Efficient GPS Measuring Methods for Land Communication Routes

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Abstract: *The concept of geodetic control network was given new meaning by the introduction of GPS technology. Thus, the most difficult element - visibility between network points - disappeared. Certainly, GPS methodology does not solve geodetic problems. There are elements that affect data quality or even compromise measurements. The most important condition for obtaining good results is sky visibility at the points where GPS receivers are positioned. Thus, determinations can neither be made in forests or tree lines, nor in areas with very large structures etc. Also, the measurement duration must be estimated, in order to have a very good GDOP (Geometry Dilution of Precision). This parameter shows satellite geometry, which needs to be optimum. By analogy with classic topography, it is similar to having known coordinate points distributed properly in the four quadrants at the resection. Based on the positioning, on the type of receivers and on the positioning time, GPS measurements can be: static measurements, real-time measurements.*

Keywords: *geodetic control network, GPS technology, Land Communication Routes.*

1. The Static Method

This is the most used method for high precision geodetic networks. The static method requires a minimum of two GPS receivers placed on two points fixed on site. The two receivers acquire their signals from the same minimum of 4 satellites and have the same positioning time. The distance between the two receivers must be of minimum 2 meters. The maximum distance is related to the visibility of the four mutual satellites. The greater the distance, the longer the positioning time will be. Also, for achieving a better efficiency and better accuracies, there are an increased number of receivers, to which permanent stations can be added.

1.1. The Two Receiver Method

In principle, one of the receivers is set on a point, and the other receiver is positioned for a while on each of the other points. (Fig.1.1). For example, the fixed station (the one that remains on the point) is placed on the known coordinate point A, the other receiver is positioned on the new points E, F,G and H, then on alt least one old point B, C or D, in which case we have only one determination for the new points.

According to the laws in force, each new point needs to have at least four position vectors (determinations), for which we have two options:

- Also positioning a fixed receiver on the old points B, C and D, and determining the other new points. Thus, we will have four independent determinations for each new point, in which case the least squares method can be applied.
- Total station determinations between each two visible points, integrating distance and direction measurements with GPS measurements in a single processing model, using the least squares method.

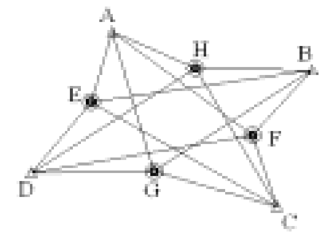

Fig. 1.1.a The two receiver method

It is not compulsory that the fixed station be positioned on a known coordinate point (Fig. 4.1.b). For example, it can be positioned on the new point H, in which case the mobile receiver is positioned on at least one old point and on all new points. If it was positioned on the old point A, the coordinates for point H are firstly determined. From point H coordinates, the other new point coordinates are also determined (for E, F and G). The procedure is then repeated, with positioning on either a new point, or an old point. At the end, each new point must have at least four determination vectors.

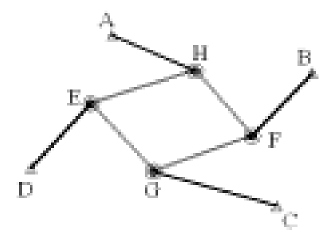

Fig. 1.1.b The two receiver method

1.2. The Three Receiver Method

In this case there are a number of options:

1. Positioning the fixed receiver on a known point, while the other two are moved onto the new points and for checking (Fig. 1.2);
2. Positioning two fixed receivers on two known coordinate points, while one of the receivers is mobile and moves onto each new point (Fig. 1.3);
3. Positioning the fixed receiver on either of the new points, while the other two are positioned on at least one known coordinate point and on all the new points (Fig. 1.4);
4. Positioning two fixed receivers on new points, the other receiver being positioned in series on all the new points and on at least one known coordinate point (Fig. 1.5);
5. Positioning two fixed receivers, one on a new point, the other on a known coordinate point, the third receiver being positioned in series on the other new points (Fig. 1.6);

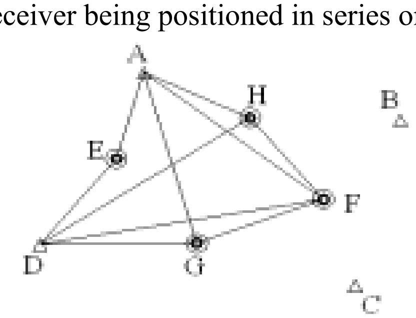

Fig. 1.2 The three receiver method

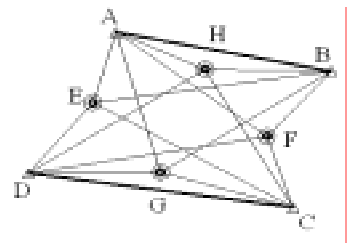

Fig. 1.3 The three receiver method

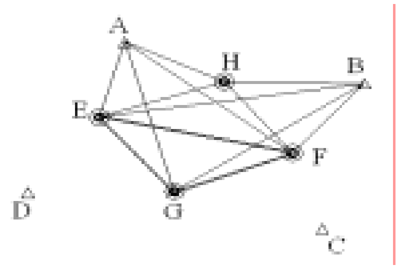

Fig. 1.4 The three receiver method

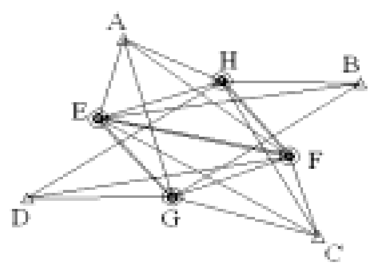

Fig. 1.5 The three receiver method

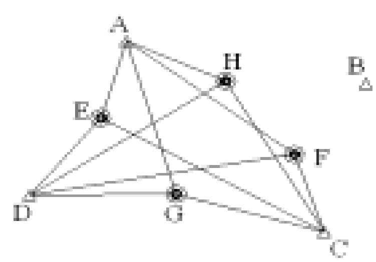

Fig. 1.6 The three receiver method

1.3. The Multiple Receiver Method

The more receivers, the greater the correctness and the accuracy of determining new points coordinates will be. In the case of 8 points, 4 known coordinate points and 4 new points, 8 receivers will determine a number of 28 vectors, the respective combinations of 8 points taken 2 at a time. All the possible combinations are thus measured.

Example of static measurements, "Arad – Timişoara" Motorway
Layout length: approx. 60 km

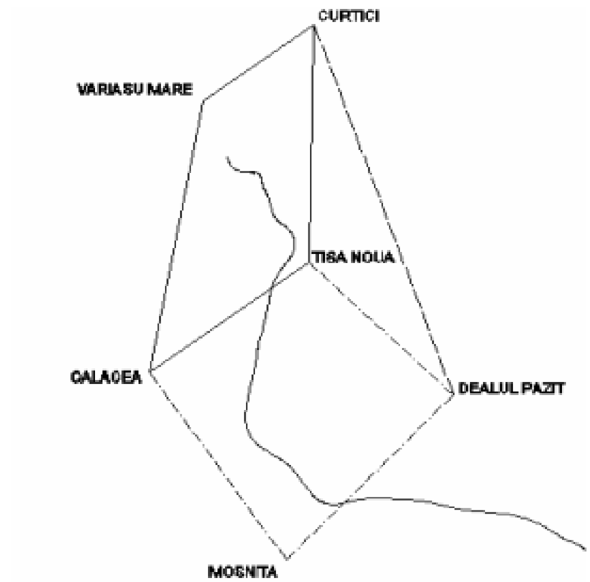

Fig. 1.7 Example of static measurements, "Arad – Timişoara" Motorway

Stages undergone

Site reconnaissance for benchmark placement

Before placing benchmarks on site, a thorough reconnaissance of the area was performed, regarding the A and B benchmarks placement.

Before placing the benchmarks, the following must be taken into account:

- the absence of magnetic fields and of reflecting surfaces, which affect the signal and cause the "multipath" phenomenon.
- there must be no obstacles at the positioning point, in order to make point observations.
- their placement at the border of cadastral parcels, in order to avoid their damaging by agricultural equipments.
- easy access to the benchmarks must be ensured.
- they are not to be placed near high-voltage power lines.

Benchmark Placement

17 type A benchmarks and 16 B type benchmarks were placed on the whole planned layout of about 60 km long.

The benchmarks were placed in protected areas, easily accessed by car, outside private property boundaries.

Planning of Measurements Regarding GPS positioning on benchmarks

In order to determine the new point coordinates, measurement sessions were planned for the positioning on the new points.

Positioning method

For the determination, 4 references were used on 4 fixed points, each measuring 4 vectors to each point.

8 GPS double frequency receivers were used, 4 fixed references and 4 mobile rovers.

During each measurement session, in order to have an elevation control, a receiver was positioned on a 1st class transit station, and benchmarks were planted close to the stations on which control geometrical leveling was performed.

2. Radio Wave RTK (real-time) Method

2.1. Principle

The principle of differential GPS system consists of observing pseudo-distances measurement errors by following every visible satellite from a reference point with an accurately known position in WGS 84 (World Geodetic System). Observing this errors allows the determination of the corrections, which are transmitted by radio, so that users (mobile stations) working in the area of interest around the reference station.

The most competitive radio transmitting systems for corrections nowadays allow for these corrections to be transmitted up to a distance of 40-50 km from the reference station. The distance can be extended by using mobile phone systems for transmitting the mentioned corrections via Internet. The deriving issue regards the fact that both the fixed station that transmits the corrections, and the mobile station need to acquire signals from a minimum of four satellites. Therefore, the distance between the two receivers cannot be greatly increased.

The main causes of GPS measurement errors are:

- Errors concerning time estimates for GPS data propagation;
- Errors related to information transmitted via satellite, regarding satellite clock and orbital data;
- Voluntary errors, caused by voluntary damaging of the GPS system;

All these errors are correlated for the entire area of interest and they are correlated by this radio data transmittal differential system.

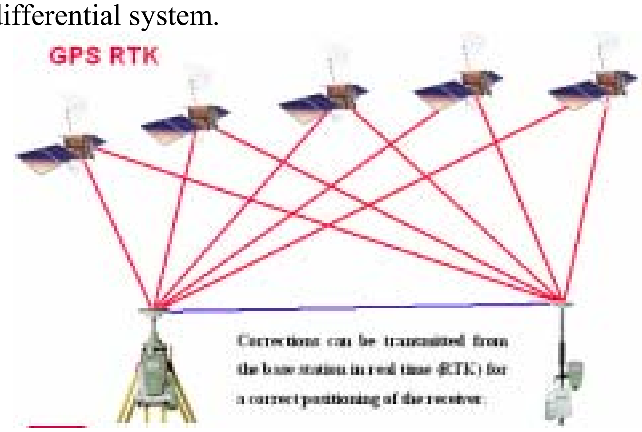

Fig. 2.a Data transmittal via radio waves

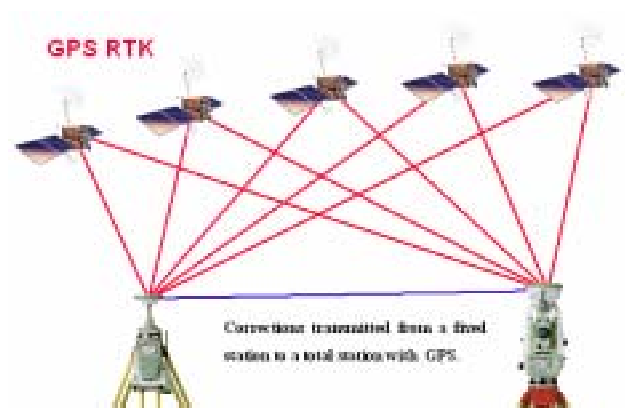

Fig. 2.b Data transmittal via radio waves

2.2. Calculating the corrections provided by the reference station and their reception at the mobile station

The corrections are calculated by a receiving module, equipped with 12/16 parallel reception channels, allowing the simultaneous computation of corrections from 12/16 satellites.

For each satellite, the reception module calculates:

- The difference between the measured distance and the theoretical distance derived from the ephemeride data and from the known position of the reference station's GPS antenna;
- The correction evolution's velocity;

Corrections are computed every 0.6 seconds for all satellites and are transmitted to the central unit that manages the transmission.

A correction message transmitted to the central unit by the GPS receiver module comprises:

- The week number;
- The Z Counter, which allows for precision dating of every correction on the GPS timescale;
- An indication of ephemeride change;
- The observed correction;
- The correction evolution velocity;
- The satellite number;
- The ionospheric correction calculated at the reference station;
- The tropospheric correction calculated at the reference station;

3. References

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