GMRT ANTENNA POINTING OFFSETS

Introduction

Pointing the antennas in the desired direction leads to better images. Incorrect pointing of an antenna leads to loss in sensitivity and positional errors. For this reason it is important to periodically estimate pointing errors for each antenna and correct them. At GMRT, typical pointing errors of 1’ for each of the elevation and azimuth axes are tolerated when correcting them.

What is pointing offsets of GMRT antenna?

Pointing offset is defined as the offset between the encoder/target antenna position and the actual source position in the sky.

Offset = Actual Source position in the sky - Antenna position in the sky

Why does pointing offset change with time?

The pointing offsets often vary with time due to various reasons, majority of which are instrumental effects. The reasons are listed below.

1. There are sudden jumps in the offsets due to the encoder change or encoder assembly work.
2. The feed positioning system (FPS) causes an error, every after feed rotation.
3. Were and tear of the mechanical systems.
4. Axis tilt.
5. Deformation of the dish due to gravity/weight, temperature, elevations angle and time etc.

Types of Offset

Pointing offsets can be deviated in to two types.

1. Fixed offsets (loaded in to SSC and ABC)
2. Variable offsets (handled by pointing model, it is the function of AZ and EL)

How do we estimate the offsets?

Various methods are developed to estimate the pointing offsets.

1. Self pointing with scanning of strong calibrator. (fixed type)
2. Cross pointing with scanning of good point source. (fixed type)
3. Grid with self/cross pointing with good point/strong source for large values. (fixed type)
4. Grid pointing with good point source for small values. (fixed type, regularly used)
5. Grid pointing with many calibrator sources for pointing model. (variable type)

Total offset

Offset = offset at SSC (fixed) + offset at ABC (fixed) + offset by pointing model (variable)

Fixed type

Reason for Pointing	Offset Value (large/small)	Method used for pointing	Loading at SSC	Loading at ABC/C&M
Encode change or encoder assembly work at any one axis. (one unknown)	Most of the time value is large (0 to 10 deg)	Self or Cross pointing scan with large angle (+/1 15 deg). larger scan rate.	If the absolute value is greater than a 1 degree, then integer part is loaded in to SSC with sign.	Fractional part (arc mins) are loaded in to C&M with sign.
Encode change or encoder assembly work at both axis. (both unknown)	Most of the time value is large (0 to 10 deg)	Grid (self/cross) pointing with large angle (+/- 15 deg). grid spacing slightly less than beam width.	If the absolute value is greater than a 1 degree, then integer part is loaded in to SSC with sign.	Fractional part (arc mins) are loaded in to C&M with sign.
After feed rotation or weekly pointing for both axis, one at a time.	Small offsets (+/- 20 arc min)	Self, cross or grid pointing can be used. We use grid pointing regularly since 2008.		Offsets are (arc mins) are loaded in to C&M with sign.

Variable type (model offsets)

Reason for Pointing	Offset Value (large/small)	Method used for pointing.	Loading at SSC	Loading at ABC/C&M
Update of the pointing model on regular basis, every after 6 months. (Deformation of the dish due to gravity/weight, temperature, elevations angle, axis tilt and time etc.)	Most of the time value is small (1 to 5 arc min)	Grid pointing on both axis with many calibrators sources.		Model offsets which derived by the function of AZ and EL for each time are added to the Fixed type offsets of C&M with sign.

1. Self pointing (one axis scan)

This method is used to find large pointing offsets in any one axis while the other axis should have known offsets. This method is not useful when both axis have a unknown offsets. Strong source is required to get the proper results, very few strong sources are available for all the time in sky. For regular use (smaller offsets) this method not used due to less accuracy. But this method is less time consuming and can work for one or many antenna at time. Possible in case of multi frequency mode.

Consider a strong, unresolved radio source whose position is known. If an antenna is moved across the source at a constant 'scan-rate' then maximum power will be observed when the beam crosses the center of source at the expected time. However, power will not peak at the expected time if there is an error in pointing in the direction of the scan. Knowing the rate of scanning and the difference between the expected and observed peak-time, it is thus possible to determine the angular error in the pointing. If position of the source is given by AZ, EL then pointing offsets in azimuth, dAZ and elevations, dEL are given by

dAZ (arc min) = (T_exp – T_obs) * cos (EL) * AZ_scan_rate / 60
dEL (arc min) = (T_exp – T_obs) * EL_scan_rate / 60

If the antenna has zero pointing offset, then the maximum power will occur at the expected time, however, if there is a pointing offset, the maximum power may occur before or after the expected time. The convention is to attribute a positive pointing offset if the peak leads the expected time and a negative offset if it lags the expected time.

Procedure.

1. Antenna/s should be ready with default setup at 1420/610/325 MHz with ALC OFF.
2. Antenna/s should be tracking the Strong calibrator source (EL < 40 deg).
3. Analog backed with default setup, ALC OFF.
4. Digital backed with default setup with 2 sec integration.
5. Load the current offsets (load 0 offset if the offsets are not known) with pointing model.
6. Power equalize done on strong calibrator source.
7. Check the corr band shapes/fringe RFI status to proceed for scanning or not.
8. Calculate the scan rate, start time, peak time and stop time.
9. Issue the scanning command with specific scan rate and target time to the particular axis just before the start time.
   (scanelsrc(20'/1m,18h30m); 20'/1m is scan rate and 18h30m is the expected peak time.)
10. start the LTA data record (scan).
11. Stop the record when time crosses the stop time.
12. Bring back the antenna from scanning to tracking mode.
13. Analysis the data by offset finding tool.
14. View the results manually.
15. Update the offset table if the results are satisfactory or within the valid range for one or many antenna. Load the offsets to ABC and/or SSC.
16. Repeat the procedure steps 5 to 15 for other axis.

2. Cross pointing (one axis scan)

This method is used to find large and small pointing offsets in any one axis while the other axis should have known offsets. This method is not useful when both axis have a unknown offsets. point source calibrator is required to get the proper results, many point sources calibrators are available for all the time in sky. For regular use (smaller offsets) this method can be used due to its high accuracy. It is less time consuming and can work for one or many antenna at time. It can not be used in multi frequency mode. Reference antenna is required, for which we can not estimate the offsets. If the reference antenna fails during the test, then test has no meaning.

Consider a good point source calibrator whose position is known. Keep one or two good working antennas as reference in to separate sub array, which will continuously track the point source. Other antennas will scan the point source. If an antenna is moved across the source at a constant 'scan-rate' then maximum cross power will be observed when the beam crosses the center of source at the expected time. However, power will not peak at the expected time if there is an error in pointing in the direction of the scan. Knowing the rate of scanning and the difference between the expected and observed peak-time, it is thus possible to determine the angular error in the pointing. If position of the source is given by AZ, EL then pointing offsets in azimuth, dAZ and elevations, dEL are given by

dAZ (arc min) = (T_exp – T_obs) * cos (EL) * AZ_scan_rate / 60
dEL (arc min) = (T_exp – T_obs) * EL_scan_rate / 60

If the antenna has zero pointing offset, then the maximum cross power will occur at the expected time, however, if there is a pointing offset, the maximum cross power may occur before or after the expected time. The convention is to attribute a positive pointing offset if the peak leads the expected time and a negative offset if it lags the expected time.

Procedure.

1. Antenna/s should be ready with default setup at 1420/610/325 MHz with ALC ON.
2. Antenna/s should be tracking the point source, reference antenna in separate sub arry.
3. Analog backed with default setup, ALC ON.
4. Digital backed with default setup with 2 sec integration.
5. Load the current offsets (load 0 offset if the offsets are not known) with pointing model.
6. Check the corr band shapes/fringe RFI status to proceed for scanning or not.
7. Calculate the scan rate, start time, peak time and stop time.
8. Issue the scanning command with specific scan rate and target time to the particular axis just before the start time. (reference antenna will keep on tracing the source) (scanelsrc(20'/1m,18h30m); 20'/1m is scan rate and 18h30m is the expected peak time.)
9. start the LTA data record for both sub arrays in single file (scan).
10. Stop the record when time crosses the stop time.
11. Bring back the antenna from scanning to tracking mode.
12. Analysis the data by offset finding tool.
13. View the results manually.
14. Update the offset table if the results are satisfactory or within the valid range for one or many antenna. Load the offsets to ABC and/or SSC.
15. Repeat the procedure from 5 to 14 for other axis.

3. Grid with self/cross pointing (two axis scan)

This method is used to find large pointing offsets when both axis offsets are unknown. One can use this in self mode or cross mode. Instead of scanning the antenna in one axis a grid of offsets in both the axis is made and loaded to the antenna in a specific sequence. It has lees accuracy but less time consuming. It finds the unknown offsets in both axis simultaneously.

Procedure

1. either self or cross pointing setup is should be ready.
2. Generate the command file of offset grid points.
3. Instead of scan command, start the grid command file.
4. Start the LTA record.
5. Stop the record after command file is over.
6. Analysis the data using pointing tool.
7. View the results manually.
8. Update the offset table if the results are satisfactory or within the valid range for one or many antenna. Load the offsets to ABC and/or SSC.

4. Grid pointing, regular use (one axis scan in steps)

This method is used to find large or small pointing offsets in any one axis at a time. This method is not useful when both axis have a unknown offsets. point source calibrator is required to get the proper results, many point sources calibrators are available for all the time in sky. For regular use (smaller offsets) this method can be used due to its high accuracy. It can work for two or more than two antenna at time. It can not be used in multi frequency mode. Total time can be minimized by reducing the number of grid points. This method is regularly used every after feed rotation or weekly.

Consider a good point source calibrator whose position is known. Instead of continuous scanning the source, antenna will scan the source in steps called grid points. Correspondingly the LTA data will be recorded in individual scans. The Gaussian fit plot of the gain points(scans) vs grid points will estimate the pointing offsets.

Procedure.

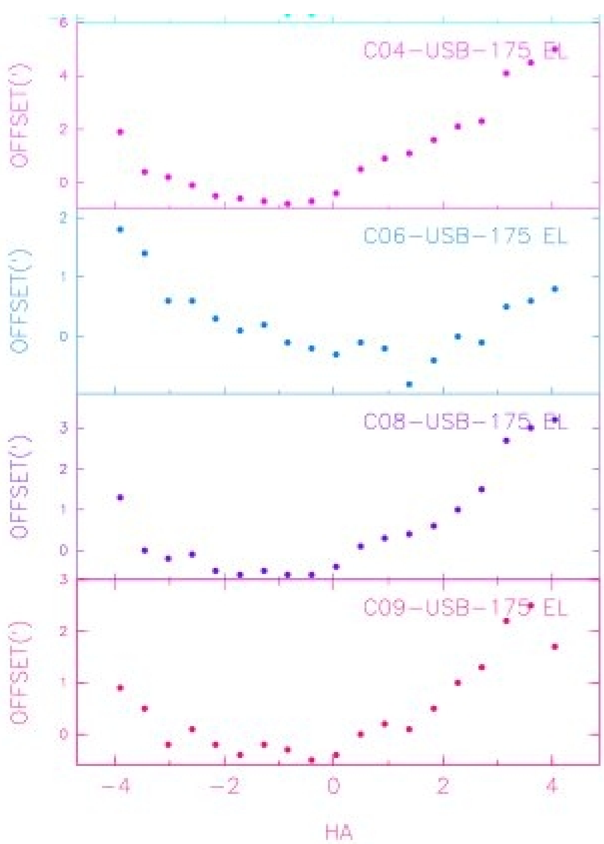
1. Antenna/s should be ready with default setup at 1420/610/325 MHz with ALC ON.
2. Antenna/s should be tracking the point source.
3. Analog backed with default setup, ALC ON.
4. Digital backed with default setup with 2 sec integration.
5. Load the current offsets (load 0 offset if the offsets are not known) with pointing model.
6. Check the corr band shapes/fringe RFI status to proceed for pointing or not.
7. Generate the command using frequency, source, total grid points for one or both axis.
8. Start the command file and LTA record.
9. Stop the record when command file execution is over.
10. Bring back the antenna to tracking mode.
11. Analysis the data by offset finding tool.
12. View the results manually.
13. Update the offset table (by script) if the results are satisfactory or within the valid range for one or many antenna. Load the offsets to ABC and/or SSC.

5. Grid pointing (for pointing model update) to handle variable type

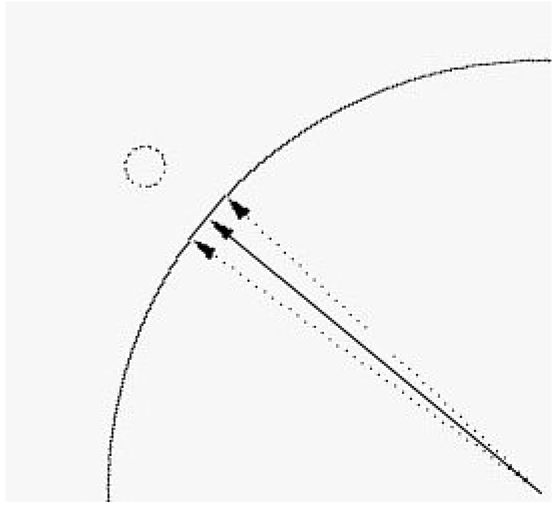
Pointing offsets can result from several reasons, majority of which are instrumental. Some of these effects are the non-orthogonality of the azimuth and elevation axis, the orientation of the tilt of the azimuth axis, encoder offsets for both elevation and azimuth encoders, errors in the feed positioning system and gravitational deformation; most of which change as a function of elevation and/or azimuth.

The model is mainly based on pointing errors arising from axes misalignment and gravitational bending which are common to any dish antenna. The model parameters are derived from analysis of the grid pointing data. It is the function of AZ and EL. The small offsets keep on changing as antenna moves in the sky with different AZ and EL.

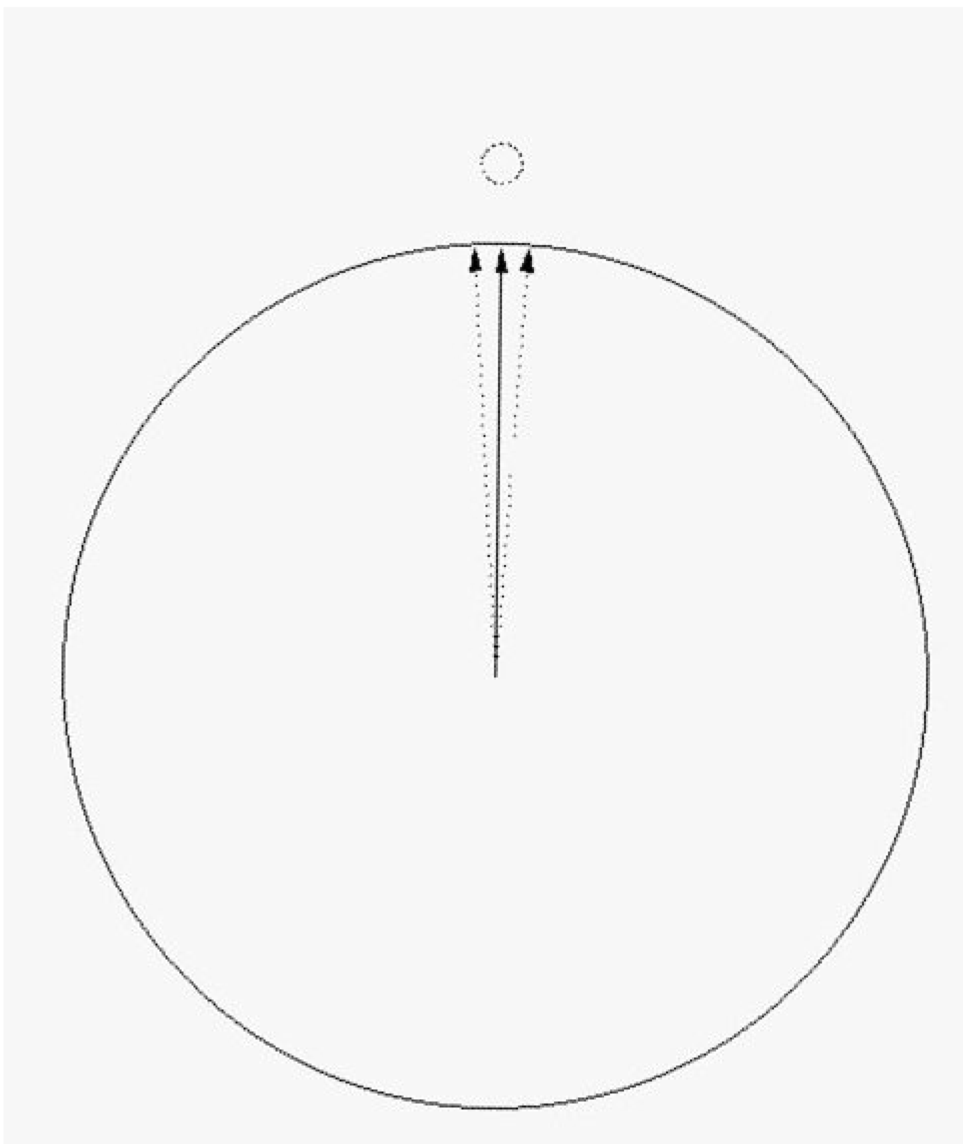
At 1420 and 610 MHz. We normally apply this offsets correction in to the C&M offsets. We not apply this correction at 325 and 150 MHz, due to larger beam widths and. But for loading default pointing offsets any frequency we apply model corrections all the time. One can apply or remove the model offset correction.



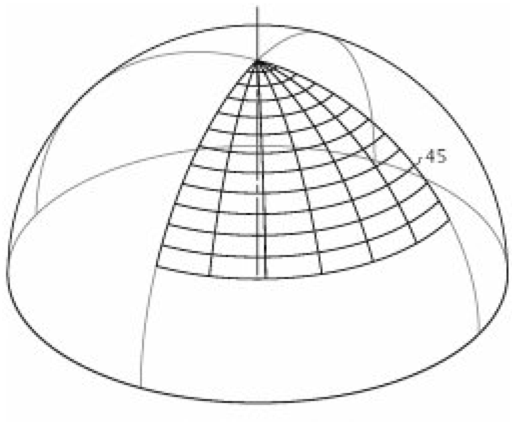
Offset change With AZ and EL change.



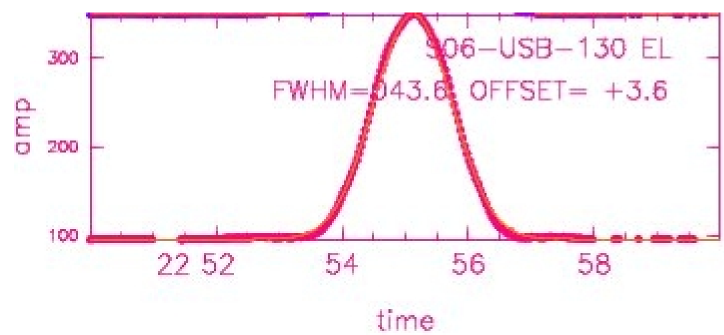
Elevation axis scan



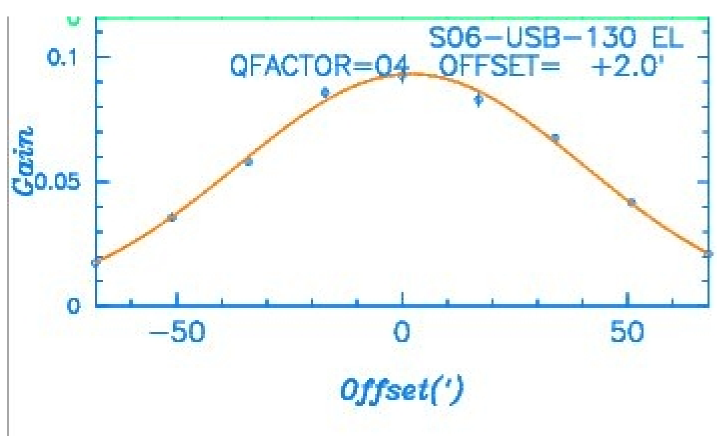
Azimuth axis scan



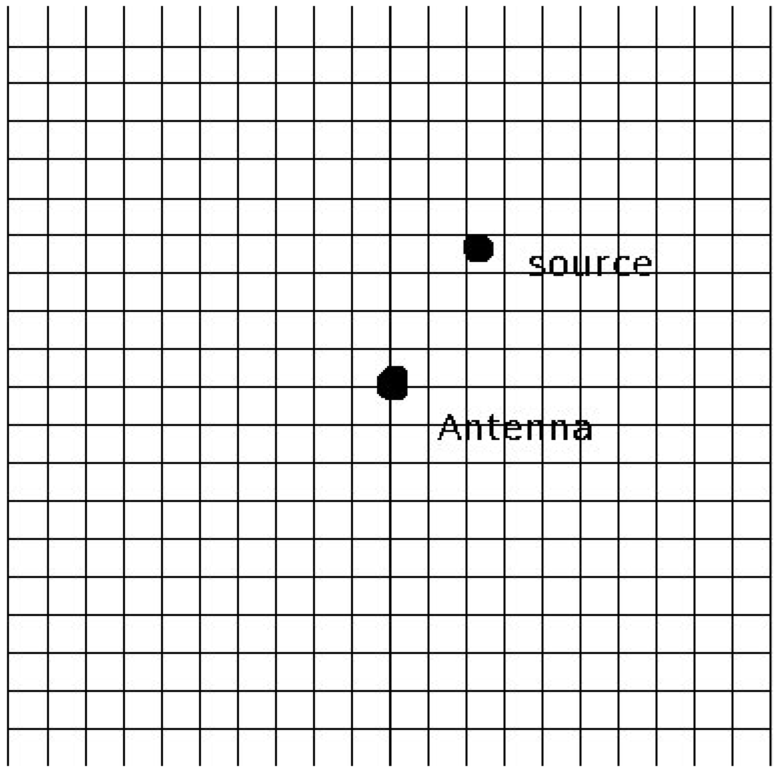
Grid pointing with self/cross mode, two axis



Self/Cross pointing continuous scan, one axis



Grid pointing scan in steps, one axis



Grid pointing self/cross scan, two axis