12-meter Control System Definition

CONTENTS

1 HARDWARE INTERFACE

The control system must control and/or monitor the following hardware:

1.1 A/D And D/A By Omniverter Or DEC AD11-K Board

1. Axial Focus - can be driven from 0 to 100 mm by setting the appropriate voltage in channel 26 of the omniverter. The focus value is determined by adding elevation and temperature terms to F0 (focus at zero degrees elevation and 0 degrees Celsius for a given receiver). The focus position may be verified by reading channel 12 of the omniverter. The axial focus is updated at the beginning of each scan, but may also be updated without taking data.

2. North South Translation Focus - can be driven from -6 to +6 mm. The equation for the focus setting is yet to be determined. The position is set by sending the appropriate voltage in channel 29 of the omniverter and is verified by reading channel 13. The focus value is updated at the beginning of each scan, but may also be updated without taking data.

3. Temperature Monitor - is read through channel 7 of the omniverter. Twenty-two temperatures are monitored. Torque motor temperatures (16-19) are monitored at the beginning of each scan.

4. Synchronous Detector - Continuum switched power is read from channels 8 and 10 and total power is read from channels 9 and 11 of the omniverter every one hundred milliseconds.

5. The position of the secondary may be monitored and commanded by channels in the omniverter. If the appropriate hardware is provided the secondary positions may be set at the beginning of each scan according to observing mode.

1.2 Digital Multiplexer

1. Optics. The vane, load and noise tube are controlled by the appropriate bits in DMUX. In the future, numerous additional optical devices may be under computer control. These may include choppers, the tertiary (central) mirror, a polarimeter, mirror position settings, and a parallactic angle tracker. All these devices will be controlled through DMUX.

2. Clock. The NRAO UT clock is read by DMUX.
3. The receiver Phase-Lock bit is read by DMUX.
4. The frequency read by the frequency counter is selected by a channel in DMUX.
5. Digital Backend. The control system must initiate data taking by the digital backend through DMUX and service the interrupt from DMUX when the data is ready. When a faster beam switcher is available a microprocessor/HP calculator will be required for managing the digital backend.
6. Servo. The servo will be controlled by a microprocessor. The control system will pass an array of 3 to 5 azimuth and elevation positions and the current LST to the microprocessor. The microprocessor will interpolate the commanded azimuth and elevation positions every one hundred milliseconds and update the servo. The microprocessor will also send back to the control system the azimuth and elevation position errors every one hundred milliseconds.

1.3 IEEE 488 GPIB

1. Hybrid Spectrometer. The Control system must provide a signal/reference bit, phase-lock bit and an on-position bit for the spectrometer and receive 1536 channels of data from the spectrometer not less than once a second. It is still unresolved which system will be responsible for the FFT.
2. Fluke Synthesizers. The fluke synthesizers will be driven via the 488 bus. The 2 GHz synthesizer should still have a manual setting mode, for circumstances when the control system computer is unavailable.
3. The fluke synthesizer frequencies will be verified by a frequency counter read by the GPIB.

1.4 Spectral Line Digital Multiplexer

The spectral line digital multiplexer dumps 384 or 512 channels (depending on filterbanks used) every one hundred milliseconds directly into the control system memory via DR11-B. The control program will have to know whether it is signal or reference and if the data is to be accepted - i.e., the telescope was on source and the receiver was locked.

1.5 Receiver Monitoring And Tuning

Provisions will be made for the control system to monitor and/or control the receiver tuning when the hardware to do so is better defined.

2 TELESCOPE MOVEMENT

The operator may freeze the telescope position, place the telescope in a predefined service position, direct the telescope to a fixed azimuth/elevation position, slew the telescope position, or initiate tracking of a sidereal or nonsidereal source.

The control system must accept source positions in all coordinate systems listed below:

1. Azimuth and Elevation
2. 1950 Right Ascension and Declination
3. 2000 Right Ascension and Declination
4. Arbitrary Epoch Right Ascension and Declination
5. Apparent Right Ascension and Declination
6. Galactic Longitude and Latitude
7. Ecliptic
8. User defined coordinate system

The difference between the commanded telescope position and the actual telescope position must be updated to the servo at least ten times a second. The error in this feedback position correction will be no greater than 0.1 arc second.

Commanded telescope positions are corrected for known position encoder errors. Additional offsets may be specified for observing purposes.

Mapping and source/reference positioning (ons/offs) are described under data collection.

3 DATA COLLECTION

3.1 Data Identification

All collected data is segregated and identified by observer and project.

3.2 Receivers

Each active receiver is identified by the operator, allowing receiver-dependent statistics to be retrieved from storage and used during data acquisition.

Local oscillator frequency and sideband parameters may be entered for each receiver. Oscillator frequencies may be entered directly, or indirectly by entering source rest frequencies and velocities.

3.3 Back Ends

Back end(s) in use are identified by the operator. Initially, available back ends will include the digital back end for continuum data acquisition, the hybrid spectrometer for spectrum data acquisition, the synchronous detector back end, and possible the 512 channel multiplexer as a secondary spectral data collection device.

3.4 Calibration

3.4.1 Continuum Calibration - Continuum calibration, computing the receiver response to a known source temperature, may be carried out on request by switching a noise source on and off in the subreflector. Effective system temperature and a conversion factor from receiver response to temperature are computed.

The noise source itself must be calibrated by comparing its strength with hot and cold loads inserted into the beam. It is anticipated that the 12m will be equipped with automatic hot and cold loads within the coming one to two years. The switching system at that time will switch between hot load, cold load, and sky, with the noise source switched on in alternate sky phases. The sky temperature, optical depth, receiver temperature, and noise source temperature will be determined by the calibration observation.

Noise source switching may also be used during data collection to provide continuous calibration information, at least when observing continuum with the digital back end. As the antenna gain may change with elevation, the new control system will allow for the automatic scaling of data from a stored gain curve.

3.4.2 Spectral Line Calibration -

Spectral line calibration is presently performed by switching between an ambient temperature absorber and the sky. The difference between sky and absorber temperatures is proportional to the effective system temperature. A scale factor, 'TC', which is a function of numerous parameters including elevation angle (or air mass) and the zenith optical depth (which must be set). The new control system will contain provisions for on-line computation of TC. Presently, the effective system temperature is computed for each filter in the filter spectrometer.

When automatic hot and cold loads are available, the calibration may change away from the 'TC' method to a more direct scaling by the optical depth. The control system may be responsible for reading digital weather instruments and computing a model atmosphere.

3.5 Focus

The position of the subreflector may be changed to optimize focus of the beam on a receiver. A procedure may be run at any time to vary the focus and determine the optimum subreflector position.

At the beginning of each 'scan', optical focus is corrected according to elevation angle and temperatures monitored on the telescope structure.

3.6 Switching

The following switching modes are available during data collection. To enable a switching mode the switch phases, switching pattern, and switching speeds must be specified.

3.6.1 Load Switching - Currently, an ambient temperature vane can be switched in and out of the optical path to provide a reference temperature to the receiver. In the future, a cold load switching mechanism may be introduced.

3.6.2 Beam Switching - Beam switching is currently accomplished using a nutating subreflector. The two positions that the subreflector nutates between are under software control, while the switching rate and whether or not the subreflector is nutating are outside software control. In future, other beam switching devices and techniques will probably be introduced.

3.6.3 Polarization Switching - Though not available now, a polarization switching mechanism will alternate between different polarization angles on a polarizing filter in the optical path.

3.6.4 Frequency Switching - The observing frequency may be shifted on and off the frequency of interest, by shifting the 400 MHz reference frequency in the LO system. This is outside software control. In the future, frequency switching will be accomplished by switching the IF oscillators via the Fluke synthesizers.

3.6.5 Focus Switching - Axial translation of the subreflector or some other technique may be used to alternately focus and defocus the incoming beam on the receiver feed.

3.6.6 Position Switching - The telescope may be pointed on and off the sky region of interest.

Focus and position switching occur at considerably slower rates than the other switch modes.

3.7 Point Sources

Point sources may be observed using any of the switching modes, or combinations of switching modes. Position switching and beam switching may be combined so that the position switch places the source alternately in the two beams.

For position switching, more than one off-source position may be specified in the switching pattern. On-source and off-source positions may be specified in absolute coordinates or relative to the source position. Any switching pattern may be specified. Standard patterns include off-on-on-off and higher order Walsh patterns.

An additional on-off position switching sequence is performed by collecting a data sample on-source, then offsetting in azimuth to track the same azimuth arc while collecting the off-source data sample.

3.8 Mapping

Data may be collected as the antenna beam is moved relative to a source position to produce a map. Continuum and/or spectrum data may be collected.

Maps may be produced by collecting data at a set of points spaced relative to the source position (a grid map) or by collecting data while the telescope moves continuously relative to the source position (a raster map). Either kind of map may cover a regular, rectangular pattern about the source or may cover an arbitrary pattern.

3.9 Drift Scans

The telescope position may be held fixed in horizon coordinates and data collected while the celestial sky drifts by. Data collection must be very efficient to collect useful data.

3.10 Sampling And Integration

Any switching modes in affect during data collection serve to time divide the signal into phases. A data sample is a set of phases from one or more channels collected at one time by the control system from one of the back ends. There may be a single or several channels, representing polarities, spectral elements, or elements of an arrayed receiver.

The control system may sum data samples for a period of time, called the sample time, to produce a data sample of longer period. A series of samples may be collected and sent to the analysis system for statistical analysis.

3.11 Data Rejection

Data samples may be rejected by the control system if one of the following conditions occur during data collection.

1. Actual telescope position is not within an operator-set tolerance of the commanded telescope position.
2. Receiver LO system loses phase-lock.

3.12 Computed Quantities

Some quantities, notably random noise estimators (RMS values), may be computed by the control system from collected data.

3.13 Beginning And Ending Data Collection

The duration of an individual data collection request can be specified in terms of number of samples or total integration time. In some cases, data collection may proceed for an indefinite time, until manually stopped.

Data collection may be interrupted at any time, either immediately or after the current sample is collected. An interrupted data collection request may generally be saved as-is, resumed, or aborted.

3.14 Timing Sequence Of Observation

I. Scan Observation (4 seconds to 20 minutes)

  A. Select Source and Track

    1. Convert from source coordinates to Azimuth and Elevation. Compute internal pointing corrections. Provide n azimuth and elevation positions per second of time to servo micro. (Once per second)

      a. Servo micro update encoders from array of commanded positions. Return commanded and actual telescope positions. (Once per 100 milliseconds)

      b. Control system set a bit high or low according to difference between actual telescope position and commanded telescope position. (Once per 100 milliseconds)

  B. Update axial and vertical focus

  C. Check thermistors

  D. Integrate samples (1 to 30 seconds)

    a. apply appropriate offsets to coordinates

    b. update header

    c. process sample and transmit data

4 DATA STORAGE AND TRANSMISSION

Collected data will be sent to the analysis system and stored on the control system for redundant recording. If communication with the analysis system is temporarily impossible, data may be stored only on the control system. When the analysis system is again available, data collected in the interim is transmitted to it.

4.1 Synchronous Detector Data

Continuum data from the synchronous detector is currently collected every one hundred milliseconds and integrated in memory. At the end of a repeat (one to four samples depending on observing technique) the data is stored by the control system and transmitted to the analysis system.

4.2 Continuum Digital Backend Data

Continuum data from the digital backend will be dumped at the end of each sampling cycle (one half second with the subreflector) and integrated in memory. At the end of each repeat (as above) the data will be stored by the control system and transmitted to the analysis system. Eventually a microprocessor/HP calculator may front-end the digital backend and the communication specifications will change.

4.3 Spectral Line Multiplexer (Filter Banks)

The spectral line multiplexer will dump 384 or 512 single precision integers directly into the control system memory every 100 milliseconds. These dumps are integrated for the specified integration time in memory and then stored by the control system and transmitted to the analysis system. The form of the data depends on the observing mode and may be signal arrays, reference arrays, or quotient arrays.

4.4 Hybrid Spectrometer Data

The hybrid spectrometer will transmit 1536 channels of data at the end of an integration, probably not less than one second or greater than one minute. The data will be stored as an individual record of the scan on the analysis system and possibly on the control system. The data will be integrated in memory for the requested number of records and stored on the control system and transmitted to the analysis system.

5 DATA ANALYSIS

Minimal data analysis will be supported on the control system as an emergency measure if the VAX is not available. A POPS based analysis package will allow the stacking and display of data including header, baseline removal, gaussian fitting, analysis of tipping, focusing and pointing scans, fourier transforms and analysis of data signal to noise. The observer may process whatever portion of the current scan that is complete. It is not necessary to end the scan before processing any of its data. Very limited procedure capability will be supported.

6 UTILITIES

The utilities listed here compute values for system parameters, i.e., pointing offsets, focus parameters, atmospheric attenuation, and calibration constants. There are several ways in which the current values of the system parameters may be changed via these utilities:

1. The utility may be directed to automatically install the new values.
2. The utility may be directed to install the new values provided some statistical goodness check is passed.
3. Once new values are determined, the utility may ask the operator whether or not to install the values.
4. The operator or observer may, after noting the results of one or more utility runs, manually install values.

All values determined by the utilities are archived by the control system, along with the time of determination, for later review. The values in use during any particular data collection run are stored and transmitted to the analysis system with the data.

6.1 Pointing Check

Telescope pointing may be checked at any time by performing a five-point or cross-scan observation of a source. This may be performed with either continuum or spectrum data.

6.2 Focus Check

The subreflector position may be varied while observing to determine optimum focus parameters.

6.3 Atmospheric Extinction

A "sky-tip", observing atmosphere at various elevation angles while load-switching, can be used to determine atmospheric attenuation. The observer may select the number of positions and specify specific elevation angles if desired.

6.4 Calibrations

Continuum or spectrum receiver calibrations may be performed. See "Calibration" under Data Collection.

7 CATALOG MANAGEMENT AND SOURCE SELECTION

The 12-meter control system will maintain some source catalogs where the source name, position, velocity, line name and frequency are given. Planet positions will be calculated from coefficients stored on disk as needed. We hope to acquire a comet program that will generate an ephemeris from the comet orbital elements. The Peter Stumpff program is preferred.

8 MONITOR DISPLAY AND ALARM SYSTEM

All parameters pertinent to the current observation will be displayed on the monitor. The system must also monitor the status of various hardware (torque motor temperatures, telescope position near the limits, receiver status, synthesizer status, etc.) and report the appropriate message to the operator when an error is detected.

The operator may also use a monitor for the setting of observing parameters before an observation including the input of thumbwheel offsets. (Thumbwheel offsets are a special case because the are applied at the moment they are set without any additional commands.)

9 OPERATOR COMMUNICATION

All control of the telescope will be managed by the telescope operator. The operator will be given a vocabulary of words which define and invoke action and inquire status. The structure of the language will allow the operator to extend the vocabulary with the existing vocabulary. The operator may use conditional statements and iterative loops within the language.

In most cases, options and parameter values required with operator requests have default values. When a new value is specified, it generally becomes the new default value. Fully qualified requests can be given a name and stored for easy retrieval. Sequences of requests can also be named and executed at a later time.