RC3000 Inclined Orbit Satellite Tracking Accuracy

There are two inclined satellite orbit tracking options available for the RC3000.

RC3000TRK

One tracking option is designated RC3000TRK. This option supports step track and memory track algorithms and are describe on our web site … The step and memory tracking algorithms are described on our web site at … http://www.researchconcepts.com/Files/track_wp.pdf.

The controller can accept two channels of analog voltage input in the range of –15 vdc to + 15vdc that varies with signal strength. Signal strength is used to 1) determine that a satellite is present (i.e. the input voltage is above a threshold), and 2) for peaking the antenna position. The analog voltage variation does not have to have high linearity with respect to received power level. An AGC signal from a modem or analog receiver is sufficient.

The controller can optionally accept a lock input, typically produced by a contact closure generated by a beacon receiver or a modem.

RC3000TLE

The RC3000TLE option adds a program track capability based on NORAD two line element (TLE) set data to the RC3000. Note that this option requires that the controller be equipped with the RC3000TRK option described above and the RC3000CRC PC serial interface option. With the RC3000TLE option orbital elements can be downloaded from the web and transferred to the controller with a Windows PC. Orbital elements are updated every 2 to 4 weeks. A wide range of information on

To track an inclined orbit satellite using two line element data, the user first has to align the antenna with the satellite. The tilt of the platform is characterized using the inclinometer that is fitted to the antenna. The user peaks the satellite and initiates program track. When program track is active the controller does not need signal strength information to track the satellite. One user of the RC3000TLE option is tracking a Ka band inclined orbit satellite. In this case, during heavy rain fades, the spacecraft's beacon cannot be detected. With program tracking, the user is able to continue tracking 'open loop'.

Step Track and Memory Track Tracking Accuracy

The biggest factor that affects tracking accuracy is the step size used for peaking. With the RC3000 the Max Track Error CONFIG mode item sets the azimuth and elevation step size. The Max Track Error CONFIG mode item specifies a step size that corresponds to a given pointing error (in dB) away from antenna boresight for each axis. Typical ranges for this value are 0.4 to 1 dB. When peaking the antenna the controller converts pointing loss (in dB) to an azimuth and elevation step size (in degrees). Note that the controller handles the dP/d_az problem correctly (i.e. for an elevation over azimuth antenna, when the elevation is greater than zero one degree of azimuth movement does not change the antenna pointing angle by one degree).

These azimuth and elevation step sizes define a grid pattern in the az/el plane. The antenna controller will always position the antenna at an intersection of the grid lines. The position of peak received power will usually not correspond to the antenna position at an intersection of the grid lines. The maximum pointing error of the antenna will ideally be a maximum of 1/2 step size in azimuth and 1/2 step size in elevation. Using some not very elegant math this probably corresponds to a maximum pointing error relative to boresight of around 0.7 times the step size.

As an example, assume that after the last peaking operation the antenna is 0.7 step size away from the satellite. With a step size of 0.4 dB (assuming 20 GHz operation) each step corresponds to about 0.084 degrees. If the antenna is 0.7 steps away from the peak the angular pointing error will be 0.7 x 0.084 deg = 0.059 degree. This corresponds to an error of about 0.2 dB. When the controller attempts to peakup assume that it steps away from the satellite initially. This will make the angular error 0.059 + 0.084 degrees or about 0.143 degrees. This corresponds to a pointing error of about 1.3 dB. Of course, the signal strength should drop and the controller should step back towards the satellite. If the specification is written such that maximum tracking error does not exceed some value, say 1 dB, the system does not meet spec. RMS error is a much easier spec to meet.

2.4 Meter Antenna Pointing Error in Degrees vs. Antenna Pointing Loss for Various Frequencies

Freq (GHz) -> Pointing Loss (dB) V	4 GHz	6	8	12	20	30
0.1	0.2110869	0.1407246	0.1055435	0.0703623	0.0422174	0.0281449
0.2	0.298522	0.1990147	0.149261	0.0995073	0.0597044	0.0398029
0.3	0.3656133	0.2437422	0.1828067	0.1218711	0.0731227	0.0487484
0.4	0.4221739	0.2814493	0.2110869	0.1407246	0.0844348	0.0562899
0.5	0.4720047	0.3146698	0.2360024	0.1573349	0.0944009	0.062934
0.6	0.5170553	0.3447035	0.2585276	0.1723518	0.1034111	0.0689407
0.7	0.5584836	0.3723224	0.2792418	0.1861612	0.1116967	0.0744645
0.8	0.597044	0.3980294	0.298522	0.1990147	0.1194088	0.0796059
0.9	0.6332608	0.4221739	0.3166304	0.2110869	0.1266522	0.0844348
1.0	0.6675155	0.4450103	0.3337578	0.2225052	0.1335031	0.0890021
1.5	0.8175362	0.5450241	0.4087681	0.2725121	0.1635072	0.1090048
2.0	0.9440095	0.6293397	0.4720047	0.3146698	0.1888019	0.1258679
2.5	1.0554347	0.7036231	0.5277174	0.3518116	0.2110869	0.1407246
3.0	1.1561708	0.7707805	0.5780854	0.3853903	0.2312342	0.1541561

Step Size Selection

The peakup performance is determined by proper selection of the Az/El Step Size CONFIG mode items. Several factors will govern step size selection including signal fading, the noise voltage present on the analog signal strength input, and the mount's mechanical hysteresis (sometimes referred to as 'slop').

For a given axis, the pointing accuracy of the antenna can be no greater than one half the step size used for peaking about that axis. Based on this it would seem that the smallest possible step size, 1 position count, would yield the greatest possible accuracy. (The resolver converter circuit employed by the RC3000 has 16 bit resolution, or 360 degrees / 2^16 unique codes => 0.005 degree resolution.) In the absence of signal fading, noise on the controller's AGC input, and hysteresis, this would be the case.

How Signal Fading, Noise, and Mechanical Hysteresis Affect Peakup Performance

To see how these factors affect the peaking process it is useful to review the basic peaking operation. When peaking the antenna, the controller measures the received signal strength by averaging for 3 seconds, moves the antenna by an amount equal to the azimuth or elevation step size for the frequency band of the current satellite, and then makes another measurement of signal strength by averaging for 3 seconds. If the signal strength measured after the move is greater than the signal strength measured before the move, the controller assumes that the movement resulted in the antenna being brought closer to the antenna peak position. Signal fades, noise, and mechanical hysteresis can sometimes result in the controller measuring greater signal strength when the antenna is moved away from the satellite. This event is referred to as a 'bad decision' by the controller.

The peakup step size has to be large enough so that 'bad decisions' do not occur when signal fades, AGC noise, and mechanical hysteresis is present.

Step Track 'Bad Decision'

The diagram at the end of this section is a graph of received signal strength as a function of time while the controller is tracking an inclined orbit satellite. The dropouts that occur around 12000 and 20000 seconds represent bad decisions by the tracker. Note that the drop in signal strength that accompanied each 'bad decision' was 'corrected' on the next peakup. The occurrence of 'bad decisions' indicates that the step size needs to be increased.

Notice also the occasional smaller dropouts in signal strength that occur. This is when the controller is peaking. When step tracking the controller will peakup … a) at a time that corresponds to a point in the controller's memory track table and b) whenever the time interval since the last peakup is great enough so that at the satellite's maximum rate of apparent motion, the angular pointing error of the antenna would result in a pointing loss of Max_Track_Error.

Signal Fading

Fading refers to the variation in received signal strength due to atmospheric conditions. The affects of fading are usually greater at higher frequencies. Moisture in the form of clouds, fog, or precipitation contribute to fading. The changes in signal strength associated with fading can occur over periods of time measured in seconds, minutes, or even hours. It is the short term time variations in signal strength that can cause the controller to make a bad peaking decision.

Here is an example of how fading can lead to a bad peakup decision. Assume that during a peaking operation the controller takes a step away from the true satellite position. If during that movement a cloud that had previously been positioned between the antenna and the satellite 'moves out of the way' the controller will record a stronger signal even though the antenna has been moved away from the satellite. To reduce the probability of this bad decision occurring the position step size can be made larger or the received signal averaging period can be made shorter to cause the peakup to occur more quickly. The controller's signal averaging interval is fixed at three seconds. Note that a reduction of the signal averaging time interval leads to an increased probability of a bad peaking decision due to noise in the receiver AGC circuits as described in the next section.

AGC Noise

The controller's signal strength input is an analog signal typically generated by a receiver's AGC output circuits. A certain amount of noise is present in any analog signal. The noise voltage is summed with the signal. The noise typically has an average value of zero volts. To minimize the affect of noise the controller's averaging interval can be increased. Note that an increase of the signal averaging time interval leads to an increased probability of a bad peaking decision due to signal fading as described in the previous section.

Mechanical Hysteresis

Mechanical hysteresis, or slop, is looseness in the antenna drive system. Hysteresis is typically caused by backlash in a linear actuator or chain drive or looseness in the actuator attachments bolts or pivot points. When the step sizes used for peaking result in antenna movements smaller than or equal to the antenna's mechanical hysteresis, a step may not result in a change in the antenna's absolute pointing angle. If this occurs, any change in measured signal strength will be due to fading or noise in the receiver's AGC circuits and the controller will make a 'bad decision' regarding the peakup.

Here is a test to quantify the amount of mechanical hysteresis in a given mount. Better results will be obtained if the winds are calm when the test is performed.

1. Jog the antenna far off of the satellite in one direction.

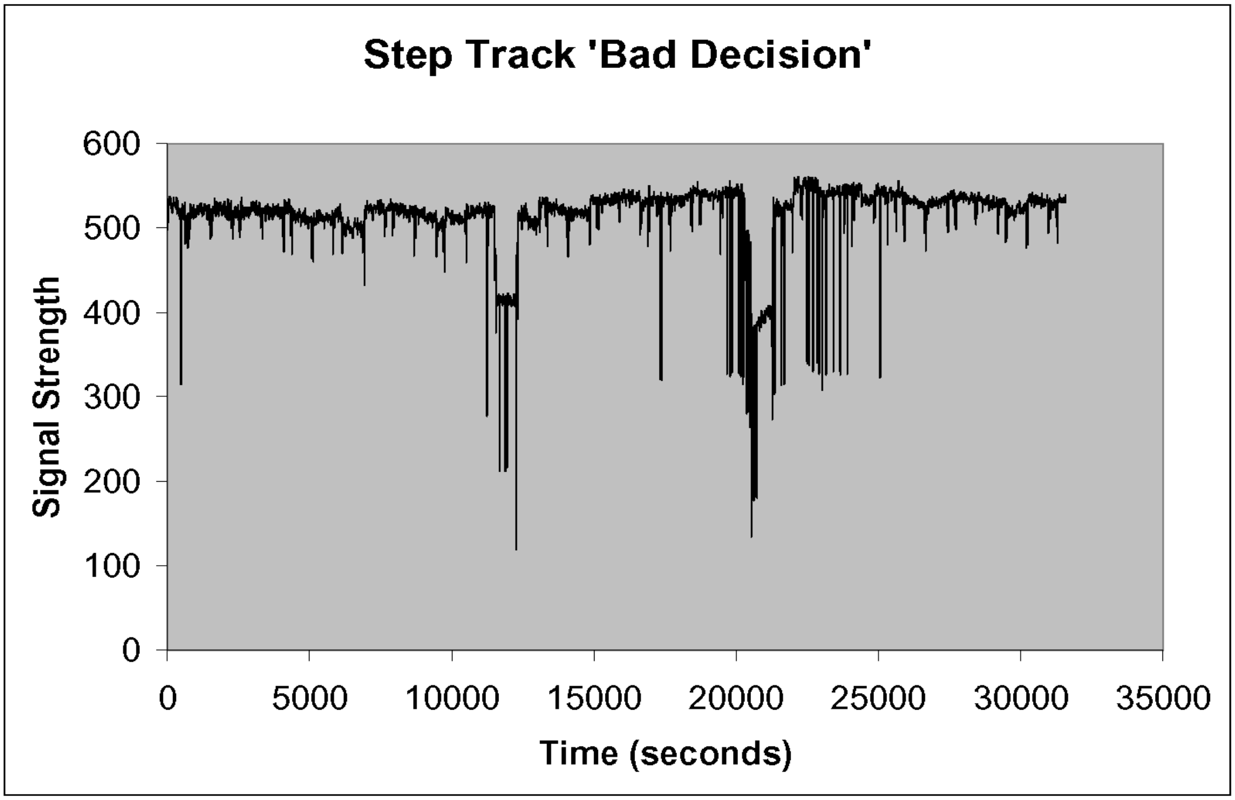
2. Jog the antenna back towards the satellite. Initially approach the satellite moving the antenna at high speed.

3. When the antenna is close to the satellite jog towards the satellite at slow speed moving a small amount each time position counts at a time. Only jog the antenna in one direction – do not back up. Record the signal strength at each position. Continue until well past the peak of the antenna pattern.

4. Next position the antenna far off of the satellite in the other direction and repeat steps 2 and 3 as you approach the satellite from the other direction.

5. Using a spreadsheet, plot signal strength vs. position for movement in both directions. Compare the plots, any difference between the peak positions is probably due to slop in the antenna.

Note that the test is more accurate for larger antennas and higher frequencies (which result in a narrower antenna beamwidth). Sometimes this test will not fully characterize slop about the elevation axis due to the weight of the antenna. Elevation slop can still affect a heavy antenna in gusty winds.


Step Track 'Bad Decision'
600
500
400
300
200
100
0
Signal Strength
0
5000
10000
15000
20000
25000
30000
35000
Time (seconds)