narrowband RFI assessment
High-sensitivity RFI assessment
Directional RFI Localization

Science Uses
All-sky transient search (PASI)
Radio recombination lines, maybe
(Post-observation customization of beam shape, Positioning of RFI-suppressing nulls, etc.)

Can run continuously (100% duty cycle)
Center frequency selectable in 10-88 MHz
Rate selectable 1 - 100 kSPS (3-dB bandwidth ~ 2/3 rate)
Output samples are 8-bit I + 8-bit Q

This mode sets the data recorder throughput requirement (~113 MB/s for all stands @ max BW)
Can do this up to ~10 hours without gaps; ~20 hours without physical intervention
(these durations double with the new 10TB DRSUs)

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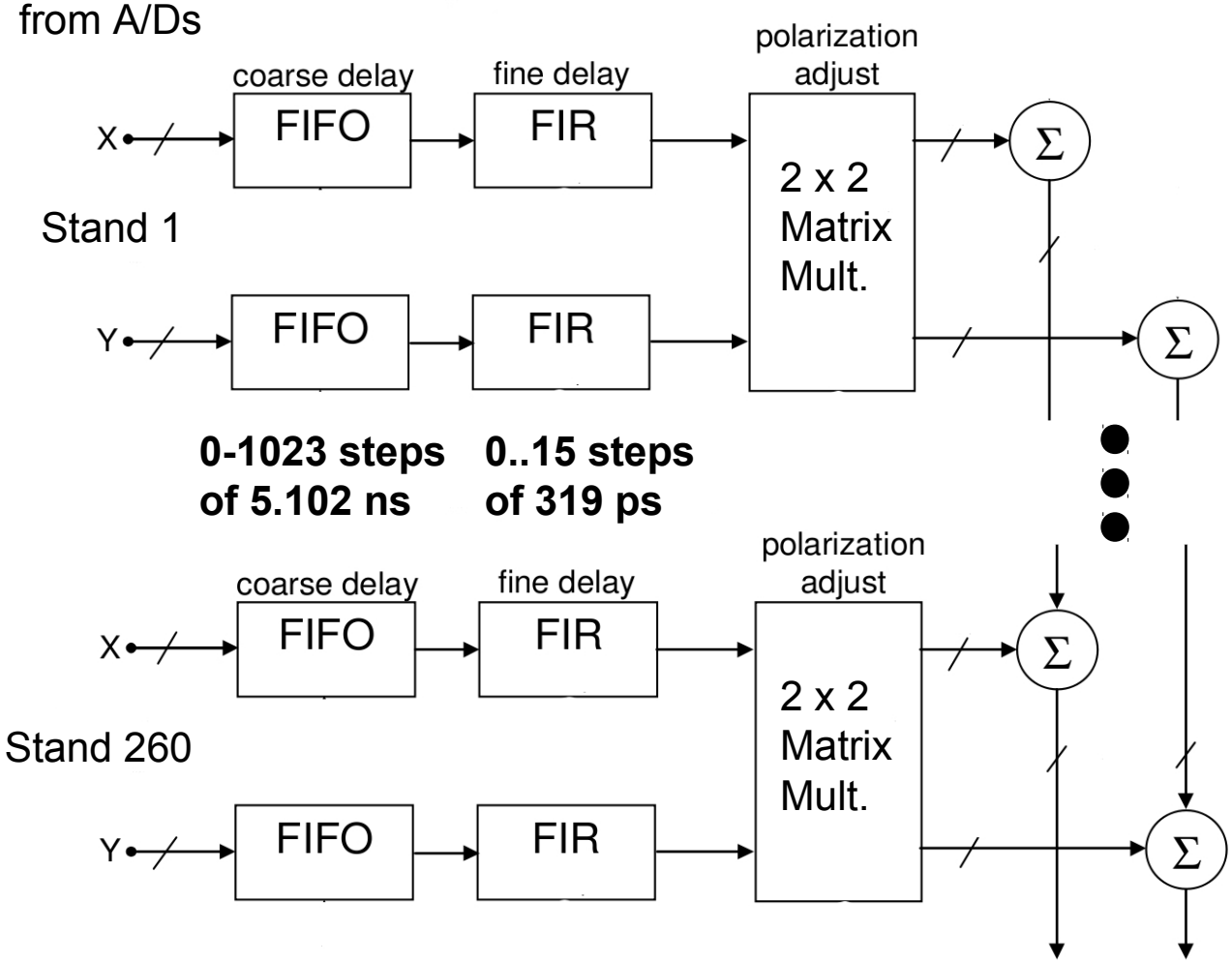
Beamformer

196 MSPS
x 12 bits
from A/Ds



To DRXs 196 MSPS x 12 bits

LWA-1 has 4 of these, each independently-pointable

Course delay, fine delay, and the 4 polarization coeffs can be user-specified if desired
- Cable dedispersion
- Optimized beamforming
- Sector beams, nulls

Polarization adjustment is narrowband. Other uses:
- dipole-to-dipole gain equalization
- "turning off" dipoles
- Trading polarizations for additional beams

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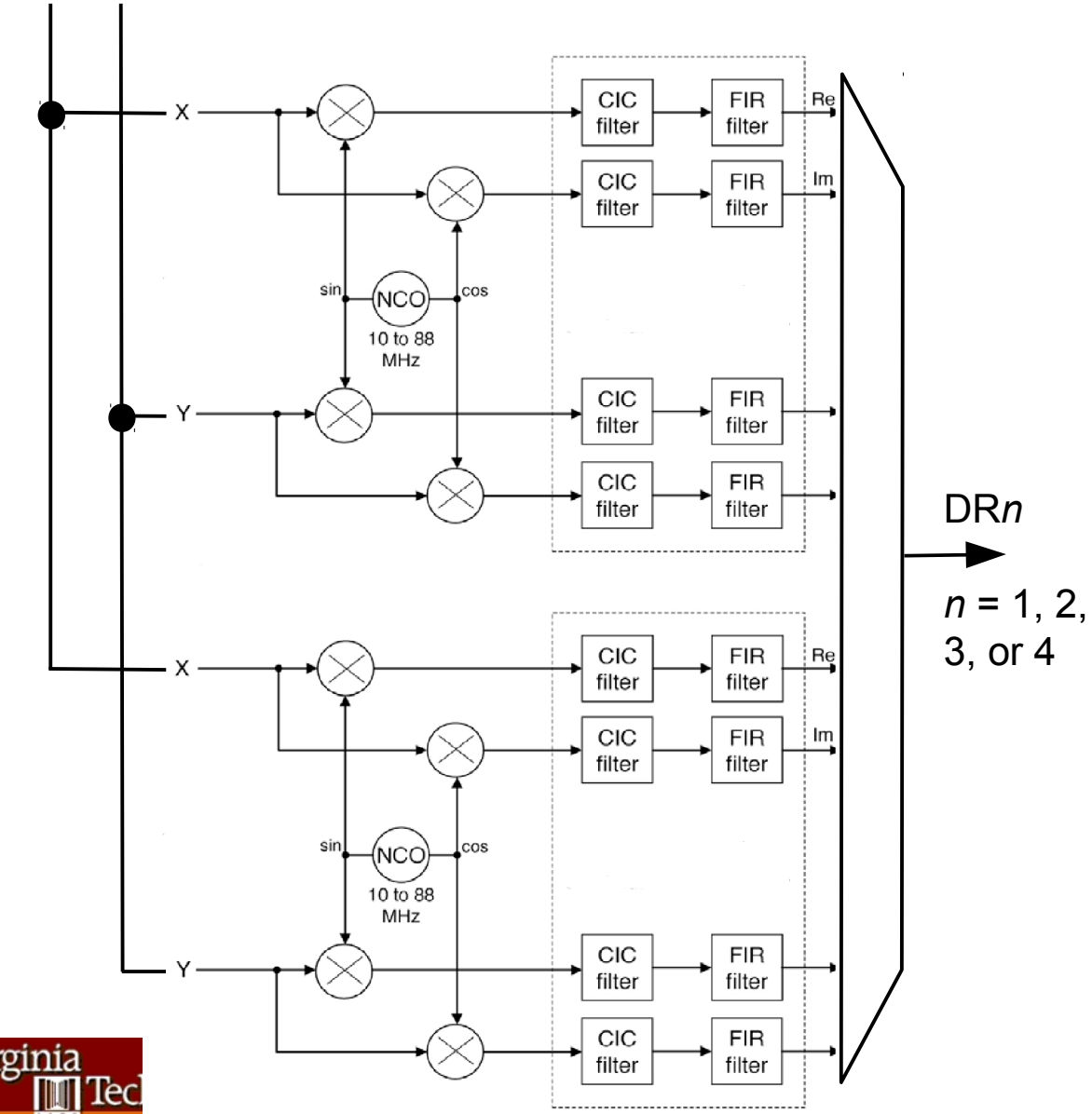
DRX ("Digital Receiver")



Each beam gets two "tunings" (10-88 MHz)

Output samples are I4+Q4

250 kSPS -- 19.6 MSPS;
(Exact ratio of bandwidth to sample rate not yet known; probably between 2/3 and 7/8)

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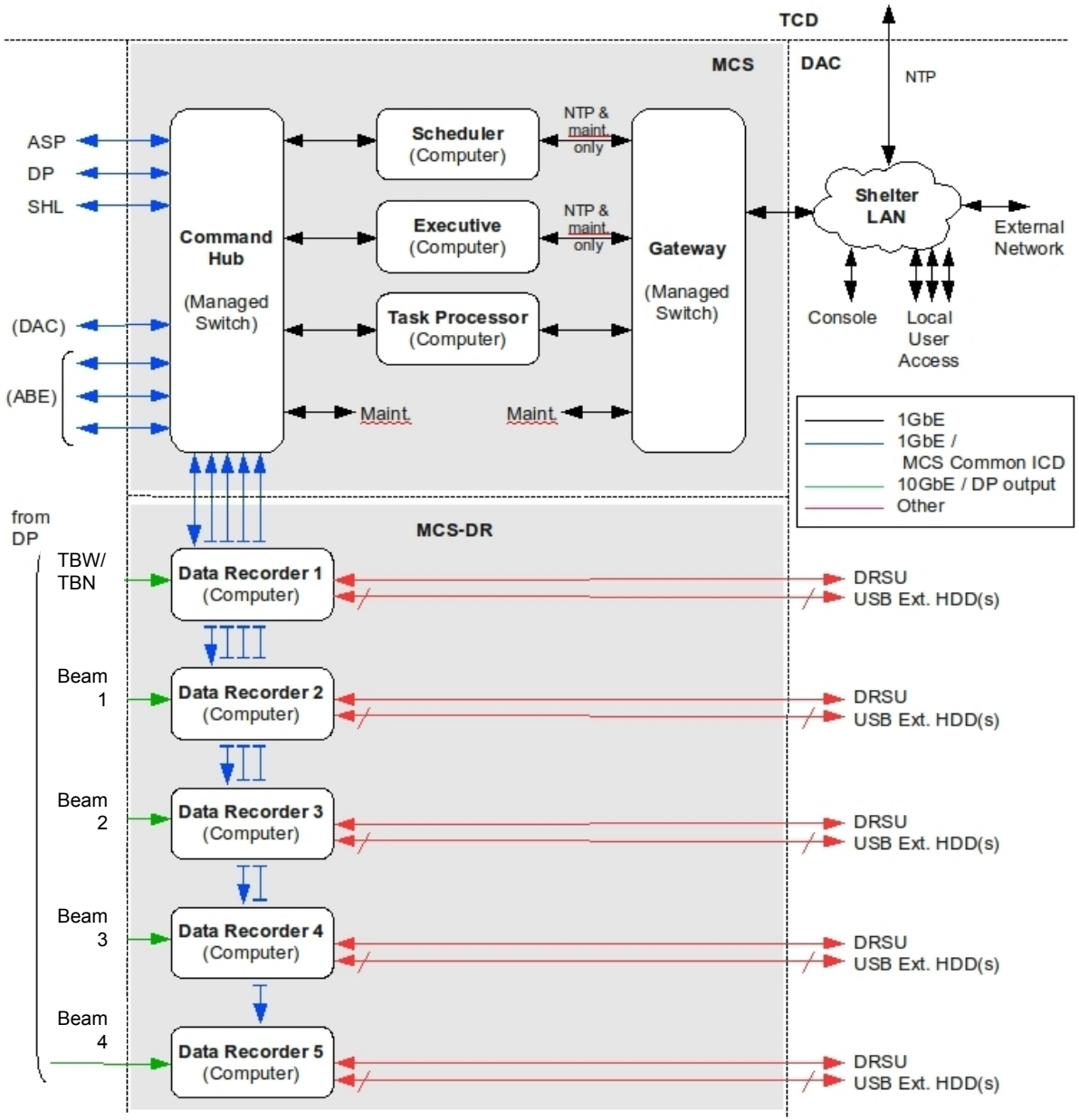
MCS & Data Recorder Architecture



- MCS is 3 PCs:
  - "Scheduler"
  - "Executive"
  - "Task Processor"
- 5 MCS-DRs
  - One per beam
  - One for TBW/TBN
  - Record to DRSUs (5TB, 10TB vers.)
  - 2 DRSU per DR
- Data Exits (see M.177):
  - DRSU
  - Ext USB HDD
  - Internet (slow)

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LWA-1 Observing Terminology

- ***Mode*: A thing you can do with a DP output (i.e., one of the 4 beams, or TBW/TBN)**
  - **TRK_RADEC: Beam tracks specified RA / DEC**
  - **TRK_SOL: Beam follows Sun**
  - **TRK_JOV: Beam follows Jupiter**
  - **STEPPED: Beam repointed/retuned in discrete steps according according to user-provided table**
  - **TBW or TBW**

- ***Observation*: Continuous use of one of the 5 DP outputs with no change in *mode* or station configuration**

- ***Session*: A contiguous set of *observations* using the same DP output**
  - **You might call this an "observing run" – the *observations* include things like multiple sources, off-source calibration observations, etc.**

- ***Project*: A set of *sessions*, not necessarily contiguous & not necessarily using the same DP output**
  - **Purely an administrative distinction; used to associate sessions with PIs and proposals**

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Details: MCS0030

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Session Definition File (SDF) – TBW

- Mininum info required to define observation
- In-file comments
- Req'd by MCS for scheduling and to organize metadata

```
PI_ID           1
PI_NAME         Ellingson, Steven

PROJECT_ID      TPSS0003
PROJECT_TITLE   Project Title
PROJECT_REMPI   Project REMPI
PROJECT_REMPO   Project REMPO

SESSION_ID      1
SESSION_TITLE   tp_session_sch SDF test #3
SESSION_REMPI   Test SDF consisting of 2 TBW observations
SESSION_REMPO   Session REMPO

OBS_ID          1
OBS_TITLE       Observation 1 Title
OBS_TARGET      Observation 1 Target
OBS_REMPI       Observation 1 REMPI
OBS_REMPO       Observation 1 REMPO
OBS_START_MJD   55616
OBS_START_MPM   0
OBS_START       UTC 2011 Feb 24 00:00:00.000
OBS_MODE        TBW

OBS_ID          2
OBS_TITLE       Observation 2 Title
OBS_START_MJD   55616
OBS_START_MPM   70000
OBS_START       UTC 2011 Feb 24 00:01:10.000
OBS_MODE        TBW
```

MPM = milliseconds past midnight (UTC)

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Session Definition File (SDF) – TBN

- Mininum info required to define observation
- In-file comments

```
PI_ID           1
PI_NAME         Ellingson, Steven

PROJECT_ID      TPSS0002
PROJECT_TITLE   Project Title
PROJECT_REMPI   Project REMPI
PROJECT_REMPO   Project REMPO

SESSION_ID      1
SESSION_TITLE   tp_session_sch SDF test #2
SESSION_REMPI   Test SDF consisting of 2 short TBN observations
SESSION_REMPO   Session REMPO

OBS_ID          1
OBS_TITLE       Observation 1 Title
OBS_TARGET      Observation 1 Target
OBS_REMPI       Observation 1 REMPI
OBS_REMPO       Observation 1 REMPO
OBS_START_MJD   55616
OBS_START_MPM   0
OBS_START       UTC 2011 Feb 24 00:00:00.000
OBS_DUR         10000
OBS_DUR+        00:00:10.000
OBS_MODE        TBN
OBS_FREQ1       438261968
OBS_FREQ1+      19.999999955 MHz
OBS_BW          7
OBS_BW+         100 kSPS
```

duration [ms]

Center freq encoded as this x (196 MHz) / 2^{32} [Hz]

Sample rate (thus, bandwidth)

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Session Definition File (SDF) – TRK_RADEC

- Mininum info required to define observation
- In-file comments

```
:
OBS_ID          1
OBS_TITLE       Observation 1 Title
OBS_TARGET      Observation 1 Target
OBS_REMPI       Observation 1 REMPI
OBS_REMPO       Observation 1 REMPO
OBS_START_MJD   55616
OBS_START_MPM   0
OBS_START       UTC 2011 Feb 24 00:00:00.000
OBS_DUR         10000
OBS_DUR+        00:00:10.000
OBS_MODE        TRK_RADEC
OBS_RA          5.6
OBS_DEC         +22.0
OBS_B           SIMPLE
OBS_FREQ1       438261968
OBS_FREQ1+      19.999999955 MHz
OBS_FREQ2       1928352663
OBS_FREQ2+      87.999999977 MHz
OBS_BW          7
OBS_BW+         19.6 MSPS (but not exactly su
```

RA [h]

DEC [deg]

Beam Type
(only SIMPLE is implemented currently)

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Session Output

- DP output goes to DRSU

- All other output is saved in a tar file on MCS (Task Processor)
  - Inprocessing log (.ipl) – Detailed information about how MCS interpreted observation instructions; much "under the hood" info
  - Session command script (.cs) – the precise sequence of actions followed by MCS to perform session
  - Session metadata file (SMF) – Info about success / failure / warnings generated during session; also, index to data files
  - Station Static MIB Initialization File (SSMIF) – Details of station "static" configuration
  - Station Dynamic MIB (sdm.dat) – Details of station "dynamic" status (including availability/status of resources)
  - Subsystems MIBs (if requested)
  - MCS log files (if requested)
  - Design info (if requested)

Some LWA-1 User FAQs

- **What is LWA(-1)?**

  M.157 and/or M.171

- **How do I define an observation (that LWA-1 can understand)?**

  Operators and experienced users: MCS0030, also, `tpss` help message

  Even easier submission process for users: See Dowell talk, this meeting

- **Where does my data go?**
  What media is used?
  Can I reduce it on site?

  M.177

- **How to read / view / analyze my data?**

  Do-it-yourselfers: DP ICD (DP output), MCS0030 (MCS output)

  Ready-to-go software: LSL (See Dowell talk, this meeting)

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Some LWA-1 User FAQs

- **What sensitivity can LWA-1 achieve?**

  A simple answer is not possible; depends on many factors

  See M.166 (astro-ph/1005.4232) for best current estimate of SEFD for a few reference cases (one summary finding shown in earlier slide)

- **What frequencies should I avoid due to RFI?**

  What effect does RFI have on LWA-1 data?

  We have much experience, but this is not currently documented in a usefull way. Ask for help from LWA-1 cadre

- **How is the station currently configured? What's broken/suspect? Same questions, but at time of observation?**

  In all cases: The SSMIF is the ultimate source of information on this.

  SSMIF Format: MCS0031 (includes example)

  SSMIF readers: `tpsdm` (also reads/interprets SDM); also LSL has one

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More LWA-1 User FAQs

- **Models for responses of system components?**

  Antennas: M.178 (patterns), M.170 (array geometry)

  Cables: M.170 (lengths, delays, and losses)

  Analog receivers (ARXs): See LWA Engineering Documents Wiki

  DP: See LWA Engineering Documents Wiki

- **What effect does mutual coupling have on LWA-1 data?**

  Sensitivity: M.166 (a.k.a. astro-ph/1005.4232)

  Beam main lobe pointing/shape: Believed to be negligible (Kerkhoff 2008)

  Beam sidelobes: Unknown. Probably significant.

- **Can I analyze my data using MCS or MCS-DR PCs (i.e., in the shelter)?**

  Limited support for this (see M.177 and Dowell's talk, this meeting)

  Considering schemes to support this better, but not currently a high priority

  Considering schemes to implement real-time / on-the-fly data reduction / analysis / gating (see Wolfe's talk, this meeting)

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Other Things Users Should Know

- TBW and TBN data are not "calibrated"
  - Corrections for antenna gain, cable delay & loss, ARX & DP responses, etc. must be applied post-observation. (This is done on-the-fly for beamforming modes)
  - The necessary information is available via SSMIF, SDM, and observation metadata

- No modes are currently calibrated to remove chromatic dispersion
  - Characterization: Antennas: M.115, 140; cables: M.136. ARX & DP: See Eng. Wiki
  - Antenna responses & cable lengths are unequal; so not safe to assume this can be perfectly corrected after beamforming

- Antennas closest to shelter and perimeter fence may have distorted patterns (M.141, M.129)

- Polarization calibration has not received any attention. Recommend saving raw linear polarizations. Here, many challenges lie ahead (M.140)

- Night is much better than day for RFI

Thanks!

Project Web Site:
http:// lwa.unm.edu

Memo Series:
http://www.phys.unm.edu/~lwa/memos
http://www.ece.vt.edu/swe/lwavt (more memos)

The LWA is on Facebook

MCS Architecture

- **Task Processor:**
  - **Converts "session definition files" (SDFs) into defined sessions that Executive can understand**
  - **Scheduling: Checks for conflicts in time and resources**
  - **Various other goodies for operators**

- **Executive:**
  - **Translates observation parameters (e.g., RA/DEC) into specific technical parameters (e.g., beamforming coefficients)**
  - **Conducts sessions (as defined in an SDF) by controlling Scheduler**
  - **Manages station-level resources & observation metadata**

- **Scheduler:**
  - **Low-level, real-time, direct access to LWA-1 subsystems**
  - **Accessible to subsystem developers and expert users**

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