# Modelling the Quality of GPS Planimetric Positioning

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**Keywords:** gps, quality, planimetric positioning, modelling, duration of observation

## SUMMARY

Compared to the conventional methods, GPS offers several advantages, mainly on the precision and costs. However, the planimetric positioning GPS quality remains influenced by several factors such as troposphere effects, duration of observation, satellites' constellation, baseline lengths and multipath effects.
This paper consists in studying and modelling the influence of two parameters on the quality of GPS positioning, these parameters are: duration of observation and baseline length.

Several experimental tests are conducted using short and medium baselines; observations are done with four different durations of observation. Data are collected using one and two frequency receivers as well.

The achieved results were used for modelling the variation of the quality of GPS positioning with respect to the duration of observation and the baseline length, for both one and two frequency receivers. The results of our experimental tests revealed that:

- For distances not exceeding 3 km, the change in the baseline length has meaningful effect on the positioning quality.
- The GPS positioning planimetric quality could be expressed as an exponential trend function of the duration of observation, the quality of position improves when the duration of observation increases.
- There exists a proportional relationship between the duration of observation and the length of the baseline.

# Modelling the Quality of GPS Planimetric Positioning

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## 1. INTRODUCTION

The Global Positioning System (GPS) has been conceived to respond to some specific military positioning needs, but it has brought a great revolution in geodesy mainly in the determination of geodetic reference frames.

GPS offers a three-dimensional positioning in a global reference frame, at any time, regardless of the meteorological conditions and over the globe. Compared to the conventional methods, GPS offers several advantages, concerning mainly the production, the cost, the precision and time saving.

However, the GPS planimetric quality of positioning by is influenced by systematic and random errors, so that the precision of positioning can reach the order of a centimetre or better depending on the type of equipment and the procedures used.

The GPS planimetric positioning quality remains influenced by several factors such as troposphere effects, duration of observation, satellites' constellation, baseline lengths and multipath effects.

The objective of this paper consists in studying and modelling the influence of two parameters on the quality of GPS positioning, these parameters are: the duration of observation and the baseline length.

Several experimental tests are conducted using short and long baselines; observations are done with four different durations of observation. Data are collected using one and two frequency receivers as well. Collected data and the results obtained are used to modelling the variation of the quality of positioning with respect to the duration of observation and the baseline length as well.

## 2. METHODOLOGY OF THE EXPERIMENTAL TESTS

The duration of observation and the number of observed satellites are two determining factors in GPS positioning. In general, more the number of satellites is greater, more the geometry is better, and more the required occupation time is shorter. According to (Hofman and al, 1996) in normal atmospheric conditions, with four to six satellites, surveys in static mode, a baseline of 1 km can be observed during 20 to 35 minutes, whereas for a baseline of 10 km, the time required varies from 35 to 60 min.

In order to assess the effect of the time of observation and the baseline length we conducted three sets of experimental tests with different variants. These experiments are summarized below.

In the first set of experiences, we used four **one-frequency** receivers, the baseline lengths vary from 400 m to 1500 m, the durations of observations were 10, 20 and 30 minutes.

In the second set of experiences, we used four **single-frequency** receivers. But, the baseline lengths vary from 3 km to 20 Km, the durations of observations were 10, 20, 30 and 40 minutes. The set of points are some geodetic network points.

In the third set of experiences, we used three **double-frequency** receivers. But, the baseline lengths vary from 3 km to 40 Km, the durations of observations were 10, 20, 30 and 40 minutes with four repetitions four each duration of observation. The points used in this case are another set of geodetic network points.

## 3. ANALYSIS OF RESULTS

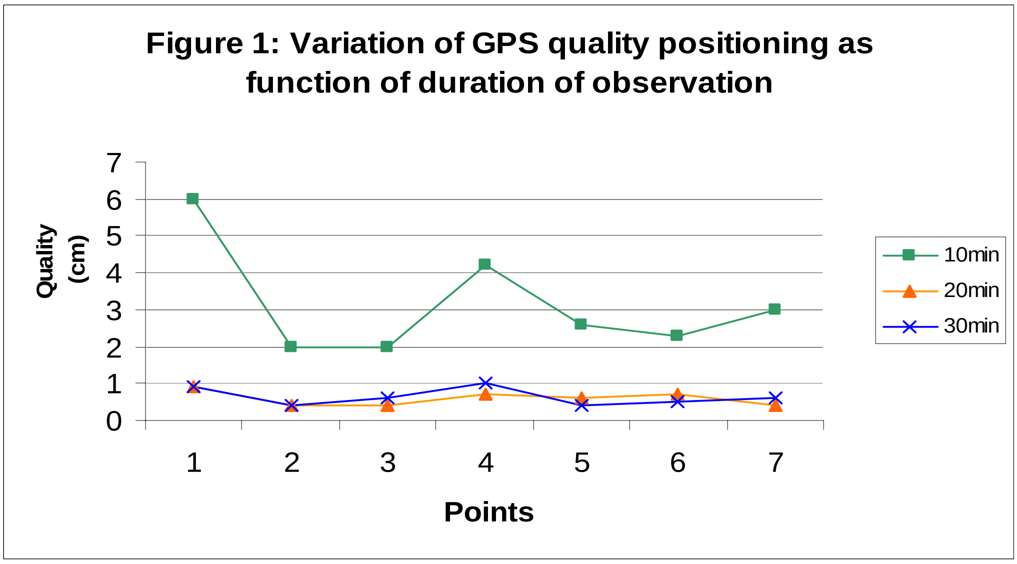
The post-treatment is done in fast static mode with an interval of registration of 10s and an elevation mask of 15°, the PDOP mask is 5. In the context of this study, the planimetric positioning quality (Qp) is expressed in terms of precision of x-y coordinates. It is calculated as the square root of the sum of the variances of the two coordinates as follow.

$$\mathbf{Qp = \sqrt{(\sigma_X^2 + \sigma_Y^2)}}$$

**Results of the first set of experiences**

The coordinates of points are computed by a least squares adjustment while fixing the Lambert coordinates of one point as an adjustment constraint. The obtained results show that the quality of positioning varies between 2 and 6 cm for 10 minutes of observation, but it’s less than one cm when the duration of observation varies between 20 and 30 minutes. Reasoning according to the duration of observation, we notice that the quality of positioning improves starting from 20 min of observation (figure 1).

On the other hand, changing the baseline length from 400 m to 1500 m does not have significant effect on the quality of positioning.




**Results of the second set of experiences**

The coordinates of observed points are computed by a least squares adjustment fixing the Lambert coordinates of one point taken as an adjustment constraint. In these experiments we can distinguish two separate cases:

- For short baselines between 3 and 5 Km, the quality of position varies from 2.9 cm and 6 cm when considering 10 minutes of observation. But it is improves and varies between only 5mm and 9 mm for 20 and 30 minutes of observation.
- For medium baselines between 5 and 20 Km, the quality of position varies from 3 mm to 7 mm for 10 and 20 minutes of observation. While it varies between 1 mm and 3 mm for 30 minutes of observation.

In this second set of experiments we can conclude that quality of position changes as function of the baseline length. For the class of baselines from 3 to 5km, this quality varies from 0.5 cm to 6 cm, but it is only between 0.1cm et 0.7 cm for the class of baselines 5km to 20km.

**Results of the third set of experiences**

The coordinates of points are computed by a least squares adjustment fixing the Lambert coordinates of one point taken as an adjustment constraint.
For all observed baselines using two-frequency receivers, and four repetitions for each duration of observation, the quality of positioning varies between 6 mm and 1.7 cm.

In this case for the same distance, the increase in time observation implies an improvement in the quality of position. For example, for baselines between 20 and 40 km, considering 10 min of observation, the quality of position varies from 1.1 cm to 1.7 cm. while it varies between 0.7cm and 0.8 cm for 40 min of observation

On the other hand, for the same duration of observation, any increase in the length of the baseline generates a slight deterioration of the position quality. For example, considering 40 min of observation, the quality of position varies between 0.1 cm and 0.2 cm for baselines between 3 and 5km, while it varies from 0.6cm to 0.8 cm for baselines between 5 and 20 km.

## 4. MODELLING

This part consists in modelling the variation of the quality of planimetric GPS positioning according to two parameters: the duration of occupation used and the length of the baseline.
All models are deducted based on the results obtained from the observations of the experimental tests. For each parameter we will distinguish between observations made using the single frequency receivers and those using the double frequency receivers

### 4.1 MODELLING THE QUALITY AS FUNCTION OF DURATION OF OBSERVATION

**Case 1: modelling using the single frequency receivers**

The former studies showed an exponential function of the precision of GPS with respect to the time of occupation (PSIMOULIS et al., 2004). In this respect, we adopted an exponential model in the following form:

$$\mathbf{q = a\ e^{-bT}}$$

Notation:

- **q** : quality of planimetric positioning (in m)
- **T** : duration of observation (in min)
- **a** : linear parameter to be determined (in m)
- **b** : parameter to be determined (in $min^{-1}$)
- **e :** the exponential function

Using the durations of observations and the quality of positioning obtained from the experimental tests; we have a sample data in the following table:

| *Duration of observation (min)* | *quality of position (cm)* |
|---|---|
| 10 | 1.5 |
| 20 | 0.5 |
| 30 | 0.6 |
| 40 | 0.1 |

The curve of tendency corresponding to the experimental data and results is given by the following formula:

With :

- **$q_{TF1}$** : quality of planimetric positioning with respect to time using one frequency receivers (in m)
- **T** : duration of observation (in min)
- **e :** the exponential function

Therefore, this model adapts well the results obtained before; it means that the quality of position improves as a function of the increase in the duration of observation.

**Case 2: modelling using the double frequency receivers**

Using the durations of observations and the quality of positioning obtained from the experimental tests using **two frequency receivers**; we have the following sample data:

| ***Duration of observation (min)*** | ***quality of position (cm)*** |
|---|---|
| 10 | 1.2 |
| 20 | 1.2 |
| 30 | 1.0 |
| 40 | 0.5 |

Hereafter, for the variation of the position quality with respect to the time of observation using **two frequency receivers**, the curve of tendency corresponding to our data is given by the following model:

$$\mathbf{q_{TF2} = 0.0205e^{-0.0347\,T}}$$

With:

- **$q_{TF2}$** : quality of planimetric positioning with respect to time using two frequency receivers expressed in meters
- **T** : duration of observation (in min)
- **e : the** exponential function

This model agrees well with the results obtained before; in other words, the quality of position improves when the duration of observation increases.

## 4.2 MODELING THE QUALITY OF POSITION AS FUNCTION OF THE BASELINE LENGTH

**Case 1: Modelling using the one frequency receivers**

The model expressing the variation of the quality of position as function of the baseline length is a linear model such as:

$$\mathbf{q' = a' + b'D}$$

Where:
- **q'** : standard deviation of the distance (en m).
- **D** : baseline length (in km).
- **a', b'** : parameters to be determined (**a'** in m and **b'** in ppm)

Observations are used to find the model corresponding to distances between 5 and 20km, which means that the deducted model is valid only for this range of distances. The tendency curve corresponding to our data is given by the following model:

$$q_{DF1} = 0.0002 + 3.10^{-5}\, D(km)$$

In this equation $q_{DF1}$ represents the standard deviation of the distance using single frequency receivers, expressed in meters, and D is the baseline length expressed in km.

**Case 2 : Modelling using the dual frequency receivers**

Note that all data used to fin the next model correspond to distances between 3 and 30km, which mean that the deducted model is valid only for this range of distances.
The model expressing the variation of the quality with respect to the baseline length using two frequency receivers is given by:

$$q_{DF2}\,(m) = 0.0013 + 2.10^{-4}\, D(km)$$

Where $q_{DF2}$ represents the standard deviation of the distance using two frequency receivers, expressed in meters, and D is the baseline length expressed in km.

## 5. CONCLUSION

In this research paper we conducted several experiments for assessing and modelling the impact of the variation of the quality of GPS planimetric positioning as a function of the duration of observation and the length of the baseline.

We conducted experimental tests using different variants such as: short and medium baselines; observations are done with four different durations of observation. Data are collected using single and double frequency receivers as well.

The achieved results were used for modelling the variation of the quality of GPS positioning with respect to the duration of observation and the baseline length, for both single and double frequency receivers. The results of our experimental tests revealed that:

- For distances not exceeding 3 km, the change in the baseline length has insignificant effect on the positioning quality. For baselines between 5 and 40 km, the factor baseline length has a very highly meaningful effect on the quality of position

- The GPS positioning planimetric quality could be expressed as an exponential trend function of the duration of observation, the quality of position improves when the duration of observation increases.
- There exists a proportional relationship between the duration of observation and the length of the baseline.

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## BIOGRAPHICAL NOTES

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