National Centre for Radio Astrophysics

Internal Technical Report

GMRT/TGC/R306

Implementation & Testing of the TGC for observation of Solar-system Objects

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Objective: At present, Tango based GMRT Control (**TGC)** system is being used to observe celestial objects defined within the ICRS or “J2000.0” Coordinate System which are assumed to have no observable angular motion. However, observation of the solar-system objects, which do have angular motion was not available yet in the TGC. Therefore, this report briefly describes implementation done for enabling the observation of solar-system object. The validation test results given in this report verifies that the TGC can be used for observation of solar-system objects mainly the Jupiter, Sun, and Moon.

Revision	Date	Modification/ Change
Ver. 1	06/01/2022	Released Version

Implementation & Testing of the TGC for observation of Solar-system Objects

Jitendra Kodilkar (Dec 24th , 2021, version 1.0)

1. Introduction :

At present, Tango based GMRT Control **(TGC)** system is used to observe celestial objects defined within the **ICRS or "J2000.0**"[1] Coordinate System which are assumed to have no observable angular motion. However, observation of the solar-system objects, which do have angular motion was not available in the TGC. Therefore, this report briefly describes implementation done in the TGC for enabling the observation of solar-system object, such as changes done in low-level modules, and associated higher level implementation to it **viz.** catalog-handling, commands (GUI, and command-line) to pass with the required arguments, unit conversion etc. Also, validation-tests executed to verify the correctness of planetary object observation are discussed in this report.

Section-2 gives details of implementation, ***section-3*** specify the methods used for the testing. And ***section-4*** mentions Standard Operating Procedure to be followed while observing the solar-system objects. To keep this report concise and readable, some testing results, which verify correctness of the observation are given in Appendix.

2. Implementation Details :

For observing any celestial source using the GMRT kind of radio telescopes, require two important functionality, **(i)** Track celestial object using Servo system, so that target source is at the primary beam centre of antenna, and **(ii)** provide target source's coordinates to correlator/beam-former backends for delay tracking (so that the same portion of a plane wavefront of radiation field coming from target source can be measured at given instance of time). In case of solar-system sources, in addition to Right Ascension (**RA**), and Declination (**DEC**) of the object, parameters such as rate of change in RA and DEC with respect to time, and the reference time at which the RA-DEC of Target body is listed must be provided.

Therefore, the legacy ONLINE control system, and TGC system send following information of target-source to the correlator backends, and LMC (Local Monitor Control) for servo tracking.

Table 1 : Required parameters for observation of Solar-system object

Correlator Backends (GSB,GWB)	LMC + Servo System
(i) Source RA-DEC (in radians) (ii) Reference Epoch (iii) Mean RA-DEC (in radians) (iv) Apparent RA-DEC (in radians) (v) DRA, DDEC (Rate of change RA-DEC in radian/radian per seconds) (v) Modified Julian Date (MJD) for the source + current UTC (units in days)	(i) Source RA-DEC (in Hrs:Minute:sec, deg:arc-min:arc-sec) (ii) Reference Epoch J2000.0 (iii) DRA, DDEC (converted to radian per radian) (iv) dradec_reftime (in hours)

2.1 TGC Catalog Format :

TGC takes Astrometry coordinates with reference to J2000 only. As an example, TGC catalog is shown in **Table-2** where DRA, DDEC is mentioned in radian per radian which is converted from rate of change in RA and DEC available in Arc-Second per Hour.

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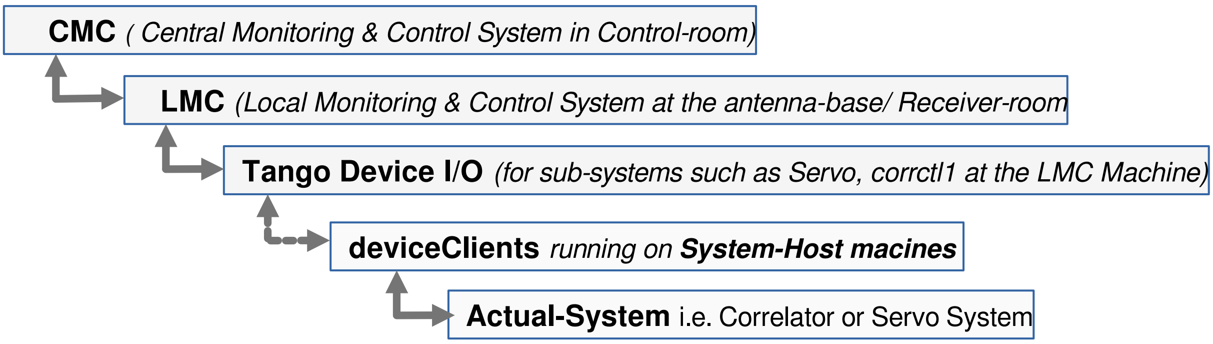
1 The extragalactic radio sources that define the ICRS (*International Celestial Reference Frame*) orientation are assumed to have no observable intrinsic angular motions. Thus, the ICRS is a "space-fixed" system and, as such, it has no associated epoch—its axes always point in the same directions with respect to distant galaxies. However, the ICRS was set up to approximate the conventional system defined by the Earth's mean equator and equinox of epoch J2000.0; the alignment difference is at the 0.02-arcsecond level, which is negligible for many applications. (Ref – User's guide to NOVAS version c3.1, U.S. Naval Observatory , March 2011)

Table 2 : Source catalog format in the TGC

Source-Name	RA	DEC	Epoch	DRA	DDEC	
MOON2045,-,	03:20:50.25,	16:59:02.00,	2000.0,	0.0274,	0.0161,	-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-
MOON2245,-,	03:23:48.55,	17:27:10.80,	2000.0,	0.0202,	0.0149,	-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-
MOON2330,-,	03:24:42.74,	17:37:03.00,	2000.0,	0.0182,	0.0142,	-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-

2.2 TGC Commands for Tracking, and astronomical/science Data-acquisition :

In TGC, commands are send from the CMC (Central Monitoring & Control) application to all GMRT subsystems through a hierarchical chain of Tango based Control-nodes, which are as follows :



Commands related to the 'Antenna tracking' and the 'Starting of astronomical Data-acquisition' given below are issued from the CMC to the antennas, and data processing backend LMCs. These commands are modified to accept the ***DRA, DDEC***, and ***dradec_reference time***.

2.2.1 Antenna tracking commands :

- *Load-source command read parameters given in the Source Catalog i.e. RA, DEC with Epoch J2000, and rate of change of RA, and DEC (DRA, DDEC).*

  load_source('MOON2045')

- The *track_array* command internally read stored values by 'load_source' command, and send it to the antenna base LMC. Reference time (*i.e. dradec_reftime)* for which DRA,DDEC is mentioned is being send manually at present.

  track_array *<subarray_id> <aztrk_in/out>* ***<dradec_reftime=``in hrs">*** *[timeout=20]*
  OR
  track_array_offset*_ra_dec <subarray id> <source_name> <outtrk> <ra_offset> <dec_offset>*
  <dradec_reftime= "in hrs">

2.2.2 Astronomical Data-Acquisition (GSB/GWB backends) commands :

- Command '*addpsource*' (add_project_source) read source-parameters from the catalog at the CMC, and send it to LMCs (GSB/GWB) for adding source-entry into system's catalog of the LMC.

  addpsource <source-name> <Correlator=GSB/GWB/BOTH>

- Command 'getpsource' associate/map the target-source values to the project-code

  getsource <project_code or subarray-id> <source_name>

- Command ***startscanproj*** or ***startscanprojagn*** is issued from the CMC, control-room to the backend LMCs i.e. GWB, and GSB. The startscanproj/startscanprojagn command at the correlator LMCs (GSB/GWB) reads internally target-source parameters (*source-name, ra_mean, dec_mean for today's reference epoch, ra_apparent, dec_apparent, and DRA, DDEC)*, along with the *dradec_reftime,* and send it to the actual correlator.

  startscanprojagn < subarray id > < corr_backend > <time_str> <dradec_reftime> [timeout=20]
  OR
  startscanproj <subarray_id> <time_str> <draddec_reftime> [timeout=20]

To implement commands mentioned above (in section 1.2.1, 1.2.2), modifications are done in *Java, CPP, Python Scripting,* and in the *GUI* at the CMC, and LMC. These modifications were required because track array, or start data acquisition, commands are special commands which requires Pre-/Post-processing, and unit conversions etc.

On *Ubuntu 20.04* Linux Operating System (with MySql 8 and upgraded Tango packages), creation and deletion of dynamic attributes relating to observation project-cde, was not happening correctly (only some attributes were getting added or removed). Also, in the existing GSB and GWB machines, attributes' properties in the *Tango*-Database were not getting removed. After accumulating these properties over ~4000 rows, or so were causing slowness, and attribute corruption problem. These two problems are resolved by modifying the code at LMC.

Appendix-I *gives the details of modification done in the TGC system at the Central Monitoring & Control, and Local Monitoring Control.*

3. Validation testing :

Validation tests are conducted for verifying the correctness of observation in three ways :

(i) Tracking validation : Validating antenna tracking values by observing the Moon over 4-5 hrs of duration, and comparing antennas' Azimuth and Elevation Target-Encoder values per minute with the expected values given by Horizons application (developed by Jet Propulsion Laboratory, NASA https://ssd.jpl.nasa.gov/horizons/).

(ii) Astrometric Values received at Correlator : ONLINE uses *SLA Positional Astronomy Library* **[1]** to pass astrometric values to the Servo-system of antenna, and Digital backends. Whereas TGC uses *NOVAS C3.1 (Naval Observatory Vector Astrometry Software* **[2])** Library with a higher level modules/APIs[2] to pass the astrometry parameters.

The planetary objects like Moon, and Jupiter observed for four to five hours using the TGC, and ONLINE simultaneously. To verify correctness, the target-source's MJD, Mean, Apparent RA-DEC values calculated using the TGC, are checked against the ONLINE system, and Horizon application as well. Inspite of different libraries/methods used in the ONLINE and TGC, resultant astrometric values for antenna-servo tracking, and delay-tracking found to be matched within the acceptable threshold.

(iii) Observation of the Jupiter : To validate correctness of planetary observation at a functional level, the Jupiter was observed, and ensured that fringes are stable within short-baselines using the central square antenna.

Five to six test observations in total were conducted using the TGC, and ONLINE. Subsequent sections gives relevant details of these validation tests.

3.1 The Moon Observation :

Moon Observation was done by controlling ten to fifteen antenna, and the GSB using the ONLINE, and remaining antennas, and the GWB using the TGC. **Table 3** mention experimental setup of the Moon observation done on Nov 15th, and Nov 24th, 2021.

3.1.1 Validation of Tracking :

Using the JPL's horizon application, Moon's RA-DEC (Equinox J2000.0) with apparent DRA, DDEC, and apparent Azimuth and Elevation of target center was obtained per minute by specifying horizon's query parameters such as observing site [*Coordinate Longitude (E) = 74.4688 degree, Latitude = 19.094166 degree, and height 0.65 KM*], observing date [Start = 2021-11-15 ,Stop=2021-11-16] etc.

(See **Section-3** for further details about resultant Horizon catalog, and TGC catalog converted from the Horizon catalog).

2 **gnovas Library/API** for the **NOVAS 3.1** by Deepak Bhong, ***calcnova TGC Library*** (API/higher level modules) to the gnovas, and ***scale_format*** library (for Unit Conversions) by Jitendra Kodilkar

- **Table 3 :** Experimental Setup for Nov 15th, and Nov 24th, 2021

Parameters	TGC	ONLINE
Antennas	C00 C02 C06 C09 C11 C13 W01 W03 W05 E02 E04 E06 S02 S04	C01 C04 C05 C08 C10 C12 C14 W02 W04 E03 E05 S01 S03 S06
Backend Settings	**GWB** Channel 2K, Bandwidth 200 MHz, Beams Off. Total Intensity Mode	**GSB** Channel 256, Bandwidth 32 Mhz, Beams Off. Total Intensity Mode
Settings	Default RF 550-750 Mhz (Nov 15) Default RF300-100 Mhz (Nov 24)	Default RF 591 Mhz (Nov 15) Default 167 Mhz (Nov 24)

Theoretical values of Apparent AZ-EL per minute from the "*Horizons Catalog"* compared with a actual GMRT Antenna AZ-EL values of Moon Tracking. **Figure-1 , and Figure 2** show plot of apparent Azimuth (Az), and Elevation (El) values provided by Horizon's catalog for the Moon's trajectory (on Nov 15th, 2021), and Antennas AZ, EL Servo-tracking positions values per second are plotted against Time. Az, and El values of Antennas are matching with that of the expected values of AZ, and EL given by the Horizon application.

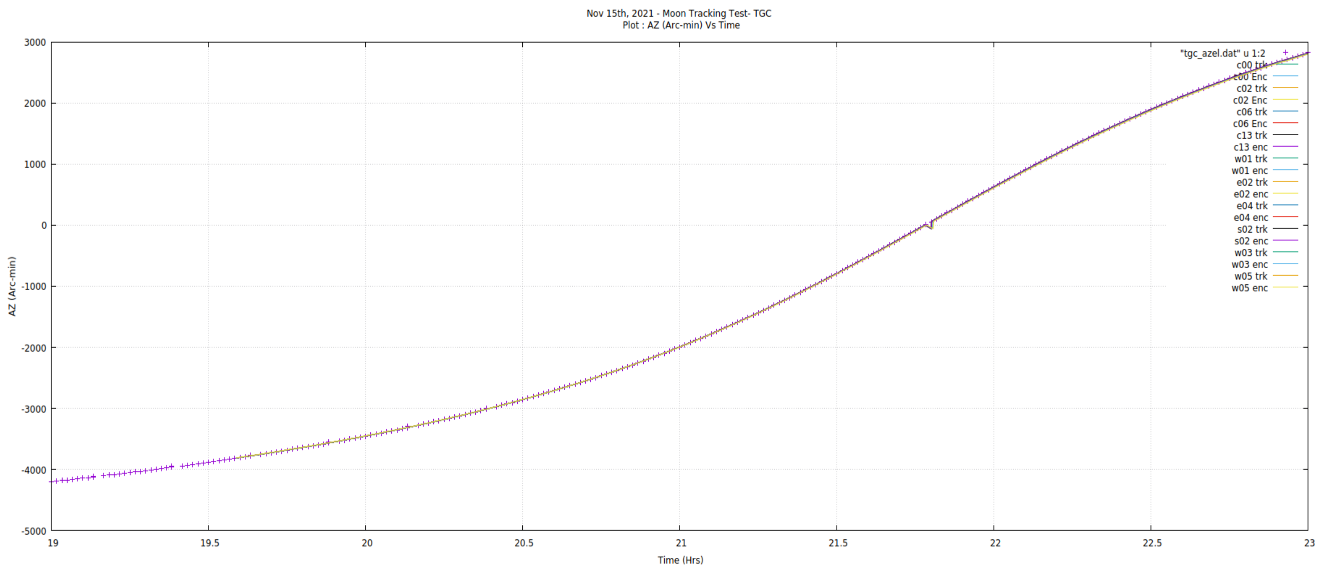


Figure 1*: TGC- Antenna AZ (in arc-min) Vs Time (hrs), matching with the Horizon's expected AZ (Marker)*

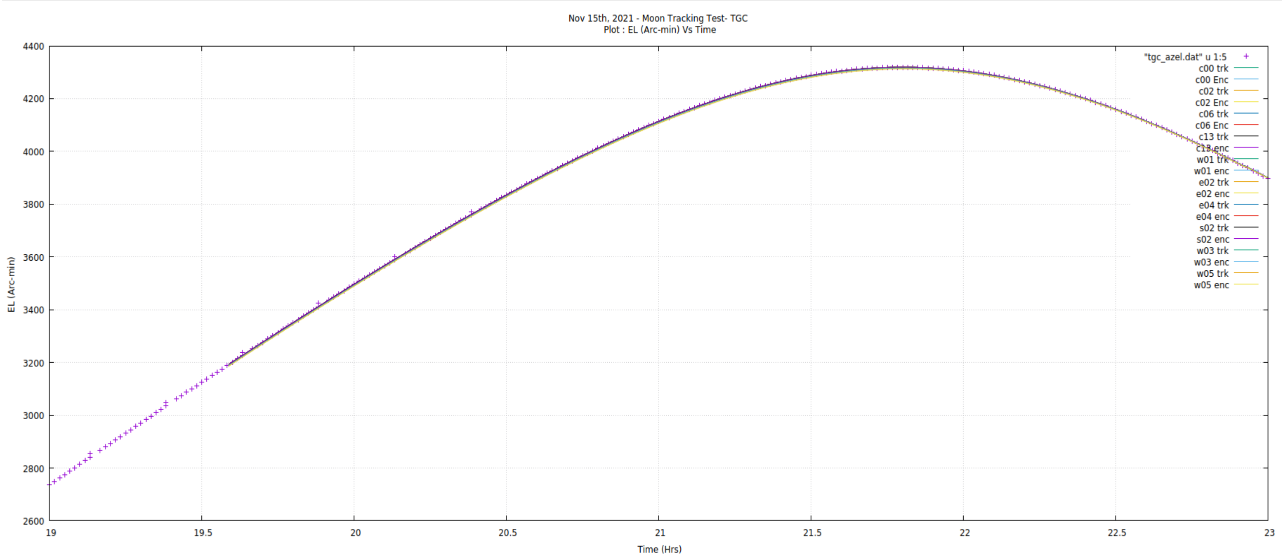


Figure 2: ***Deviation of Antenna EL values from the expected (Horizon's EL) values***

Figure 3, and **Figure 4**, shows the deviation of actual AZ, and EL of each GMRT antenna tracked under the TGC from the expected apparent values of AZ, and EL respectively given by the horizon catalog. **Figure-3** shows Azimuth tracking of all antennas under the TGC control are deviate within ~ 0 to 2 arc-minutes, whereas **Figure-4** depict that Elevation tracking values of all antennas are deviate within ~1 arc-minute.

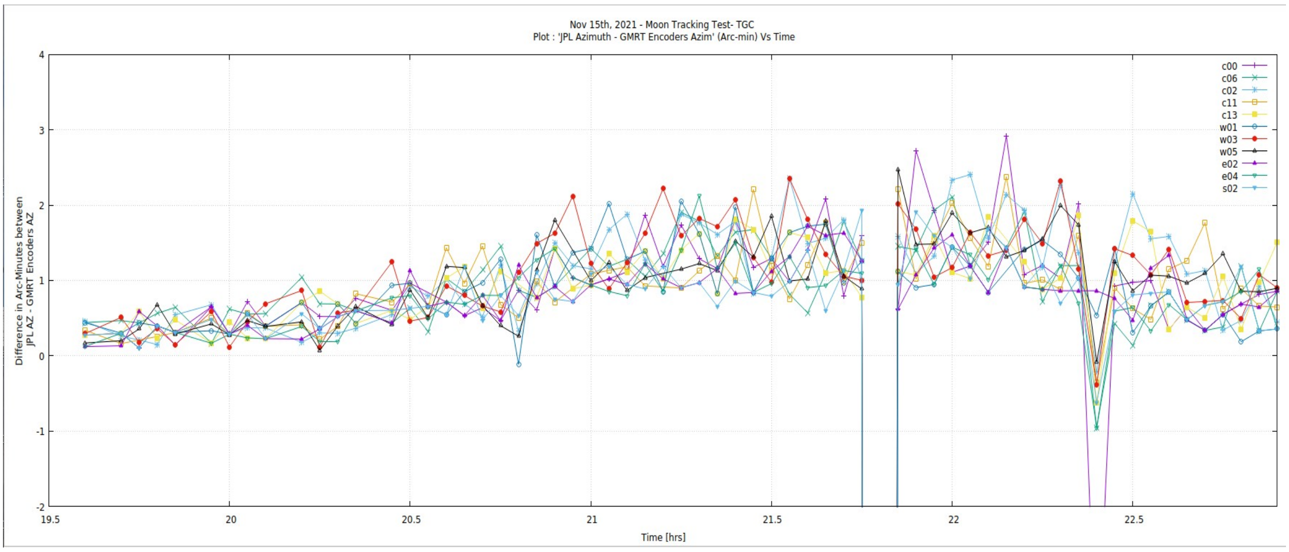


Figure 3: ***Deviation of Antenna AZ values from the expected (Horizon's AZ) values***

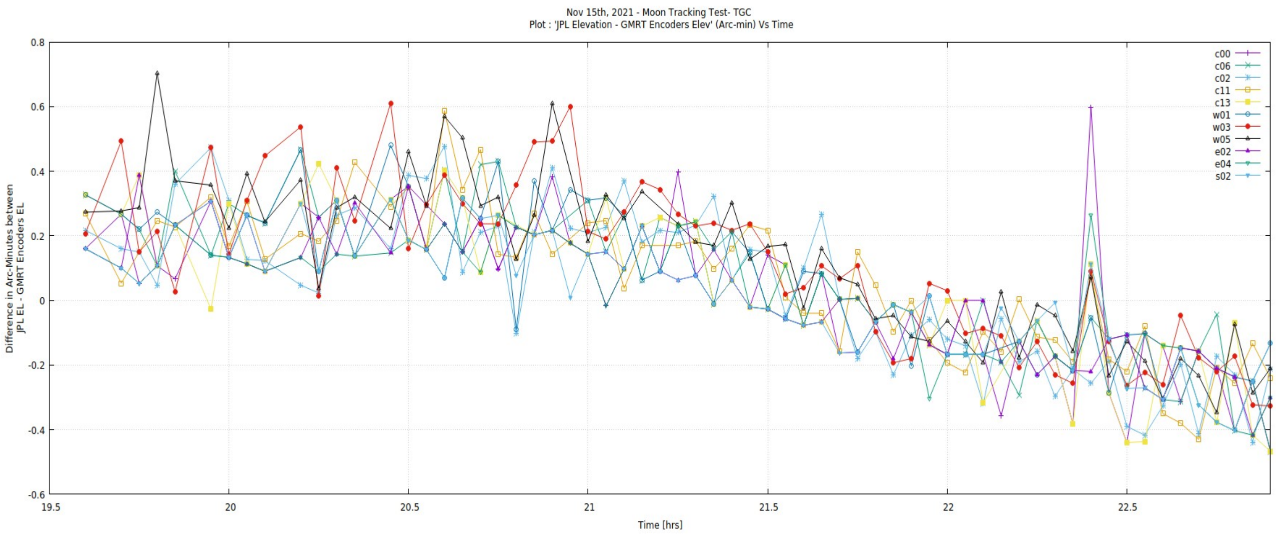


Figure 4: ***Deviation of Antenna EL values from the expected (Horizon's EL) values***

3.1.2 Verification of Backend Parameters :

The ONLINE, and TGC uses different libraries for calculating the initial astrometric values of target-source which need to be provided to the data processing backends. In the online, values of DRA, DDEC, and dra-ddec's reference-time are given using the command line interface or script. The online process these inputs locally using the SLA library to calculate today's Mean RA-DEC, apparent RA-DEC, and MJD values. The calculated values are then passed directly to the correlator. Whereas in the TGC, parameters DRA, DDEC are mentioned in the catalog, and reference-time is given at command-line which are passed to the LMC. LMC uses NOVAS library to calculate today's Mean RA-DEC, apparent RA-DEC, and MJD of the given target.

On Nov 15th, Moon observing session done using the ONLINE , and TGC simultaneously, with a separate control of the GSB to the ONLINE, and the GWB control with the TGC. The *LTA headers* of the acquired astronomical data using the GSB , and GWB were compared to check the source-MJD, Mean (RA-DEC), and Apparent (RA-DEC) values, along with the DRA, DDEC rates. In the correlator, apparent RA-DEC values are used for the delay tracking along with the DRA, and DDEC values.

Figure-5 shows that the apparent RA-DEC given by the GSB- and GWB -LTA headers of every data scans are matching with the theoretical values given by the Horizon's application. The difference of the horizon's apparent RA, and DEC values in the ONLINE is more as compare to the TGC. Probably this may be because, conventionally apparent RA-DEC are given in the ONLINE catalog which are again first precessed to the today's epoch, and then reused to calculate apparent RA-DEC values.

The LTA header table of the GSB, and GWB given in **Appendix-II** shows that the MJD, DRA, DDEC values are matching exactly, and mean & apparent values of RA, and DEC are having less than <= 0.02s, and <= 0.51" difference respectively over four to five hours of observing run.

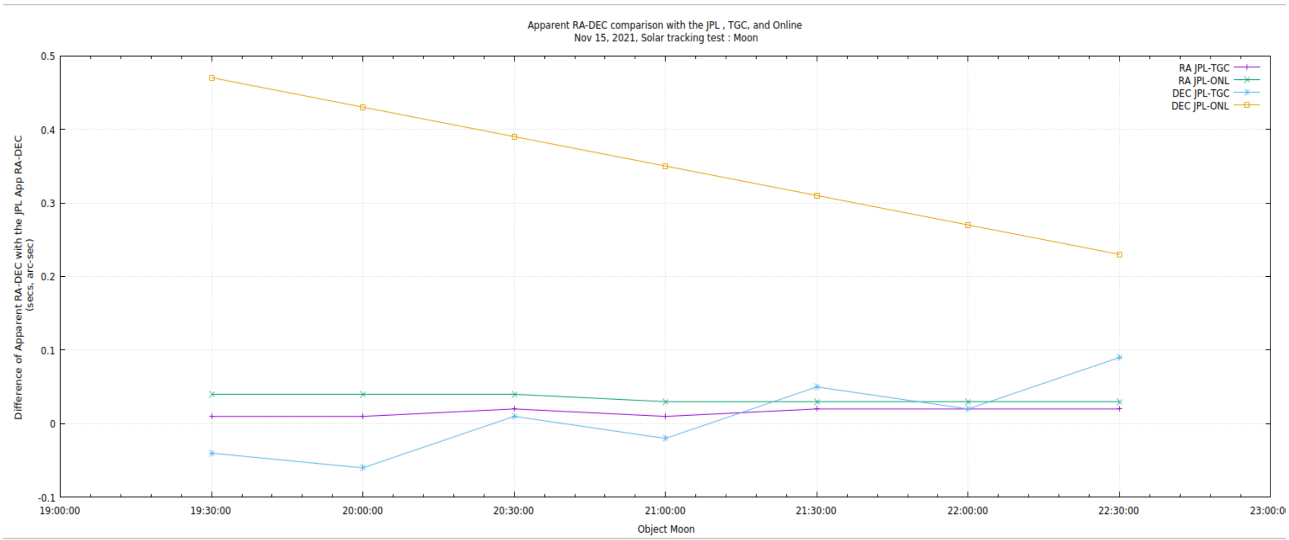


Figure 5: ***Apparent RA-DEC difference between Horizons Expected Values and the TGC/ONLINE (in sec, arc-sec respectively) Vs time***

2.3 Observation of the Jupiter :

Observation of the Jupiter source at Band-4 (RF – 550 Mhz) was done on Nov 16th, 2021 using the TGC. Both the GWB, and GSB data acquired on the Jupiter from 15 to 18 Hrs, with five minutes of phase calibrator (2136+006) observation interspersed every after thirty minutes of the Jupiter observation. **Figure 6** shows that cross-visibility phases observed on the Jupiter using short baselines are stable for antenna C00, C01, C02, C04, C05, C06, C09, C10, C12, C13, C14, E02, S01, and W01. Thus, plot verifies that Jupiter source is being tracked, or observed correctly.

Table 4 : Experimental Setup on Nov 16th, 2021 for Jupiter Observing session

Control System	**TGC**
Antenna	All available antennae (total 27, except C03, C08, C11)
GWB	Bandwidth 200 Mhz Channel 2K RF – 550 Mhz Beams : OFF, Total Intensity Mode
GSB	BW ~ 33 Mhz Channel 256 RF : 591 Mhz Beams Off, Total Intensity Mode

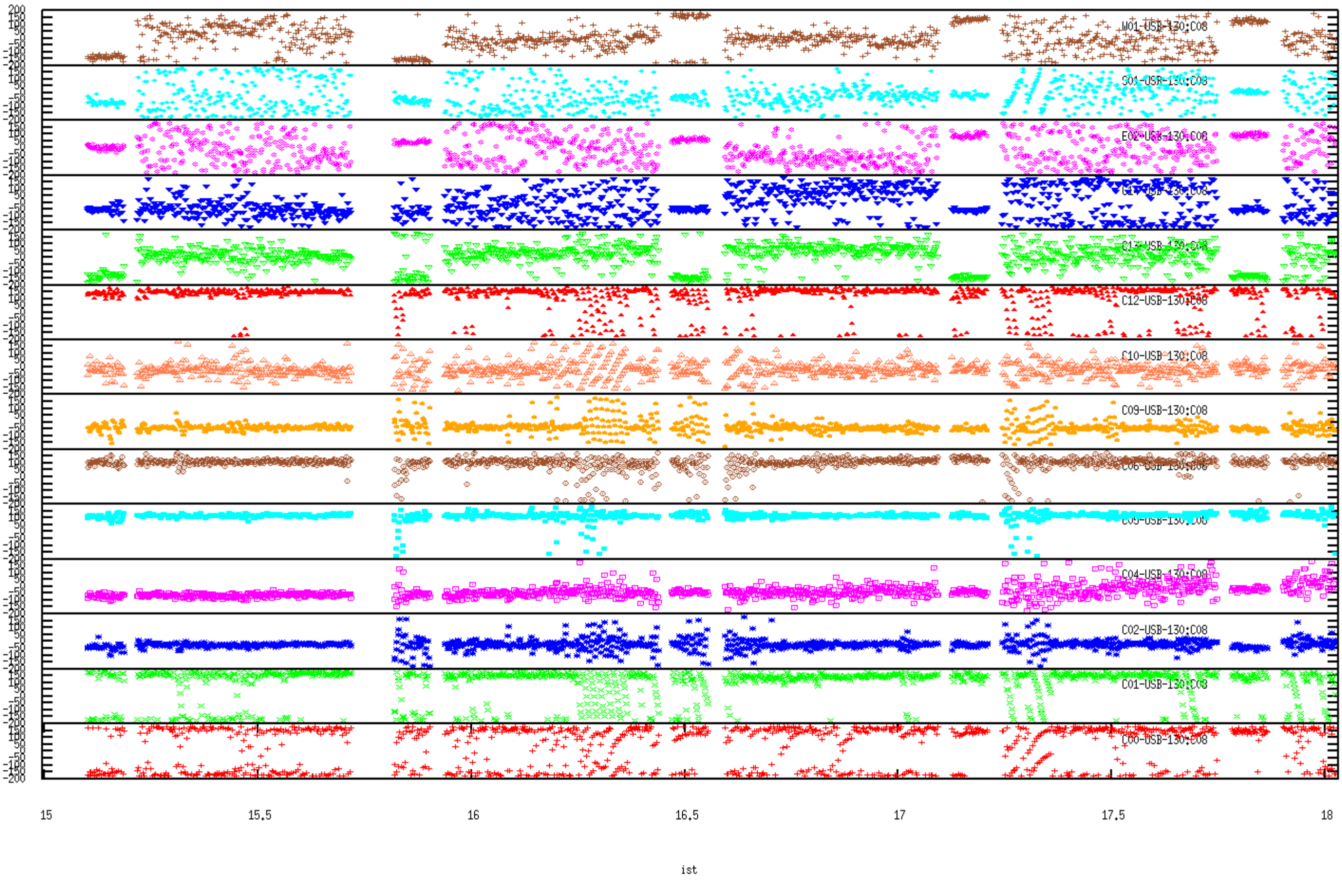


Figure 6: ***Central Square, short-baselines fringes on the Jupiter @ RF-591 MHz (GSB data)***

4.Standard Operating Procedure for Control-room :

To observe solar-system object using the TGC, following are guidelines at present. GUI/Web Interface for creating source-catalog, and observing batch-file is in progress. At present, please execute following steps using the command-terminal :

step-1 :

Use '***horizons2tgc.py***[3]' tool to generate the TGC-format catalog for the desired solar-system object

horizons2tgc.py -i <Target-ID> [-d YYYY-MM-DD (default: today) -t STEP-SIZE in minutes (default: 30 m)] OR -f <Horizons-Catalog>

* Specify The Target-ID Body

10 Sun [Sol]
199 Mercury
299 Venus
499 Mars
599 Jupiter
699 Saturn
799 Uranus
899 Neptune
301 Moon [Luna]
501 Io (JI)
502 Europa (JII)
503 Ganymede (JIII)
504 Callisto (JIV)
505 Amalthea (JV)
506 Himalia (JVI)
507 Elara (JVII)

(Note : If the given catalog is having different format, first align available fields with that of horizon's format, and give option '-r' to calculate dRA,dDEC from RA-DEC. Do not use '-r' option while using the horizon's catalog where

3 ***horizons2tgc.py*** tool written by Jitendra Kodilkar to generate the solar-system object catalog in the TGC format.

dra, ddec is already provided.
Ref : https://ssd.jpl.nasa.gov/horizons/app.html

e.g.

```
> horizons2tgc.py -i 301 -d 2021-12-21 -t 30

  Class gmrtCatalog ::
  Input parameters :   horizon_1640002313.in
  Horizons Catalog :   horizon_Moon_30m.txt      // Horizon catalog produced
  TGC Catalog      :   horizon_Moon_30m.csv      // TGC format catalog produced
```

After giving mandatory '***object-id***' as required by the horizon-application, *horizons2tgc.py* tool download the horizon-catalog as per the input provided, and convert it into the TGC format. In example mentioned above, Horizon Catalog – '***horizon_Moon_30m.txt***' , and the TGC Catalog – '***horizon_Moon_30m.csv'*** are produced.

Step-2 :

Use '***solarsyscmd***[4]' tool to create observing command file in the TGC format, which is nothing but a python-script. Mandatory arguments are the name of 'TGC catalog' in csv format, and phase-calibrator.

> solarsyscmd -f <TGC Catalog> -p <Phase Calibator> *[-s start-time HH:MM -e end-time HH:MM -i data-Acq-interval (default 5 min for phase) -I data-Acq-interval (default 30 min for target) -a solar-attenuation]*

e.g.

```
>solarsyscmd.py -f test.csv  -p '3c287'  -s 11:00  -e 14:00  -I 50  -a 14
  tgc_catalog = test.csv
  phase_cal = 3c287 data_phase_interval = 300 sec
  start_time = 11.0 stop_time = 14.0
  data_target_interval = 3000.0 sec, solar_attn = 14

Observing command file created : test.py
```

OR

Step-2 (Manually giving commands) :
The TGC format catalog list the Source_name appended with the IST time, as given in example below from 'horizon_Moon_30m.csv' catalog -

```
Source_Name, Alias_Name,RA_MEAN,DEC_MEAN,EPOCH,DRA, DDEC,...

MOON0530,-,   07:20:18.41,   +25:54:03.8, 2000.0,  0.0246, -0.0079,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-
MOON0600,-,   07:21:09.21,   +25:50:24.7, 2000.0,  0.0262, -0.0084,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-
MOON0630,-,   07:22:03.28,   +25:46:33.9, 2000.0,  0.0279, -0.0088,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-
MOON0700,-,   07:23:00.79,   +25:42:34.1, 2000.0,  0.0297, -0.0091,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-
MOON2130,-,   08:02:20.15,   +24:51:19.0, 2000.0,  0.0296,  0.0009,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-
MOON2200,-,   08:03:17.10,   +24:51:41.4, 2000.0,  0.0278,  0.0006,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-,-
```

Using the TGC python-shell interface '***MNCScriptManager***' give following commands :

e.g. for source "MOON0630"

```
MNCGMRTScriptManager[1] : add_user_catalog(' /home/cmcuser/horizon_Moon_30m.csv','type1')
```

4 ***solarsyscmd.py*** tool written by Jitendra Kodilkar to generate the observing command file for solar-system object. It is for temporary usage at present.

```
// Define following variables
MNCGMRTScriptManager[2] : subarray_id = 0            // Subarray Numer in the TGC for antenna group
MNCGMRTScriptManager[3] : source_name =' MOON0630'                   // Source-Name
MNCGMRTScriptManager[4] :  trk_az_path =  0     // Antenna Azimuth track for Inner = 0 or Outer=1 path
MNCGMRTScriptManager[5] :  backend = 'BOTH'        // Correlator ='GSB' or 'GWB' or 'BOTH'
MNCGMRTScriptManager[6] :  dradec_reftime = 06.5
                                        // DRA-DEC Reference Time in hours from sourceName<HHMM>

MNCGMRTScriptManager[7] : load_source(source_name)                              // Load source name

MNCGMRTScriptManager[8] : track_array(subarray_no,trk_az_path,dradec_reftime, timeout=20)

MNCGMRTScriptManager[9] :   addpsouce(source_name, backend)
MNCGMRTScriptManager[10] :  set_source(backend, source_name)

MNCGMRTScriptManager[11] :  start_proj(backend, source_name,dradec_reftime, timeout=5)
MNCGMRTScriptManager[12] :  stop_proj(backend, subarray_id,timeout=5)
```

Conclusion :

The validation test results given in this report verifies that the TGC can be used for observation of solar-system objects mainly Jupiter, Sun, and Moon. Following points can be noted :

(i) In spite of different astrometry libraries , SLA, and NOVAS used in the ONLINE, and TGC respectively, antenna tracking errors found to be within accepted limits (i.e. 1-2 arc-min in Azimuth, and 1 arc-min in Elevation axis). The GSB, and GWB LTA header's data show that apparent values calculated for the RA and DEC are matching within the 0.02 seconds, and 0.51 arc-sec respectively. Similarly, apparent MJD values for current time at the start of each data-scan are matching.

(ii) Observation of Jupiter shows stable fringes for short-baselines over 3-4 hours of observation, one need further verification by making continuum image.

(iii) NOVAS library has separate planetary modules (like ***app_planet***) to calculate apparent RA, DEC of planetary objects in our solar system. Since the GMRT antenna tracking accuracy is ~ 1 arc-min, a separate planetary module usage may not be desirable. If need arise, one may require to modify the '*gnovas*' library in future.

(iv) Preparation efforts for observation of solar-system object has been significantly reduced, and simplified with the help of python modules cum scripts, 'horizons2tgc.py', and ' solarsyscmd.py'.

References :

[1] *Subprogram Library A, Starlink Software Project, 2013 (P.T. Wallace, 2005 Manual)*

[2] Bangert, J., Puatua, W., Kaplan, G., Bartlett, J., Harris, W., Fredericks, A., & Monet, A. 2011, User's Guide to NOVAS Version C3.1 (Washington, DC: USNO)

Appendix-I

Detail of modifications done in the TGC code for enabling planetary object observation

File	Modules	Description
Code modification at the Central Monitor & Control		
mnc_custom_db.sql	Command, command_assoc_argument, argument_default_value, argument_valid_range	Tables modified for startscanproj, startscanprojagn, startscanbeam, track_array_offset_ra_dec, track_array to accept the 'dradec_reftime', 'time_str' arguments.
Preprocessing.java	Thread	Thread modified to take *dradec_reftime* as an argument for the track_array, track_array_offset_ra_dec commands.
Track.java	setSubarrayAttributeValues ()	set dynamic attribute value of "dradec_reftime" for subarray
CommandFormation.java	replaceSubarrayWithPrjCode ()	for 'startscanproj' command add the arguments and values for *time_str,* and *dradec_reftime*.
OperationControl.py	onclick_MultiSubarrayTrackArray()	For multi-subarray tracking (Tab), accept dradec_reftime in (Hrs). (for startscan in operationalControl window takes dradec_reftime=0 at the movement).
cmcapi.py (Scripting Manager)	track_array(), trkdecoff(), trkraoff()	To Accept dradec_reftime with the default or user-given value.
Corrapi.py	start_proj()	time_str (advance time-stamp in other context not relevent to planetary tracking), and dradec_reftime
Calcnova.c (Cdist Library) CMC, LMC Both	getAZEL()	Convert dradec_reftime from hrs to radian
Code modification at the Local Monitor & Control (Antenna & Backends)		
CommandFormation.java	FormCommandForStartProj (), formCommandForStartBeam ()	changes to get time_str, and dradec_reftime as argumet for command
GmrtLibraryCalculation.java	calculateMJDValue()	dradec_reftime for dra-ddec in form of the MJD
	radianToradPerSec()	Conversion of dra-ddec values (radian per radian) to per second change as delay
HibernateUtils.java	-	modified for mysql-8 version.
Dynamic_attributes, and properties (Database, and Ubuntu 20.04)		
LMCDS.java	AddDeleteProjAttrs()	(i) Added synchronization to the 'GlobalVariables.prjDynamicAttrs' Hash-map arrays (because while deleting dynamic Attributes addresses were mismatching) (ii) Exception block put to handle tango exceptions so that next or remaining dynamic attributes can be removed after exception occurs. (iii) Added RemoveAttribute, and remove attribute properties separately.
GlobalVariables.java	Class globalvariables	Hashmap is used , instead of

		concurrent hash-map because it was giving problem.
ProjectScalar.java	Class ProjectScalar	set polling period and other properties of dynamic attribute relating to the Project are commented as it was giving problem in Ubuntu 20.04 LTS
PostProcessing.java	run() //Thread	(i) checked updateDynAttrValue for null, and if it is then used addcorrMask attribute call to create first corrmask and set value of 'corrmask' given by corrmask. (ii) delete project Command - handled efficiently first sending the response of command, and then deleting attributes as deleting attributes forcefully may take more time.
SystemStartup.java/ Initializer.java	run()//Thread	corrmask attribute at the corrconfig command handled in SystemStartup.java instead of Initializer
AttributeOperation.java	removeDynamicAttribute()	ade more efficient by using synchronization, taking dynamic attribute list, then preparing individual call to remove attributes, instead of concurrentHashmap directly.

APPENDIX-II

Values from the GSB and GWB LTA data headers per scan using the ONLINE and TGC respectively. Observation done on Nov 15th, 2021

SCAN	GSB	GWB	Difference
0	OBJECT = **3C48** MJD_SRC = 59533.000000 RA_MEAN = 01h38m56.51 DEC_MEAN = +33d16'13.75" RA_APP = 01h38m56.58 DEC_APP = +33d16'19.38" DRA = 00h00m00.00 DDEC = +00d00'00.00"	OBJECT = **3C48** MJD_SRC = 59533.000000 RA_MEAN = 01h38m56.52 DEC_MEAN = +33d16'13.73" RA_APP = 01h38m56.59 DEC_APP = +33d16'19.44" DRA = 00h00m00.00 DDEC = +00d00'00.00"	0 0.01s 0.02" 0.01s 0.06"
1	OBJECT = **OMOON2000** MJD_SRC = 59533.604167 RA_MEAN = 00h51m10.32 DEC_MEAN = +00d38'02.10" RA_APP = 00h51m10.28 DEC_APP = +00d38'01.67" DRA = 00h00m00.02 DDEC = +00d00'00.23"	OBJECT = **MOON2000** MJD_SRC = 59533.604167 RA_MEAN = 00h51m10.34 DEC_MEAN = +00d38'02.61" RA_APP = 00h51m10.31 DEC_APP = +00d38'02.16" DRA = 00h00m00.02 DDEC = +00d00'00.23"	0 0.02s 0.51" 0.03s 0.49" 00 00
2	OBJECT = **OMOON2030** MJD_SRC = 59533.625000 RA_MEAN = 00h51m40.70 DEC_MEAN = +00d45'00.40" RA_APP = 00h51m40.66 DEC_APP = +00d45'00.01" DRA = 00h00m00.02 DDEC = +00d00'00.23"	OBJECT = **MOON2030** MJD_SRC = 59533.625000 RA_MEAN = 00h51m40.72 DEC_MEAN = +00d45'00.79" RA_APP = 00h51m40.68 DEC_APP = +00d45'00.39" DRA = 00h00m00.02 DDEC = +00d00'00.23"	0 0.02s 0.39" 0.02s 0.38" 0 0
3	OBJECT = **OMOON2100** MJD_SRC = 59533.645833 RA_MEAN = 00h52m09.95 DEC_MEAN = +00d51'58.30"	OBJECT = **MOON2100** MJD_SRC = 59533.645833 RA_MEAN = 00h52m09.97 DEC_MEAN = +00d51'58.69"	0 0.02s 0.39"

SCAN	GSB	GWB	Difference
	RA_APP = 00h52m09.92 DEC_APP = +00d51'57.95" DRA = 00h00m00.02 DDEC = +00d00'00.23"	RA_APP = 00h52m09.94 DEC_APP = +00d51'58.32" DRA = 00h00m00.02 DDEC = +00d00'00.23"	0.02s 0.37” 0 0
4	OBJECT = **OMOON2130** MJD_SRC = 59533.666667 RA_MEAN = 00h52m38.52 DEC_MEAN = +00d58'55.60" RA_APP = 00h52m38.49 DEC_APP = +00d58'55.29" DRA = 00h00m00.02 DDEC = +00d00'00.23"	OBJECT = **MOON2130** MJD_SRC = 59533.666667 RA_MEAN = 00h52m38.54 DEC_MEAN = +00d58'55.89" RA_APP = 00h52m38.50 DEC_APP = +00d58'55.55" DRA = 00h00m00.02 DDEC = +00d00'00.23"	 0 0.02s 39” 0.01s 0.26” 0 0
5	OBJECT = **OMOON2200** MJD_SRC = 59533.687500 RA_MEAN = 00h53m06.85 DEC_MEAN = +01d05'51.90" RA_APP = 00h53m06.82 DEC_APP = +01d05'51.63" DRA = 00h00m00.02 DDEC = +00d00'00.23"	OBJECT = **MOON2200** MJD_SRC = 59533.687500 RA_MEAN = 00h53m06.86 DEC_MEAN = +01d05'52.18" RA_APP = 00h53m06.83 DEC_APP = +01d05'51.88" DRA = 00h00m00.02 DDEC = +00d00'00.23"	 0 0.01s 0.28” 0.01s 0.25” 0 0
6	OBJECT = **OMOON2230** MJD_SRC = 59533.708333 RA_MEAN = 00h53m35.40 DEC_MEAN = +01d12'46.90" RA_APP = 00h53m35.37 DEC_APP = +01d12'46.67" DRA = 00h00m00.02 DDEC = +00d00'00.23"	OBJECT = **MOON2230** MJD_SRC = 59533.708333 RA_MEAN = 00h53m35.41 DEC_MEAN = +01d12'47.08" RA_APP = 00h53m35.38 DEC_APP = +01d12'46.81" DRA = 00h00m00.02 DDEC = +00d00'00.23"	 0 0.01s 0.18” 0.01s 0.14” 0 0