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PdB Axis Velocity Loop Analysis

(and much more)

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Change Record

REVISION	DATE	AUTHOR	AFFECTED SECTION/PAGE	REMARKS
1st release	20080925	A.Perrigouard		
2nd release	20081211	A. Perrigouard	Section 5. Position servo loops	
3rd release	20091116	A.Perrigouard	Section 6. System time delays	

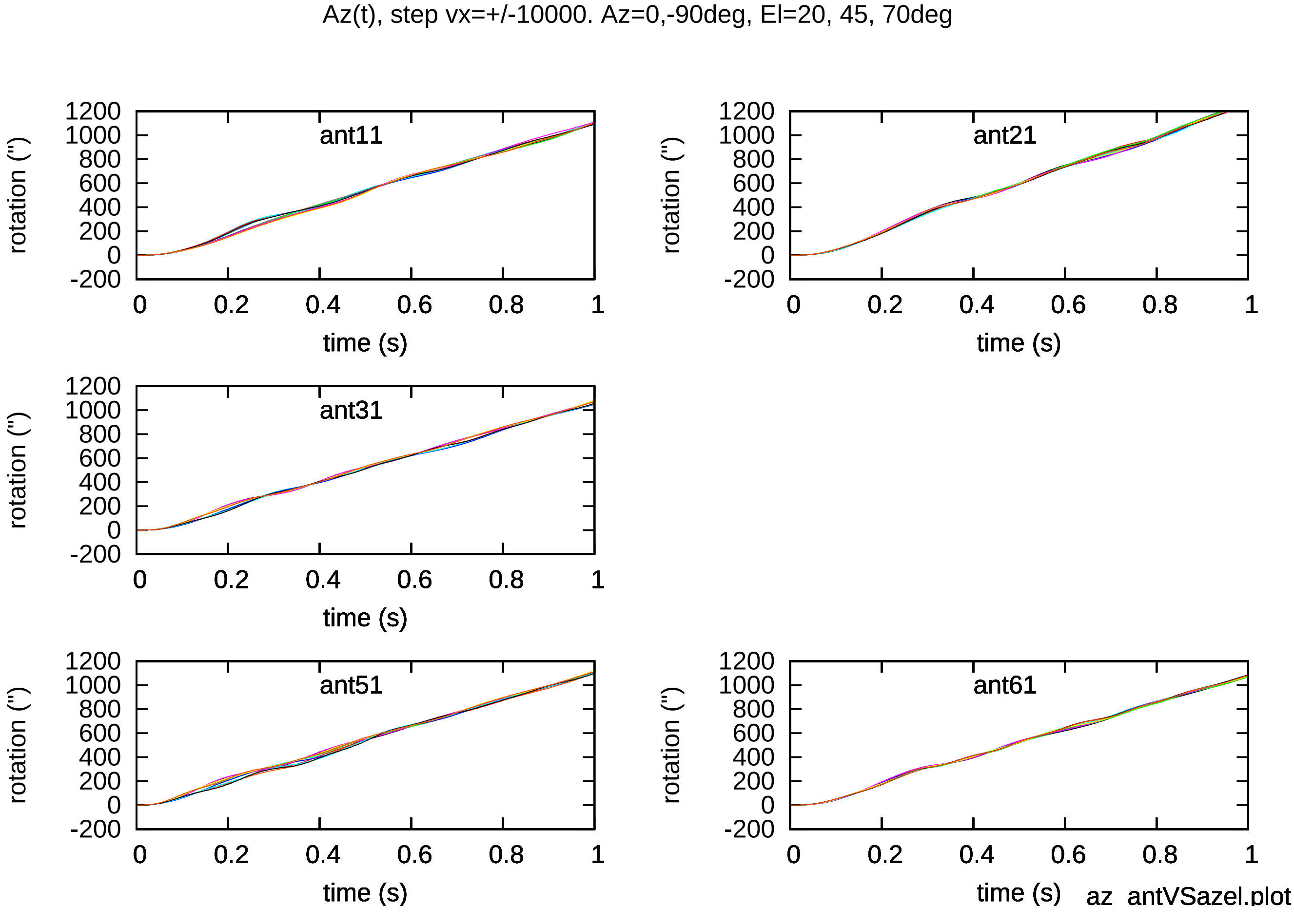
Content

1 Velocity servo loop step response

Versus several azimuth and elevation starting positions
Positive and negative steps of +-3V have been applied to the azimuth and to the elevation servo velocity loops for different positions of the antennas. Az=0deg, 90deg, and –90deg. El=20deg, 45deg and 70deg.

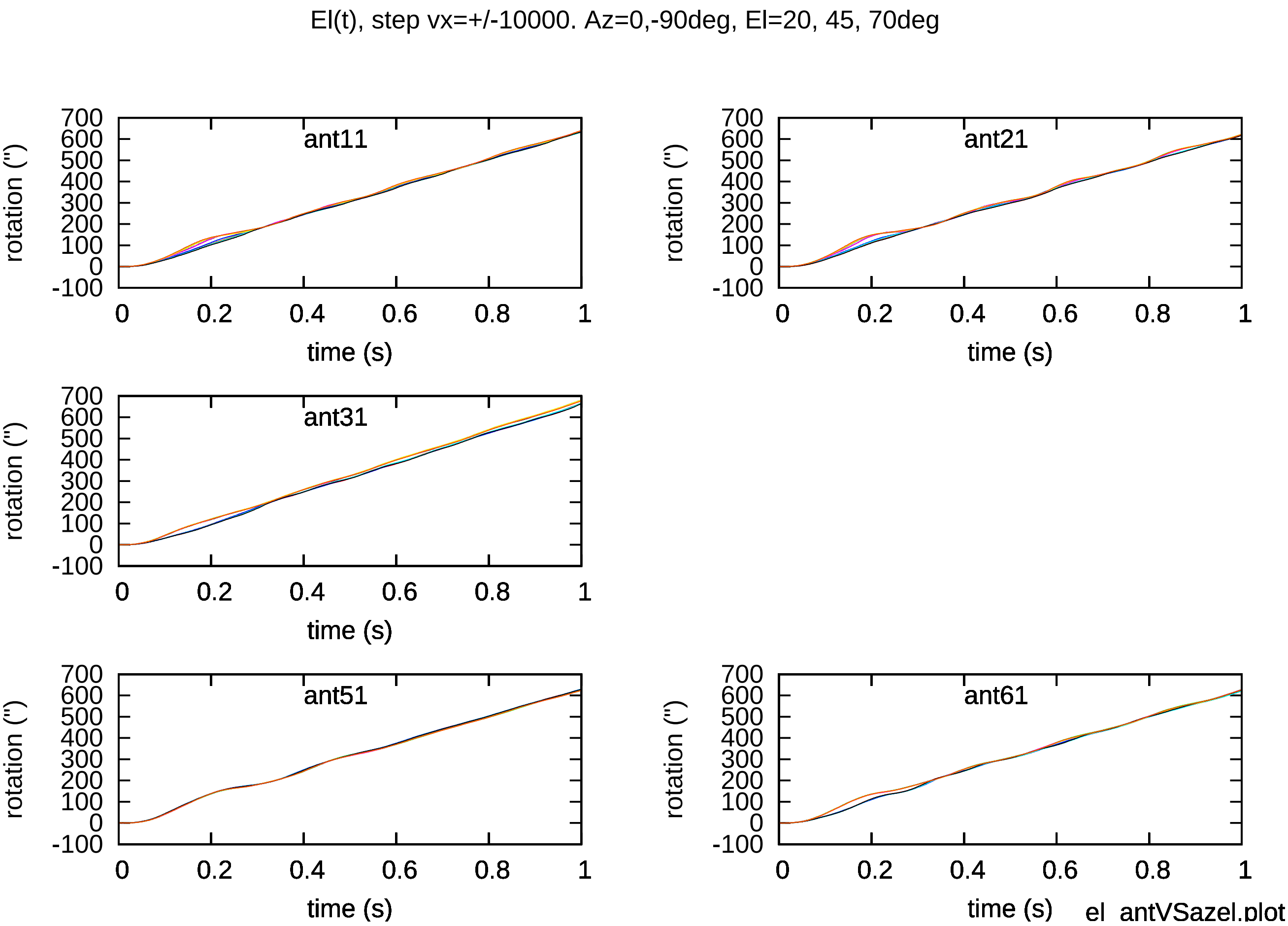
1.1 Azimuth step response

The input DAC step command is equal to +-10000. The DAC is a 16 bit converter (10V*10000/2^{15}~=3V). The output is the encoder measurement. It is the response of the velocity servo loop and it is a ramp in a first approximation, i.e. the integration of the input step.



The responses are very little dependent on the azimuth and, above all and surprisingly, on the elevation.

1.2 Elevation step response

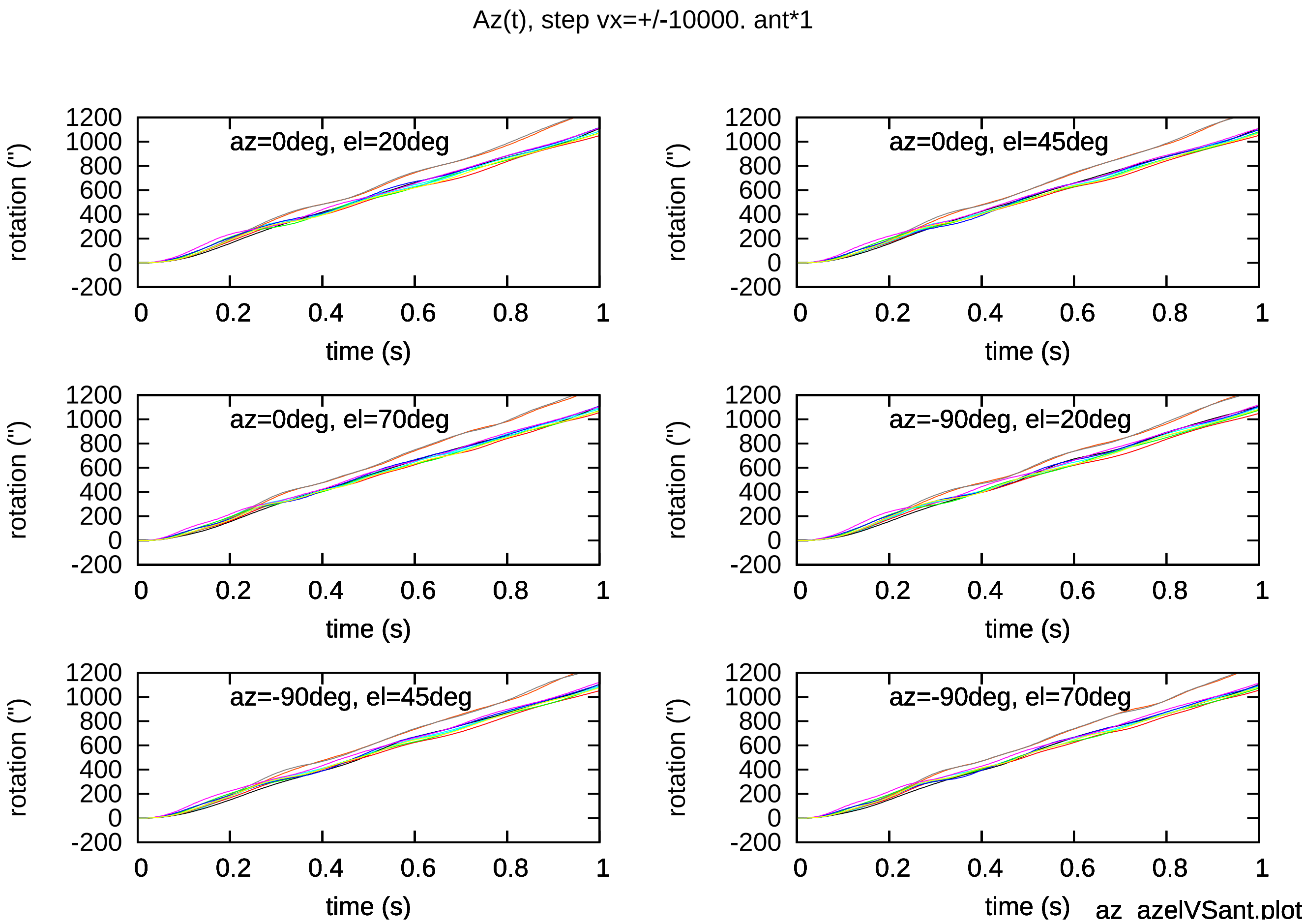


The responses are very little dependent on the azimuth and on the elevation.
For some antennas one can see differences at the beginning of the ramp, around 0.2s, between positive and negative step requests, i.e. between upward and downward motions. It shows some imbalance of the cabin+dish.

2 Velocity servo loop step response

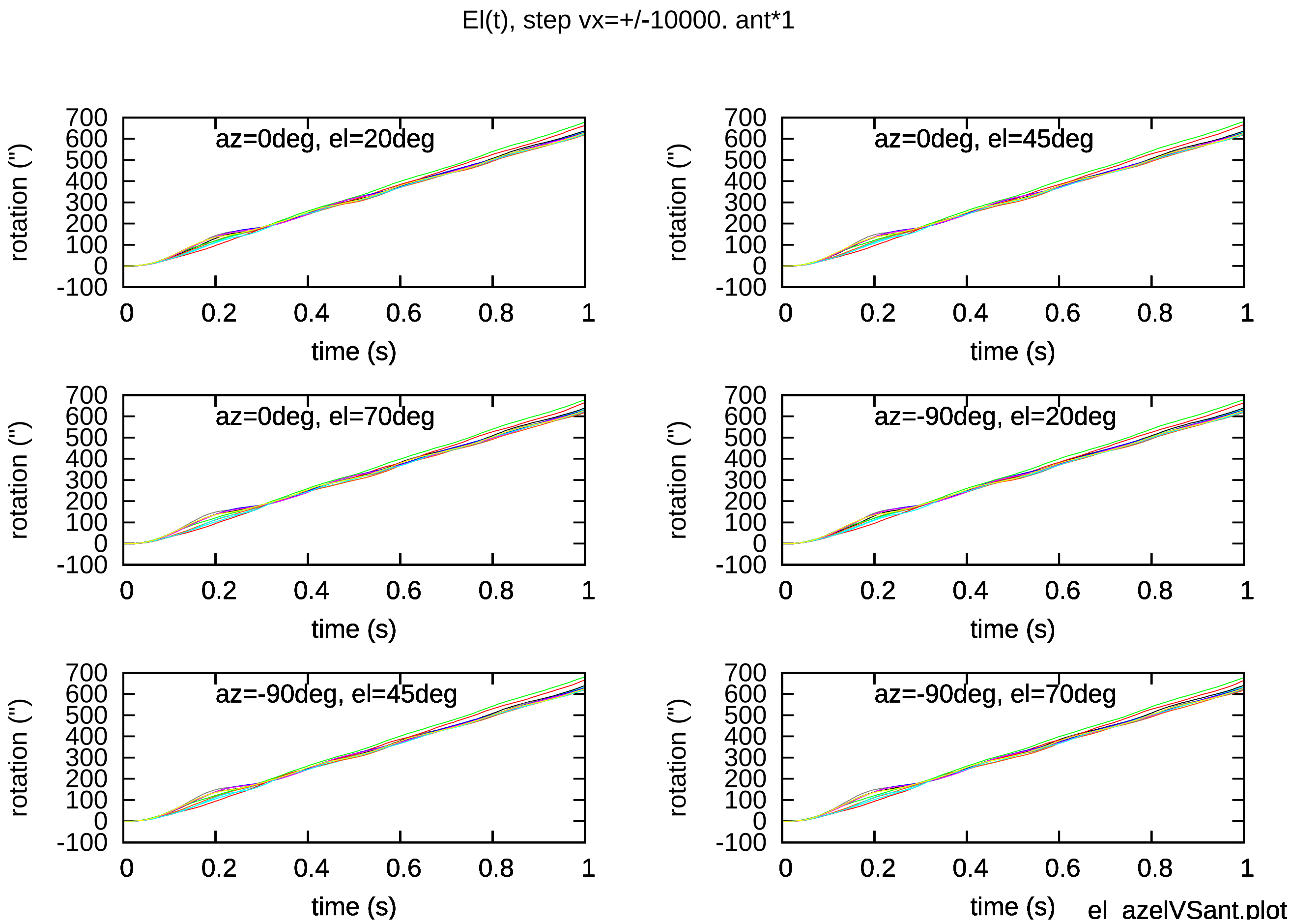
Versus the antennas.

2.1 Azimuth step response



For antennas 1, 3, 5 and 6 the overall gain of the velocity loop is 365”/s/V.
For antenna 2 the gain is 427”/s/V, 17% higher.
Evaluation done with a 16bit DAC, +-2^{15}==+-10V.

2.2 Elevation step response

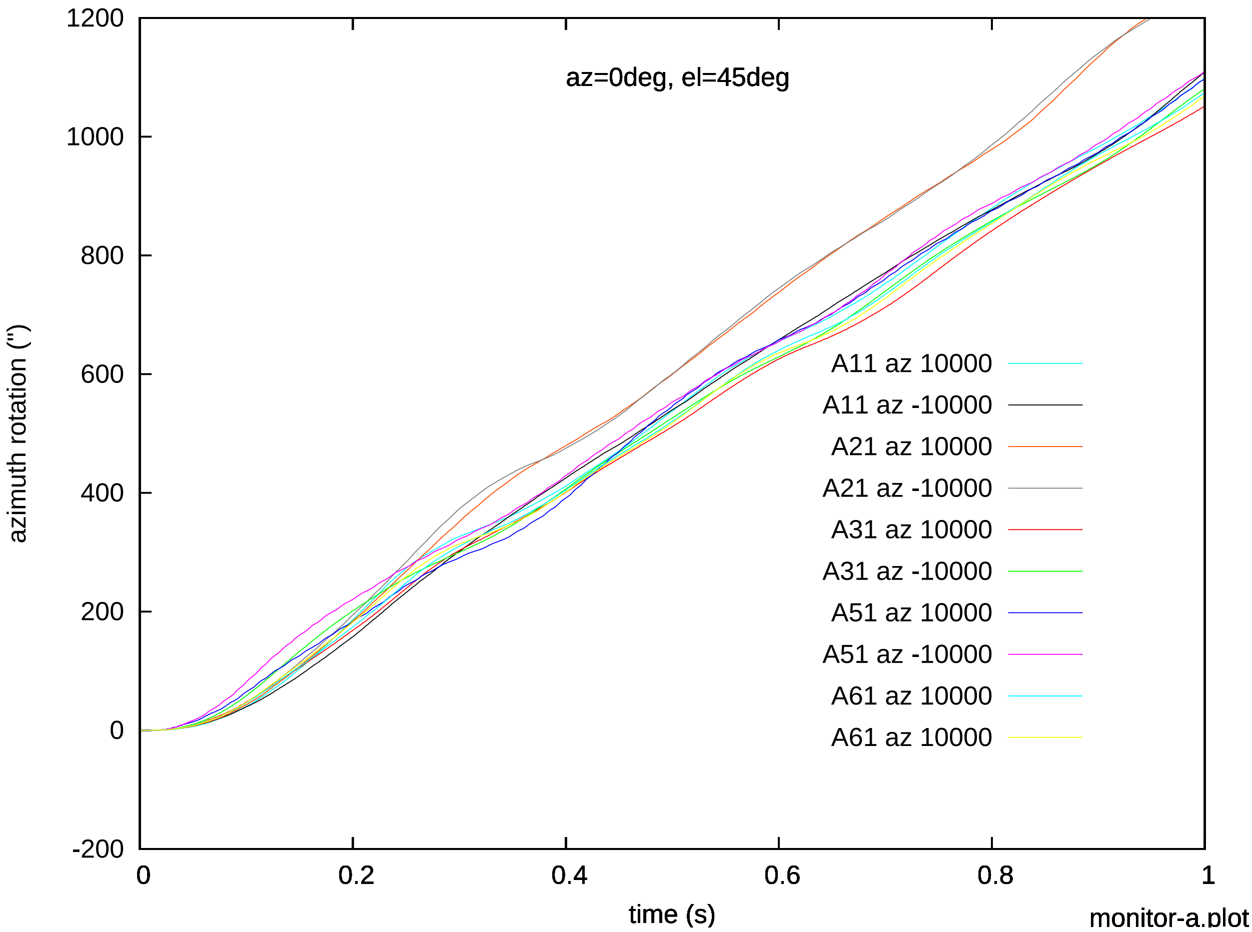


It can be noted some dispersion on the static gains (the slopes of the ramps), in particular around 0.2s and between upward and downward movements.
This difference between positive and negative requested steps implies non-linearity and as consequence, extra phase shift.

3 Frequency analysis

As the ramps are independent of the starting positions in a first approximation, the output curves resulting of positive and negative steps of 3V for az=0deg (south) and el=45deg are analyzed hereafter. To be complete the same study should be performed for different step levels in case, as it is probable, the output is not linear due in particular to the frictions.

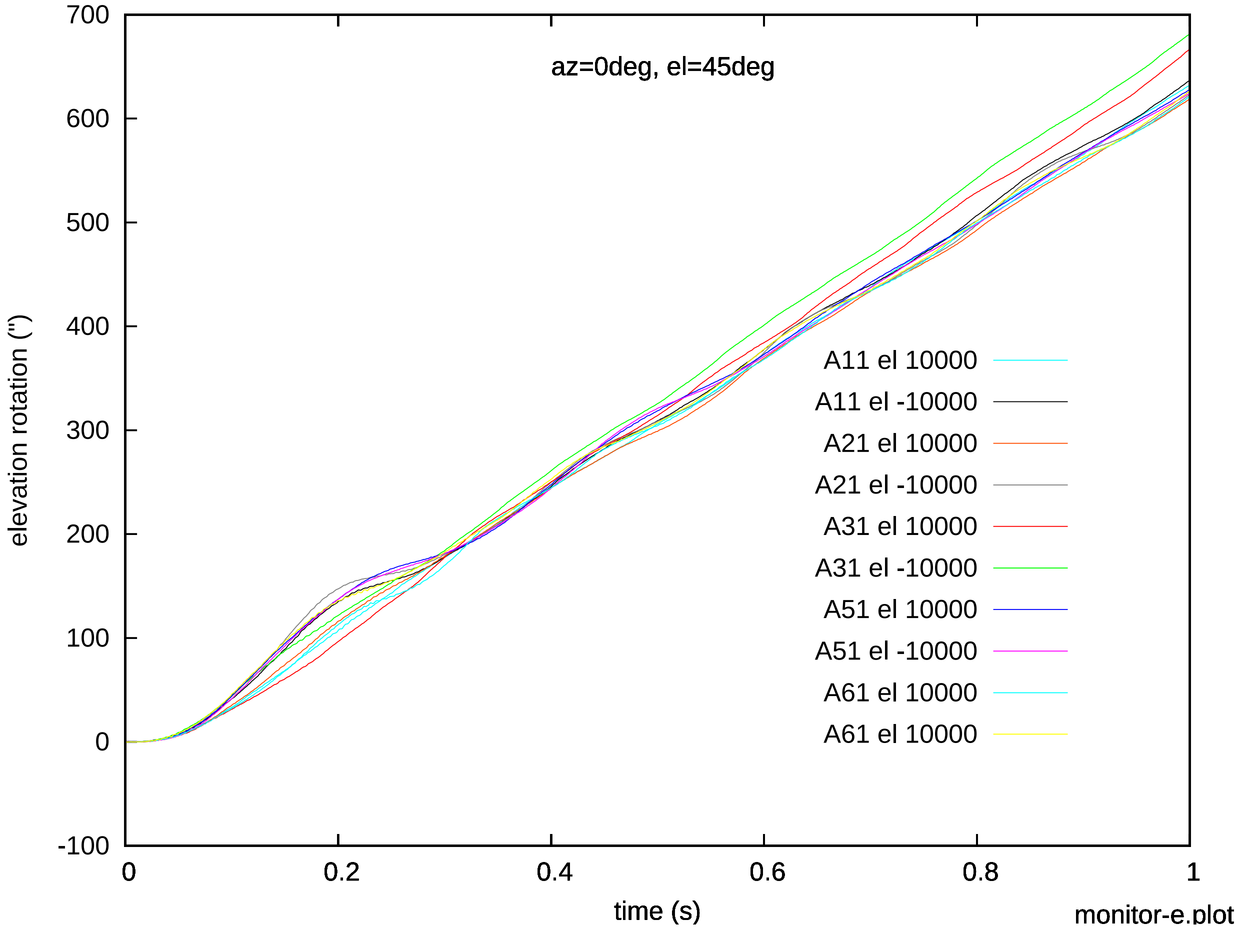
3.1 Azimuth:



There is a position measurement roughly every ms.
The position resolution is the encoder resolution that is 1/10".
For each data sample, 2 numbers are recorded: The exact time in microseconds and the position in encoder units.

Here we see clearly the particular case of antenna 2

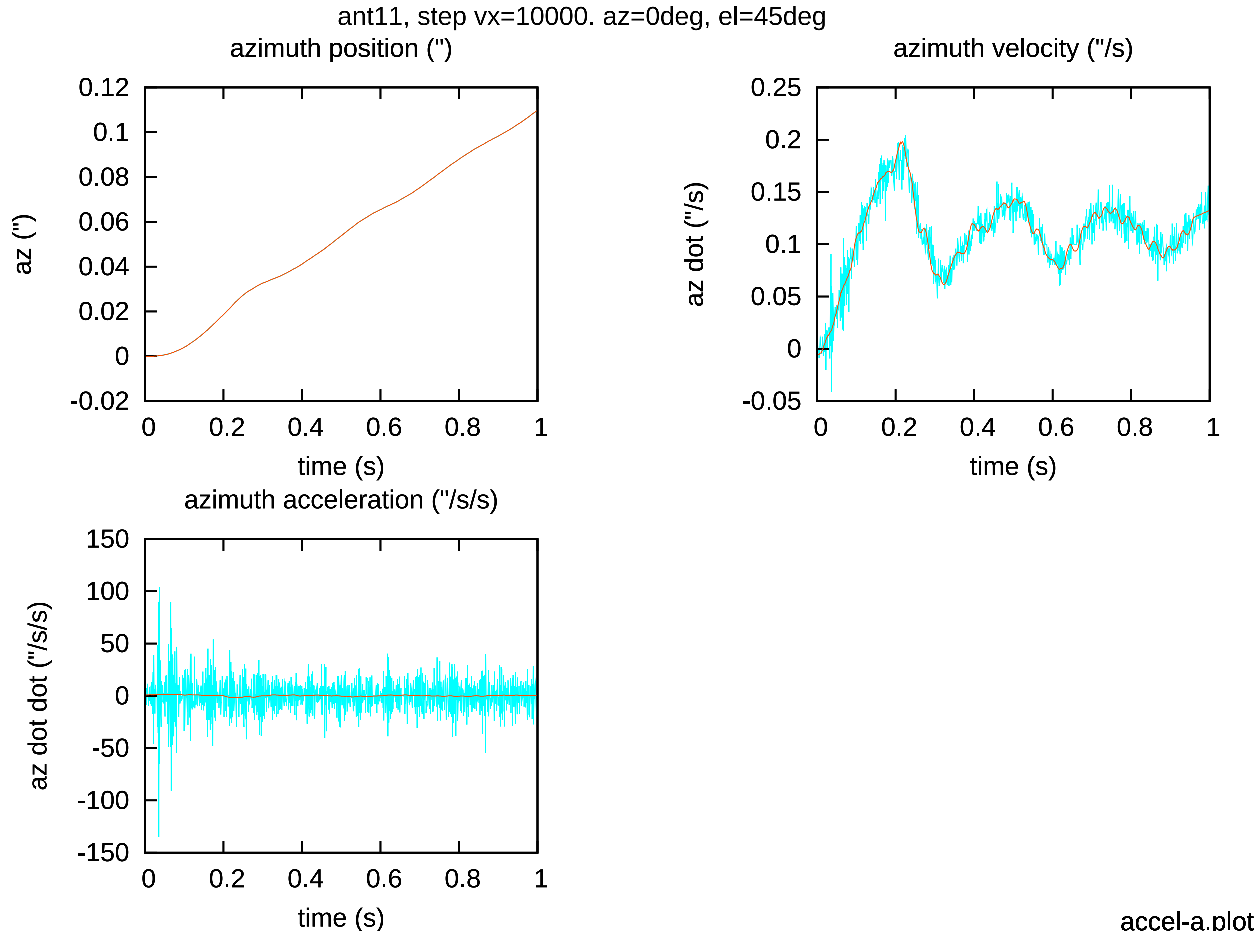
Elevation:



Here we see the effect of the antenna imbalance in elevation.
It is clear that a frequency analysis would require getting the same ramps, except the sign, for positive and negative input steps.

3.2 Bode Analysis. Data preprocessing:

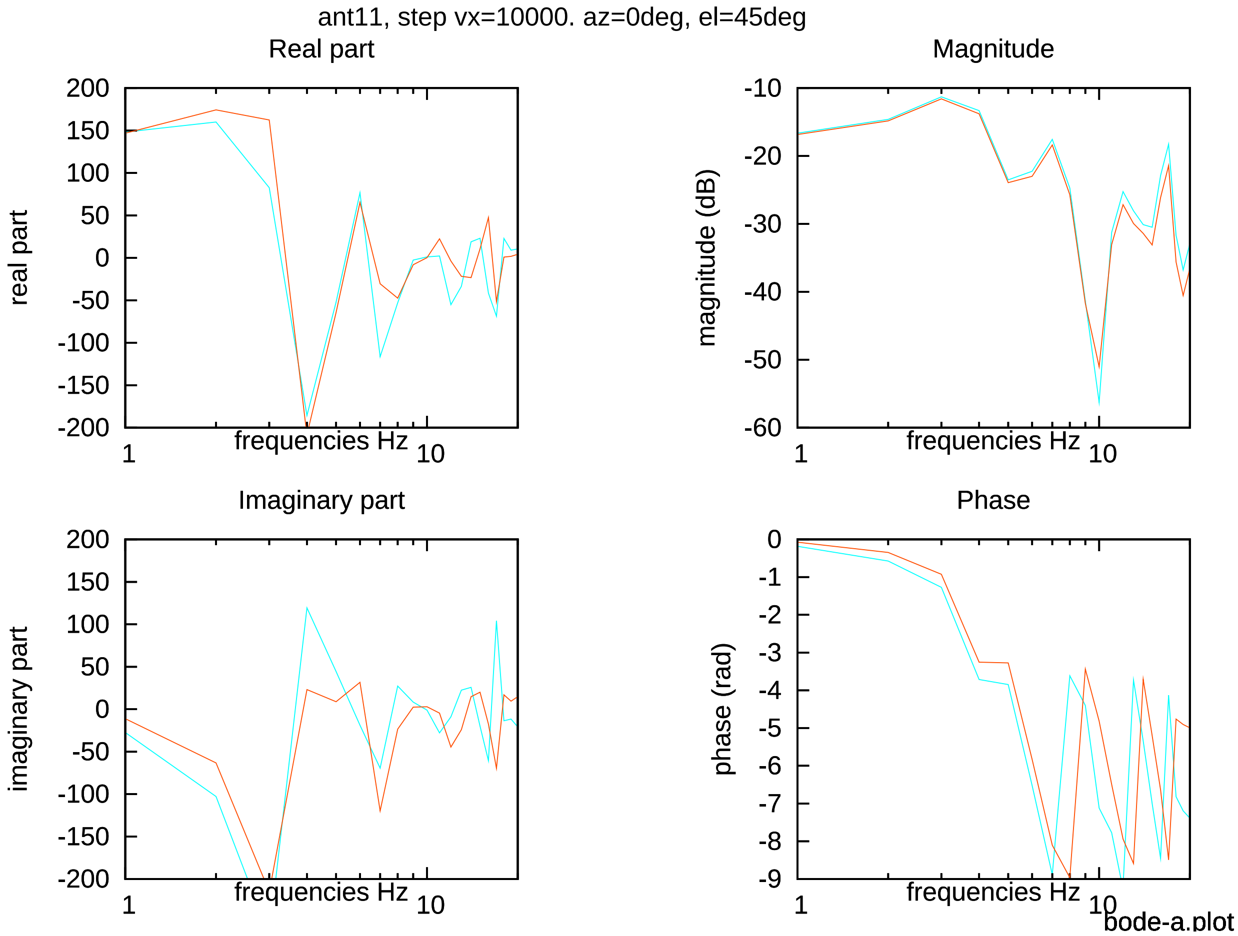
Recorded data needs to be re-sampled before a Fast Fourier transform may be applied.
The recording duration of one second is re-sampled into 1024 periods.
Only the acceleration, i.e. the output second derivative, with a theoretical exponential decrease, may be considered as a potential candidate to a FFT.
As it can be seen on the next plots, a derivation process is very noisy.
A sliding polynomial fit on 40 consecutive samples for a 4^{th} degree polynomial is a method for rejecting the high frequencies of the 2^{nd} derivation and for the re-sampling interpolation.
However we will see that the FFT gives practically the same results, for the low frequencies, for an acceleration directly numerically calculated and thus, noisy, or with an acceleration deduced from a filtering process.



The blue lines are the normalized azimuth position and the numerically calculated 1^{st} and 2^{nd} derivatives.
The "normalized azimuth position" means the position expressed in arc-second divided by the input step amplitude (+-10000).
The red lines are the filtered and interpolated variables, position, velocity and acceleration.

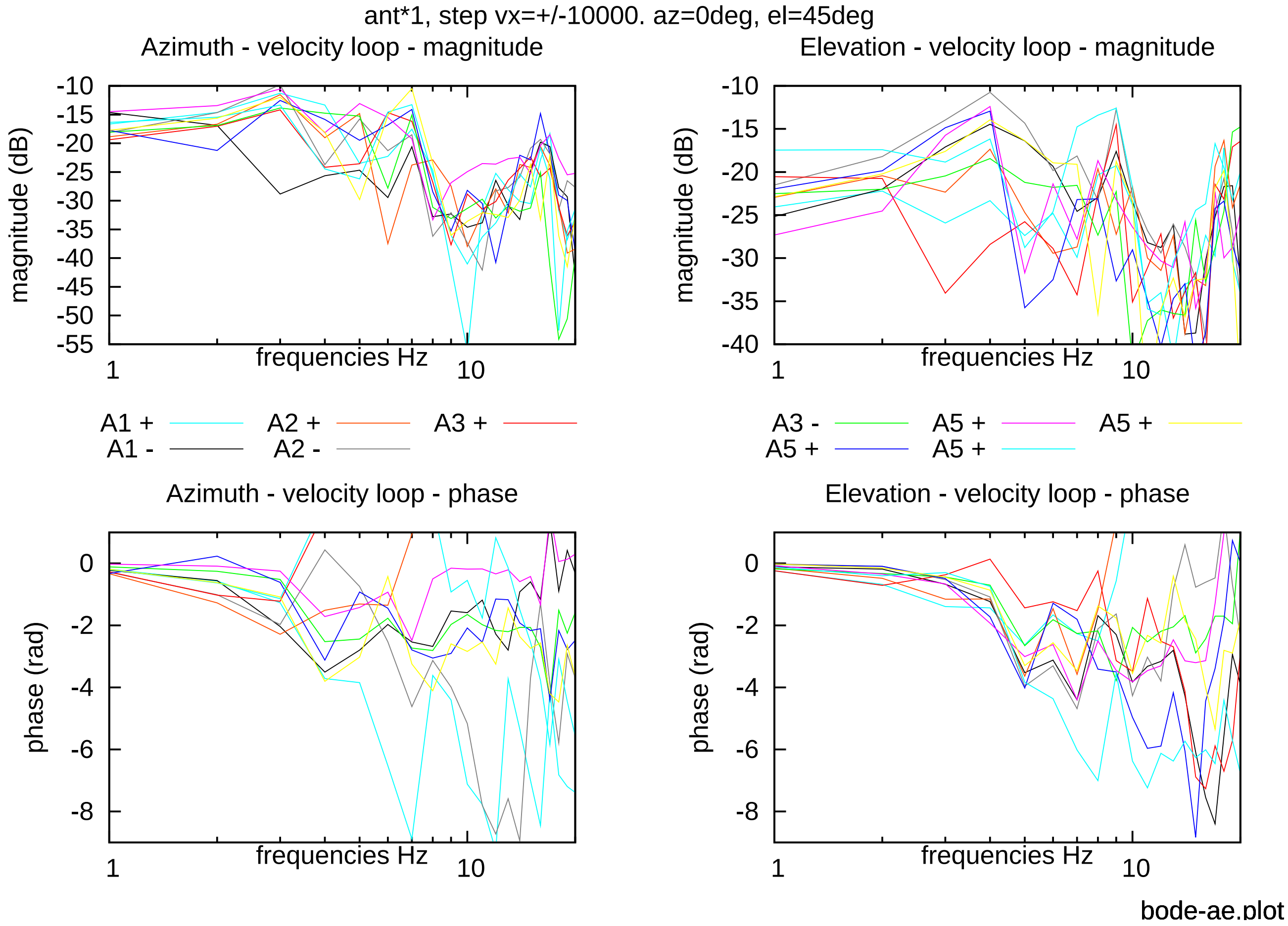
3.3 Transfer function

Comparison of the FFT of the 2 calculated accelerations for the very low frequencies (up to 20Hz)



The 2 FFTs are very similar. The noise resulting of the numerical acceleration calculation does not convey any information at low frequency.
Here a resonance around 7Hz is visible (peak on the magnitude and phase shift of more than PI).

The same processing is applied to all antennas for the azimuth and the elevation.
The fact that a difference is visible between the positive step and the negative one, shows the non-linearity of the transfer function and the limits of the Bode analysis.



The interpretation is limited by the lack of data at low frequency. A longer recording would be an advantage.
However a resonance is visible around 7Hz in azimuth and 9Hz in elevation.

4 Ideal case analysis

The velocity loop transfer function (velocity versus DAC input command) should be of the form

$$\dot{Y} = \frac{G}{1+\frac{s}{\omega}} X$$ with $\dot{Y}$ the axis velocity and X the DAC input

G Is the static gain in "/s/bit (In principle it could be in rad/s/V, knowing that X=2^{15} == 10V)
ω is the corner or cutoff frequency in rad/s

The input is a step function:
$X = U/s$ U is a constant (here 10000)
and the position output looks like:

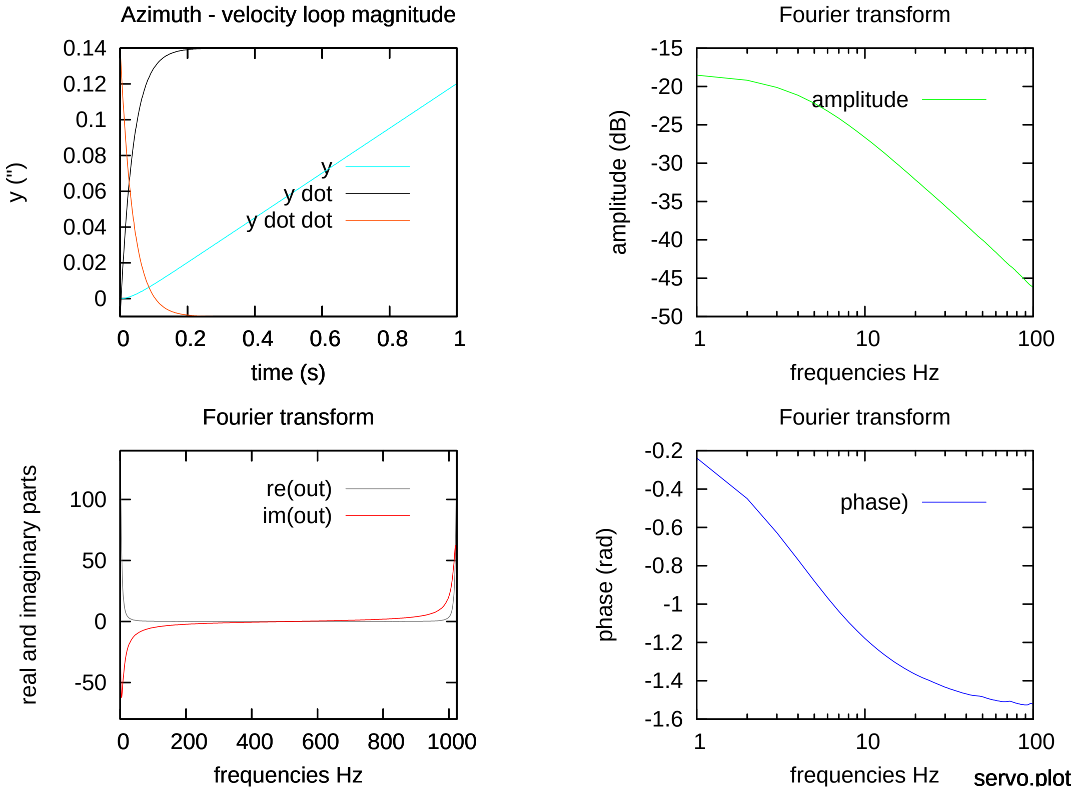
$$Y = \frac{G}{1+\frac{s}{\omega}} \frac{U}{s^2}$$

In the time domain

$$\frac{\ddot{y}(t)}{U} = G\omega e^{-\omega t}$$

$$\frac{\dot{y}(t)}{U} = G - Ge^{-\omega t}$$

$$\frac{y(t)}{U} = -\frac{G}{\omega} + Gt + \frac{G}{\omega} e^{-\omega t}$$



with $G = .1250$ "/s/bit == 409.6"/s/V
and $\omega = 26 rad/s == 4.13 Hz$

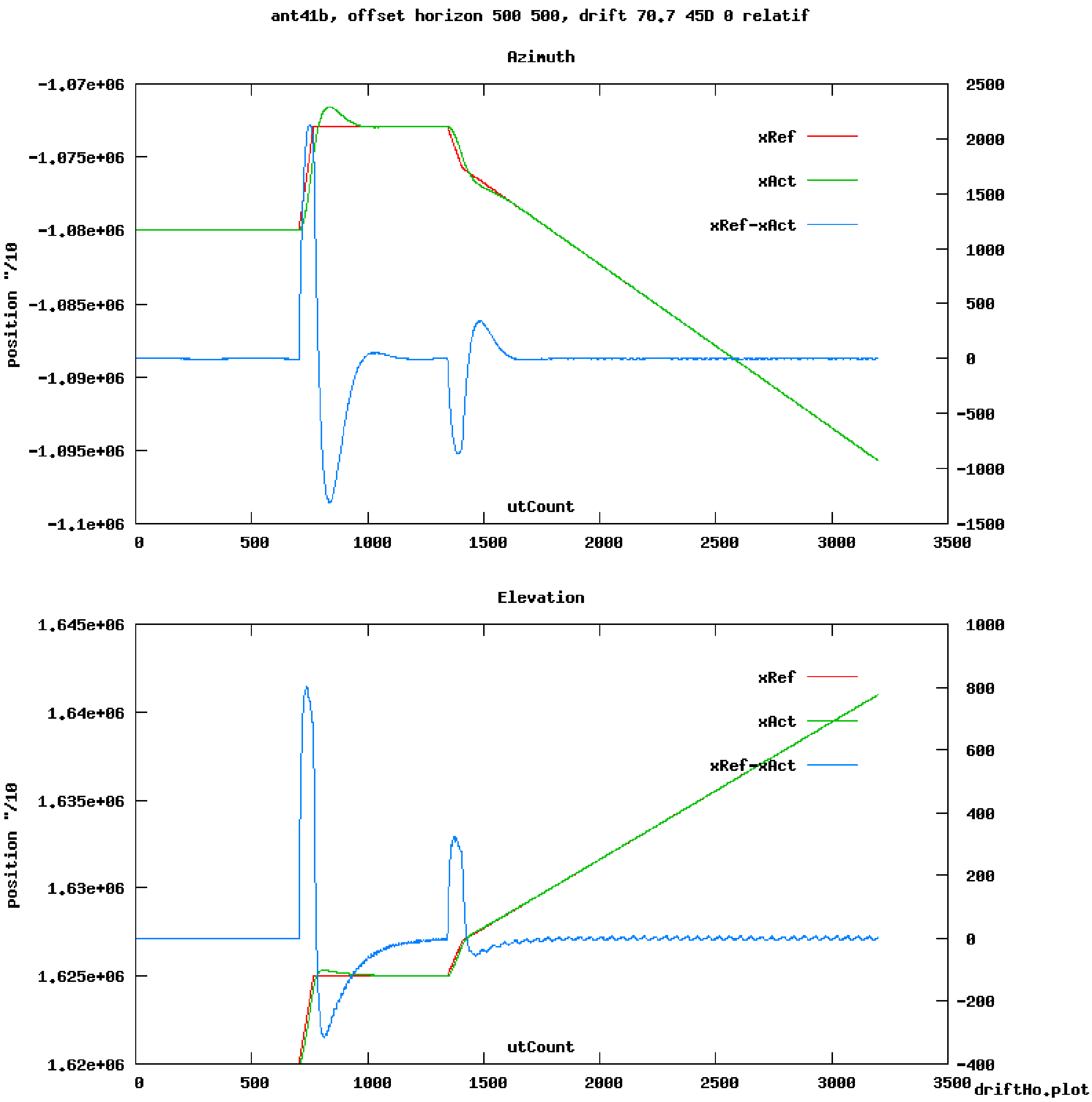
5 Position servo loops

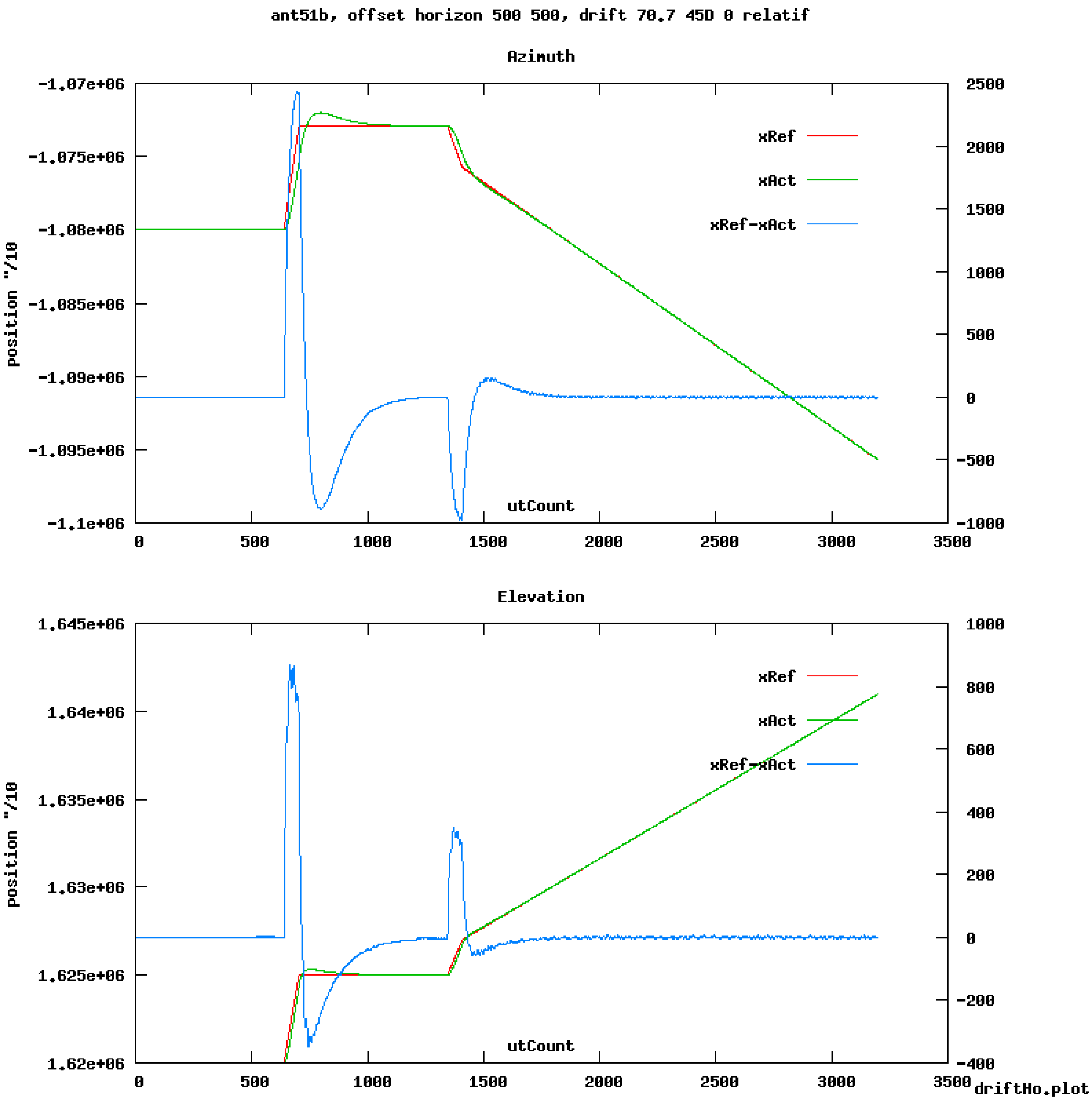
Both axis are studied from tracking on a fixed position in the horizon coordinate system, then an offset compatible with the position tracking is applied. Finally a drift is added on top.
The commands from bure1b looks like this for antenna x, from 1 to 6:

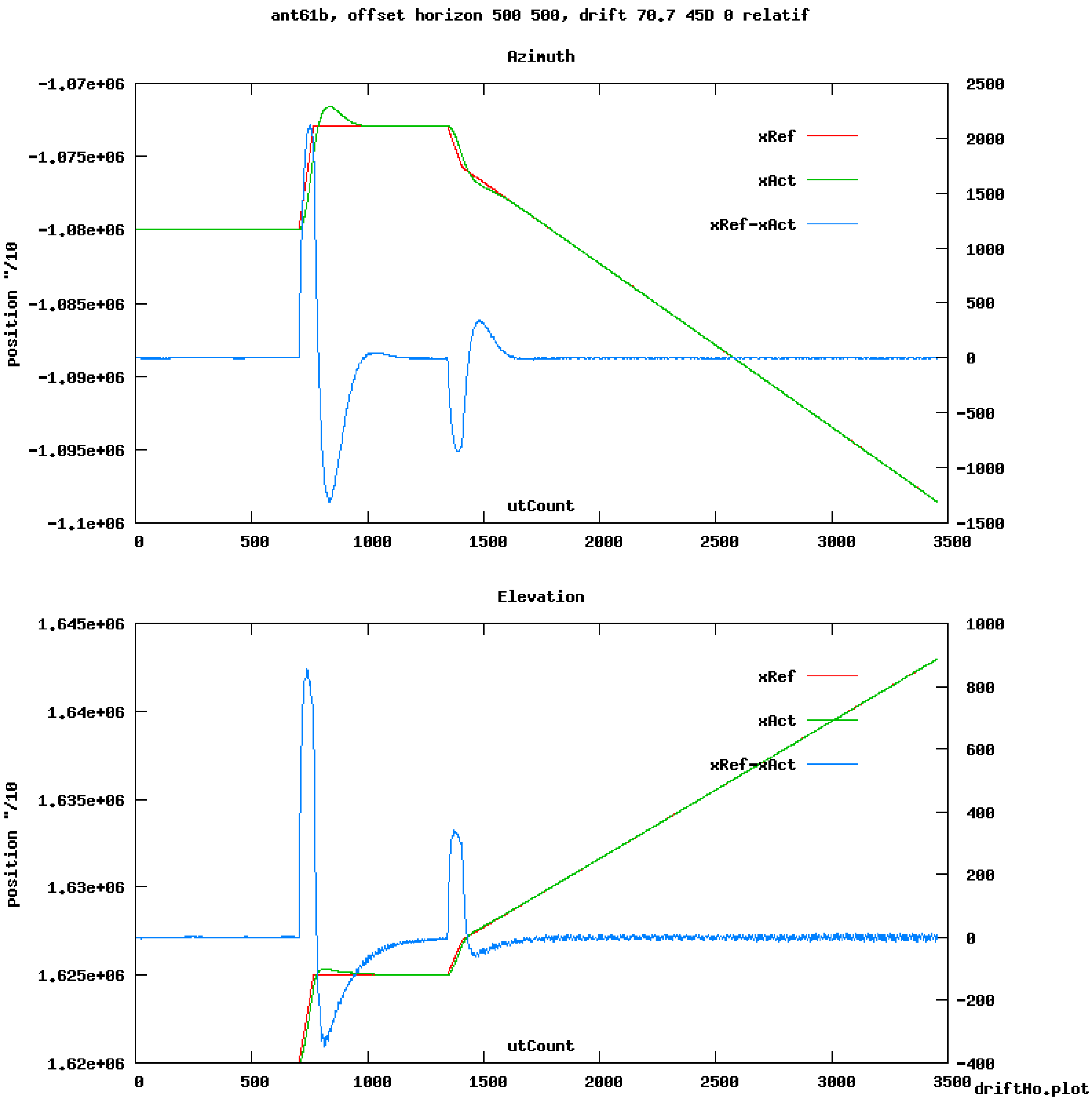
```
coo antenna x horizon -30D 45D
off antenna x horizon 500 500
dri antenna x horizon 70.7 45D 0 relatif
```

There is a delay of 3s between the moment the command dri is issued and the moment the command is applied. It is explained by the periodic execution of interp which send the command to the antenna, and all the coordinate computation calculated some time ahead in the pedestal processor.

Due to some imperfections in the scripts for the tests, the measurements do not yet cover antennas 1, 2 and 3 in this horizon tracking mode.

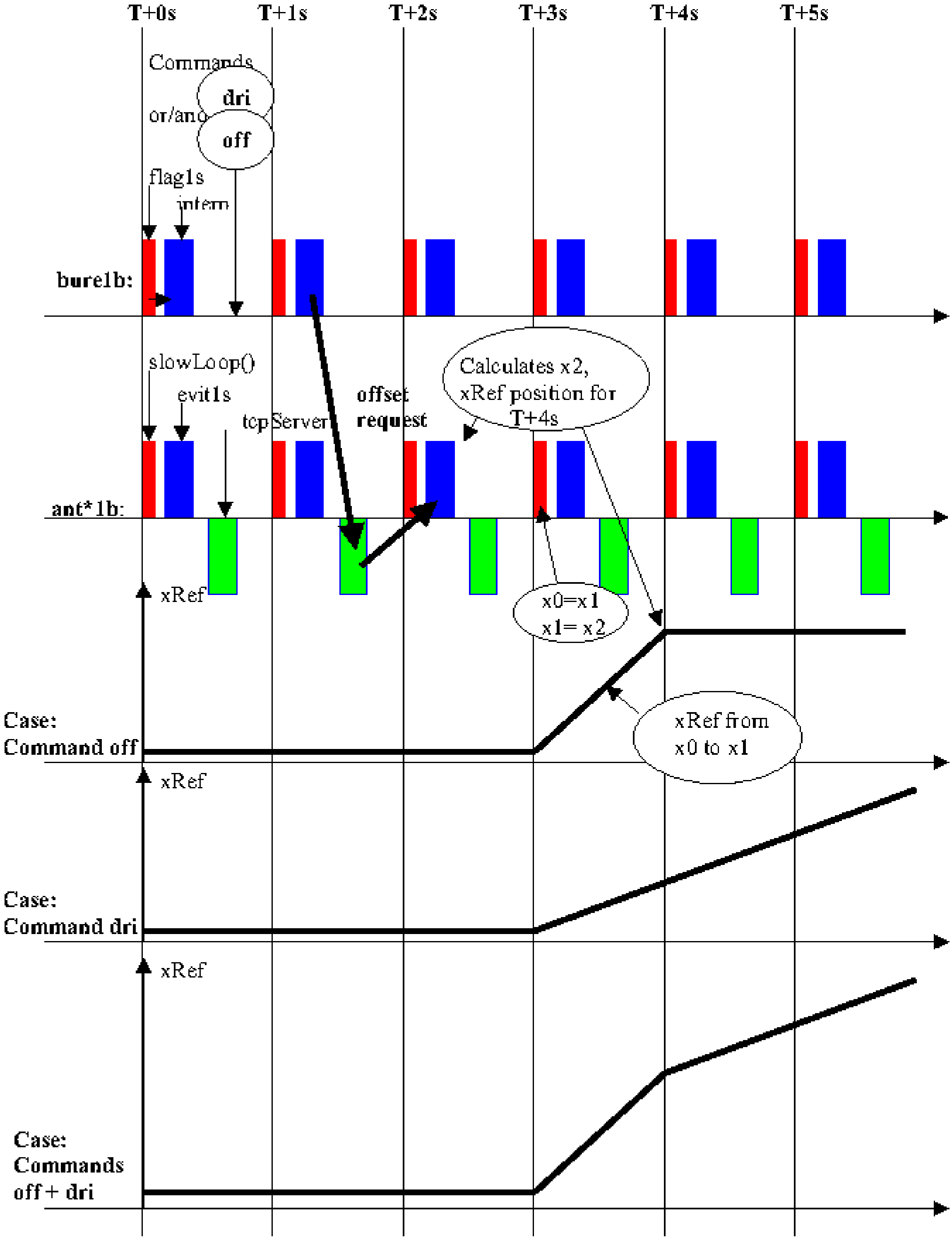


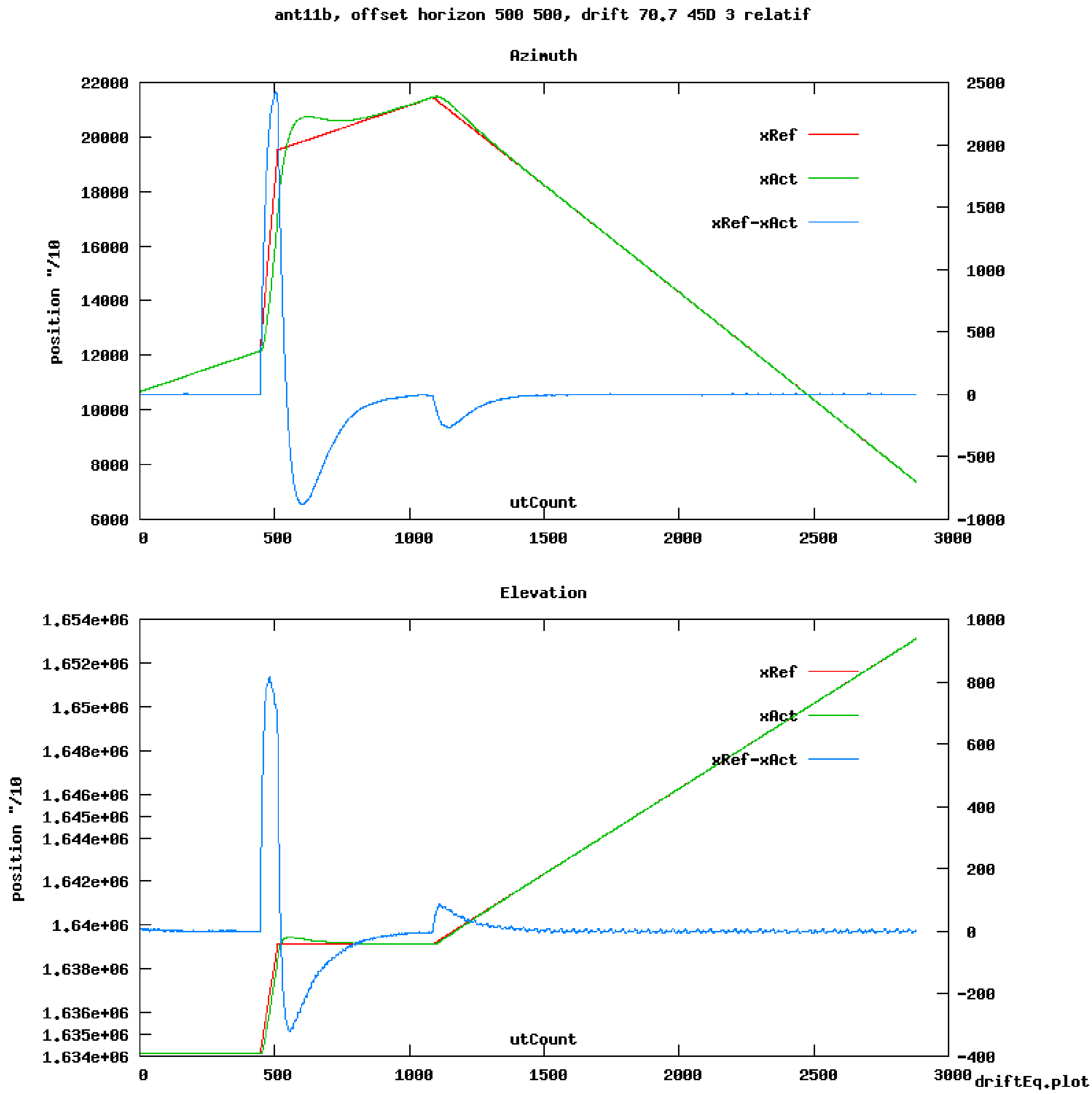

ant51b, offset horizon 500 500, drift 70.7 45D 0 relatif
Azimuth
position "/10
-1.07e+06
-1.075e+06
-1.08e+06
-1.085e+06
-1.09e+06
-1.095e+06
-1.1e+06
2500
2000
1500
1000
500
0
-500
-1000
xRef
xAct
xRef-xAct
utCount
0
500
1000
1500
2000
2500
3000
3500
Elevation
1.645e+06
1.64e+06
1.635e+06
1.63e+06
1.625e+06
1.62e+06
1000
800
600
400
200
0
-200
-400
driftHo.plot

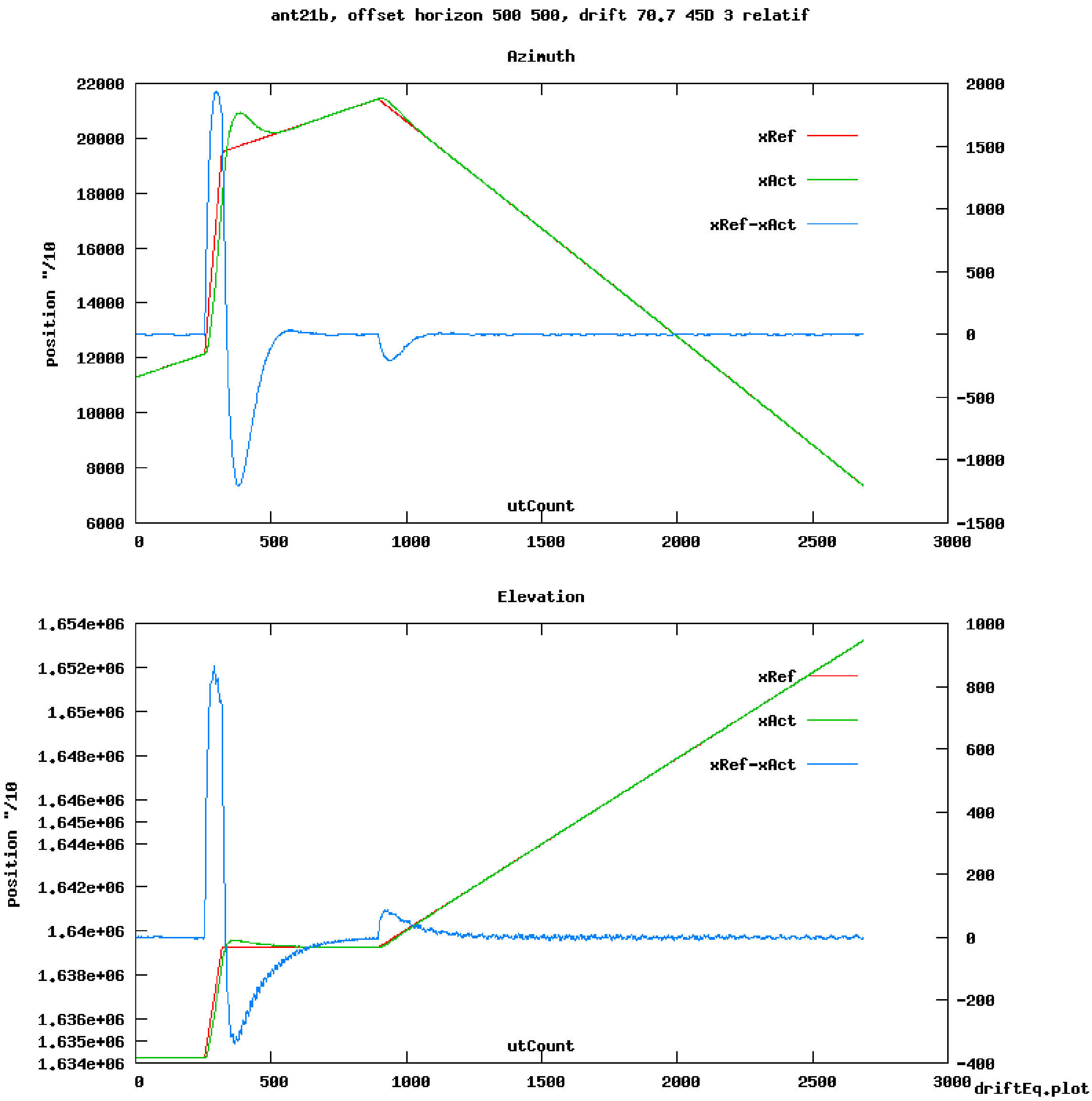

ant61b, offset horizon 500 500, drift 70.7 45D 0 relatif
Azimuth
position "/10
utCount
xRef
xAct
xRef-xAct
-1.07e+06
-1.075e+06
-1.08e+06
-1.085e+06
-1.09e+06
-1.095e+06
-1.1e+06
2500
2000
1500
1000
500
0
-500
-1000
-1500
0 500 1000 1500 2000 2500 3000 3500
Elevation
position "/10
utCount
xRef
xAct
xRef-xAct
1.645e+06
1.64e+06
1.635e+06
1.63e+06
1.625e+06
1.62e+06
1000
800
600
400
200
0
-200
-400
0 500 1000 1500 2000 2500 3000 3500
driftHo.plot

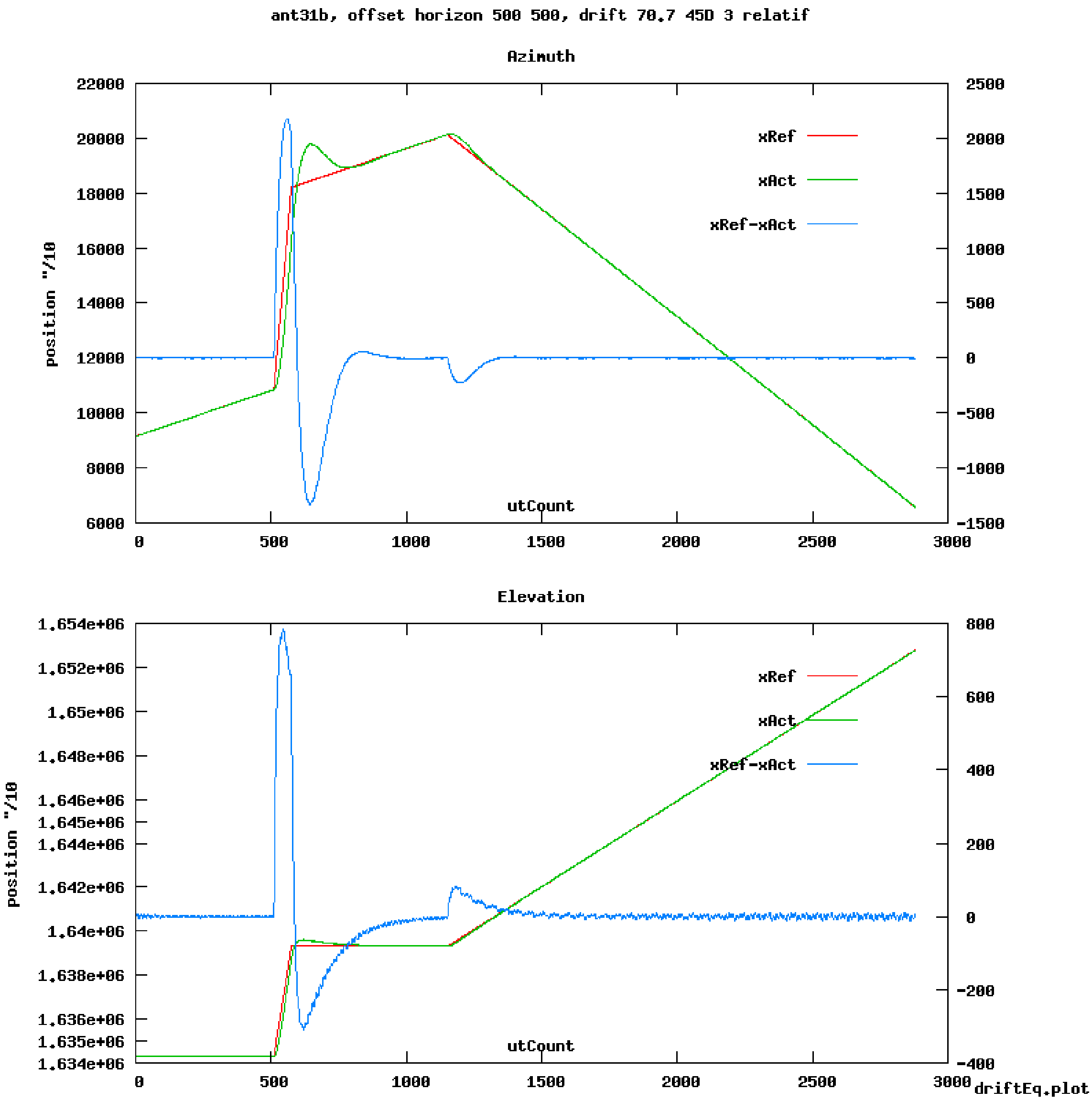
Both axis are studied while tracking on a fixed position in the equatorial coordinate system, then an offset compatible with the position tracking is applied. Finally a drift is added on top.
The commands from bure1b looks like this for antenna x, from 1 to 6:

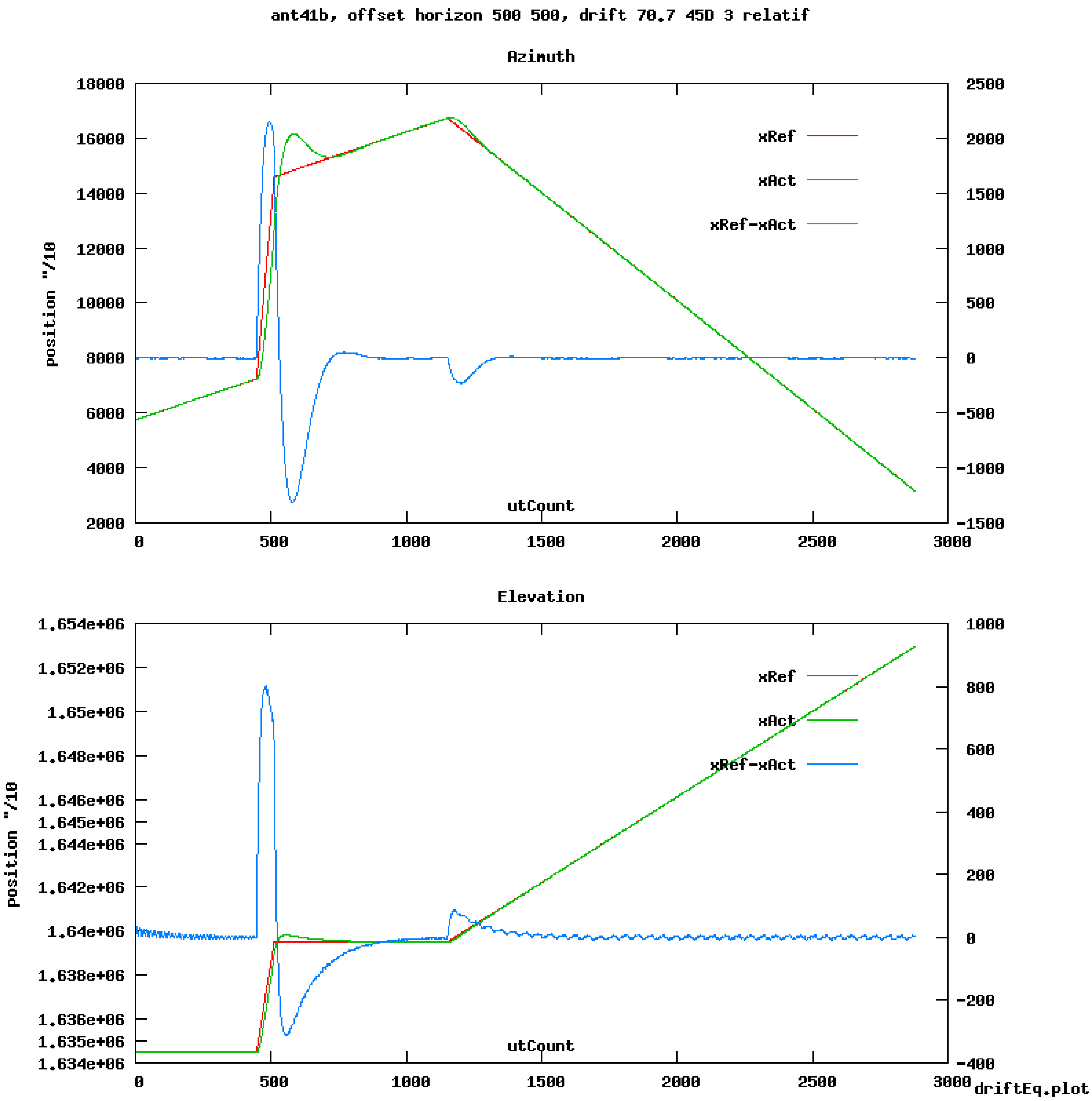
```
coo antenna x equatorial <sideral time> 0
off antenna x horizon 500 500
dri antenna x horizon 70.7 45D 3 relatif
```

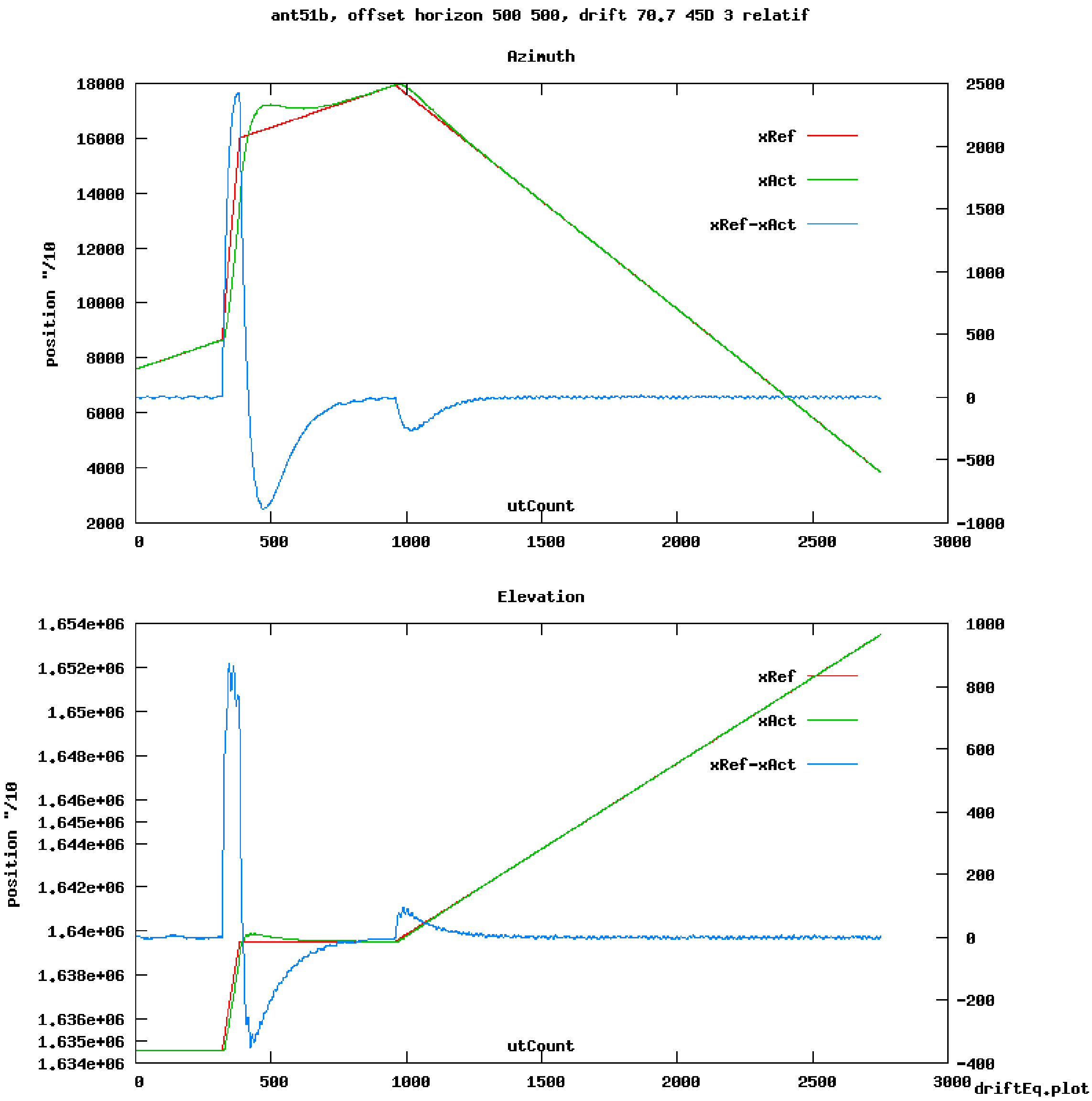

T+0s
T+1s
T+2s
T+3s
T+4s
T+5s
Commands
dri
or/and
off
flag1s
interm
bure1b:
slowLoop()
evit1s
tcpServer
offset
request
Calculates x2,
xRef position for
T+4s
ant*1b:
xRef
x0=x1
x1= x2
xRef from
x0 to x1
Case:
Command off
xRef
Case:
Command dri
xRef
Case:
Commands
off + dri

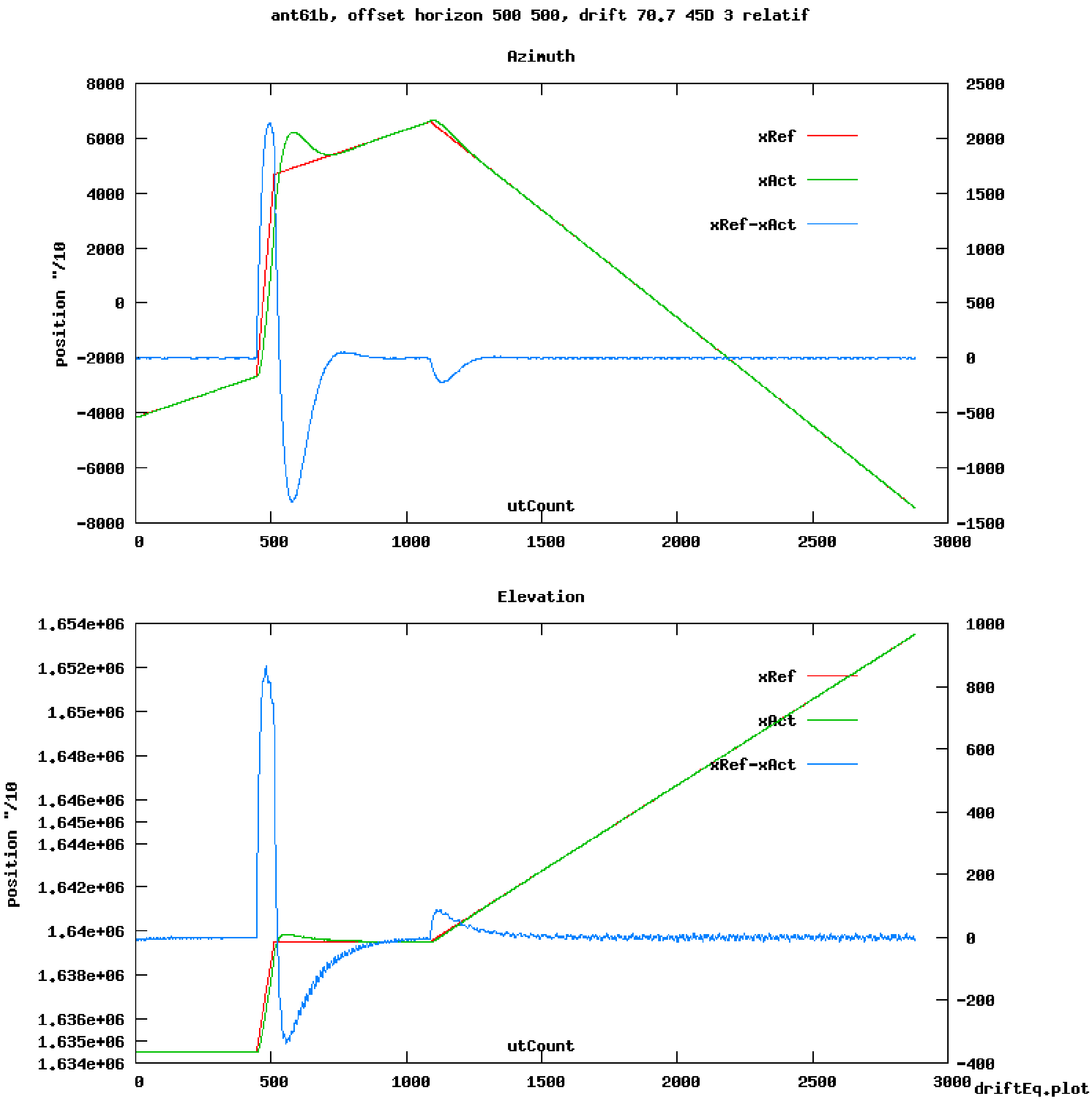

ant11b, offset horizon 500 500, drift 70.7 45D 3 relatif
Azimuth
position "/10
utCount
xRef
xAct
xRef-xAct
22000
20000
18000
16000
14000
12000
10000
8000
6000
2500
2000
1500
1000
500
0
-500
-1000
0
500
1000
1500
2000
2500
3000
Elevation
position "/10
utCount
xRef
xAct
xRef-xAct
1.654e+06
1.652e+06
1.65e+06
1.648e+06
1.646e+06
1.645e+06
1.644e+06
1.642e+06
1.64e+06
1.638e+06
1.636e+06
1.635e+06
1.634e+06
1000
800
600
400
200
0
-200
-400
driftEq.plot


ant21b, offset horizon 500 500, drift 70.7 45D 3 relatif
Azimuth
position "/10
utCount
xRef
xAct
xRef-xAct
Elevation
driftEq.plot


ant31b, offset horizon 500 500, drift 70.7 45D 3 relatif
Azimuth
position "/10
xRef
xAct
xRef-xAct
utCount
22000
20000
18000
16000
14000
12000
10000
8000
6000
2500
2000
1500
1000
500
0
-500
-1000
-1500
0
500
1000
1500
2000
2500
3000
Elevation
1.654e+06
1.652e+06
1.65e+06
1.648e+06
1.646e+06
1.645e+06
1.644e+06
1.642e+06
1.64e+06
1.638e+06
1.636e+06
1.635e+06
1.634e+06
800
600
400
200
0
-200
-400
driftEq.plot

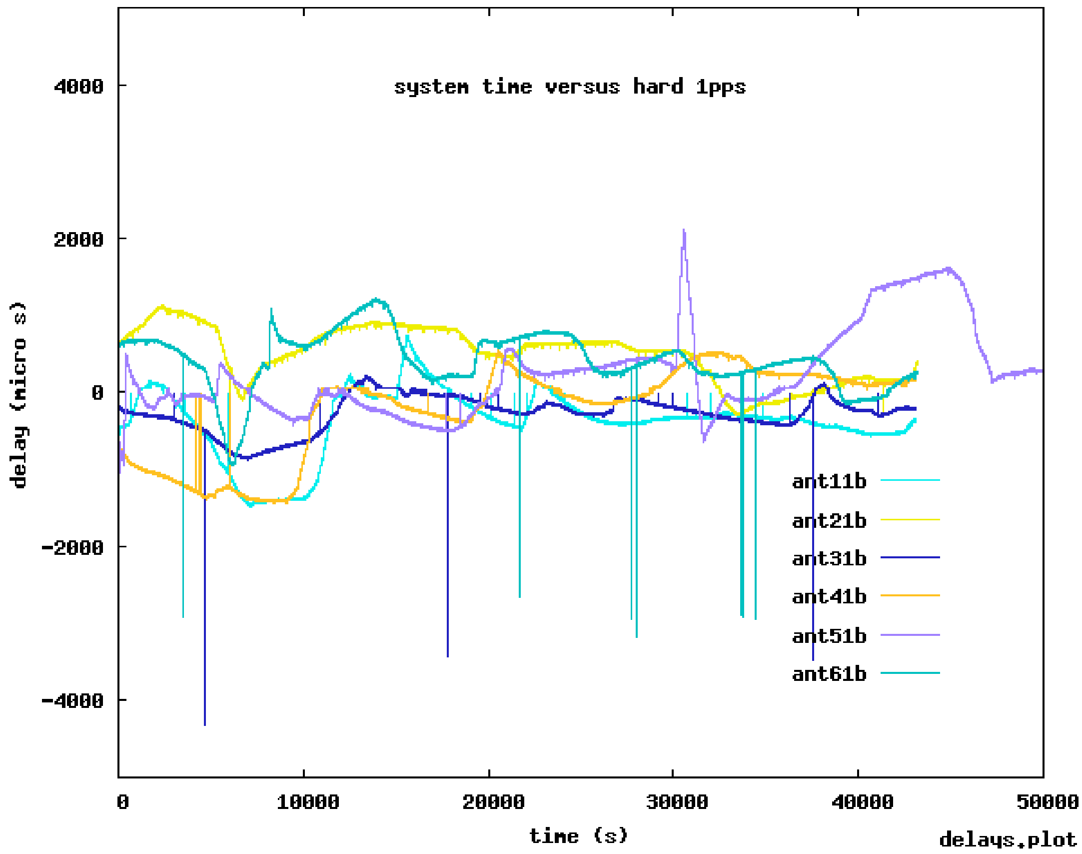

ant41b, offset horizon 500 500, drift 70.7 45D 3 relatif
Azimuth
position "/10
xRef
xAct
xRef-xAct
utCount
Elevation
driftEq.plot


ant51b, offset horizon 500 500, drift 70.7 45D 3 relatif
Azimuth
position "/10
xRef
xAct
xRef-xAct
utCount
18000
16000
14000
12000
10000
8000
6000
4000
2000
2500
2000
1500
1000
500
0
-500
-1000
0
500
1000
1500
2000
2500
3000
Elevation
position "/10
xRef
xAct
xRef-xAct
utCount
1.654e+06
1.652e+06
1.65e+06
1.648e+06
1.646e+06
1.645e+06
1.644e+06
1.642e+06
1.64e+06
1.638e+06
1.636e+06
1.635e+06
1.634e+06
1000
800
600
400
200
0
-200
-400
driftEq.plot



6 System time delays

The next plot shows, for all antennas, the variation of the system time at the 1pps time bus event time, from just after a reboot of the pedestal processor and for around 12 hours. In other words at each interrupt generated by the time bus signal, i.e. every second, the fraction of the second of the system time synchronized on the ntp system is recorded. The fraction of the second is expressed in micro seconds. We see that the time difference does not vary more than +-2ms, from the beginning , which is small enough to guarantee the identification of each period of the fast (64Hz) loop by just reading the system time.



Reminder:
On each antenna the command **ntpq -p** shows the current status of the ntp synchronization.

```
ant11b root:~ # ntpq -p
     remote           refid      st t when poll reach   delay   offset  jitter
==============================================================================
*clockb.iram.fr  .TRUE.      1 u   41  256  377    0.339    0.452   0.339
```

The current estimated delay, offset and dispersion of the peer (clockb) are expressed in milliseconds.

The server ntpd is started at boot time with the command:

```
/usr/local/bin/ntpd -A -c /etc/ntp-broadcast.conf &
```

`-A` Disable authentication mode
`-c` Specify the name and path of the configuration file

```
ant11b root:/home/introot # cat /etc/ntp-broadcast.conf
broadcastclient                 # broadcast client
driftfile /tmp/ntp.drift
```