First steps in gravitational deformation modelling of the VLBI Yebes radio telescopes

A. Prudencio(1), E. Azcue (2), J. López-Ramasco(3), S. Garcia-Espada (4) ,Y. Gómez-Espada (2), V. Puente (2) , M. Valdés (2)

anpruden@ucm.es / eazcue@fomento.es / javier.lopez@oan.es / susana.g.espada@azores.gov.pt / becario.yge@fomento.es / vpuente@fomento.es / mvaldes@fomento.es

(1) Complutense University of Madrid, Madrid, Spain
(2) National Geographic Institute of Spain, General Ibañez de Ibero 3, 28003, Madrid, Spain
(3) Astronomical Center of Yebes - National Geographic Institute of Spain, Cerro de la Palera s/n, 19141 Yebes, Guadalajara, Spain
(4) RAEGE Santa Maria - National Geographic Institute of Spain, Azores, Portugal

1. Introduction

Geodetic VLBI is one of the **most accurate** geodetic techniques for the study of the size and shape of the Earth, its rotation and time variations. This accuracy is achieved **taking into account all the error sources** involved in the process.

The effect of **gravity** in VLBI antennas is one of these errors that should be taken into account in the analysis of VLBI data. This effect can reach several millimeters and it has to be determined specifically for each radio telescope.

Figure 1. *IGE VLBI infrastructure in Yebes: 40 m antenna (left) and parabola of the 13m antenna (right).*

The **National Geographic Institute of Spain** (IGE) works to achieve the optimal operation in their stations. This includes the determination of this effect. In this poster the **first steps to the antenna gravitational deformation modelling** and the tools developed for the data processing are shown.

2. Goal

The aim of this work is to present the **first steps in gravitational deformation modelling of the Yebes radio telescopes.** At the end of 2018, the IGE acquired a Terrestial Laser Scanner (LS) that will be used to measure the gravitational deformation at different elevations of the IGE telescopes.

Before the campaign planning, a **preliminary study** of this effect has been made. The objective was to start **developing some tools** that could be useful to plan the campaign and to model the LS cloud in the future. **Four Matlab routines** were developed with the next objectives:

- To **study** and **analyse** the gravitational influences on large VLBI telescopes. **Simulation** of a LS measurements affected by structure's self weight and white noise.
- To **determine** the best fit paraboloid to the point cloud simulated and to **estimate** the deformation parameters (3 translations, 2 rotations and focal length variation).
- To **compare** the best fit paraboloid obtained with the original data.
- To **contrast** the gravitational deformations at different telescope elevations and to plot these differences**.**

3. Routines

3.1. Gravity Deformations Simulation

A **simulation** of deformations in a generic antenna was made by using **the Finite Element Method** (FEM). It was considered in the model that the deformation caused by the structure's self weight is proportional to the square of the height [1] and some boundary conditions were taking into account. This deformed dish together with white noise added **simulate the measurements of a LS** and it will be used in the next routines as a test point cloud. Several point cloud densities and sigma for the white noise can be selected.

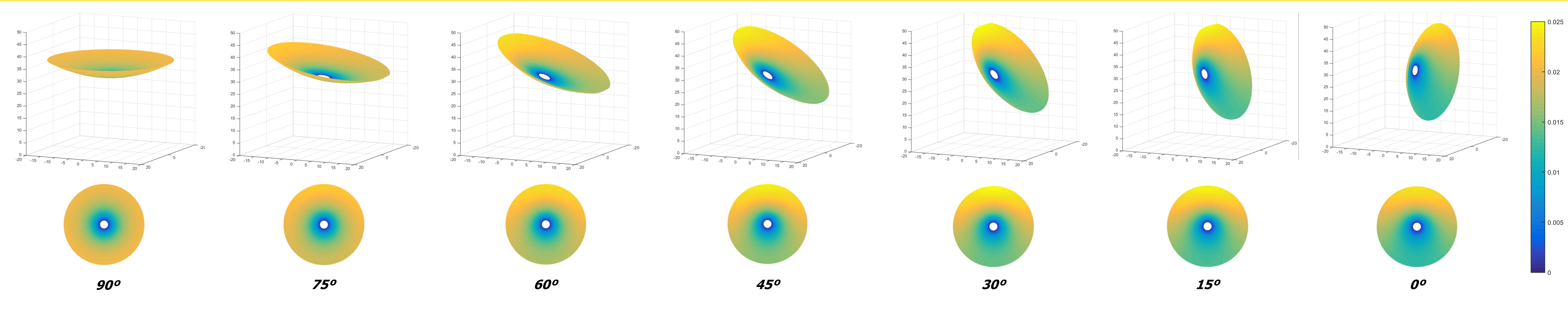

Figure 2*. Simulation of the gravitational deformation of the dish at different elevations in 3 and 2 dimensions (along the elevation axis). A 40 m antenna and 15m focal length was considered, similar to 40 m Yebes antenna. Deformations in meters.*

3.2. Best-Fit Paraboloid Estimation

In order to associate the model to a best-fit paraboloid, a Matlab function was written. A **least-squares adjustment** is computed to estimate six parameters: three translations to transform the origin of the model in the vertex of the paraboloid, two rotations to solve any misalignment between them and the focal length variation.[2]

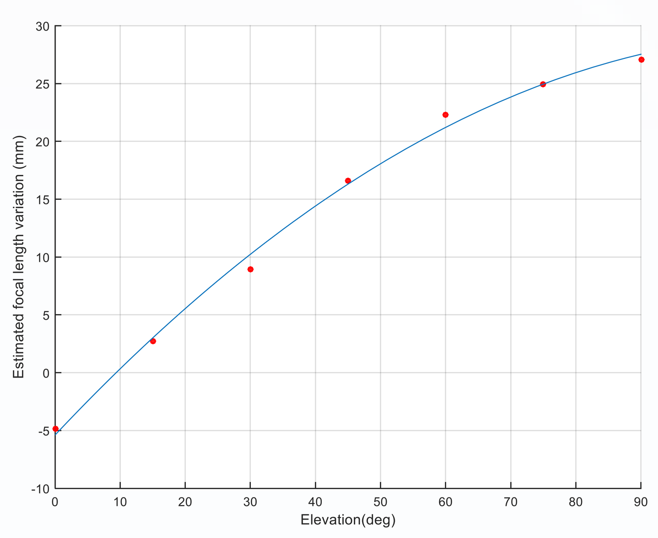

Figure 3. *Focal length variations estimated for the 40 m antenna simulated at different elevations. In red the estimated values, in blue the 2nd polynomial adjusted.*

3.3. Best-Fit Paraboloid Comparison

A Matlab function was programmed for doing a **comparison between the point cloud and the best fit paraboloid**. This function generates a plot output and some statistics of the adjustment

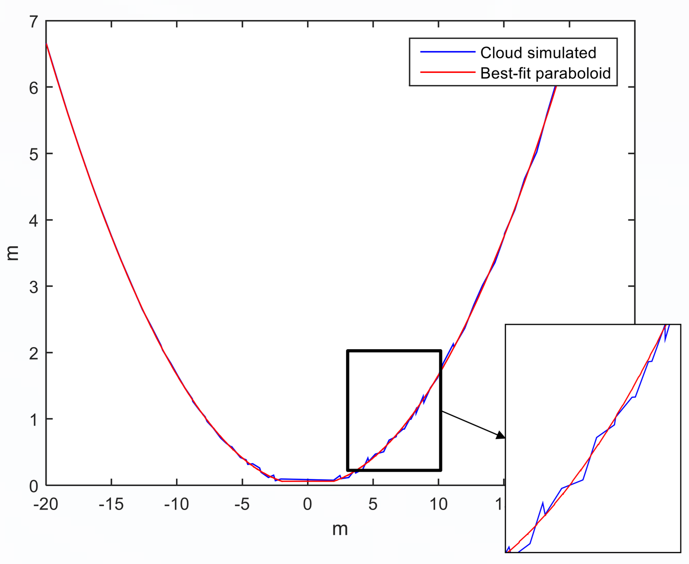

Figure 4. *Transect of the deformed model and the best-fit paraboloid along the elevation axis at 30 degrees elevation.*

3.4. Different Elevations Comparison

A Matlab function was programmed for studying the **relative deformations of the dish at different elevation angles**. An interpolation between clouds to a common grid is done for evaluating the differences in that points. Also a summary of the best-fit paraboloid parameters in each angle is done.

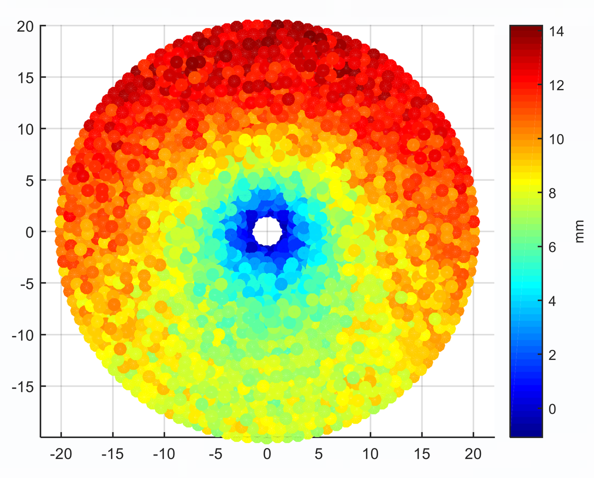

Figure 5. *Relative deformations of the dish between the model at 30º and the one at 90º.*

4. Conclusions and future plans

Comparing the model to different bibliography, these programs seems to work correctly. In the light of these results, it's expected to use these routines with the real data measurements of the scanner that will be used to determine gravitational influences on Yebes antennas. **Future plans**:

1. To **improve the simulation** function incorporating more information of the antenna's structure. Currently a very simple and generic model was used because its primary aim was only to simulate the measurements of the laser for developing the rest of the programs.

2. To plan and carry out the **survey** in the Yebes antennas with the laser scanner over the next months.

3. To **contrast these results** with the model obtained with the laser scanner data

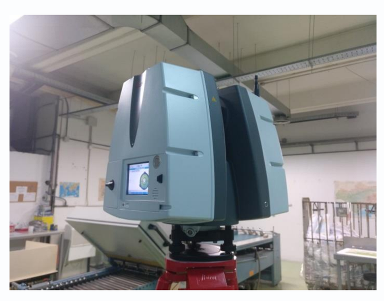

Figure 6. *LS that will be used for the survey of the Yebes Antennas*

5. References

[1] The Principles of Astronomical Telescope Design. Jingquan Cheng

[2] Laser Scanner and Terrestrial Surveying Applied to Gravitational Deformation Monitorin of Large VLBI Telescopes' Primary Reflector. P. Sarti, L. Vittuari, C. Abbondanza

[3] A complete VLBI delay model for deforming radio telescopes: the Effelsberg case. T. Arzt, A. Springer, A. Nothangel.

[4] Deformations in VLBI Antennas. T. A. Clark, P-Thomsen