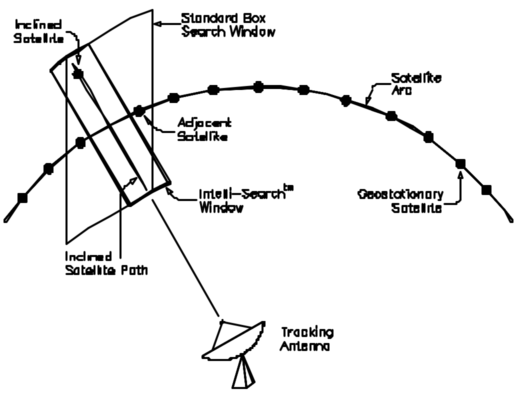
Single Axis Tracking with the RC1500B

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 - http://www.researchconcepts.com/Files/track_wp.pdf) 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 it's 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 www.celestrak.com 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 support@researchconcepts.com 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.