MEASURING POINTING OFFSETS USING IF DETECTORS

Pradeep Gothoskar & A. Pramesh Rao
NCRA, Pune
Sept. 97

AIM

Estimation of pointing error for each of the 30 GMRT antenna is a tedious and time-consuming process. Here we present a method of estimating pointing offsets simultaneously for a group of antennas, using data obtained from the IF detectors via 'online'.

INTRODUCTION

Incorrect pointing of an antenna leads to loss in sensitivity and positional errors for single-dish, total-power observations. For this reason it is important to periodically estimate pointing errors for each antenna and correct it. Such measurements are essential after an antenna has undergone mechanical servicing. Initially, pointing errors in the elevation and azimuth axes are obtained by moving each antenna around the expected position of radio source, till iteratively a maximum signal is obtained. The data from IF or Base Band (BB) is measured either on a chart recorder or by a computer. The first-order elevation and azimuth offsets thus obtained are stored into the servo computers of the currently available antennas.

This method of obtaining offsets is, however, tedious, time consuming and to some extent subjective. Further, the method is impractical for routine measurement of large number of antennas. We have evolved an easier method of determining pointing offsets simultaneously for many antennas. The method uses data from the IF detectors, read through the MCM (Monitor and Control Module) via the the facility provided by ONLINE software.

PRINCIPLE

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 centre crosses the source at the expected time. However, power will not peak at the expected time if there is 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 (θ_{azim}, θ_{elev}) then pointing offsets in azimuth, $\Delta\theta_{azim}$, and elevation, $\Delta\theta_{elev}$, (in degrees), are given by,

$$\Delta\theta_{azim}(i) = (T_{exp} - T_{obs}(i)) \times \frac{cos(elev) \times R_{azim}}{60.0} \quad (1)$$

$$\Delta\theta_{elev}(i) = (T_{exp} - T_{obs}(i)) \times \frac{R_{elev}}{60.0} \quad (2)$$

where, R_{azim} and R_{elev} are the scan-rates in the azimuth and elevation (arc minutes per minute), T_{exp} is the expected peak-time and $T_{obs}(i)$ is the observed peak time (in hours) for the i^{th} antenna.

PROCEDURE

Using ONLINE, define a sub-array of antennas whose pointing is to be deteremined. Switch off the IF ALCs (Automatic Loop Control) and for each antenna set IF attenuators to their default values. Put MCM 9 in the 'data-scan' mode so that the IF detector output is made available through ONLINE. Select a strong radio sources, position the array on the source and track the source. Some commonly used radio sources are Virgo, Caseopia, Crab and Hydra. ONLINE provides two commands, namely, scanazim and scanelev, to move antennas at a constant rate in azimuth and elevation, respectively. Typically, **scan-rate of 10′ / 1 minute** is used for both azimuth and elevation scans. **Expected peak time, 10 minutes ahead of the current time** is given and scan is continue for about 20 minutes. This provides adequate data on either side of the source. Note that, when a source is at high elevation, $cos(elev) \times R_{azim}$ becomes small, hence the azimuth scan needs to be taken for a longer duration.

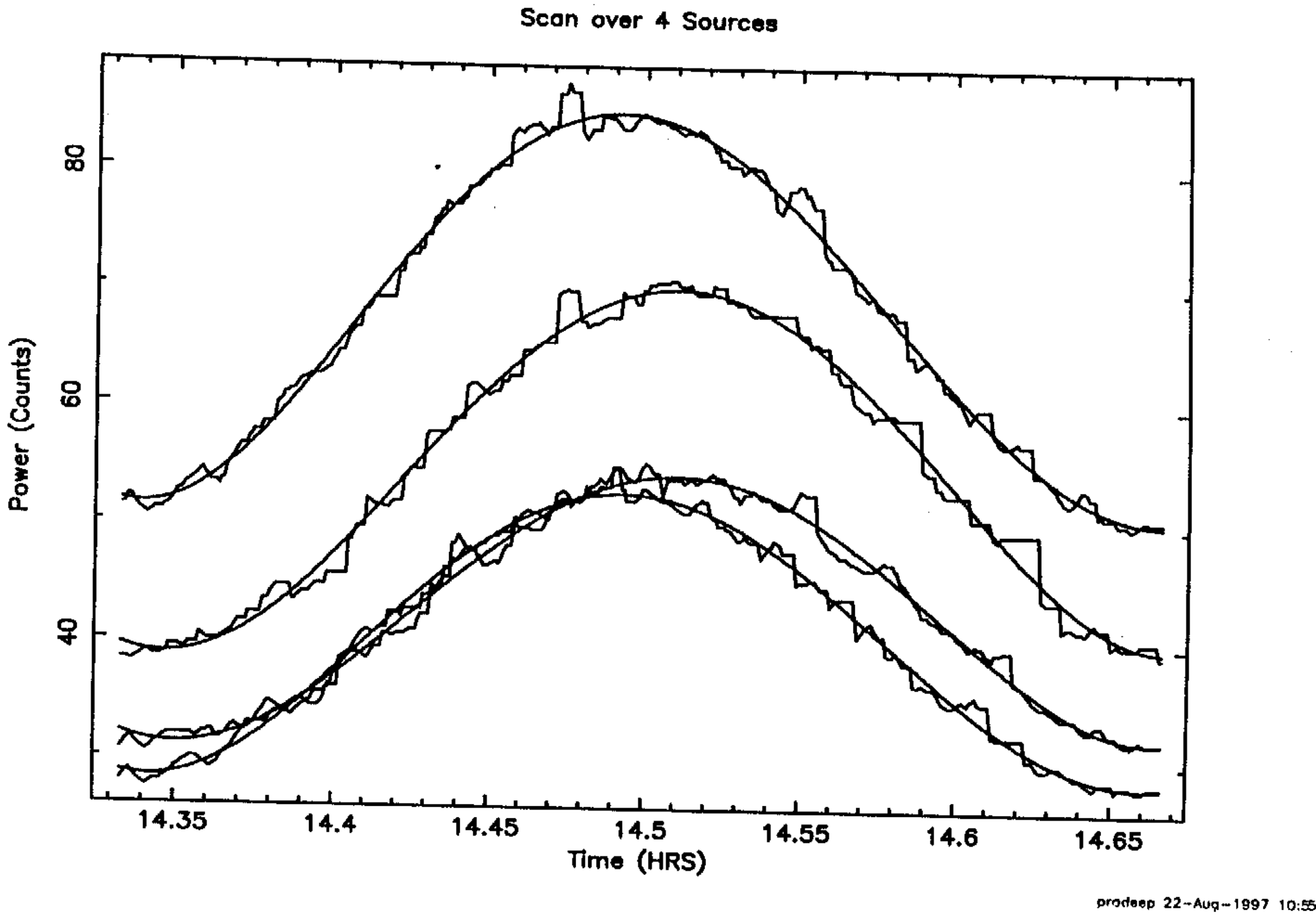


Figure 1 : Elevation scan over Virgo for four antennas. Expected peak-time was 14.5 hrs. Note that the observed peak-time does not coincide with the 14.5 hrs.

The IF data available via ONLINE is extracted and stored in a file for pointing computation. This is done by running the table program from the user shell when the scan is in progress. Sampling of 3 second is selected for the table program. Data is extracted for both the IF channels of all 30 antennas using a the selection file pointing.sel. Output of table is re-directed to a file which is named after the source, date and expected time. For example, file for elevation scan over Virgo at 14:30 hrs on 19 August is named virgo19aug1430e.dat.

Program pointing is used to generate the final offset values. This program clips interference above two-sigma level after running mean subtraction and generates a smoothed time series for each antenna. A polynomial is fitted to this data which is then used for further computation. Figure 1 shows the time series and the polynomial fits for four antennas. The program needs above data file as input and parameters such as scan rate (in arc minutes per minute), expected peak time (hours and minutes) and elevation. Elevation is to be provided for azimuth scan data, while it is set to zero for elevation scans. An example run of the azimuth and elevation pointing is given in the following.

EXAMPLE RUN

ONLINE		USER SHELL	
ONLINE>			
ONLINE>	gts 'virgo'		
ONLINE>	sndsacsrc		
ONLINE>	posn	CHITRA>	
ONLINE>	trksacsrc 5h	CHITRA>	
ONLINE>	stabct	CHITRA>	
ONLINE>		CHITRA>	
ONLINE>	**scanelof(10'/1m,14h30m)**	CHITRA>	**tabel** > virgo19aug1430e.dat
ONLINE>		CHITRA>	selection file : pointing.sel
ONLINE>		CHITRA>	sampling time : 3 sec
ONLINE>		CHITRA>	
ONLINE>	(...Elevation Scanning...)	CHITRA>	(... Log the Elevation data...)
ONLINE>		CHITRA>	
ONLINE>	gts 'virgo'	CHITRA>	C (stop the table)
ONLINE>	sndsacsrc	CHITRA>	
ONLINE>		CHITRA>	
ONLINE>	**scanazof(10'/1m,15h00m)**	CHITRA>	**table** > virgo19aug1500a.dat
ONLINE>		CHITRA>	selection file : pointing.sel
ONLINE>		CHITRA>	sampling time : 3 sec
ONLINE>		CHITRA>	
ONLINE>	(... Azimuth Scanning...)	CHITRA>	(... Log the Azimuth data...)
ONLINE>		CHITRA>	
ONLINE>	gts 'virgo'	CHITRA>	C (stop the table)
ONLINE>	sndsacsrc	CHITRA>	
ONLINE>		CHITRA>	**pointing**
ONLINE>		CHITRA>	Input file : virgo19aug1430e.dat
		CHITRA>	rate,time,elev : 0.167 14 30 0.0
		CHITRA>	
		CHITRA>	(... Computing Elevation pointing...)
		CHITRA>	
		CHITRA>	**pointing**
		CHITRA>	Input file : virgo19aug1500a.dat
		CHITRA>	rate,time,elev : 0.167 15 00 67.0
		CHITRA>	
		CHITRA>	(... Computing Azimuth pointing...)
		CHITRA>	

RESULT

The output of pointing program is stored in a default file pointing.dat. Typical output of the pointing program is presented on the following page. The first column gives list of antennas, according to their ABC (Antenna Based Computer) numbers. The offsets (degree, minute, second) for the two IF channels are given in columns 2-4 and 5-7, respectively. Columns 8, 9, 10, 11 give the mean and sigma of the IF data. Columns 12-14 and 15-17 provide error messages for the two IF channels. The first error flag , '**o/p**', is set if no IF signal is detected (as in case of antennas whose MCMs are not in scan mode). Second error flag, '**sig**', is set when *rms* of the data is found to be larger than a set value. This can happen if a) there is strong interference from the antenna or, b) if IF output is extremely quantized due to detectors being in non-linear range (see the comment of linearity of IF detectors). Third error flag, **def**, is set when no deflection is observed for a source above a threshold value. This can happen if the pointing error is more than 4 to 5 degrees, beyond the range of present method. The antennas for which no error flags are set are to be short-listed and their offsets are used as the final pointing errors. An example of pointing.dat on the next page shows 12 antennas (printed in bold) for which the elevation offsets were determined from a single elvation scan. pointing program also generates an ascii file pointing.plot which can be used to judge the quality of the data and fit. The file contains scans and corresponding polynomial fits, which can be plotted using any of the plotting pakages such as gnuplot or qdp.

ACCURACY

The accuracy of pointing offsets thus measured primarily depends on how well one can determine the observed peak time. For a scan-rate of $10'/1m$ and sampling of 3 seconds, each sample would correspond to an angle of about $30''$ and a scan of 20 minutes (10 minuts on either side of the source) would thus have about 400 samples. It is observed that for these set of parameters, pointing offsets can be determined to an accuracy of few arc minutes. That is to say, the offset values remain consistent with each other in the repeated scans to a few arc minutes. Smaller variations observed in the offsets values are due to presence of noise which jitters the peak position of the fitted polynomial around an average position. Note that, the offset values obtained for the two IF channels are consistent with each other within this limit. Occasionally, one of the IF channels may not provide IF data in which case, values from the other IF channel are to be used. Accuracy and self-consistancy of the present method was also determined by adding the offset values to the first-order offsets for each antenna and checking that the pointing error reduces to a small number in the successive scans.

File : virgo19aug1430e.dat0 **Rate : 0.17 Time :14 30 Elev : 0.00**

	POINTING OFFSETS						DATA QUALITY				ERROR FLAGS					
	Ch	1		Ch	2		Ch1		Ch2			Ch1			Ch2	
Ant	dd	m	ss	dd	m	ss	Mean	Sig	Mean	Sig		Err			Err	
CEB	+01	39	30	+01	39	30	0.00	0.00	0.00	0.00	o/p	sig	def	o/p	sig	def
C03	+01	39	30	+01	39	30	0.00	0.00	0.00	0.00	o/p	sig	def	o/p	sig	def
C12	-00	01	10	+00	01	50	11.90	0.62	17.05	0.49						
C04	-00	11	40	-00	12	00	25.85	1.15	34.05	1.32						
C09	-00	04	20	-00	04	50	28.00	0.70	51.10	0.76						
C02	+00	06	30	+00	06	00	38.55	0.49	31.05	0.86						
C01	-00	17	40	-00	16	50	32.75	0.82	40.35	1.65						
C00	+01	39	30	-00	16	10	33.65	0.47	16.50	0.67			def			
W01	+01	39	30	+01	39	30	0.00	0.00	0.00	0.00	o/p	sig	def	o/p	sig	def
C11	+01	39	30	+01	39	30	0.00	0.00	0.00	0.00	o/p	sig	def	o/p	sig	def
C14	-00	47	10	-01	23	00	2.00	0.00	7.40	0.49		sig				
C13	+01	39	30	+01	39	30	0.00	0.00	0.00	0.00	o/p	sig	def	o/p	sig	def
C10	-01	09	40	-01	36	20	3.40	0.49	4.30	0.45						
W02	-00	05	19	-00	05	59	39.10	0.43	26.25	0.43						
W03	-00	02	20	-00	04	20	53.55	1.93	45.75	1.75						
W04	+00	02	50	+00	00	49	46.95	1.46	56.65	2.28						
W05	+01	39	30	+01	39	30	0.00	0.00	0.00	0.00	o/p	sig	def	o/p	sig	def
E02	+00	01	19	+00	02	20	33.60	0.91	23.60	0.49						
E03	+01	39	30	+01	39	30	0.00	0.00	1.00	0.00	o/p	sig	def		sig	def
C05	-00	03	29	-00	03	49	55.75	1.47	44.35	1.15						
C06	-00	02	39	-00	02	20	45.20	1.32	41.75	0.76						
E04	+01	39	30	+01	39	30	0.00	0.00	0.00	0.00	o/p	sig	def	o/p	sig	def
E05	+01	39	30	+01	39	30	0.00	0.00	0.00	0.00	o/p	sig	def	o/p	sig	def
E06	+01	39	30	+01	39	30	0.00	0.00	0.00	0.00	o/p	sig	def	o/p	sig	def
C08	-00	08	00	-00	06	50	33.25	0.69	38.30	0.71						
W06	+01	39	30	+01	39	30	0.00	0.00	0.00	0.00	o/p	sig	def	o/p	sig	def
S01	+01	39	30	+01	39	30	0.00	0.00	0.00	0.00	o/p	sig	def	o/p	sig	def
S02	+01	39	30	+01	39	30	1.00	0.00	0.00	0.00		sig	def	o/p	sig	def
S03	+01	39	30	+01	39	30	0.00	0.00	0.00	0.00	o/p	sig	def	o/p	sig	def
S04	+01	39	30	+01	39	30	0.00	0.00	0.00	0.00	o/p	sig	def	o/p	sig	def
S06	-00	00	10	-00	00	10	0.00	0.00	0.00	0.00	o/p	sig		o/p	sig	

LINEARITY OF IF DETECTORS

The IF power is detected by detectors, which are used to provide feedback to the IF ALCs. A pair of IF detctor and ALC is designed and characterised to give linear response over the prescribed range of IF power. Lab-measurement of input-output characteristics of several such pairs is given in a report by Venkatasubramani and Somsekar[1]. For present excercise, it was important to have good variation in output of IF detector with the variation in input IF power. We thus measured the response of IF detectors of several antennas in the ALC off mode. This was done by switching on the 'Extra-High' noise source for each antenna and successively putting IF attenuations. Attenuations were put in steps of 2 + 2 dB from 10 dB + 10 dB to 30 + 30 dB for pre- and post- IF attenuations. Figure 2 shows the response of IF detectors for several antennas. For most antennas, a range of 10 to 14 dB was seen over which the detection was found to be linear. However, antennas such as C10 and E03 were found to have a very limited range of detection.

On a strong source like Cygnus A, many of the IF detectors are found to saturate. One need to put additional 2 to 4 dB attenuation in those antennas inorder to be in linear regime.

PRECAUTIONS

To ensure good offset measurements, some suggestions can be made based on experience so far. Please add any additional comments that you may find relevant.

1. Set the time for ONLINE and the antennas using `stabct` command within ONLINE. Note that error in time will appear as error in pointing if UNIX and SERVO time is not correct.

2. Chose optimal scan-rate (10 arc minutes per minute). Putting scan-rate large in order to save the time does not help as only few samples will be available around the expected peak time.

3. Azimuth offset measurement is best done when sources is at lower elevation.

4. Elevation offset measurement is best done when sources is at higher elevations.

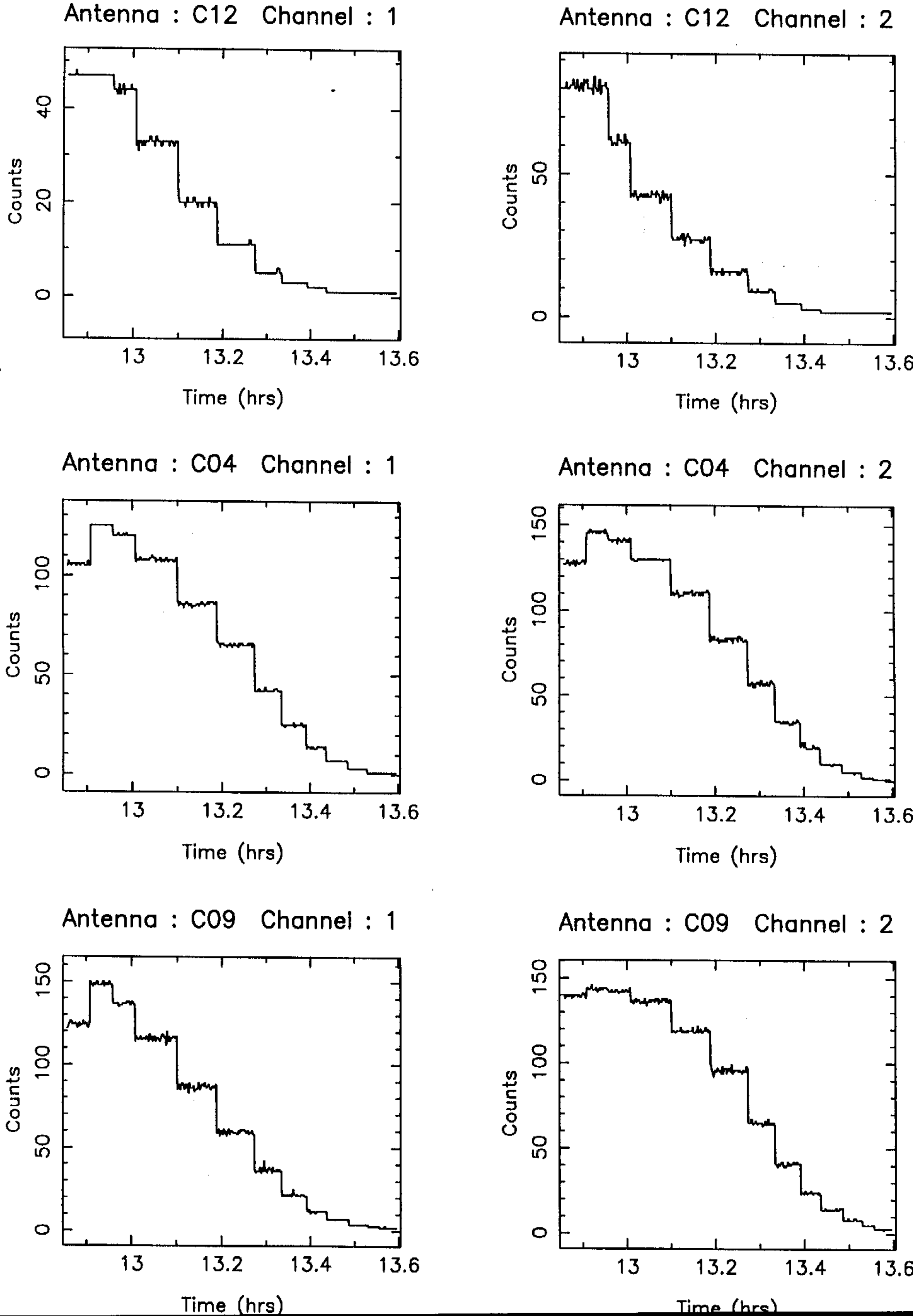
5. Take sufficiently long scan (about ± 15 minutes) for azimuth and (about ± 10 minutes) for elevation measurement. This is to provide good baseline and enough data off the beam.

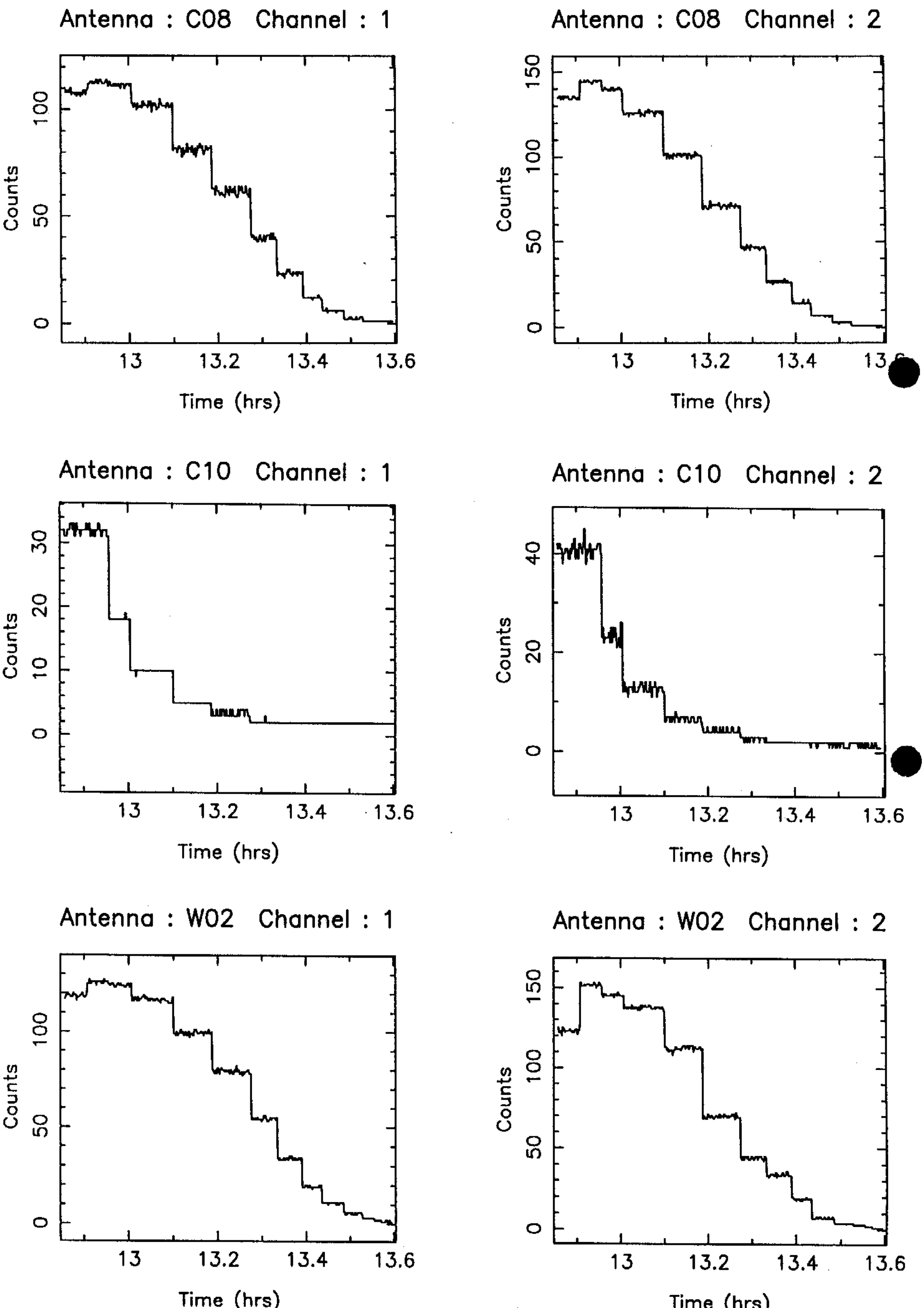
CORREECTING POINTING ERRORS

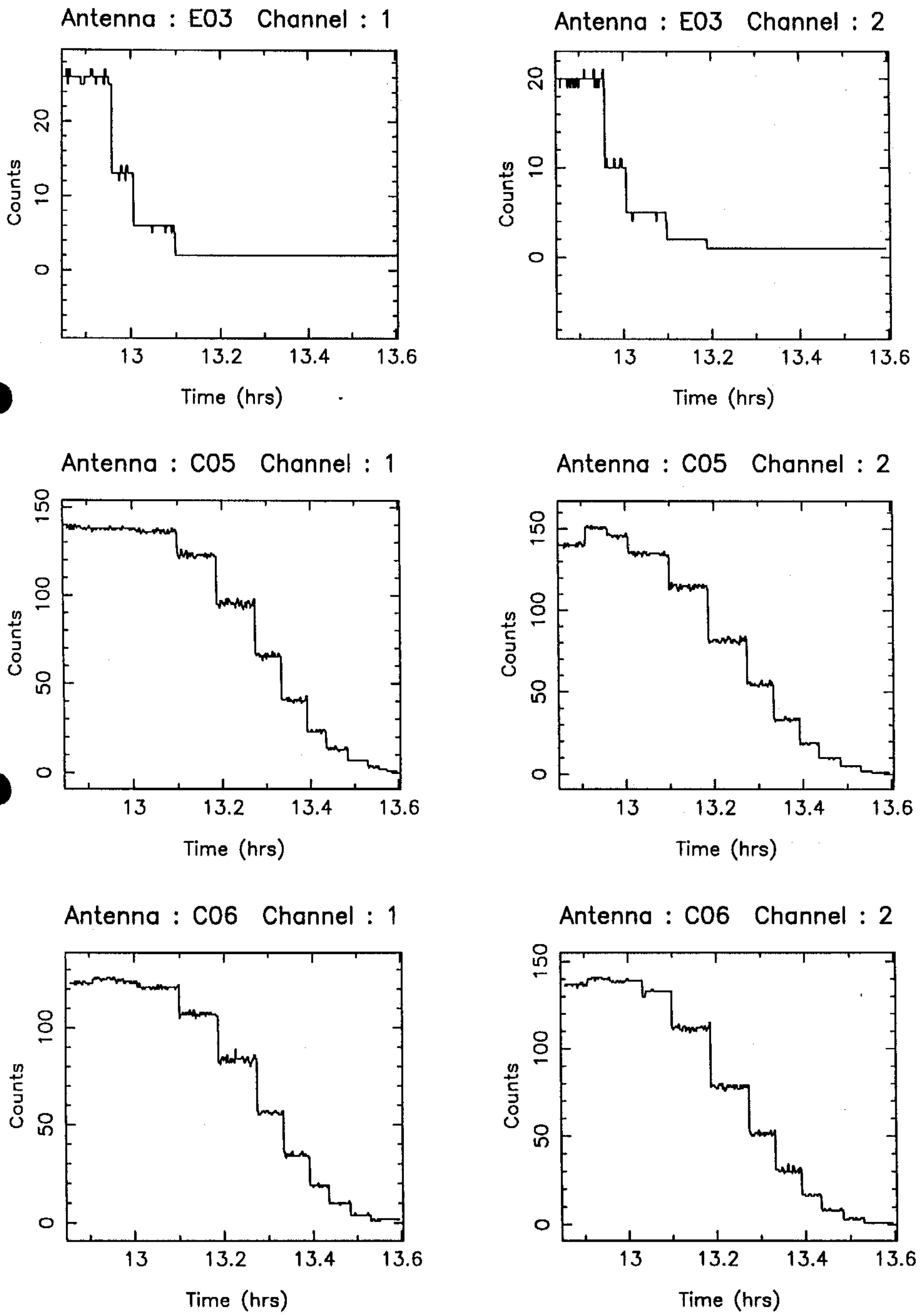
Azimuth and elevation offsets thus obtained are to be **added** to the existing offsets for each antenna. If following observations shows reduced pointing error then the new offsets in should be communicated to the Observer on duty, who would then store them as default offsets to be used for later observations. This is done to maintain consistency and record of pointing corrections.

REFERENCE

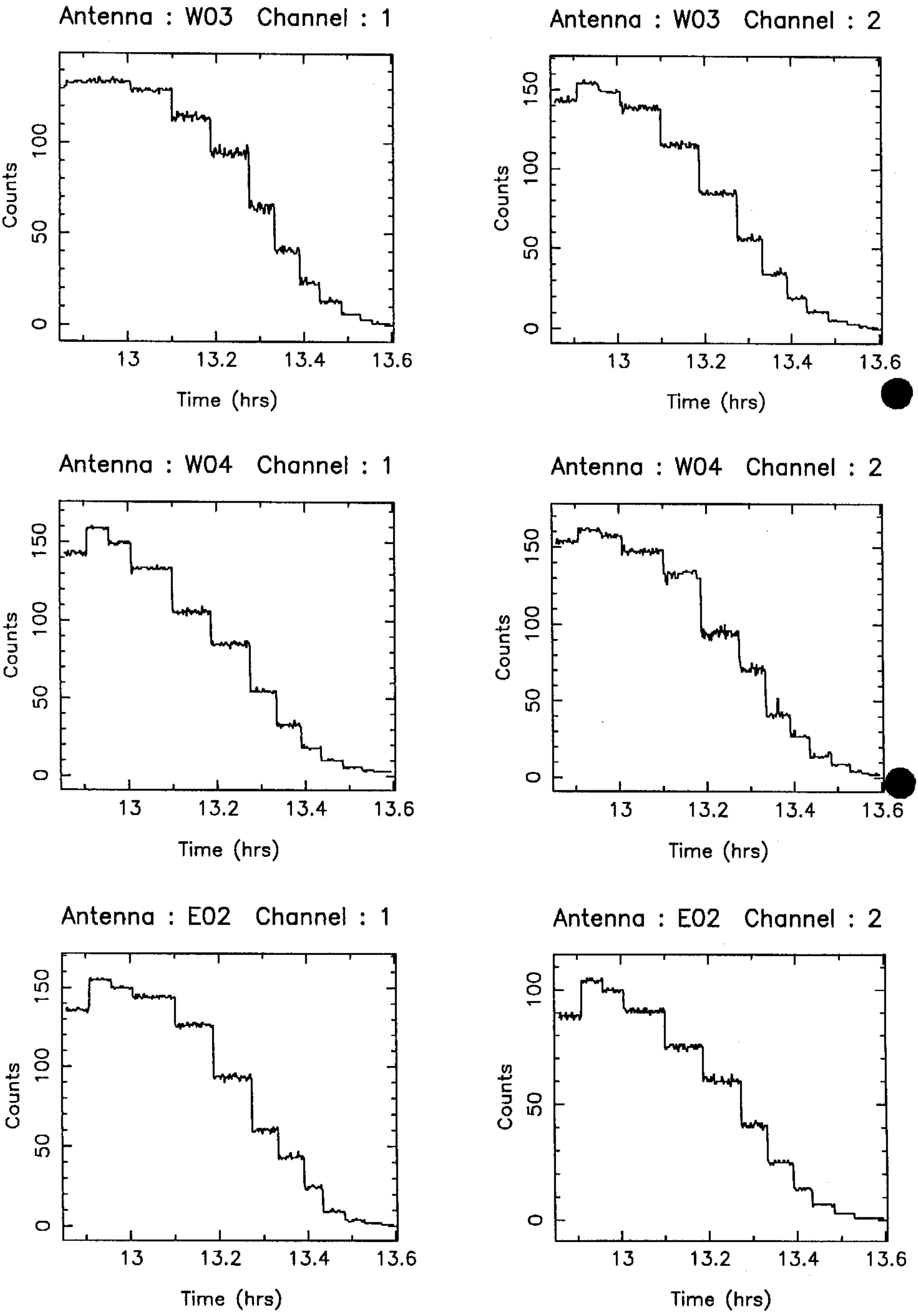
Venkatasubramani, T.L., Somsekar, R., Performance of PIUs of the IF system and a study of their repeatability and inter-changeabilty. NCRA Technical Report, Acc. No. R00106, 1995.


Antenna : C12 Channel : 1
Antenna : C12 Channel : 2
Antenna : C04 Channel : 1
Antenna : C04 Channel : 2
Antenna : C09 Channel : 1
Antenna : C09 Channel : 2
Counts
Time (hrs)
0
20
40
50
100
150
13
13.2
13.4
13.6

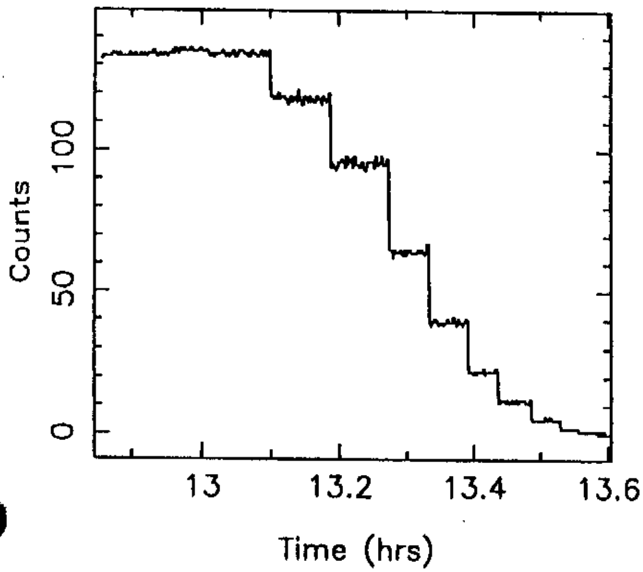

Antenna : C08 Channel : 1
Counts
Time (hrs)
Antenna : C08 Channel : 2
Counts
Time (hrs)
Antenna : C10 Channel : 1
Counts
Time (hrs)
Antenna : C10 Channel : 2
Counts
Time (hrs)
Antenna : W02 Channel : 1
Counts
Time (hrs)
Antenna : W02 Channel : 2
Counts
Time (hrs)



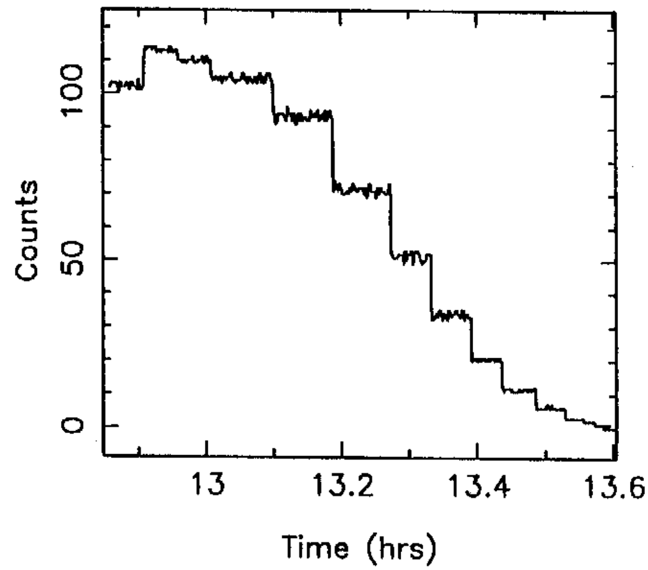
Antenna : E03 Channel : 1
Antenna : E03 Channel : 2
Antenna : C05 Channel : 1
Antenna : C05 Channel : 2
Antenna : C06 Channel : 1
Antenna : C06 Channel : 2
Counts
Time (hrs)
13
13.2
13.4
13.6


Antenna : W03 Channel : 1
Antenna : W03 Channel : 2
Antenna : W04 Channel : 1
Antenna : W04 Channel : 2
Antenna : E02 Channel : 1
Antenna : E02 Channel : 2
Counts
Time (hrs)

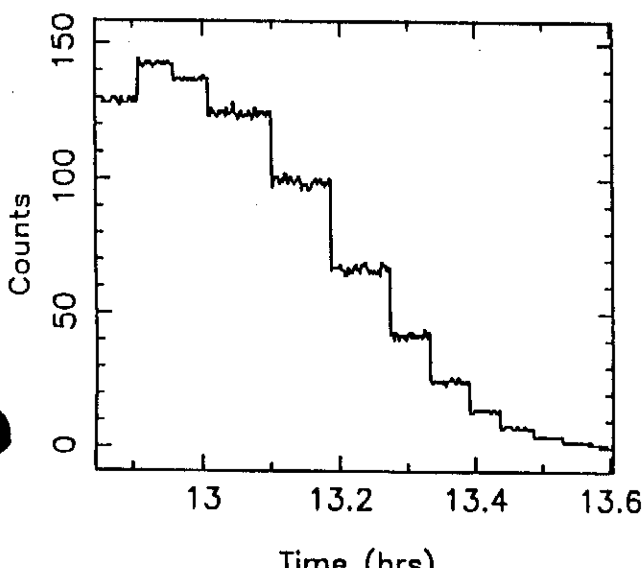
Antenna : C02 Channel : 1



Antenna : C02 Channel : 2



Antenna : C01 Channel : 1



Antenna : C01 Channel : 2