Determination of the Pointing Offsets and Beam Pattern for the 4-m Telescope

1 Goal of the experiment

The aim of the experiment is to align the 4-m telescope at NCRA East campus with the proper ALT/AZ coordinate system allowing it to be pointed to the given astronomical source.
This requires determining the offsets between the electronic reference of the telescope and the astronomical ALT/AZ coordinate system at the observatory. Using the calculated offsets, scans in AZ and ALT direction are taken to calculate the beam width of the 4-m telescope.
The understanding of the issues of practical astronomy is tested by the brain teaser section, which requires solutions to problems listed in this sheet and familiarization with
directions in sky. The procedure for the initialization of the telescope and receiver should be followed first, which is given in the previous document. The procedure of the experiment is described which includes the operation of the telescope and receiver system. The observation section provides a log sheet for the experiment, which requires observations of Sun to determine ALT and AZ offsets. It is followed by an analysis section which consists of analysis procedure and log.
Finally a results section is provided for listing results along with the errors.

2 Brain Teasers

1. Go out on the terrace and identify different directions on the sky. If sun is visible, roughly find the direction of North pole, which is one of the reference for telescope control system. Indicate approximately the Alt-azimuth position of the telescope.
Ans.:

2. Track the path of the Sun on the sky. How does the azimuth and altitude change through the day at NCRA campus? How would this change if you were located +500N at the time of the experiment? How would this change if you were located -500 N at the time of the experiment?
Ans.:

3. Find out the RA/Dec of Sun and the constellation in which the Sun is, at the time of observation. Familiarize yourself with the equatorial coordinate system as it is visible from the telescope location. In what direction then RA/Dec increases/decreases? Where is the 0,0 RA/Dec point located in the sky?
Ans.:

4. What is the angular size of Sun disk in the sky? What is the resolution of an typical optical telescope (let's take D=10cm)? What should be the diameter of the telescope at 21 cm, to achieve the same resolution?
Ans.:

3 Procedure for the experiment

Before starting with the experiment, initialization of the telescope and receiver has to be done. For this purpose please refer to the document titled 'Initialization of the 4-m Telescope System'. Follow the experimental procedure given below.

3.1 Experimental Procedure

This experiment can be done by visually pointing the antenna towards the Sun if the sky is not cloudy. Look at the shadow of the feed at the center of the dish and rotate the antenna till the shadow is centered approximately. If the sky is cloudy, then the experiment is not recommended. Then, the following procedure is to be followed.

3.2 Observation Log

3.2.1 Observation Table for Azimuth Scans

	Azimuth Scan 1	Azimuth Scan 2
Azimuth Angle	Starts : End :	Starts : End :
Altitude Angle	Starts : End :	Starts : End :
Slew speed		
Time/Step		

Scan Receiver Data file name 1

Scan Encoder Data file name 1

Scan Receiver Data file name 2

Scan Encoder Data file name 2

3.2.2 Observation Table for Elevation Scans

	Altitude Scan 1	Altitude Scan 2
Azimuth Angle	Starts : End :	Starts : End :
Altitude Angle	Starts : End :	Starts : End :
Slew speed		
Time/Step		

Scan Receiver Data file name 1

Scan Encoder Data file name 1

Scan Receiver Data file name 2

Scan Encoder Data file name 2

3.3 Analysis Procedure and Log

3.3.1 Procedure

1. Login into a linux system.
2. Copy your encoder data file and receiver data to a subdirectory or Desktop in linux.
3. Open Terminal window by selecting that option in Accessories drop down menu.
4. Access your subdirectory (where data files are copied) or Desktop directory by using "cd <dirname>".
5. Then separate the Azimuth and Elevation angles by using the command "awk '{print $1}'
<encoder file> > azimuth" (it will write the values in this file) and this will give you the Azimuth values (Eg: awk '{print $1}' SunEL(or)AZ.batch<nn>.position.<hrmmss.ddmmyy> > azimuth)
6. Similarly, create elevation encoder data file with "awk '{print $2}' SunEL(or)AZ.batch<nn>.position.<hrmmss.ddmmyy> > altitude" and this will give you the Altitude values.
7. Copy receiver data file for your scan to your subdirectory as "altscan" or "azscan" and remove the header line after noting down the start time as well as trailing zeros in the data file using an editor such as "vi" or "gedit" or "Notepad".

Analysis with MATLAB

1. Click on MATLAB icon
2. Change the working directory of MATLAB to the directory where you have copied your data files.
3. Load encoder data in MATLAB using load data command with your file name. "load altitude" or "load azimuth"
4. Similarly load data of Receiver values in MATLAB using "load altscan".
5. The number of data points should be declared as "n=300"(you may change according to the length of your data.
6. Generate X axis using >> for i=1:n x(i)=altitude(i); end or >> for i=1:n x(i)=azimuth(i); end
7. Generate Y axis using >>for i=1:n y(i)=altscan(i); end
8. plot data using >>plot(x,altscan)
9. Choose data points near the peak of the deflection on Sun
10. Copy these data points to two arrays "datax" and "datay"
11. To fit a curve >>cftool(x,y)
This will open an interactive data plot.
12. Select "datax" and "datay" as X and Y arrays in "DATA" tab
13. Click on - Fitting - New fit.
14. Select Gaussian in "Type of fit".
25. Then select the Gaussian function "a1 * exp-((x-b1)/c1) ", from the list.
26. Click "Apply".
27. Note down values of the fitting parameters a1,b1 and c1. (Parameter b1=position of
Gaussian/measured position of Sun.
28. From the Almanac, calculate the Al/Az coordinates of the Sun at the time of the scan. The
difference between the calculated Az/Al and the Peak of Gaussian (for both Az and Al scans) are
the offset of the telescope.
19. Parameter $c_1 = \sqrt{2}\sigma$, where σ is the root-mean-square width of the Gaussian. The FWHM
is then calculated from σ as FWHM = 2.35*σ
20. To save the plot obtained in cftool, go to "File-print to figure"
21. Insert labels
22. "File - save as - name.jpg - save"

Analysis with GNUPLOT

Merge the two files into one with the help of paste command.
>> paste 'SUNEL.batchno' 'altscan' > 'output file name'
Open GNUPLOT by typing gnuplot in linux terminal window.
Plot the output file using plot command in gnuplot.
>> plot 'output file name' w l using 1:2
Fit the data with the Gaussian using a Gaussian function as follows:
>> f(x) = a*exp(-((x-b)**2/(2*c**2)))
Give the approximate values of a,b,c with the help of the plot.
Fit Gaussian using the following command.
>> fit f(x) 'output file name' via a,b,c
This will fit the data with the Gaussian function. Note down the value of a, b and c with its error.
If you wish to see the fit, plot it using the following command
>> plot 'output file name' w l, f(x)
Note down the a,b,c values with erros also note down the reduced chi square value.
Repeat the same for all the other altitude as well as azimuth scans.

3.4 Log

3.4.1 Altitude Scans

	Altitude scan 1	Altitude scan 2
Data point selected		
Peak of Gaussian (Deg)	±	±
FWHM of Gaussian (Deg)	±	±
Expected Azimuth	Deg.	Deg.
Expected Altitude	Deg.	Deg.
Offset	Deg.	Deg.

3.4.2 Azimuth Scans

	Azimuth scan 1	Azimuth scan 2
Data point selected		
Peak of Gaussian (Deg)	±	±
FWHM of Gaussian (Deg)	±	±
Expected Azimuth	Deg.	Deg.
Expected Altitude	Deg.	Deg.
Offset	Deg.	Deg.

4 Results and Discussion

The estimate of pointing offsets are as follows –

1. Azimuth Offset : Deg.

2. Altitude Offset: Deg.

The Beam-Width of the 4-m telescope is the FWHM obtained from the beam pattern is Deg. The theoretical expected value is Deg.
The sources of error in my experiment are as follows –

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