# Appendix TRK – Inclined Orbit Tracking Option

Revision: 7 October 2016

This appendix describes the unique functions of the RC4000's inclined orbit tracking option.

## 1.1 Manual Organization

This appendix is provided as a supplement to the baseline RC4000 manual. The corresponding paragraphs in the baseline RC4000 manual are referred to when data specific to the inclined tracking option are described.

Section 1 provides background with respect to inclined orbit tracking.

Hardware and software configuration procedures which must be performed prior to initiating a track on an inclined orbit satellite are described in section 2.

Section 3 describes inclined orbit tracking operations.

Section 4 provides troubleshooting tips related to inclined orbit tracking performance.

## 1.2 RC4000 Features

This option provides the RC4000 controller with the ability to perform basic STEP and MEMORY tracking of inclined orbit satellites.

Software Configuration. If the inclined orbit tracking option is purchased, the tracking option designator will appear as "T".

Example: the software for a RC4000 purchased with GPS and Fluxgate, inclined orbit tracking and remote control capability would be designated RC4K-xx-G**T**R.

## 1.3.2 System Interface Requirements

The same interface requirements as are needed by the normal tracking option are required to mechanize ephemeris tracking. Most notable is the requirement for high resolution (resolver or pulse counting) sensors on the azimuth and elevation axis.

## 1.3 Theory of Operation - Tracking Inclined Orbit Satellites

This section describes the characteristics of inclined orbit satellites and the basic tracking algorithms available on the RC4000. The section begins with a tutorial on inclined orbit satellite operation, and continues with a description of the controller's tracking algorithms.

### Geostationary and Inclined Orbit Satellites

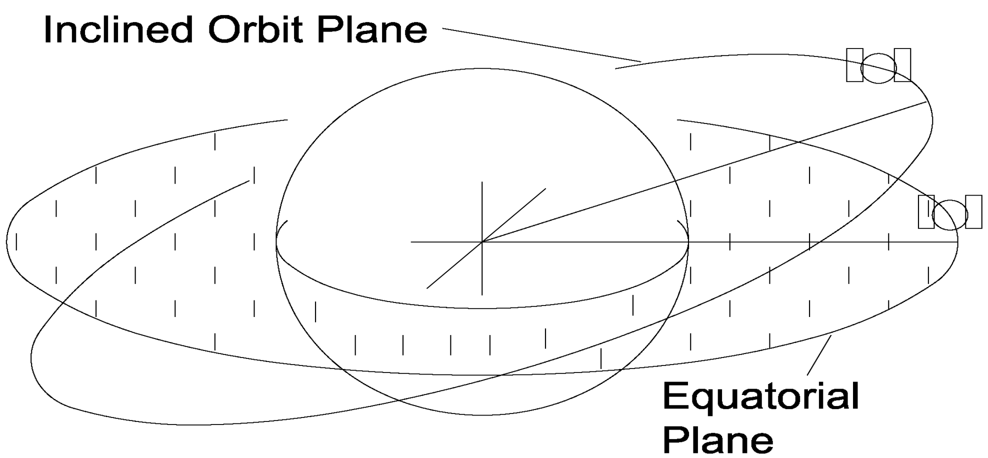
To successfully track inclined orbit satellites with the RC4000 it is beneficial to become familiar with the characteristics of the satellite's apparent motion as seen by the antenna. A geostationary satellite appears fixed in space to an observer at any point on the earth. In reality, the earth is rotating about its axis, and the satellite appears to be stationary because it is orbiting in the earth's equatorial plane with a period identical to the earth's rate of rotation.

Many forces act on a satellite in geostationary orbit that tend to tilt the satellite's orbital plane away from the earth's equatorial plane and to pull the satellite out of its assigned longitudinal position. These forces are due to the gravitational attraction of the moon (which also gives rise to ocean tides) and the nonspherical earth. A discussion of these forces is beyond the scope of this presentation. A geostationary satellite must expend propellant to perform station-keeping maneuvers to maintain an orbit at the proper longitudinal position within the earth's equatorial plane.

East-West station-keeping maneuvers are performed to maintain the satellite's longitudinal position and North-South station-keeping maneuvers are performed to keep the satellite's orbital plane aligned with the earth's equatorial plane. Between 20 and 40 percent of the satellite's launch weight is due to station-keeping propellant. A satellite's design life is determined by the amount of station-keeping fuel onboard. A satellite is sometimes allowed to drift into an inclined orbit to extend its operational life. For a geostationary satellite, approximately 90 percent of the propellant is expended for North-South station-keeping activities. If North-South station-keeping ceases, the operational life of the satellite may be greatly extended.

The following diagram shows that the orbital plane of an inclined orbit satellite is 'inclined' with respect to the earth's equatorial plane. Note that in the figure the inclination angle between the inclined orbit satellite's orbital plane and the earth's equatorial plane is greatly exaggerated. Typical inclination angles are less than 10 degrees. When satellite North-South station-keeping activities are suspended, the inclination of the satellite's orbit increases by approximately 0.9 degrees per year. Whereas a geostationary satellite appears fixed in space, the apparent position of a satellite in an inclined orbit varies with time.

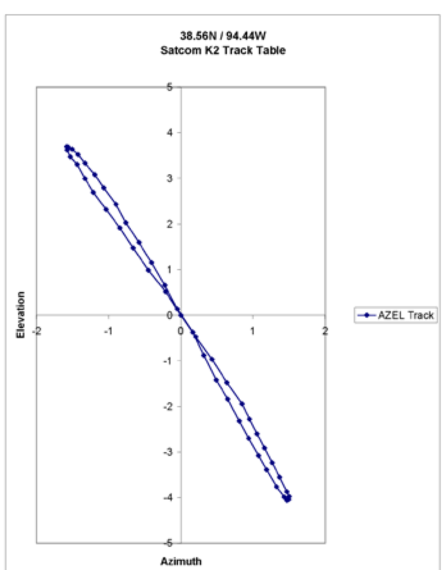
If an inclined orbit satellite could be viewed by an observer located at the center of the earth, the apparent motion of the inclined orbit satellite would be a figure eight centered on the earth's equatorial plane. The




eq5.dwg

motion of the satellite is periodic, which means that the figure eight pattern repeats itself. The period of the motion is 23 hours, 56 minutes, and 4 seconds. The angle subtended by the figure eight pattern from North to South (i.e. height of the figure '8') is twice the inclination angle. The angle subtended by the figure eight pattern from East to West (i.e. width of the figure '8') is approximately the inclination angle (in degrees) squared and divided by 115.

These relationships are strictly valid only if the motion is viewed from the center of the earth. The apparent motion is slightly greater and somewhat skewed when viewed from the surface of the earth.



The exact shape of the pattern varies with the longitudinal position of the satellite and the place on the earth from which the satellite motion is viewed. To estimate the height and width of an inclined orbit satellite's motion as viewed from the surface of the earth, a good approximation is to multiply the results of the equations above by 1.2.

Examination of these relationships show that the figure eight pattern is much taller than it is wide. For example, if the orbital plane of a satellite is inclined with respect to the earth's equatorial plane by 5 degrees, the apparent height and width of the figure eight pattern of the satellite's apparent motion as viewed from the surface of the earth is:

Height : 1.2 * 2 * 5 = 12 degrees

Width : (1.2 * 5 * 5) / 115 = 0.26 degrees

This example shows that the apparent motion of the satellite is practically a straight line. As shown in the following graph, the apparent motion of the satellite is oriented in a direction perpendicular to the “arc of satellites. This knowledge of the satellite's apparent motion as viewed by the antenna is exploited by the RC4000 tracking antenna controller.

The 23 hour, 56 minute, and 4 second period of the satellite's apparent motion is referred to as a sidereal day. A sidereal day is the time that it takes the earth to complete exactly one revolution. The '24 hour' solar day is the period of time that it takes the sun to reach the same point in the sky. The solar day is longer than the sidereal day because the earth is in orbit around the sun and the earth must rotate more than 360 degrees for the sun to reach the same point in the sky.

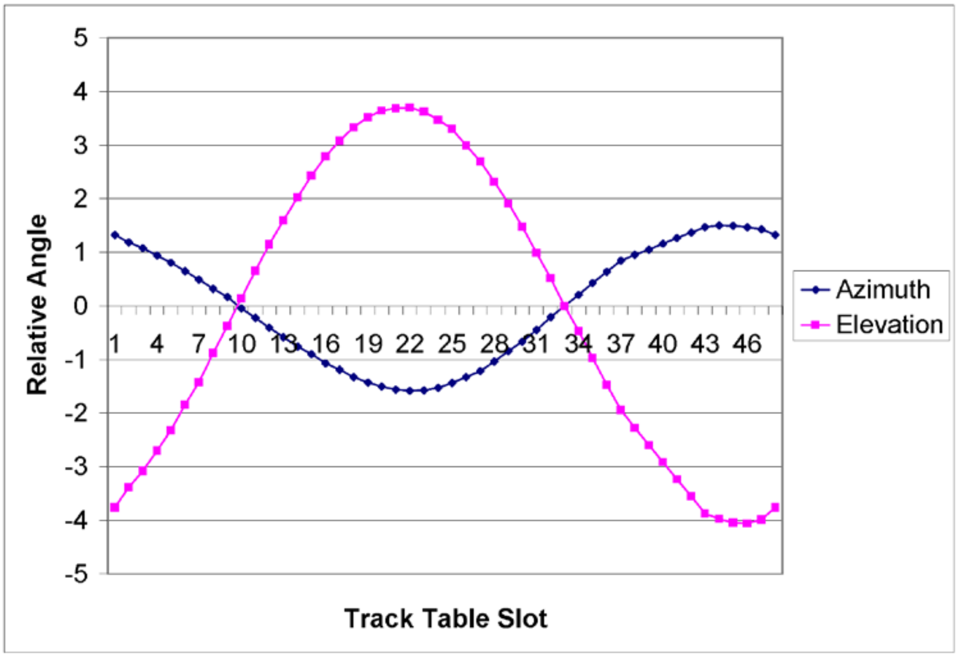
Sidereal time refers to the time reference used to record time during a sidereal day. A sidereal time clock would progress up to 23 hours, 56 minutes, 3 seconds and then wrap around to 0 hours, 0 minutes, 0 seconds. All sidereal times used by the RC4000 controller and referenced in this manual are in seconds.

**Tracking Algorithms**

The basic tracking algorithm used on the RC4000 can be divided into 3 distinct parts, or submodes - STEP_TRACK, MEMORY_TRACK, and SEARCH. A TRACK_ERROR submode is also implemented. These submodes are summarized here to provide an overview of the tracking algorithm. Notice that certain words are italicized in the following discussion. The italicized text refers to parameters which are specified by the user either at the time of system installation (via CONFIG mode), when a track is initiated (via STORE mode), or once a track has been established (via the TRACK MENU submode). The idea is to get the user familiar with the parameters which he or she must either specify or adjust. All of these parameters are described in more detail in chapter 3.

The TRACK submodes will be described in chronological order as seen by a user initiating a track on an inclined orbit satellite. A track is initiated from STORE mode. The user peaks the antenna on the inclined orbit satellite, selects the *satellite name*, *longitude*, *inclination* and *band*, and then sets the satellite's horizontal and vertical polarization positions. At this point the controller enters STEP_TRACK mode.

In the STEP_TRACK submode the controller periodically performs peakups on the inclined orbit satellite. It stores azimuth and elevation positions of these peaks in a track table in non-volatile memory. The track table divides the sidereal day into 48 time segments. Whenever the current sidereal time equals the starting time for one of the 48 time segments, a peakup occurs and the antenna azimuth and elevation values are stored into the appropriate position within the track table. The track table stores a map of the satellite's apparent motion as seen by the antenna. The following graph shows an example set of track table points.

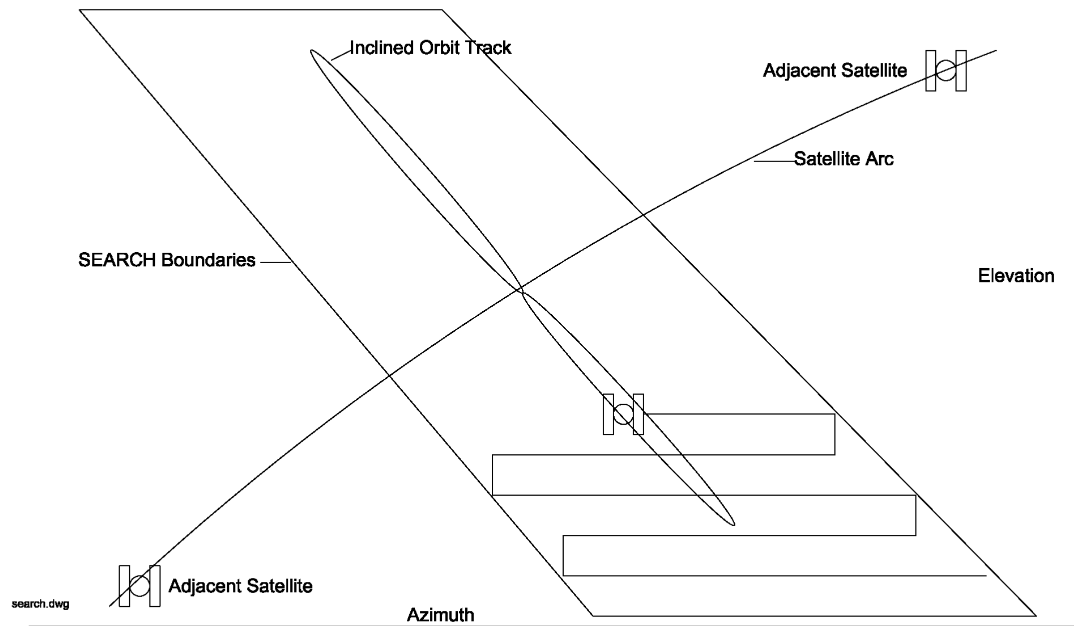



During a step_track operation, the controller peaks the antenna by monitoring the received signal strength. Signal strength information is available to the controller via the signal strength input. The signal strength input accepts a DC signal generated by the AGC circuits of a satellite receiver, or by a beacon receiver. The signal strength setup and configuration procedure is described in section 4.1.11 of the baseline manual.

The signal strength input is used to peak up the antenna while step tracking. The step tracking operation positions the antenna so as to maximize the received signal strength. Signal strength is also used to determine whether or not a satellite transponder is currently active. If the signal strength reading falls below a threshold set by the user, the controller assumes that a satellite signal is not present. If the satellite signal is lost while step tracking, the SEARCH sub-mode receives control. When the MEMORY_TRACK sub-mode is active, the presence of a satellite signal governs whether or not track table update operations are performed.

The MEMORY_TRACK submode is active whenever a satellite's track table contains valid satellite position data for the current sidereal time. When MEMORY_TRACK is active the antenna smoothly tracks the satellite by interpolating between track table azimuth and elevation position entries. Once a complete track table has been established for a satellite, the controller will remain in the MEMORY_TRACK submode.

The SEARCH submode is active when the satellite signal is lost and track table data is not available. In this submode the controller performs a search for the satellite in the region where it calculates the satellite will be found, based on its knowledge of the satellite's apparent motion. If the satellite is found while the controller is performing a search, the STEP_TRACK submode will receive control. If the satellite is not found while performing the search, the controller will wait *Search Retry Interval* minutes and perform another search. If while waiting for the *Search Retry Interval* to expire, the sidereal time advances to a time for which valid track table data is available, the MEMORY_TRACK mode will become active.




The automatic search may be disabled via the Search Enable CONFIG mode item. If the automatic search is disabled, the user is prompted to manually position the antenna on the satellite.

The TRACK_ERROR submode becomes active whenever an error occurs. Some of the errors which can occur are: antenna jammed, antenna limit reached while tracking, antenna runaway, track table data corrupted, system CONFIG data corrupted, or a peak limit error has occurred (while peaking the antenna the controller had to move too far - possibly peaking on an adjacent satellite).

The operational descriptions of the tracking functions are contained in section 3.2.2.9.

## 2.0 INSTALLATION

In addition to normal calibration, several items must be particularly well calibrated to ensure good tracking performance.

High resolution sensors (resolvers and pulse sensors) must work correctly to achieve repeatable precise movements during tracking. It is suggested that small automatic movements (approximately 0.2 dB beamwidth) be simulated via the AZEL mode. If the controller struggles to make good repeatable movements of this size, then tracking performance will not be optimal. Movements based on counts (resolver or pulses) may be adjusted via the Azimuth and Elevation Pulse Drive configuration items (3.3.1.3.3 and 3.3.1.3.6 in baseline manual).

Azimuth and elevation pulse limits should also be determined and entered into the pulse configuration screens.

The signal strength input used for tracking should also be well calibrated. See section 4.1.11 of the baseline manual.

## 3.0 DETAILED OPERATION

Prior to first entering TRACK mode, a LOCATE function should be performed to initially place the antenna on the satellite. The nominal pointing solution to the satellite is used later by the tracking algorithms. Following positive identification of the satellite, TRACK may be initiated via the STORE mode (3.2.2.4 in baseline manual).

### 3.2.2.9 Track Mode

TRACK mode is invoked from either the STORE or RECALL modes to track inclined orbit satellites. TRACK Mode consists of 5 sub-modes: STEP, SEARCH, MEMORY, MENU and ERROR. The track sub-mode which is currently active is displayed on line 3 below the SAT label. The state of the submode is displayed to the right of the sub-mode along with a brief description of the current state on line 4. The frequency band (C,Ku,CK,Ka,X,S,L) of the transponder which the controller assumes that it is tracking is displayed next to the signal strength value.

```
AZIM: 31561        SS2:735(Ku)     TRACK
ELEV: 11060        SAT:BRASIL A1
 POL:   8.2       STEP:IDLE        20:36
WAITNG TO PERFORM NEXT PEAKUP    <0>MENU
```

Whenever a track submode is IDLE:

a) the current system time is displayed in an hours.minutes format (00:00 to 23:59) with the colon flashing

b) the <0>MENU message is displayed if expert access is enabled

c) the CW, CCW, H, and V keys may be used to adjust the polarization if remote mode has been disabled

The <0>MENU display indicates that the user can hit the 0 key to activate the TRACK MENU sub-mode. From the TRACK MENU sub-mode the user can view the contents of the track table, see the current sidereal time and the scale factors for the satellite currently being tracked, modify certain parameters, and initiate certain operations. See section 3.2.2.9.4 for a description of the TRACK MENU sub-mode.

If TRACK mode receives control via STORE mode, the controller will perform some data initializations and switch to the STEP track sub-mode. System errors may be detected during the initialization. These are described in TRACK Mode Errors.

If TRACK mode receives control via RECALL mode, the controller will check for the presence of track table information for the current sidereal time. If track table information is found, the controller will activate the MEMORY track sub-mode. If track table information is not available, the SEARCH sub-mode will receive control.

These sub-modes are described in the following sections.

### 3.2.2.9.1 Step Track

In the STEP_TRACK sub-mode, the controller will periodically jog the antenna in elevation and azimuth to peak up the antenna's received signal strength. This step_track operation will be referred to as a peakup. The STEP_TRACK sub-mode is active whenever there is no track table information available for the current sidereal time and a satellite signal is present.

When the STEP_sub-mode is active, two events can trigger a peakup. The first is when the current sidereal time reaches a value that corresponds to one of the 48 track table entries. The second is when the controller calculates that the antenna pointing error exceeds the value specified by the user. The *Max Track Error* CONFIG mode item allows the user to specify the maximum tracking error in tenths of a dB. The controller constantly calculates this error based on the following data:

1) the apparent motion of the satellite (determined by the inclination),
2) the antenna's beamwidth and radiation pattern (determined by the antenna size and the satellite frequency band) and
3) the length of time since the last peakup. When the controller determines that the length of time since the last peakup has allowed the satellite to move away from the boresight of the antenna further than allowed by the max track error, a new peakup will be initiated.

The size of the azimuth and elevation movements (or step sizes) for the step_track operation is also determined by the max track error value. The step size corresponds to the angular movement of the antenna which would change the received signal strength by max track error tenths of a dB. It is calculated based on the antenna's beamwidth and radiation pattern. The RC4000 determines the number of counts to move by converting the calculated angular movement to pulse counts by using the azimuth and elevation pulse scale factors.

Reducing the *Max Track Error* value results in more frequent step track operations with smaller step sizes. There are limits to how small the max track error may be. This is discussed in section 4 (troubleshooting). Step_track operations will occur more frequently for satellites with larger orbital inclination values, or with larger antenna sizes. For a given antenna size and satellite inclination, step track operations will occur more frequently for Ku band transponders than for C band transponders. (The user is prompted to enter satellite band data during setup.) For hybrid satellites (both C and Ku band), the TRACK menu system allows the user to switch bands.

The TRACK MENU system may be used to immediately trigger a peaking operation. See section 3.2.2.9.4 for a description of the TRACK MENU system.

When the Step Track submode is active, the following status messages may be displayed:

**STEP:IDLE**
**WAITING FOR NEXT PEAKUP**

The STEP:IDLE state indicates that satellite signal strength is present and the controller is waiting to perform the next peaking operation.

**STEP:PEAKING**
**JOGGING ANTENNA TO FIND MAXIMUM SIGNAL**

The antenna is currently being jogged to find the azimuth and elevation position which corresponds to the maximum received signal strength.

**STEP:SIGNAL LOST**
**WAITING FOR SIGNAL TO RETURN**

The signal strength input indicates that a satellite signal is not present (the AGC level is below the appropriate threshold level). The controller will wait approximately 5 minutes for the AGC to return before activating the SEARCH sub-mode.

The STEP_ TRACK sub-mode will pass control to these TRACK mode submodes on the following conditions:

**MEMORY_TRACK**..receives control when the current sidereal time equals a time for which track table data is available.

**SEARCH**..receives control if the satellite signal is lost.

**ERROR**..receives control if any error is encountered.

**3.2.2.9.2 Memory Track**

When the MEMORY sub-mode is active, the controller smoothly positions the antenna to azimuth and elevation positions derived from the track table, regardless of whether a satellite signal is present or not. The track table holds a map of the satellite's apparent motion (in antenna azimuth and elevation position counts) as a function of sidereal time. The controller performs a linear interpolation between adjacent track table entries to determine the correct antenna position.

In MEMORY_TRACK submode antenna movement occurs whenever the controller calculates that the error between the antenna's current position and the antenna's proper position as determined from the track table exceeds *Max Track Error* tenths of a dB. To determine the error between the current and calculated antenna position, the controller calculates the antenna beamwidth based on the *Antenna Size* and the frequency *Band*. If the *Max Track Error* parameter is decreased in value, the antenna pointing error will be less, but the antenna will move more often, which increases wear on the antenna's motors and actuators.

The MEMORY_TRACK submode also periodically performs peakups (similar to STEP_TRACK submode) to check the accuracy of track table entries. If the discrepancy between the peakup position and the position stored in the track table is greater than that specified by the *Max Track Error* parameter, the update flag for each entry in the track table is set TRUE. The frequency at which these track table accuracy checks occur is determined by the *Update Check* parameter. When a receiver AGC signal is present and the sidereal time is equal to that associated with a track table entry whose update flag is reset, a peakup occurs, the peakup azimuth and elevation position count values are placed in the track table, and the update flag for that track table entry is reset. The default *Update Check* interval is 72 hours, but it can be changed by the user to any value in the range of 1 to 999 hours (via the TRACK MENU system).

If the current sidereal time reaches a value that corresponds to an entry in the track table whose update flag is set TRUE, and the current signal strength level indicates that a satellite signal is present, a peakup will occur, the track table entry will be updated, and the track table update flag is reset FALSE. If the satellite signal is not present the update flag remains set TRUE and the system will try again in 23 hours, 56 minutes, and 4 seconds. The user can view the contents of each track table entry and examine the present state of the update flag. In addition the user can invoke the *Force Update* or *Reset Update* functions to force the update flag for each entry in the track table to be either set TRUE or reset FALSE, respectively. These functions are accessible via the TRACK MENU system, which is described in more detail in section 3.2.2.9.4.

The TRACK MENU system may be used to immediately trigger a reposition of the antenna to the azimuth and elevation position derived from the track table, and to view the contents of the track table. The TRACK MENU system also allows the user to specify the time interval between peakup operations which check the accuracy of the data in the track table. Additionally, the TRACK MENU system allows the user to clear the track table.

When the PROGRAM sub-mode is active the following messages may be displayed:

**MEMORY:IDLE**
**WAITING TO REPOSITION**

The PROGRAM track sub-mode is active. The controller is waiting to reposition the antenna.

**MEMORY:REPOSITION**
**MOVING TO STAY WITHIN MAX TRACK ERROR**

The controller has determined that the antenna pointing error is greater than that specified by the max track error parameter, and is currently repositioning the antenna to a position derived from the track table.

**MEMORY PEAKING:**
**CHECKING OR UPDATING TRACK TABLE**

The controller is performing a step track operation to either check the accuracy of or update a track table entry.

The MEMORY_TRACK submode will pass control to the other TRACK mode submodes under the following circumstances:

**STEP_TRACK**..receives control when the current sidereal time reaches a value for which there are no valid track table entries and a valid satellite signal is present.

**SEARCH**..receives control when the current sidereal time reaches a value for which there are no valid track table entries and a valid satellite signal is not present.

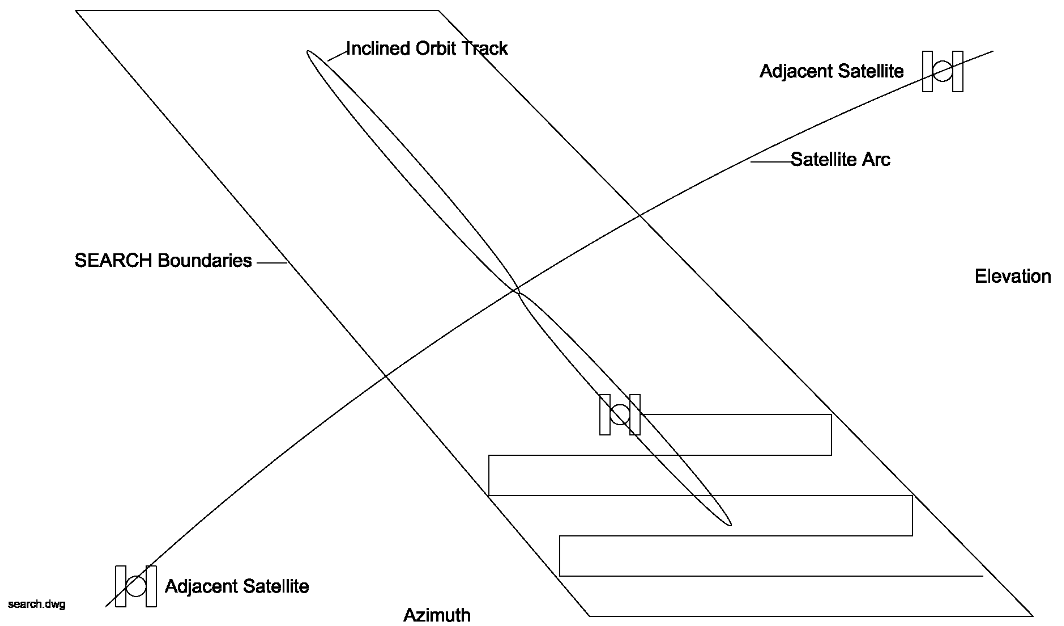
**ERROR**..receives control when any error is encountered

**3.2.2.9.3 Track Search**

The SEARCH submode receives control whenever the satellite signal is lost and the track table does not contain antenna azimuth and elevation position data for the current sidereal time. Whenever the SEARCH submode is active the controller periodically performs a search over the region where the controller has calculated that the satellite will be found. The Intelli-Search algorithm determines the extent of the search region based on the *Satellite Longitude*, the *Antenna Latitude* and *Antenna Longitude*, the antenna beamwidth (as calculated from the *Antenna Size* and frequency *Band*), and the elevation and azimuth scale factors. The *Azim* and *Elev* scale factors refer to the mapping of antenna azimuth and elevation position counts to antenna azimuth and elevation angles.

The use of the Intelli-Search algorithm relieves the user of the task of having to specify the controller's search region. Other tracking antenna controllers limit the search to a box shaped region and force the user to determine the boundaries of the search region, which is often a trial and error process. Please refer to the following diagram. If the box shaped region specified by the user is too small the controller may not search the entire region where the satellite's apparent motion takes it, and for some segments of the satellite's movement, the controller may not be able to find the satellite. If the box search region is too large, the controller may find an adjacent satellite. If the search region is not centered properly, both of the error conditions described above could occur.

In most cases the search region is shaped like a parallelogram. The long dimension of the parallelogram




is calculated based on the satellite inclination angle specified by the user when the track is initiated from SETUP mode. The width (or short dimension) of the parallelogram is specified by the *Search Width* parameter entered via CONFIG mode. The *Search Width* has a range of values of 1 to 10, with 1 specifying the narrowest search window and 10 specifying the widest window. The default value of 3 is adequate for most situations.

If a satellite signal is found during a search, the controller switches to the STEP_TRACK submode. If a satellite signal is not found during the search, the unit waits awhile and then performs another search. If during the wait the sidereal time advances to a value for which there is valid track table data, the controller will switch to the MEMORY_TRACK mode. The wait period between successive searches is determined by the value of the *Search Retry Interval* parameter. The default value of this parameter is 10 minutes, but it can be changed to any value between 0 and 999 minutes via the TRACK menu.

The search consists of successive sweeps separated from one another by an angle corresponding to a 2 dB rolloff of the antenna pattern. The antenna pattern is calculated based on the *Antenna Size* and frequency *Band*. The controller will sweep in azimuth, increment the elevation angle, and then sweep again in azimuth. This will continue until the entire search region has been covered. The automatic search may be enabled or disabled via the *Search Enable* CONFIG mode item. When the automatic search is disabled, the user is prompted to manually jog the antenna onto the desired satellite, and then hit the ENTER key.

The following conditions lead to activation of the SEARCH sub-mode:

1) TRACK mode is entered from AUTO Mode and program track data is not available in the track table for the current sidereal time;

2) the STEP TRACK submode is active and the signal strength (satellite transponder goes down) is lost

3) MEMORY TRACK submode is active, and the AGC inputs indicate that a satellite signal is not present when the sidereal time advances to a value for which track data is not available in the track table.

The behavior of the controller when the SEARCH sub-mode is active is determined by the state of the *Search Enable* CONFIG mode item. If the search is disabled, when the SEARCH sub-mode activates, the controller will prompt the user to manually align the antenna with the satellite (by using the jog keys) and hit the ENTER key to transfer control to the STEP TRACK sub-mode. If the sidereal time advances to a value for which track data is available in the track table, control will transfer to the PROGRAM TRACK sub-mode.

If the *Search Enable* CONFIG mode item is enabled, the controller will perform a search for the satellite using the Intelli-Search algorithm. When the search is performed, the controller will sweep the antenna in a serpentine shaped pattern over the region where it has calculated the satellite will be found. The width of the search box is controlled by the *Search Width* CONFIG mode item. If during the search a signal is detected above the appropriate AGC threshold (either C or K/L) the antenna will return to the position where the signal was detected and control will transfer to the STEP TRACK sub-mode. If the search is unsuccessful, the controller will wait for *Search Retry* minutes before initiating another search. The *Search Retry* parameter may be inspected and modified via the TRACK MENU - Modify menu.

When the SEARCH sub-mode is active, the following messages will be displayed to the right of the satellite name on the bottom row of the display.

**SEARCH :DOING SWEEP #**
**PERFORMING MAX SIGNAL SEARCH PATTERN**

A search is in progress. If a satellite is found, the STEP track sub-mode activates.

**SEARCH:IDLE**
**WAITING TO SEARCH AGAIN**

A search has been performed and a satellite was not found. The controller is waiting to perform another search. The TRACK MENU function may be invoked to initiate another search, or to change the Search Retry Interval. If the sidereal time advances to a value for which track table data is available, the PROGRAM track sub-mode will activate.

**SEARCH:PEAK FOUND**
**MOVING TO PEAK POSITION**

### 3.2.2.9.4 Track Menu

The TRACK mode MENU system allows the user to view and modify data relating to the satellite being tracked. The MENU system may be invoked whenever the CONFIG mode *Expert Access Flag* is set by hitting the 0 key while in the SEARCH IDLE, STEP IDLE, and PROGRAM IDLE states. When the menu system is invoked, the user will be presented with the following display, referred to as the main MENU display. The current sidereal time is updated in the lower right corner.

```
AZIM:   8.3  32974 SS1:756(Ku)     TRACK
ELEV:  35.3   8824 SAT:SBS 4
TRACK MENU:<1>PEAKUP NOW   <2>VIEW TABLE
<3>MODIFY FACTORS <ENTER>EXIT      83216
```

The action performed by the <1> selection depends on the track submode which is currently active. Note that track operations cease when the MENU system is active. Make sure that you always exit the MENU system. Hitting the ENTER key repeatedly will always cause the MENU system to terminate by returning control to the IDLE state.

**<1>PEAKUP NOW**

If MENU was entered from the STEP submode, this action causes the controller to immediately repeak the antenna.

**<1>ALIGN NOW**

If MENU was entered from the MEMORY submode, this action causes the controller to reposition the antenna based on the current sidereal time and the data in the track table.

**<1>SEARCH NOW**

If MENU was entered from the SEARCH submode, this action causes the controller to initiate another search.

**<2>VIEW TABLE**

When viewing the track table the table entry number (0-47), sidereal time (in seconds) for table entry, azimuth pulse count, elevation pulse count and update flag status is displayed on line 4. The user may scroll through the 48 table entries by using the Scroll Up and Scroll Dn keys.

```
AZIM:   8.3  32974 SS1:756(Ku)     TRACK
ELEV:  35.3   8824 SAT:SBS 4
MENU-VIEW TRACK TABLE <ENTER>EXIT
47 84365 33124 10312 * ^v-SCROLL   83234
```

The asterisk next to the elevation count indicates that the update flag for that table entry is set. A blank in that field indicates that the update flag for that entry is not active.

**<3>MODIFY FACTORS**

```
AZIM:   8.3  32974 SS1:756(Ku)     TRACK
ELEV:  35.3   8824 SAT:SBS 4
MENU-MODIFY ^v-SCROLL       MAX ERROR: 3
MAX TRACK ERROR 1/10 dB<1-30><ENTER>EXIT
```

There are 8 data items that the user is allowed to modify with this option. Each is successively accessed by pressing the SCROLL UP/DN keys and advancing through the list.

**MAX ERROR:**
**MAX TRACK ERROR 1/10 dB<1-30>**

Specifies the maximum tracking error in tenths of a dB. Default value is 10.

**SEARCH WIDTH:**
**<1-NARROW 10-WIDE 3-NOMINAL>**

Specifies a normalized scaling factor that increases or decreases the width of the search window. Values greater than 3 increase it, less than 3 decrease it. Default value is 3.

**TABLE CLEAR:**
**<1>CLEAR TRACK TABLE ENTRIES**

Press 1 to clear the track table entries, or 0 to leave as is. Be careful with this one!

**RESET UPDATE:**
**<1>RESET TABLE UPDATE FLAGS**

Press 1 to clear the UPDATE flags for the track data, 0 to not modify the existing data.

**FORCE UPDATE**
**<1>SET TABLE UPDATE FLAGS**

Press 1 to set UPDATE flags, 0 to not modify the existing data. (Opposite function of RESET UPDATE.)

**UPDATE CHECK**
**UPDATE INTERVAL<0-999 HOURS>**

The period of time between track table basepoint update checks. Default 72 hours.

**SEARCH RETRY:**
**RETRY WAIT<0-999 MINUTES>**

The period of time between successive SEARCH attempts when no signal is present and track table data is not available. Default 10 minutes.

**TRACK BAND:**
**<0>C BAND <1>Ku BAND or NO MOD-NOT A DUAL BAND SAT**

For dual band inclined orbit satellites, this prompt allows the user to change the frequency band. Note that the current band is displayed next to the signal strength indication.

To exit this option, press ENTER any time to return to the MENU screen.

### 3.2.2.9.5 Track Error

The ERROR sub-mode activates whenever an error is detected. No tracking occurs while the ERROR submode is active. The only way to exit from the ERROR submode is to exit TRACK mode by hitting the MODE key, or via a Track Reset command received by the serial port. The various track mode errors are described below.

```
AZIM:   8.3  32974 SS1:756(Ku)     TRACK
ELEV:  35.3   8824 SAT:SBS 4
 POL:  71.1 V    ERROR:PEAK_LIMIT
ERROR-TRACKING HALTED , <MODE> TO EXIT
```

**ERROR:CREEP_JAMMED**

If the controller does not sense feedback/position pulses from the pulse sensor while it asserts the drive lines, it will halt the drive signals and display the JAMMED message. Check to make sure the drive circuit breaker has not tripped or mode to RESET and reset the axis that was shut down.

**ERROR:CREEP_LIMIT**

The controller encountered an azimuth or elevation pulse limit during a track movement operation. This represents a serious error because it means the limits have to be changed to allow tracking of this satellite, and all position values will become invalid when the limits are moved. Be sure to set the limits wide enough to allow ample tracking over the entire range.

**ERROR:CREEP_DRIVE**

This error indicates a runaway or unexpected count input on the sensor lines. The controller will shut down the drive experiencing this error and will have to be reset in DRIVE RESET mode.

**ERROR:PEAK_LIMIT**

This error indicates that the antenna moved too far in either azimuth or elevation while attempting to peak the antenna. This error is described in section 5- Tracking Problems

**ERROR:TRACKING SYSTEM**

System errors are summarized in section 4 (troubleshooting) of the baseline manual.

**ERROR:TRACK_CHECKSUM**

This error indicates the memory in the satellite's track table or header has been corrupted. The only way to correct this error is to re-initialize the satellite by re-storing it via the STORE mode.

## 3.3 Programming Group

### 3.3.1.3.12 Track Factors

```
   SEARCH: 3  SIG:1         CONFIG-TRACK
MAX ERROR: 3 TIME: 2   MODE:2
  HOLDOFF:120 LOG:0    AZDP:1.0
<0-MANUAL,1-NARROW,3-NOMINAL,10-WIDE>
```

**SEARCH:** **<0-MANUAL,1-NARROW,3-NOMINAL,10-WIDE>**

The track_search_scale_item specifies whether or not the Intelli-Search algorithm is enabled or disabled, and if enabled it controls the width of the sweeps which occur during execution of the Intelli-Search algorithm. When the STEP TRACK submode is active and the signal strength input indicates that the satellite transponder has gone down, the controller will switch to the SEARCH sub-mode.

If the *Search* item is disabled (by setting it to 0-MANUAL), the user is simply prompted to manually position the antenna on the satellite and hit the ENTER key to continue. The Intelli-Search should be disabled for transmit applications. It may also be advantageous to disable Intelli-Search for antennas which move very slowly.

If the *Search* CONFIG mode item is enabled, the controller will execute the Intelli-Search algorithm. During an Intelli-Search, the controller will perform a serpentine-shaped search over a region where the controller has calculated that the satellite's apparent motion will take it. If the satellite is not found during the Intelli-Search, the search is periodically repeated until either signal strength information is available, or track table information becomes available.

If the angular extent of the sweeps is too large, the controller could mistakenly align the antenna with an adjacent satellite. A search with narrow sweeps takes much less time to complete, but may not sweep over a region which is wide enough to find the satellite.

The *Search* width is not an absolute value - increasing its value results in wider sweeps, and decreasing its value narrows the sweeps. The actual pointing angle over which search sweeps occur is a function of the antenna beamwidth and the Search Width parameter. For a given Search Width value, the search sweeps of an antenna with a narrower beamwidth will be greater than for an antenna with a larger beamwidth.

The default *Search* value of 3 is appropriate for satellites with 2 degree spacing. For faster searches, the value can be lowered to 1 or 2.

**MAX ERROR:** **ENTER MAX ERROR IN TENTHS OF A dB<1-30>**

The max_track_error_tenths_db item specifies the maximum antenna tracking error in tenths of a DB. This parameter has more influence over the operation of the tracking system than any other. The significance of this variable is described in detail in sections 3.2.2.9.1 and 3.2.2.9.2 of this manual, which cover the operation of the controller in the STEP TRACK and MEMORY TRACK sub-modes.

In the STEP TRACK sub-mode, the value of this parameter determines how often peaking operations occur. The controller will peak the antenna often enough so that between peakups the signal strength variation due to antenna pointing error will not exceed *Max Track Error* tenths of a dB.

In the PROGRAM TRACK sub-mode, the controller tracks that satellite based on the current sidereal time, and data in the track table. The controller will reposition the antenna often enough so that the error between the antenna's azimuth and elevation position and the azimuth and elevation positions derived from interpolation of track table data is less than *Max Track Error* tenths of a dB.

The *Max Track Error* parameter specifies the azimuth and elevation step sizes during peaking operations which occur during the STEP TRACK and PROGRAM TRACK sub-modes. Some users erroneously conclude that the smallest value of *Max Track Error* leads to the tightest track. When the value of this parameter is reduced to a point where the peakup azimuth or elevation step sizes approach the value of the mechanical hysteresis (slop) of the antenna mount, the controller can not peakup properly. This can lead to PEAK LIMIT errors, or the antenna peaking itself off of the antenna.

Here is the mechanism which can lead to this undesirable result:

1. The *Max Track Error* parameter is set to a 'low' value which results in an elevation peakup step size of just one position count.

2. When a peakup occurs, the controller measures the signal strength at the current antenna position, and then moves the antenna up or down in elevation in an attempt to find the strongest satellite signal. After recording the signal strength at the starting position, the controller moves the antenna up in elevation by one position count.

3. Due to mechanical hysteresis, the antenna's pointing angle does not change even though the antenna's elevation actuator has moved one position count.

4. Thermal noise in the receiver's AGC circuit or changing atmospheric conditions result in the controller measuring a stronger AGC input at the 'new' antenna position.

5. Since a stronger signal was measured when the antenna moved up, the controller concludes that the satellite has moved up. The controller will record the signal strength at the current antenna position, and again move up by one position count. At the new position, the controller will measure the signal strength again to determine if the signal is stronger at the new position than at the starting position. This process will continue until a weaker signal strength is recorded. When that occurs, the controller will back up one step and conclude that it has found the elevation peak.

6. A problem occurs if the controller makes the wrong decision at step 4. Any time the controller step size is comparable in magnitude to the antenna's mechanical hysteresis, a problem WILL eventually occur.

For most antennas the *Max Track Error* should not be made smaller than 5 (0.5 dB).

**HOLDOFF: SET PEAKUP HOLDOFF TIME<1 - 999 SECONDS>**

The peakup_holdoff_interval configuration item specifies the number of seconds before a track table entry point (basepoint) that the controller will disable a normal periodic peakup operation. The reason for this holding off of a non-track-table-entry peakup is to avoid a situation where a scheduled peakup takes too long and the time that a track table entry is to be updated is passed by.

The peaking holdoff interval should be longer than the worst case time that it takes to perform a peaking operation. The worst case peakup time will correspond to the portion of the satellite’s apparent motion when the satellite is passing through the earth’s equatorial plane (i.e. moving fastest).

**SIG: SIGNAL SOURCE <2>SS1 <3>SS2**

The selected_signal_source configuration item specifies which signal source channel is to be used when tracking. Note that the RF channel is not allowed for tracking.

Note:

**TIME: SIGNAL SAMPLE TIME <2-99 SECONDS>**

The track_sample_time item specifies the number of seconds that will be spent sampling signal strength following each peakup move. A longer time will allow a better chance to distinguish at which position the higher average signal strength was present but will also make total peakup actions proportionately longer.

**LOG: <0>DISABLE <1>ENABLE TRACK DATA LOGGING**

Contact the factory if track logging is required.

The RC4000 may be setup to output a stream of data in ASCII format that can be read/recorded through HyperTerminal or similar programs. The track data that is output at regular time intervals and is also output each time a new command is carried out during the tracking process.

The track log is output through a serial port that may or may not be accessible from existing user interface panel connectors.

**MODE: <1>STEP/MEMORY <2>STEP ONLY**

The track_option_item specifies whether the ACU will go into a memory track mode once the track table has been completed (typically after the first sidereal day of successful step-tracking) or whether the ACU will remain in step track.

**AZDP: AZ/EL DELTA FACTOR <0.5 – 1.5>**

The track_az_dp_item allows step sizes to be biased for different effective azimuth and elevation diameters. The default value of 1.0 will calculate steps assuming the antenna’s azimuth and elevation diameters are the same. A value of 1.1 will increase elevation steps by 10% and decrease azimuth steps by 10%. A value of 0.9 will decrease elevation steps by 10% and increase azimuth steps by 10%.

### 4.0 Troubleshooting

### 4.7 Inclined Orbit Tracking

This section discusses problems that can occur while tracking an inclined orbit satellite. TRACK mode contains an ERROR submode which displays an error message when it is active. This section discusses the most common problems.

**LIMIT ERROR**. The LIMIT error occurs when an antenna limit (either azimuth or elevation) is encountered when tracking an inclined orbit satellite. This error will only occur while the STEP TRACK or MEMORY TRACK submodes are active. The SEARCH submode will not attempt to move outside of the azimuth or elevation limits. This error generally means that the azimuth or elevation (usually elevation) limits are not set wide enough. This error could also mean that the mount is operating close to the physical limit of movement in the azimuth and/or elevation axis.

**PEAK LIMIT ERROR**. A PEAK LIMIT error indicates that the controller had to move the antenna too far during a STEP TRACK peaking operation. The maximum movement of the antenna from the starting position for a STEP TRACK operation is limited. This is to prevent the antenna from peaking up on an adjacent satellite. This problem can be caused by a number of situations:

1) Specifying too large of an antenna diameter, or specifying too high of a band satellite (example: Ku band when tracking a C band satellite.) These cause the controller to calculate too narrow of an apparent antenna beamwidth. This beamwidth is used to determine the maximum allowable movement from the starting position for a STEP TRACK operation.

2) Specifying too small of a satellite inclination. In STEP TRACK mode, the controller performs peakups often enough to avoid exceeding the maximum antenna pointing error specified by the Max Track Error CONFIG mode item. If the specified satellite inclination is too small, the peakups will not occur often enough, and the antenna may move far enough during a peakup to trigger the PEAK LIMIT error.

3) The AGC Threshold is set too low. If the threshold value is set too low, when the transponder powers down, the AGC signal of the receiver may be above the threshold when the antenna is looking at noise. In this case the controller would mistakenly assume that the satellite signal is present, and attempt to peak up on the noise.

4) If the error occurs during a peakup operation while the MEMORY TRACK sub-mode is active, it may be that the Update Check Interval TRACK mode MENU item is set too large.

5) There may not be a sufficient number of position counts-per-degree of antenna movement about one of the antenna axes. If a move of less than one count is specified, the antenna will round the step size up to one count. Note that all systems will have one count of play or looseness in the antenna - see the next section. A good rule of thumb is that there should be 10 position counts over the antenna’s 3 dB beamwidth for each axis. This should be an unlikely problem in the RC4000 except for very large, short wavelength antennas.

NOTE: for resolver-based mounts, one ‘count’ is equivalent to 360 / 65,536 = 0.005493°. This number represents the <u>resolution</u> of the angular measurement system of the RC4000. In this case the RC4000 can position an antenna to no better than within 0.005493° of the target position

6) Play or looseness between the antenna axis of rotation and the sensor can cause problems. The user can test to see if the antenna peaks on a satellite at different positions depending on which way the antenna approached the satellite. This should be an unlikely problem when using resolvers on the fundamental axis of rotation.

**THE MEMORY TRACK TABLE HAS GAPS EVEN THOUGH THE SATELLITE TRANSPONDER HAS NOT POWERED DOWN.** In the STEP TRACK sub-mode, the controller periodically peaks the antenna. Two events can trigger a peaking operation. The antenna will peakup at the sidereal times corresponding to entries in the track table and store the peak azimuth and elevation antenna positions. A peaking operation will also occur whenever the controller calculates that the antenna pointing error could exceed the error specified by the Max Track Error CONFIG mode item because of the satellite's apparent motion. The controller determines this time interval by knowing the satellite's inclination (specified when the track is initiated via STORE Mode) and the antenna beamwidth (calculated by having information on the antenna size and frequency band.)

Since the track table has 48 entries and a sidereal day is 23 hours, 56 minutes and 4 seconds long, a track table-inspired peakup will occur roughly every 30 minutes. A problem can arise if a Max Track Error inspired peakup is in progress when the track table peakup should occur - the controller will not perform the track table peakup, and no azimuth and elevation position data will be stored in the track table. This causes gaps in the track table data (which may be examined via the TRACK MENU - VIEW function). To prevent this from occurring, the controller will not initiate a Max Track Error peakup within “Peakup Holdoff Interval” seconds prior to a sidereal time which corresponds to a track table entry. The typical default value for the Peakup Holdoff Interval is 120 seconds.

The user can change the Peakup Holdoff Interval by changing the value in the TRACK FACTORS CONFIG mode item. The Peakup Holdoff Interval should be longer than the worst case time that it takes to perform a peaking operation. The worst case peakup time will correspond to the portion of the satellite's apparent motion when the satellite is passing through the earth's equatorial plane.