On the Generation Algorithm of VRS Virtual Observations

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Abstract In the past few years, network RTK positioning technology, especially the VRS technology, has been widely used in some parts of China and in many countries around the world. The principle of the VRS technology is discussed with corresponding formula deduction, and detailed descriptions and applications of VRS corrections and virtual observations generation algorithm are given.

Keywords network-RTK; VRS; corrections generation algorithm; virtual observation

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Introduction

The GPS virtual reference station (VRS) positioning is a network RTK technology based on multiple reference stations. At least three reference stations are needed with this technology, and the geodetic coordinates of the reference stations are precisely known. These reference stations continuously track the GPS satellites’ signal in order to determine the dispersive and non-dispersive biases. Those biases can be interpolated to the virtual reference station, so the rover around the VRS can take advantage of that information to get a better positioning accuracy. Meanwhile, the rovers have to send their approximate coordinates to a data processing center (usually the master reference station) so that the virtual observations can be generated at the approximate coordinate according to the approximate coordinates of the rover and the corrections of the dispersive and non-dispersive biases.

In fact, the VRS is established exactly at the approximate coordinate. Generally, the approximate coordinates are obtained from the pseudo range single positioning whose accuracy can be controlled in meters or tens of meters. Since the baseline between the VRS and the rover is very short, meaning the high coherence of some distance-based biases between the rover and the VRS, a better result can be derived from the traditional double-differential position method.

According to the traditional relative positioning theory, the longer the baseline, the less the coherence of the distance-based bias. It is a long-lasting contradiction in RTK application. The development of VRS technology has successfully solved that problem and extended the coverage of RTK service from 15 km to at least 50 km. This technology greatly improves the accuracy of the relative positioning in the middle and long baseline. Within the coverage of network-RTK service, even the single-frequency receiver can rap-
idly remove the ionospheric delay and solve the integer ambiguity. Also, cm-level positioning accuracy can be easily achieved, which is very encouraging. Besides, the platform of multiple reference stations could be fully utilized in some other services like for example in GPS meteorology and deformation monitoring. Such departments as survey, meteorology, traffic, tourism, agriculture, and environmental protection will benefit a lot from this system. The focus of this paper will be on the virtual observations generation algorithm at the virtual reference station.

1 Biases analysis

According to the GPS theory, the GPS positioning error can be divided into three parts.

1) Related to the GPS satellite, for instance the satellite clock bias. For one certain satellite, the satellite clock bias for the certain epoch is a constant, so it can be eliminated by differencing.

2) Related to the propagating path. This part comprises of ionospheric delay, tropospheric delay and multipath.

   The tropospheric delay is non-dispersive, whose variation is relatively slower compared to the ionospheric delay. In traditional GPS survey, this bias can be diminished by applying a model correction. But in network RTK application, it was eliminated by the interpolated algorithm whose data originated from the multiple reference stations. The algorithm will be discussed in the latter section. Since the tropospheric delay is more sensitive to the altitude, the designers of the RTK network should consider such influence.

   The ionospheric delay is dispersive. It is related to the frequency of the signal and the ionospheric double-differenced corrections can be derived from pairs of reference stations by using a dual-frequency GPS receiver. Since it is clear that the ionosphere is more active and varies quickly especially around equator regions, the refreshing rate of the dispersive biases (e.g., ionospheric delay) should be faster.

   On the other hand, the multipath is difficult to diminish. The best way to avoid it is to choose better surroundings for observation or using an antenna that can restrict the multipath. In VRS application, an ad-

visible interpolated method can also diminish the multipath to some extent.

3) Related to the receiver. This part comprises of the receiver clock bias and noise. A high quality receiver can efficiently diminish this kind of error.

2 Generation algorithm for double-differenced corrections between multiple reference stations

For the purpose of convenience, we assume that all the multipath and noise, as well as the orbit bias have already been controlled in a reasonable level. Subscripts \(a\) and \(b\) denote the reference station, superscripts \(m\) and \(n\) denote satellites. According to the GPS theory, double-differenced observation equation can be described as:

\[
\lambda (\nabla \Delta N_{a,b}^{m,n} + \nabla \Delta \phi_{a,b}^{m,n} ) = (\nabla \Delta \rho_{a,b}^{m,n} - \nabla \Delta \rho_{a,b}^{m,n} + \nabla \Delta T_{a,b}^{m,n} )
\]

(1)

where \(\nabla \Delta\) is the symbol of double-difference; \(\nabla \Delta \phi_{a,b}^{m,n}\) is the double-differenced carrier phase observations; \(\nabla \Delta N_{a,b}^{m,n}\) is the double-differenced integer ambiguity; \(\lambda\) is the wavelength of the signal; \(\nabla \Delta \rho_{a,b}^{m,n}\) is the double-differenced geometrical distance between the satellite and the phase center of receiver antenna; \(\nabla \Delta T_{a,b}^{m,n}\) is the double-differenced ionospheric delay; \(\nabla \Delta T_{a,b}^{m,n}\) is the double-differenced tropospheric delay.

In the equation above, \(\nabla \Delta \phi_{a,b}^{m,n}\) can be calculated from the phase observations. Since the coordinates of the reference stations are precisely known and the coordinates of the satellites can be obtained from the GPS ephemeris, the term \(\nabla \Delta \rho_{a,b}^{m,n}\) is determined. After solving for the double-differenced integer ambiguity \(\nabla \Delta N_{a,b}^{m,n}\), the double-differenced ionospheric delay \(\nabla \Delta I_{a,b}^{m,n}\) and the double-differenced tropospheric delay \(\nabla \Delta T_{a,b}^{m,n}\) can eventually be obtained. It is clear that the key approach is to correctly determine the double-differenced integer ambiguity \(\nabla \Delta N_{a,b}^{m,n}\). In network RTK, reference stations tens of kilometers apart from each other, the distance-dependent bias notably increases, making the ionospheric delay the most powerful influence on the integer ambiguity solution.