Establishment of a Network of Permanent GPS Stations and a Basic Geodetic Network in Algeria

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Abstract. – This article summarizes the IT equipment requirements (software and hardware) and technical methodologies for establishing a network of permanent GPS stations and a basic geodetic network for Algeria.

Résumé. – Cet article résume les besoins en équipements informatiques software et harware et les méthodologies techniques pour l'établissement d'un réseau de stations GPS permanentes ainsi qu'un réseau géodésique de base pour l'Algérie.

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To the memory of my Colleague and Friend
the Geodesist Abdelkader SELLAL (1946-2017)

1 Introduction

Establishing a permanent GPS network across Algerian territory is an extremely complex task that presents a real challenge. The objective assigned to the acquisition and installation of these permanent stations is to lead to the definition of a three-dimensional reference system in Algeria that complies with the standards of the $ITRF$ system and is well-defined with respect to $ITRF$. Such a system would then become a subset of the latest determination of the $ITRF$ system, which is $ITRF2000$.

The applications will be scientific for geodesy and geodynamics, technical for cartographic needs in Algeria, and practical for positioning and navigation.

To define such a three-dimensional reference system, the modern methodology is to build a network of known points with high precision following various GPS campaigns, including among these sites nodes of the Algerian leveling system to make the connection and combination between the basic network of GPS points and the general Algerian leveling system.

The positions of permanent GPS stations must be accurate to within $1\,cm$ at all times, while the densification points of the basic network defining the Algerian reference system must be known to within $5\,cm$ at a given date.

2 The Necessary Hardware

The first thing that is complex is the equipment: GPS receivers, telecommunications equipment and computer hardware. The typical installation diagram of a permanent station may in itself seem relatively simple, but it is not easy to use continuously and in real time.

For the equipment, Ashtech $Z - XIII$, Ashtech $Z - XII - 3$, or $\mu Z - 12$ receivers and an Ashtech Dorne Margoline antenna (700936 D_Mradom) will suffice. A standard microcomputer will be used to download the data from the receiver.

As a telecommunications system, an Internet connection will need to be installed to ensure file transfer using the FTP protocol, as well as a backup modem in case the first one installed fails. It is also necessary to ensure the security of the electricity supply by having a backup power unit and supplementing this with air conditioning in the room where the installation will be located.

The best place to install the antenna would be on a roof, even in a seismically active area. To monitor potential ground deformations around the building where the antenna mast will be installed, a micro-network of four points can be constructed around the building and monitored during specific observation periods.

The accompanying software is usually supplied with the hardware. It is best to install it on a second computer, which could be placed in the office, in a separate building from the station, with a suitable intranet connection. The operating system is most often Windows NT, 2000, or XP. GPS processing software options include Terrasat's GPS-Base or Thales-Ashtech's GBSS. Appropriate software also allows for managing the sending of data via the Internet.

Currently, to launch this project, there are only three[1] Ashtech $UZ - 12$ GPS receivers planned for installation at future permanent points in Algeria. This number of three is very low considering the size of Algerian territory. By comparison, a country as small as Germany has around one hundred permanent GPS stations, while in France, the RGP (Réseau Géodésique Permanent-Permanent Geodetic Network) has 43, many of which meet the criteria of the EUREF, IGS, and ITRF systems. In another country like Austria, twenty times smaller than

[1]This was the number of receivers available at the time of preparation of this manuscript.

Algeria, there are 28 permanent stations, eight of which belong to the EUREF network.

So, first question, what can we do with three permanent GPS points in Algeria? Three permanent GPS points on Algerian territory will allow for a complete qualitative work in order to properly control all successive stages of construction of a more extensive permanent geodetic network. In addition, by attaching about thirty other non-permanent points to these permanent stations, but by observing them for example over about two weeks, we will be able to define what we would call the Algerian Geodetic Reference Network.

Here is an example of a seismic monitoring network or a system for tracking deformations of the Earth's crust that could be applied to the northern part of Algeria:

- Reference network: 25 permanent GPS stations.
- Baseline network: 60 points observing periodically.
- Overall network covering the northern part of the territory: approximately $1,000$ GPS points.
- A computing center for archiving, processing, and analyzing data and results.

The first thing that is easy to control is collecting observations correctly and reliably. Therefore, the first objective assigned to the operation of these stations will be to disseminate data with daily frequencies initially, and then hourly frequencies.

3 The Computing Equipment

To ensure a significant technology transfer through the implementation of such permanent stations, it is necessary to move from the passive stage of simple data acquisition to the active stage of validation, analysis, and calculation of local area network observations. This means that our institute must also become an operational center for the analysis of data and local area network solutions.

A computing center or operational center is equipped with heavy computer hardware, two servers, one for the Intranet and the other for the Internet connection; data from the permanent stations first pass through this server; they are then sent to a Workstation for receiving, organizing and maintaining observations; another workstation will be used via the Intranet server to perform different combinations of hourly, daily and weekly calculations on the points of the permanent network and to make connections to points of international networks, EUREF, IGS, ITRF; one workstation will be reserved for the validation of data and results while two other Workstations will be devoted to the development part of the project.

As we can see, the investment will be both substantial and significant if we want this system to become immediately operational according to international standards; otherwise, it will not fulfill the functions for which we intend it. This is a true computing center for collecting, validating, and disseminating data from permanent stations over the internet, performing hourly, daily, and weekly calculations, and distributing the corresponding solutions online.

Hourly calculations using the ultra-fast, precise ephemerides of the IGS serve for initial data control and validation and for near real-time applications.

Calculations based on a day of observations using rapid ephemerides from the IGS can be used to measure and calibrate local networks and to calculate more precise atmospheric parameters.

Finally, weekly calculations, using the final accurate ephemerides of the IGS and updated Earth rotation parameters, are used for the determination of basic geodetic networks.

To detect gross errors in data or solutions, calculations or solutions can be combined over a week of observations.

Combinations of observations spread over several years at the same points allow us to determine the positions of these points to within 5 mm in a chosen reference frame. These same multi-year combinations will also allow us to integrate some of the points we have observed into the EUREF, IGS, or ITRF systems.

These procedures will also allow for the construction and calculation of the basic Algerian geodetic network, composed of several thousand GPS points.

The above constitutes the minimum infrastructure for a network of permanent stations in Algeria, necessary for geodetic purposes.

There are several aspects that we cannot address immediately that stem directly from the existence of a permanent network and that relate to real-time or near-real-time applications, GPS navigation and DGPS.

4 Some Aspects of the Calculations of the Observations

The first link is an operational computing center, i.e., a server controlling a network of microcomputers, a component of a global network such as EUREF, IGS, CORS, etc., which communicates the requested data or results to a second link, another center known as a distribution center. This distribution center then distributes the information to the third link, consisting of users, via internet and/or mobile phone connections. This information can include standard RTCM corrections for DGPS, kinematic, navigation, or real-time applications; and raw GPS data in RINEX format.

There are currently 13 operational centers, mostly in Europe, each capable of handling up to 300 real-time data streams or transmissions, serving up to $1,500$ potential users. NASA and JPL operate what they call a global DGPS system based on the internet. Its main components are a central computing center, a network of GPS data receiving stations distributed around the globe (called NASA's Global Real-Time Network), and a space-based telecommunications relay. Users are on Earth, in the air, or in space, whether stationary or mobile. This system is freely accessible via the internet.

The European Space Agency also maintains its own network of stations and real-time product distribution. The IGS delivers precise, ultra-fast (hourly frequency) and rapid (daily frequency) ephemerides with its weekly finished products, data, ephemerides, and Earth rotation parameters. The entire IGS network is intended to become a real-time product distribution network. A similar system for real-time product dissemination and transmission is also being introduced in the form of tests within the EUREF project.

A first task and concern would be to control access to the products of these different networks by means of the computer and telecommunications structures described above and which will therefore exist in our country once we have completed the installation of our permanent stations.

In fact, to overcome all the qualitative issues caused by these real-time systems, all you need is a high-performance workstation connected to these networks via a good internet connection. If we can master the full use of all the products already deployed on the internet by the various global and regional centers and networks—IGS, EUREF, BKG, IGN, and others—then we will be better equipped to build and manage our own system.

To achieve this, we first need minimal facilities: a few workstations with a good internet connection while we wait for the more substantial infrastructure described earlier, which is necessary for our own system. We will then seek to build our own system for distributing and disseminating real-time data and results, having previously gained practical experience in implementing such a system by learning how to use existing global or regional systems.

Some GPS service providers are easier to access than others. For example, UCAR's Local Data Manager and SOPAC's GSAC (GPS Seamless Archive).

Another example of a network providing real-time data is the GEONET network, which covers all of Japan and has been enhanced with real-time broadcasting capabilities. The number of stationed points has increased from 947 to 1200. The antennas are of the Choke Ring brand. The receivers have a data rate of 1 Hz and are capable of providing real-time data. Observations are also made at a frequency of 1 Hz with a mask angle of 50. Data transfer via the internet uses IP-VPN (Virtual Private Network) protocols, which secures and personalizes the connection. A complete analysis of the entire network is provided every three hours. It is possible to measure networks of up to fifty stations in real-time kinematics.

Classical calculations are of three types and are performed using the Bernese software:

- Ultra-fast: observation duration: 6 hours. Calculation frequency: 3 hours. IGS IGU (ultra-fast) ephemeris. This is near real-time.
- Rapid: observation duration: 24 hours. Calculation frequency: daily. IGS IGR (rapid) ephemeris.
- Final: observation duration: one day. Calculation frequency: weekly. Final IGS ephemeris. The calculation can be repeated throughout a week.

Urgent calculations are performed for a set of no more than 50 sites. Such calculations are conducted when it is necessary to detect overall displacements on the order of $5\,cm$ in less than 5 minutes. The software used is RTNET from GPS Solutions. The calculations are performed in real time and then asynchronously using the IGU (ultra-fast) products from IGS.

Operational ephemerides are used when it is not possible to download the ultra-fast, precise ephemerides in a timely manner. This type of calculation is particularly performed during large-scale earthquakes.

The minimum hardware to be acquired initially to prepare this project will consist of a workstation with ample disk space and memory.

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