GMRT SERVO SYSTEM

Introduction

The GMRT servo control system is located at the base of each antenna and facilitates the accurate tracking of targets by positioning the Azimuth and Elevation axes of the antenna as per command received from the remote command center (CEB). Each axis is driven by two number of 6 HP DC servo motors which have in-built fail-safe brake, tacho-meters and thermostat. AZ/EL axes are coupled to respective motor pair through reduction gears. Motors are coupled in counter_torque arrangement so as to reduce back-lash errors.

The 45 meter diameter parabolic dish of the antenna is mounted on Elevation axis, which in turn rests on AZ axis. AZ axis is steerable in the range of -270 deg to +270 deg (around cable wrap center which is south) and EL axis can be steered from 15 deg (near Horizon) to 110 deg (near Zenith). The array of 30 such antenna making up GMRT, spread over a 14 km radius are designed to be controlled from a single central location (CEB). Fiber optic links carry the servo system related parameters to and from the central control room and each antenna base. Antenna base computer (ABC) located at each antenna base provides interface between central (CEB) computer and station servo computer (SSC). ABC interfaces to SSC through RS232C/RS422, asynchronous serial link and packet based messaging protocols.

Antenna can be fully, remotely operated, through cold-start to close, so that antenna sites can be unmanned. Both axes can be commanded to move along a desired trajectory with minimum pointing errors. The trajectory may be astronomical source path or user defined artificial path. All analog, digital parameters are available on request to the remote host. Any faults and events are sent to the remote host without the need for host to poll for them.

Limit switches, Encoders.

In AZ axis position limit switches are mounted at about +270 and -270 deg positions (i.e East and West) near the bottom of AZ shaft. Cables from the top (AZ,EL drive, Feed drive and receiver cables) pass down through a cable wrap arrangement and cables can take up to -300 deg to 300 deg twist. Cable wrap limit switch is positioned so as to toggle some where between 0 and 45 deg (between south and west). 17 bit absolute encoder is coupled to the free end of the AZ shaft through flexible coupling. Elevation limit switches are positioned so as to get actuated at 15 deg and 110 deg. 17 bit absolute encoder is coupled to one end of the EL shaft. EL encoder is adjusted to read 0 deg in horizon and then as the antenna is moved up the angle read out increases.

Stow Motor and limit switches.

Antenna can be stowed in EL axis at 90 degree by inserting motor driven stow pins into slots in the antenna. Limit switches are mounted to indicate to the control system, stow position, stowed and stow released status.

Wind Meters.

Two wind meters are mounted on the periphery of the dish. The frequency of the pulse train sent by these is measured and is available for display. These readings are also used by control system to cause automatic parking operation under high wind conditions.

Motor, Brakes and Tacho.

The motors used are 6 HP low inertia DC servo motors with integral fail-safe brakes. Brakes are normally applied and released on application of 100 V supply. The tacho meter provides DC voltage proportional to the speed of the motor and is used in speed control and over-speed protection.

Amplifiers and analog loops.

Each motor is driven by 4 quadrant regenerative thyristorised DC servo amplifiers. The amplifiers have regenerative brake provision. They include current controller electronics, current limiting circuits, over-speed trip, over-load indication etc. The analog bin contains torque-bias speed-loop controller circuits and other analog circuits for both axes.

Station Servo Computer (SSC)

The Station Servo Computer is built around bus structured processor and I/O boards. The bus master is 8086-2 processor running at 8 MHz. The field I/O is interfaced to the SSC through back-panel mounted D connectors. It interfaces to the following equipments.

- AZ/EL position encoders and potentiometers.
- 2 no. of wind meters.
- console switches, status indicators and display.
- motor brakes and status outputs.
- stow mechanism.
- Amplifiers.
- Hand Held Terminal
- antenna base computer (ABC)
- position limit switches.

The SSC performs the following functions.

- Closed loop position control in local and remote modes of operations.
- Handling control and monitor commands from remote ABC.
- Generating demand angel trajectory every 100 msec based on data received from ABC.
- Position measurement and display after off-set correction.
- Scanning contact inputs; performing operational safety interlocking logic and driving relay outputs.
- Limit release operation.

- Stow, stow release and parking operations.
- Monitor currents, speeds, wind speeds etc. And generating trip and inter_lock conditions.
- Handling user commands from HHT for setup, display and control.
- Watch dog trigger.
- Time of Day
- Power on self test and diagnostics.

The control philosophy

The main goal of the GMRT servo system is to support precision tracking of starts from a remote location, with minimum pointing errors, even under disturbing wind conditions. It is equally important to secure the safety of the antenna at all times. From a control system point of view, each axis control is made up of three control loops viz. Position, speed and current.

Current loops:	2 per axis – perform closed loop control of motor currents.
Speed loops:	1 per axis – perform closed loop control of the average of the tow motor speeds.
Position loop:	1 per axis – perform closed loop control of the antenna axis position.

Current loops are the inner most loops; speed loop is out side the current loops and then position loop encloses the speed loop. Thus output of the position loop controller is fed as demand speed to the speed loop, whose output in turn becomes demand current to the two current loop controllers.

Counter torque scheme is implemented so as to reduce gear back-lash error. This is achieved by biasing the motor currents by equal and opposite value.

Tracking

SSC is capable of driving the antenna to follow a trajectory of angle vs time co-ordinates. The desired trajectory is fed as target angle and target time. SSC calculates intermediate angle for every 100ms time step and calculates error from this. The desired target angle is calculated to better than 10” accuracy and cumulative error are avoided.

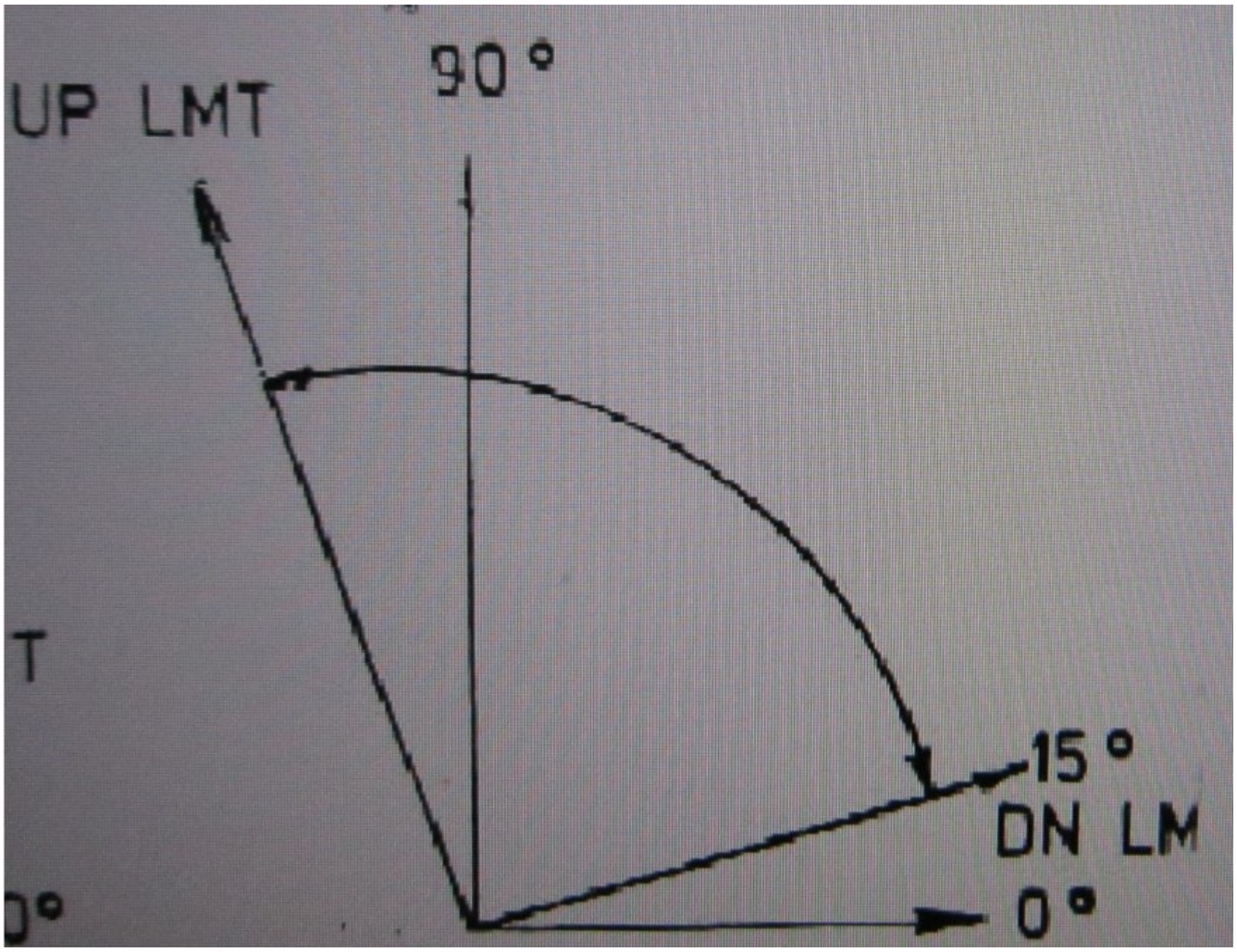
ABC provides desired trajectory information at regular intervals. A single element queue is maintained by the SSC so that a new pair of co-ordinates can be given in advance by the ABC. This new co-ordinate will be picked up by the SSC from the queue on reaching the previously established target time.

Azimuth system

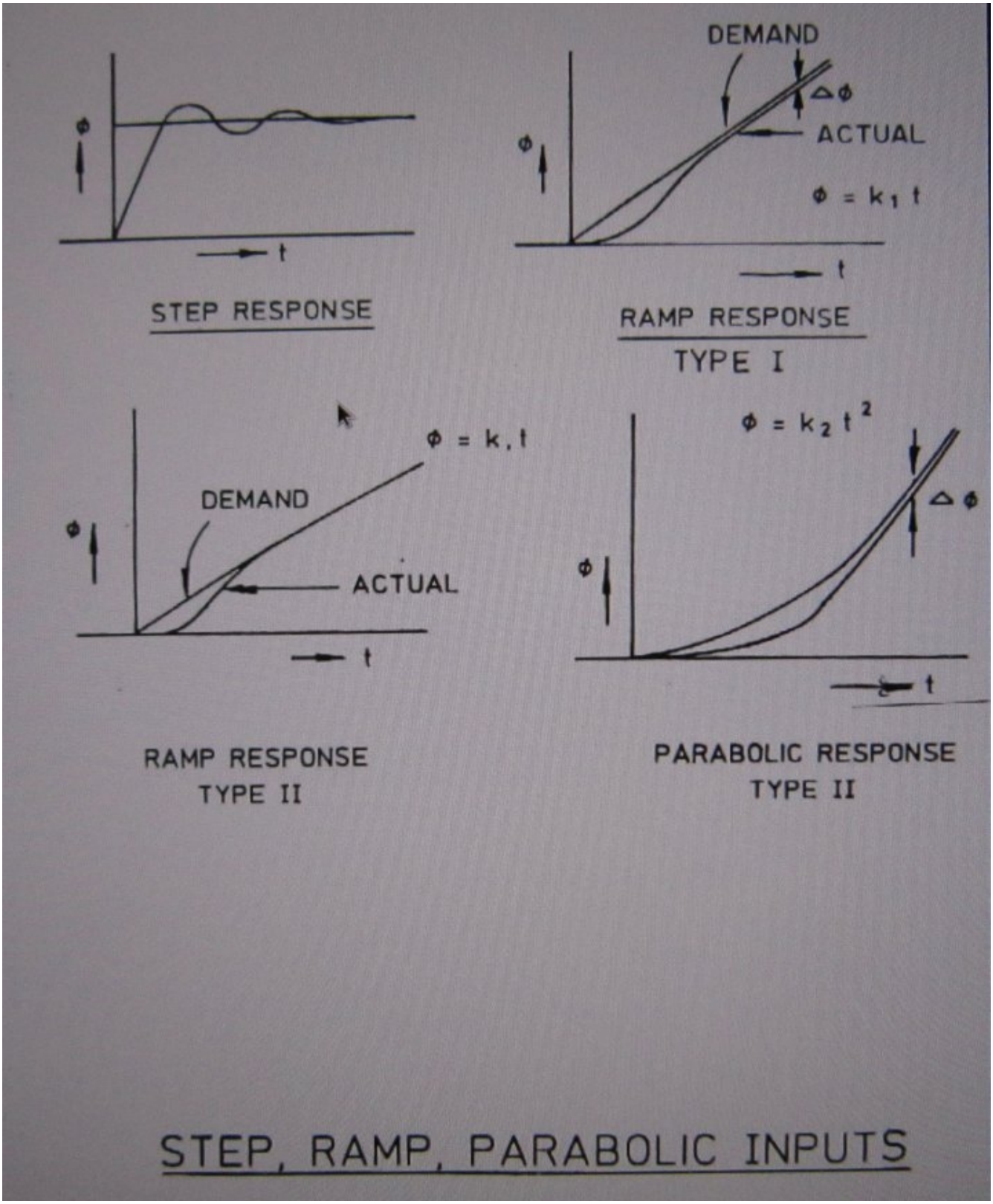
Yellow color – Astronomical co-ordinates (0 to 350, 0 indicates North)
Black color – Antenna co-ordinates (-270 to +270, 0 indicates South)
Red color – Outer track (-90 to +270)
Blue color – Inner track (-270 to +90)

NORTH

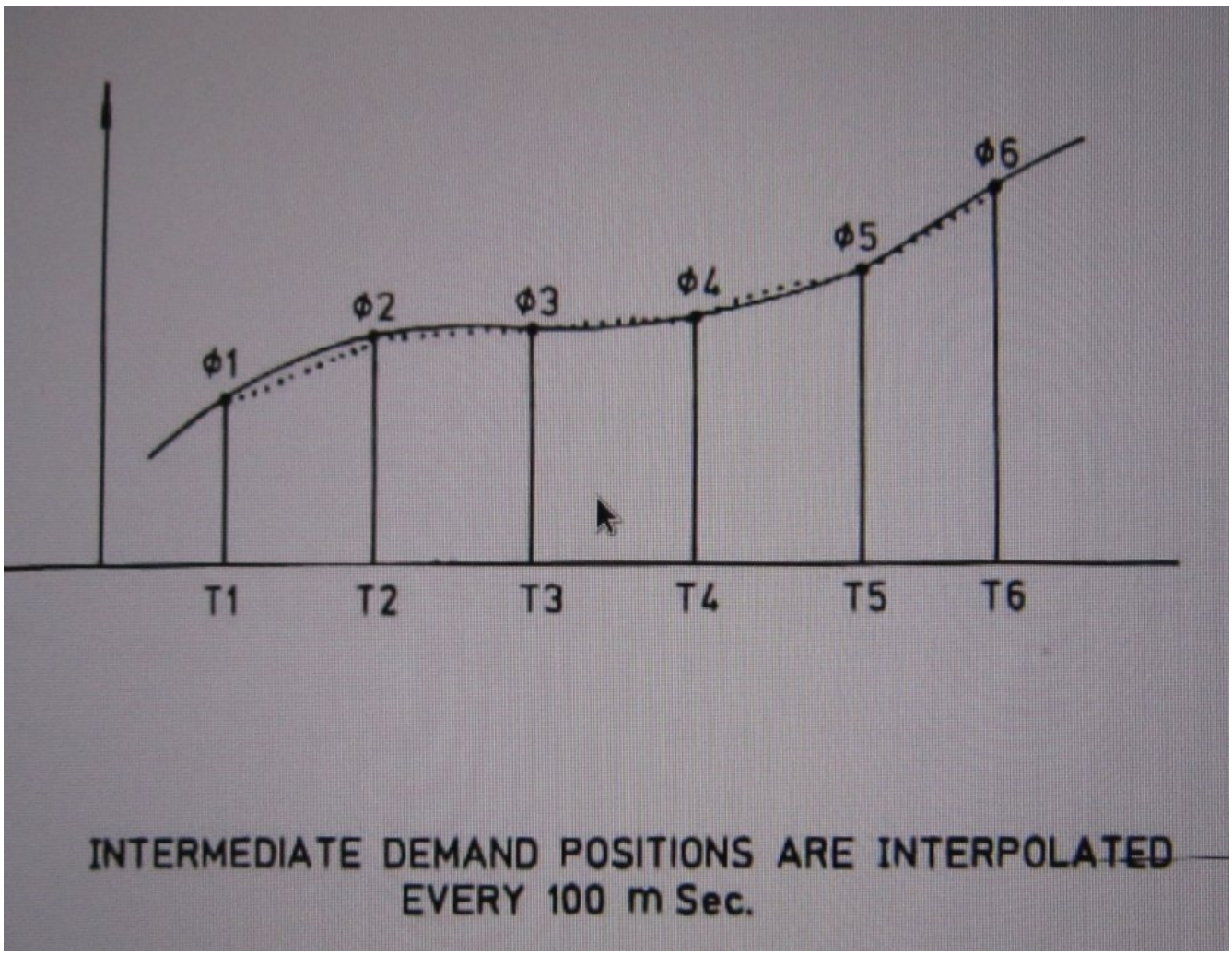
Elevation system.



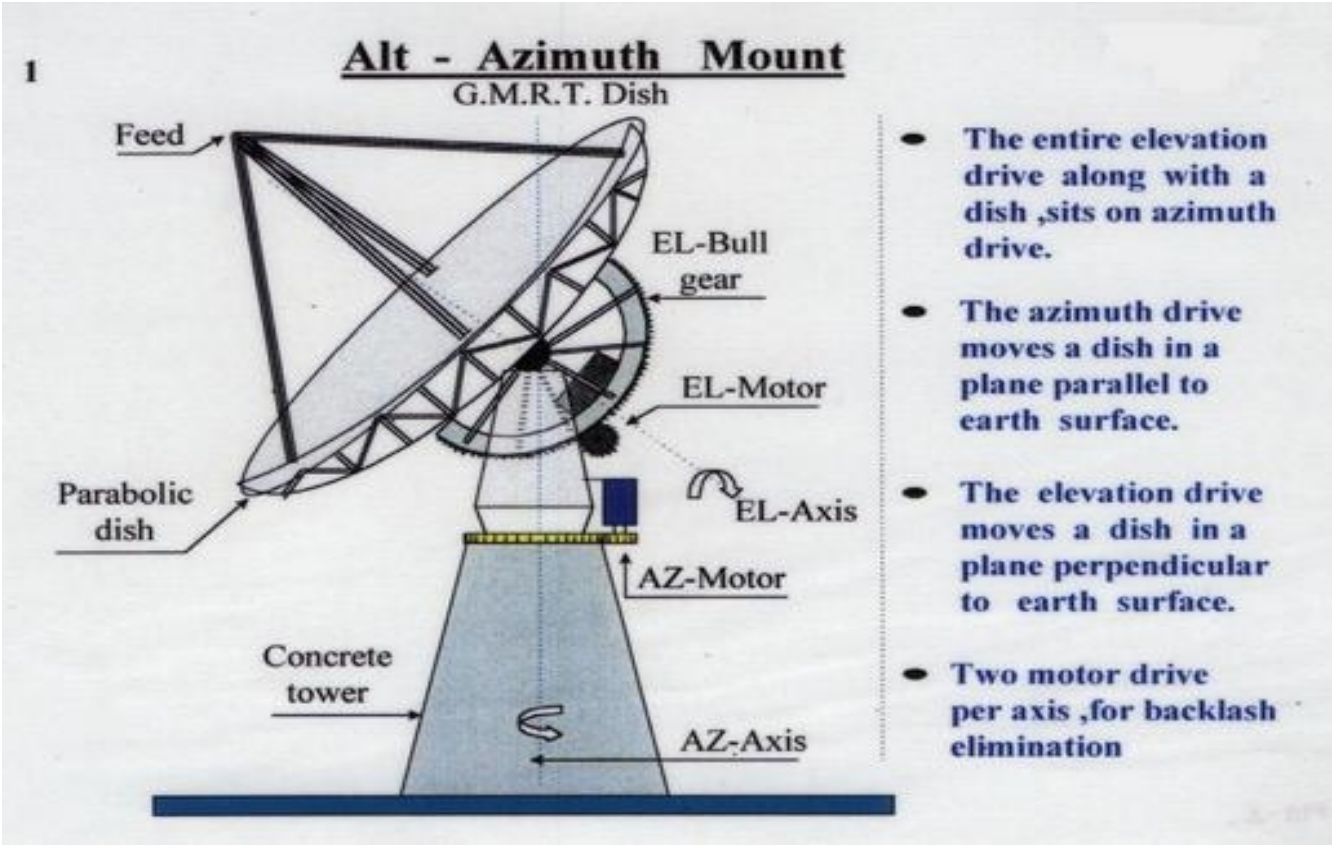
Tracking response



Tracking.


φ1
φ2
φ3
φ4
φ5
φ6
T1
T2
T3
T4
T5
T6
INTERMEDIATE DEMAND POSITIONS ARE INTERPOLATED EVERY 100 m Sec.

Dish Alt – Azimuth Mount.



Servo Monitoring window.

Terminal

File Edit View Search Terminal Help

```
|DATE: 2013jan28    TIME: 22:55:18      LST: 06:54:03.4     PACKET: 1481577
 USR4 1481323    user4.5: ABC SET TIME22:53:49,28-01-2013
|sacw
└------------------------------------------------------------------------------┘

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| ProgID: 4   TRUE         NoAnt:  30     State:TRKG   OUTTRK                  |
| Source: 3C147      5h42m36.13 49d51'07.2       Phs Center:                   |
| Target: Az: 159d30'56.7"     El:  56d11'22.5"   Offs:                        |
|                                                                              |
| C00  C01  C02  C03  C04  C05  C06  C08  C09  C10  C11  C12  C13  C14  E02    |
| 3"   22"  28"  16"  -15" 11"  23"  -5"  16"  2'   2'   3"   2'   2'   -2'   |
| -44" -19" -10" -87' -18" -3'  -2'  -64" -62' -8"  1"   -54" -28" 11"  -34"   |
|                                                                              |
|                                                                              |
|                                                                              |
| E03  E04  E05  E06  W01  W02  W03  W04  W05  W06  S01  S02  S03  S04  S06    |
| -4'  -5'  -7'  -8'  77"  3'   2'   3'   3'   4'   16"  81"  89"  2'   4'     |
| -34" -13" -41" -16" 18"  83"  2'   4'   5'   7'   -2'  -3'  -4'  -5'  -8'   |
|                                                                              |
|                                                                              |
|                                                                              |
└------------------------------------------------------------------------------┘
┌------------------------------------------------------------------------------┐
```
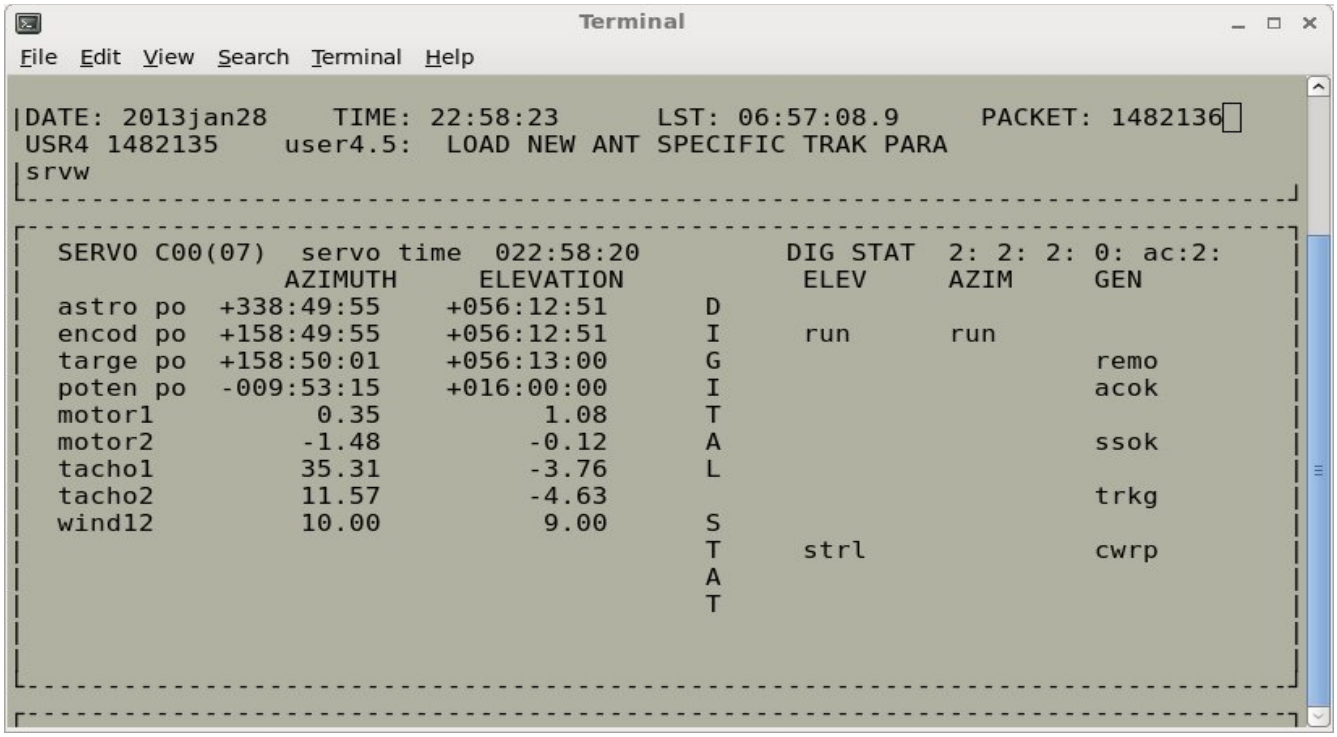

servo window for single antenna.



Servo System Specifications.

Dish mount	**: Alt-Azimuth mount.**
Dish movement	**: +/-270 deg. In Azimuth axis.** **: 15 deg to 110 deg in Elevation axis.**
Dish speed (Max)	**: 30 deg/min in Azimuth axis, 1600 RPM.** **: 20 deg/min in Elevation axis, 14 RPM.**
Gear reduction ratio	**: 18963 – AZ, 25162 – EL.**
Max servo pointing error while tracking (wind < 20 kmph)	**: 1' RMS.**
Angle resolution	**: 10” (17 bit encoder).**
Tracking accuracy	**: 10”**
Operating Temperature	**: up to 45 deg. C.**
Design wind speed	**: Operational up to 40 kmph, Slew up to 80 Kmph**
Survival wind speed	**: 133 kmph.**

Servo commands

GMRT is the Alt-AZ mount type telescope. Servo system controls azimuth and elevation axis independently. Servo System Computer (SSC) which controls the servo system at the antenna base receives the servo commands from the ABC and ABC receives commands from C&M. The return response comes back from SCC to ACB and from ABC to C&M. SSC accepts a set of basic commands from ABC. In case of emergency/failure SSC sends messages (servo events) to ABC without ABCs request.

While using the servo system, user may or may not send the basic servo commands but sends much higher level commands which are finally converted to basic servo commands by C&M and ABC. User issues the higher level servo commands from C&M console either manually or through command file. C&M sends these commands to ABC. And the finally the ABC sends it to servo computer for actual execution in basic command form.

Basic servo system commands are listed here.

Operational commands

1. Cold-start – stow release and holds the axis in the current positions
2. Position – positions the specified axis to the specified positions.
3. Track – tracks the specified axis so as to reach the target positions at the specified time.
4. Hold – holds one or both axis at the current position.
5. Stop – the drives are turned off and the brakes are applied to one or both axis.
6. Close – turns off the drive and parks the antenna.
7. Stow – drives the specified axis to the stow position.
8. Stow release – releases the stow on the specified axis.
9. Abort – aborts the previous command undertaken if any.
10. H/W reset – issues hardware reset command to the SCC.

Display/monitor commands

1. Read angles – returns current positions, target positions and pot positions.
2. Read analog vars – returns data packet containing all analog variables.
3. Read digital vars – returns data packet containing all digital variables.
4. Read set parameters – returns loop parameters, offset angels etc.
5. Read antenna state – returns antenna states.
6. Read version – returns version no.

Set system parameters commands

1. Set Time of Day.
2. Set stow angle.
3. Set s/w Hi limit.
4. Set s/w Lo limit.
5. Set Wind velocity Limits.
6. Set Current Limits
7. Set Speed Limits

The higher level usages of the servo system are listed here.

1. Pointing to astronomical source. (RA, Dec)
2. Tracking the astronomical source. (RA, Dec)
3. Tracking the planets (RA&dRA/dt, Dec&dDec/dt)
4. Tracking RA, Dec.
5. Track change outer/inner.
6. Scanning the source with specific speed in AZ, EL, RA and Dec.
7. Offset tracking the source in AZ, EL, RA and Dec.

To fulfill the above requirements/usages the higher level functions are developed and integrated in to C&M.

Functions of C&M for servo

1. User can send basic command to SSC from C&M console. C&M just passes the basic command to SSC (axis tracking, brakes, hold etc.).
2. In Case of higher level commands, C&M and ABC do some internal calculations and converts it in to basic commands, then sends to SSC (source tracking).
2. ABC on its own sends some display commands to SSC on regular intervals for monitoring. (encoder reading, analog and digital variables)
3. Some Set parameters are set in to ABC (pointing offsets, antenna coordinates etc.)
4. Some Set parameters are set in to C&M (EL and AZ soft limits, STP position, IN/OUT track etc.)
5. Source coordinate list is handled by C&M.
6. C&M provides some astronomical functions (Rise Set Time, Precession, LST, AZ-EL position)
7. Along with built-in park command, one can park the antenna by moving to STP and stowing.
8. In high wind speed, servo automatically parks the antenna, but C&M also warns to control-room as per algorithm for parking the entire array.
9. C&M/ABC take care if EL to move above 90d or not (variable has to set in C&M)
10. C&M checks weather all working antenna in the array are reached to source target or not.
11. C&M alarms to control-room in case of any servo failure or any limit hit.
12. As the tracking is continuous process, C&M provides the real time servo monitoring display to keep track on tracking status of the array (ondisp, tracking errors).
13. C&M keep the servo flags records of servo system, which is used for flagging the antenna wile analyzing the data. (log flags).
14. In case of failure or emergency, SSC sends to servo events to ABC without any request from ABC.
15. Offset tracking, source scanning, planet tracking, Ra-Dec tracking handled by ABC.

Higher Level Command Executions.

Example : Tracking the astronomical source “3c48”

1. before tracking the source, the file containing source coordinates should be loaded in to C&M.
2. Source should be up in the sky (check rise and set time).
3. Servo systems of the array antennas are communicating to C&M and are working fine.
4. Choose the appropriate track (IN/OUT).
5. Issue the gts'3c48' to read the source parameters and precess it.
6. Issure the sndsacsrc(1,12h) command for position and tracking.
7. C&M sends these parameters to each ABC in the Array.
8. ABC sends to position command to SCC so that antenna can point to source.
9. After the antenna are reached the target, each ABC converts the source coordinates in to AZ,EL and time format.
10. Each ABC keeps on providing this parameters to SCC for actual tracking the source every after 30 seconds.
11. This tracking continues till the source is up in the sky or the time provided by the user.

Offset tracking in AZ,EL,RA and Dec.

On top of source tracking ABC can add the offsets to the above parameters and then sends it to SSC for executions.

Scanning the source with specific speed in AZ, EL, RA and Dec.

On top of source tracking ABC can add specific speed to the above parameters and then sends it to SSC for executions.

Tracking the planets (RA&dRA/dt, Dec&dDec/dt)

ABC can take care of dRA/dt and dDec/dt for tracking the solar planets.

In/Out track change.

This IN/OUT track change is handled by C&M.

Pointing procedure.

It is the C&M procedure is used to calculate the Antenna offsets in AZ and EL.

STP check procedure.

It is the C&M procedure is used to check the stow position of antenna.

All basic and higher level servo command list.

No	C&M		ABC		SSC
	(C&M – ABC) set parameters				
	LDANTPARAM Loads the Antenna base coordinates, Latitude, Longitude and Altitude to ABC.	>	Use these coordinate for AZ and EL calculations.		
	RDANTPARA Read the antenna base coordinates	> <	ABC sends the loaded parameters to C&M.		
	LDANTOFF Loads the Antenna AZ and EL offsets to ABC.	>	Use these coordinate to add in to AZ and EL positions.		
	RDANTOFF read the antenna base offsets	> <	ABC sends the loaded antenna base offsets to C&M.		
	LDSRCPARM load source specific parameters for local tracking.	>	Use these parameters for AZ EL calculations.		
	RDSRCPARM read the source specific parameters	> <	ABC sends the loaded source specific parameters		
	LDTIMTRK load time parameters parameters for local track	>	Use these parameters for AZ EL calculations.		
	RDTIMTRK read time parameters	> <	ABC sends the loaded time parameters.		
	DISSRVLINK disable servo link from ABC	>	Disable ABC to SSC communication.		
	ENASRVLINK enable servo link from ABC	>	Enable ABC to SSC communication.		
	GOINNER request ABC to move antenna in Inner track	>	ABC sets the Inner track for AZ calculations.		
	GOOUTER request ABC to move antenna in Outer track	>	ABC sets the Outer track for AZ calculations.		

	(C&M – ABC – SSC) general servo commands				
	STABCTIM Sets the ABC time and LST	>	Sets ABC time and SSC time.	>	Sets time.
	ABRTPRKANT abort antenna parking sequence	>	ABC send abort command to SSC.	>	SSC aborts previous command undertaken.
	COLD-START/CLOSE cold start of antenna/ close servo system	>	ABC passes it to SSC.	>	Cold start of servo/close down the servo system.
	HOLD/HLDAZ/HLDEL release the antenna brakes.	>	ABC passes it to SSC	>	Request servo to release the brakes on axis/es.
	BRAKES/BRKAZ/BRKEL Apply the brakes on axis	>	ABC passes it to SSC	>	Request servo to apply the brakes to the axis/es.
	STOW/STRELE apply/release stow.	>	ABC passes it to SSC	>	Stow the antenna/Release the stow of antenna.
	SWELE/SWRELEV stow el/stow release el	>	ABC passes it to SSC	>	Stow the antenna in EL/release EL stow of antenna.
	STOP abort the servo command	>	ABC passes it to SSC	>	Abort servo's previous command (to stop moving both the axis)
	ABRTSRVCMD abort eh servo command	>	ABC passes it to SSC	>	Abort servo's previous command.
	RDSRVSPC read servo set parameters	> <	ABC passes the display command to SSC and sends back the received parameter from SSC to C&M	> <	SSC returns the set parameters to ABC.
	RSTSERVO reset servo	>	ABC passes it to SSC	>	Issues the reset command.
	STSRVTIM sets servo time t secs ahead.	>	ABC passes it to SSC	>	Sets servo time ahead by t sec.
	(C&M – ABC – SSC) Position commands				
	MV(az,el) move antenna to AZ and EL target (astro coordinates)	>	ABC converts it to Antenna coordinate and sends it to SSC.	>	SSC takes the action by position command.
	AMV(az,el) move antenna to AZ and EL target (antenna coordinates)	>	ABC passes it to SSC.	>	SSC takes the action by position command.
	MVAZIM(az) move antenna to AZ target (astro coordinate)	>	ABC converts it to Antenna coordinate and sends it to SSC.	>	SSC takes the action by position command.

	AMVAZIM(az) move antenna to AZ target (antenna coordinate)	>	ABC passes it to SSC.	>	SSC takes the action by position command.
	MVELEV(el) move antenna in EL target. (astro/antenna)	>	ABC passesit to SSC.	>	SSC takes the action by position command.
	(C&M – ABC – SSC) Tracking commands				
	TRACK(az,el,time) servo track to az and el at time t (astro coordinate)	>	ABC converts it to Antenna coordinate and sends it to SSC.	>	SSC takes the action by track command.
	ATRACK(az,el,time) servo track to az and el at time t (antenna coordinate)	>	ABC passes it to SSC.	>	SSC takes the action by track command.
	TRKAZIM(az,time) servo track to az at time t (astro coordinate)	>	ABC converts it to Antenna coordinate and sends it to SSC.	>	SSC takes the action by track command.
	ATRKAZIM(az,time) servo track to az at time t (antenna coordinate)	>	ABC passes it to SSC.	>	SSC takes the action by track command.
	TRKELEV(el,time) servo track to el at time t (astro/antenna)	>	ABC passes it to SSC.	>	SSC takes the action by track command.
	STRTLOCTRK start local track for antenna	>	Starts calculating, sending AZ-EL and time parameters to SCC on regular intervals (30 sec).	>	SSC starts tracking the antenna.
	STPLOCTRK stop the local track for antenna	>	Stops sending track command and issues the stop command to SSC.	>	Aborts the tracking command and stops.
	(C&M – ABC – SSC) higher level commands.				
	ADDLIST 'file name' loads the source coordinates file in to C&M user.				
	GTS 'source name' displays the rise and set time of source , does the coordinate precession and loads the source coordinate to C&M user.				
	SNDSACSRC(1,time) position and start tracking antenna to the source for specific period of time.	>	1. ABC calculate the AZ-EL form source parameters, then issues position command to SSC	>	1. SCC Executes the position command.

			and waits till antenna points to the source. 2. After pointing is over ABC starts calculating the AZ-LE and keep on sending the tracking command to the SSC on regular interval of time (30 sec).	> >	2. SSC keeps on receiving and executing tracking command.
	TRKSACSRC track the source.	>	ABC starts calculating the AZ-LE and keep on sending the tracking command to the SSC on regular interval of time (30 sec).	>	SSC keeps on receiving and executing tracking command.
	TRKELOFF(el)/ TRKAZOFF(az) TRKANTOFF(az,el) track the source with az/el offsets.	>	After the AZ/EL calculations ABC adds the offsets AZ/EL and then keeps on sending the track command to SSC on regular intervals(30sec).	>	SSC keeps on receiving and executing tracking command.
	TRKRAOFF(ra) TRKDECOFF(dec) track the source with ra/dec offsets	>	After receiving source parameters, ABC adds the Ra/Dec offset to it and then calculates the AZ-EL. Then keeps on sending the track command to SSC on regular intervals(30sec).	>	SSC keeps on receiving and executing tracking command.
	SCANELSRC(time,del/dt) SCANAZSRC(time,daz/dt) scan the antenna in az/el axis while tracking the source with specific speed.	>	ABC takes care of scan rate during AZ/EL calculations and then keeps on sending the track command to SSC on regular intervals(30sec).	>	SSC keeps on receiving and executing tracking command.
	SCANRASRC(time,dra/dt) SCANDECSRC(time,ddec/dt) scan the antenna in ra/dec while tracking the source with specific speed.	>	ABC takes care of scan rate during AZ/EL calculations and then keeps on sending the track command to SSC on regular intervals(30sec).	>	SSC keeps on receiving and executing tracking command.
	STPSACTRK stop the sub array track for antennas	>	Stops sending tracking command and issue STOP command to SSC.	>	Aborts the tracking command and stops.

	GOTOSRC Waits till sub array antenna reaches to target.				
	(ABC – SSC) Monitoring commands				
	This information is used for monitoring	<	DISPLAY ABC sends the display command to SSC every after 1 sec to read the angles, analog variable, digital variable and state parameter.	> <	SSC Executes the Display command and returns the information to ABC.
	(SSC – ABC – C&M) servo events.				
	This information is used for high priority monitoring.	<	ABC Passes it to C&M	<	EVENTS SSC sends event message to ABC in case of failure or emergency conditions.