MLLN Note #8

43m Bi-static Radar Station Design Overview

Glen Langston, John Ford, Roger Norrod, Tim Weadon

NRAO Green Bank

May 12, 2005

ABSTRACT

The NRAO 43 Meter telescope is the receiving station for bi-static radar experiments for study of the ionosphere. The MIT-Lincoln Labs-NRAO project requires a reliable, flexible computer system for controlling the 43m antenna.

This MLLN note describes the Radio Frequency Electronics path and the computers used to configure the system for pointing tests and bi-static tracking observations.

Change Record

Revision	Date	Author	Sections/Pages Affected
	Remarks		
1.0	2005-May-06	G. Langston	All
	Initial version.		
1.1	2005-May-12	G. Langston	All
	Add S/X and normal configuration figures.		

1. Background

The ionospheric study group at MIT-Lincoln Laboratories (MIT-LL) has successfully conducted tracking and bi-static radar observations of Low Earth Orbit satellites using the Green Bank Telescope (GBT). In order to allow more regular access to a large aperture receiving station, they wish to outfit the NRAO 43 Meter telescope for bi-static radar observations for approximately 20 hours per week for a period of 1-5 years.

The following document describes the basic requirements of the MIT-LL project, the tasks required to restore the 43 Meter telescope to operational status, requirements to equip it for the mission.

The mechanical condition of the 43 Meter, including the hydraulic systems, appears sound. The System Development and Implementation phase requires mechanical reinstatement of the telescope, conversion of the antenna control system to meet MIT-LL needs, and installation of automated sensing equipment that will allow efficient and economical remote operation from the Green Bank Jansky Laboratory. The development will be highly leveraged through the use of existing hardware and software designs, including the GBT-based 85-1 polar mount control system, the servo package designed for the 45 Foot antenna, and the VLA encoder package. The Operations Phase will provide for approximately 20 hours of observations and data collecting per week, operational maintenance and supervision by NRAO staff, and efficient protocols for system configuration and observational control.

2. Technical Requirements

2.1. Tracking

The demands on the antenna for satellite tracking are different for LEO and GEO. GEO satellites move very slowly and can easily be tracked by the 43-m antenna at modest drive rates. LEO satellites move across the sky quickly – as fast as 2/sec for satellites passing directly overhead. The maximum tracking rates in both hour angle and declination for the 43 Meter are presently 0.33/sec (20/minute). This is comparable to the GBT tracking rates for which a successful demonstration observation has been conducted. MIT-LL has indicated that this tracking rate is adequate for LEO satellites that are relatively low on the horizon. MIT-LL has noted that faster rates would give more flexibility and has requested that NRAO investigate the possibility of faster tracking as part of the control system outfitting.

2.2. Antenna Feeds

MIT-LL will develop the particular feeds for their receiving frequency coverage. It is anticipated that MIT-LL will develop at least two feeds that will be mounted on their receiver box. The box will be mounted at the 43 Meter prime focus and will be compatible with the existing 43 Meter prime focus mounting structure. In the normal course of operations NRAO has the requirement to be able to swap out the feeds per a reasonable and pre-arranged data collection schedule. The antenna will have to be brought down to the horizon and the feed service-tower moved over so that the feed-box swap can be accomplished. This will likely take 2 hours each time a feed is interchanged. NRAO expects that this will be arranged for normal weekday business hours and can be coordinated with other weekly maintenance requirements on the site. Feed / receiver box mounts and lifting points must be reviewed with NRAO as part of the interface specifications.

2.3. Signal receiving system and data recording

MIT-LL will provide all receiving and data recording systems as part of its work package.

Normal satellite tracking and bi-static signal data collection activities are envisioned to be conducted with as little human interaction as possible. MIT-LL plans to transmit a daily schedule of tracking activities in enough detail to configure both the antenna drive and control system as well as the receiving and data collection system so that an operator is not required to directly interact with the 43-m during daily operations. This requires NRAO to provide information to MIT-LL on the antenna control system and to facilitate the reception and implementation of the detailed software scheduling information. NRAO will have an "Operations computer" in the Jansky laboratory to operate the 43-m antenna and will parse and display all the appropriate data from the MIT-LL-provided schedule for operations. Further, NRAO will provide local timing signals and antenna status information (e.g. antenna pointing and rates) electronically to MIT-LL for recording.

3. Operations and scheduling

MIT-LL's preliminary request is for the 43 Meter telescope to provide data acquisition for about 20 hours per week, starting approximately October 2005. The 43 Meter may be operated from the control room in the pedestal of the 43 Meter during implementation testing and early operations phases. Once the new antenna controls are verified, it can be remotely monitored and operated from the NRAO Green Bank Joint Operations Facility in the Jansky Lab, or possibly from the MIT-LL facilities. The 43 Meter station will require continuous operator / technician presence during operations until all remote monitoring equipment is fully operational.

The project will be run as efficiently as possible through re-use of existing designs and equipment, to minimize impact on GBT operations and development and to ensure that MIT-LL has a system that meets its operational needs.

3.1. System Development and Implementation

This phase involves the specific developments that MIT-LL requires to undertake the project, and the facility modifications necessary to achieve reliable and economic operation of the 43 Meter in this application. This work may be performed by the NRAO staff, or sub-contracted to an external firm, according to which approach is deemed most efficient.

3.2. Telescope Control Software

In order to meet the MIT antenna tracking requirements, a new control system is required. To provide remote operations, this development must be done in a manner that allows the NRAO Telescope Operations Division to operate the facility with minimal operator interaction and minimal new training, i.e., the system should be consistent with other facilities on site. To allow quick implementation of the system, existing control packages that are maintainable and extensible may be adopted.

NRAO intends to replace the current 43 Meter control system with a system based on the 85 Foot system developed in ∼2002. A clone of the new servo controller recently developed for the 45 Foot antenna will be used to close the velocity and position loops on the 43 Meter. Parts of the GBT Monitor and Control (M&C) system, Very Long Baseline Array (VLBA), and Orbiting Very Long Baseline Interferometer (OVLBI) software will be used when convenient for development. Any appropriate language may be used, e.g. Glish, Python, C, C++, Assembly, etc.

Off-line scheduling software, pointing analysis software, and orbit prediction handling software for the 43 meter system will be adapted from existing software used for the 85 Foot and GBT control systems.

3.3. Antenna control system implementation plan

The plan for implementing both the hardware and software on the 43 Meter control system is as follows:

Encoder: Replace the encoder electronics with a new system based on the VLA encoder electronics.

ACU: Adapt the 45 Foot Antenna Control Unit (ACU) to the 43 Meter hardware, integrating it with the 85 Foot upper-level control software and the software control screen.

Scheduler: Complete and install the new antenna manager and servo controller.

4. Computer systems

A new computer system will be required on the telescope to meet tracking and remote operations requirements of performance parameters of the MIT-LL specifications. There will up to three computers in the 43m control room, a Station Computer (Linux), an Antenna Control Unix (Linux), and a computer dedicated to monitoring the 43m hydraulics and environmental parameters.

4.0.1. Station Computer

The station computer will sequence the hardware configuration for tracking observations. The station computer will be used to convert log term schedules to station commands and these station commands will be initiated by the station computer.

The station computer will communicate only desired antenna positions (current hour angle and declination) to the ACU, after application of the 43m pointing model. The station computer will monitor the current antenna status based on the results of queries to the ACU. (Ie the station computer will have no direct link to the 43m antenna.) The station computer will require the ACU to be operational, in order for proper execution of a tracking observation.

The Operations computer will record MCB total power measurements from the detector systems.

The Station Computer will have an connection to the Sensaphone to allow call-out for hardware/software anomalies.

4.0.2. Antenna Control Unit

A control system based on the GBT M&C system will be utilized for high-level antenna control unit (ACU). NRAO will replace the H316 with the ACU system. The ACU will provide "manual" operation of the 43m, will monitor and log the 43m position readouts, close the 43m servo position, rate and acceleration loops and implement an "RPC" interface to the station computer.

The ACU will not require the Station computer for manual control of the 43m.

4.1. Operations computer

The operations computer (Ops) will be located in the Joint Operations Center. Ops will have a two-monitor Linux computer system, and will be provided for monitoring the 43m status and occasional problem diagnosis. This machine will be of the same capabilities of the current GBT operator's console computer. There will be no special computer hardware requirements.

The Operations Computer will not have an connection to the Sensaphone.

4.1.1. Encoder Readout Units

The antenna control electronics upgrades are minimal. NRAO will replace the encoder electronics with a VLA encoder electronics box. A new power amplifier will be used for the hydraulic servos.

4.2. RF/IF and Data Acquisition Subsystems

4.2.1. RF/IF hardware systems

Electronic components for the conversion are minimal. We propose the following:

4.3. RF subsystem

NRAO will provide a suitable 43 m low noise amplifier (LNA) front-end system for pointing checks and initial tests, if necessary. The estimated cost to refurbish and install this system will be about $7,000. For the production operational system required for Phase II, MIT-LL will provide an LNA system compatible with their feed designs. These amplifiers will be housed in a temperature controlled box compatible with the existing 43 Meter prime focus mounting structure.

4.3.1. Cables

Cable replacement will occur for front-end signals and for temperature control power and thermistor operations at the front end. Fiber optics to the prime focus will be provided.

4.3.2. Timing Signals

Spare fiber optic modules will be provided for redundancy to the GBT timing center systems.

4.4. RF transmission system

The RF signals from the receiver will be piped to the Jansky Lab via a fiber optic transmission system. Fibers are already in place at the 43 Meter that can be spliced in and used to carry the signals. A pair of RF modems will be purchased, along with one spare.

4.5. Continuum detector (DAR)

The 43 Meter antenna will require a detector system for collecting pointing data. NRAO will utilize the detector system used by the NRAO 20m VLBI antenna for the MLLN project. The 20m optical receiving modules will be left in their current position in the JOC tape room. The 20m LNA/feed will be refurbished but be otherwise un-modified for this project. When the MLL front end arrives and is installed on the antenna a down-conversion and fiber optic transmission unit will be used to transmit the RF signals to the JOC for detection using the 20m system. The NRAO will update an existing data reduction system to reduce the pointing data.

4.6. Test Equipment.

Various pieces of test equipment (spectrum analyzers, etc.) will be required at the 43 Meter to allow installation and diagnosis of RF and digital hardware. One spectrum analyzer will be located near the Operations console in the JOC for use in monitoring proper station operations.

5. System Development for full operational status

The tasks described in this section will provide for efficient and reliable operation and will include all the specific developments, implementations and integration needed for the MIT-LL project.

5.0.1. 43 Meter infrastructure inspection and outfitting

NRAO will provide a complete inspection of the following systems and replace or install those systems that will increase the operational stability and reliability of the project.

Brake springs - in-kind replacement brake springs is budgeted. Another option is to redesign the brake mechanism to eliminate the breaking of the springs which may lower operational costs in the long run. We will examine which of these is the most cost effective. Structural inspection of critical members by qualified inspectors. Security System due to remote operation.

5.1. Remote operations requirements

The 43-m telescope will be remotely operable from the Jansky Lab control rooms, utilizing NRAO's expertise in this mode of operation with the 45 Foot, the 20 Meter, the Green Bank Interferometer, and the 85-3 Pulsar monitoring program. In order to implement remote operations, the telescope will be outfitted with sensors of various types.

5.1.1. Hydraulic pressure sensors

One of the primary differences between the 43 Meter and the other telescopes is the extensive use of hydraulics for driving the main axes, the hydrostatic bearing circuits, brakes, etc. It is essential in any remotely operated system that the hydraulic pressures are available for the operator and the computer systems to monitor. Ten pressure sensors will be provided.

5.1.2. Hydraulic oil-level sensors

Three oil-level sensors will be provided for determination of possible system leaks.

5.1.3. Oil temperature sensors

Five oil temperature sensors will be provided to measure the temperature of the oil in the hydraulic circuits from the operator's remote control station, as well as from within the computer control system.

5.1.4. Air temperature sensors

Air temperature sensors throughout the building will be used to ensure that the environmental controls are operating. The current fire detection and suppression system will be left as is. Five air temperature sensors will be provided.

5.1.5. Fault circuit monitoring

Fault detection circuits exist in the telescope. These systems will be incorporated into the remote monitoring system. Each of these faults will be independently brought into the system, and will be available to the operator and the computer. Thirty-two digital bits will be provided for this monitoring capability.

6. Conclusions

An implementation plan for the MLLN bi-static radar system is presented in this document.

REFERENCES

This and all other MLLN notes are available on the web at:

`http://wiki.gb.nrao.edu/bin/view/Projects/MLLNProjectNotes`

Glen Langston, Larry D'Addario, 1993, NRAO. The OVLBI Memo Number 44. "Global Schedule File Design Document".

`http://www.gb.nrao.edu/ovlbi/memos/es44_globalSched.pdf`

Glen Langston, Mike Shields, John Stueve, 2005, NRAO. MLLN Note 2. “MLLN Interface file formats”

`http://wiki.gb.nrao.edu/pub/Projects/MLLNProjectNotes/mllnNote002.pdf`

Glen Langston, Mike Shields, John Stueve, 2005, NRAO. MLLN Note 3. “Long Term Sequence of Events and Local Hour Angle Declination Files”

`http://wiki.gb.nrao.edu/pub/Projects/MLLNProjectNotes/mllnNote003.pdf`

Glen Langston, Mike Shields, John Stueve, 2005, NRAO. MLLN Note 5. “Tracking Log File”

`http://wiki.gb.nrao.edu/pub/Projects/MLLNProjectNotes/mllnNote005.pdf`

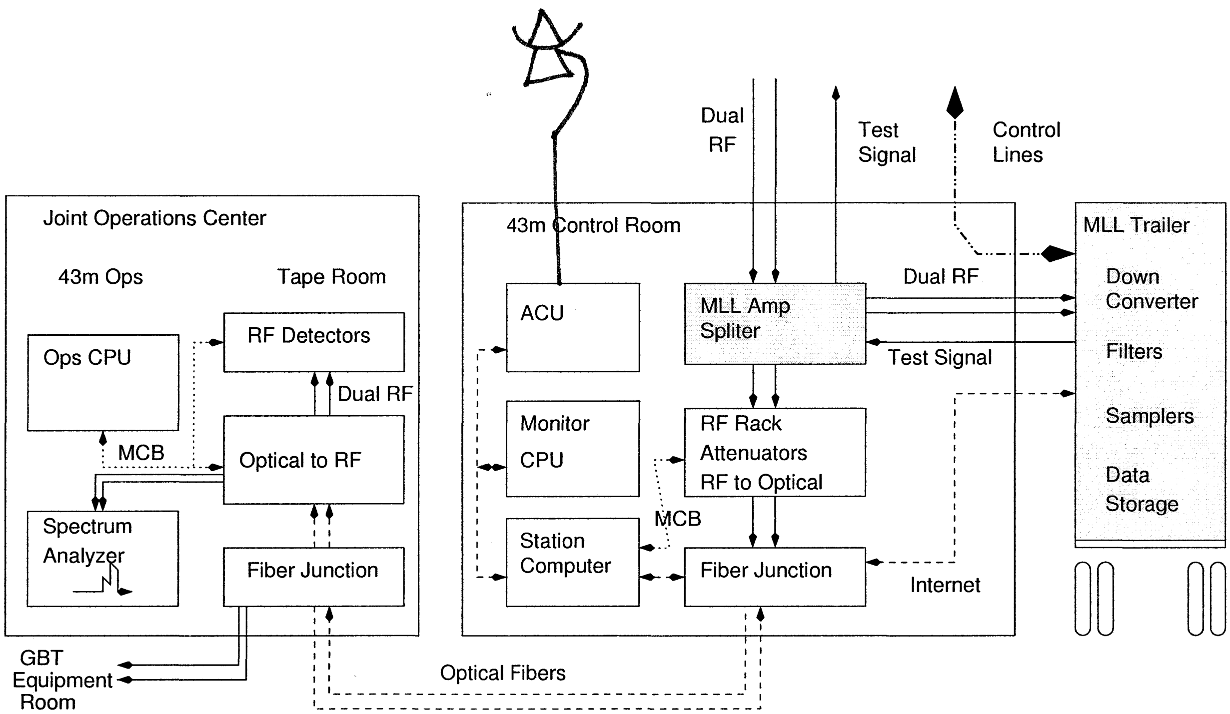

Fig. 1.— Station design overview, showing the connections between the Joint operations center, 43m control room and MIT-Lincoln Labs equipment trailer. This diagram shows the station configuration overview

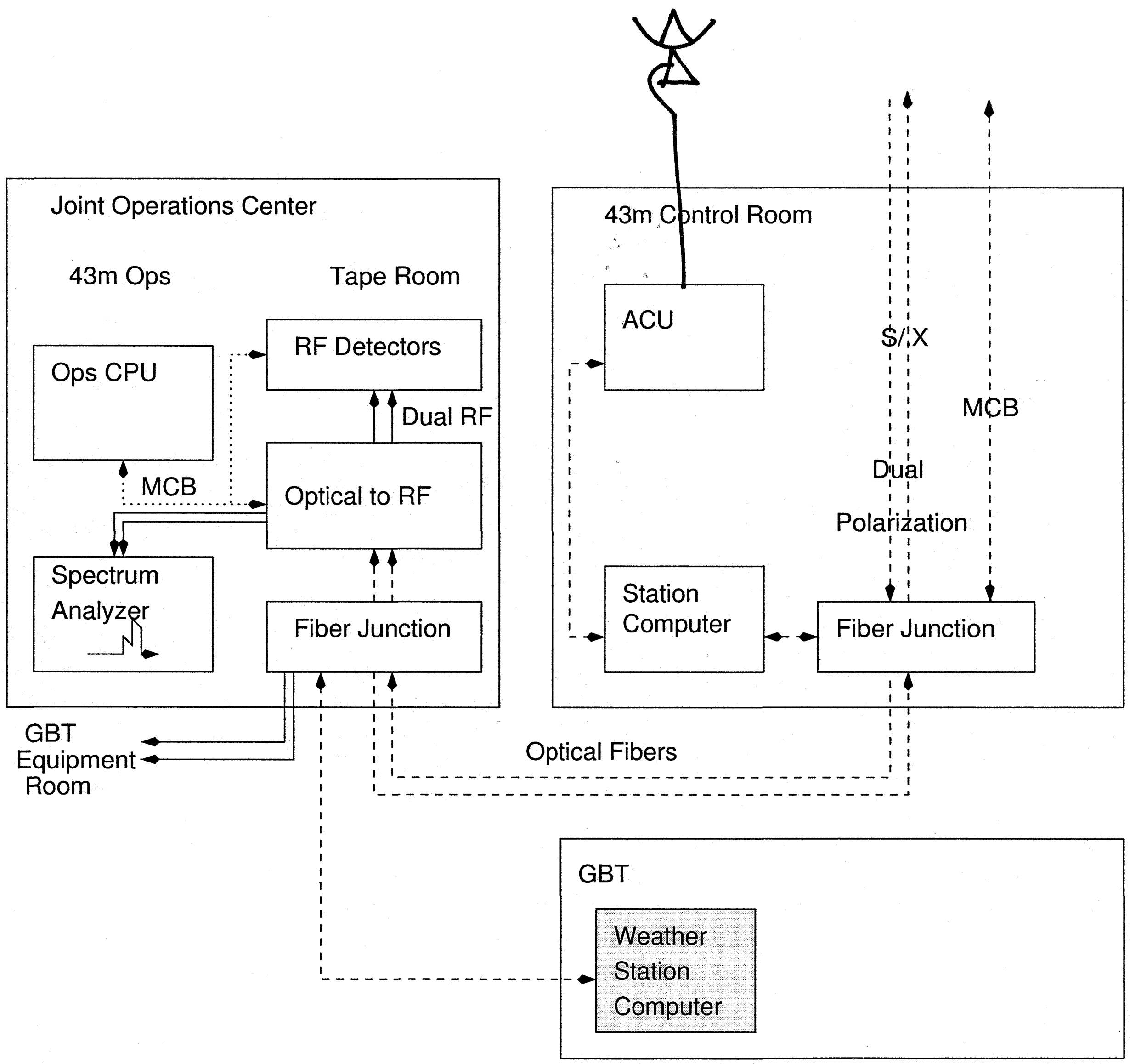

Fig. 2.— Station configuration for pointing test observations.

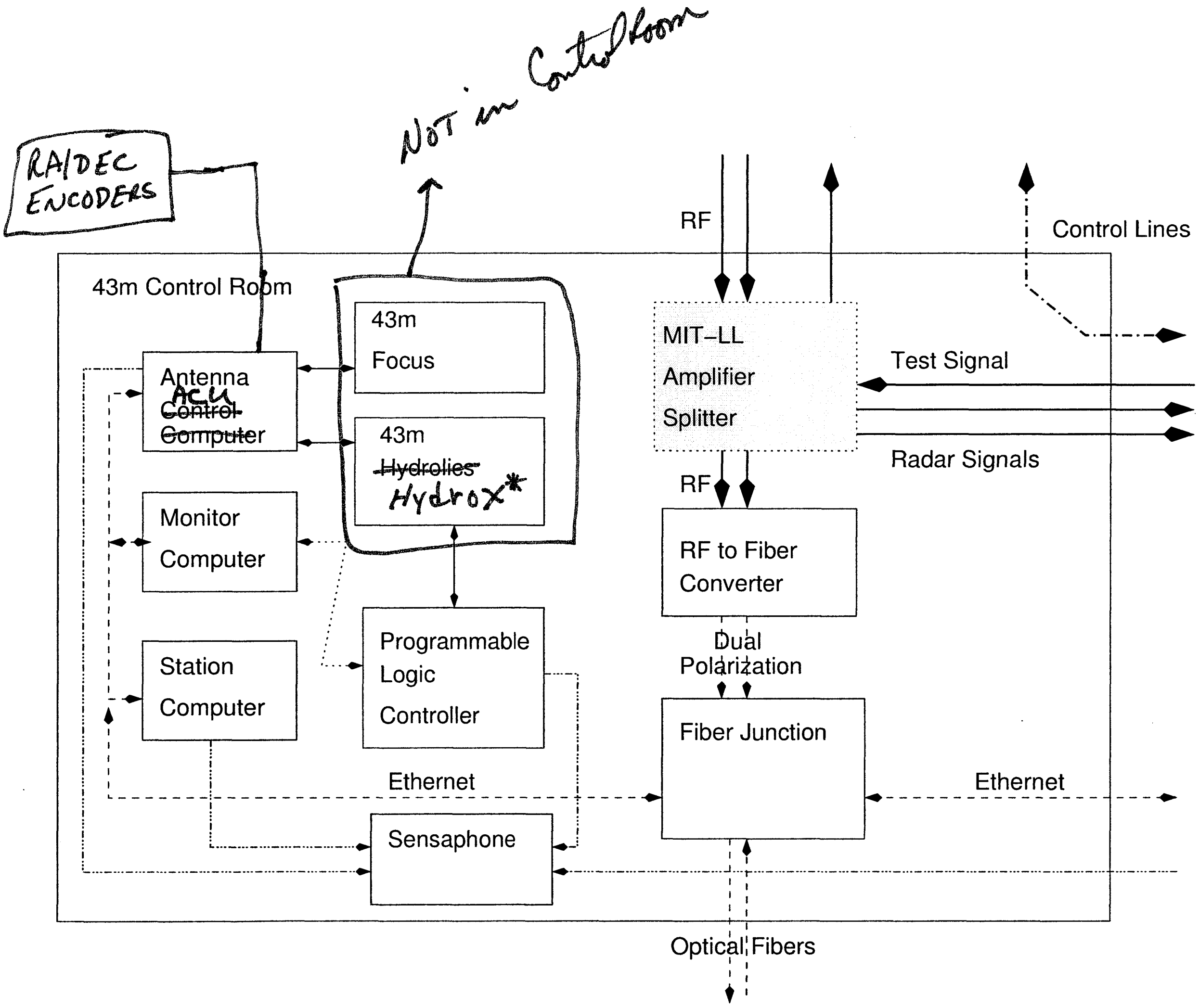

Fig. 3.— Control Room configuration for normal operations.

* The ACU Needs Cookies to properly function.