CNR - Istituto di Radioastronomia

Technical Report

Analysis of Performances of Noto Station Radiotelescope

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1. Position Track Mode operation : AZIMUTH

A first type of experiment performed is a scan with a step response of 0.05 degree in azimuth in POSITION TRACK operation mode at 45 and 30 degree of elevation; the scan total azimuth gap is 5 degree with a duration of 10 seconds for scan . The signal most often studied is the position error that is represented in Fig.1 and measured **either in CW or in CCW direction**.

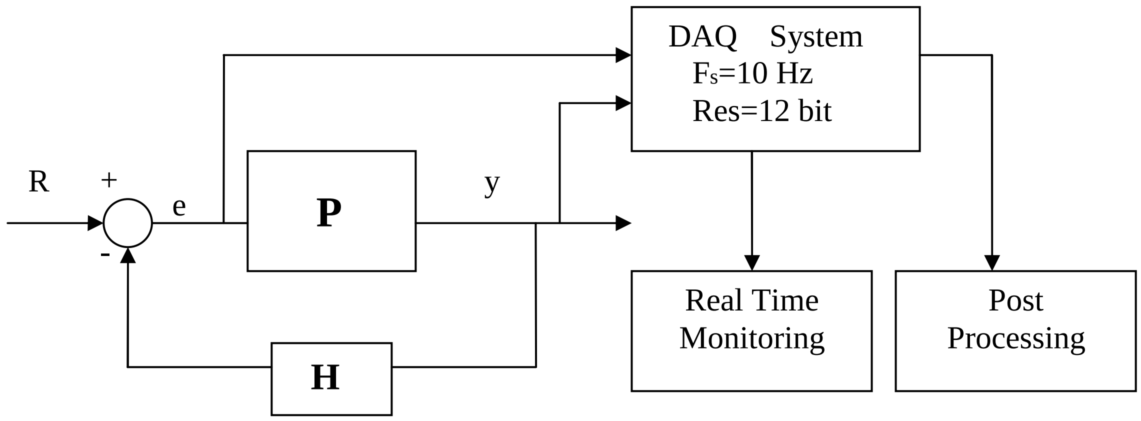

Fig 1 Scheme of error position evaluation

Error signal and current position are acquired by a DAQ card with a 10 Hz sampling rate and a 12 bit resolution; in particular error signal is coded with a range 0-1 V so that it's possible to sample with a 2mV resolution. Spectral characterization of system is compatible with signal bandwith of 5 Hz that result from 10 Hz sampling.

Azimuth analysis with elevation at 45 deg.

It's possible to summarize the results as follows:

1) a first type of behaviour in CW direction is a shaded trend of error position that should be near to the correct way for the system to reach the commanded position; the time elapsed to reach 10% of the maximum value is about 2.4 seconds, so it's possible to approximate the trend with an exp function exp(-t/1.0423); it could be validated also by the spectral analysis of both signals. Moreover there is a residual error in the steady condition that is about -0.5 mdeg (Fig 2).
2) a second type of behaviour is a vibrating shaded trend, that is an undesired way of reaching the commanded position, because it is the superimposition of two important behaviour: a shaded one, that is quite similar to the previous 1), and a vibrating one at a frequency that is about the auto frequency of the antenna. Previous work had fixed this auto frequency at F_r=1.87 Hz, but latest upgrading of Noto radiotelescope system has produced a change in antenna's parameters, as weight and moment of inertia and so

modifying the original auto frequency narrow band, spreading it and shifting toward less values, as you can see comparing Fig.3 and Fig 4.

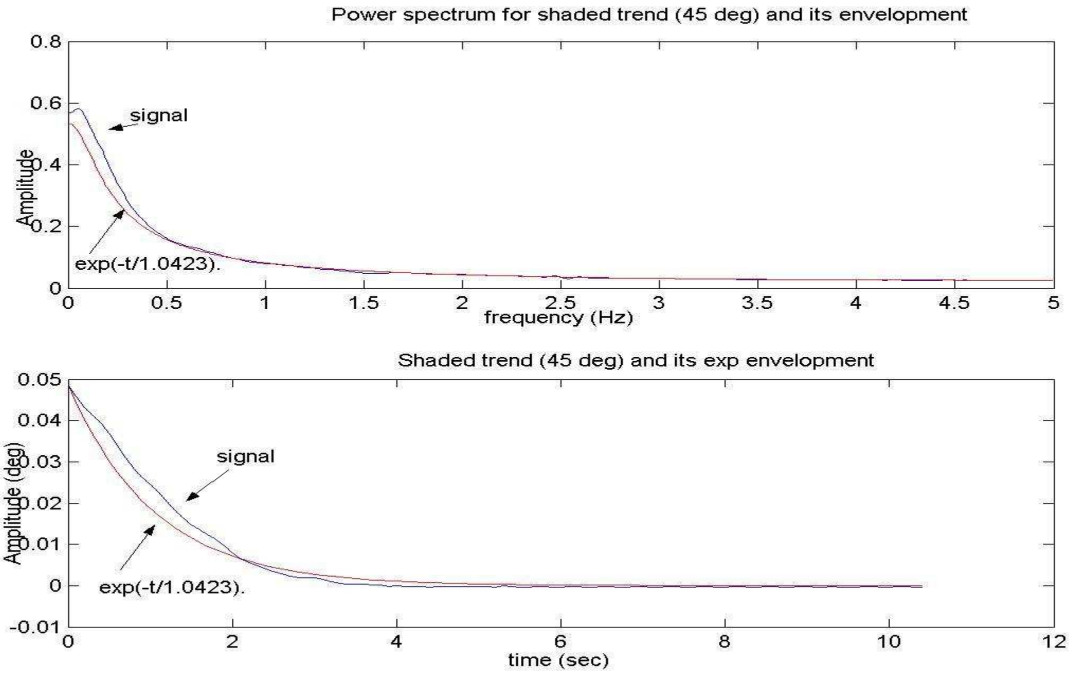

Fig 2. Position error shaded trend and its spectrum at el. 45 deg

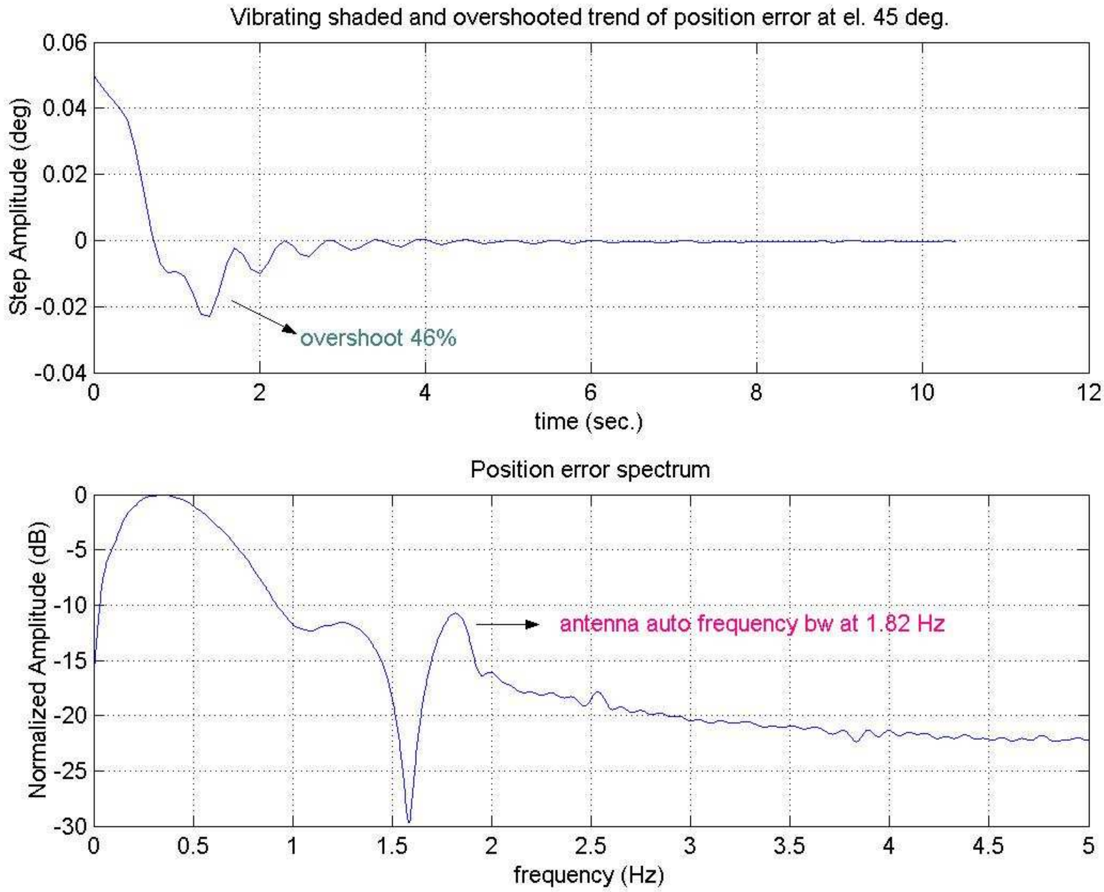

Fig 3. Vibrating shaded trend and its spectrum at el. 45 deg.

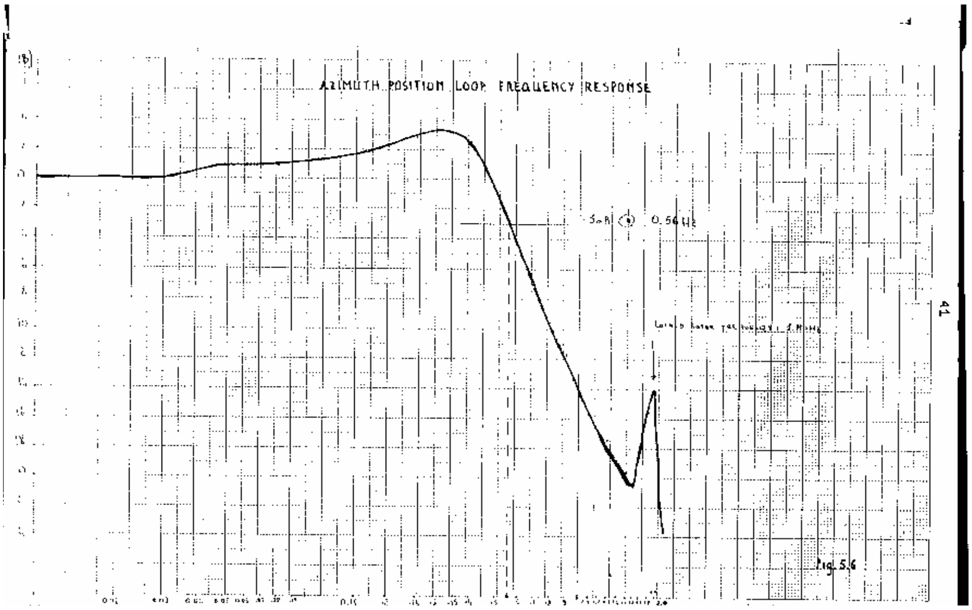

Fig 4. Auto frequency BW for Noto Antenna before 2001

Moreover the trend has an overshoot of about 45% of maximum step value , that cannot be acceptable**; this phenomenon has a particular evidence in CW direction, while in CCW direction is less frequent.**

It’s possible to correlate this trend with an undesired behaviour of the antenna; in particular when it is often commanded a position in a desired direction (CCW, CW) the antenna movement is in the reverse direction for few time, then inverts its trend towards the desired position.

This phenomenon that it would called Reverse Direction Bursts (RDB) is also correlated with the next type of oscillating behaviour described below.

3) the third type of trend recorded in azimuth is a behaviour with oscillations supported to one equal frequency approximately to 1.225 Hz; to notice that this frequency never has not appeared till now and he is not seems lied to phenomena of the structure resonance that indeed are attenuated, as you can see in fig.5; here is observed a typical notch filter behaviour at auto frequency bw of the structure. It could rather be thought that this phenomenon is related to mechanical or atmospheric perturbations, like can be observed from spectra of fig 9 where is represented a high sensitivity to 0:1.5 Hz bandwith (and in particular at 1.3 Hz) when the antenna wheels cross rail junctions.

However these phenomena have been recorded for various values of azimuth, therefore not only in proximity of rail junctions, and in various atmospheric conditions (i.e. for various values of intensity of the wind); a more deeper analysis related to the atmospheric conditions is not realistic

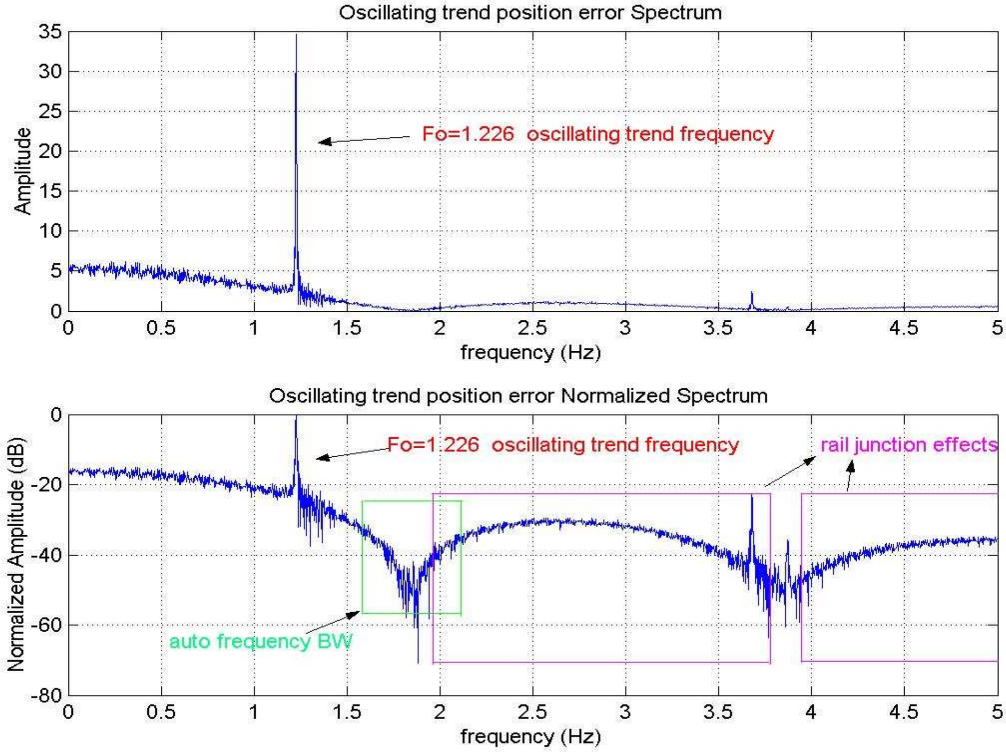

Fig 5. Oscillating frequency trend and rail effects

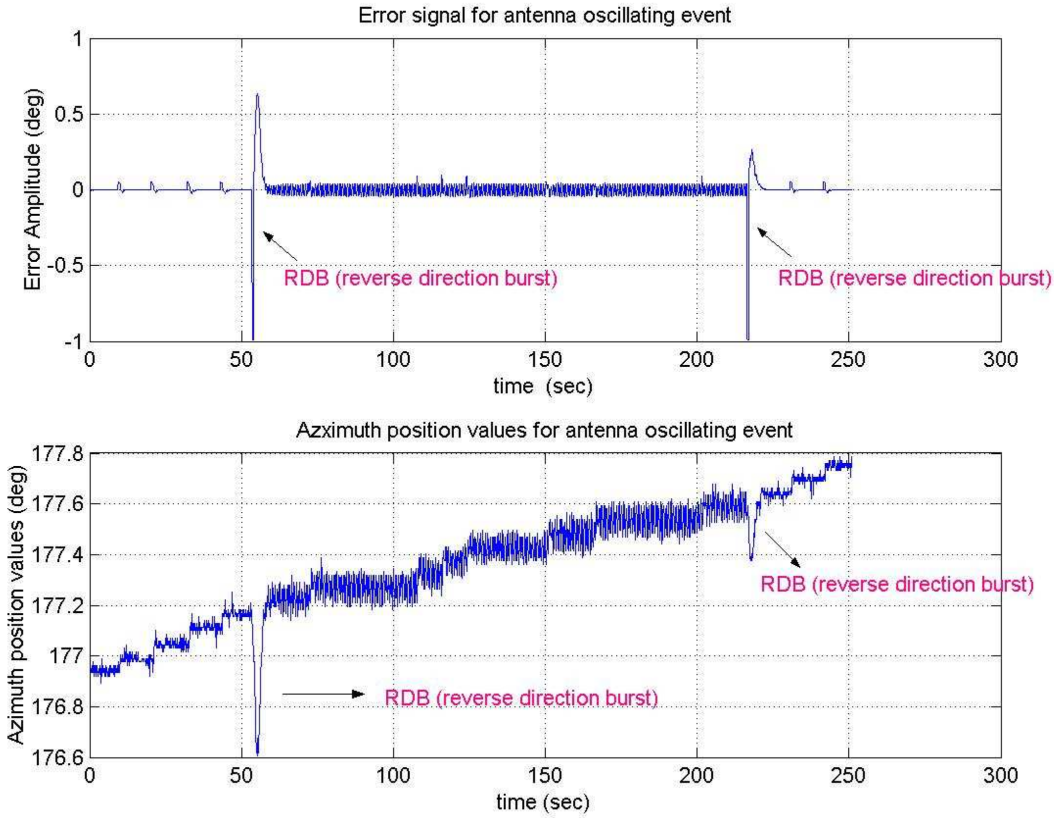

Fig 6. Oscillating frequency trend; azimuth position and its error

one, because too much dependent to aleatory and strongly variable conditions during the year. However it can be deduced that this oscillating trend, that it must absolutely be to eliminate, is an anomalous answer to external perturbations that make the system unstable.

A more accurate graphical inspection of error position signal in azimuth, finds that the antenna catch up the position commanded, oscillating itself around, with an amplitude approximately equal to the amplitude of the testing step, in particular 0.05 degrees that is the typical value for which this phenomenon it is more often introduced.

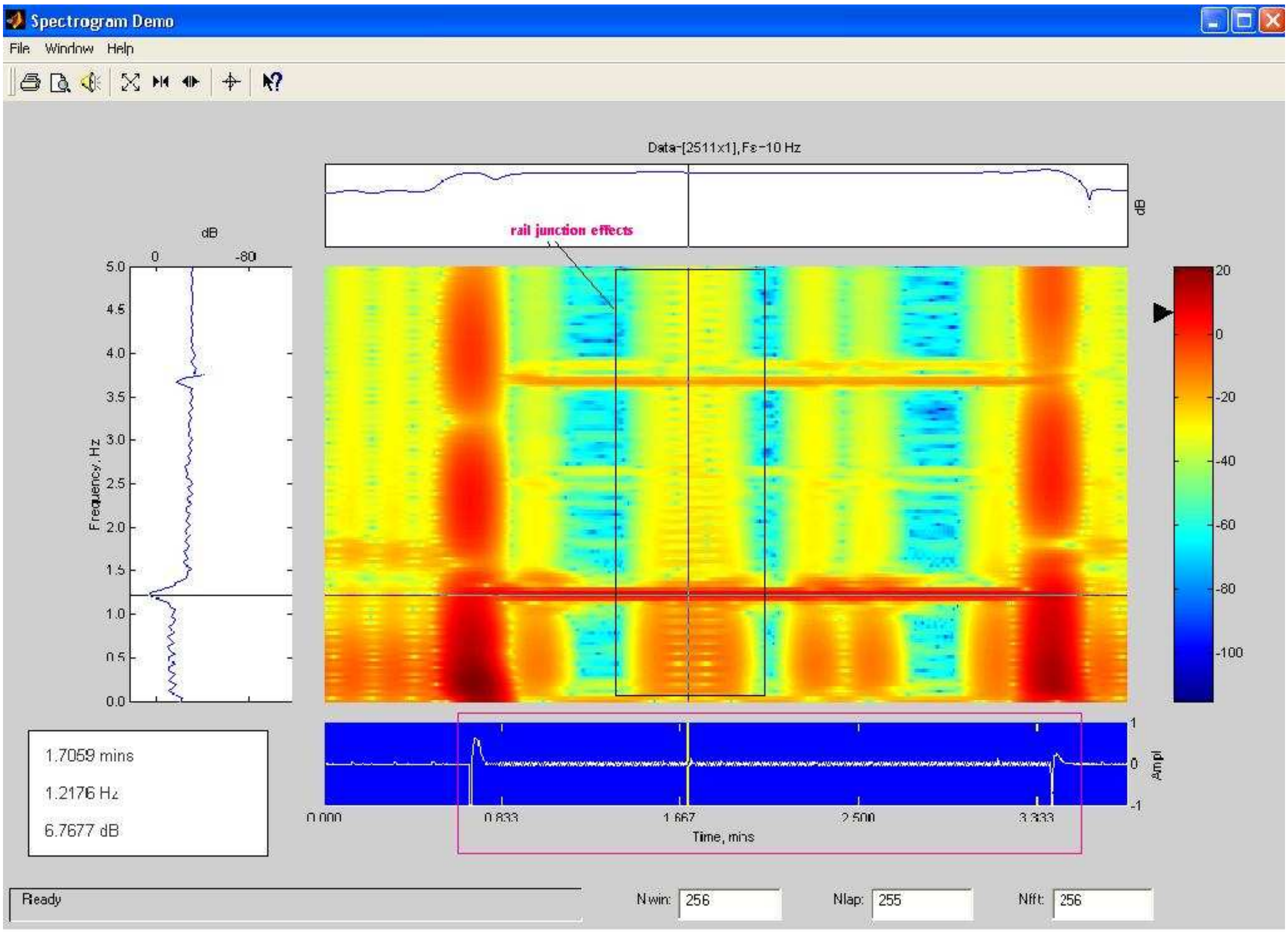

Fig 7. Oscillating frequency trend; spectrogram and rail junction effects

The same spectral behaviour has been observed analyzing others test signal like the speed and the torque of both motors, just in case of these oscillating events. Results are quite similar, that is the response of this signals has a narrow band centered at1.225 Hz.

Azimuth analysis with elevation at 30 deg.

Important considerations can be made comparing the behaviour at 45 and 30 deg of elevation:

a) at 30 degree of elevation the antenna behaviour is more sensitive to its auto frequency bandwith; as you can see in Fig 8; the peak spectrum at auto frequency bw is not so higher than 45 deg elevation spectrum, but the bw is narrower and centered at a lower frequency, probably because moment of inertia makes worse mechanical load conditions.

b) It's possible to see that are not present shaded trend as 1), while system always reach its position with a vibrating shaded behaviour.

c) In Fig 9 it's possible to confirm this idea, because is described the antenna behaviour near the rail junctions. This type of noise make lower the antenna auto frequency and narrower the bw.

In general the position of antenna at 30 deg of elevation, (for any azimuth position) make it more sensitive to the auto vibrating behaviour in a band centered near 1.75 Hz, so that for a

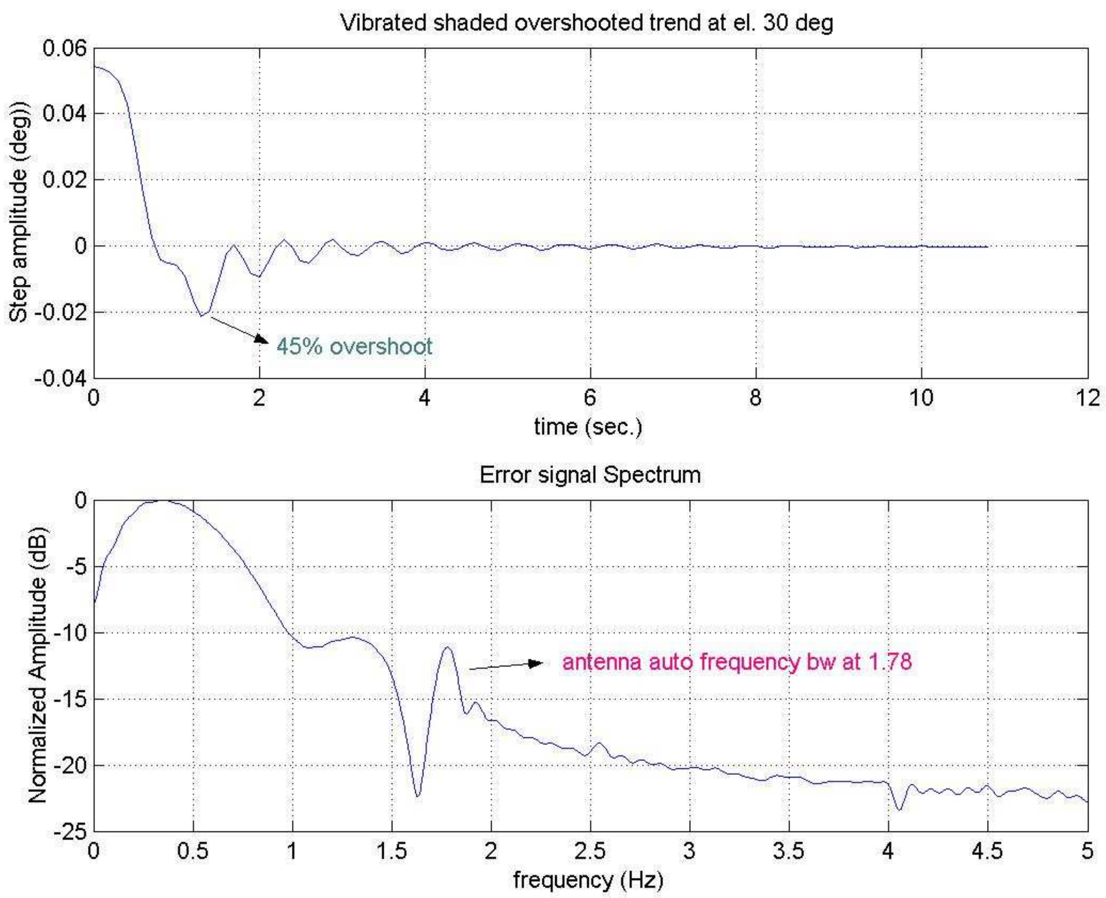

Fig 8. Vibrating shaded trend and its spectrum at el. 30 deg.

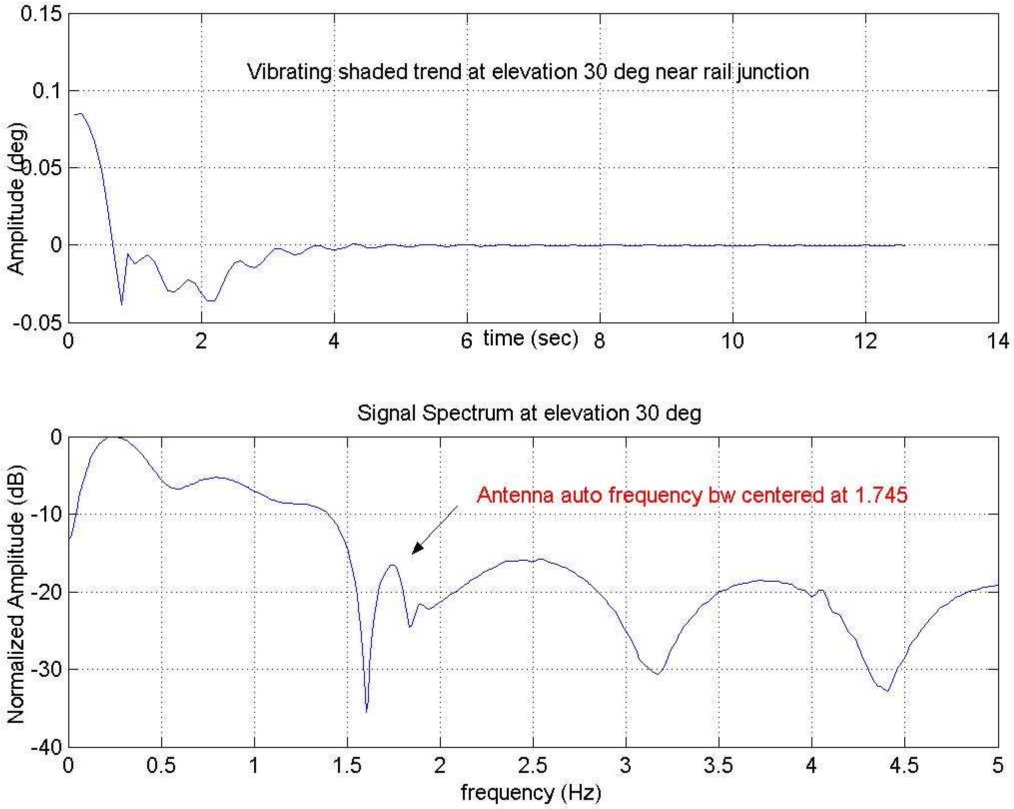

Fig 9. Position error trend and its spectrum at el. 30 deg near rail junction.

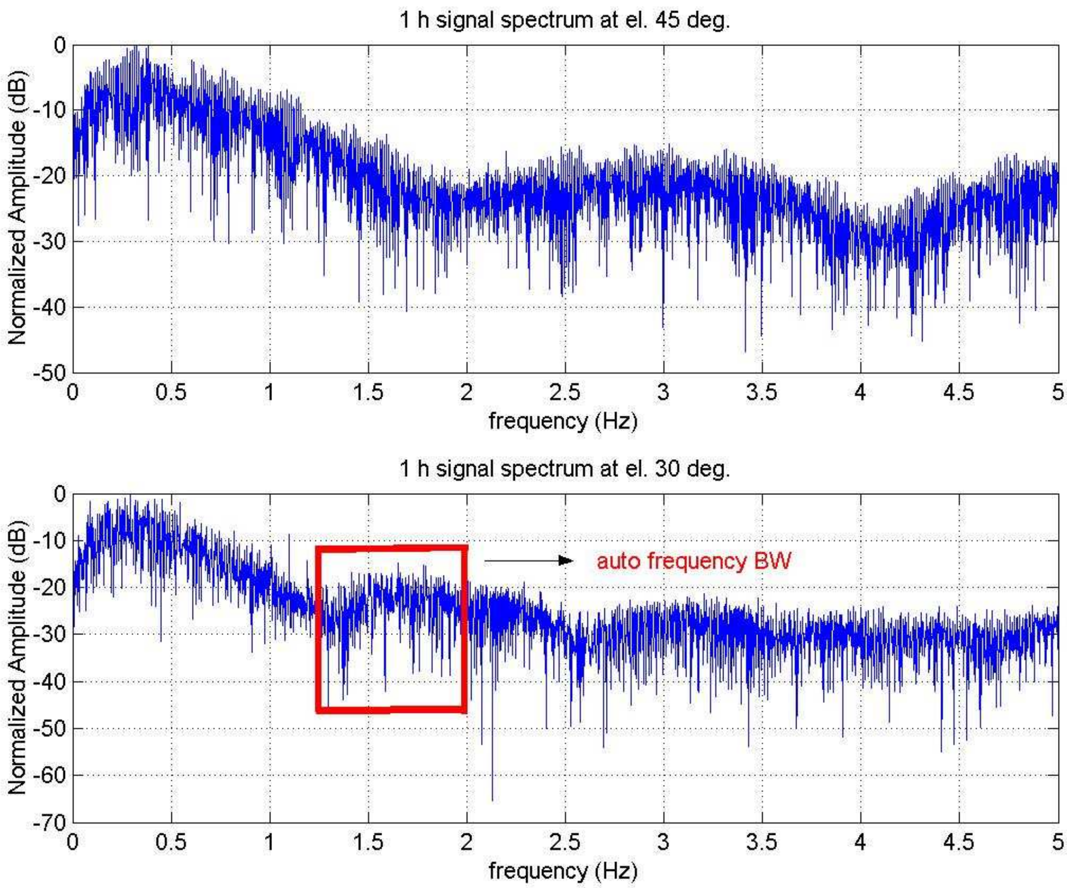

Fig 10. Comparison for spectrum at 45 and 30 deg of elevation.

possible future antenna behaviour improvement its necessary to operate at low value of elevation. In Fig. 10 this comparison is more evident, because it's possible to focus the auto frequency bw as to the behaviour at 45 deg. of elevation.

2. Preset Mode operation: AZIMUTH

A second type of experiment performed is a scan with a step response of 0.01 and 0.05 degree in azimuth in PRESET mode operation mode at 45 and 20 degree of elevation ; each scan has a duration of 15 seconds in order to analyze the open loop long term fluctuations of position error. It's possible to notice a different behaviour for the antenna for this mode of operation than the POSITION TRACK;

1) It's less sensitive to its auto frequency even with a lower step (0.01) as you can see in Fig. 11;
2) Error at steady condition is less, about 2 mdeg but has fluctuations oscillating at a frequency 0.14 Hz; this frequency in POSITION TRACK mode is attenuated even near the junction rail;
3) Are not present reverse direction bursts (RDB) neither in CCW nor in CW direction and are not present vibrating shaded trend, so it's possible anymore to correlate themselves.
4) Is not present vibrating undesired and overshooted behaviour that can disturb the correct antenna trend in transient and in steady condition of a commanded scan;
5) For 0.05 deg of azimuth step value the auto frequency BW is more attenuated in comparison than previous experiments, as you can see in Fig 12.

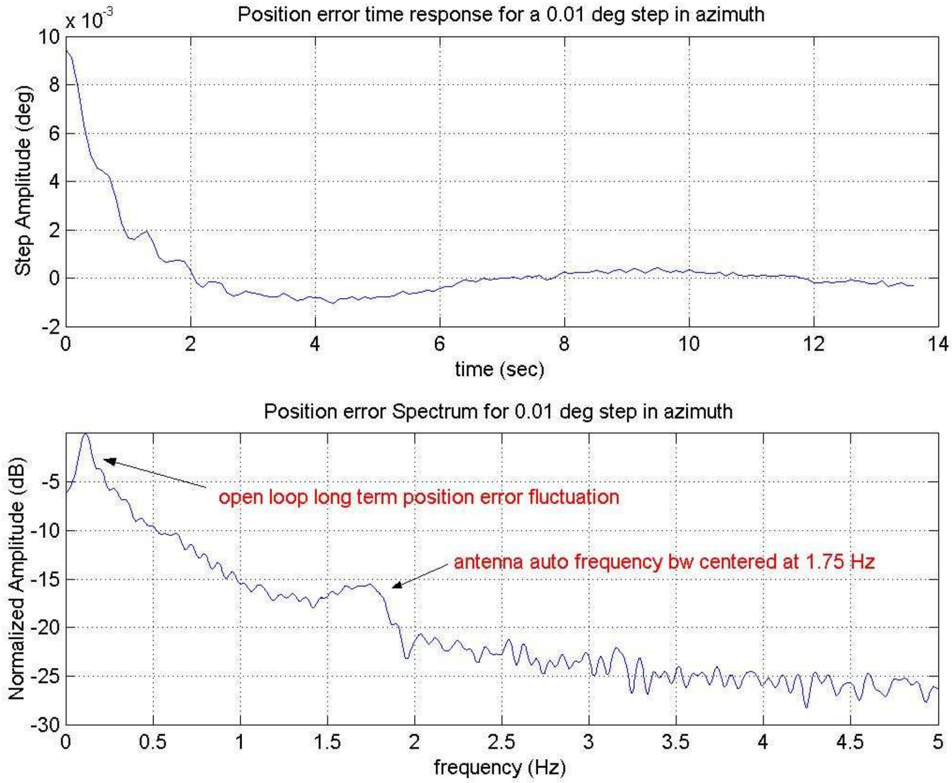

Fig 11. Position error for a 0.01 deg azimuth step in PRESET MODE

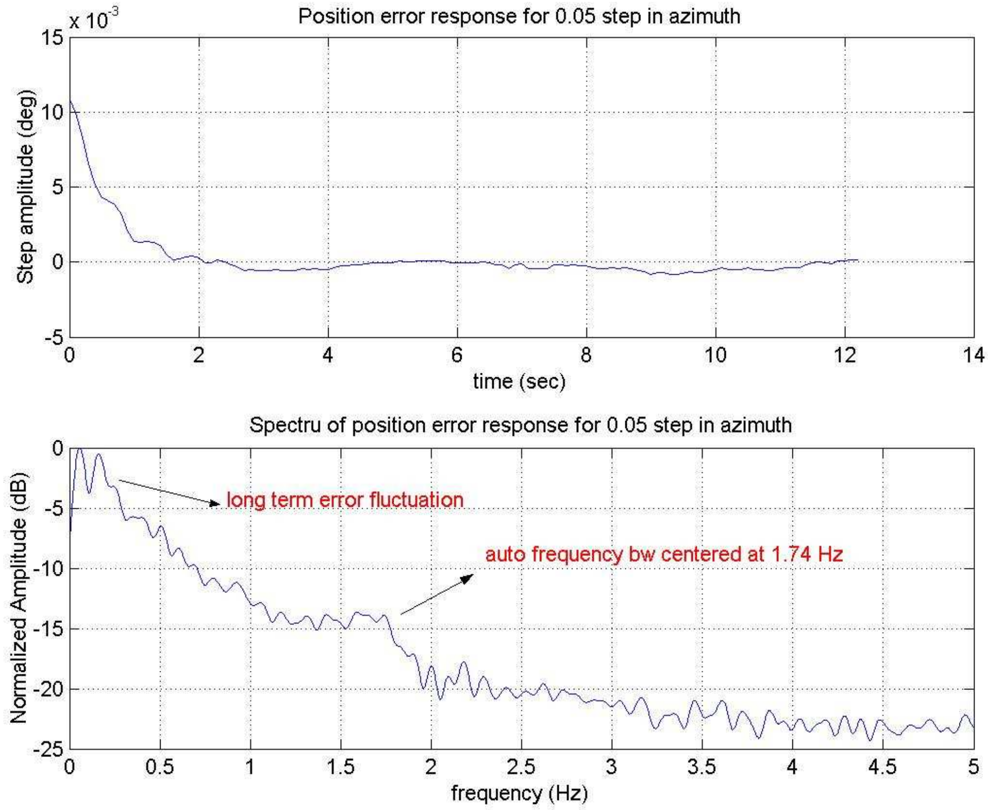

Fig 12. Position error for a 0.05 deg azimuth step in PRESET MODE

3. Position Track Mode operation : ELEVATION

The analysis of Position Track Mode has revealed 2 particular trends:

1) a first type of behaviour in elevation is a shaded trend of error position that should be near to the correct way for the system to reach the commanded position, but it is not because is present an overshoot beginning that is corrected just in time (Fig. 13). After this, it's possible to approximate the error signal with an exp function; it could be validated also by the spectral analysis of signal, but here is more evident the contribution of antenna auto frequency . Moreover there is a residual error in the steady condition that is about -0.5 mdeg (Fig 2). **This trend is rare at Noto**, but is a regular behaviour at Medicina.

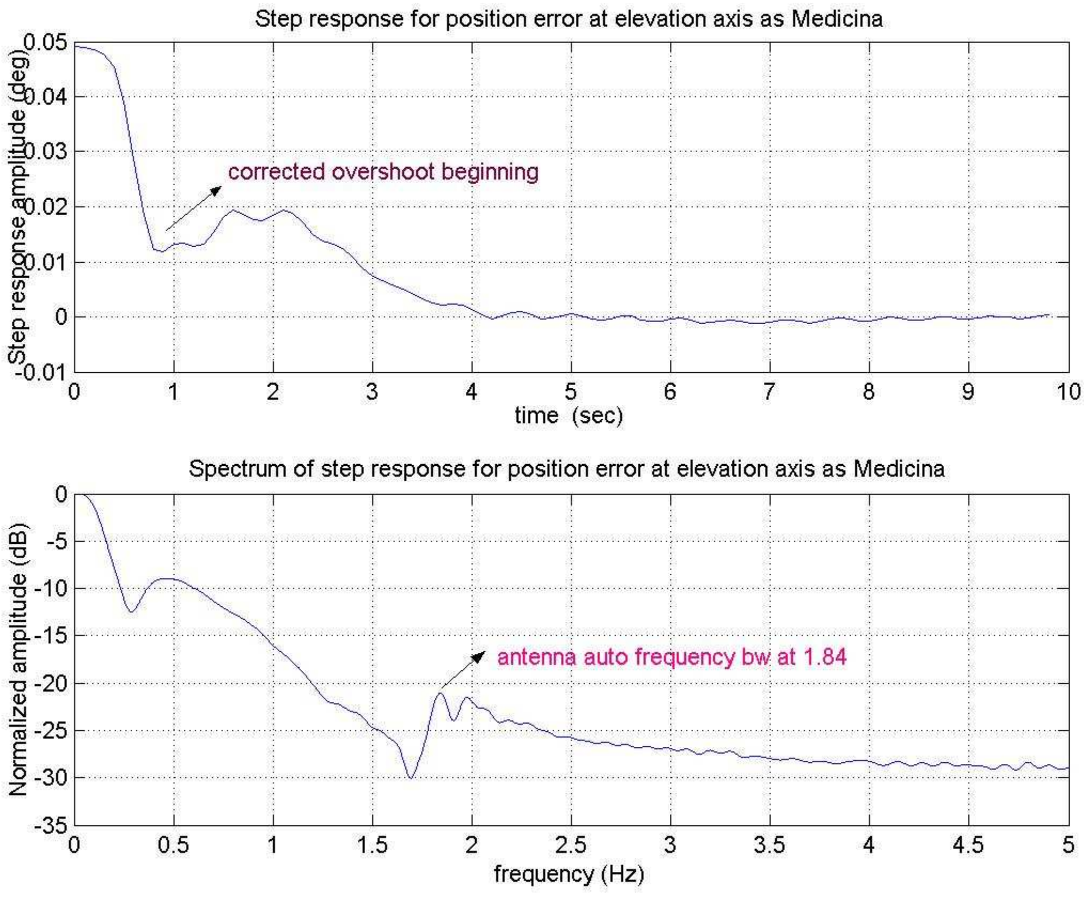

Fig 13. Position error for a 0.05 deg elevation step in POS TRACK as Medicina

2) a second type of behaviour is a shaded vibrating trend, that is an undesired way of reaching the commanded position, because it is the superimposition of two important behaviour: a shaded one with a remarkable contribution to low frequencies , and a vibrating one at a frequency that is about the auto frequency of the antenna (Fig. 14) . Moreover it is also evident an overshoot of about 35% of the maximum step value, either for 10 mdeg step, or for 50 mdeg step; obviously this trend hat to be eliminated, as in azimuth.

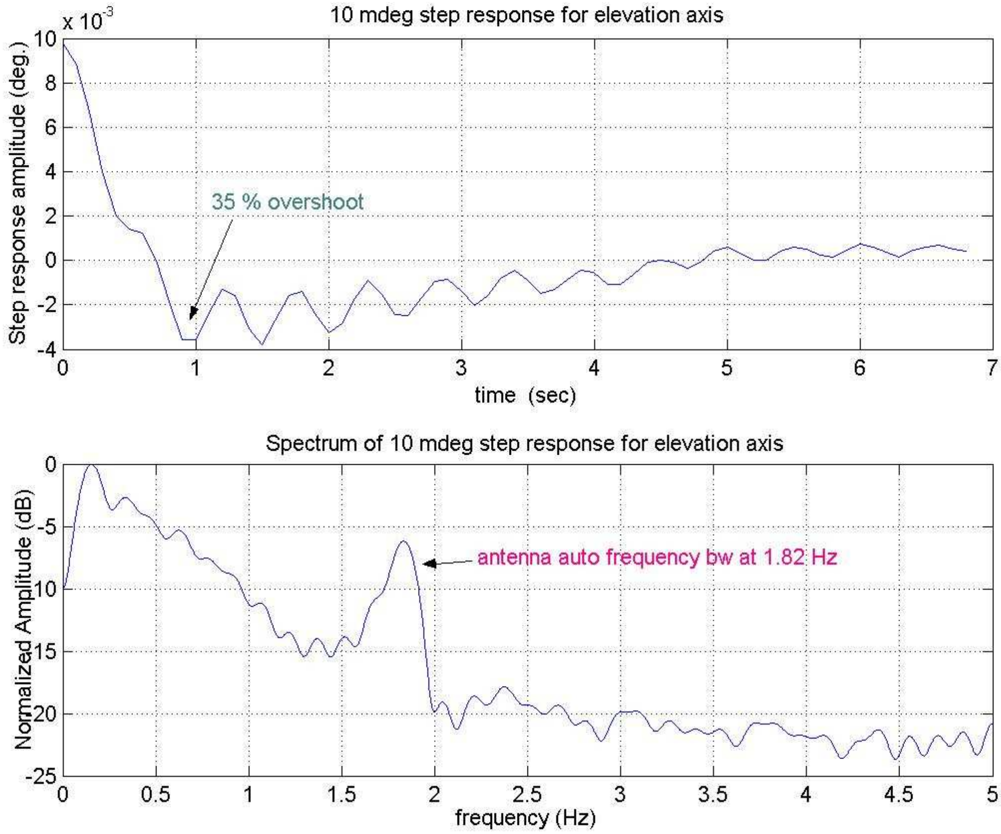

Fig 14. Vibrating overshooted for a 0.01 deg elevation step

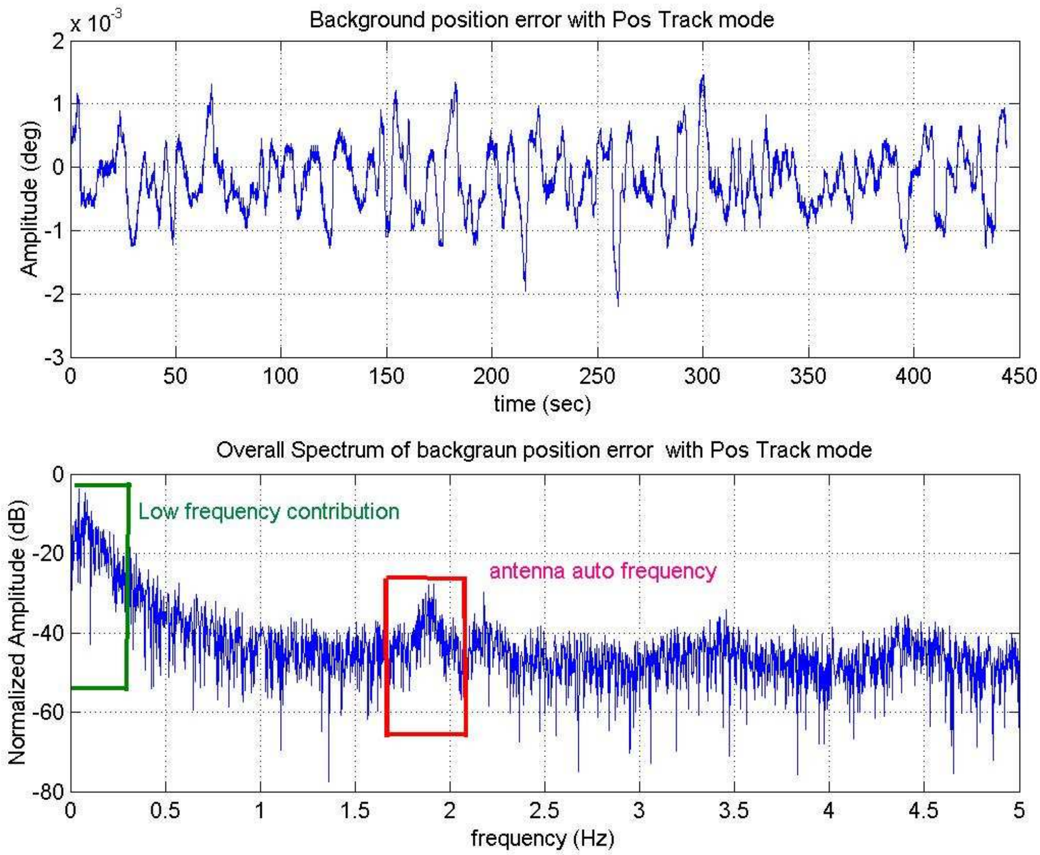

Fig 15. Overall Spectrum position error with Pos Track Mode

Both signal are an incorrect trend because, also for elevation axis, the system is too sensitive to antenna auto frequency, setting an error at steady state that is oscillating near a constant value. But even more serious it's the overshoot that affect the most part of step responses, and that make the long term positioning slower than a shaded trend.

A background analisys of error in a commanded position in Pos Track mode (Fig. 15) reveals as error is not composed only by noise (sample, electrical, mechanical) but is quite sensitive to the auto frequencies of antenna and to a long period variation.

4. Preset Mode operation: Elevation

As azimuth, has been also performed a scan with a step response of 0.01 and 0.05 degree in elevation axis in PRESET mode operation mode at 45 degree of elevation ; each scan has a duration of 15 seconds in order to analyze the open loop long term fluctuations of position error .

It's possible to notice a different behaviour for the antenna for this mode of operation than the POSITION TRACK;

1) It's less sensitive to its auto frequency even with a lower step (0.01) as you can see in Fig. 16;
2) Error at steady condition is less, about 2 mdeg but has fluctuations oscillating at a frequency 0.14 Hz;
3) Are not present reverse direction bursts (RDB) neither in CCW nor in CW direction and are not present vibrating shaded trend, so it's possible anymore to correlate themselves.
4) Is not present vibrating undesired and overshooted behaviour that can disturb the correct antenna trend in transient and in steady condition of a commanded scan;
5) For 0.05 deg of azimuth step value the auto frequency BW is more attenuated in comparison than previous experiments, as you can see in Fig 17.

Noto, April 22, 2004

Francesco Schillirò

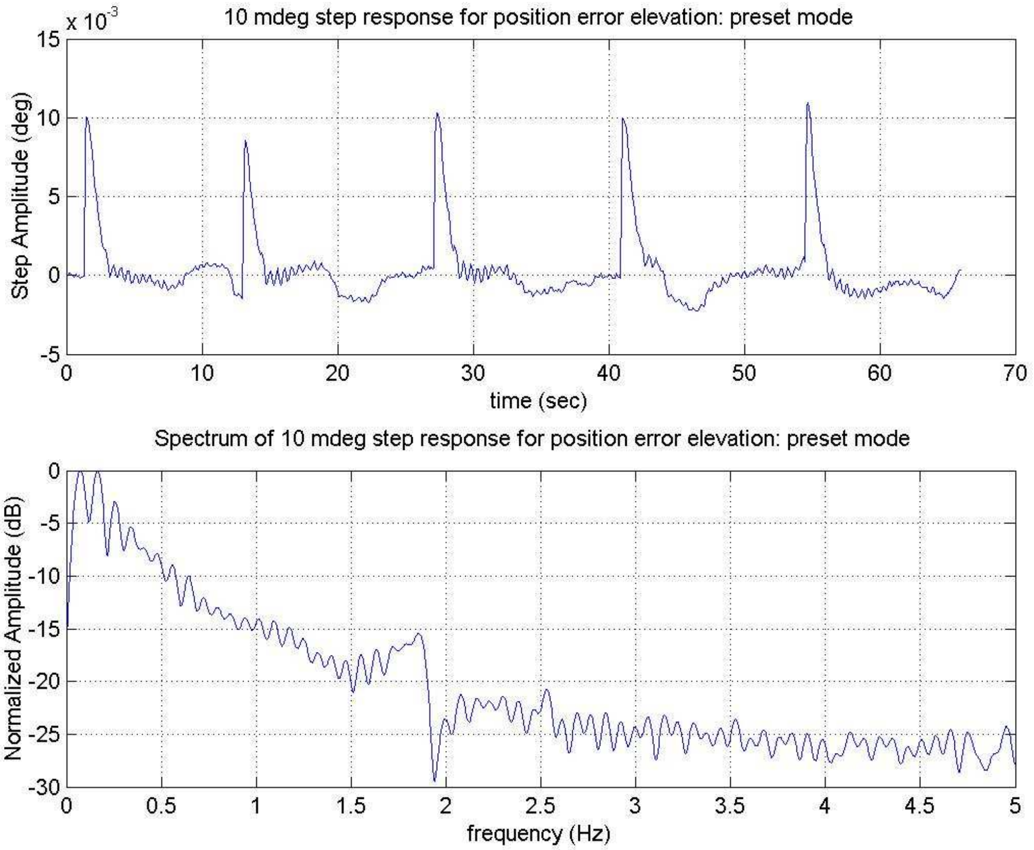

Fig 16. Position error for a 0.01 deg elevation step in PRESET MODE

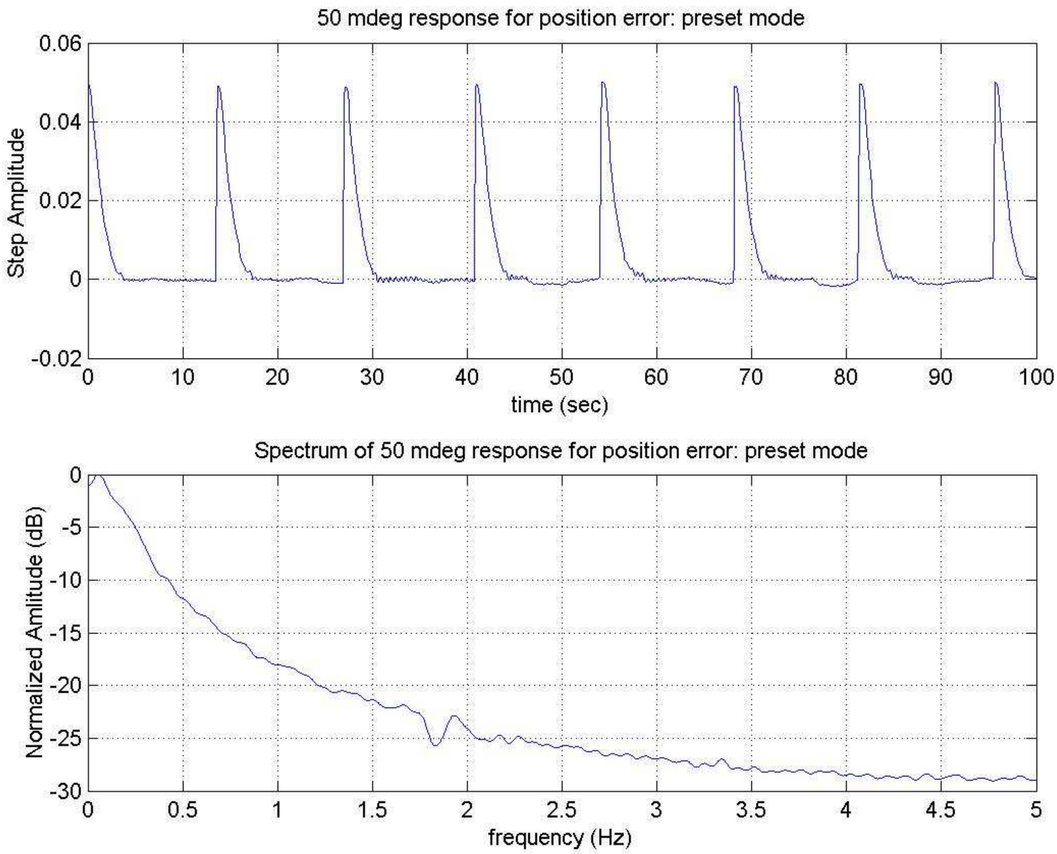

Fig 17. Position error for a 0.05 deg elevation step in PRESET MODE

5. Error Step responses for elevation axis.

It follows a series of step responses in elevation axis in time domain.

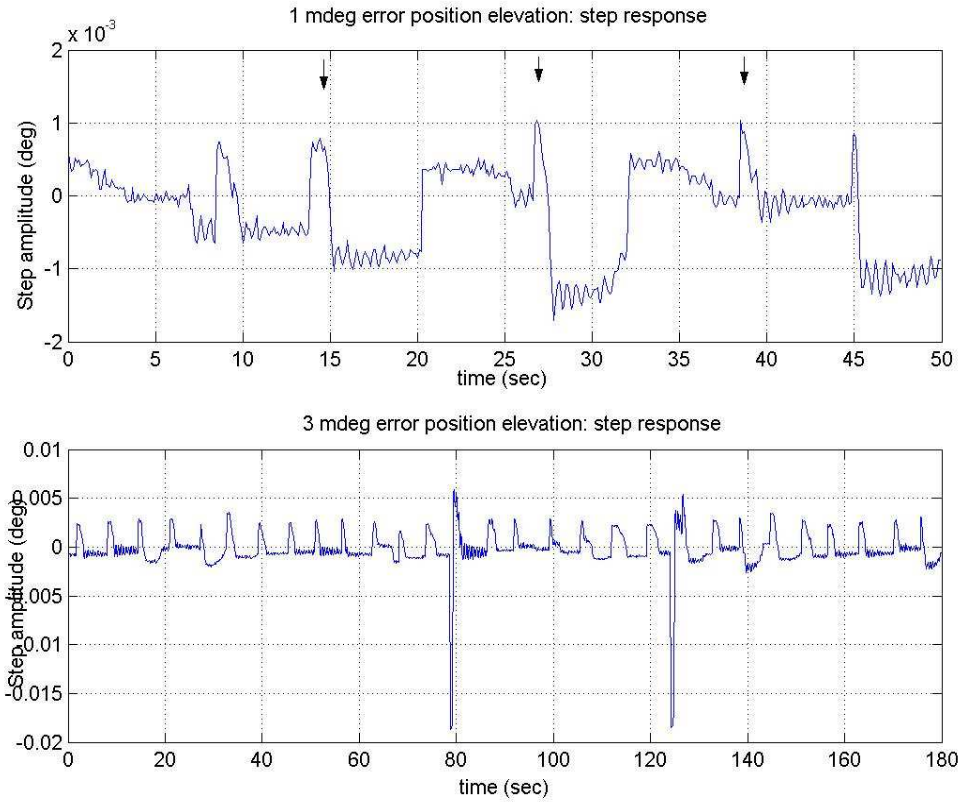

Fig 18. Position error for a 0.001 and 0.003 deg elev step in POS TRACK MODE

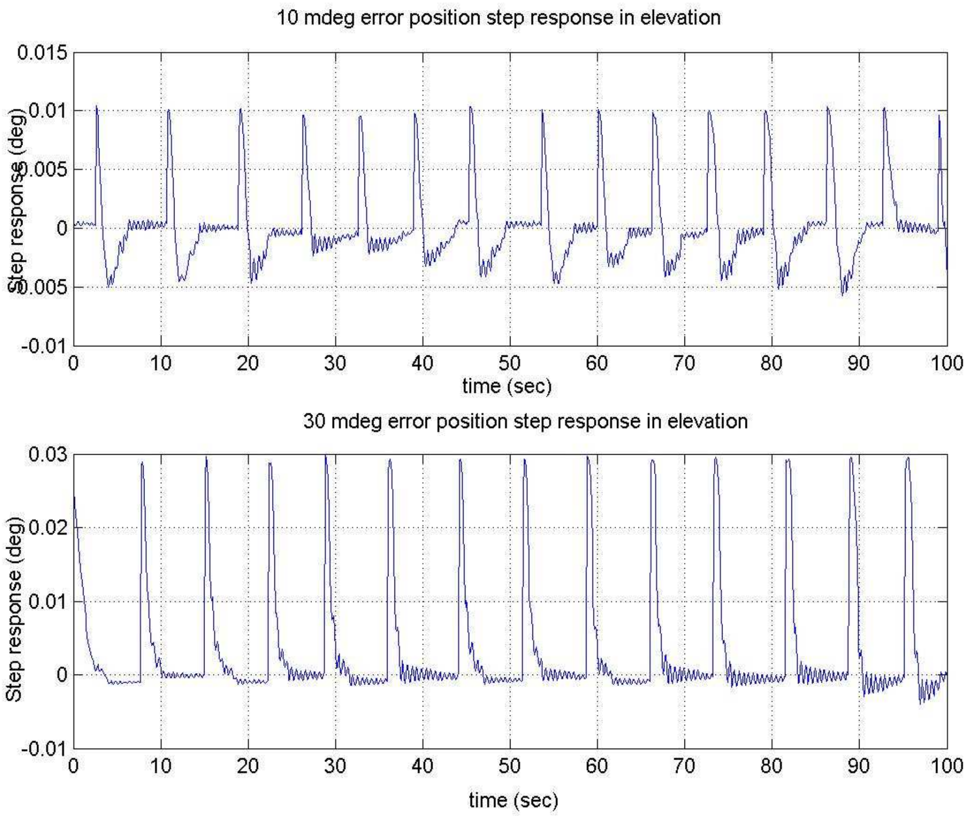

Fig 19. Position error for a 0.01 and 0.03 deg elev step in POS TRACK MODE

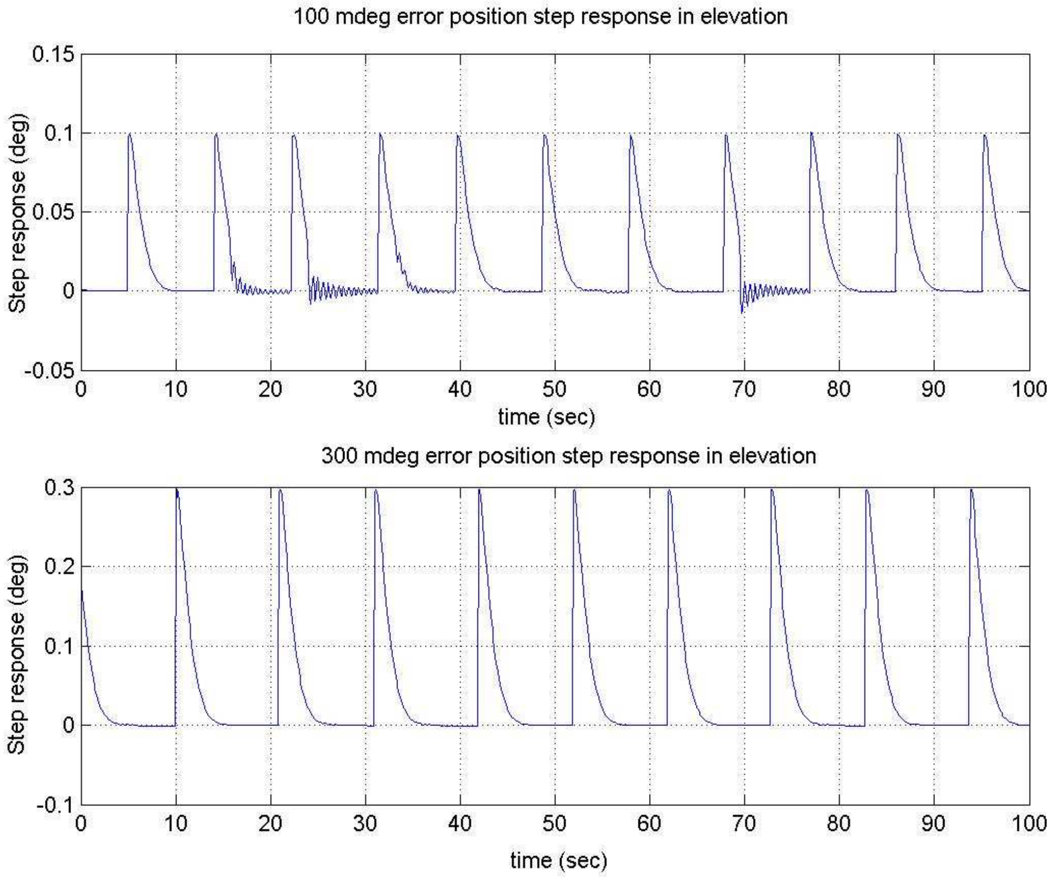

Fig 20. Position error for a 0.1 and 0.3 deg elev. step in POS TRACK MODE

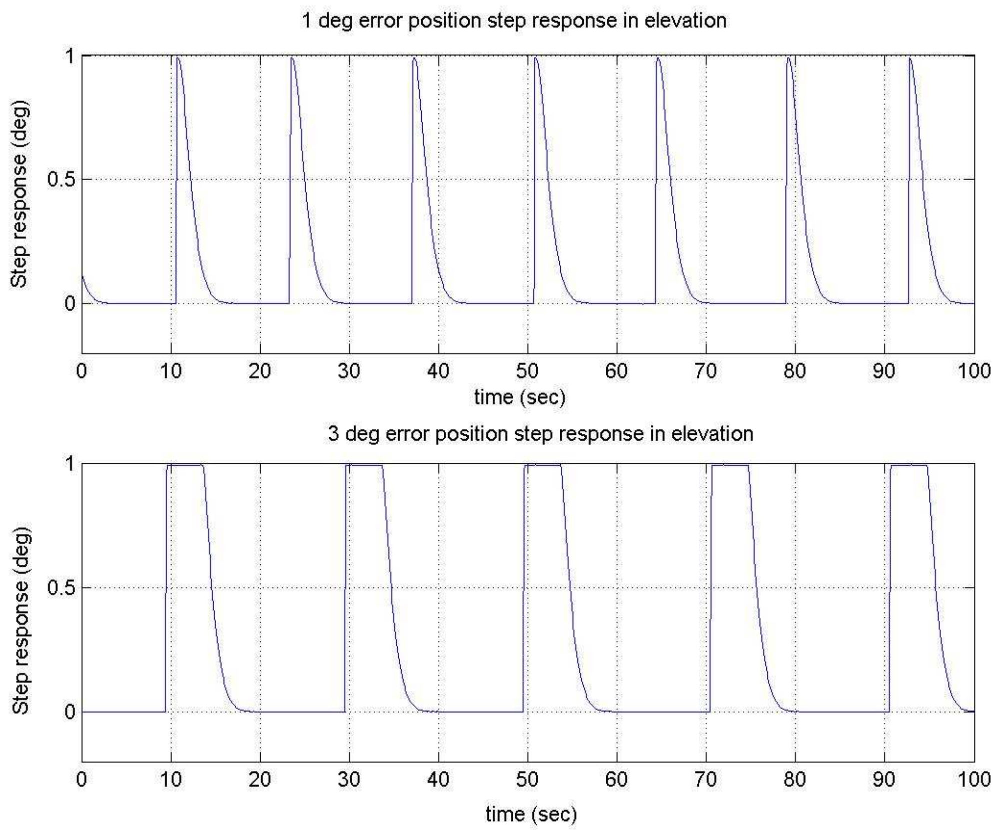

Fig 21. Position error for a 1 and 3 deg azimuth step in POS TRACK MODE