Local Tie Works in Yebes

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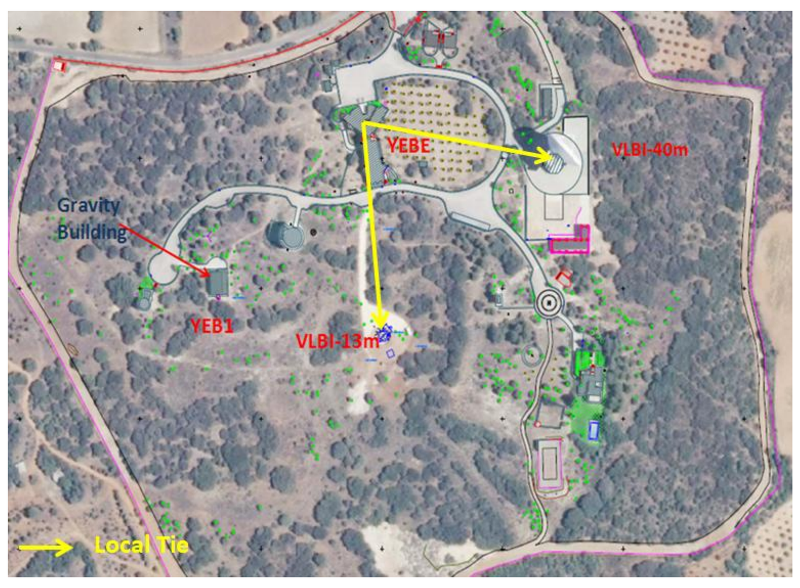
An important requirement to convert Yebes Station in to a Fundamental Geodesic Station is to relate the different techniques through Local Tie, consisting in ties that join the different techniques with accuracy below 1 mm. Yebes Observatory is provided with two VLBI antennas and two GNSS antennas. With the goal of relating all the techniques and getting the requirement accuracy is necessary calculate the Invariant Reference Point (IRP) of each technique and create a pillar network in the area of the Observatory.

YEBES OBSERVATORY

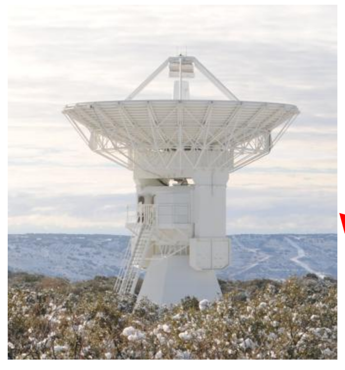
Yebes Observatory is located 70 kilometers far from Madrid, in the center of the Iberican Peninsula, a strategic place in the limit of the European Tectonic Plate.



In yellow Local Tie between YEBE - VLBI40 m and YEBE -VLBI13 m

Available Techniques in the Observatory

VLBI 13 m- ANTENNA (RAEGE)



GNSS ANTENNA (YEBE)
EUREF Permanent Network

VLBI 40 m- ANTENNA

Other involved instrumentation

YEB1- GNSS ANTENNA
Spanish Network ERGNSS

RAEGE 13M-RADIOTELESCOPE INVARIANT REFERENCE POINT DETERMINATION

The Invariant Reference Point (IRP) of a radio telescope is defined as the intersection between its azimuth and elevation axis if this intersection exists. Otherwise it is defined as the projection of the elevation axis on the azimuth axis. Usually this point is inaccessible or it is not materialized. There are several methodologies to calculate it. A big advantage of the new 13 meters RAEGE radio telescope in the Observatory is that measurements can be performed inside the cabin with a robotic total station, located on the central pillar of the radio telescope.

METHODOLOGY AND MEASUREMENTS

The antenna was moved around the elevation and azimuth axis with increments of 20°. In total 18 possible azimuts and 5 elevations moving the antenna for each counterweigth.

Measurements in the 13-meter RAEGE radio telescope of Yebes were performed inside the cabin with a robotic total station Leica TS50 with an angular and distance accuracy of 0.5" and 0.6 mm respectively, located on the central pillar of the radio telescope, on a tripod.

Corner cube reflector "RRR Hexagon" with a manufacturing precision of 0.0001 mm was attached magnetically to the inner sides of both antenna counterweights

ANALYSIS AND RESULTS:
Mixed Model Least Squares with constraints adjustment

Observations have been adjusted to circles in space, this is, the intersection of a sphere and a plane. Also, the center of the sphere must satisfy the plane equation. In this adjustment the parameters for each sphere (center and radio) and for each plane have been determined.

Sphere:

$$F(L,X) = (x_i - a)^2 + (y_i - b)^2 + (z_i - c)^2 - r^2$$

Plane:

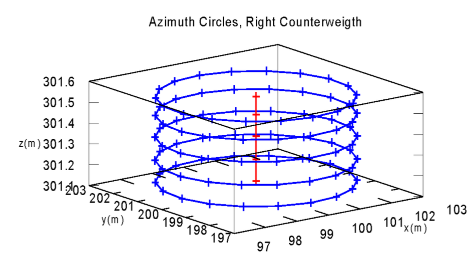
$$G(L,X) = A \cdot x_i + B \cdot y_i + C - z_i = 0$$

Constraints:

$$H(L,X) = A \cdot a + B \cdot b + C - c = 0$$

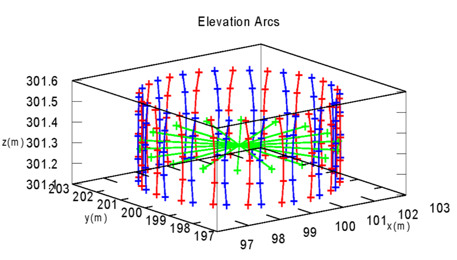
where *(a,b,c), r* are the center and the radio of the sphere and *A, B, C* are the plane parameters.

Azimuth axis
Observations to the targets on the rotation of the radio telescope around the azimuth axis for different elevation have been taken



A total of 5 circles for each Counterweight (10 in total) were adjusted. Each circle adjusted from 18 observed points. 52 parameters have been adjusted from 360 observation equations.

Elevation axis
Observations to the targets on the rotation of the radio telescope around the elevation axes for different azimuths have been taken. Centers from both circle arcs generate the elevation axes



A total of 18 circle arcs for each Counterweight (36 circle arcs in total) and 18 elevation axes have been adjusted.

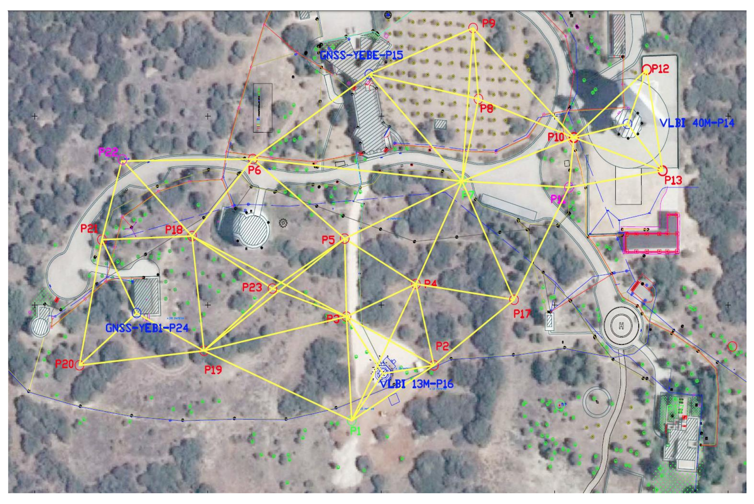
Radio telescope geometric parameters

	Value			Standard Deviation		
Invariant Reference Point (m) Coordinates	99.99774	199.99226	301.314795	0.00005	0.00005	0.000014
Eccentricity (m)	0.00013			0.00007		
Azimuth axis inclination from the vertical (")	8.3			0.3		
Non-orthogonality angle between azimuth and elevation axes (")	5.6			0.9		

FEASIBILITY AND DESIGN OF THE GEODETIC NETWORK OF PILLARS IN THE OBSERVATORY

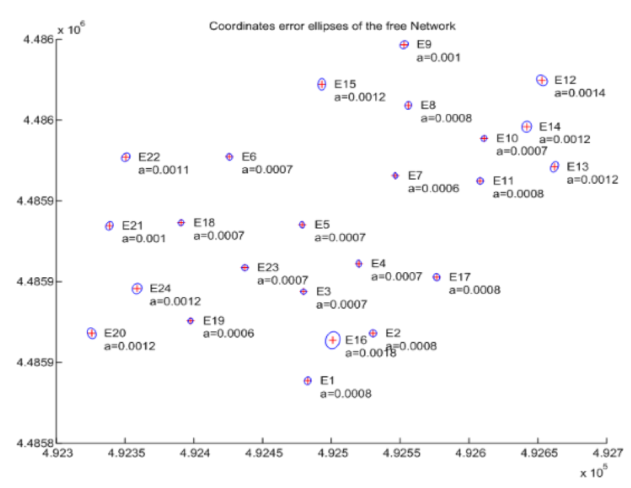
Studies to define the best network configuration of pillars has been done. (*)

FINAL DESIGNED NETWORK



This network allow to us to get the local tie with an accuracy below 1 mm. The complet network is composed by 24 vertex including on it the radiotelescopes and the GNSS antennas. Each radiotelescope or GNSS antennas is surrounded by visuals and there is a connection between all the techniques

FEASIBILITY OF THE NETWORK: METHODOLOGY



Distances and angles data with an error of 0.6 mm + 1 ppm and 2.5" respectively have been generated to simulate the network. Variation of coordinates adjustment has been used, taking into account distances and angle equations, and some internal constrains which has the property that the estimated solutions has a minimum variance

Local Tie	Accuracy (m)
VLBI13-GNSS (YEBE) (~159m)	0.0008
VLBI40-GNSS(YEBE) (~151m)	0.0007

(*) Acknowledgements to Wettzell Observatory for their good advices on the design of the network

BUILDING PILLARS

The network has been materialized with pillars which are made of concrete and iron and are compose by a 30 cm diameter cylinder inside a tube protector. In between there is a free space of 5 cm to isolate the interior. The height is 1.30 cm and at the top of the exterior tube has a metal lid to prevent the entry of water, and a drainage hole at the bottom of the pillar. The top of the interior pillar is made of stainless steel of 5 mm thickness. At the center there is a 5/8" standard screw for fixing total station or prism reflector tribrachs.

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