Elements and Experiments of Shenzhen Continuous Operating Reference Stations (SZCORS) System

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ABSTRACT  Real-time kinematic GPS precise positioning has been playing an increasing role in both surveying and navigation. Based on the city's fibre LAN network, Shenzhen Continuous Operating Reference Stations (SZCORS) system has been established and consists of GPS reference stations, system control center, user's data center, and real time datacom network. The SZCORS system provides users the real-time centimeter positioning or post-processing millimeter positioning. This paper makes discussion on the structure of SZCORS system. Some experiments have been made to test the usability, and then the data has been analyzed.

KEY WORDS  GPS; continuous operating reference stations system; virtual reference station (VRS)

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Introduction

Situated in southeast China, Shenzhen has an area of over 1900 km². The Shenzhen continuous operating reference stations (SZCORS) system was built up by Shenzhen Municipal Planning and Land Resources Bureau in conjunction with the GPS Center of Wuhan University. The project began in May 2000, and was accomplished in September 2002.

The SZCORS system includes five subsystems, which are GPS reference stations, one control center, user's data center, user's application system, datacom system. The data service of the system are in two ways: one is that the control center provides dial-up service for the user who can dial to server via GSM data communication acquiring the real-time high-precise positioning; the other is to visit the internet WEB-server (http://www.szgps.com), download the RINEX data for post-processing needed.

The SZCORS system adopts the VRS (virtual reference station) technique, issued by Terrasat Co. Ltd., Germany in 1999. Compared with classical RTK, VRS deals well with the corrections of ionosphere and troposphere. The computer at the control center continuously gathers observation data from all receivers and creates a living database of regional area corrections which are used to create a virtual reference station, situated only a few meters away from where any rover located, together with the raw data which would have come from it. The rover uses the data just as if it comes from a real reference station. The user of the VRS services can be equipped with RTK receivers of any types. The receiver can be connected to a modem pool, with which at most 30 users can work simultaneously.

1 System structure

1.1 GPS reference stations

These continuous operating reference stations (CORS) are the data source of the system, all
receivers track the GPS signals, gather and record the observation data, transfer the data to the control center. Each reference station consists of a choke ring antenna in the field and an equipment room. The main equipments of each station include a Trimble 4800 dual-frequency GPS receiver, power supply (UPS batteries), a computer, a Switch (or a Router) through which the communication to the control center, is implemented.

1.2 Control center

The control center is the core of SZCORS system and includes network equipments, servers and computers running software. The control center connects the five CORS via optical fiber cable network. The software, running on computers and servers, consists of network RTK processing software (GPSNet software) and the system management software that are GPS-MS, GPS-RS, GPS-US etc.

As the most important part of SZCORS system, the control center conducts data processing, system control, information service and network supervision.

Data processing is to analyze and evaluate the quality of the data transferred from five GPS CORS, to process data synthesizing, data storing, and to use the VRS technique to form the RTCM corrections for the user’s data center.

System monitoring is to automatically monitor the equipment of subsystem, to conduct remote control over the equipment, to judge the faults of the equipment and to give out the warning.

Information service is to provide the data service and other computing service for post-processing user by means of Internet Web-server.

The management of network and user is to manage the whole network, to ensure security of the network, to provide the http and ftp service, to manage user’s register and query, and to record the visiting history.

1.3 User’s data center

The user’s data center (UDC) includes two functions, by which the users can acquire the data needed. The first function is that many users (at most 30) can connect to the data server via E1-PRI digital relay line simultaneously. When the user dialed into control center with GSM mobile phone, the server running GPSNet software will send RTCM corrections data to the rover. The other is the user can download the data file, which is stored by GPSNet software in RINEX and OBS-File format for post-mission services like post-processing or download via Internet Web-server.

To ensure the smooth communication, the UDC takes some compatibility methods to prevent the trouble. More E1-PRI digital relay lines can be used to increase the capacity of visit. The wireless relay station can be set up by broadcasting station, the user can make use of the RDS (radio data system), which broadcast the RTCM corrections. And the user can continue his work by the classical RTK mode using the signals sent by only one reference station.

1.4 User’s application system

The user’s application system is an important unit of CORS system. There are several categories of users according to different application: survey and engineering users, with centimeter or decimeter precision; vehicle navigating and positioning users, with meter precision; and high precision users, with millimeter precision by post-processing.

2 System Performance

The technical performance of the SZCORS system is checked by test, as shown in Table 1, and many functions are provided:

1. Real-time GPS surveying with VRS technique is used for engineering surveys and cadastral surveying with only one GPS receiver via GSM communication mode.

2. Post-processing high precision positioning is realized by means of Internet WEB-server and downloading the GPS data. These GPS data (in a RINEX data format) is available for GPS users by Internet access for free, along with satellite
navigation files and precise ephemeris files for post processing.

③ The permanent reference stations will upgrade to the Chinese national GPS reference stations if needed.

| Table 1 Performance of SZCORS system |
|--------------------------------------|
| **Item**                       | **Type** | **Performance**                                   |
|---------------------------------|----------|--------------------------------------------------|
| Navigation                      |          | Navigating (land or sea); GIS data collection    |
| Positioning                     |          | Survey, cadastration, planning, engineering construct, deformation monitoring |
| RTK survey                      |          | Hor. < 3 cm                                      |
|                                 |          | Vertical < 5 cm                                  |
| Post-processing positioning     |          | Hor. < 5 mm                                      |
|                                 |          | Vertical < 10 mm                                 |
| Navigating                      |          | Hor. < 5 m                                       |
|                                 |          | Vertical < 7 m                                   |
| Navigating                      |          | 95.0% (one year); 95.0% (one day)                |
| Availability                    |          | Positioning                                      |
|                                 |          | 95.0% (one year); 95.0% (one day)                |
| Alarm time                      |          | < 6 s                                            |
| Security                        |          | Misinformation probability                       |
|                                 |          | < 0.3%                                           |
| Compatibility                   |          | Navigating & positioning                          |
|                                 |          | RTCM-SC104 V2.2, CMR Plus, RINEX                 |

3 Data analysis

3.1 RTK survey accuracy

Some experiments were carried out for testing the accuracy of RTK positioning in March, 2003 by use of a Trimble 5700 GPS double-frequency receiver. Thirty-five points of known coordinates were measured using the real-time kinematic positioning mode, and 3,403 fixed-solutions were acquired.

The RMS of Shenzhen local coordinates can be calculated under the condition that the known points are given. The accuracy of the local coordinate is decided by three factors: system accuracy, known coordinate accuracy and coordinate transform accuracy. The RMS of Shenzhen local coordinate is shown in Table 2.

| Table 2 Statistics of the local coordinates' accuracy |
|-----------------------------------------------------|
| **Item** | **RMS/m** |
|-----------|-----------|
| Max.      | 0.047     | 0.064    |
| Avg.      | 0.017     | 0.021    |
| Ratio (<20 mm) | 65.6% | 53.1%    |
| Ratio (20-40 mm) | 31.3% | 37.5%    |
| Ratio (>40 mm) | 3.1%  | 9.4%     |

3.2 Availability

The network RTK software of SZCORS system (i.e. GPSNet software) gives out availability parameters, according to the satellite performance and calculation. Though the observation environment of rover has been neglected, the parameter will be regarded as an important reference for time availability because it has taken the potential intervention of ionosphere, troposphere, satellite plot and other related factors into consideration. Fig. 1 shows the statistics.

3.3 Data statistics analysis

The all-weather availability of the system will be achieved after repeatedly surveying the same point, and then comparing the RMS at different
epochs. Table 3 shows the changes of surveying and positioning of the same point at different epochs. The data and the graph indicate that the results of GPS positioning at different epochs are almost the same, and the vertical systematic error is related with the wrong antenna correction during observation. The data analysis shows that the time availability of SZCORS system has reached 95 percent in all-weather condition.

### Table 3 Comparison of RMS at different epochs

| Time gap   | Satellites number | Initialization time | Observations | RMS $B/\text{"}$ | RMS $L/\text{"}$ | RMS $H/m$ |
|------------|-------------------|---------------------|--------------|------------------|-----------------|-----------|
| 10:00-10:20 | 7                 | 14                  | 206          | 3.072E-04        | 1.875E-04       | 0.031     |
| 15:00-15:20 | 6                 | 14                  | 307          | 2.918E-04        | 4.964E-04       | 0.025     |
| 21:00-21:30 | 7                 | 12                  | 208          | 4.865E-04        | 2.390E-04       | 0.044     |
| Total      | 721               |                     |              | 3.627E-04        | 3.607E-04       | 0.033     |

### 3.4 Initialization time

The initialization time is a certain period of time to observe, to calculate and to obtain RTK fixed solution after the user GPS receiver gets float solution. It is essential because repeated calculation of ambiguity will be needed in the course of phase differential positioning. The main factors affecting RTK initialization time include: number of observation satellites, satellites plot, distance to reference station, observation environment and so on. Table 4 is the statistics of initialization time of RTK. It can be seen easily from the data that five satellites in use in RTK results in the largest ratio, six satellites in use results in the fastest initialization time, and the initialization time in condition of network RTK is much less than that in classical RTK, with nothing to do with the distance.

### Table 4 Initialization time

| Satellites number | Observations | Ratio/% | Initialization time | RMS Avg. | Max. |
|-------------------|--------------|---------|---------------------|-----------|------|
| 5                 | 17           | 38.64   | 20.3                | 40        |      |
| 6                 | 13           | 29.55   | 14.2                | 20        |      |
| 7                 | 13           | 29.55   | 26.2                | 120       |      |
| 8                 | 1            | 2.27    | 12.0                | 12        |      |
| Total             | 44           |         |                     |           |      |

### 4 Conclusions

Since the past two years, the SZCORS system has been put into use and the main technical parameters not only meet but also overpass the requirements. A core platform of dynamic geodetic information network in Shenzhen has been basically built up, and a large leap forward real-time geodetic survey has been made.

As the first CORS system in the mainland China, the SZCORS system integrates a great deal of up-to-date scientific and technological achievement in fields of geodetic survey, satellite geodetic survey, wireless communication and computer network. It is one of the foundations of digital city. Therefore, the built-up of SZCORS will have profoundly impact on traditional survey and service as well.

### REFERENCES

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