# Experimental Tests with GPS RTK in The realisation of a Project of Allotment (Platted Properties)

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**Key words**: allotments, Global Positioning System RTK, total station, survey, establishment, precision, cost.

## SUMMARY

In Morocco, up to now, only conventional topographic instruments have been used in projects of allotments (platted properties). Such instruments present some limitations like the problem of inter-visibility and their dependence upon weather conditions.

Since RTK techniques are best suited for topographic surveys, because of short occupation time required for each point, private surveying societies are interested to know the advantages of applying Global Positioning System (GPS RTK) in a project of allotment.

The present article presents experimental tests with GPS RTK in a project of allotment, which includes both establishment works and survey operations as well. The main purpose of this study is to test and evaluate the efficiency of the GPS RTK in the realisation of field operations of a project of allotment and compare its performances to the conventional method using total station.

The achieved results from the experimental case studies carried out show that:

- The integration of the GPS RTK in field operations of an allotment project is well suited when the terrain doesn't present obstructions.
- The GPS RTK is faster than the total station concerning the establishment operations.
- The establishment and the survey by total station are less expensive and more precise than GPS RTK. But at the same time, the precision of the GPS RTK in the establishment operations respects the Moroccan cadastral tolerances.
- The GPS RTK and the total station can be used in a complementary fashion.

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## 1. INTRODUCTION

Global Positioning System (GPS) technique knows more and more developments and great expansion especially in the fields of geodesy, cartography photogrammetry and topography. Nowadays, the fields of application of GPS are very diversified.

Within the department of geodesy and topography of the IAV HASSAN II, the Real Time Kinematic GPS (GPS RTK) was tested in land consolidation projects and in cadastral surveys as well. But in urban allotment projects this technique is not practiced yet.

In general, projects of allotment (platted properties) are carried out in the urban environment, which is characterized by the existence of buildings, non-homogeneity of the reference frames, and the required precision is higher in urban area compared to the rural one. Any project of allotment is composed of several stages among which the urban design of the allotment, the establishment of the project and the boundary stones' survey.

In Morocco, up to now, only conventional topographic instruments have been used in projects of allotments. Such instruments present some limitations like the problem of inter-visibility and their dependence upon weather conditions. Since RTK techniques are best suited for topographic surveys, because of short occupation time required for each point, private surveying societies are interested to know the advantages of applying GPS RTK in a project of allotment.

The present article presents experimental tests with GPS RTK in a project of allotment, which includes both establishment works and survey operations as well. The main purpose of these tests is to evaluate the efficiency of the GPS RTK in the realisation of field operations in this kind of project and compare its performance to the conventional method using total station.

To reach this objective, the following methodology is adopted:

- Conceive a methodology for the experimental tests.
- Carry out several experimental tests using the GPS RTK and total station for the establishment and survey operations of an allotment project.
- Accomplish a comparative study between the GPS RTK and the total station concerning precision, cost and time of execution.

## 2. THE REAL TIME KINEMATIC GPS

Compared to the conventional methods, the Global Positioning System has several qualities. In fact, this system is independent of weather conditions, the observations can be carried out day and night, and it exceeds the problem of inter-visibility (Dupraz, 1997). GPS method can be used in differential mode or in real time kinematic mode. Using GPS in differential mode, results are available only after the combination of all receivers' data processing with suitable software.

The advantage of using GPS in real time kinematic mode is that, data collected by the base receiver (the reference station) are immediately transmitted to the rover receiver by means of a radio link from the base receiver to the rover. Therefore, data of the two receivers are combined and treated by integrated software in the mobile receiver. Consequently, the user posses the results immediately after data collection and processing in the field.

## 3. EXPERIMENTAL TESTS

All the experimental tests were conducted in a zone located within the city of Berrechid at about 35 Km from the city of Casablanca. The area of this zone is about one hectare. It is limited North, South and West by constructed allotments.

### 3.1 Methodology

For a suitable evaluation of the performances of the RTK GPS in an allotment project, it would be useful to make the establishment and survey by the conventional method using a total station and realize the same operations using the GPS RTK. Such a procedure will permit us to perform a comparison (precision, time and cost) between the two methods in order to evaluate the efficiency of the GPS in this kind of project.

The methodology adopted in this experimental study is composed of the following steps:

- Establishment and survey of allotment's boundary stones using total station
- Establishment and survey of allotment's boundary stones using GPS RTK with site calibration
- Establishment and survey of allotment's boundary stones using GPS RTK without site calibration
- Control and compare distances between established boundary stones for different tests
- Perform analysis on precision, cost and time of execution

### 3.2 Equipment

The equipment used during this experimental study is composed of:

- Two receivers of the type TRIMBLE 4600 LS, 12 channels with single frequency, designed to carry out GPS measurements in static, fast static and Kinematic modes. The horizontal accuracy of this system in Stop and Go Kinematic mode (for distances less or equal to 10 Km) is ± 1 cm + 1 ppm (Trimble, 1997)
- Two electronic notebooks type TSC1

- Two radio operator modems of type TRIMTALK 450S with their antennas allowing data transmission from the reference station to the rover station
- Trimble Geomatics Office software for post-treatment, version 1999
- Total station type SOKKIA SET 3C: that has the following accuracies (Sokkia, not dated): ± 3 mm + 3 ppm for distances and ± 10 mgon for the directions.
- Field survey accessories

### 3.3 First Experimental Test: Establishment and Survey Using Total Station

Using a total station we proceed to the establishment of thirty boundary stones that compose a bloc of eighteen lots of an allotment project. The boundary stones are materialized by iron piquets painted in red to differentiate them from those piquets that will be established by GPS method.

Control of the establishment: In any allotment project, the establishment is checked by comparing known distances (computed from the project study) between measured boundary stones and distances between established boundary stones. According to the Moroccan cadastral standards, the differences between known and measured distances should not exceed 6 cm, otherwise the boundaries stones should be reestablished.

After the establishment using a total station, we have measured the distances between the established boundary stones. The maximum difference found is 4 cm which is lower than the allowed tolerance of 6 cm. These control results show that using a total station the boundary stones are established within the tolerance. Consequently, the boundary stones established by this method will be used as a reference to control the establishment by GPS RTK.

### 3.4 Second Experimental Test: Establishment and Survey Using GPS RTK with Site Calibration

Before going to the field, we used the Quick plane software for planing the GPS mission. Once data on the test site and the days of observations are introduced, we get suitable periods of observations and the graph of visible satellites and the PDOP.

#### 3.4.1 Technical Procedure using GPS RTK

The establishment using GPS RTK requires the use of an electronic notebook. In the office, we introduce the codes, the numbers and the coordinates of boundary stones to be established. In the field, the controller TSC1 guides the operator towards the position to be established by means of an interactive drawing, either by a distance azimuth separating the mobile stick from the searched position, or by X and Y displacements that are shown on the screen of the electronic notebook. Once the X and Y displacements are acceptable, we establish the boundary stone and proceed immediately to the its survey.

With GPS RTK three various styles of survey are possible. For the purpose of our tests, we chose the style of survey RTK with recording of the data in order to take advantage of its benefit. Note that the observations are carried out by respecting the following standards:

Number of satellites >= 4 ,
PDOP < 7 ,
survey mode: stop & go,
Line of base < 1 km
Time: 2 to 3 min
Interval: 5 seconds.

Site calibration : The calibration of the site was based on 4 points which are determined in two different fashions: first by a double determination from two known points, second by using GPS in fast static mode.

#### 3.4.2 Establishment and Control

After site calibration we proceed to the establishment and the survey of the boundary stones using GPS RTK. Consequently, we carried out control by measuring distances between established boundary stones. This control showed that a group of 7 distances between boundary stones are greater than the allowed tolerance of 6cm.

An additional check is used to identify the erroneous boundaries, it consists in measuring the horizontal distances between the boundary stones established by GPS with calibration and the boundary stones established by total station. These measurements show that all distances between established boundary stones are greater than 6 cm (that is the tolerance applied by the cadastre). In an attempt to explain these inconsistencies, we realized another experimental test that is the establishment without site calibration.

### 3.5 Third Experimental Test: Establishment Using GPS RTK Without Site Calibration

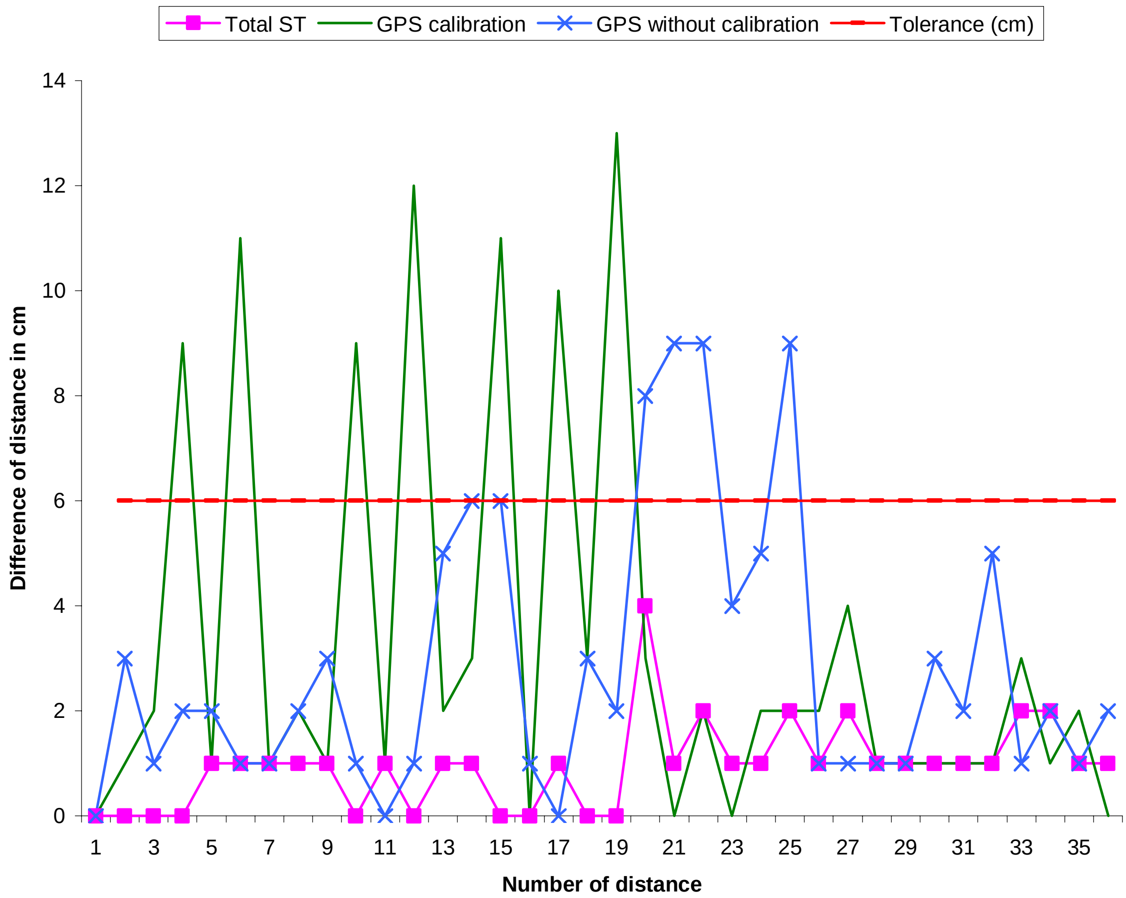
The establishment without site calibration consists in specifying uniquely the parameters of the projection system. Next, we proceeded to the control by checking the distances between boundary stones and also by measuring the difference in position between the boundary stones established using total station and those established using GPS.

These results show that, except four boundary stones among 30, all the other boundary stones were established within the allowed tolerance.

Figure 1 presents results of the control for the established boundary stones using three methods, namely:

- establishment by total station
- establishment by GPS RTK with site calibration
- establishment by GPS RTK without site calibration

Figure 1 : comparison of differences of distances between established boundary stones




Each curve represents the variation of the differences between established boundary stones and known positions of boundary stones. From this figure we can notice that in several points the curve representing the differences using GPS with calibration is above the tolerance (red horizontal line). On the other hand, the curve representing the differences using a total station is always under the tolerance line. However, the curve representing results of GPS without calibration is situated between the two others, but it is inferior to the tolerance except in four points.

## 3.6 Interpretation of Results

### 3.6.1 Interpretation of the Establishment and Survey Results

After the realization of the establishment by total station, we proceed to the control of the distances between boundary stones. All the distances between boundary stones were established within the cadastral tolerance. Thus, we decide to use the total station establishment measurements as a means for checking the establishment by GPS in RTK.

Concerning the establishment using GPS without calibration of the site, the control of the establishment shows that 26 boundary stones among 30 were established within the cadastral tolerance (6 cms). For four boundary stones, the control by total station, shows that these points are out of the tolerance. These conflicts can be explained by three facts:

- The multipath phenomenon
- Changing the reference station: during the experimentation, we were obliged to change the reference station three times, because it was destroyed, the influence of this change generates a light variation on the coordinates (± 2 cm).
- Interruption of the radio link between the reference station and the rover station.

### 3.6.2 Analysis of Precision

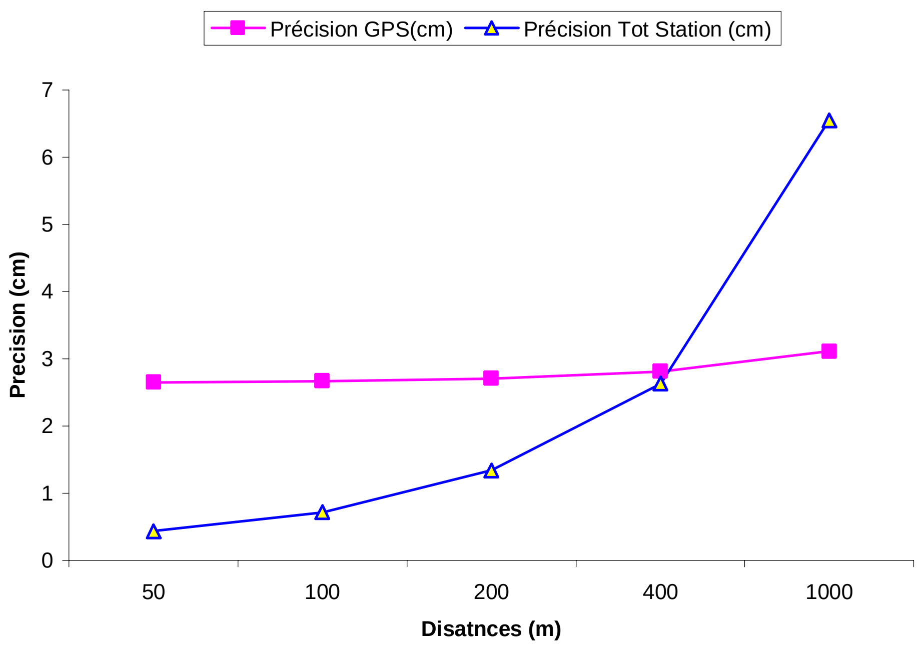
This analysis consists in calculating the horizontal precision of the determination of coordinates position by two processes, namely: the GPS RTK mode and the total station.

Applying the law of propagation of errors to the following mathematical model (coordinates position):

$$Xm = Xr + Dh * \sin(Az)$$
$$Ym = Yr + Dh * \cos(Az)$$

Where Az stands for bearing, Xr, Yr for coordinates of the reference station, and Dh is the horizontal distance.

**Figure 2 : Variation of precision as function of distances**



Application for GPS **:**
Given that the TRIMBLE 4600 LS accuracy on the azimut is (Trimble web site):

$$\sigma_{Az} = \pm 1' + 5 / (\text{ligne de base en Km})$$

and on the distance is (Trimble web site):

$$\sigma_{Dh} = \pm 1 \text{ cm} + 1 \text{ ppm} ( \leq 10 \text{ Km}).$$

Application for Sokkia total station :
SOKKIA SET3C total station specifies its accuracy on the azimut as:

$$\sigma_{Az} = \pm 15 \text{ dmg (SOKKIA):}$$

For distances varying from 50 m to 1000 m, we can calculate the horizontal position precision as follows (figure 2):

$$\sigma = \sqrt{\sigma^2_{XM} + \sigma^2_{YM}}$$

The results from figure 2 show that the horizontal position precision of this total station is better than that of the system GPS (in Kinematic mode for l distances less than 1 km). But as soon as the distance becomes greater, the horizontal position precision of the total station decreases.

### 3.6.3 Economic Analysis

The analysis of the economic consequences is a very difficult task, it requires the choice of an analytical method according to the particularities of each project and the evaluation of a number of economic factors.

In this study our approach for the economic analysis consists in comparing cost and time execution based on the experimental tests. Additionally, in the framework of this study, we evaluate cost and time only for the establishment and survey operations.

The Basis of estimation : In this approach, we take into account the following considerations (Ardaoui and Ouissoune, 2002):

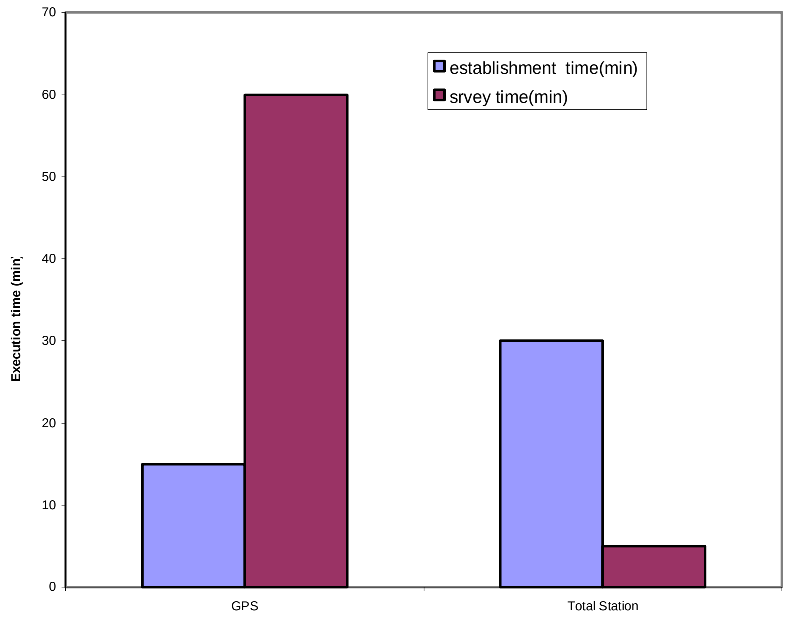
- The price of rent is the basic price to estimate the cost of using equipment
- Respect the cadastral standards used in survey stop and go mode (2 to 3 min of observations by station)
- Execution time is estimated based on our experimental tests
- Staff expenses are deducted from the monthly salary

Estimation of time execution are made on the basis of one working day of 6 hours, while the estimation of cost is based on one unit (equivalent to one Dirham, the Moroccan currency.)

There is a significant difference of required time for the establishment and survey of one boundary stone between the two methods: the survey using GPS, respecting the cadastral standards, needs more time (2 to 3 min) than the total station (10 s). However, the establishment by GPS necessitates half time (30 sec) that required by total station (60 sec).

According to these estimations, we can deduce that the necessary execution time for the establishment of 30 boundary stones using GPS is 15 min, while the total station requires 30 min for the same operation. Nevertheless, the survey of 30 boundary stones with GPS will necessitate 60 min, while the total station will require only 5 minutes. These results are shown on figure 3.

**Figure 3 : Comparison of execution time**




The Sokkia Set3C total station will allow the establishment and survey of 309 boundary stones during a period of 6 hours work. But, using the GPS we will only make the establishment and survey up to 144 boundary stones. This operation will cost 1275 units when using a total station and 3928 units when using the GPS. Consequently, we can consider that with a total station, the establishment and survey of a boundary stone will cost between 4,5 units and 9 units, while it will cost between 27,5 units and 38,5 units with a GPS.

## 3.7 Conclusion

The main purpose of the present study is to test and analyze the performances of the GPS RTK in a project of allotment. The analysis concerns essentially two main levels, the precision of establishment and survey, and the cost of field operations.

Initially, the interpretation of the results revealed the effect of the multi-ways phenomenon, the change of the station of reference and the existence of the interruption of the radio link to be the cause of the exceptional results on 4 boundary stones.

Then, the analysis of precision highlighted the weak change of the precision of the positions given by GPS RTK as far as we move away from the reference station. However, the precision of the total station remains better compared to that of the GPS RTK for short distances; but decreases for distances greater than 1 km.

Concerning the economical analysis, GPS RTK necessitates more time for both survey and establishment in the field compared to the total station, and the cost of operations during 6 hours work is very high.

Nevertheless, the GPS and the total station have each other qualities that can be more effective in a case without being powerful in another. Thus, we can say that the GPS and the total station can be used in a complementary fashion.

In the case of an allotment project, the survey and the establishments in a terrain free of obstructions, it would be preferable to use the GPS RTK technique. But for short distances (less than 1 km) and when obstructions exist, it would be preferable to use total station.

Finally, we recommend using GPS RTK in urban zones for work of allotments projects, only in the following cases :

- Terrain free from obstacles (trees, hedges, etc.) and high buildings
- Avoid the multipath phenomenon

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