PROPAGATION EFFECTS IN GPS ACCURACY. THE PRECISION IMPROVEMENT OF POSITIONING IN REAL CONDITIONS OF PROPAGATION

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Accuracy of GPS positioning depends of bias errors which can be removed or significantly reduced from the direct observables by using empirical models, or by differencing direct observables.

Because of the dependency on solar radiation, on ionization density of ionosphere layers, the resulting propagation characteristics are highly dependent on solar activity variations, seasonal and diurnal variations. Group delay and phase advance for GPS signal can reach ~150 m near the horizont. Ionospheric effect can be removed by using a dual frequency receiver, but for a receiver that process only C/A code, ionosphere-induced errors can reach 5 m even for an optimal geometry.

For the tropospheric propagation influence exists empirical models (functions of temperature, pressure and relative humidity) used to eliminate major part of the effects. Total effect in the zenith direction reaches 2.5m and increases up to 20-28 m at 5° elevation.

The goal of this paper is to present the experimentally results of improving accuracy positioning in real conditions of propagation. The experimentally measurements were concentrated to determine and reduce the influence of a given propagation environment. The data acquisition was used to get the influence of various atmospheric parameters on precizion pozitioning and suggest a methode to improve the accuracy, usable for a receiver that process only C/A code.

To get the influence of propagation environment for certain weather conditions and for a geographical interest aria, was made experimentals measurements, at certain times with maximum and minimum ionospheric influence, at several temperatures and relative humidities. Finaly, was traced a "correction table" for point positioning with GPS receiver, getting in this way an improvement of positioning accuracy.

Keywords: propagation effects, GPS accuracy, C/A code

1. INTRODUCTION

Developed initial for military interest, the Global Positioning System (GPS) become in short time accessible for civilian use, witch have consequence a surprising extention of applications in the fields of recreation, public health and safety, environmental monitoring, fleet management, engineering and construction, agriculture, geosciences, etc.

GPS is a radionavigation and positioning system in any weather condition, any time and any place. An user can determine one's position at any point on the earth's surface, starting from known position of many satellites.

The GPS system contain three main components [1]:

- **Space Segment** consist of GPS satellites which transmits any time messages with their position and the time;
- **User Segment** consists of the GPS receivers and the user community
- **Control Segment** consist of all ground stations used for monitoring and the satellites control.

Each GPS satellite transmits low power radio signals at two carrier frequencies, called L1 (1575,42 MHz) and L2 (1227,60 MHz).

The selection of L band is the result of the compromise between many criterions, from wich most importants are the attenuation increasing with f^2 in free-space propagation and lower industrial noises at high frequencies.

Being in microwave domain, the propagation of the GPS signals are in line-of-sight, wich means that GPS receiver work properly in open spaces, with open view to the sky.

These two carriers are used to transmit three type of data informations:

1. ***Navigation message*** consists of binary data signal wich describe the GPS satellites orbits (ephemeris), clock corrections, almanach data (ephemers not processed for all satellites) and other system parameters;
2. ***C/A Code*** („coarse/acquisition") is a pseudo random noise code, (PRN - Pseudo Random Noise). Main information in this code is the moment (in satellite time system) of signal transmision. Each satellite has its own unique PRN code.

This two signals, *navigation message* and *C/A code*, forms the segnal used to modulate the L1 carrier wich represent the base for Standard Positioning Service SPS, civilian accessible.

3. ***P Code*** (Precise) is aldo a PRN code wich contain the message transmition moment but with 10 times better than the information from C/A code. P code may be crypted by a process known that „anti-spoofing" (AS) becoming this named ***Y code***. Employment of this Y code is possible if the recever contains a special module AS and is available only authorised users, with appropriate cryptographic keys. P(Y) code the basis for the Precise Positioning Service PPS.

The purpose of this paper is the finding some way for the accuracy increasing of civilian GPS receivers.

2. POSSIBILITIES OF ACCURACY IMPROVEMENT

2.1 GPS error sources

Are two main categories of errors: bias errors and white noise.

1. **Bias errors** that can be removed from the direct observables, or at least significantly reduced, by using empirical models (eg., tropospheric models), or by differencing direct observables. In this category are: satellite and receiver clock errors, satellite orbit errors, atmospheric effects (ionosphere, troposphere) and multipath propagation

2. **Noise** errors are the combined effect of PRN code noise (around 1 meter) and noise within the receiver noise (around 1 meter).

For the first category, exists few possibilities to reduce the errors due to propagation environment, if its well understud how they appear. Propagation environment affects in major mode by two layers: the ionosphere (50-1000 km) and the troposphere (up to 50 km).

2.1.1 Ionosphere

The presence of free electrons in the geomagnetic field causes a nonlinear dispersion of electromagnetic waves traveling through the ionized medium. The group delay and phase advance, are frequency dependents and can reach ~150 m near the horizont.

The propagation delay depends on the *total electron content* along the signal's path and on the frequency of the signal itself and as well on the geographic location and time (ionosphere is most active at noon, quiet at night; Sun spot cycle is 11 years).

Estimated ionospheric group delay efferct for GPS Signal L1 is 16 m.

Differencing technique and ion-free combination of observations on both frequencies, L1 and L2, eliminate effects for the short baselines. On the long baselines the differential effect is 1-3 cm. So, by using dual frequency receivers, the ionospheric effect can be removed.

2.1.2 Troposphere

In this environment the propagation is the same for all frequencies below 15 GHz (troposphere is not dispersive for frequencies below 15 GHz), and group and phase delay are the same, so that elimination by dual frequency is not possible. They affects relative and point positioning. To eliminate major part of the effect are used empirical models (functions of temperature, pressure and relative humidity).

The tropospheric propagation effect is usually represented as a function of temperature, pressure and relative humidity, obtained by integration of the refractivity N_{trop} [2].

It is separated into two components: *dry* (0-40 km) and *wet* (0-11km):

- The *dry* component, which is proportional to the density of the gas molecules in the atmosphere and changes with their distribution, represents about 90% of the total tropospheric refraction. It can be modeled with an accuracy of about 2% that corresponds to 4 cm in the zenith direction using surface measurement of pressure and temperature.
- The *wet refractivity* is due to the polar nature of the water molecules and the electron cloud displacement. Since the water vapor is less uniform both spatially and temporally, it cannot be modeled easily or predicted from the surface measurements. As a phenomenon highly dependent on the turbulences in the lower atmosphere, the *wet* component is modeled less accurately than the *dry*. The influence of the *wet* tropospheric zenith delay is about 5-30 cm that can be modeled with an accuracy of 2-5 cm.

The tropospheric refraction as a function of the satellite's zenith distance is usually expressed as a product of a zenith delay and a mapping function.

Tropospheric refraction accommodates only the systematic part of the effect, and some small un-modeled effects remain. Moreover, errors are introduced into the tropospheric correction via inappropriate meteorological data (if applied) as well as via errors in the zenith mapping function. These errors are propagated into station coordinates in the point positioning and into base components in the relative positioning.

For example, the relative tropospheric refraction errors affects mainly a baseline's vertical component (error in the relative tropospheric delay at the level of 10 cm implies errors of a few millimeters in the horizontal components, and more than 20 cm in the vertical direction). If the zenith delay error is 1 cm, the effect on the horizontal coordinates will be less than 1 mm but the effect on the vertical component will be significant, about 2.2 cm. The effect of the tropospheric refraction error increases with the latitude of the observing station and reaches its maximum for the polar sites. It is a natural consequence of a diluted observability at high latitudes where satellites are visible only at low elevation angles.

The use of a civilian GPS receicer, wich work only on L1 frequency make inaccessible the differential GPS techniques for improvement accuracy. The goal of this paper was the identification of some methods usable with a such receiver. Was founded two methods, each with utility in certain conditions.

1. **the reducing of atmosphere effects** by correction of measurements with coeficients depending by certain weather conditions and for a geographical interest aria
2. **pseudo-differential method**, based on reporting of measurements on points-marks with coordinates precisely known, similar at the receivers from terestrial staions used to monitoring and satellites controls.

2.2 Minimisation of atmospheric effects

The experiments done to determine the tropospheric effect have purpose the positioning inequalily that appears if two from three factors have kept constants (eg. pressure and relative humidity). In this way we get three families of results, wich enable the tropospheric influence estimation, with minimal ionospherice influence and comparative identical.

After the determination of three factor influence, temperature, pressure and relative humidity, has calculate *tropospheric range correction*. The results enable the transit of the second stage of experiments, the *ionospheric influence* determination.

We have started from two facts:

- ionospheric influence is maximum at noon and minimum at night;
- satellites geometry in sight is repeatible at one time in 12 hours.

This means that a positioning made at noon and remade after 12 hours in the same place must to carry out the same results. The experimental results have reveal the existence of a different positioning wich depends by ionospheric and tropospheric effects. If the influence of temperature, presure and humidity day/night is known, may be estimated and the ionospheric effect.

2.3. Pseudo-differential method

In condition of use a GPS receiver that can process only C/A code (L1 carrier), even if the differential GPS mode (DGPS) is implemented, the absence of terrestrial stations for monitoring and control in a geographical area make inoperable the DGPS working. But is possible to use points-marked or landmarks from the interest area, wich position is precisely known. Making with the same receiver positioning measurements in the landmarks, can be identified the errors on real propagation environment. In the geographical area near by points-marked or landmarks, the propagation conditions are almost identical, enabling the correction of measurements.

Obvious, the method is usable in wild touring zones, in wich exist points-marked or landmarks.

3. RESULTS

Are 3 cathegories of experimental results:

- For determination of troposphere influence:
    - Variable temperature, constants pressure and relative humidity
    - Variable relative humidity, constants temperature and pressure
    - Variable pressure, constants temperature and relative humidity
- For determination of ionosphere influence
- Pertaining of measurements at points-marked or landmarks (precisely known coordinates).

All this measurements have made with a GPS receiver single-frequency in the same geographical area, using topographic marks.

4. CONCLUSIONS

The goal of these experiments was to put on evidence the influence of real propagation conditions, different by typical models implemented in the receiver software and the suggestion of achievement a software to enable the run of some functions to augment the accuracy:

- seting for wheater parameters (temperature, humidity, pressure)
- autocalibration (by measuring points-marked or landmarks, by data acquisitions with minimum ionospheric influence)
- download for specifical data for certain zones

5. REFERENCES

[1] *2001 Federal Radionavigations Systems*, published by Department of Defense and Department of Transportation

[2] *GPS Signal and Basic Observable*, http://geodesy.eng.ohio-state.edu/course/gs609/