NRAO Collaborations and Support to NASA

Three categories:

Use of NRAO infrastructure as part of a NASA or NASA-related space science project Supplying ground station as part of space VLBI – VSOP/HALCA Use of NRAO computing capabilities (VLBA correlator) for VSOP Production of advanced receivers, etc Station electronics/observing system/data decoding electronics for VSOP at multiple sites

Spacecraft Tracking and Telemetry from Green Bank P. R. Jewell 19 January 2005

1. Past projects

1.1 VSOP/HALCA.

NRAO Green Bank Operations very successfully participated in an orbiting VLBI project for five years (terminating in early 2002). The station electronics and observing system were designed and built by NRAO staff. The station was originally envisioned for the Russian-led Radioastron project, but was adapted for use by the Japanese-led VSOP/HALCA project (NASA Co-I). The station utilized the 45-Foot (14-m) telescope at Green Bank. A maser time/frequency tone was uplinked to the satellite and VLBI data were downlinked. NRAO built data decoding electronics that were subsequently replicated for use at a Russian station. The NRAO 45 Foot Earth Station had the best success rate for tracking passes for VSOP of any of the earth stations used for this project around the globe (>94% of all possible data recorded successfully). NASA was extremely pleased with the operation of the NRAO station in Green Bank, to the best of our knowledge. NRAO thus established an excellent reputation of efficient, cost-effective contract operations with this project. Our NASA contract managers for this project were James Costrell and Charles Holmes.

The contract with NASA for the Green Bank Earth Station was ~$900k/yr in the latter years of operation. VLBA correlator operations in Socorro for VSOP/HALCA data were handled separately and were described in Jim Ulvestad's text.

1.2 Huygen's Probe

Described by Jim. The GBT made the first signal acquisition of the probe and thus confirmed that it was alive and functioning following entry into the Titan atmosphere. The GBT was used to track the Doppler data from the probe's carrier signal in total power mode as well as participating in the VLBI network. The combination of the VLBI positional data and the Doppler data will give the 3-D trajectory through the atmosphere. As noted by Jim, this will be the only Doppler wind data available.

2. Future Possibilities

2.1 Small-Diameter Earth Stations

The 45 Foot Telescope used for VSOP is presently being used for the Solar Radio Burst Spectrometer project, funded by an NSF grant (PI - Bastian). However, NRAO Green Bank also has a modern 20 meter antenna presently available that could be used for spacecraft tracking or other contract projects. This antenna was built in 1994 for the U.S. Naval Observatory for an earth orientation VLBI operation that terminated a few years ago. The antenna was transferred to the NSF at the conclusion of that contract and is available for NRAO operations or for contracts to be administered by NRAO.

2.2 140 Foot

The 140 Foot (43 Meter) telescope is potentially available for NASA contract operations within a few years. We are presently negotiating an outfitting and operations contract with MIT Lincoln Laboratory for use of the 140 Foot for low earth orbit satellite tracking. The tentative arrangement with Lincoln Lab calls for outfitting and modification to occur during FY05, and operations to follow during FY06 and FY07. The 140 Foot will be substantially modified for this task and will include a new control system and remote monitoring system. Lincoln Lab presently plans to use the 140 Foot for only 20-30 hours per week during the operations phase, so it is conceivable that other operational tasks could be multiplexed during the FY06-07 period, and certainly afterward. Since the Lincoln Lab project will cover the modernization costs, subsequent operations costs will be very reasonable.

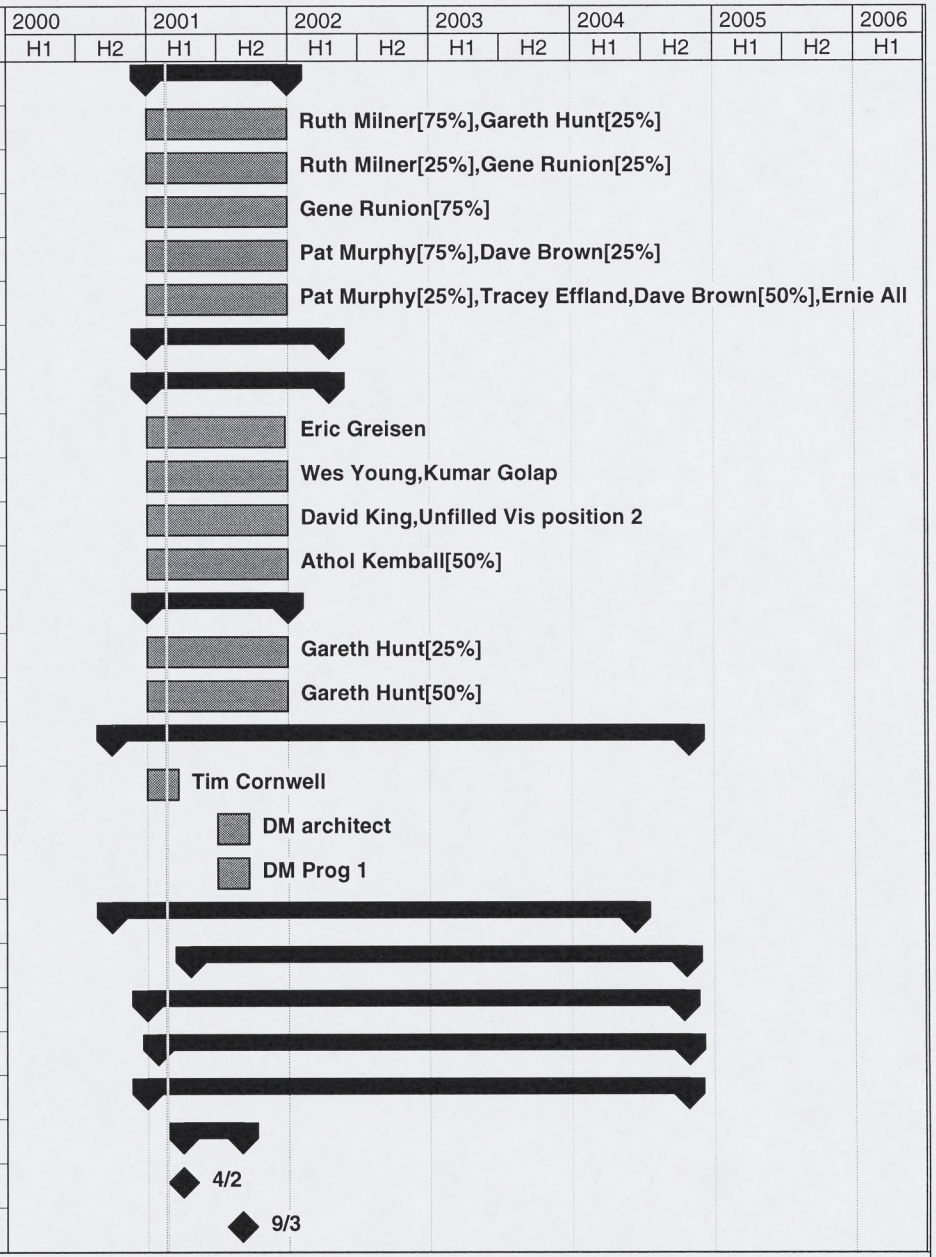
It should be noted that while NRAO-GB did accommodate a low-power uplink for the VSOP/HALCA project, high-power uplinks are generally problematic for RFI reasons. In past discussions with NASA, telemetry downlink only operations were still attractive to them, as the downlink is the most time-intensive operation and command uplinks can be handled elsewhere within the DSN.

NASA has inquired in the past about using the 140 Foot for telemetry downlink, most recently for use with SOHO in the fall of 2003. We declined that offer because the very short timescale required and the associated impact on other operations at the time made the project infeasible for us. Past contact on such project possibilities has been through Barry Geldzahler and Charles Holmes.

2.3 The GBT

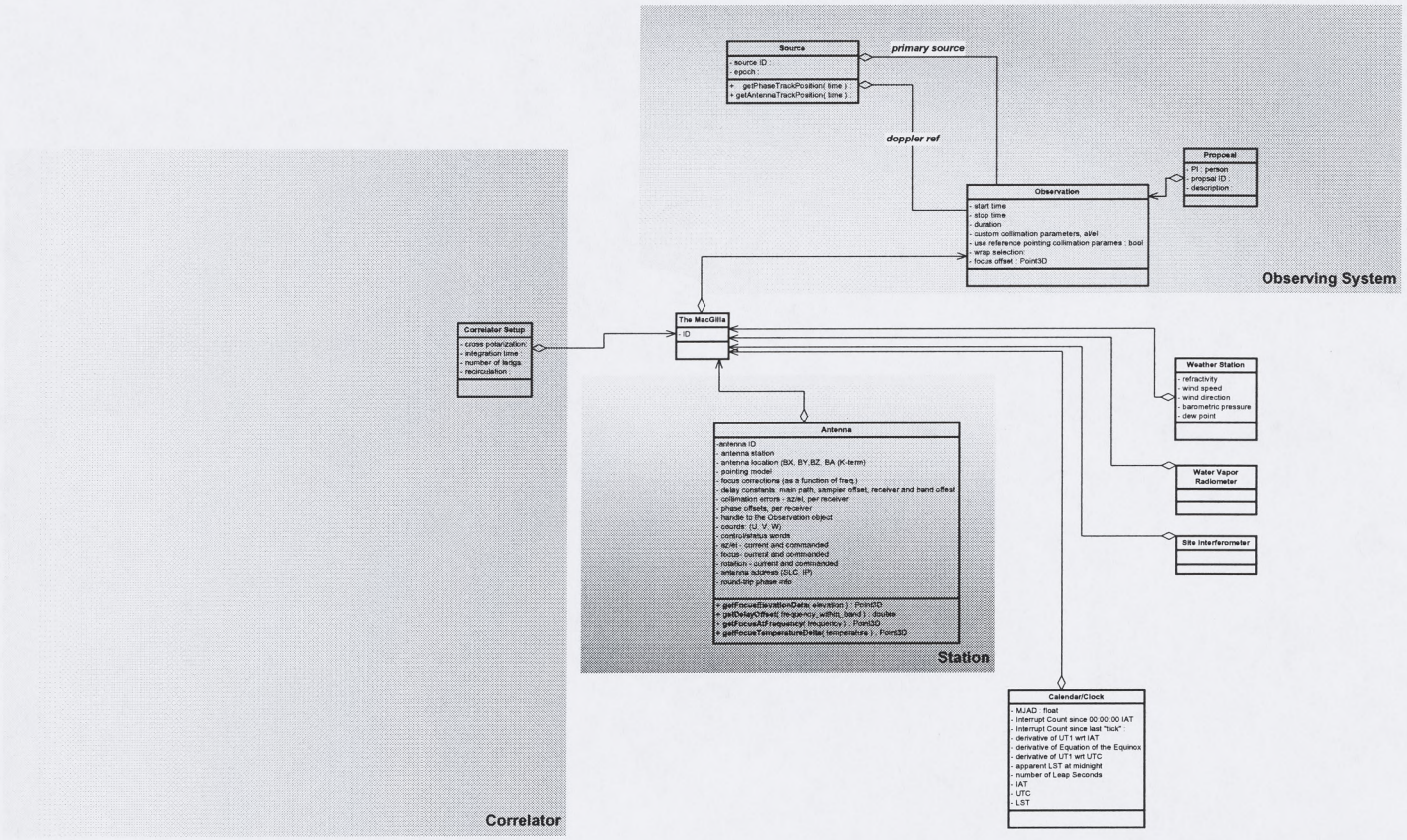
Although we should not offer the GBT for routine spacecraft tracking, the Huygens Probe experiment illustrates the unique capabilities of the GBT for special purpose, high-profile experiments or for tracking in emergency situations such as failure of a craft's high-gain antenna or failure of other DSN ground stations at critical times. The GBT is, of course, one of the highest sensitivity facilities on Earth. Signals from all Green Bank antennas including the GBT, 140 Foot, 20 Meter, 45 Foot, etc., can be brought back to the central Jansky Lab control room via fiber cable. It is a relatively straightforward operation to

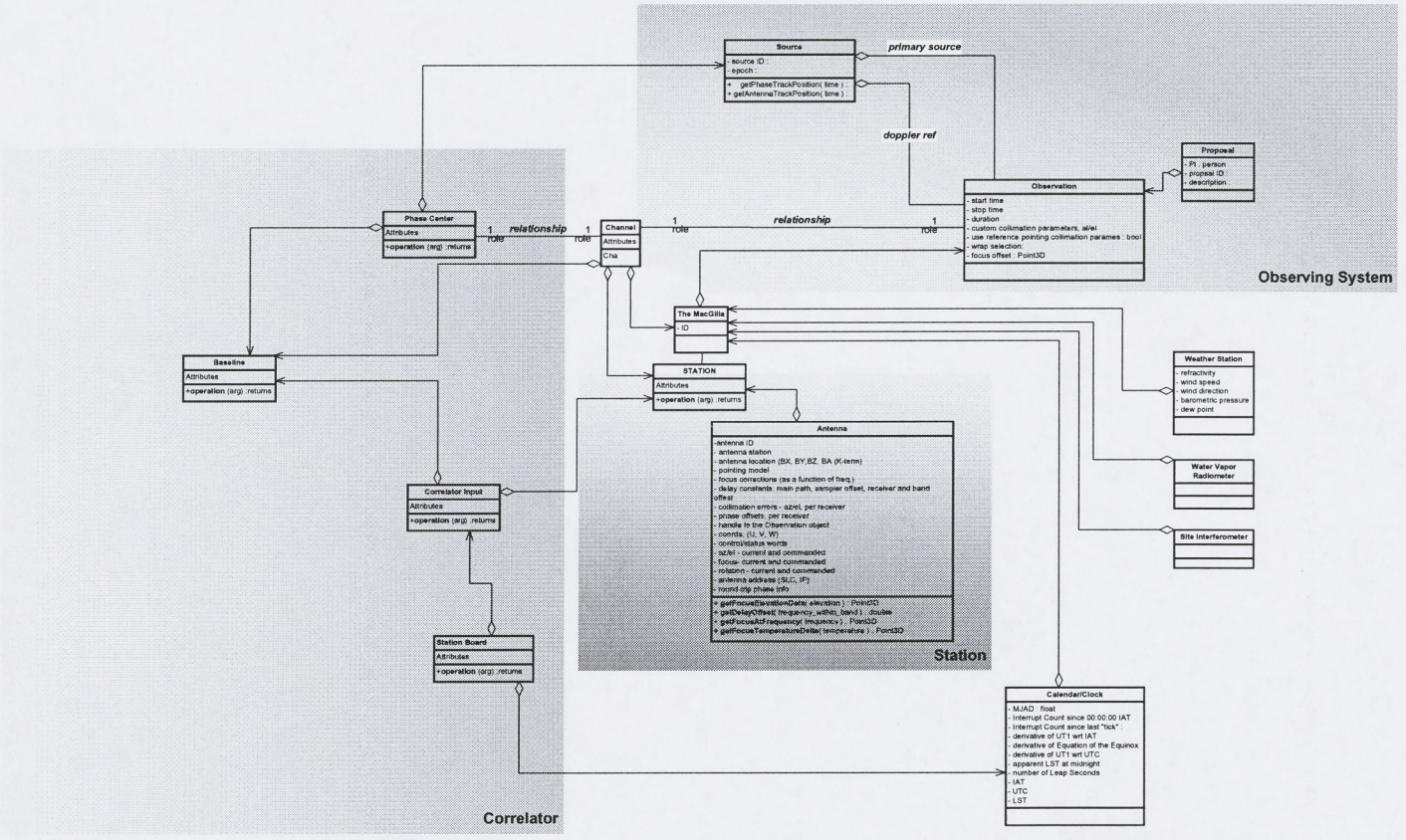
ID	WBS	Task Name
1	**1.7.1**	**Central computing services**
2	1.7.1.1	Observatory wide computing
3	1.7.1.2	Observatory computing security
4	1.7.1.3	Observatory communications
5	1.7.1.4	Observatory information infrastructure
6	1.7.1.5	HQ Computing support
7	**1.7.2**	**Technology development**
8	**1.7.2.1**	**AIPS++**
17	1.7.2.2	AIPS
18	1.7.2.3	III-NCSA
19	1.7.2.4	NSF/CISE Visualization
20	1.7.2.5	Technology infrastructure
21	**1.7.3**	**Telescope computing**
22	1.7.3.1	Coordination and oversight
23	1.7.3.2	VLA Control and Monitor management
24	**1.7.4**	**Data Management Initiative**
25	1.7.4.1	Establish and document processes
26	1.7.4.2	Establish overall architecture
27	1.7.4.3	Data dictionary construction
28	1.7.4.4	Proposal handling
41	1.7.4.5	Pipelines
62	1.7.4.6	Archive
80	1.7.4.7	Scheduling tool
97	1.7.4.8	Dynamic scheduling
113	**1.7.5**	**COBRA proposal**
114	1.7.5.1	Develop and submit full proposal
115	1.7.5.2	COBRA funding starts



Project: dm
Date: Sun 2/18/01

Task
Split
Progress
Milestone
Summary
Project Summary
External Tasks
External Milestone
Deadline


Source
- source ID :
- epoch :
+ getPhaseTrackPosition(time) :
+ getAntennaTrackPosition(time) :
primary source
doppler ref
Proposal
- PI : person
- proposal ID :
- description :
Observation
- start time
- stop time
- duration
- custom collimation parameters, az/el
- use reference pointing collimation parames : bool
- wrap selection
- focus offset : Point3D
Observing System
Correlator Setup
- cross polarization:
- integration time :
- number of lags
- recirculation :
The MacGilla
- ID
Weather Station
- refractivity
- wind speed
- wind direction
- barometric pressure
- dew point
Water Vapor Radiometer
Site Interferometer
Antenna
-antenna ID
- antenna station
- antenna location (BX, BY,BZ, BA (K-term)
- pointing model
- focus corrections (as a function of freq.)
- delay constants: main path, sampler offset, receiver and band offset
- collimation errors - az/el, per receiver
- phase offsets, per receiver
- handle to the Observation object
- cosines: (U, V, W)
- control/status words
- az/el - current and commanded
- focus - current and commanded
- rotation - current and commanded
- antenna address (DLC, IP)
- round-trip phase info
+ getFocusElevationDelta(elevation) : Point3D
+ getDelayOffset(frequency, within_band) : double
+ getFocusAtFrequency(frequency) : Point3D
+ getFocusTemperatureDelta(temperature) : Point3D
Station
Calendar/Clock
- MJAD : float
- Interrupt Count since 00:00:00 IAT
- Interrupt Count since last "tick" :
- derivative of UT1 wrt IAT
- derivative of Equation of the Equinox
- derivative of UT1 wrt UTC
- apparent LST at midnight
- number of Leap Seconds
- IAT
- UTC
- LST
Correlator


Source
- source ID :
- epoch :
+ getPhaseTrackPosition(time) :
+ getAntennaTrackPosition(time) :
primary source
doppler ref
Proposal
- PI : person
- proposal ID :
- description :
Observation
- start time
- stop time
- duration
- custom collimation parameters, az/el
- use reference pointing collimation parames : bool
- wrap selection:
- focus offset : Point3D
Observing System
Phase Center
Attributes
+operation (arg) :returns
1 role
relationship
1 role
Channel
Attributes
Cha
1 role
relationship
1 role
The MacGilla
- ID
Baseline
Attributes
+operation (arg) :returns
STATION
Attributes
+operation (arg) :returns
Weather Station
- refractivity
- wind speed
- wind direction
- barometric pressure
- dew point
Water Vapor Radiometer
Site Interferometer
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- antenna station
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Station
Correlator Input
Attributes
+operation (arg) :returns
Station Board
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+operation (arg) :returns
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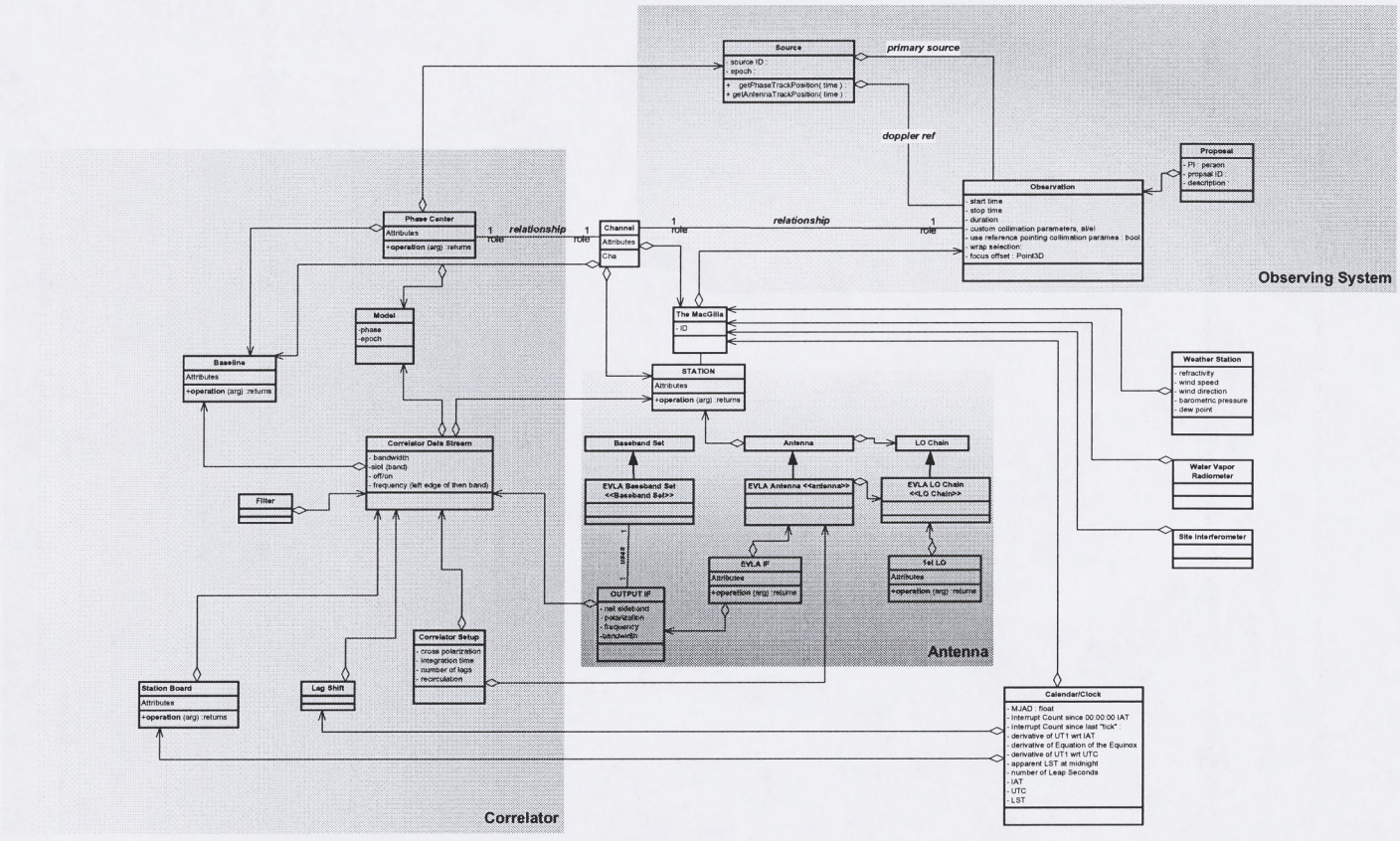
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Attributes
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Model
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-epoch
Baseline
Attributes
+operation (arg) :returns
The MacGilla
- ID
STATION
Attributes
+operation (arg) :returns
Weather Station
- refractivity
- wind speed
- wind direction
- barometric pressure
- dew point
Water Vapor Radiometer
Site Interferometer
Correlator Data Stream
- bandwidth
- slot (band)
- offset
- freq:ency (left edge of then band)
Filter
Baseband Set
Antenna
LO Chain
EVLA Baseband Set <<Baseband Set>>
EVLA Antenna <<antennna>>
EVLA LO Chain <<LO Chain>>
gets
EVLA IF
Attributes
+operation (arg) :returns
1st LO
Attributes
+operation (arg) :returns
OUTPUT IF
- net sideband
- polarization
- frequency
- bandwidth
Antenna
Correlator Setup
- cross polarization
- integration time
- number of lags
- recirculation
Station Board
Attributes
+operation (arg) :returns
Lag Shift
Calendar/Clock
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Correlator