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ID & ASSOCIATES

TS2000 Antenna Tracking & Control Unit

Reference Manual.

For Model: 23031999 tracking systems only.

TS2000 ANTENNA TRACKING & CONTROL UNIT

Reference Manual

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Table of Contents

1	Operational Description of the		3.7.1	Standby.	12
TS2000	4		3.7.2	Intelsat Immediate.	12
1.1	General Control	4	3.7.3	Intelsat Delayed.	13
1.2	ATCU Keyboard Control	4	3.8	System Status	15
2	Status Display	4	3.8.1	Mode (Current)	15
2.1	Software Revision	4	3.8.2	Antenna (Current)	15
2.2	Status Display Parameter		3.8.3	Tracking	15
Definitions		4	3.8.4	Initialisation Stage	16
2.2.1	Az (deg) Parameter		4	The Alarm List Page.	17
definition.	4		5	The Maintenance Pages.	18
2.2.2	El. (deg) Parameter		5.1	Azimuth, Elevation and	
definition.	4		Polariser Setups.		19
2.2.3	Beacon Level. (dB)	4	5.1.1	Coarse Angle. (deg)	19
2.2.4	Satellite Name.	5	5.1.2	Offset Angle (deg)	19
2.2.5	Polariser. (deg) Parameter		5.1.3	Gear Ratio.	19
definition.	5		5.1.4	Est. Speed. (deg/sec)	19
2.2.6	ATCU Mode.	5	5.1.5	Dead Band. (deg)	19
2.2.7	Time & Date.	5	5.2	SW Travel Limits.	20
2.2.8	Last Alarms	5	5.2.1	Beacon Limits. (dB)	20
2.2.9	Keyboard Controls	5	5.2.2	Gradient. (V/dB)	20
3	The "Tracking Control" page.	7	5.2.3	Max Rate. (dB/sec)	20
3.1	Commands	7	5.2.4	Tracking Parameters.	21
3.2	ATCU Mode Selection	8	5.2.5	Beamwidth. (deg)	21
3.3	Manual Antenna movement.	9	5.2.6	Move Size. (deg)	23
3.4	Watchdog Timer	9	5.3	Scanning Data. (Table 5)	23
3.5	Manual Polariser movement.	9	5.3.1	Time Limit. (min)	23
3.6	ATCU Modes of Operation	11	5.3.2	Box Limit. (deg)	23
3.6.1	Standby Mode	11	5.3.3	Track Sepn. (deg)	23
3.6.2	Position Mode	11	5.3.4	Station Data.	23
3.6.3	Intelsat Mode	11	5.3.5	Latitude. (deg)	23
3.6.4	Autotrack Mode	11	5.3.6	Longitude. (deg)	23
3.6.5	Initialisation Mode	11	5.3.7	Height. (Km)	23
3.7	Setting The Fallback Mode	12			

5.3.8	Mount "Tilt" and "Twist". (deg)	23	13	MAINTENANCE	41
5.4	Serial Communications.	25			
6	Stored Satellite Data.	26			
6.1.1	Name.	26			
6.1.2	Beacon.	27			
6.1.3	Ref Lvl.	27			
6.1.4	Pol Ang. (deg)	27			
6.1.5	Ref Lat. (deg)	27			
6.1.6	Intelsat Parameters.	28			
6.1.7	Durat. (days)	29			
7	CMU Message Traffic.	30			
8	Alarms	31			
8.1	Major	31			
8.2	Minor	31			
8.3	Major Alarm List	32			
9	TS2000 Hardware Specifications	34			
10	INSTALLATION AND COMMISSIONING	35			
10.1	Physical	35			
10.2	Dead Band	35			
10.2.1	Initial Setup	35			
10.3	Calibration with Beacon Receiver	35			
10.3.1	Stepped Attenuator.	35			
10.3.2	Set parameters.	35			
10.4	Decrease 1.0dB.	36			
10.5	Tolerance.	36			
10.6	Gradient.	36			
10.7	DC Offset.	36			
10.8	Normalised.	36			
10.9	1.0dB drop.	36			
10.10	-5dB on loss of power.	36			
10.11	Carrier to Noise Ratio	37			
10.12	Results	37			
11	Calibration for Position Sensors (Resolver / Synchro Setup)	38			
11.1	How accurate should my positioning system be.	40			
12	Software Protection.	41			

Introduction to the TS2000

TS2000 Antenna Control and Tracking system is designed for those medium-sized satellite communications antennae which, although requiring automatic steering, do not need the high pointing accuracy of a fully closed-loop position control system. It combines active and passive satellite tracking facilities with an on-off antenna drive control, and is designed for operational control via serial data links from up to two separate control stations. Polariser drive control (Optional), similar in operation to the antenna axis drive control, is provided. This will automatically set the Polariser angle to the angle preset for the selected satellite.

The TS2000 Antenna Control and Tracking system consists of:

- One Antenna Tracking Control Unit (ATCU) &
- One Reference Power Supply (RPS).
- A Display Unit and Keyboard can be supplied as an option, providing local control facilities without requiring the use of user-supplied Control and Monitoring Units (CMU's).

The ATCU is an industrial-grade computer, which performs all computations, and issues commands for use by the antenna motor drive systems.

The RPS provides the reference signal for angle Resolver / Synchros, and DC voltage which powers limit switch and interlock circuits. It also provides the termination point for all external circuits, with the exception of the primary power and serial communication links.

The industrial computer hardware used as the TS2000 platform is designed to operate under a greater range of operating environments than a standard desk top personal computer, while implementing compatible software. Careful consideration has ensured the Industrial PC will automatically initiate and operate correctly when power is applied, even after extended power outages.

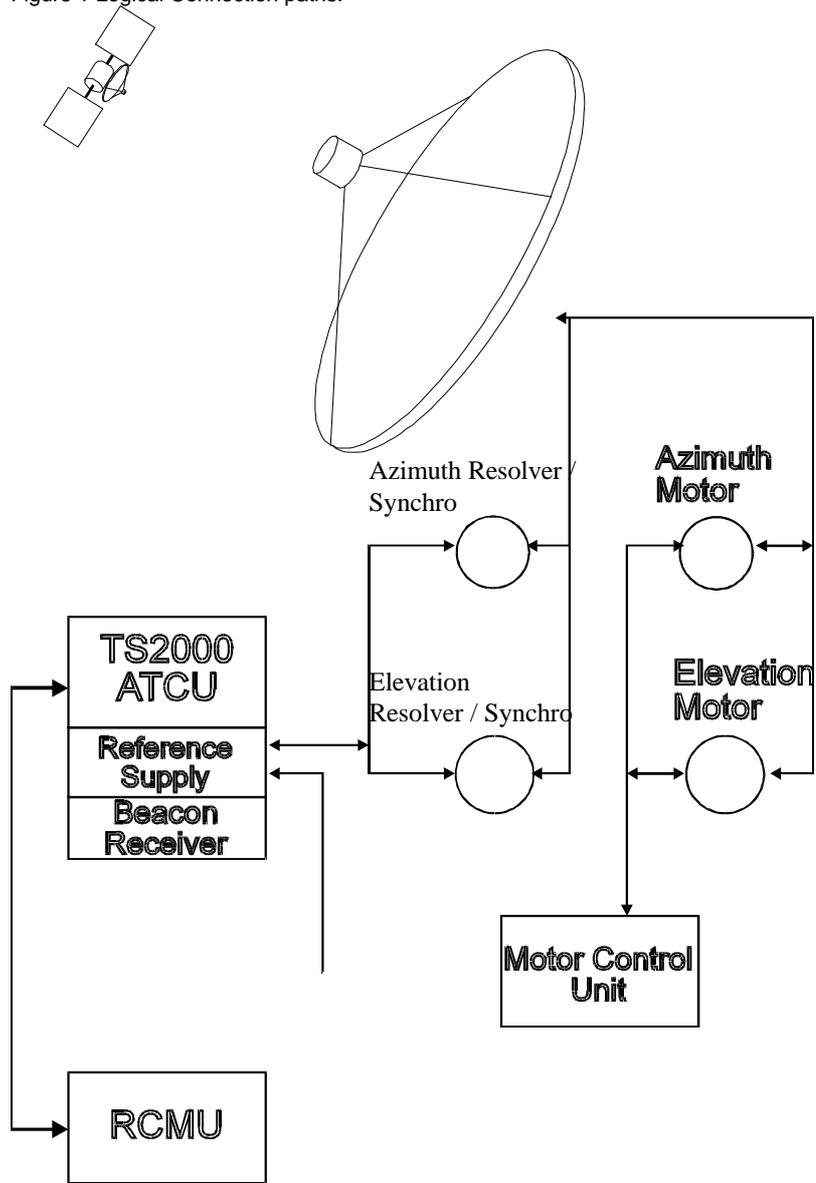
A positively pressurised case, fitted with an air filter, ensures that the contents of the case remain dust free. A fan blowing cooling air past the PC boards, assists in maintaining the on-board components at reasonable operating temperatures in hot environments.

The passive ISA backplane of the Industrial PC allows for expansion or easy upgrade.

The ATCU program is stored in a solid state disk, which serves the dual purpose of storing the TS2000 software and, through the use of the on-board static RAM (SRAM), non-volatile storage of tracking and system parameters, and alarm information.

Use of the solid state disk allows factory software, complete with default settings, to be shipped ready for installation in the ATCU.

Figure 1 Logical Connection paths.



1 Operational Description of the TS2000

1.1 General Control

The usual operational interface to the TS2000 is through Local or Remote, Control & Monitoring Units (L/R CMU's) operating via serial data links. ID & ASSOCIATES presently have a CMU that has been created with Citect to run on a standard desktop computer running Windows 95/NT/2000. This graphical form of control presents an easy to use Human Machine Interface for the operator. Alternatively the CMU can be integrated with the customers existing Citect control system.

1.2 ATCU Keyboard Control

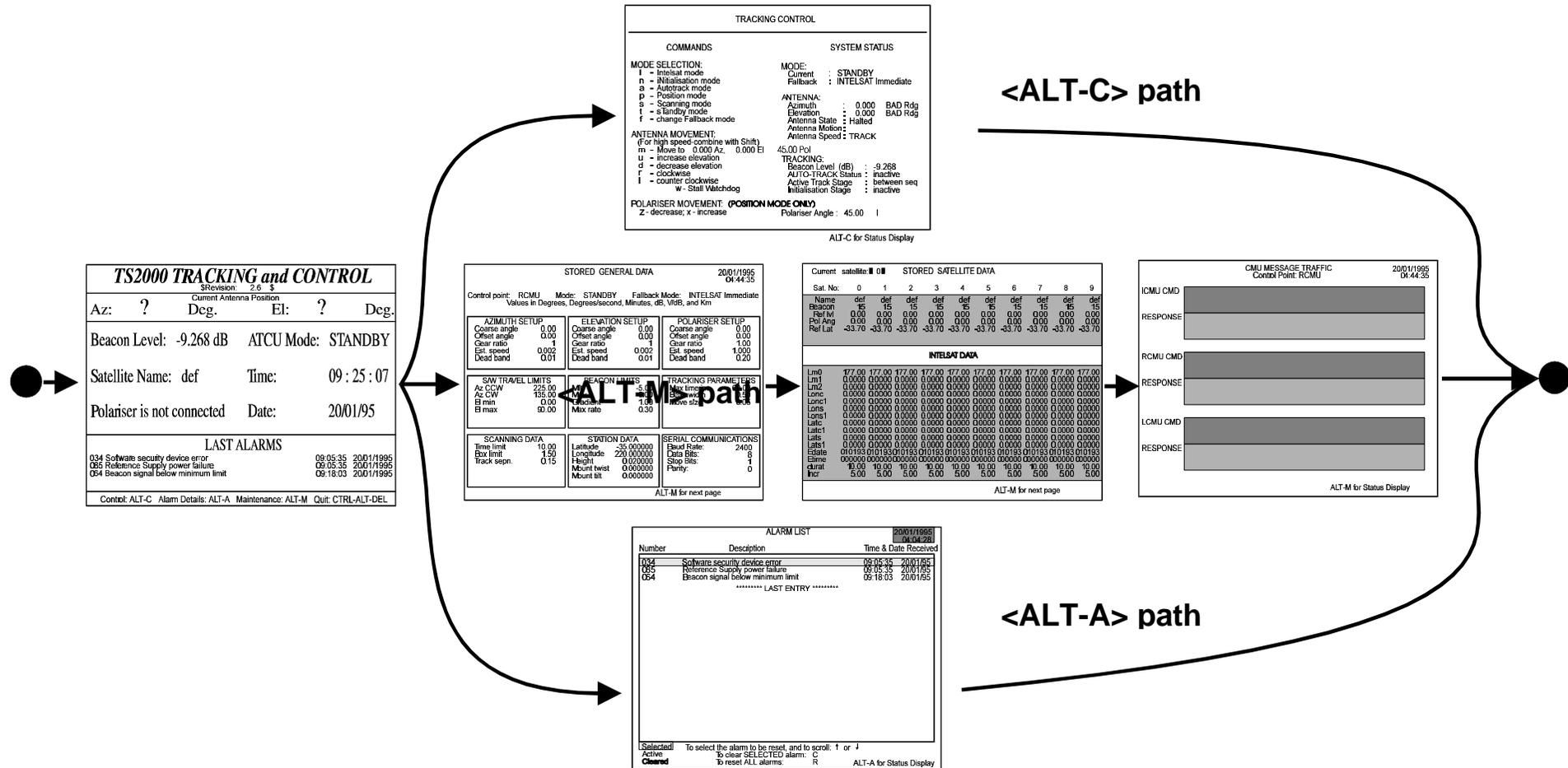
The TS2000 allows stand alone operation with the addition of a keyboard and monitor. All control functions and parameter-setting operations can be performed without the use of a Control and Monitoring Unit (CMU). This method of control must be used during the Installation and commissioning phase, as there are a number of critical parameters that can only be entered directly into the ATCU.

The ATCU user interface presentation is in the form of a number of display pages. Each of these pages is designed for a specific task. Page selection is accomplished through <Alt-Plus One Key> keystroke combinations.

The first page presented when the ATCU is started is the Status Display. From this page movement to the Alarm List log, Control and Maintenance pages can be done.

The following sections describe the contents of each page and give definitions and explanations for the contents.

Figure 2 ATCU Standard Pages.



2 Status Display

The first page presented when the TS2000 ATCU is powered up is the Status Display. This page shows the major operating parameters of the TS2000.

Figure 3 Status Display Page



<i>TS2000 TRACKING and CONTROL</i>				
\$Revision: 2.6 \$				
Current Antenna Position				
Az:	?	Deg.	El:	? Deg.
Beacon Level:	-9.268 dB	ATCU Mode:	STANDBY	
Satellite Name:	def	Time:	09 : 25 : 07	
Polariser is not connected		Date:	20/01/95	
LAST ALARMS				
034 Software security device error		09:05:35	20/01/1995	
085 Reference Supply power failure		09:05:35	20/01/1995	
064 Beacon signal below minimum limit		09:18:03	20/01/1995	
Control: ALT-C Alarm Details: ALT-A Maintenance: ALT-M Quit: CTRL-ALT-DEL				

Note: The “?” character indicates a LOS (Loss Of Signal) this feature is not present in systems utilising the SDC-14560 Synchro Hybrid IC.

2.1 Software Revision

The Revision number of the TS2000 software is shown at the top of this page. The current revision number is “**\$Revision 3.0 \$**”.

2.2 Status Display Parameter Definitions

2.2.1 Az (deg) Parameter definition.

Current azimuth angle of the antenna dish in degrees. 0 degrees is north. Clock Wise (CW) and Counter Clock Wise (CCW) is the movement of the Antenna whilst looking down from above.

2.2.2 El. (deg) Parameter definition.

Current elevation angle of the antenna dish in degrees. 0 degrees is the Antenna looking to the horizon. 90 degrees is the Antenna looking to Zenith.

2.2.3 Beacon Level. (dB)

Strength in dB of the received beacon signal sent by the tracked satellite.

2.2.4 Satellite Name.

Three character name given to an individual satellite. Often the satellite orbital position is used to name the satellite.

e.g. 063 may signify that the 63_E longitude satellite is being tracked.

2.2.5 Polariser. (deg) Parameter definition.

Displays the polarizing angle ONLY if a Polariser is used on the antenna dish. If a Polariser is not used then a message 'Polariser is not connected' is displayed. If the System uses the SDC-14560 Synchro/Resolver to digital converters and there is no Polariser system installed then the Est. Speed setting should be set to 0 (zero).

2.2.6 ATCU Mode.

The current mode of the ATCU is shown here.

2.2.7 Time & Date.

(HH:MM:SS), (DD:MM:YY): The current time and date appear, relative to the global position of the satellite. Time is usually set to GMT. This time is required by the Intelsat Data in order to commence the Intelsat Mode of tracking.

2.2.8 Last Alarms

The five most recent, and still active alarms will appear in this section of the Status Display page. To view and selectively clear these alarms, go to the Alarm List log using the key-strokes **<Alt-A>**.

2.2.9 Keyboard Controls

At the bottom of the Status Display page there is a row of keyboard controls which enable the operator to view and edit other relevant TS2000 data.

<Alt-C> Control Mode selection and manual antenna control.

<Alt-A> Alarm List Log of all alarms past and present, generated by the TS2000 system.

<Alt-M>Maintenance. Three sets of pages containing information regarding antenna and satellite parameters. These include the Intelsat parameters. The last page also shows the serial communications traffic between the ATCU and a remote computer.

<Ctrl-Alt-Del>Quit This command will terminate the TS2000 ATCU program. This can be done at any time, and returns the operator to the DOS prompt. From here two actions are possible (other than normal DOS commands):

type:- **ts2 <Enter>** Restarts the T2000 ATCU program.

or

type:- **nvclear <Enter>** And follow the instructions.

Note that this action clears all of the permanently stored data such as the alarm log, the setup data, and Intelsat data. It also reloads all operating defaults from the FLASH RAM. Warning: this operation will permanently **ERASE** all setup data.

3 The "Tracking Control" page.

<Alt-C> opens the Tracking Control page.

Figure 4 Tracking Control Page.



TRACKING CONTROL	
COMMANDS	SYSTEM STATUS
MODE SELECTION:	MODE:
i - Intelsat mode	Current : STANDBY
n - iNitialisation mode	Fallback : INTELSAT Immediate
a - Autotrack mode	
p - Position mode	ANTENNA:
s - Scanning mode	Azimuth : 0.000 BAD Rdg
t - sTandby mode	Elevation : 0.000 BAD Rdg
f - change Fallback mode	Antenna State : Halted
	Antenna Motion :
ANTENNA MOVEMENT:	Antenna Speed : TRACK
(For high speed-combine with Shift)	
m - Move to 0.000 Az, 0.000 El	45.00 Pol
u - increase elevation	TRACKING:
d - decrease elevation	Beacon Level (dB) : -9.268
r - clockwise	AUTO-TRACK Status : inactive
l - counter clockwise	Active Track Stage : between seq
w - Stall Watchdog	Initialisation Stage : inactive
POLARISER MOVEMENT: (POSITION MODE ONLY)	
z - decrease; x - increase	Polariser Angle : 45.00 I

ALT-C for Status Display

3.1 Commands

All antenna and Polariser controls are available on this page, although if no Polariser is attached, the Polariser controls will not be visible.

3.2 ATCU Mode Selection

Table 1 ATCU Mode Selection



Command	Resultant Mode
I	Intelsat
N	Initialisation
A	Autotrack
P	Position
S	Scanning
T	Standby
F	Set Fallback mode

The Autotrack mode is the mode most commonly used by the TS2000. The ATCU must perform an initialisation sequence before it can enter the Autotrack mode for the first time. The general sequence is

1. Position Mode or Intelsat move to general Satellite position.
2. Scan Mode until Satellite Beacon is found.
3. Initialisation Mode so ATCU can calculate Satellite location.
4. Autotrack Mode. Satellite acquisition complete ATCU will now track the satellite until stopped.

For more information on these modes see section 3.6 below

3.3 Manual Antenna movement.

The azimuth and elevation angles can be set to user defined values to enable a 'Position' mode movement of the antenna dish.

Table 2 Manual Antenna movement.

Command	Result
u,U	↑ Increase the commanded elevation angle.
d,D	↓ Decrease the commanded elevation angle.
r,R	Increase the commanded azimuth angle (clockwise).
i,I	Decrease the commanded azimuth angle anti-clockwise.
m,M	Execute a 'Position' mode movement of the antenna dish.

Note:

The lower case commands provide fine angle adjustments. The uppercase commands provide coarse angle adjustments. The lowercase 'm' executes a move at track speed whilst an uppercase 'M' executes a move at slew speed.

3.4 Watchdog Timer

The watchdog timer supervises the software by requiring that the software write to a particular port at set intervals. If the software fails to write to the port than the Watchdog will issue a hardware reset so that the Tracking system can re initialise itself. In the event of a reset occurring, the ATCU will be temporarily interrupted whilst it reboots and recommences operation.

Table 3 Watchdog Timer

Command	Result
W	Stops the software writing to the watchdog timer.

3.5 Manual Polariser movement.

These two commands enable the Polariser angle to be changed.

Table 4 Manual Polariser movement

Command	Result
X	↑ Increase the commanded Polariser angle.
Z	↓ Decrease the commanded Polariser angle.

One key stroke of either of these keys starts a continuing change in the angle. A second key stroke halts the angle change.

Note that this action causes the existing Polariser angle to be stored as the preset angle for the satellite currently being tracked.

Press <Alt-C> to return to the Status Display.

3.6 ATCU Modes of Operation

The TS2000 has six modes of operation, described as follows:-

3.6.1 Standby Mode

In this mode, all computer activation of the motor drives is inhibited and the ATCU is in a safe state for the alteration of basic parameters. This mode is used while the antenna or tracking system is undergoing maintenance or diagnostic procedures.

3.6.2 Position Mode

Position mode has been provided to allow the antenna to be driven to a specified azimuth and elevation. The desired position is entered while the ATCU is in Standby or Position mode, and Position Mode is selected to initiate the move. Upon completion of the move, the antenna is automatically halted and returned to the Standby mode. (see previous page for keyboard command keys).

3.6.3 Intelsat Mode

This mode of operation utilises standard Intelsat ephemeris parameters to determine the location of the satellite. In the event that Intelsat mode becomes active, the ATCU will determine, from this data, the pointing information for the selected satellite at the current system clock time. The parameters for up to 10 satellites may be programmed into the ATCU at any time.

At regular, user defined intervals, the antenna pointing values are calculated and the antenna position is updated to continue operation with the satellite.

Since the system is not closed loop, the tracking accuracy is limited by the accuracy of the model and parameters, the user defined update interval, the accuracy of the system clock, the mechanical and structural accuracy of the antenna, and the position encoding electronics.

3.6.4 Autotrack Mode

The principal operation of the TS2000 is the Autotrack mode. In this mode, the ATCU uses beacon signal measurements to determine the accuracy with which it is pointing to the satellite, and information from previous moves to develop a model of the satellite's motion.

The model of the satellite orbit allows the ATCU to minimise tracking system moves while maintaining the most consistent signal levels. This is particularly important for satellites in highly inclined orbits. It also permits accurate tracking to continue during periods of lost or degraded beacon performance.

3.6.5 Initialisation Mode

This mode is used when tracking is first commenced on a satellite, or restarted after the tracking model has deteriorated. This mode is often referred to as the "cold start" mode signifying a tracking start with no useable tracking model available. After completing the initialisation, the TS2000 ATCU will automatically select the Autotrack mode, unless interrupted by selection of an alternate mode, or a valid tracking signal was not found. (see page 17 of 36 for Initialisation pattern, Figure 9.)

Scanning Mode

The scanning mode moves the antenna in a counter-clockwise 'square' spiral. The track separation and box limit are set by the operator. The scan mode will continue until:-

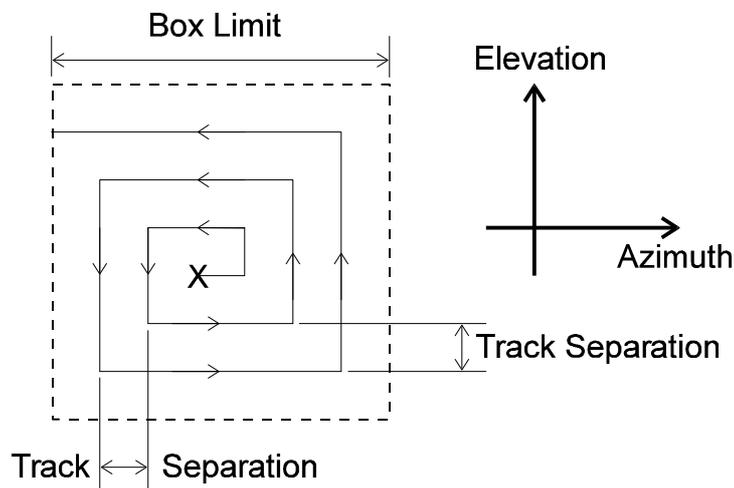
The deviation from the initial position 'X' exceeds + the box limit.

The time since commencing the scan exceeds the user specified limit.

The beacon signal becomes valid. That is, the beacon signal returns to within the user specified limits, and the signal's rate of change is not positive.

Initialisation will commence upon reception of a valid beacon signal. If no beacon signal is found, the ATCU will fall back into Standby mode.

Figure 5 The Scanning Pattern



No fixed procedure is required when selecting a new operational mode as each mode change is preceded by an automatically generated halt instruction, before the new mode becomes effective.

3.7 Setting The Fallback Mode

Three different fallback conditions may be programmed into the ATCU. This may be done in the Tracking Control page. Typing <f> several times, toggles between the three choices.

These modes take effect if, in Autotrack mode, the beacon signal moves beyond the set minimum or maximum. The fall back conditions selectable are:

3.7.1 Standby.

The ATCU reverts to Standby mode, bringing all antenna motion operations to a halt.

3.7.2 Intelsat Immediate.

The ATCU reverts to Intelsat mode. Intelsat mode is entered if all of the following are true:

TS2000 is operating in Autotrack mode.

Beacon signal strength moves outside the present limits.

Intelsat data for the current satellite is valid.

3.7.3 Intelsat Delayed.

The ATCU stays in Autotrack mode until the model is too old. It then moves to Intelsat mode. Intelsat mode is entered if all of the following are true:-

TS2000 is operating in Autotrack mode.

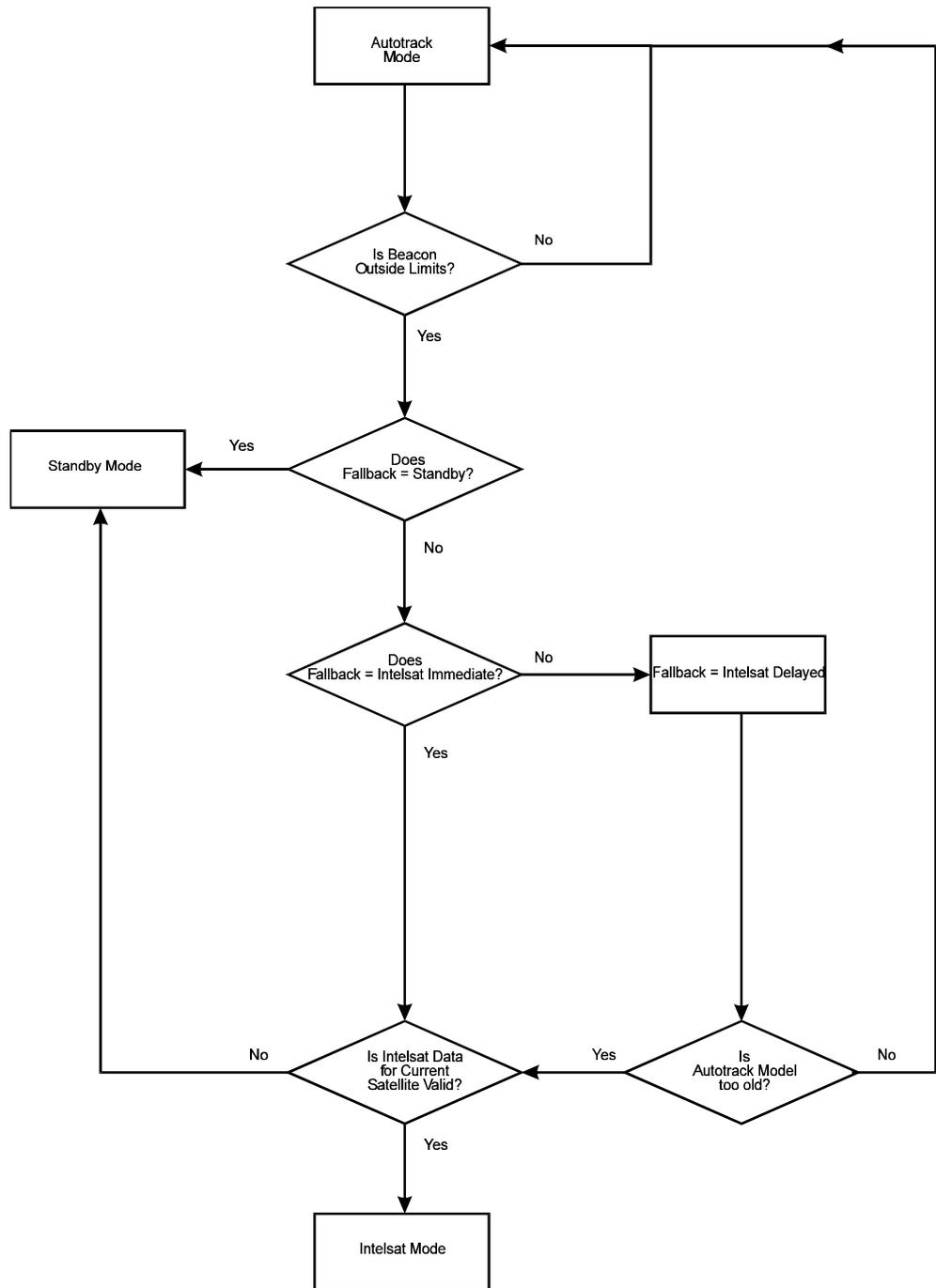
Beacon signal strength moves outside the present limits.

Autotrack has been following its model for long enough for the accuracy to be deteriorating.

Intelsat data for the current satellite is valid.

The on shows how the ATCU will select which mode it will enter when the beacon signal exceeds its limits.

Figure 6 ATCU Fallback Modes.



3.8 System Status

3.8.1 Mode (Current)

Shows the current ATCU mode and the currently selected Fallback mode.

3.8.2 Antenna (Current)

The current antenna pointing elevation and azimuth angles are shown. The antenna state of motion is shown as halted or moving. The antenna motion at the present time is shown as one or a combination of the following:

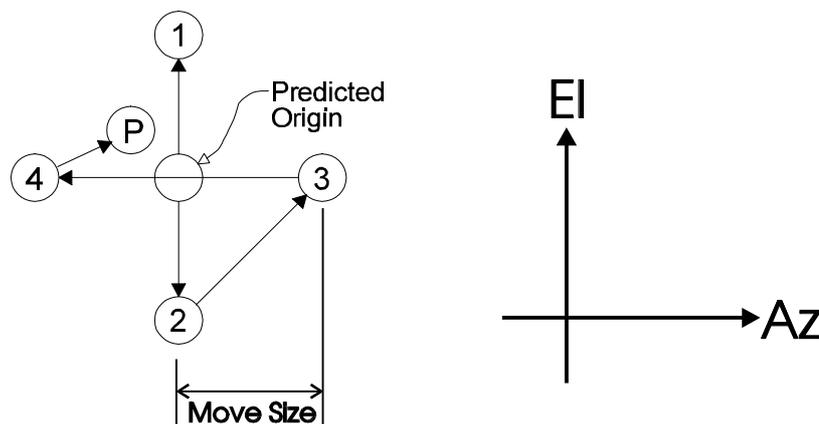
AzCW	Clockwise Azimuth direction
AzCCW	Counter-Clockwise Azimuth direction
EIUp	Elevation up direction
EIDown	Elevation down direction

The antenna speed shows whether movement is selected to move fast (slewing) or slow (tracking). Slewing speed will only operate for a 'Position' mode movement. For all other movement modes, tracking speed is set as default.

3.8.3 Tracking

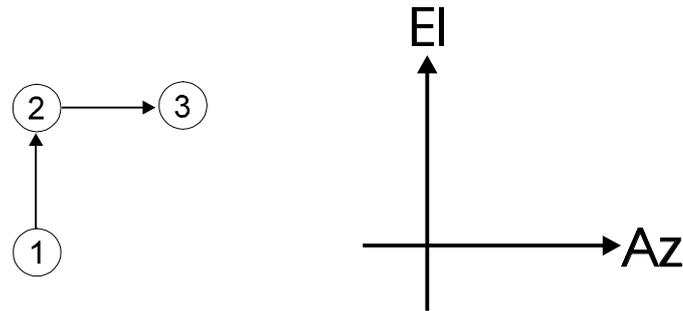
Shows the beacon signal strength, Beacon level (dB). The Auto-track status shows whether the ATCU is actively tracking a satellite in Autotrack mode (*tracking*), or not (*inactive*). The Active track stage shows the sequence that the TS2000 is completing. If no sequence is active "between seq.' is displayed. Different levels of a four point scanning sequence may be shown, which occurs regularly to update the auto-track model.

Figure 7 Four point, scanning sequence.



When the confidence in the ability of the model to accurately predict the satellite motion is sufficiently high, the ATCU will use a 3 point scan, further minimising antenna movements.

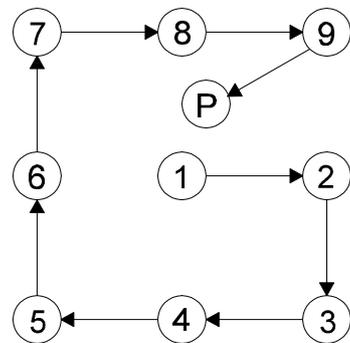
Figure 8 Three point, scanning sequence.



3.8.4 Initialisation Stage

The Initialisation stage shows the steps of the initialisation mode, which is a nine point scanning sequence to determine the most accurate pointing angle to the satellite.

Table 5 Nine Point Scanning Sequence



4 The Alarm List Page.

<Alt-A> opens the Alarm List shown in **Error! Reference source not found.** page.

<ALT-A> a second time will return you back to the Status Page.

Figure 9 Alarm List.



ALARM LIST		20/01/1995 04:04:28	
Number	Description	Time & Date Received	
034	Software security device error	09:05:35	20/01/95
085	Reference Supply power failure	09:05:35	20/01/95
064	Beacon signal below minimum limit	09:18:03	20/01/95
***** LAST ENTRY *****			
<div style="display: flex; justify-content: space-between;"> <div style="border: 1px solid black; padding: 2px;">Selected</div> <div>To select the alarm to be reset, and to scroll: ↑ or ↓</div> </div> <div style="display: flex; justify-content: space-between;"> <div>Active</div> <div>To clear SELECTED alarm: C</div> </div> <div style="display: flex; justify-content: space-between;"> <div>Cleared</div> <div>To reset ALL alarms: R</div> <div>ALT-A for Status Display</div> </div>			

This page is a historical log of alarms both active and inactive which have occurred to TS2000 since the last deletion¹ of the non-volatile RAM (NVRAM). A brief description of each alarm is shown as well as the time and date of each alarm occurrence.

The following single key operations can be performed on this page:

- Scroll through the logged alarm list.
- C** Clear or reset a selected (highlighted) alarm.
- R** Reset all active alarms.
- <Alt-A>** Return to Status Display.

¹ See NVCLEAR command.

5 The Maintenance Pages.

<Alt-M> opens the first of three maintenance pages, from the Status Display.

Maintenance is a series of three pages. The first two provide access to parameters stored in non-volatile RAM within the ATCU. The third page provides a view of any communication flow between the ATCU and controlling and/or monitoring CMUs.

All parameters on the first two pages, other than the Control point, Operating and Fallback modes, may be changed. The cursor is shown as text in reverse colour to all other text. The cursor can be moved within a group using arrow keys, and beyond to other groups using the **<Tab>** key. The selected item is altered by typing the new value and pressing the **<Return>** key.

Figure 10 Stored General Data.



STORED GENERAL DATA		20/01/1995 04:44:35																																				
Control point: RCMU Mode: STANDBY Fallback Mode: INTELSAT Immediate Values in Degrees, Degrees/second, Minutes, dB, V/dB, and Km																																						
<table border="1"> <thead> <tr><th colspan="2">AZIMUTH SETUP</th></tr> </thead> <tbody> <tr><td>Coarse angle</td><td>0.00</td></tr> <tr><td>Offset angle</td><td>0.00</td></tr> <tr><td>Gear ratio</td><td>1</td></tr> <tr><td>Est. speed</td><td>0.002</td></tr> <tr><td>Dead band</td><td>0.01</td></tr> </tbody> </table>	AZIMUTH SETUP		Coarse angle	0.00	Offset angle	0.00	Gear ratio	1	Est. speed	0.002	Dead band	0.01	<table border="1"> <thead> <tr><th colspan="2">ELEVATION SETUP</th></tr> </thead> <tbody> <tr><td>Coarse angle</td><td>0.00</td></tr> <tr><td>Offset angle</td><td>0.00</td></tr> <tr><td>Gear ratio</td><td>1</td></tr> <tr><td>Est. speed</td><td>0.002</td></tr> <tr><td>Dead band</td><td>0.01</td></tr> </tbody> </table>	ELEVATION SETUP		Coarse angle	0.00	Offset angle	0.00	Gear ratio	1	Est. speed	0.002	Dead band	0.01	<table border="1"> <thead> <tr><th colspan="2">POLARISER SETUP</th></tr> </thead> <tbody> <tr><td>Coarse angle</td><td>0.00</td></tr> <tr><td>Offset angle</td><td>0.00</td></tr> <tr><td>Gear ratio</td><td>1.00</td></tr> <tr><td>Est. speed</td><td>1.000</td></tr> <tr><td>Dead band</td><td>0.20</td></tr> </tbody> </table>	POLARISER SETUP		Coarse angle	0.00	Offset angle	0.00	Gear ratio	1.00	Est. speed	1.000	Dead band	0.20
AZIMUTH SETUP																																						
Coarse angle	0.00																																					
Offset angle	0.00																																					
Gear ratio	1																																					
Est. speed	0.002																																					
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Gear ratio	1.00																																					
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Dead band	0.20																																					
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5.1 Azimuth, Elevation and Polariser Setups.

The following sections describe the parameters used with regard to axis measurements.

5.1.1 Coarse Angle. (deg)

The coarse angle is the angle at which the antenna is pointing the instant the TS2000 begins to monitor the Synchro / Resolvers. These values of azimuth and elevation, let the position encoder (Resolver or Synchro) know in which sector the angle lies, which it is measuring.

5.1.2 Offset Angle (deg)

The offset angle is used to finely tune the pointing angle.

$$\text{Offset Angle} = \text{Coarse Angle} - \text{Displayed Angle.}$$

5.1.3 Gear Ratio.

This value allows for the use of high accuracy, multiple speed synchro / resolvers. Eg. for a 5 x speed synchro, the gear ratio will be 5 (5:1). Multiple speed means that the Synchro or Resolver is electrically or mechanically geared so that it will measurably rotate faster than the antenna. In the above example the synchro or resolver would pass through $5 * 360$ degrees for one revolution of the antenna.

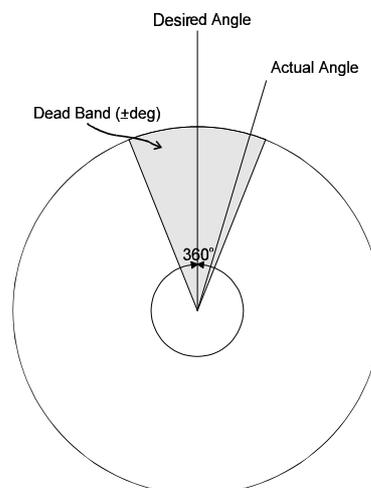
5.1.4 Est. Speed. (deg/sec)

The established speed is defined as the track speed of the antenna. This should be measured during installation or from known information on the antenna.

5.1.5 Dead Band. (deg)

The angle between the actual position and desired position when motion is inhibited. This value should be increased if oscillations occur on any of the antennas axes, though the size of the value becomes a trade-off between the pointing accuracy of the antenna and its ability to not oscillate (or hunt) during movement.

Table 6 Dead Band.



5.2 SW Travel Limits.

These angles may be set to limit the angle of movement of the dish if a fault occurs. They must be set outside the normal motion angles.

Table 7 Software travel limit description.

Parameter	Description
Az CCW	maximum azimuth angle.
Az CW	minimum azimuth angle.
EI min	minimum elevation angle.
EI max	maximum elevation angle.

5.2.1 Beacon Limits. (dB)

The maximum and minimum beacon limits (dB) are specified to give the Autotrack mode a valid range of beacon levels from which to build its tracking model. Typical values are:

Maximum Beacon Limit = 5 dB

Minimum Beacon Limit = -5 dB

5.2.2 Gradient. (V/dB)

The beacon sensitivity is the Gradient between the RF input to the beacon receiver and the DC output of the beacon receiver.

If the gradient is set to 1 V/dB, a 1 dB decrease in the RF input beacon signal should result in a 1 V decrease in the DC output voltage.

If a decreasing (i.e. a more negative) DC voltage represents an increasing beacon level, then the gradient must be set to its negative value, otherwise it should be positive.

5.2.3 Max Rate. (dB/sec)

This is the maximum beacon slew rate that the earth station should expect to see from a particular satellite being tracked. This parameter is used to reduce the effect of beacon signal fades and scintillation's. If, during a tracking sequence and while the antenna is stationary, the average (over a 3.5 second interval) beacon rate of change exceeds this value, the beacon measurements from this tracking sequence will not be used to update the model. Typically the TS2000 has a maximum rate:

Max rate = 0.3 dB/sec.

5.2.4 Tracking Parameters.

Max Time Inc. (min)

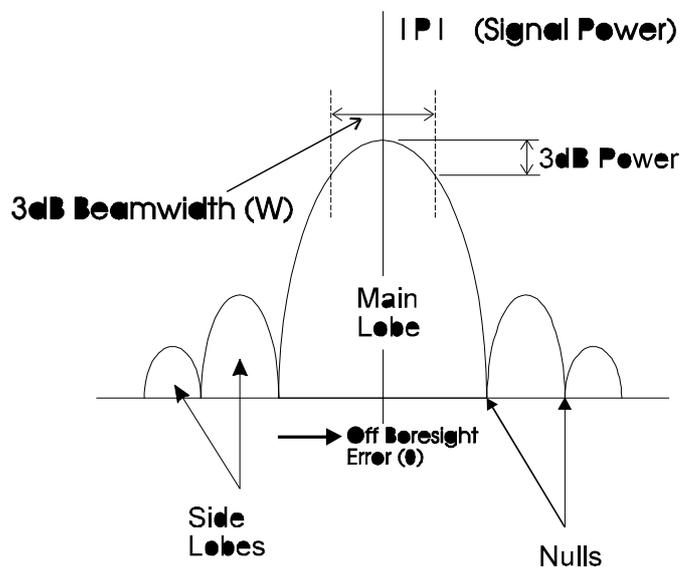
Setting this value forces to TS2000 to repoint at least once within that time limit, in addition to several other predicted moves it must make. This is mainly of use for satellites on low inclination orbits where it is not necessary to perform frequent moves for tracking. The value is normally specified as:

Max time inc = 60 minutes.

5.2.5 Beamwidth. (deg)

The radiation pattern of electromagnetic waves from an antenna is typically of the following form:

Figure 11 Antenna Signal Radiation Pattern.



The 3dB (half power) beamwidth is the distance between the 3dB points of the main lobe. This ensures that a strong signal is received. For an ideal antenna, the 3dB beamwidth may be approximated as follows:

$$W = 3dB\text{Beamwidth} \approx \frac{21.1}{fd}$$

Where: f = Signal Frequency (GHz), of the beacon/tracking signal

d = Antenna Dish Diameter (m)

The beam pattern near the peak is assumed to be approximately

$$P = P_0 - 12 \frac{q^2}{W^2}$$

5.2.6 Move Size. (deg)

This is the step size used in Autotrack and the Initialisation mode. It influences the time between moves and the size of moves in Autotrack mode. A smaller move size will generally result in the ATCU generating a larger number of smaller size movements. This limit prevents the dish from drifting away from the satellite. The move size is usually specified to be 5% to 10% of the 3dB beamwidth in order to give a 0.05dB tracking accuracy. The specified move size is for the elevation only. The azimuth move size is secant corrected internally in the ATCU as:

$$\text{Az Move Size} = \frac{\text{Move Size}}{\cos(\text{Elevation})}$$

5.3 Scanning Data. (Table 5)

5.3.1 Time Limit. (min)

The time limit is the maximum period of time that the ATCU can perform a scanning command.

5.3.2 Box Limit. (deg)

The box limit limits the area in which the scanning occurs. If the deviation from the initial pointing angle exceeds + the box limit, the scanning ceases.

5.3.3 Track Sepn. (deg)

The track separation is the separation between each sweep during the scan.

5.3.4 Station Data.

This is the location of the earth station.

5.3.5 Latitude. (deg)

Earth station latitude: N: positive.

S: negative.

5.3.6 Longitude. (deg)

Earth station longitude: E: positive.

W: negative.

5.3.7 Height. (Km)

Distance of earth station above sea level.

5.3.8 Mount "Tilt" and "Twist". (deg)

Mount twist and mount tilt are correction angles for the Intelsat azimuth and elevation angles only, where non-standard mounts are used, or a misalignment of the structure occurs.

The given "untilted" azimuth and elevation coordinates (spherical) are converted to a unit vector in Cartesian coordinates:

$$x = \cos(e) \cos (az)$$

$$y = \cos(\theta) \sin(\alpha z)$$

$$x = \sin(\theta)$$

Where: x is the local north direction
 y is the local east direction
 z is the local zenith

Twist is a rotation about the local zenith (vertical) by:

Equation 1 Twist.

$$\begin{bmatrix} \bar{x} \\ \bar{y} \\ \bar{z} \end{bmatrix} = \begin{bmatrix} \cos(\text{twist}) & -\sin(\text{twist}) & 0 \\ \sin(\text{twist}) & \cos(\text{twist}) & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix}$$

With the newly located x and y axes (i.e. the “twisted” axes), the axes are tilted about the new y axis as follows:

Equation 2 Tilt.

$$\begin{bmatrix} x' \\ y' \\ z' \end{bmatrix} = \begin{bmatrix} \cos(\text{tilt}) & 0 & \sin(\text{tilt}) \\ 0 & 1 & 0 \\ -\sin(\text{tilt}) & 0 & \cos(\text{tilt}) \end{bmatrix} \begin{bmatrix} \bar{x} \\ \bar{y} \\ \bar{z} \end{bmatrix}$$

The final Cartesian coordinates (x' , y' , z') are converted to spherical coordinates to give the required tilted azimuth and elevation.

5.4 Serial Communications.

The serial communication parameters for connection with a CMU can be set here. The default settings are (options in brackets):

Table 8 Serial Communications settings.

Parameter	Default	Range of allowed values
Baud Rate:	2400	(1200, 2400, 4800, 9600)
Data Bits:	8	(7, 8)
Stop Bits:	1	(1, 1.5, 2)
Parity:	0	(0 = None, 1 = Odd, 2 = Even)

Note:

These settings should match the settings on the Control and monitoring unit, CMU.

6 Stored Satellite Data.

<Alt-M> move from “maintenance page one” to maintenance page two (Stored Satellite Data).

This page will hold the Intelsat data for up to 10 individual satellites. It also shows the current satellite being tracked.

Figure 12 Stored Satellite Data.



Current satellite: 0		STORED SATELLITE DATA									
Sat. No:	0	1	2	3	4	5	6	7	8	9	
Name	def	def	def	def	def	def	def	def	def	def	
Beacon	15	15	15	15	15	15	15	15	15	15	
Ref lvi	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Pol Ang	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Ref Lat	-33.70	-33.70	-33.70	-33.70	-33.70	-33.70	-33.70	-33.70	-33.70	-33.70	
INTELSAT DATA											
Lm0	177.00	177.00	177.00	177.00	177.00	177.00	177.00	177.00	177.00	177.00	
Lm1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
Lm2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
Lonc	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
Lonc1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
Lons	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
Lons1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
Latc	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
Latc1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
Lats	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
Lats1	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
Edate	010193	010193	010193	010193	010193	010193	010193	010193	010193	010193	
Etime	000000	000000	000000	000000	000000	000000	000000	000000	000000	000000	
durat	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	
incr	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	
ALT-M for next page											

6.1.1 Name.

This is the satellites given name.

6.1.2 Beacon.

The beacon receiver is often programmed so that a four bit number corresponds to a certain beacon frequency sent by the satellite, as all satellites send these beacon signals at different frequencies. The beacon number set on this page, tells the beacon receiver which beacon frequency it is looking for, in order for the TS2000 to accurately track the satellite with that beacon signal frequency.

Note

The beacon DC TRACKING SIGNAL (J2 on the Reference Supply) does not supply the beacon select data. This comes from BEACON RX connection (J1 on the Reference Supply) in the form of a four bit binary signal with a strobing command signal.

6.1.3 Ref Lvl.

The reference level is an adjustment that allows the optimal or 'Blue Sky' beacon level to be set to 0dB, in order to give a reference to the strength of future beacon signals.

6.1.4 Pol Ang. (deg)

This is the angle of the polariser (Unavailable) on the satellite with respect to vertical. (0° is vertical).

6.1.5 Ref Lat. (deg)

A satellite in an inclined orbit is continually repositioned so that it points at a single "reference" earth station. This is the latitude of the reference earth station, and is required if linear polarisation is used.

6.1.6 Intelsat Parameters.

These parameters are provided by the satellite operator. The first 11 parameters describe the satellites motion. This is referred to as 'Ephemeris Data'. The epoch date and epoch time are used as a basis for the ephemeris data. The symbols used on this maintenance page correlate with those used by Intelsat².

Table 9 Ephemeris Data.

	Symbol	Quantity
1	Lm0	Mean longitude (East of Greenwich).
2	Lm1	Drift rate.
3	Lm2	Drift acceleration.
4	Lonc	Longitude oscillation-amplitude,
5	Lonc1	& rate of change COS term.
6	Lons	Longitude oscillation-amplitude,
7	Lons1	& rate of change SIN term.
8	Latc	Latitude oscillation amplitude,
9	Latc1	& rate of change COS term.
10	Lats	Latitude oscillation-amplitude,
11	Lats1	& rate of change SIN term.
A	Edate	Date at which ephemeris data is based.
B	Etime	Time at which ephemeris data is based.

Note:

If the satellite being tracked causes numerous satellite orbit change alarms to be generated, even when the satellites orbit is known not to have changed, this may be due to an unusually large amplitude in the oscillation parameters.

² Inclined Orbit Satellite Operation in the Intelsat System, R Chang & L Veenstra, March 1989.

6.1.7 Durat. (days)

The duration is the number of days over which the Intelsat data should be valid for. This is usually a period of seven days. It may be set to more or fewer days depending on the required accuracy. A warning will alert the operator when the duration has expired.

Incr. (min)

The increment is a period of minutes between antenna moves when operating in Intelsat Mode. The shorter the time period, the more accurate the pointing angle but also the more wear and tear on the elevation and azimuth jack screws. The increment size depends on orbit inclination and desired tracking accuracy.

For a given accuracy, (e.g.: x dB), a bore sight error is required as follows:

Equation 3 Bore sight error.

$$\Delta q_B = (x/12)B^{1/2}W$$

This error, if equally spread between the two axes, means a tracking error for each axis (secant corrected for azimuth) as follows:

Equation 4 Tracking error.

$$\begin{aligned} f &\approx 2p(\mathbf{a})\text{Deg} / \text{Day}. \\ &\approx 0.004(\mathbf{a})\text{Deg} / \text{Day}. \end{aligned}$$

Since the ATCU predicts ahead by 0.5(Incr), the worst case error is:

Equation 5 Worst case error.

$$\Delta q_A = (1/2)(\text{Incr}) \cdot f = 0.0022(\mathbf{a})(\text{Incr}) \text{deg}.$$

Comparing this with the above Equation 5, gives:

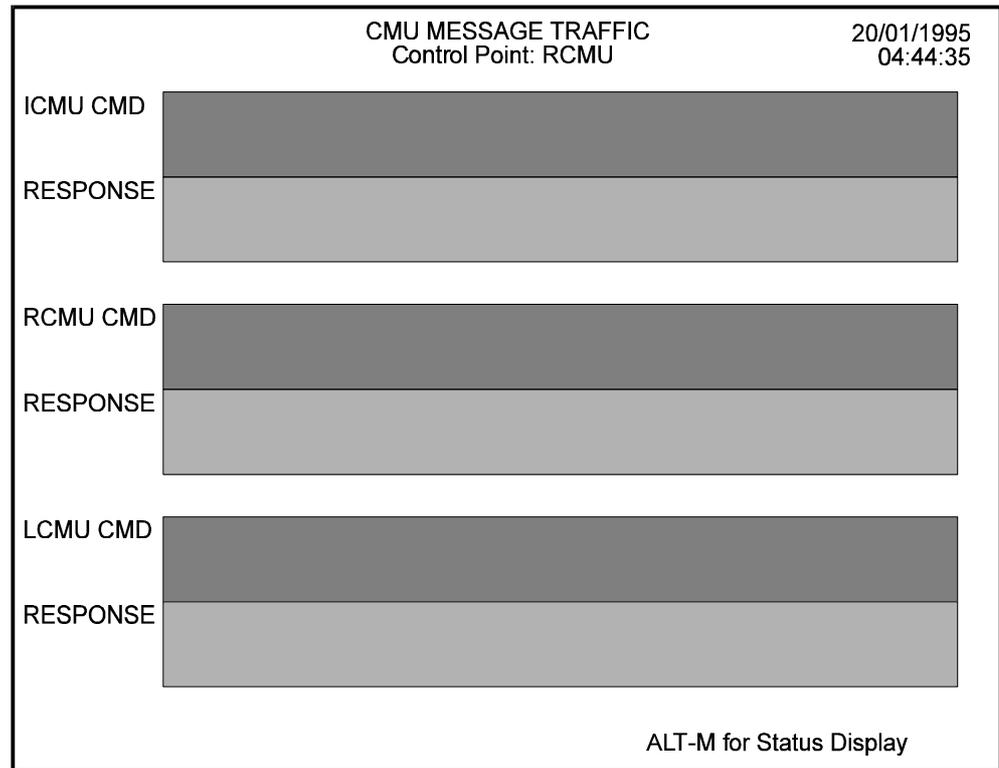
Equation 6 Incremental Period.

$$(\text{Incr}) = (\sqrt{x}W/a)(93) \text{min}.$$

7 CMU Message Traffic.

<Alt-M> to move from maintenance page 2 (Stored Satellite Data) to maintenance page 3 (CMU Message Traffic).

Figure 13 CMU message traffic.



This maintenance page shows messages received on each of the two CMU serial data channels, and the ATCU's response. A third window shows message traffic between the ATCU and its own in-built "Internal CMU". This window together with the keyboard, may be used to check the ATCU response messages entered via the keyboard, which comply with the CMU message protocol. (Not normally required for use).

<Alt-M> moves back to the Status Display.

8 Alarms

There are two levels or categories of alarm generated within TS2000. The category of alarm depends upon its severity as determined by its potential to cause loss of traffic or danger to the integrity of the antenna and personnel.

8.1 Major

Alarms indicate conditions that are of sufficient severity to make unsafe or unwise the continued operation of the tracking system until the cause has been rectified. Upon the generation of a major alarm TS2000 will automatically select the Standby mode, halting tracking. Until the alarm condition is cleared, TS2000 will not accept a subsequent mode change command.

8.2 Minor

Alarms indicate the existence of a condition that, if left unattended, may become of significance and cause tracking to cease. Some minor alarms, that is Beacon Level alarms and Reference Supply Failure alarm are self clearing if the fault condition clears. All other alarm indications must be cleared by the operator.

In addition to providing an alarm indication on the CMU terminal a Major and Minor alarm summary contact is provided for connection to local alarm boards or PLC equipment.

8.3 Major Alarm List

The following table provides a list of the Major Alarms generated by the ACU and a brief explanatory note on the likely cause. It must be noted that in a system as complex as a tracking system the indicated cause may represent only a symptom of the actual fault condition. That is, the fault detected by TS2000 may not necessarily be the root cause of the problem.

Table 10 Major Alarm List.

Alarm Number	Description	Cause
000	Emergency stop pressed	The emergency stop switch circuit is open.
001	Clockwise hardware limit	The Clockwise limit switch circuit is open.
002	Anticlockwise hardware limit	The Anticlockwise limit switch circuit is open.
004	Up hardware limit	The Up limit switch circuit is open.
005	Down hardware limit	The Down limit switch circuit is open.
009	Command is beyond Clockwise software limit	An azimuth move command has been received requiring an antenna position outside the set Clockwise software limit.
010	Command is beyond Anticlockwise software limit	An azimuth move command has been received requiring an antenna position outside the set Anticlockwise software limit.
011	Command is beyond Up software limit	An elevation move command has been received requiring an antenna position outside the set Up software limit.
012	Command is beyond Down software limit	An elevation move command has been received requiring an antenna position outside the set Down elevation software limit.
015	Timeout on antenna move	The ACU has activated the antenna motor drive for an excessive amount of time without detecting that the antenna has reached the commanded position.
033	Intelsat data is not current	While in INTELSAT Mode, the data was determined to be more than 2 days past the set data duration.
034	Software security device error	The software security dongle was not present or operating.
035	Data store checksum failure	Data requested from non-volatile storage was garbled.
036	Illegal clock data at startup	The clock has illegal time and or date.
044	Autotrack warm start attempted with no model	Autotrack mode was entered when no model existed.
045	Bad beacon signal during Initialisation	No acceptable beacon signal level was detected during the Initialisation sequence.
046	Beacon signal bad and Autotrack model too old	While tracking in Autotrack mode, the tracking signal fell outside the set limits, the model was too old to use, and a fallback to Intelsat mode was not possible.

Alarm Number	Description	Cause
047	Reference Supply failure during Initialisation	A Reference Supply failure was detected during the Initialisation sequence.
049	New STORE files started	On startup, no pre-existing stored data was found. Default values will be used.
050	No STORE available	No non-volatile storage hardware is available.
051	Drives are under Manual control	The antenna drives are under manual control.
064	Beacon signal below minimum limit	The beacon level has dropped below the set level (self cancelling).
065	Beacon signal above maximum limit	The beacon has risen above the set maximum (self cancelling).
066	Model accuracy poor	While tracking in Autotrack mode, the tracking signal fell outside the set limits, the model accuracy was low but useable, and a fallback to Intelsat mode is not possible.
070	Apparent change in satellite orbit change detected	Autotrack Mode has detected a possible orbit change in the satellite. Update of INTELSAT parameters may be required.
072	Azimuth encoder signals low	Low signal has been reported from the azimuth encoder. This inhibits antenna motion commands.
074	Elevation encoder signals low	Low signal has been reported from the elevation encoder. This inhibits antenna motion commands.
076	Intelsat data is decaying	While in INTELSAT Mode the INTELSAT data has been used for longer than the defined duration.
077	Processor reset due to watchdog timeout	A processor reset has been initiated by the watchdog timer.
078	Fallback to Intelsat model has occurred	While in Autotrack mode, a fallback to Intelsat mode has occurred.
081	Remote CMU syntax error	A syntax error was detected in a message from the RCMU.
082	RCMU command value out of range	The RCMU-initiated command contained a value outside the allowed range for the function.
083	Two sec timeout on remote CMU message	Only part of an otherwise valid message was received from the RCMU.
084	RCMU command not obeyed - Wrong control point or mode	A valid command was received from the RCMU, but it could not be executed as the RCMU did not have control or TS2000 was in the wrong mode.
085	Reference Supply power failure	Reference supply power failure, while the mode was other than Initialisation (self cancelling).
086	Sequencer overrun has occurred	A program cycle exceeded its normal time limit.
088	Scan has found a beacon	Termination of a successful scan search for a beacon.
089	Scan has not found a beacon within the time limit	Termination of an unsuccessful scan search for a beacon, due to expiration of the set time limit.
090	Scan has not found a beacon within the search box	Termination of an unsuccessful scan search for a beacon, due to the search reaching the set search box limits.
091	Local CMU syntax error	A syntax error was detected in a message from the LCMU.
092	LCMU command value out of range	The LCMU-initiated command contained a value outside the allowed range for the function..
093	Two sec timeout on local CMU message	Only part of an otherwise valid message was received from the LCMU.
094	LCMU command not obeyed - Wrong control point or mode	A valid command was received from the LCMU, but it could not be executed as the LCMU did not have control or TS2000 was in the wrong mode.
105	Polariser is at its clockwise limit	The polariser clockwise limit switch circuit is open.
106	Polariser is at its anticlockwise limit	The polariser anticlockwise limit switch circuit is open.
107	Timeout on Polariser move	The ACU has activated the polariser motor drive for an excessive amount of time without detecting that the polariser has reached the commanded position.

9 TS2000 Hardware Specifications

Table 11 Hardware specifications.

<u>Front Panel Controls</u>	Power ON/OFF CPU Reset	
<u>Front Panel Indicators</u>	Power On	
<u>Rear Panel Connectors</u>		
<i>Inputs</i>	240VAC 50Hz Beacon Motor Control Limit Switches Elevation Resolver / Synchro Azimuth Resolver / Synchro Polariser Resolver / Synchro	
<i>Outputs</i>	Azimuth Control Elevation Control Beacon Select Polariser Control Emergency Stop Major Alarm Minor Alarm	
<u>Power</u>	240VAC_10% 5A max	
<u>Environmental</u>	Temperature Humidity	0°C to 50°C 95% at 40°C
<u>Mechanical</u>	All units are designed for mounting in a standard 19" equipment rack	
	ATCU	4 rack units(180 mm)
	Reference Supply	3 rack units (133 mm)
	Monitor (optional)	8 rack units (355 mm)
	Keyboard (optional)	1 rack unit (45 mm)
<u>Tracking Signal Input</u>	Level Range Sensitivity Stability	-10VDC to +10VDC 0.1 to 1.0 V/dB 0.1dB/sec

10 INSTALLATION AND COMMISSIONING

10.1 Physical

Inspect hardware for damage incurred during shipment. Ensure that the components used in the industrial computer have not become dislodged or damaged during transport. Securely mount the ATCU and reference supply in the rack positions allocated. Power up the ATCU and verify that the TS2000 boots correctly. Connect input power and wiring in accordance with the External wiring connections in Appendix A.

If the ATCU is to be installed in a location where the mains power supply is poor, consideration should be given to placing a power line conditioner between the ATCU and the mains. This will ensure reliable, long term operation.

10.2 Dead Band

Why is a dead band setting required? Due to the antenna's mass, the drives and the mechanical system latency, the antenna will not achieve instantaneous deceleration. Basically it will not stop when we tell it to stop, but shortly thereafter. The dead band should be adjusted after the positional encoders have been installed and calibrated.

The dead band setting is twice the magnitude of the measured antenna position minus the desired antenna position. Let us call this difference the *positional error*. If positional error is greater than half the dead band than the ATCU will assume that the drive system is capable of responding accurately enough to decrease the positional error, based on this assumption the ATCU will drive the antenna towards the desired position. If the dead band is too small then the antenna will overshoot the desired position. If the dead band is set too large than we will not gain the full accuracy of the system and signal strength may suffer.

- **Time.**
- **Date.**
- **Satellite Number.**
- **Satellite Name.**
- **Software Travel.**
- **Limits.**

10.2.1 Initial Setup

The following parameters at left should be set or verified prior to any other parameters or prior to the commencement of tracking. These parameters are:

10.3 Calibration with Beacon Receiver

Beacon Signal Strength and Beacon Reference parameters must be set in order to calibrate the ATCU with the tracking signal source, usually a Beacon Receiver.

This procedure **must not** be performed if the Beacon Signal is fluctuating or is not at its clear sky level due to a rain fade or other level instability.

10.3.1 Stepped Attenuator.

Connect a stepped attenuator at the RF input to the Beacon Receiver and peak the antenna on the satellite using Position Mode on the control page.

10.3.2 Set parameters.

Set the Beacon Parameters to the following initial settings:

Table 12 Beacon Receiver Calibration.

Parameter	Value	Location
Gradient	-0.5 V/dB	Figure 10 Stored General Data.
Ref Lvl	0.0 dB	Figure 12 Stored Satellite Data.
Min (limit)	-5 dB	Figure 10 Stored General Data.
Max (limit)	+5 dB	Figure 10 Stored General Data.

10.4 Decrease 1.0dB.

Using a stepped attenuator, decrease the input signal level by 1.0dB and note the change on the ATCU beacon reading.

10.5 Tolerance.

Adjust the DC gain of the Beacon Receiver tracking signal output until the change on the ATCU for a 1.0dB input change is 1.0 ± 0.1 dB. If the ATCU reading increases instead of decreases then change the sign of the gradient in step 2 from negative to positive.

10.6 Gradient.

In the event that the Beacon Receiver DC gain is not readily adjustable, then change the "gradient" parameter in the ATCU until the required 1.0 ± 0.1 dB change is obtained.

10.7 DC Offset.

Adjust the DC offset of the Beacon Receiver tracking signal output to obtain a beacon level of +5dB (or preferably +8dB) on the ATCU. If this level cannot be obtained, and the DC gain of the Beacon Receiver tracking output is adjustable, reduce the "gradient" parameter and repeat from step 3. This process aims to set the DC operating point such that the minimum beacon level corresponds to a DC voltage greater than 0V. This allows the ATCU to detect a beacon failure if the Beacon Receiver fails or is powered off since the DC voltage will fall to 0V under these conditions.

If the DC offset is not adjustable proceed with step 10.9 below.

10.8 Normalised.

Set the "Ref lvl" parameter to the value indicated on the ATCU Beacon level when the stepped attenuator is set to 0.0dB. This will result in the ATCU Beacon reading being normalised to 0.0dB.

10.9 1.0dB drop.

Switch in 1.0dB attenuation and verify that the ATCU beacon reading drops by 1.0 ± 0.1 dB.

10.10 -5dB on loss of power.

Turn off the Beacon Receiver and verify that the ATCU beacon level drops more than 5.0dB. Turn the power back on and confirm that the level is restored to 0.0dB.

10.11 Carrier to Noise Ratio

Note the antenna azimuth and elevation values before moving the antenna so that the satellite can be easily reacquired. Using Position Mode, drive the antenna off the satellite by at least 2 degrees in azimuth and record the decrease in the beacon level as the tracking signal "Carrier to Noise Ratio".

10.12 Results

Record all Beacon parameters and the C/N ratio for future reference.

11 Calibration for Position Sensors (Resolver / Synchro Setup)

For the TS2000 ATCU to display true pointing angles, it must be calibrated with the position sensors installed on the two axes of the antenna. The following procedure outlines the setup.

While carrying out the following, it is important that the antenna is peaked at the satellite. If the setup is carried out without the antenna being fully peaked, then serious errors will occur in pointing the antenna at the satellite during tracking modes. Accurate pointing can be ensured by checking the signal level displayed on the TS2000 ATCU.

1. Select Standby Mode.
2. Set the Az Offset to zero, see Figure 10 Stored General Data.
3. Set the EI Offset to zero, see Figure 10 Stored General Data.

Note down the following values as they can be used to locate the satellite should the calibrated values be lost for any reason.

Record The Values Here
AZ Uncal.

EI Uncal.

Time/Date

- Azimuth angle displayed on Figure 3 Status Display Page.
- Elevation angle displayed on Figure 3 Status Display Page
- ATCU time and date.

Azimuth and elevation angles noted above are both non-calibrated angles.

4. Determine the pointing angle for the satellite you wish to track. This can be done in a number of ways.

Record The Values Here
AZ Intelsat.

EI Intelsat.

Time/Date

- Using Intelsat Mode of the ATCU.
- Use the IESS program available free from the intelsat web site.

If using the Intelsat printout, go to set 13 and instead of commanded angles, select Azimuth and Elevation angles from the Intelsat computer printout for the particular time and date. Use these Azimuth and Elevation angles as coarse angles.

The best and most accurate way to calibrate the ATCU with the position sensors is by using Intelsat Mode to determine the pointing angle. The requirements for this are as follows:

- The standard 11 Intelsat Parameters, which are provided on a weekly basis by Intelsat. (Put in Stored Satellite Data page)
- The earth station latitude, longitude, and height above sea level.
- Durat & Incr

When these values have been entered, and the travel limits have been set, the ATCU can be put in Intelsat Mode. In doing this, ensure that the motor control unit is set to Auto. From here, continue with the following steps.

5. Set the Auto/Manual switch in the motor control cabinet to Manual. This will stop the antenna from moving.
6. Select Intelsat Mode.
7. The Status Display will show the Azimuth Commanded angle and Elevation Commanded angle. Note down these angles.
8. Select Standby Mode if the ATCU has not already gone back to this mode.
9. Using Position Mode, peak up the antenna.

10. Calculate Az Offset as follows:

$$\text{Az Offset} = \text{Az Course} - \text{Az Displayed}$$

11. Enter the Az Offset obtained in Step 10. The ATCU will then display the desired Az look angle.

12. Calculate El Offset as follows:

$$\text{El Offset} = \text{Az Course} - \text{Az Displayed}$$

13. Enter the El Offset obtained in step 12. The ATCU will then display the desired El look angle.

Note

To reverse the direction of a resolver swap S1 and S3. This may be required for example: if the ATCU measures the antenna as moving CW when it is in fact moving CCW. The best place to swap S1 and S3 is in the DB15 connector on the input to the reference supply.

11.1 How accurate should my positioning system be.

Basically any error in the positioning of the antenna will result in a Gain Loss of the signal you are trying to receive. To find the absolute pointing error allowable based on a Gain Loss figure in dB use the following equation obtained from *Inclined orbit satellite operation in the intelsat system*. prepared by Rory Chang and Les Veenstra 1991.

$$\text{GainLoss}(dB) = 27.21 \times 10^{-3} f^2 D^2 g^2$$

f is the frequency at which the antenna operates, D is the diameter of the dish, γ is the absolute pointing error. This only applies when gain loss is less than 3dB.

12 Software Protection.

The TS2000 system has been coded to run only when the supplied dongle is connected to the parallel port of the TS2000 computer. If the dongle is missing or faulty the TS2000 supplier should be contacted immediately to ensure earliest restoration of service. The dongle should be labeled with the serial number on the ATCU.

13 MAINTENANCE

At regular intervals, depending upon the dust and particle content of the air, clean or replace the air filter element fitted to the front of the ATCU. To do this, open the air filter door, lift out the element and wash it in clean water. Allow to dry before reinserting in the ATCU.

Once every three years, replace the glass cartridge fuse in the Reference Power Supply. The correct fuse is listed in Appendix B - Bill of Materials. There is no fuse in the ATCU - the power supply is self-protecting.