Comparison of different precision differential GPS positioning technology

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Abstract. In order to eliminate the influence of errors in the differential GPS positioning process, this paper first introduced the basic principle of differential GPS positioning technology and error source, then introduced the positioning principle and algorithm of differential position, differential pseudo range and differential carrier phase, the advantages and disadvantages of these three kinds of differential positioning technology are summarized accordingly. In the end, the research direction of integrating different precision differential GPS positioning technology into mobile phone positioning is proposed.

Introduction

By the middle of 1990s, GPS starts the overall operation, it becomes a new generation of satellite navigation and positioning system and cover three-dimensional space. [1] Although the GPS positioning method is simple and can realize rapid real-time positioning, there are some errors in the positioning, so GPS positioning is difficult to meet the demand of high precision positioning.

The development of differential GPS positioning technology can eliminate the effect of errors in the process of positioning in a certain extent.

The principle of differential GPS positioning technology

Differential GPS positioning technology uses two receivers, one of which is placed at a fixed position and the other is placed on a moving object, these two receivers can continuously observe the same GPS satellite at the same time. According to the known coordinates of the base station, the coordinate correction of the base station can be calculated, sent this coordinate correction to the mobile user through the data link so as to improve the positioning accuracy of mobile users.[2]

There are three kinds of errors which may be produced in the process of GPS positioning, the first one is the common error of the receiver such as ephemeris error, satellite clock error, Ionospheric error etc. the second one is the propagation delay error of GPS signal, the third one is the inherent error of receiver such as receiver noise, Multi path effect etc. [3]The composition of this system is shown in Figure 1:

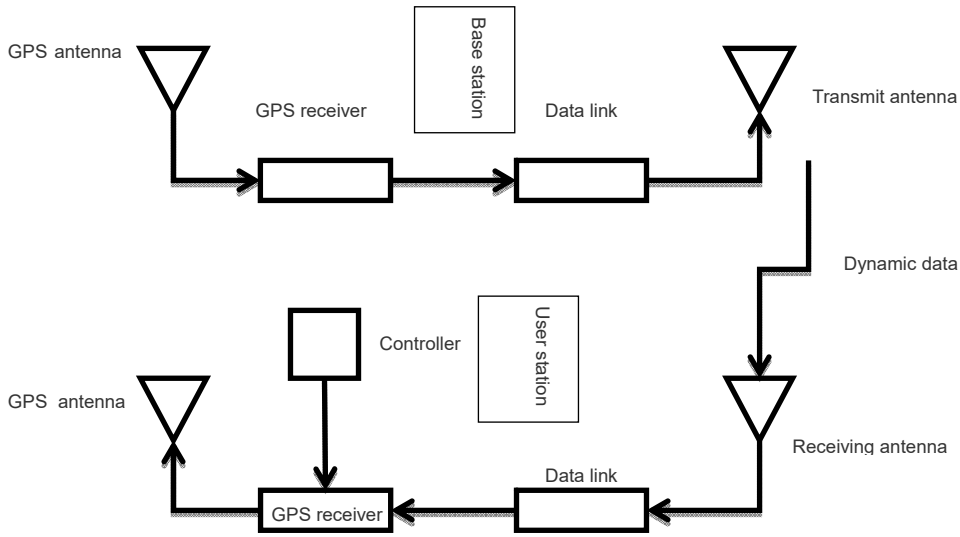

Figure 1 Schematic diagram of differential GPS system

The specific error estimates are shown in Table 1. Using differential GPS positioning technology, the first kind of errors can be completely corrected, especially the ephemeris error and the satellite clock error, most of the second kind of errors can be corrected by the correction model, the third kind of errors are difficult to correct.

Table 1 Error estimation for GPS and differential GPS positioning [4]

positioning error	GPS	DGPS
satellite ephemeris error/m	100.00	0.00
satellite clock error/m	5.00	0.00
Ionosphere/tropospheric delay error/m	6.41/0.40	0.15
receiver noise/quantization error /m	2.44	0.61
receiver channel error /m	0.61	0.61
Multi path effect /m	3.05	3.05
UERE/m	100.40	3.97
horizontal position error（HDOP=1.5）/m	150.60	5.95
Vertical position error（VDOP=2.5）/m	251.00	9.91

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differential position

(1) principle of differential position

The GPS receiver at base station can continuously receive signals from 4 or more than 4 visible satellites, demodulate these signals and calculate the measured coordinate of base station. There is a difference (that is the correction) between the measured coordinate and the real coordinate of base station because of the existence of errors, the base station send this correction to the user station through a data link, the user station can correct its own coordinate according to this correction so as to realize the differential position.

(2) algorithm of differential position

Suppose the measured coordinate of base station is (X_0^*, Y_0^*, Z_0^*), the real coordinate of base station is (X_0, Y_0, Z_0), the correction for measured coordinate and real coordinate is $(\Delta X, \Delta Y, \Delta Z)$, that is:

$$\begin{aligned} \Delta X &= X_0 - X_0^* \\ \Delta Y &= Y_0 - Y_0^* \\ \Delta Z &= Z_0 - Z_0^* \end{aligned} \tag{1}$$

differential pseudo range

(1) principle of differential pseudo range

The GPS receiver on the base station measures the distance of all the visible satellites, compare this measured distance with the real distance, the deviation between the measured distance and the real distance is obtained by the filter(that is pseudo range correction).

(2) algorithm of differential pseudo range

The GPS receiver on base station demodulates ephemeris file and calculates the coordinate of visual satellite (X^i, Y^i, Z^i), using the real coordinate of base station (X_0, Y_0, Z_0), calculate the true distance from the visual satellite to base station R^i:

$$R^i = \sqrt{(X^i - X_0)^2 + (Y^i - Y_0)^2 + (Z^i - Z_0)^2} \quad (3)$$

The GPS receiver on base station measures the pseudo range of all visible satellites ρ^i, ρ^i contains a variety of errors, the deviation between ρ^i and the true distance is the pseudo range correction $\Delta\rho^i$ and pseudo range change rate $\Delta\hat{\rho}^i$, that is:

$$\Delta\rho^i = R^i - \rho^i, \ \Delta\hat{\rho}^i = \frac{\Delta\rho^i}{\Delta t} \quad (4)$$

Base station sends $\Delta\rho^i$ and $\Delta\hat{\rho}^i$ to user station, user station add $\Delta\rho^i$ to the measured pseudo range ρ_u^i so as to obtain the corrected pseudo range ρ, calculate the true coordinate of user station by using ρ.

$$\rho = \rho_u^i + \Delta\rho^i + \Delta\hat{\rho}^i (t - t_0) \quad (5)$$

differential carrier phase

(1) principle of differential carrier phase

Differential carrier phase technique is also called RTK technique. The GPS receiver on base station continuously observes satellite, user station not only receive its own satellite carrier but also receive the carrier and coordinate which is sent by base station, then user station processes these received data in real time so as to calculate its own coordinate.

(2) algorithm of differential carrier phase

The GPS receiver on base station continuously observes satellite j, the calculated pseudo range and pseudo range correction is ρ_b^j and $\Delta\rho_b^j$ respectively:

$$\Delta\rho_b^j = R_b^j - \rho_b^j \quad (6)$$

In formula (6), R_b^j is the true distance from base station to satellite j.

Correct the pseudo range of user station by using the pseudo range correction which is calculated by base station:

$$\Delta\rho_b^j + \rho_u^j = R_u^j + \Delta d\rho = \sqrt{(X^j - X_u)^2 + (Y^j - Y_u)^2 + (Z^j - Z_u)^2} + \Delta d\rho \quad (7)$$

In formula (7), ρ_u^j is the observed pseudo range of user station, R_u^j is the true distance from user station to satellite j, (X_u, Y_u, Z_u) is the coordinate of user station, (X^j, Y^j, Z^j) is the coordinate of satellite j, $\Delta d\rho$ is various residual error of the same observed epoch.

The observed carrier phase is:

$$\rho_0^j = \lambda\left[N_0^j + N_0^j (t - t_0) + \varphi_0^j\right] \quad (8)$$

In formula (8), N_0^j is fuzzy degree of initial phase, $N_0^j (t - t_0)$ is fuzzy degree of the whole cycle between the initial epoch and the observed epoch, λ is the wavelength of carrier wave, φ_0^j is the fractional part of phase.

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