RC1500 Antenna Controller Implementation

The RC1500 is derived from the RC2000C Polar dual axis antenna controller. The RC2000C Polar controller tracks inclined orbit satellites with a polar mount that provides for either a motorized declination or motorized latitude angle adjustment. The feed wiggler system is similar to the variable declination polar mount.

The RC1500 product is currently 'hosted' on an RC2000. The back panel of the RC1500 is labelled identically to an RC2000. On the '1500, use the azimuth motor drive and sense lines to interface to the antenna actuator.

LCD Display

The RC1500 employs a 16 column by 2 row display. The RC2000 employs a 2 x 40 LCD. The screens of the RC2000 were shrunk to form the RC1500's display. On the RC1500 the controller's current operating mode is displayed in a three character field in the lower right hand corner of the display. Here are the three character mode designations...

MAN – Manual mode, AUT – Auto mode, SET – Setup mode, FIX – Fix or Resync mode, REM – Remote mode, RST – Reset mode, CFG - Configuration, LIM – Limit mode, STP – Track mode Step Track sub-mode, SEA – Track mode Search sub-mode, MEM – Track mode Program (or Memory) sub-mode, MNU – Track mode Menu Sub-mode, ERR – Track Mode Error sub-mode.

Tracking Algorithms

The tracking algorithms of the RC1500 have been simplified relative to those of the RC2000.

Step Tracking - On the 1500 two CONFIG mode items control the performance of the tracker. The Step Size CONFIG mode item specifies the step size (in actuator position counts) that the controller takes. The Pk Interval CONFIG item controls the time between peaking operations (in seconds).

Automatic Search – The limits of the search will be from the (down_limit + 10 cnts) to the $(up_limit - 10 cnts)$.

Program (or Memory) Track – When memory tracking, the controller will reposition the antenna whenever the difference between the actual antenna position and the antenna position derived from the track table differ by (Step Size / 2) or more. Step Size refers to the CONFIG mode item.

Track Menu – Whenever track mode is active and the time is displayed on the bottom line of the display the user can hit the 0 key to invoke the track mode menu.

Setup Mode

In SETUP mode, for inclined orbits satellites, the controller will prompt for satellite lat/lon and inclination. These values are not used by the tracking algorithms and these prompts will be removed in a future revision of the software.

PC Remote Control

The controller's REMOTE mode has not been tested. The software was modified to support remote operation. The comm protocol of the RC1500 is nearly identical to that of the RC2000. With the 1500, for the Query Status command, antenna position and status are reported in the RC2000's azimuth fields. The elevation fields in the reply have been blanked out.

For the Auto Move to Target Position command the antenna position should be reported in the azimuth field.

For the Miscellaneous - Reset Axis command, to remotely reset a drive fault either the 'A' or 'E' sub parameter will reset the drive.

Single Axis Tracking with the RC1500B

The apparent motion of an inclined orbit satellite appears as a narrow figure 8 pattern aligned perpendicular to the geo-stationary satellite arc. As the inclination of the satellite increases both the height and the width of the figure 8 pattern increase. The single axis tracker can follow the long dimension of the figure 8 but cannot compensate for the width of the figure 8 pattern. A paper (available on our web site - <u>http://www.researchconcepts.com/Files/track_wp.pdf</u>)



describes the height and width of the figure 8 pattern as a function of the inclination of the satellite's orbit.

Note that the inclination of the satellite increases with time. The maximum rate of increase is approximately 0.9 degrees per year. As the inclination increases, the width of the figure 8 pattern will also increase. This has two implications for system performance.

One, the maximum signal loss due to antenna misalignment will increase with time, and two, the antenna must have range a of motion

sufficient to accommodate the greatest satellite inclination that will be encountered.

Many people feel that single axis tracking is viable for antenna's up to 3.8 meters at C band and 2.4 meters at Ku band. Implicit in this is the fact that the inclination of most commercial satellites is not allowed to exceed 5 degrees. This assumption should be verified before a system is fielded.

A single axis tracking system must be in precise mechanical alignment to minimize loss due to the mount's inability to compensate for the width of the figure eight pattern. For this reason, a single axis tracker is more difficult to setup than other inclined orbit satellite tracking mounts.

Conversely, the operation of a single axis tracking antenna is more straightforward than that of dual axis antennas. The satellite will always be located somewhere within the antenna's range of travel so there is no danger of peaking up on an adjacent satellite. The controller can be operated with the search feature enabled – even for transmit applications.

Control Axis Tilt for a Single Axis Tracking Satellite Antenna

The control axis of the antenna should be rotated by an amount equal to...

-ATAN[sin(delt_L) / tan(L)]

where L is the earth station latitude and delt_L is the difference in longitude between the satellite and the antenna. The sense of the angle is relative to an observer located behind the antenna looking through the antenna at the satellite. Positive angles correspond to a clockwise deflection from vertical, negative angles correspond to a counter-clockwise deflection from vertical. This result was obtained from the publication Inclined Orbit Satellite Operation in the Intelsat System written by Rory Chang and Les Veenstra, revised July 1991.

Many people make the mistake of plotting satellite azimuth vs. elevation and obtaining an 'angle' by looking at the ratio of azimuth to elevation movement. The problem with this approach is that at elevation angles greater than zero, one degree of azimuth movement does not change the antenna pointing angle by one degree. When antenna elevation angle is 90 degrees, changing the antenna azimuth angle does not change the antenna pointing angle at all (it does change the polarization, however).

RC1500.XLS Spreadsheet

A spreadsheet has been developed that performs a number of calculations related to single axis tracking.

The spreadsheet takes as its inputs...

- 1. Antenna operating frequency and diameter,
- 2. Satellite longitude and inclination. Inclination of the satellite's orbital plane with respect to the earth's equatorial plane. This data can sometimes be obtained from www.lyngsat.com (select a satellite, from the satellite page select Sat Tracker, a summary of satellite info is given) or from a two line element (TLE) set see 'Setting Up a Single Axis Tracker', step 1, for the data format of a TLE set.
- 3. Earth station latitude/longitude

Given this information, the spreadsheet calculates the following quantities...

- 1. Antenna 3 dB beamwidth (in degrees),
- 2. Height and width of the figure eight pattern of the satellite's apparent motion (the height and width are the angular extent of the satellite's motion in degrees),
- 3. The maximum signal loss (in dB) due the single axis tracker's inability to compensate for the width of the figure eight pattern.
- 4. The tilt of the control axis (in degrees)

The spreadsheet uses a parabolic function to characterize the relationship between antenna angular misalignment and signal loss. The spreadsheet also calculates signal loss given antenna pointing error and vice versa.

RC1500B Tracking Algorithms

The apparent motion of an inclined orbit satellite repeats itself every 23 hours, 56 minutes, and 4 seconds. The tracking scheme used in the RC1500B employs a step track algorithm to build up a track table which logs the satellite position versus time (a real time clock powered by a lithium

battery is present in the controller). If the current time corresponds to a portion of the satellite's apparent motion for which there are valid entries in the track table, the controller switches over to a memory track algorithm. When the memory track algorithm is controlling antenna movement, the antenna smoothly tracks the satellite based on linear interpolation of the position data stored in the track table.

If the satellite transponder goes down while the controller is step tracking, the controller enters a search mode. Two search modes are supported: manual and automatic. In the manual search mode the user is prompted to manually position the antenna on the satellite and hit a key to continue tracking. With the automatic search mode, the controller periodically scans the antenna looking for signal strength. The user can select manual or automatic search via the controller's CONFIG mode.

For implementing the step track algorithm, the controller requires an analog voltage that varies with received signal strength. The controller can accept voltages from 0 to 10 volts. The analog voltage required for tracking can be obtained from a beacon receiver or from an AGC (automatic gain control) or signal strength tuning meter output from an analog receiver or modem.

Setting Up a Single Axis Tracker

The following steps represent the ideal method to configure a single axis tracking system. In practice, this method may not be practical because it requires that the installer initially configure the tracker and then return to the site to readjust the mount. This procedure also assumes that the antenna pointing angle and control axis tilt can be set independently.

1. Obtain ephemeris data on the satellite. This provides the azimuth bearing and elevation angle to the satellite as a function of time.

Two common methods are employed to obtain satellite ephemeris. One employs the SDP4 algorithm using Two Line Element (TLE) parameters compiled by NORAD (North American Air Defense) Command. See <u>www.celestrak.com</u> for a program that implements the SDP4 algorithm and TLE data sets.

The other method is to use the IESS-412 software and parameters available from Intelsat (www.intelsat.com). IESS-412 data is generally only available for Intelsat satellites. An SDP4 program is also available from Research Concepts, Inc. Contact <u>support@researchconcepts.com</u> for more information on this program.

Note that the third data field on the second line of a two-line element data set entry is the inclination of the satellite's orbital plane with respect to the earth's equatorial plane. The first data field on the second line of a two-line element set always contains '2'.

2. Use a geostationary satellite antenna pointing solution calculator to determine the satellite's nominal azimuth and elevation pointing solution. Nominal position here refers to what the az/el position of the satellite would be if it were geostationary. An antenna pointing calculator (such as ANTENNA.EXE, available for download at http://www.researchconcepts.com/antenna.htm) can provide this information given the latitude/longitude of the earth station and the longitude of the satellite.

- 3. With the nominal satellite azimuth and elevation angles and the ephemeris data, determine the time at which the satellite will be at the nominal position (sometimes also called 'center of box') and the times which the satellite will be at the top and bottom of the figure eight pattern. The time that corresponds to center of box is when the az/el from ephemeris data matches the nominal az/el angle.
- 4. Determine the control axis tilt for the single axis antenna. This quantity can be calculated using the equation given above or the RC1500.XLS spreadsheet described earlier.
- 5. Position the antenna in the center of it's range of travel. Adjust the control axis tilt angle to the value calculated in step 4. Mechanically adjust to the antenna pointing angle to be the nominal az/el position.
- 6. When the satellite is at the 'center of box', adjust the antenna pointing angle mechanically to peak up the received signal strength. Do not adjust the control axis tilt.
- 7. When the satellite is at either endpoint of the figure eight pattern adjust the control axis tilt.

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Chapter 1 INTRODUCTION

The RC1500B antenna controller is designed to control an single axis, inclined orbit satellite tracking antenna. The standard model is designed to interface to 36 volt actuators with pulse type position sense feedback. Another version of the RC1500B is designed to interface to motorized antenna feed translation systems. These controllers provide a 12 volt DC output to the antenna actuator. These 'Low Voltage' output models can be identified by the 'LV' suffix in the controllers model number designation on the serial number plate found on the back panel of the controller.

Here is a brief listing of the capabilities of the RC1500B ...

- 1. The controller utilizes a solid state drive system capable of providing 8 amps to the antenna actuator. The drive system has built-in over-current sensing with mechanical relay backup to disconnect the drive from the actuator in the event of a fault.
- 2. The controller can control polarization via a polarotor (or servo) type interface. The AUTO_POL feature allows the polarization to be controlled via a digital input or contact closure supplied by a receiver to the controller. An RC2KPOL option is available to provide control for a Seavey type two or four port feed with potentiometer feedback. If no polarization control device will be present in a given installation configure the controller for the servo option by setting the *24 vdc Rot Feed* CONFIG mode item to '0'.
- 3. Position sensing feedback can be supplied by any pulse based sensor reed switch, Hall effect, or electro-optical. There is no need for special sensors or actuators. The RC2000C keeps track of both rising and falling pulse edges from the pulse sensor for increased accuracy.
- 4. The RC1500B can maintain multiple tracks for a given satellite. In addition, a number of fixed positions can be programmed into the controller's memory.
- 5. The Adapti-Drive variable speed control system allows the user to specify the desired slow speed for the fundemental axis. The Adapti-Drive system will then adjust the actuator voltage (via a pulse width modulation scheme) to maintain the speed selected by the user. This alleviates the problem of poor speed regulation with varying direction along a given axis associated with constant voltage slow speed systems.
- 6. The RC1500 is equipped with an RS-422 communications port. This allows the controller to interface with a PC. The communication protocol used is compatible with the popular SA-Bus protocol. An optional RS-232 to RS-422 interface converter, designated RC1KADP, is available to convert the RS-232 interface (which is standard on PC's) over to the RS-422 interface required for the SA-Bus protocol used on the RC1500.
- 7. The tracking scheme used in the RC1500B employs a step track algorithm to build up a track table which logs the satellite position versus time (a real time clock powered by a lithium battery is present in the controller). If the current time corresponds to a time interval for which there are valid entries in the track table, the controller switches over to a memory track

algorithm. In this mode the antenna smoothly tracks the satellite based on position data stored in the track table.

If the satellite transponder goes down while the controller is step tracking, the controller enters a search mode. Two search modes are supported: manual and automatic. In the manual search mode the user is prompted to manually position the antenna on the satellite and hit a key to continue tracking. With the automatic search mode, the controller periodically scans the antenna looking for signal strength. The user can select manual or automatic search via the controller's CONFIG mode.

1.1 Organization of this Manual

This manual is divided into two broad parts, Installation and Reference. The Installation part of this manual is designed to familiarize the user with the controller and guide him or her through the installation and configuration of the controller. The Reference portion of the manual gives a detailed description of all of the features and capabilities of the controller.

The Installation portion of the manual is comprised of Chapters 2 through 4. Chapter 2 explains the user interface and the basic operation of the unit. Chapter 3 guides the user through the physical installation and wiring of the unit as well as the initial software configuration. Chapter 4 covers all aspects of tracking inclined orbit satellites. It begins with a brief discussion of some of the theoretical aspects of the inclined orbit, and continues with a description of the algorithms used by the RC1500B for tracking inclined orbit satellites. Chapter 4 concludes with a step by step procedure which guides the user through the entry of track parameters and the initialization of a track on an inclined orbit satellite.

The Reference portion of this manual is comprised of chapters 5, 6, and 7 as well as the appendices which follow. These chapters of the manual describe the fields on the screens which the user will encounter, as well as the data which can be entered at any prompt. After the initial installation, when the user has become familiar with the operation of the controller, these chapters will probably be the only ones consulted by the user to handle the routine chores of adding new satellites and deleting old ones.

1.2 Before You Begin

Please read and understand the manual. Time invested in understanding the installation and operation of the controller will insure satisfactory results. The unit has been tested thoroughly and will work accurately and reliably if it is installed and configured properly. There is an old saying in the controller business - "Garbage in, garbage out".

Chapter 2 BASIC FUNCTION DESCRIPTION

This chapter describes the controller's front panel layout, user interface and basic operation. When the user has completed this chapter, he or she should have a basic understanding of the various operating modes of the unit, and be able to use the keyboard and liquid crystal display (LCD) to navigate through those modes.

2.1 Front Panel

The front panel (figure 2.1) of the RC1500 contains an ON/OFF switch, a 2 row by 16 column backlit LCD, and a 4 by 4 matrix keypad with tactile feedback. The controller's back panel is described in chapter 3.



Figure 2.1

The three character field in the lower right hand corner of the LCD is reserved for the display of the current mode of the controller. The various modes are introduced in the following section. If an error condition is active, an error message will periodically flash across the bottom row of the display. Error messages are discussed in chapter 7. Chapter 5 explains the contents of every field on the display for all of the various controller modes.

An examination of the keyboard in figure 2.2 reveals that many of the keys have 2 or more labels. The function of each key is determined by the current operational mode of the controller. The various modes are discussed in the following section.



Figure 2.2

MODE

Toggling this key allows the user to set the desired mode of the controller. There are two mode groups – operational and programming. See section 2.2 – Changing Modes with the Mode Key. The MODE key is always active.

SCROLL UP/SCROLL DOWN

These keys are used to scroll up or down through a list of items.

YES/NO

These keys are used to supply an answer to a yes or no question.

ENTER

This key is used to select an entry from a list, terminate a prompt for some action by the user, or to complete the entry of numeric data.

0-9/DECIMAL POINT (with the stop key)/BKSP/+/-

These keys are used for numeric entry. The BKSP key causes the cursor to move one column to the left writing over the character which was there. During the entry of numeric data, if the cursor is in the first position of the data entry field, hitting the +/- key will toggle the sign of the numeric input.

SPEED

This key toggles the antenna speed from fast to slow and vice versa.

ARROW KEYS - 2/4/6/8

These keys are used to manually jog the antenna in some modes. The left and down arrow keys jog the antenna one direction while the right and up arrow keys jog the antenna in the other direction.

CCW/CW/H/V

These keys control the Polarization. The CCW and CW keys skew the polarization control device counterclockwise and clockwise. The H and V keys are used to either select or specify the polarization position associated with a given satellite.

Note that all of these keys are not active simultaneously. The function of each key is dependent on the current mode of the controller. In some modes certain keys are ignored.

2.2 Changing Modes with the MODE Key

The user can switch the current controller mode by use of the MODE key. The MODE key is always active - when the MODE key is depressed and released, the controller's current mode will change.

There are two mode groups – operational and programming.

Operational modes consist of MAN (manual mode), AUT (auto mode), REM (remote mode), STP (track mode, step track sub-mode), SEA (track mode, search sub-mode), MEM (track mode,

memory track sub-mode), MNU (track mode, menu sub-mode), ERR (track mode, error sub-mode).

Programming modes consist of SET (setup mode), LIM (limits), CFG (config), DEL (delete), FIX (resync mode), RST (reset mode).

The Operational modes are the ones used in everyday operation of the controller.

To switch between modes **in a group**, press the MODE key and release. The new mode will display in the upper right hand corner of the display. To switch to the **other group** of modes, hold the MODE key in for five seconds and release. This scheme was designed to help keep inexperienced personnel from inadvertently changing any of the programmed parameters specified during system setup. It is also recommended that Expert Access be used to safeguard the integrity of the data (see section 2.5).

2.3 Mode Descriptions

The mode system on the RC2000C antenna controller resembles the menu system used with many personal computer (PC) programs. On a PC program a menu system allows the user to perform operations or to enter in data. The user must navigate through the menu structure to the particular menu which allows access to the function or data that the user wishes to manipulate. On the RC2000C the mode which is currently active is always displayed in the upper right hand corner of the LCD. Here is a summary of the modes implemented on the RC2000C.

MANUAL

1673	50 H	247
GALA	XY 6	F
MAN		

In manual mode you can:

- 1. Jog the antenna about the fundemental control axis using the ARROW KEYS
- 2. Toggle the speed from fast to slow (and vice versa) with the SPEED key.
- 3. Jog the polarization with the CCW/CW keys.
- 4. Use the H/V keys to toggle between the preset H and V polarizations of the satellite which was the last target of an AUTO move.

When MANUAL mode is active the following information is displayed on the top row of the LCD: antenna position, polarization position, polarization position code (H or V) and the current signal strength. The signal strength is derived from a receiver or modem automatic gain control (AGC) output or a dedicated beacon receiver.

The bottom row of the LCD displays the satellite name and the antenna speed ('F' for fast, 'S' for slow). While jogging the antenna at slow speed a symbol is displayed to the right of the 'S'

banner. The symbols displayed are $\dots \setminus |, /, -, \setminus, .., and + and a function of the voltage applied to the drive.$

The RC1500 employs a software servo system to maintain a constant slow speed. The user specifies a slow speed via the Slow Speed CONFIG mode item. As the antenna moves at slow speed the controller determines the antenna speed by measuring the time interval between successive position pulses. The voltage applied to the drive is adjusted to maintain a constant antenna speed. As the voltage applied to the drive increases the $\langle, |, /, \text{ and } - \text{ symbols}$ appear to rotate clockwise. Similarly, as the voltage ramps down the symbols appear to rotate counter-clockwise. The . symbol is displayed when the minimum voltage is applied to the drive.

AUTO

SELECT SAT	
GALAXY 6	
AUT	

This mode allows the user to automatically position the antenna on any satellite that has been programmed into memory via SETUP mode. The list of programmed satellites is reviewed via the SCROLL UP/DOWN keys, and the ENTER key initiates the automatic move. The STOP key will terminate the move. When the antenna is positioned, the controller will switch to MANUAL mode for a geostationary satellite, and track mode is activated for an inclined orbit satellite.

REMOTE

1673 50 H 247 GALAXY 6 F REM

In this mode the controller receives and acts on commands received via the communications port. This mode can only receive control if enabled via the *Remote Enable* CONFIG mode item. The only key which is active is the MODE key, which can be used to switch to a different mode.

SETUP

761	74 H	132
TELS	TAR3	602 F
SET		

This mode allows the user to store satellite position and horizontal/vertical polarization values into the controller's non-volatile memory. Once stored in memory, the satellite is available for recall by AUTO mode.

When SETUP mode is invoked ...

- 1. the user peaks the antenna up on the desired satellite
- 2. the SCROLL keys are used to scroll through a list of satellite names stored in the controller's EPROM memory. When the desired name is found,
- 3. the ENTER key assigns it to the current position and polarization. (If the user wishes to assign a name which is not stored in the satellite's EPROM memory, the USER can manually enter the name. See page 56.)

The user is then prompted to specify the H and V polarization values for the satellite. If the antenna does not employ motorized polarization adjustment the user must still specify the H and V polarization values to the controller. For this case, the 24 vdc Rot Feed CONFIG mode item should be set to No to indicate to the controller that a 3 wire servo type polarization control system is present. A servo polarization device does not provide feedback to the controller.

When the controller is configured for servo based polarization control, when specifying the satellite horizontal and vertical polarization positions at the H and V prompts make sure that the polarization position is not at the CW or CCW limit.

When the user has entered in all of the requested data, the controller will respond with "DATA ACCEPTED", and the user can jog the antenna to another satellite and repeat the procedure. If the satellite just entered was an inclined orbit satellite, the controller will transfer control to TRACK mode to initiate tracking on the satellite.

RESET

JAMMED OK A/E-1,2-PL:_ RST

This mode allows the user to examine the error status of the motor drive circuits and reset them if a fault has occurred. The drive systems of each axis are independent. The status of the antenna drive is displayed on the top line below the 'POS' banner and the status of the polarization drive is displayed below the 'POL' banner. Polarization errors will only be shown if a rotating feed is present (the 24 vdc Rot Feed CONFIG mode item is set to Yes).

A DRIVE error indicates that the drive circuits detected an over current fault and shut down. A JAMMED error indicates that the antenna actuators were commanded to move but no movement was detected. A RUNAWAY error indicates that antenna movement was detected when the actuators were not energized. A SENSOR error indicates backwards movement of the pot. Any antenna drive error condition can be reset by pressing the key designated on the bottom line of the display. Errors are covered in chapter 6.

DELETE

SELECT SATELLITE



This mode allows the user to delete satellites from non-volatile memory. The SCROLL UP/DOWN and ENTER keys are active.

RE-SYNC



The antenna azimuth and/or elevation position can be corrupted by any number of causes (sensor failure, lightning strike, faulty shield connection, etc). If there is an error in the position counts, the controller cannot properly position itself on the satellites stored in non-volatile memory, and the limits are not valid. In this situation, it is necessary to re-synchronize the controller's internal position counts.

To do this, the operator positions the antenna on a known satellite which has previously been stored in the controller's non-volatile memory (preferably a Ku band satellite, since the beamwidth of the antenna is narrower at Ku band than at C band). The user then activates RE-SYNC mode, and uses the SCROLL UP/DOWN keys to select the satellite name with which the antenna is currently aligned. When the ENTER key is hit, the controller's internal position counts for that satellite are initialized to the current position, and a corresponding adjustment is made to all other satellite positions across the arc.

CONFIG

AUTOPOL ENABLE:* 0-NO, 1-yes CFG

This mode allows the user to view and enter configuration data into the controller. This data is stored in non-volatile memory and is used to set certain parameters and enable or disable certain controller options. The following parameters and options are controlled or configured via data entered into the controller from CONFIG mode:

AUTOPOL Remote communication port parameters time and date elevation zero position slow speed control parameter polarization options drive systems options tracking system parameters

In CONFIG mode, the SCROLL UP/DOWN keys are used to select the parameter to be viewed or modified. Asterisks in data entry field implies that the present value of the CONFIG item is invalid. The CONFIG mode item can be modified using the numeric keypad to key in a new value. For the value to be accepted the entry must be terminated by the hitting ENTER key. The

prompt message on the bottom row of the display provides data entry instructions. For some CONFIG mode items, one of the two possible data values lower case text. For these items the upper case prompt specifies the default value of the parameter.

LIMITS

705	24	431	
7-SE	ГСС	CW/DN	
LIM			

This mode allows the user to set the antenna's logical limits. To set a logical limit the user jogs the antenna to the position of the desired limit and hits the 7 key. The azimuth CCW or elevation DOWN limits are set first. After this limit is set the user is prompted to set the azimuth CW or elevation UP limit. Once the limits are set the antenna cannot be moved (except in LIMITS mode) to a position that is not within the logical limits. In LIMITS mode the controller will not detect an antenna jammed condition. When the first limit is set the antenna position is initialized to 30.

TRACK

567 56 H 668 PEAKING STP

TRACK mode is activated to track an inclined orbit satellite. TRACK mode is slightly different than the other modes described above in that TRACK mode cannot be reached directly through the use of the MODE key. TRACK mode can be entered only via the SETUP or AUTO modes.

When TRACK mode is active the track sub-mode is displayed in the lower right hand corner of the display. The TRACK sub-modes are step track (STP), search (SEA), memory track (MEM), menu (MNU), and error (ERR). TRACK mode is described in Chapters 4 and 5.

More detailed information is available concerning each of the modes described above in Chapter 5 of this manual.

2.4 Mode Access

Access to some modes is restricted in some circumstances. Here are the conditions which can restrict access to certain modes:

- 1. TRACK mode can only be entered via the AUTO or SETUP modes it cannot be entered via the MODE key. When TRACK mode is active it is treated as if it were in the operational mode group. If TRACK mode is active and the user presses the MODE key, control will transfer to the MANUAL mode. If TRACK mode is active and the user holds the MODE key in for five seconds and releases, control will transfer to SETUP mode.
- 2. REMOTE mode is only accessible when the *Remote Mode Enable* CONFIG mode item is set to 1. When enabled, REMOTE mode can be activated either via the MODE key or by the receipt of a command on the serial port. Note that most commands received via the serial port may be processed while TRACK mode is active.

3. The expert access system can restrict access to certain modes. The intent is to avoid corruption of the operating parameters by inexperienced personnel. The expert access system is described in the next section.

2.5 Expert Access

An Expert Access flag is maintained by the controller. The user can inspect and change the state of this flag via the CONFIG mode *Expert On* CONFIG mode item. When the flag is set (1) the user has access to all controller modes (subject to the state of the Remote Enable CONFIG mode item). When the Expert Access flag is reset (0), the user only has access to the MANUAL, AUTO, REMOTE, RESET, and CONFIG modes.

The Expert Access flag also controls access to CONFIG mode items. When the flag is reset (0), the user only has access to the *Autopol Enable*, *Remote Enable*, and *Expert Access* CONFIG mode items. The user can toggle the state of the Expert Access flag by entering a 5 digit code at the CONFIG mode *Expert On* CONFIG item. This 5 digit code is contained in a removable appendix B at the end of this manual, to safeguard from any accidental corruption of operating parameters by inexperienced personnel. Note that the Expert Access flag is set whenever the controller's memory is cleared via the *Reset Sys* CONFIG mode item.

2.6 AutoPol

The AutoPol feature slaves the RC1500's polarization control to an output derived from a satellite receiver. The RC1500 has an AutoPol input accessible via connector J1 on the back of the unit. When the controller is operating in MANUAL or REMOTE modes, this input is monitored and the polarotor is controlled according to a digital level present at this input.

To configure the controller for AutoPol operation, the user must have:

- 1. a suitable output available on the satellite receiver which is connected properly to the AutoPol input of the RC1500,
- 2. the polarity of the AutoPol input must be specified (Autopol Level CONFIG mode item), and
- 3. the AutoPol feature must be enabled (*Autopol Enable* CONFIG mode item).

When the polarity of the AutoPol input is specified, the user is informing the controller that a given AutoPol input level (high or low) corresponds to vertical polarization. Configuring the AutoPol system during installation is covered in more detail in chapter 3, and the CONFIG mode prompts which enable and specify the polarity of the AutoPol input are described in Chapter 5 in the CONFIG mode section.

Chapter 3 INSTALLATION/SETUP

This chapter guides the installer through the mechanical and electrical installation of the controller as well as initial software setup.

This chapter describes the electrical connectors on the back panel of the controller, cabling requirements, installation of optional polarization control devices, antenna limits, and configuration of the antenna slow speed system.

3.1 Before You Begin

Before installing the unit the installer must ensure that the controller's line voltage setting is correct, the controller's memory has been cleared, and that he or she is familiar enough with the mode system described in Chapter 2 to place the controller in any desired mode.

The RC1500 can be configured to operate on either 115 VAC or 230 VAC. The AC input voltage the unit is currently configured for is displayed in a window located in the fuse holder that is built into the IEC power entry module on the back panel of the controller. To change the AC input voltage selection, remove the fuse holder and reverse the jumper assembly (on which the '115' and '230' labels are located).

The fuse holder is designed to accommodate 1/4" by 1 1/4" fuses. If the RC1500 is configured for 115 VAC operation, use a 5 amp slow blow (type 326) fuse. If the RC1500 is configured for 230 VAC operation, use a 3 amp slow blow (type 326) fuse. For low voltage models (identified by the LV suffix on the serial number plate found on the controller's back panel) a 3 amp type 326 fuse should be used for 115 VAC installations and a 230 VAC fuse should be used for 230 VAC installations.

When the AC line voltage has been verified, before the controller is interfaced to the antenna the installer should become familiar with the controller's user interface. It is not necessary to understand every aspect of the controller's operation to install the unit, but the installer should be familiar with the mode structure of the RC1500 and be able to use the MODE key to place the controller in any of the modes described in Chapter 2.

After the AC line voltage is verified and the user has become acquainted with controller's user interface the unit may be powered up. When the unit is powered up, it should be verified that the controller goes to LIMITS mode ('LIM' displayed in the lower right hand corner of the LCD). Before the controller is shipped from the factory, the memory is cleared and the controller's logical limits are invalidated. Whenever the unit is powered up and the limits are invalid, the controller automatically places itself in LIMITS mode. Note that there may also be a limits alarm message flashing on the bottom row of the display.

If the unit does not power up in LIMITS mode the installer should perform a system reset to place the controller into a known state before proceeding with the installation.

To perform a system reset:

- 1. Use the MODE key to place the controller into CONFIG mode ('CFG' displayed in the lower right hand corner of the LCD).
- 2. Use the SCROLL keys to bring up the *Reset Sys* screen. If the *Reset Sys* item does not appear, the Expert Access flag (see section 2.5) may need to be reset.

To inspect the status of the Expert Access flag, use the SCROLL DOWN key (while still in CONFIG mode) to bring up the *Expert On* CONFIG mode item. If a 1 does not appear in the data entry field, enter the 5 digit code described in section 2.5 to toggle the Expert Access flag on. This will allow access to the *Reset Sys* CONFIG mode item.

3. At the *Reset Sys* screen enter the same 5 digit code followed by the ENTER key.

3.2 Mechanical and Electrical Installation

Use 4 #10-32 mounting screws to secure the unit to a standard 19" rack. The controller's back panel is depicted in figure 3.1.

The back panel contains...

- 1) An IEC AC voltage input module with built-in fuse and line voltage select. Fusing requirements and line voltage selection is described in section 3.1.
- 2) A removable, clamp style, 11 position connector (designated J1) that interfaces to ...

a) the antenna actuator position sense lines (antenna position sense connections are described later in this section),

b) the analog receiver, modem or beacon receiver analog output voltage that is proportional to antenna received signal strength (interface described in section 4.x),

c) the Autopol input (section 3.8),

d) and the Polarotor 3 wire servo polarization control device (section 3.3). Please refer to section 3.3 even if your system does not support polarization control.

Terminal 1 of connector J1 is labeled.

- 3) A removable, clamp style, 6 position connector (designated J2) to interface to the antenna drive motor. The antenna actuator interface is described in this section. Terminal 1 of connector J2 is labeled.
- 4) A DB-9 female connector (J3) for the SA-Bus compatible remote control interface. Interfacing to the RC1500's remote control connector is described in the appendices.

- 5) Optional A removable, clamp style, 5 position connector (designated J4) that interfaces to a rotating feed powered by a DC motor that employs a potentiometer for position feedback. This connector will only be present if the RC2KPOL option is installed in the controller. The RC2KPOL option is described in section 3.3. Terminal 1 of connector J4 is labeled.
- 6) Four potentiometers labeled AGC1 Gain, AGC1 Offset, AGC2 Gain, and AGC2 Offset. The adjustment of these potentiometers is described in section 4.x.
- 7) A circuit breaker to protect the antenna drive (12 amps for a standard unit, 5 amps for a low voltage model). When a circuit breaker of this type trips, it will protrude from its mounting bezel. To reset a circuit breaker, turn the power switch off, wait a few minutes for the circuit breaker to cool down, then depress the breaker so that it latches and is even with the bezel.

3.2.1 Antenna Motor Drive

The antenna actuator motor drive is interfaced to the controller via the connector J2, terminals 4 and 6, labeled AZ1 and AZ2, respectively. In figures 3.2 and 3.3, these connections are to the 'Azimuth Motor'. Note that the RC1500 only supports a single axis antenna – the terminals labeled EL1 and EL2 on J2 are not active.

The conductors that interface the controller to the antenna actuator must be sized appropriately so that sufficient voltage is supplied to the motors. The voltage supplied to the motors will be the output voltage from the controller less the voltage drop caused by the resistance of the wires.

The output voltage of the controller is a function of the current supplied to the motors. The voltage drop in the wires connecting the controller to the antenna is determined by the wire size, the wire length, and the current supplied to the motors.

Low voltage versions of the controller typically interface to feed translation type antenna actuators. These actuators draw low current and can be interfaced to the controller via 16 AWG conductors.

Figure A-1 in the back of this manual shows the relationship between the controller output voltage and load current (for the standard 36 VDC output controller).

The following tables show the separation between the controller (36 VDC output model) and the antenna which will result in 28 and 22 volts being applied to the antenna drive motors as a function of motor current and wire gauge. The tables take into account the controller output loading and resistive losses in the conductors.

Wire Size \rightarrow	16 AWG	14 AWG	12 AWG	10 AWG
Motor Current \downarrow				
2 amps	600	950	1500	2410
3 amps	340	520	830	1350
4 amps	220	340	550	880
6 amps	90	140	230	340
8 amps	30	40	70	120

Separation (in feet) between controller and antenna which will result in 28 volts being applied to the motors:

Separation (in feet) between controller and antenna which will result in 22 volts being applied to the motors:

Wire Size \rightarrow	16 AWG	14 AWG	12 AWG	10 AWG
Motor Current \downarrow				
2 amps	970	1530	2430	3930
3 amps	580	920	1460	2370
4 amps	400	640	1020	1650
6 amps	220	340	550	880
8 amps	120	190	310	500

A typical 36 volt actuator will draw 2 to 4 amps and will run at voltages down to about 12 volts.

3.2.2 Position Sense

Shielded cable with a bare drain wire MUST be used to minimize noise pickup. The conductors that interface the controller to the sensor is often incorporated into a cable that includes the motor drive conductors. If discreet sensor cable is required, Belden 8772 (consisting of three 20 AWG conductors enclosed in a foil shield with a bare drain wire) can be employed.

Position count errors resulting from improper shielding is the most frequent problem that occurs during the installation of the RC1500. Please observe the following precautions ...

- 1. A shielded cable equipped with a bare drain wire must be used to interface the controller to the position sensor.
- 2. The drain wire that provides an electrical connection to the shield must be connected to the J1-6 terminal labeled Sensor AZ -. The Sensor AZ terminal is at ground potential. The shield must not be allowed to come in contact with earth potential at any other location.
- 3. At the sensor the shield must be left open. A short piece of heat shrink tubing can be employed to insulate an frayed foil shielding from any metal objects at the sensor. If the shield is allowed to come in contact with earth ground at the antenna ground currents could flow in the shield which could induce noise in the sensor input circuitry.

4. If the sensor cable is spliced the or is routed through a connector, the drain wire should be spliced an not allowed to come in contact with earth ground.

See the Operation Troubleshooting Tips section of Chapter 7 for more information on count problems.

The RC1500 supports two different pulse type positions sensor – Hall effect and reed switch. Both types of sensors employ one or more rotating magnets.

For a Hall effect sensor, the magnetic field causes a Hall effect transistor to alternately switch on and off to create the pulse waveform. A Hall effect sensor has three connections to the controller. 5.7 volts DC (J1-11 labeled 5.7V), ground (J1-6 labeled Sensor AZ -), and the pulse output (J1-7 labeled Sensor AZ +). The drain wire must also be connected to the J1-6 terminal labeled Sensor AZ -. Some Hall effect sensor modules employed by Thomson Saginaw in their actuators employ an unusual color scheme. The red lead is connected to 5.7 VDC, the black lead is the pulse output (connected to Sensor AZ +), and the green lead is the sensor ground connection which is tied to the Sensor AZ – terminal.

With a reed switch type sensor, the alternating magnetic field causes a mechanical switch to make and break. A reed switch sensor has two connections to the controller: ground and the pulse input. Internally, the pulse input of the controller is tied to 5.7 volts through a pullup resistor. A reed switch sensor is not polarized, either output wire from the reed switch module can be connected to either terminal of the controller. One of the reed switch outputs should be connected to the controller's J1-6 terminal (labeled Sensor AZ –). The other reed switch output should be connected to the controller's J1-7 terminal (labeled Sensor AZ +). The drain wire of the interface cable MUST be connected to the controller's J1-6 terminal (labeled Sensor AZ –).

Some installers feel that Hall effect switches are more reliable because they contain no moving parts. Hall effect sensors, however, are more vulnerable to lightning strikes because of the Hall effect transistor device.

Figures 3.2 and 3.3 detail the connection of an RC2000 to reed switch and Hall effect type sensors, respectively. For the RC1500, connect the antenna actuator in a manner similar to that depicted for the azimuth position sensor and motor. Under no circumstances should the motor drive current be carried within the same shield as the position sense lines. Note that satellite antenna actuator cable typically includes two unshielded 14 or 16 AWG conductors for motor current and a shielded triple with bare drain wire for the sense lines all enclosed in a common insulating jacket – this type of cable works well with the RC1500.



Figure 3.1 RC1500 Back Panel Diagram



Figure 3.2 Reed Sensor Diagram



Figure 3.3 Hall Effect Diagram

3.3 Polarization Control

The RC1500 supports two types of polarization control. The standard polarization control device is a Chapparel type Polartor device. There is an optional polarization control device (designated RC2KPOL) that interfaces to a rotating feed powered by a DC motor that employs a potentiometer for polarization position sense. The RC1500 always assumes that a polarization control device is connected to the system – even if in fact no polarization control device is present at all.

3.3.1 Configuring the RC1500 for Use in an Installation that Does Not Employ a Polarization Control Device

When programming satellite's into the controller's non-volatile memory or initiating a track on an inclined orbit satellite, the user will be prompted to specify the horizontal and vertical positions associated with the satellite. If no polarization control device is present in a given installation the controller must be configured so that it think's that a Polarotor device is present in the system. This is accomplished by setting the *24 vdc Rot Feed* CONFIG mode item to 0 (No).

This works because the controller controls the Polarotor in an open loop manner. The Polarotor provides no position feedback to the controller so the controller cannot tell if a Polarotor is actually connected to the system or not. Once the controller is configured for Polarotor operation, the installer should insure that the controller does not think that the Polarotor is at a limit. To check for this, go to the MANUAL mode. If the controller thinks that the Polarotor is at a limit "CW" or "CCW" will be displayed in the polarization position field. To correct this condition depress the Pol CW or Pol CCW key to 'position' the polarotor away from the limit.

3.3.2 Configuring the RC1500 for use with a Polarotor

The Polarotor is a 3 wire servo that controls the orientation of probe in the throat of the feed assembly. To configure the RC1500 to control a Polarotor device, set the 24 vdc Rot Feed CONFIG mode item to 0-No.

The Polarotor was originally developed by Chaparrel Communications. Most Polarotor modules use a standard wire coloring convention (outlined in the following table). A shielded cable with a bare drain wire should be used to interface the Polarotor to the controller. The shield is used in a manner identical to that described for the antenna position sense interface in section 3.2.2.

Figures 3.2 and 3.3 show the connection of the Polarotor to the controller. The following table details the interface of a Polarotor to the RC1500 ...

RC2000 Connection	Signal Description	Polarotor Wire Color (typical)
J1-11 labeled 5.7 VDC	DC Power for the Polarotor	Red
	module.	
J1-10 labeled PULSE	Pulse Output to the Polarotor	White
	module.	
J1-9 labeled RTN	DC Power return	Black
J1-9 labeled RTN	Cable Drain Wire	Must be open and isolated
		from ground at the polarotor.

The Pulse output waveform is has an on time that varies from 0.8 to 2.2 milliseconds. Varying the output waveform on time over this range results in approximately 200 degrees of mechanical movement of the polarotor output shaft. The waveform off time is between 15 and 20 msec. Note that the waveform is only present when a polarization skew operating is in progress or immediately after an operation terminates.

3.3.3 Rotating Feed with Potentiometer Position Feedback

With the RC2KPOL option, the RC1500 can control a 24 volt DC rotating feed with potentiometer feedback (400 ma max motor drive current). The RC2KPOL is frequently used to control a Seavey Engineering model 124 ESA rotating feed. The RC2KPOL is a daughter board that is mounted on standoffs above the controller's digital board. If the RC2KPOL is installed a 5 position, removeable, clamp style connector will protrude from a rectangular opening in the controller's back panel above the AGC adjustment pots. The connector is labeled J4.

If the RC2KPOL daughterboard is not present the rectangular opening will be covered with silver tape. Note that the RC2KPOL daughterboard can optionally be configured at the factory for other output voltages. Contact the factory for more information. If the current rating of the RC2KPOL motor drive outputs is not sufficient for a given application, please contact the factory for other options.

3.3.3.1 Verifying the Potentiometer Center Position

The most common problem experienced during installation of a rotating feed is damage to the potentiometer due to the potentiometer reaching its mechanical limit before the feed reaches its mechanical limit. This problem has occurred quite often with Seavey feeds.

Before using a Seavey ESA 124 rotating feed with the RC1500, it is recommended that the user verify that the feed's range of mechanical movement is within the position sense potentiometer's range of mechanical movement. If the mechanical limit of the pot is reached before the mechanical limit of the feed is reached, the torque of the motor can destroy the pot. The original pot used with the Seavey feed was a Spectrol model 533 (1K ohm, 3 turn). Later models employ a Contelec PD2205-5K (5k ohm, 5 turn.) To see if the potentiometer is centered properly, the following procedure may be performed on a workbench.

Verifying Pot Center Position

- 1. Verify the total resistance of the potentiometer. This may be done by either reading the value written on the side of the pot, or by measuring between the two non-wiper terminals of the pot. For the Spectrol pot this will be terminals 1 and 3.
- 2. Connect an ohm meter between the wiper of the pot (terminal 2 on the Spectrol or Contelec) and one of the other two terminals. Note that when the shaft position of the pot is near one of the pot's mechanical limits, the ohm meter will read either less than 25 ohms, or the value found in step 1.
- 3. With a bench power supply, automobile battery charger, or some other voltage source, carefully apply power to the feed's DC motor to move it towards one mechanical limit or the other. (Note that the feed motor for the Seavey feed nominally requires 24 volts DC at approximately 150 mA. The feed motor should move with an applied voltage of 6 to 12 volts DC.)
- 4. While movement is in progress, monitor the ohm meter to insure that the pot's mechanical limit is not reached. If the ohm meter indicates that the pot's mechanical limit is being approached, quickly disconnect the power source and perform the procedure outlined in the section entitled "Centering the Pot".
- 5. If the feed can safely move to one of its mechanical limits, reverse the power supply leads and move the pot towards the other mechanical limit. Once again, monitor the ohm meter to insure that the pot's mechanical limits are not exceeded. If the feed cannot be moved to its mechanical limit without approaching the pot's mechanical limit, perform the procedure outlined in the following paragraphs.

Centering the Pot

The procedure outlined here may be used to center the feed's range of travel within the pot's mechanical limits.

- 1. Find the total resistance of the pot. See step (1) above.
- 2. Loosen up the allen screw which holds the shaft of the pot to the gear.
- 3. Apply power to the feed motor (as in step (3) above) to center the feed in the middle of its range of travel. As the feed rotates, make sure that the shaft of the pot does not turn.
- 4. When the feed has been centered in its range of travel, connect the ohm meter between the wiper and one of the other terminals of the pot. Rotate the shaft of the pot until the resistance read from the ohm meter is one half of the value of the pot's total resistance (obtained in step (1)).
- 5. Tighten the allen screw and verify that the pot is properly centered by performing the procedure outlined earlier in this section.

3.3.3.2 Connecting the RC1500 to the Rotating Feed

To configure the RC1500 software to work with the RC2KPOL option the controller's 24 vdc *Rot Feed* CONFIG mode item should be set to 1-Yes.

Figure 3.4 documents the interface of the RC1500 to the rotating feed. Two sets of electrical connections are required to interface an RC1500 equipped with the RC2KPOL option to the rotating feed device. Two conductors are required for the DC motor drive and a shielded triple with bare drain wire is required to interface the potentiometer. The drain wire of the shielded potentiometer cable should be tied to the Signal Return terminal, J4-1. The treatment of the shield on the potentiometer interface cable is the same as for the antenna position sense lines – see section 3.2.2

The RC2KPOL option can supply around 400 ma to the feed motor. 16 AWG or 18 AWG is usually sufficient for the drive motor connections.

The potentiometer position sense interface wiring carries minimal current -22 or 20 AWG conductors are typically used to connect the controller to the potentiometer. Belden 8772 is a 3 conductor, shielded cable with a bare drain wire that can be used for the potentiometer interface. Under no circumstances should a 5 conductor shielded cable be used to carry both the motor current and the potentiometer position sense signals.

Figure 3.4 depicts the connection of a rotating feed device with the RC1500. Note that the potentiometer interface cable's drain wire is connected to the Signal Return terminal (1) of connector J4.



FIGURE 3.4 Rotating Feed Interface (RC2KPOL Option Only)

Use the following procedure to configure the RC2000C for use with a 24V DC polarization motor.

- Connect the polarization/sensor assembly as shown in figure 3.4. Note that shielded cable is required for the sensor and that the shield MUST be connected to the GROUND terminal (1) at the back of the controller and MUST NOT be connected to anything at the antenna.
- 2. The CONFIG mode item *Rotating Feed Present* must be set to YES (1). Activate CONFIG mode and use the SCROLL DOWN key to bring up the *Rotating Feed Present* item and key in a 1 followed by the ENTER key. (If the *Rotating Feed Present* item is not accessible in CONFIG mode, the *Expert Access* flag has been reset. If this occurs, perform a system reset as described in section 3.1.)
- 3. In this step the polarity of the polarization motor and sensor wiring is checked. The motor polarity is somewhat arbitrary. The polarization jog keys are labeled CW and CCW. The user is free to define the direction sense as they wish. To change direction or motor rotation associated with CW and CCW, swap the motor drive wires attached to connector J4 terminals 4 and 5 (DRIVE).

The important thing is that when the polarization motor is jogged CCW, the position count MUST INCREASE. If this is not the case, the wires attached to the connector J4 terminals labeled 3 (REF) and 1 (RTN) must be reversed. Note that the shield must always be connected to the RTN terminal.

To check the polarity of the polarization motor, the rotating feed limits must be set so that unrestricted movement of the feed is possible. To achieve this, the *Rotating Feed CW Limit* CONFIG mode item must be set to 0, and the *Rotating Feed CCW Limit* must be set to 1023. These items are accessed in a manner identical to that described in the previous step of this procedure.

The polarization motor may be jogged in MANUAL mode. Jog the pol motor and make sure that movement is in the proper direction - position count decreasing for CW movement, and increasing for CCW movement. Note that once the rotating feed limits have been set as described above, there are no limits on polarization movement. The user must be careful to not move the motor past a limit.

Damage to the rotating feed, polarization motor, or potentiometer may occur if the limits are exceeded. If the user attempts to jog the polarization motor and no movement is detected on the position sense lines, or movement is detected in the wrong direction, the ANTENNA POL alarm will activate. If a polarization alarm is active, an error message will flash on the bottom row of the display, and the polarization drive will be disabled. The alarm can be de-activated via RESET mode.

Once the polarity of the motor drive and sense lines have been verified, the pol limits may be set. To set the limits, the pol motor is jogged to each position where it is desired to set a limit. This is done from MANUAL mode (with the *Rotating Feed CW Limit* and *CCW Limit* CONFIG mode items set as described above).

It is recommended that an assistant be stationed at the antenna to ensure that the polarization motor's (or sensor's) mechanical limits are not exceeded. Record the count shown on the display at each of these positions for CW and CCW limit. Return to CONFIG mode, and enter these new limits for *Rotating Feed CW Limit* (the lower value) and *Rotating Feed CCW limit* (the greater value).