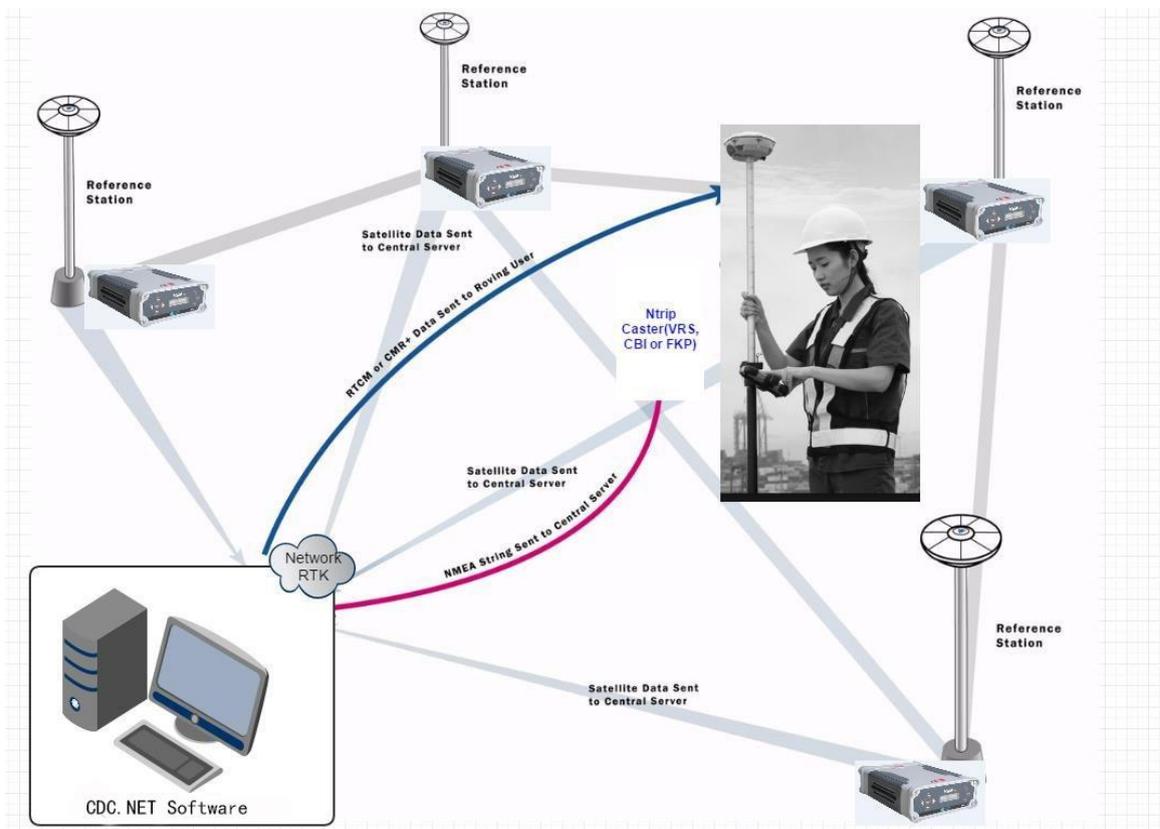


ComNav Technology CORS Solution



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Chapter 1 CORS Technology Introduction

1.1 Introduction of CORS

The use of the Global Navigation Satellite System (GNSS) for positioning and mapping has been steadily increasing since its introduction in the late 1980's. In the last few years, the use of GNSS has exploded across many countries, primarily due to the establishment of regional or state-wide CORS (Continuously Operating Reference Station) networks that provide real-time correction data.

CORS are geodetic quality GNSS receivers and antennas that are permanently installed. These stations collect GNSS data continuously, and transmit data via the Internet to a central server. At the server, the data is archived for future use, and made available for download by any user. The incoming data is also processed at the server to generate corrections which are made available over the Internet to users in real-time.

1.2 Combine Network with RTK

Real-Time Kinematic (RTK) is a method of surveying with GNSS that provides positioning accuracy at the 1-3 cm level. This is a form of differential GNSS requiring two receivers, one stationary (base) located at a known control station, and one rover to locate new positions. Since the base is located at a station with known coordinates, corrections can be computed and transmitted in real-time to the roving receiver, where they are applied to the raw positions being collected.

However, the conventional RTK is limited by the baseline length between the two receivers, the communication jamming, rapidly moved reference station and high cost. The CORS stations will serve as permanent bases. A group of CORS will be linked to central server and work as a network. Users with only one receiver can use the network RTK service in the coverage of this network.

Network RTK has many advantages over conventional RTK: modeling GNSS error over the entire network area; increased positioning robustness against RSs failures; increased mobility and efficiency--no need for temporary reference stations; quicker initialization times for rovers; extended surveying range; no restriction on the network size; capable of supporting multiple users and applications; continuous operation 365/24/7; provide data & corrections in a consistent datum; allow central control and monitoring of all stations--high integrity monitoring scheme; apart from RTK GNSS corrections, other services provided include: RINEX datasets for post-processing, GNSS corrections for DGPS, wide exploitation for geospatial, meteorological, transport, environmental and engineering applications.

1.3 Mainstream RTK implementations

1.3.1 VRS (Virtual Reference Station)

Rover sends its approximate position to the Central Processing Facility (CPF) via GSM, GPRS, or 3G. CPF predicts the distance dependent errors at the rover user position. These errors are determined using the data gathered from reference stations within the network by means of linear or other more sophisticated error models. A VRS is created by CPF close to the user's location and its data (corrected for the rover site) is transmitted to the user in standard RTCM 2.X or 3.X

formats. At the rover side position is obtained in a normal single baseline RTK mode. Bidirectional communication is required.

1.3.2 FKP (German acronym for Area Correction Parameters)

Network coefficients (FKPs) are calculated at CPF for every satellite, covering ionosphere, tropospheric and orbit effects for a specific area, at certain time intervals (at least every 10 s). Uncorrected master reference stations' measurements are broadcast in RTCM 2.X or 3.X formats plus network coefficients (FKPs) for interpolation, e.g. via RTCM message type 59. Rover interpolates the messages to correct master RS data, or converts the data into VRS corrections, in order to get its position.

1.3.3 MAC (Master Auxiliary Concept)

Network sends raw master data and "correction differences" for auxiliaries. User interpolates correction differences to rover location, applies them to raw master observations, and then computes double difference baseline between master and rover.

1.3.4 NRS (Network Reference Station)

NRS we used is based on the technology of VRS and combine the advantages of VRS, FKP and MAX. VRS uses the correction data of the three reference stations around to generate the correction data for a virtual station. FKP and MAX use the whole network to calculate correction message but the data they transmitted is quite a heavy burden on the wireless data transmission and cannot be compatible with conventional RTK receivers. NRS transmit correction for a virtual station computed from the three stations around and other surrounding stations. Therefore, ComNav uses NRS technology to provide more reliable and efficient CORS network service.

Chapter 2 ComNav CORS Introduction

2.1 Technical basis

The technical basis to ComNav CORS system is mainly basis on Global navigation satellite system continuously operating reference station network construction specifications, including UNAVCO and IGS guide lines. Also some standard is basis on GB (short for Guo Biao in Chinese, means Chinese standard). The related standard is as follows:

Name	NO.	Approved organization	Index
UNAVCO Reference Station	1	UNAVCO (http://www.unavco.org/)	
IGS Reference station	2	IGS (http://igscb.jpl.nasa.gov/)	
Construction lighting protection	3	GB (Chinese standard)	
Land survey GNSS receiver calibration	4	GB (Chinese standard)	
GNSS urban topographic survey standard	5	GB (Chinese standard)	

ComNav CORS stations could be expected to function as ITRF reference stations.

2.2 Project Target

1. The data communication between Reference station and CORS server
2. The dataflow divide, GNSS raw data processing in CORS server
3. High accuracy post processing service, by using internet the user can download service for post processing
4. By using GSM, GPRS, CDMA mobile network to broadcast correction message real time.

2.3 Project Construction Content

1. Select the place to fix reference station, house and observation pillar.
2. Establish Internet connection between control center and Reference station
3. Built multiples connection port for high accuracy correction and ordinary navigation correction message broadcast
4. End user hardware and software device, to get centimeter and sub meter accuracy

2.4 System Function

Two main function of ComNav CORS system: firstly use the internet to broadcast centimeter (sub meter) correction in real time; secondly by using internet to provide the post processing service.

1. In the CORS cover area, by using GNSS RTK Rover to get the correction message from CORS can get centimeter accuracy, which is mainly used for cadastral, topography survey.
2. RTK connection message, RTCM3.X, CMR broadcast by internet, those messages are compatible with all GNSS brands.
3. The post processing service, the FTP service of Rinex DATA download, by using those data post processing can get millimeter accuracy.
4. The autonomous integrity monitoring of system, end user account management.

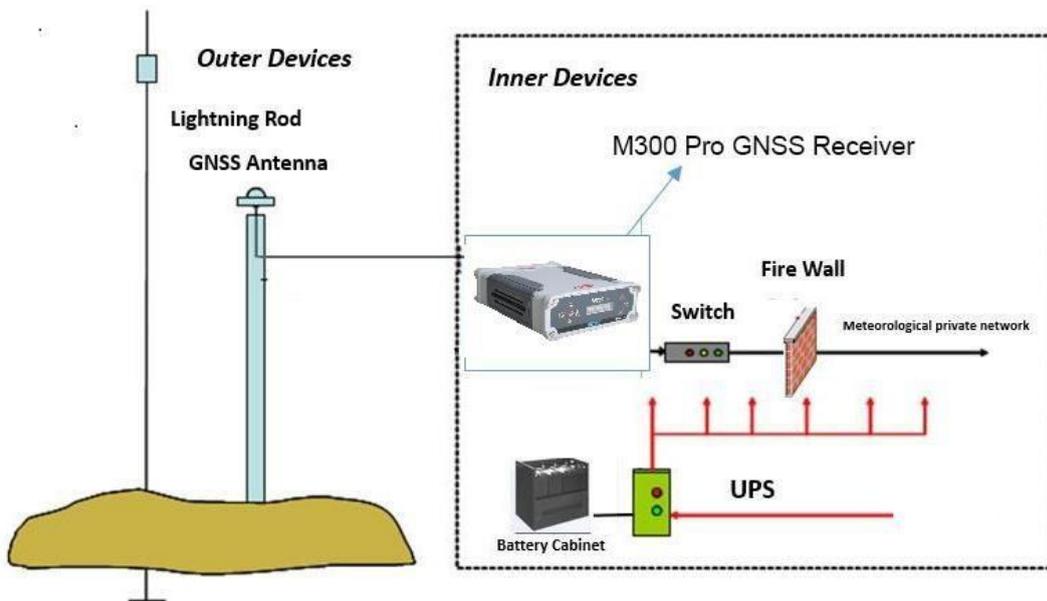
Chapter 3 ComNav CORS System Components

According to GNSS Continuously Operation Reference station (CORS) construction standard, the CORS system has the three main components as following chart:

3.1 GNSS Reference Station

Choose the suitable place to construct GNSS reference station. Construct monument and use orienting & leveling device to couple Choke Ring GNSS antenna and monument. Construct or use existed civil construction such as house to keep the other devices, like GNSS receiver, UPS, batteries, etc. and to provide power supply. Lightning rod is required to prevent GNSS antenna and house from lightning.

The schematic diagram of the reference station is shown below.



3.1.1 GNSS Antenna and Protection

ComNav Choke Ring Antenna meets the demanded high precision and have passed the phase center certification in IGS. It is designed to mitigate multipath and ability to track low elevation satellites. Antenna and monument would be coupled by orienting / leveling device. Lightning rod and surge protection would be installed to protect antenna and GNSS receiver.



Specification:

<ul style="list-style-type: none"> • Antenna <p>Frequency Range:</p> <ul style="list-style-type: none"> -BDS B1/B2/B3 -GPS L1/L2/L5 -GLONASS G1/G2 -SBAS, QZSS -GALILEO E1/E2/E5a/E5b/E6 <p>Impedance: 50 Ohm Polarization: RHCP Axial Ratio: ≤ 3dB Azimuth Coverage: 360° Noise Figure: ≤ 2.0 Gain at Zenith: 7dBi Phase Center Accuracy: ± 1mm</p>	<ul style="list-style-type: none"> • LNA <p>LNA Gain: 40dB Noise Figure: ≤ 2dB VSWRo: ≤ 2.0 Ripple: ± 0.5dB Operation Voltage: 3-12VDC Operation Current: ≤ 60mA Group Delay: < 5ns</p> <ul style="list-style-type: none"> • Physical <p>Dimension: $\Phi 379 \times 312$mm Connector: TNC Female</p>
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3.1.2 M300Pro GNSS Receiver

ComNav M300Pro CORS GNSS receiver is based on ComNav own technology, which can track all constellations signals in any mode. It also has the multiply communication, 1 2-pin lemo port for power supply and battery charging , 1 GNSS antenna port, 1 Pulse Per Second output port, 1 Event marker input port, 1 external frequency scale port, 2 serial ports (Port 1 supports system debugging and static data download from internal SD card; Port 2 supports parameters configuration and connecting meteorological sensor/barograph/inclinometer as well as external storage disk to extend storage capacity), 1 RS-232 serial ports and 1 RJ45 LAN port for internet connection. M300Pro is a ready to install device and the best option for reference station.



Key Features

- (1) Convenient front panel display for clear view and easy configuration.
- (2) Compact housing with a variety of interfaces for different external devices access.
- (3) Powerful remote control capacity for access, configuration, programming, data download, reboot/restart, firmware update, code registration, etc.
- (4) Large capacity internal memory and expendable RAM for long term massive data storage.
- (5) Small Auto-Reset function for restoring earlier parameters automatically after power-off recovery.
- (6) Integrated battery serves as either the primary power source or the stand-by Uninterrupted Power Supply (UPS) backup.
- (7) Powerful built-in web user interfaces provide full information such as receiver status, configuration, firmware update and data access control.
- (8) Static data downloading accessible (when authorized) anywhere, no longer restricted in data control center only.

Technical Specifications

Signal Tracking

- 496 channels with simultaneously tracked satellite signals
- GPS: L1 C/A code, L1/L2 P code, L2C, L5
- BeiDou: B1, B2, B3
- GLONASS: L1, L2
- Galileo: E1, E5-A, E5-B
- QZSS: Reserved
- SBAS: WAAS, EGNOS, MSAS, GAGAN
- Advanced multipath mitigation technology
- Low noise carrier phase measurements with <1 mm precision in a 1 Hz bandwidth
- High precision multiple correlators for GNSS pseudo range measurements
- Signal Noise Ratios reported in dB-Hz

Time Precision

- GPS+Glonass+Beidou 10ns

Positioning Specifications

- Post Processing Static
- Horizontal: 2 mm + 0.5 ppm RMS
- Vertical: 4 mm + 0.5 ppm RMS
- Single Baseline RTK(<30KM)
- Horizontal: 8 mm + 1 ppm RMS
- Vertical: 15 mm + 1 ppm RMS
- Network RTK
- Horizontal: 8 mm +0.5ppm RMS
- Vertical: 15 mm + 0.5ppm RMS
- E-RTK
- Horizontal: 0.2 m +1 ppm RMS
- Vertical: 0.4 m + 1 ppm RMS
- DGPS : 0.5 m 3D RMS
- SBAS : 1 m 3D RMS
- Standalone : 1.5 m 3D RMS

Communications

- 3 Lemo Ports
- 1 Lemo port(2 pin): power supply and battery charging
- 2 Lemo ports(7 pin): USB UART port, system

Data Format

- Correction data I/O:
 - RTCM 2.x, 3.x, RTCM3.2 MSM4,MSM5, CMR (GPS only), CMR+(GPS only)
- Positioning data outputs:
 - ASCII: NMEA-0183 GSV, RMC, HDT, VHD, GGA, GSA, ZDA, VTG, GST, PJK, PTNL
 - Extended NMEA-0183 BDGGA, GPNTR, GPCDT, GPHPR
- Observations
 - ComNav binary, BINEX, RTCM3.X, compatible with major CORS software (VRS, FKP and iMax).

Data logging

- Loop recording data function supports long time record
- Data logging frequency, maximum 50Hz
- Storage capacity
 - 32 GB internal memory
 - 1TB External memory maximum
- File format
 - Rinex 3. X or 2.X or ComNav binary format
- File log session
 - Days or hours can be set by user
- Data transfer
 - FTP access download directly

Physical

- Size (L x W x H): 202mm x 163mm x 75mm
- Weight: 2.4 kg
- Case: Rugged and light high performance metal

Environmental

- Operating temperature: -40°C to +80°C
- Storage temperature: -45°C to +85°C
- Humidity: 100% no condensation
- Water proof and dust proof: IP67, survives the temporary immersion to a depth of 1 m
- Shock: rugged aluminium case plus plastic ring seal, designed to survive a 1m drop onto concrete

<p>debugging and static data download; RS485 Protocol configuring and connecting with external device(meteorological sensor/barograph/inclinometer)</p> <ul style="list-style-type: none"> • 1 DB9 male port - Standard RS232 protocol • 1 Standard USB port, - Connect with external storage card • 1 RJ45 LAN Ethernet port (10/100M Bit) supports protocols HTTP, HTTPS, TCP/IP, UDP, FTP, NTRIP • 3 SMA male connectors - 1 PPS output - Event input - Reserve for WLAN and Bluetooth • 2 TNC connectors - GNSS Antenna connector - Frequency-marker oscillator input connector 	<p>Antenna</p> <ul style="list-style-type: none"> • AT300 GNSS Geodetic Antenna • AT500 GNSS Choke Ring Antenna <p>User Interface</p> <ul style="list-style-type: none"> • Button and front LCD panel - 5 functional buttons on the left and 3 buttons on the right - LCD panel shows the status and setting • ComNav M300 Pro Web Server • CRU software
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3.2 Internet for data communication

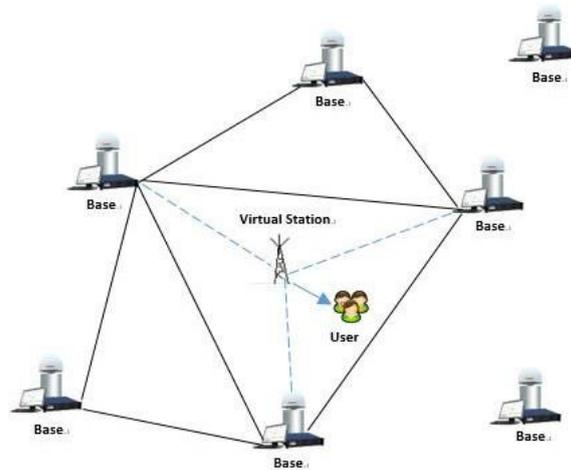
The stability of internet connection is a key factor to ensure the operation of CORS system. We suggest to setup the independent local network, so all the reference stations are linked to local network, by using this way the dataflow will more efficiency. Also as the Data center, we must use static IP.

3.3 CORS Server software

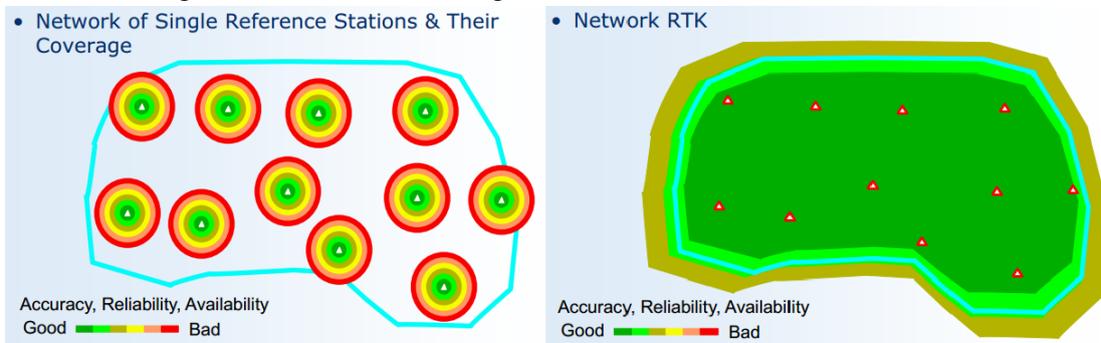
Data processing and management, all the reference station data will be processed in this data control center. After processing the data and generate the Ntrip Caster, this caster is broadcast by internet to end users. Also in Service software, there is another function called user management, all users log on server can be managed.

Chapter 4 ComNav CORS Server Software -- CDC.NET

In the bidding, we use our own CORS software CDC.NET, which is based on the technology of virtual reference station. CDC.NET uses the data from three station near the rover with whole network data to generate a virtual reference station near the rover.



Compared with single base station RTK, ComNav CORS system combines all stations together as a network and model GNSS errors over the entire network. It extends surveying range and improves availability of the service. Following two schematic diagrams shows its advantages.



4.1 The three main function of CDC.NET

❖ Reference station data processing

According to the raw GNSS observations of reference station, by using the precise ephemeris or broad ephemeris, CDC.NET will calculate the position of reference station.

Cycle slip modifies--use the algorithm to detect the cycle slip real time, according to the epoch and time SYNC to modify the slip.

Integer ambiguity resolution--after the two steps before, then use the dual pseudo-range and phase observation filter the width and narrow ambiguity. Use the known ambiguity fixed to check the quality of others.

Perceptible water vapor--use the parameters module to get the troposphere and ionosphere modify module.

- ❖ Generate the Virtual reference station

The RTK user logs on CDC.NET server. Firstly the RTK User will send the current approximate position to Server. After get the current position of user, the CDC.NET server will generate the data of virtual reference station near the rover, considering and modelling the GNSS error of the entire network. The GNSS error includes ionosphere error, troposphere error (water vapor considered), error in ephemeris, etc.

- ❖ Virtual reference station correction broadcast

Use the RTCM data code regulation; send the virtual reference station raw observation data to user.

4.2 CDC.NET functional module introduction

There are 4 functional modules of CDC.NET: Satellite Orbit, Stations, Service, User and Map.

1) Stations

Station is distributed in different parts of the GNSS receivers. Include the following parts:

- Stations management(new, edit, check, delete)
- Show satellite tracking, sky view and Base station information
- Show environment factors such as multipath, Ionosphere Troposphere and data utilization rate.

2) Service

- Deliver customized services in a wide range of formats
- Any combination of GPS, BDS, GLONASS and Galileo streams
- Standard RTCM streams

3) User

- User management (new, edit, check, delete)
- Monitoring user status

4) Map

- Show station and user in google map
- Electronic fence

4.3 CDC.NET Key technology

4.4.1 ComNav reference station high stability and high accuracy positioning technology and its dynamic reference frame

ComNav reference stations are permanent tracking station, whose data can be united computed with data of national permanent tracking stations or IGS (International GNSS Service) tracking stations to generate the location information.

ComNav reference stations in global reference frame. The stability of one reference station antenna pier on the bedrock can be checked by other reference stations by analyzing the relative position changes. Thus the regional reference frame can be established with regard to global reference frame and the regional reference stations can be checked and adjusted every year. It can determine the overall displacement of the whole region or some parts and provide the coordinate transformation parameters to surrounding area.

4.4.2 Rapid and kinematic GNSS position technology

Once the whole regional CORS network established, users can use one single or dual-frequency GNSS receiver in designed region to obtain centimeter level accuracy with the correction data from CORS in few minutes (rapid) or dozens of seconds (kinematic). The key technology used is rapid and real-time kinematic positioning technology and development and application of corresponding software. Utilizing Network RTK with multi-station will be the most important method.

4.4.3 Earthquake and high precision engineering deformation monitoring technology

Install the GNSS antenna and other sensing elements on engineering geological structures and buildings, and use tracking data broadcasted by CORS network, to obtain millimeter or even sub-millimeter level accuracy deformation monitoring data and alarm once monitored object get any safety problem.

System can send alarm to the configured email address.

4.4.4 Coordinate transformation technology

Because ComNav CORS system is based on local geocentric reference frame, it needs to transform the coordinates in dynamic geocentric reference frame to local coordinates system which can satisfy the work of surveying, mapping and civil engineering. Consequently, CORS control center should compute and provide the transformation parameters every year. The accuracy of these parameters should satisfy the criteria.

To obtain elevation above mean sea level in real time, 2km*2km grid geoid model with $\pm 5\text{cm}$ accuracy level is needed. Users can directly obtain the geoid height with the accuracy better than $\pm 10\text{cm}\sqrt{L}$ (L is the distance between the measured point and the nearest grid point in unit of km).

4.4.5 Integrity monitoring technology

ComNav CORS system is composed of several sub systems. If any segment in any subsystem breaks down or GNSS satellites break down, ComNav CORS system can detect it and send alarm to users. At the same time, it should be remote controlled and repaired as soon as possible.

Main technologies are as follows:

- GNSS satellite signal fault monitoring and alarm technology
- The ionosphere abrupt change monitoring and alarm and prediction technology
- System equipment fault monitoring and remote control technology

System can send alarm to the configured email address.

4.4.6 Multi-function data processing and service network management

To satisfy different users' requirement, ComNav CORS system can provide RTCM 2.1 pseudo-range differential data for navigation, carrier phase differential data for RTK solution and RINEX V2.0 data with any time interval for precision positioning. These data should be sent to different data transmit equipment after data shunting. At the same time, they should also be store into database.

In addition, this system will compress, encode, encrypt, store, query, modify and update raw observation data and CORS products. Thus, the technology used in processing center is one of the most important technologies.

4.4.7 Reliability of system

ComNav CORS system is designed according to the high standards to insure the well function. The main technique is that increasing the number on reference stations, the redundancy of observation and key equipment, the fault-tolerant ability of the software and the monitoring capability of the whole system.

Chapter 5 Construction and Standard of Reference Stations

5.1 Site Selection

The suitability of a site for a CORS installation is dependent on many factors. Firstly, need to make a survey for the site and surrounding environment. Secondly, construct a temporary station and collect the observation continuously for 24 hours. Thirdly, make a observation data quality analysis to check this station.

5.1.1 Environment Survey

For selecting a suitable site, we need to do the comprehensive consideration for the environment. The following is the list for all factors.

Site Environment Survey

- Site must be safe and stable so that can be long-term preservation. And the site should be easy for construction of pillar and the antenna installation. In addition, the transportation should be convenient.
- Site should be based on solid geological conditions, far from geologically unstable area, such as fault fracture zone, prone to landslides, subsidence, etc.
- Open view of the sky, the site should be no obstructions above 10° above the horizon of the antenna.
- The distance need to be more than 200 meters with the ground object that can produce multipath effect, such as Water and metal reflective surfaces.
- Far away from the signal interface area and high voltage transmission line, such as UHF power radio, television tower.
- The site should be safe, such as guard against theft, defending breakage.
- If there are new buildings around or may grow up trees shade environment in the future.
- If there is lightning protection zone, the lightning rod, ground the flash device, etc. near the site.
- Save all information and photos to site environment survey table

Observation room environment

- The observation room shouldn't be damaged or re-construct in the following years.
- The distance between observation room with pillar is less than 70 meters.
- If there is a 220 v AC power supply of safe and reliable.
- The site has operator network access
- The site should have air conditioning, fire extinguishing, anti-static floor and other facilities.

- Whether meet the requirements of rack placed space, determine the cabinet in the location of the observation room.
- Whether reserved in observation room threading pipe.
- Save all information and photos to Observation room environment survey table

5.1.2 Check the observation data quality

Construct the temporary site

Observation data quality is extreme important for site selection. Generally, we need to construct the temporary site and collect the observation data for 24 hours, then to analyze the data quality.



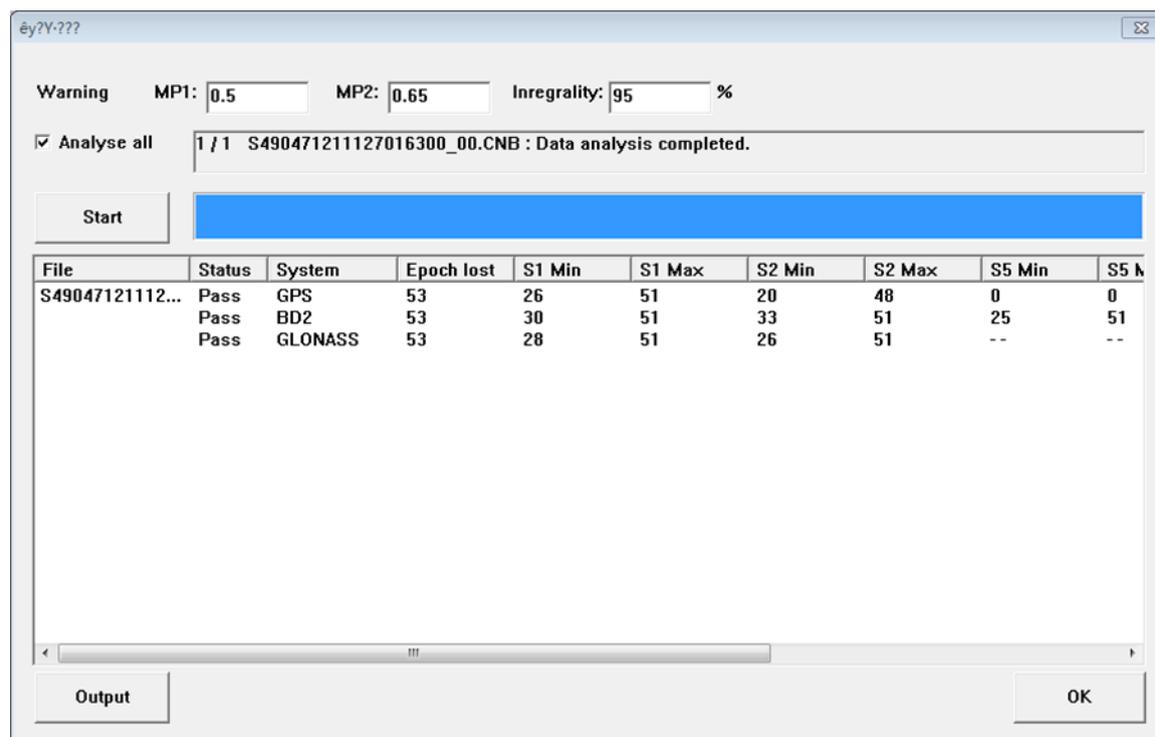
Observation data quality check

The quality of site observations can be checked by software and Compass Solution and TEQC, using long period observation data. The main items are the data integrity, MP1, MP2 and Cycle slips etc. For every station, need to save the raw data and enter the all result into data quality check table.

TEQC Result

	first epoch	last epoch	hrs	dt	#expt	#have	%	mp1	mp2	o/slps
SUM 16	4 19 01:35	16 4 19 10:05	8.508	30	14845	13925	94	0.44	0.39	4642

Compass Solution



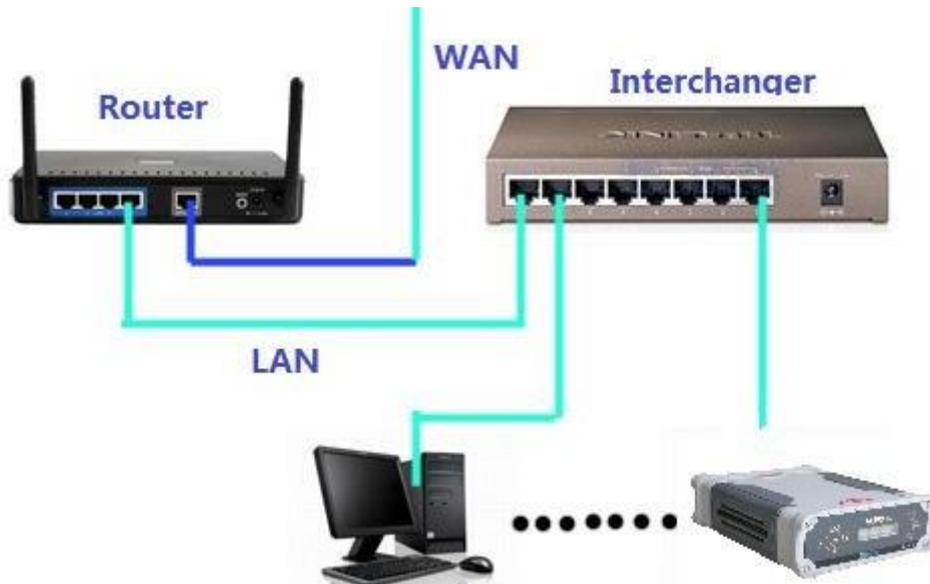
First, the site for a reference station needs a good observation environment. Sky visibility from the CORS antenna location must be adequate to support the intended applications of the facility. The antenna should keep away from constructions that will cause multipath effects, e.g., tall buildings, trees and water, and should have a better than 10 degree elevating angle of satellites visibility conditions. Also, a CORS receiver antenna should be in an environment that is free of radio frequency interference. GNSS users have problems when attempting to collect data in the presence of conflicting signals. Problematic signals might originate from facilities such as microwave broadcast antennae or, if located close enough, from transmission facilities utilizing other portions of the electromagnetic spectrum. The quality of site observations can be checked by software TEQC, using long period observation data.

Second, the site for a reference station needs a stable geological environment. The antenna must be installed on stable blocks and keeps away from fault zone, landslides areas and subsidence areas. The flooding areas are also undesirable.

Finally, maintenance environment is also an important factor. Basic utilities such as electrical power and a telephone line or computer network connection are essential for CORS operation. Selection of a CORS installation site often involves a tradeoff between security and access. The site should be protected from casual visitation by the public. Even well intentioned visitors to the site could cause problems with data collection simply by standing too near to a CORS antenna. Although a CORS ideally requires only infrequent visitation by personnel, there will be times when the site needs to be accessed for maintenance or inspection.

5.2 Internet Access

For CORS reference station must use the stable internet to support the data transmission. The following is one method of internet access.



5.3 Hardware Component Configuration

In developing a CORS, a variety of issues pertaining to the configuration of the hardware must be addressed. These issues include the characteristics of the GNSS receiver: the antenna, model, and type; the selection of an on-site computer, if necessary; peripheral equipment such as an uninterruptable power supply, a weather station, an accurate timing reference, and miscellaneous sensors; and the mechanism for connecting the facility to the outside world, such as modem and telephone line or network connection. Issues of redundancy and reliability must be carefully considered as they will have a significant impact on many hardware-related decisions. One reference station consists of two main components: equipment shelter and observation pillar.

5.3.1 Observation Pillar Construction

Observation pillar used to support GNSS antenna. It can be installed either on bedrock or roof. PVC pipeline is preinstall in the pillar for cabling. The antenna should be protected by the radome made of wave-transmitting material. Antenna and observation pillar (monument) should be coupled by using orientating and leveling device. Following snapshots shows the installation of the observation pillar step by step.



Photo by 株式会社 F2.81/100



Photo by 株式会社 F3.21/250



Photo by 株式会社 F8.21/1000



Photo by 株式会社 F2.81/1000



Photo by 株式会社 F5.21/500



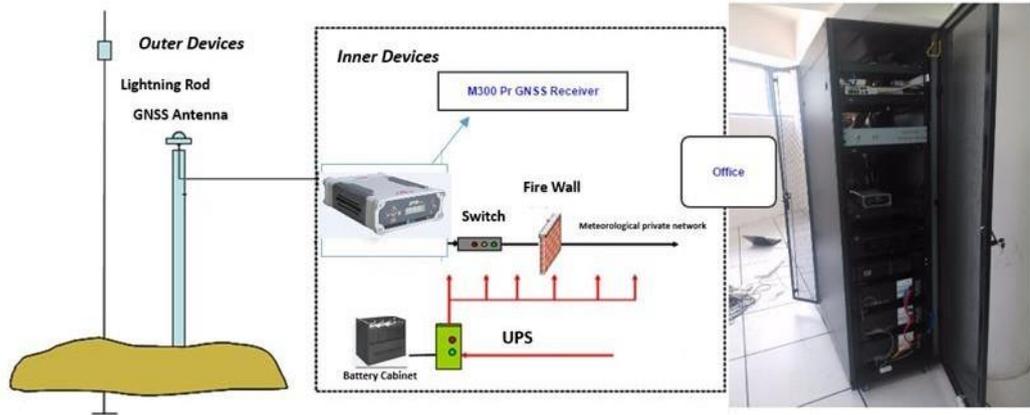
Photo by 株式会社 F4.01/167





5.3.2 Equipment shelter

The CORS installation must include a structure to house the GPS receiver and peripheral equipment. This structure provides protection from the elements and security for the equipment. If possible, an existing building near the CORS GPS antenna and monument can be utilized. Alternatively, a small field structure specifically constructed to house the equipment might be required. In either case, there may need to be some type of climate control capability in order to provide for proper operating conditions for all of the hardware components. The structure must be sufficiently close to the location of the observation pillar and antenna to allow the antenna cable to reach from the receiver to the antenna. The maximum standard antenna cable length is usually 30 meters. Longer cables exist, but often require an amplification of the signal before it is sent from the antenna to the receiver.



The necessary instruments placed in the shelter including GNSS receiver, UPS & batteries and network devices. One Cabinet of around 80cm*80cm*150cm (L*W*H) would be used to install GNSS receiver, UPS & batteries and network devices.



In order to allow for the monitoring and controlling of a CORS, as well as to facilitate transfer of the GNSS data collected, the CORS must be connected to the outside world. This connection frequently takes place through a high speed modem and telephone line. If the CORS is located in a facility with a direct connection to a computer network, such as the INTERNET or a local area network, the CORS should be directly connected to the network.

5.3.3 Lightning and surge protection

Lightning rod can protect the antenna and shelter from lightning. If lightning hits the structure, it will preferentially strike the rod and be conducted to ground through the wire, instead of passing through the structure, where it could start a fire or cause electrocution.



Besides, surge protective device should be installed on the entry point of power line, between the antenna and receiver. Following snapshots are surge protective device for power line and radio frequency cable respectively.



5.3.4 Power and UPS

For a CORS facility to provide a high level of reliability, it should be able to operate during periods of power outage. This functionality is usually provided by an uninterruptable power supply (UPS), which is always ready to provide power for the operation of a CORS through power outages up to a few minutes duration. Batteries would be able to provide more than 24 hours power backup.



Chapter 6 GNSS RTK Rover Units

6.1 ComNav T300 Introduction

ComNav T300 is the advanced multi-frequency RTK receiver, which combines lots of advantages: ultra-small and light, hot-swappable batteries and simple internal structure, etc.



RTK robust enough for challenging environments, in a device that is light and easy to carry

With decades of experience in the surveying GNSS receiver, the T300 is a product which combines lots of market proved advantages together. It can track all the working GNSS constellations. By using ComNav's unique QUANTM algorithm technology, it can function in RTK mode with all the GNSS constellations or by using any single GNSS constellation such as GLONASS or BeiDou. The strong anti-interference ability of the receiver makes it possible to work in any environment.

Design driven to improve user experience

ComNav R&D people are always thinking about how to improve the physical experience of users and workflow in the field. With this in mind, the T300 integrates a cutting edge GNSS board, Bluetooth®, UHF (Rx&Tx) into a compact board. Smart design makes the T300 the lightest and smallest (volume) receiver in the world.

Hot swap battery design

Extending the field working time is also a passion for our R&D people. They do lots

of tests and analysis to reduce the power consumption, and make the whole system work more efficiently. In parallel, they've designed in the capability to hot swap the battery source. When the warning sounds and LED flashes, put your second battery in place. Then recharge the first while you keep working.

Consumer grade batteries... always available

Losing power in the field is significantly inconvenient for users, as the batteries for GNSS receivers are often unusual types and not readily available. Once again our R&D people developed a solution so that the T300 runs on normal consumer batteries.

6.2 T300 Specification

Signal Tracking

- 256 channels with simultaneously tracked satellite signals
- GPS: L1 C/A, L1 C, L2 P, L5
- BeiDou: B1, B2, B3
- GLONASS: L1, L2
- SBAS: WAAS, EGNOS, MSAS, GAGAN

Performance Specifications

- Cold start: <50 s
- Warm start: <30 s
- Hot start: <15 s
- Initialization time: <10 s
- Singal re-acquisition: <2 s
- Initialization reliability: >99.9%

Positioning Specifications

- Post Processing Static
- Horizontal: 2.5 mm + 0.5 ppm RMS
- Vertical: 5 mm + 0.5 ppm RMS
- Real Time Kinematic
- Horizontal: 8 mm + 1 ppm RMS
- Vertical: 15 mm + 1 ppm RMS
- E-RTK₁ (baseline<100 km)
- Horizontal: 0.2 m + 1 ppm RMS
- Vertical: 0.4 m + 1 ppm RMS
- Code differential GNSS positioning
- Horizontal: 0.25 m+ 1 ppm RMS
- Vertical: 0.5 m + 1 ppm RMS
- SBAS: Typically <1 m 3D RMS
- Standalone: <1.5 m 3D RMS

Communications

- 1 Serial port (7 pin Lemo), Baud rates up to 921,600 bps.
- Radio modem: Tx/Rx with full frequency range from 410-470 MHz₂
- Transmit power: 0.5-2W adjustable
- Range: 1-4 km
- Position data output rates: 1 Hz, 2 Hz, 5 Hz, 10 Hz
- 5 LEDs (indicating Power, Satellite Tracking, Bluetooth® and Differential Data)
- Bluetooth®: V 2.X protocol, work compatible with Windows 7, Windows mobile and Android

Data Format

- Correction data I/O:
 - RTCM 2.x, 3.x, CMR (GPS only), CMR+ (GPS only).
- Position data output:
 - ASCII: NMEA-0183 GSV, RMC, HDT, VHD, GGA, GSA, ZDA, VTG, GST, PJK, PTNL
 - ComNav Binary update to 20 Hz

Physical

- Size(W×H): 15.8 cm × 7.5 cm
- Weight: 0.95 kg (include 2 batteries)

Environmental

- Operating temperature: -40 °C to + 65 °C (40 °F to 149 °F)
- Storage temperature: -40 °C to + 85 °C (40 °F to 185 °F)
- Humidity: 100% condensation
- Waterproof and dust proof: IP67 protected from temporary immersion to depth of 1 meter, floats
- Shock: survives a 2 meter drop on to concrete

Electrical

- Input Voltage: 5-27 VDC
- Power consumption: 2.85 W (3 constellations)₃
- Li-ion battery capacity: 2 × 1800 mAh, up to 8 hours typically
- Memory: 256M internal with up to 16 GB pluggable memory card

Chapter 7 Applications and Cases of ComNav CORS

ComNav CORS can provide various service items already and more applications for social services will be continuously developed in the future. This chapter introduces and analyzes these applications.

7.1 Applications types

ComNav CORS network is the infrastructure for the services of urban information management and geospatial information processing. Its application area involves surveying and mapping, territorial planning, cadastral management, engineering construction, traffic monitoring, public security, and deformation monitoring. Its users and potential users can be divided into different types.

According to real-time requirement, they can be divided into static state users and real time kinematic state user; according to accuracy requirement, they can be divided into meter level, decimeter level, centimeter level and high accurate users.

Application area	Main purpose	Accuracy requirement	Real-time requirement
Surveying and mapping engineering	Mapping, construction control	$\pm 0.01\text{m} \pm 0.1\text{ppm}$	Quasi real-time or post processing
Earth surface and building deformation monitoring	Safety monitoring	$\pm 0.001\text{m} \pm 0.005\text{ppm}$	Quasi real-time or post processing
Engineering construction	Construction, layout and management	$\pm 0.01\text{m} \pm 0.1\text{ppm}$	Quasi real-time
Geographic information update	Urban planning and management	$\pm 0.1\text{m} \pm 5\text{ppm}$	Quasi real-time
Track construction of communication, electric power, petroleum, chemical, ditches, etc.	Construction and completion surveying	$\pm 0.1\text{m} \pm 5\text{ppm}$	Quasi real-time
Ground traffic control	Car and ship trip management and navigation	$\pm 1\text{m} \pm 10\text{ppm}$	Latency $\leq 3\text{s}$

Air traffic control	Aircraft approach and landing	$\pm 0.5\text{m} \pm 6\text{ppm}$	Latency $\leq 1\text{s}$
Public security	Special vehicle monitoring, emergency affairs	$\pm 1\text{m} \pm 10\text{ppm}$	Latency $\leq 3\text{s}$
Agricultural management	Precision agriculture, land leveling	$\pm 0.1\text{m} \pm 0.3\text{ppm}$	Latency $\leq 5\text{s}$
Harbor management	Ship, vehicle and aircraft scheduling	$\pm 0.5\text{m} \pm 1\text{ppm}$	Latency $\leq 3\text{s}$

7.2 Surveying and mapping application

In accordance with the table above and the construction principle of ComNav CORS network, the current main users are in the area of surveying and mapping. The working modes of these users contain high-accuracy survey, control survey, large scale mapping, construction layout, etc.

7.2.1 High-accuracy survey

This type of users is mainly in construction surveying and deformation monitoring. Observation time: 8 hours each observation period, repeat observing 2 to 4 times in different time. More details are as follows:

Sampling rate: 30s

Instrumentation: multi-frequency GNSS receiver Processing software: Gamit, Bernese, etc.

Accuracy: baseline accuracy: 3×10^{-7}

Coverage of application: deformation monitoring, precise engineering survey, etc. Method:

1. Conduct static observation
2. Download data of the nearest reference station through internet and precise ephemeris from IGS website
3. Conduct post processing using Gamit or Bernese, etc.

7.2.2 Control survey

Control survey is an important item in surveying work. ComNav CORS can provide two types of data for control survey: real-time or 2min after event.

(1) Static mode

Static mode utilizes observation data of users and the raw synchronous observation data of the reference station to process. More details are as follows:

Observation time: 1 to 2 hours sampling rate: 15s

Instrumentation: dual-frequency GNSS receiver

Processing software: commercial software from GNSS receiver provider Accuracy: <2cm horizontal

Coverage of application: urban control survey, engineering control survey etc. Method:

1. Conduct static observation
2. Download data of ComNav CORS through internet (3 station at least)
3. Conduct baseline processing using commercial software
4. Conduct network adjustment and obtain coordinates of the control point

(2) Kinematic mode

Kinematic mode employs the RTK function of ComNav CORS system. More details are as follows:

Observation type: RTK fixed solution, 10 to 180 epochs

Instrumentation: dual-frequency GNSS receiver, GSM/CDMA/GPRS module, PDA handbook

Accuracy: <3cm horizontal, <5cm vertical

Coverage of application: urban control survey, engineering control survey etc. Method:

1. Call ComNav CORS system using GSM/CDMA/GPRS module to access, or access specified IP or domain of ComNav CORS network.
2. Keep the antenna of the rover stable to conduct initialization and get the RTK solution fixed. The time of this step will take 15 to 80 seconds, depending on observation environments and Satellite status.
3. After the RTK solution fixed, keep the antenna on the specific point and record data 3 times (180s sampling rate).
4. Calculate the precise coordinate using least square method
5. If initialization fails, move the antenna of the rover to less difficult environment to reinitialize, then move to specific points and follow the step 3.
6. If RTK fixed solution lost (change to floating solution or single-point solution), initialization for RTK solution is needed.

7.2.3 Large scale mapping

Large scale topographical mapping is an important item in surveying work. ComNav CORS can provide data for real-time kinematic surveying and mapping. More details are as follows:

Observation type:

RTK fixed solution, 5 epochs for important points

RTK floating solution, 1 epoch for common points

Instrumentation: dual-frequency GNSS receiver, GSM/CDMA/GPRS module, PDA handbook

Accuracy: <3cm horizontal for important points

<8cm horizontal for common points

Coverage of application: urban control survey, engineering control survey etc. Method:

1. Call ComNav CORS system using GSM/CDMA/GPRS module to access, or access specified IP or domain of ComNav CORS network directly.
2. Keep the antenna of the rover stable to conduct initialization and get the RTK solution fixed. The time of this step will take 15 to 80 seconds, depending on observation environments and Satellite status.
3. For common points, RTK floating solution is enough; for important points, RTK fixed solution and averaging 5 epochs is required.
4. Edit, code and store the coordinates in the field work; conduct mapping in the office work.
5. If initialization fails, move the antenna of the rover to less difficult environment to reinitialize, then move to specific points and follow the step 3.
6. If GNSS observation is unavailable due to environments, conduct control survey and set up a control point, then use conventional measuring instruments to survey.
7. If RTK fixed solution lost (change to floating solution or single-point solution), reinitialization for RTK solution is needed.

7.2.4 Construction layout

Similar to mapping, construction layout is also a main application of ComNav CORS. More details are as follows:

Observation type: RTK fixed solution, 10 epochs

Instrumentation: dual-frequency GNSS receiver, GSM/CDMA/GPRS module, PDA handbook

Accuracy: <3cm horizontal

Coverage of application: engineering setting-out Method:

Calculate coordinates of setting-out and input them into PDA handbook

Set up the instrument around setting-out area, then call ComNav CORS system using GSM/CDMA/GPRS module to access, or access specified IP or domain of ComNav CORS network.

Keep the antenna of the rover stable to conduct initialization and get the RTK solution fixed. The time of this step will take 15 to 80 seconds, depending on observation environments and Satellite status.

Follow the guide of PDA, move the antenna to the right coordinates.

Observe 10 epochs on the specific points as the result of setting-out.

If initialization fails, move the antenna of the rover to less difficult environment to reinitialize.

If RTK fixed solution lost (change to floating solution or single-point solution), reinitialization for RTK solution is needed.

7.25 GIS data collection

With the rapid economic development and urbanization, GIS data collection becomes a main application in surveying work. GIS data contains location information and property information. The navigation and monitoring applications in the industry of public security, transportation, electric power, telecommunications, oil, municipal, forestry, agriculture, etc., require emergency systems. Thus, besides location information, the information of surrounding geography, spare resources, device status, optimal path, etc., is also required to provide more efficient response in emergency management. ComNav CORS system can satisfy the requirement of GIS data collection.

(1) Post processing mode

Post processing mode collects property information and GNSS raw observation data in the field work and process the data in the office work. More details are as follows:

Sampling rate: 1 to 5 seconds per observation

Instrumentation: single or dual-frequency GNSS receiver

Processing software: commercial software from GNSS receiver provider

Accuracy: 0.5 to 1.0 meter, horizontal

Method:

1. Conduct field work, collecting property information and GNSS observation data with single GNSS receiver
2. Download ComNav CORS data through internet.
3. Process with commercial software and edit GIS topographic map

(2) Real-time mode

Real-time mode utilizes the RTD function of ComNav CORS system. More details are as follows:

Observation type: RTK floating solution, 1 epoch

Instrumentation: dual-frequency GNSS receiver, GSM/CDMA/GPRS module, PDA handbook

Accuracy: <0.5m horizontal

Method:

1. Call ComNav CORS system using GSM/CDMA/GPRS module to access, or access specified IP or domain of ComNav CORS network.
2. Keep the antenna of the rover stable to conduct initialization and get the RTD solution. The time of this step will take 15 to 120 seconds, depending on observation environments and Satellite status.
3. After getting RTD and staying for 2 to 5 seconds, GIS data collection work can be conducted.
4. If initialization fails, move the antenna of the rover to less difficult environment

- to reinitialize, then move to specific points and follow the step 3.
5. If RTD fixed solution lost (change to single-point solution), reinitialization for RTK floating solution is needed.

7.3 Other application

With the development of GNSS technology and network RTK, relative positioning technique is continuously employed in transportation, agriculture, rescue, etc.

7.3.1 Application in transportation

GNSS plays an important role in vehicle navigation. Industries of taxi, car rental service, logistics distribution, etc. utilize GNSS technology to track, schedule and manage vehicles. It can reduce energy consumption and operation cost. Civil aviation uses GNSS to help with landing, taking off and driving and parking on the land.

7.3.2 Application in agriculture

At present, developed countries have introduced GNSS technology into agricultural production, i.e., precision agriculture. This method employs GNSS to obtain farmland information including production monitoring and soil samples with location information. Computer system can decide the control measure applied to the farmland precisely including the work of fertilizing, spraying and harvesting. It can reduce the cost of agricultural production, and lower the pollution caused by fertilizing and spraying.

7.3.3 Application in rescue

Utilizing GNSS positioning technical, fire truck, ambulance and police can be efficiently dispatched. It can improve the response efficiency of dealing with fire alarm, crime, traffic jam and other emergencies. With the help of GNSS, rescuer can search and rescue in difficult environment like ocean, mountain and desert; special vehicle, e.g., Securicor, can call the police with location information once emergency appears.

7.3.4 Application in timing and frequency adjustment

1. Time synchronization for network of electricity and communication.
2. Accurate time service
3. Accurate frequency adjustment service

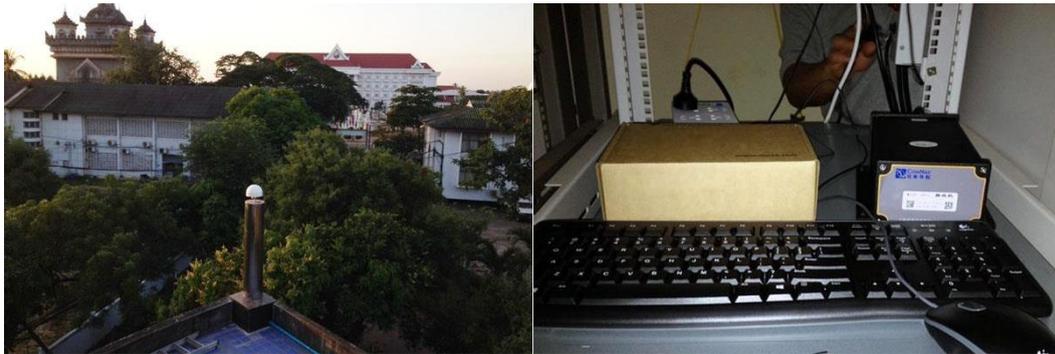
7.4 ComNav CORS Cases

ComNav M300Pro receiver has been applied in many projects of CORS station establishing. In this section, we will take three of these projects for example.

7.4.1 Laos First BeiDou CORS Station

On November 25, 2013, the Association of Southeast Asian Nations (ASEAN) established the first BeiDou continuous operation reference station in Laos, this is the first foreign BeiDou CORS reference station. This station adopts the high precision GNSS receiver (M300) which is independently designed by ComNav Technology Ltd.

The following snapshots show the observation pillar and the connection of the inner devices.



7.4.2 Single Base CORS Station in Agriculture University

Recently, ComNav performed a project of single base CORS station in the Agricultural University of China. The project adopted ComNav M300-NET receiver as the solution engine, mainly used for the BeiDou high precision navigation and positioning in the field of precision agriculture. The following snapshot is the choke ring antenna of this station, which is installed in the office roof.



7.4.3 CORS Project in the Third Traffic Information Center

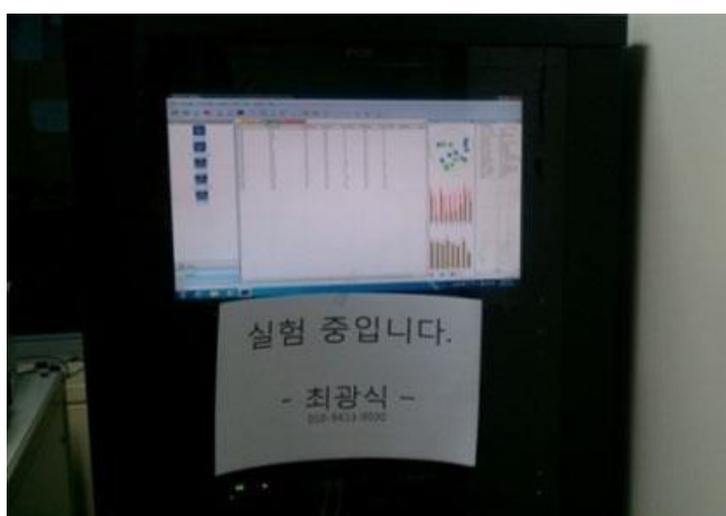
In 2013, the Third Traffic Information Center of China purchased 3 sets of M300-NET CORS receiver from ComNav, mainly used for Route navigation.

This CORS system provide high accuracy vehicle navigation service with vehicle terminal positioning device also provided by ComNav.



7.4.4 Application in South Korea CORS Center

From May 2011, after one year of research, coordination and organization SJTN lead many domestic cooperating units composed by ComNav through many challenges launched out “the Beidou demonstration system application in Korea”.



At the ICG seventh congress, Korean experts, on behalf of the overseas user, reported the whole Beidou system testing status regarding the preliminary survey data quality which was obtained highly approvals and value in the whole world. Especially the high precision receivers with Beidou technology form ComNav played an important role in this testing.

7.4.5 Application of the Beidou Radio Beacon-Differential Beidou Navigation Satellite System in East China Sea

December 31, 2013, the Beidou Radio Beacon-Differential Beidou Navigation Satellite System officially launched navigation positioning service for the coastal vessels about 300 kilometers around Daji Mountain.

According to the feedback of data analysis collected during the period of operating, the CORS system positioning precision can be within one meter, better than using GPS. In addition, the Beidou Radio Beacon-Differential Beidou Navigation Satellite System is also compatible the GPS single, which means the vessels installed differential Beidou terminal not only use the Beidou navigation system, but can use the Beidou and GPS combined system for navigation together.

What's more, with the Beidou Radio Beacon-Differential Beidou Navigation Satellite System, the navigation positioning precision of narrow waterways in harbor water has been improved effectively and better to ensure the safety of vessels.