A METHODOLOGY FOR MONITORING VERTICAL DYNAMIC SUBCENTIMETER DISPLACEMENTS WITH GPS

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OUTLINES

- INTRODUCTION
- METHODOLOGY
- FIELD EXPERIMENTS
- DATA PROCESSING
- DATA ANALYSIS
- CONSIDERATIONS

INTRODUCTION

THE REASONS

- **GPS growing utilization to monitor deformations of structures;**
- **There are few publications about GPS utilization to monitor deformation of structures in Brazil and**
- **The first good results obtained in field experiments.**

METHODOLOGY

- Based on the analysis of residuals from the double difference static processing;

- In the data processing, the antenna is assumed to be static - static processing.

METHODOLOGY

Static double difference data processing

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Calculation of the phase residuals at each epoch

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Vector combination :

- **receiver phase noise,**
- **atmosphere phase propagation noise,**
- **antenna phase center distribution and**
- **phase contribution from the rover antenna**

METHODOLOGY

The antenna presents an almost periodic movement

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It will reflected an almost periodic “phase noise”

The method is based on the fact that each one of the residual components can present a different time variation.

METHODOLOGY

- The phase noises from the receiver and from the atmosphere normally change fast;

- The multipath is usually a slow time dependent function;

- The double difference antenna phase center can be assumed to be a static contribution ;

METHODOLOGY

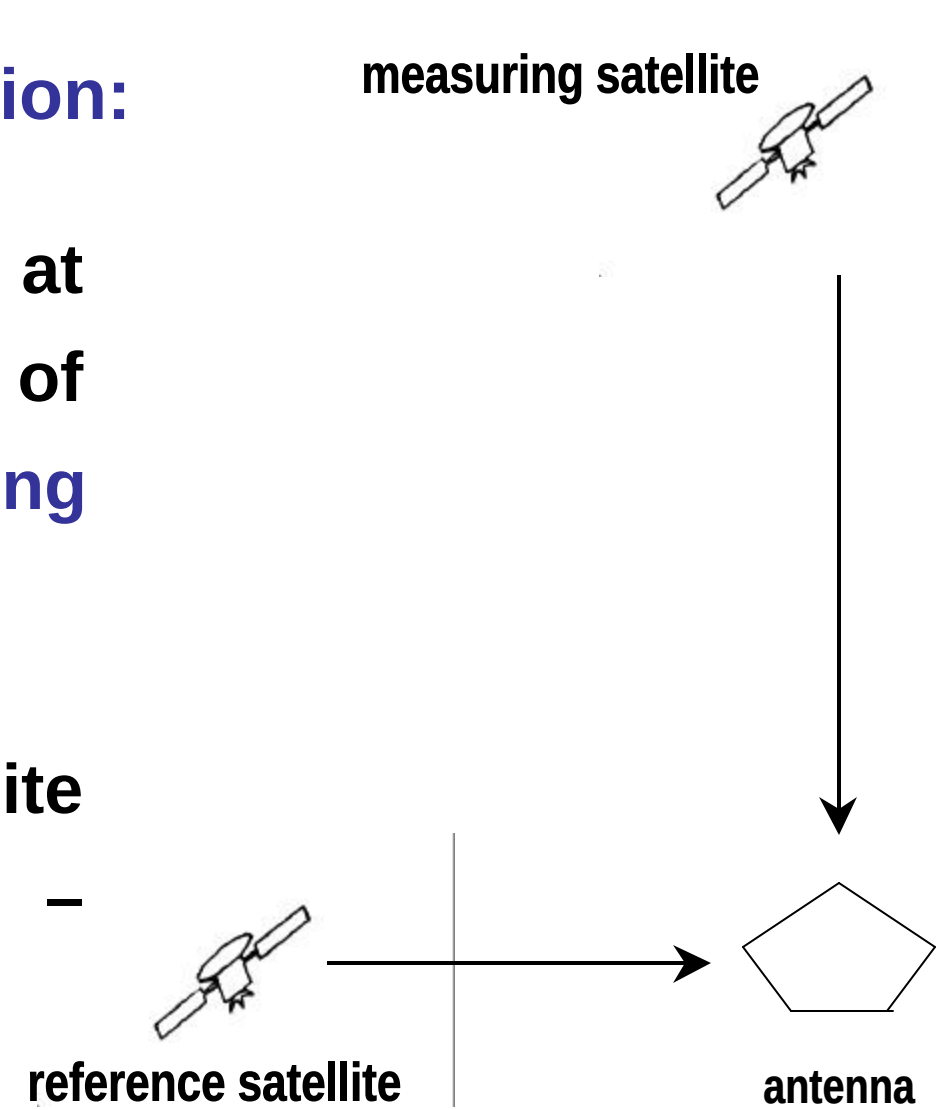
- The phase contribution from the rover antenna will depend on the natural frequency oscillation of the structure to be measured and

- The relative direction of both the reference and the measuring satellites.

METHODOLOGY

»During the observation:

- one satellite should be at least over 75 degrees of elevation - measuring satellite;
- at least one satellite close to the horizon – reference satellite.



METHODOLOGY

- The vertical movement will be another component of the phase residual.

- The higher the elevation of the measuring satellite, the lower the degradation of the displacement residuals.

sin(measuring satellite elevation angle) x amplitude residual = displacement

sin(angle) ~ 0,99...

METHODOLOGY

- Small antenna movement will not appear clearly in the raw residuals data.

- It is necessary to clean the residuals by

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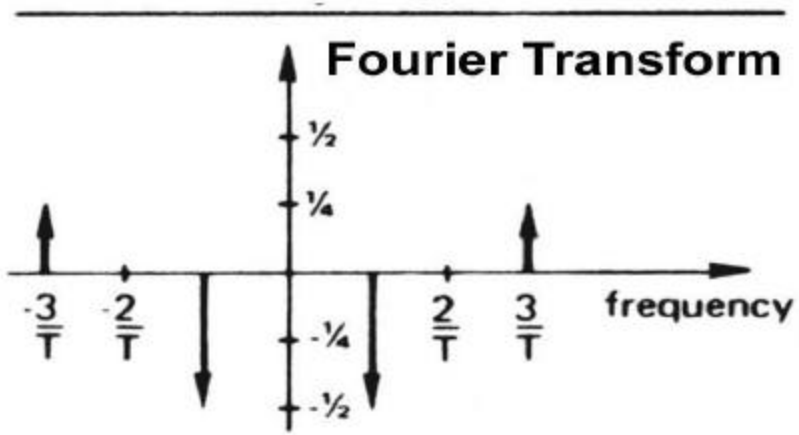
FFT band pass filtering

METHODOLOGY

Fourier transform

Construct a diagram which displays amplitude and frequency of each sinusoid



METHODOLOGY

»**Mathematically it is stated as:**

$$S(f) = \int_{-\infty}^{+\infty} s(t) e^{-j2\pi ft}\, dt$$

METHODOLOGY

- **The FFT is a computational algorithm which reduces the computing time.**

- **The application of a FFT band pass filtering on the residual domain frequency, makes it possible to:**

  - **remove all high frequencies arising from undesired noise and**
  - **cut most of the frequencies that arise from multipath.**

METHODOLOGY

»It is necessary to reconstruct the waveform

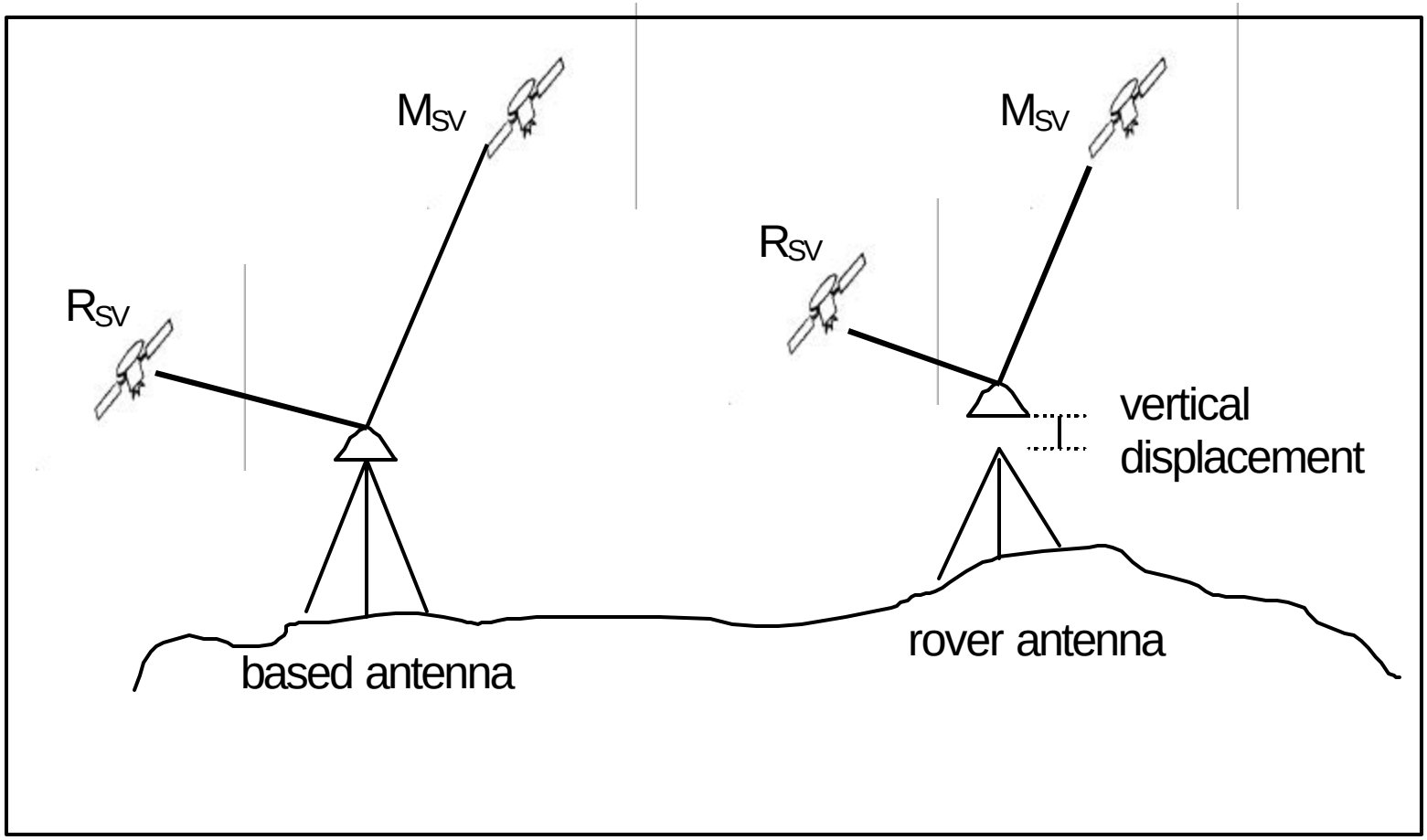
↓

Inverse Fast Fourier transform

»Finally, it is possible to see quite clearly the vertical displacements of a GPS antenna in the phase residuals.

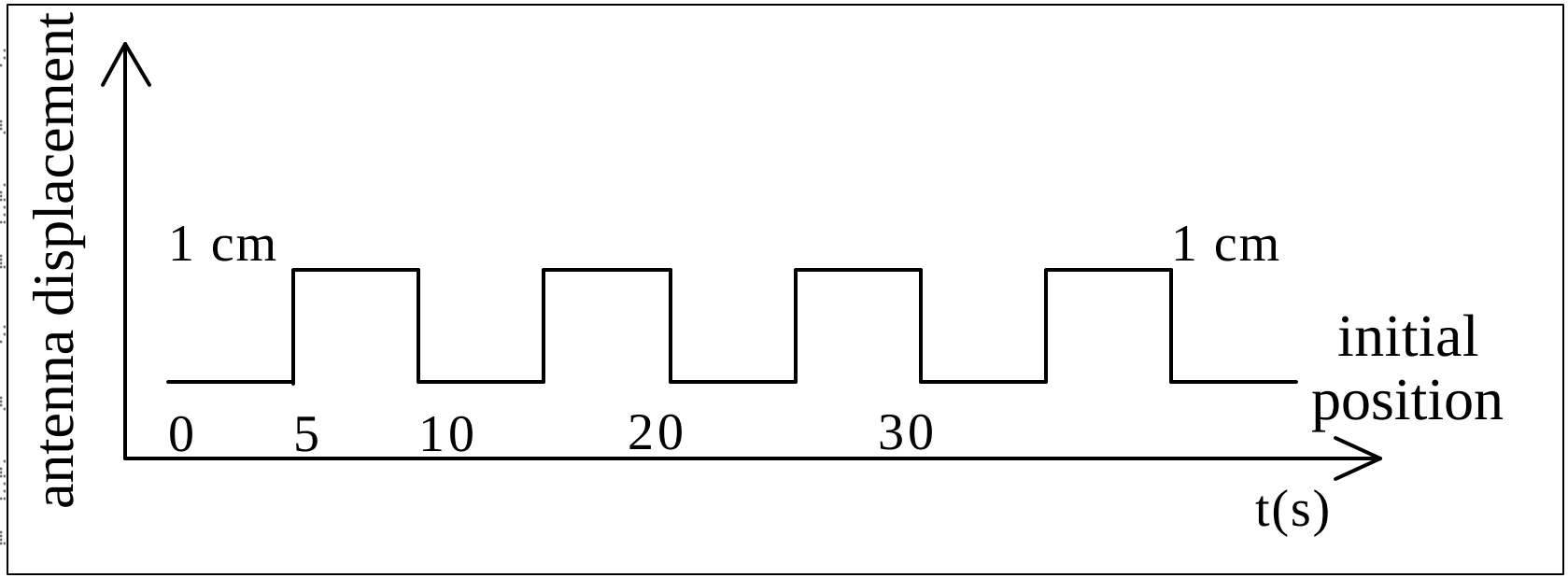
FIELD EXPERIMENTS

- Pair of Leica SR 9400 with highest rate of 1 Hz.
- Manual movements with the antenna.



FIELD EXPERIMENTS

»**The displacement made with the rover antenna:**



FIELD EXPERIMENTS

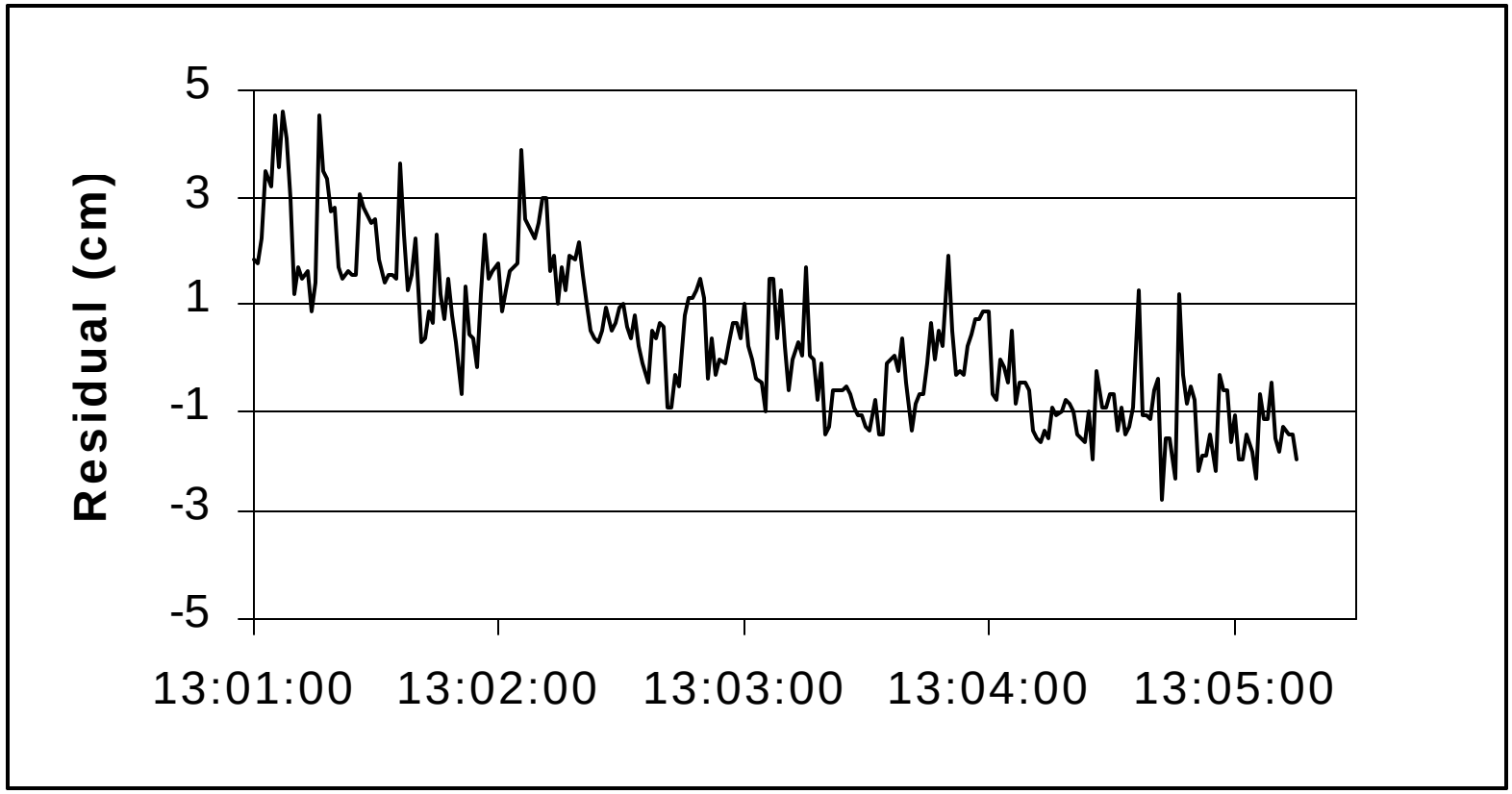
» During the observation there were:

- One satellite - measuring satellite - at 77 degrees of elevation and
- One satellite - reference satellite - at 11 degrees of elevation.

» sin(77°)=0.974 - residual of the displacement not very much degraded.

DATA PROCESSING

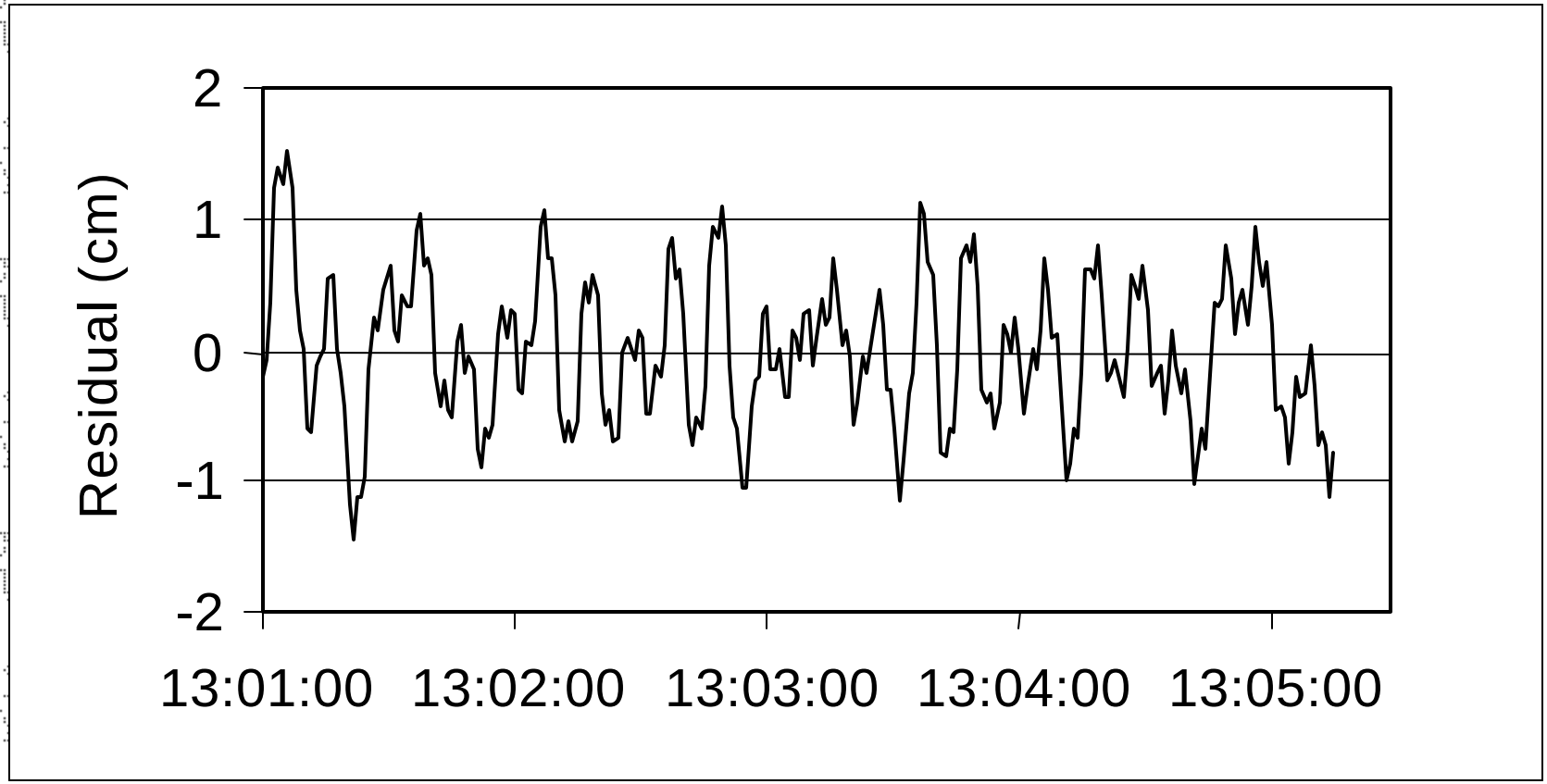
- **OMNI processing program**
  - **Permits to choose the reference satellite,**
  - **Generates ASCII file of the residual values.**



Raw phase residuals generated by OMNI

ANALYSIS OF DATA

- **MATHCAD program**
  - **FFT band pass filtering technique**
  - **Inverse FFT.**



Phase residuals after FFT filtering

CONSIDERATIONS

- This methodology is under development.
- The FFT band pass techniques and multipath perturbations are being studied.
- Development of an electro-mechanical device to control the rover antenna movement.
- Field experiments have been carried out with Leica SR 530 and Novatel Propak receivers.

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