DEVELOPMENTS IN REAL−TIME PRECISE DGPS APPLICATIONS CONCEPTS AND STATUS

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1 CURRENT SITUATION AND DEVELOPMENT TENDENCIES

In many of today's precise GPS applications it is required to obtain the coordinate results in real−time. This is in particular true for marine and airborne applications, as well as for the control of land based vehicles and machines and for modern developments in cadaster and GIS surveying. Key factor is the rapid and reliable solution of ambiguities. Powerful algorithms are available, however, they still suffer from certain restrictions. The inter−station distance is limited to about 10 km, and rapid (few epochs) solutions are not always available.

Another problem is the required data rate to transmit the necessary carrier phase corrections from the reference to the mobile station. With the RTCM−2.1 format, a data frame of more than 4800 bits is required for all−in−view, that means for twelve satellites. Most real−time high−precision applications want an update rate of one second, thus a data rate of at least 9600 bits per second (bps) is required. Only some frequencies in the radio spectrum allow such an high data rate to be transmitted reliably.

2 CONCEPTS OF GNRT−K

GNRT is the software package from Geo++ for real−time applications of DGPS. GNRT−K is an optional module to GNRT which uses the carrier phase observations. It solves for the phase ambiguities and allows sub−centimeter accuracies in real−time.

2.1 Development of RTCM++ Format

RTCM++ is an enhancement to RTCM−2.0 and RTCM−2.1. The RTCM++ extension is a compact data format for the carrier phase corrections. With RTCM++, the complete data set for all−in−view satellites requires less than 2400 bits. Thus many more frequencies are possible candidates for the broadcasting of carrier phase corrections. The RTCM++ extensions are compatible to RTCM−2.0 and RTCM−2.1 data frames, using RTCM message type 59, which is reserved for proprietary messages. The type 59 records enclose the complete information to reconstruct the code and carrier phase corrections on the mobile side. Thus, with a converter the mobile user has full RTCM−2.1 phase corrections available. Normal RTCM−2.0 code corrections remain unchanged in the RTCM++ data stream.

2.2 Technical Concept of GNRT and GNRT−K

GNRT rsp. GNRT−K were designed with the following features in view:

- *PC based, multitasking OS*
  The PC platform allows cheap and flexible hardware. The multitasking operating system OS/2 allows the integration of GNRT with commercial or user provided software.
- *Graphical user interface*
  The graphical user interface, combined with a pen driver, is useful especially in the field. Moreo−ver, it makes a keyboard no longer necessary.
- *Real time capabilities*
  are neccessary to produce reasonable response times. A predictable delay of one or two seconds between measurement and result, mostly due to delays in the receiver and in transmission paths, is in general tolerable.
- *Modular system*
  GNRT as a modular system allows to build all components of a DGPS system from its compo−nents: reference station, mobile station, precise mobile station or other special approaches like reverse or relative DGPS (see below).
- *Receiver independent*
  The receiver module is only one component in the GNRT system. For almost every receiver with RS−232 interface and programmable input/output a receiver module can be developed. Currently modules for Ashtech, Navstar, Novatel, Trimble and Zeiss are available, others, as for Leica, are under development.
- *Compatibility to standard formats*
  Today a DGPS software package has to support the standard formats in GPS and DGPS. These standards are RTCM, NMEA and RINEX, and are all supported by GNRT. With these interfaces in a multitasking environment GNRT is a very flexible system.
- *Combined ambiguity search algorithms*
  The state of the art in carrier phase ambiguity solving is a very sophisticated ambiguity search al−gorithm. GNRT−K, the phase module of GNRT, has implemented the algorithms from the well known GEONAP GPS post−processing software. It starts multiple threads simultaneously to make all information available for the ambiguity resolution.
- *Network of multiple reference stations*
  To reduce the dependency from the distance to the reference station, GNRT is prepared to use some new features of the RTCM++ format. The concept is to build a net of reference stations and compute a more general set of correction parameters. These parameters are valid not only in the near environment of the reference station, but over the whole region covered by the reference sta−tion network. The GNRT net module will be able to generate the additional parameters, and RTCM++will transport them to the GNRT mobile station. The effect is that the mobile station has corrections available as if the reference station is very close to the mobile station.

2.3 GNRT Components

The components or modules of the GNRT DGPS software system are:

- *Receiver interface*
  It collects the raw data from a GPS sensor, managing data flow from and to GPS receiver.

- *RTCM interfaces*
  It consists actually of two modules, one for input and one for output of DGPS corrections in RTCM format. All input and output is RTCM−2.0 and RTCM−2.1 compatible, all RTCM++ en− hancements are contained in message type 59 records.
- *Special purpose interfaces*
  Modules for Relative DGPS or Inverse DGPS, NMEA compatible output etc.
- *DGPS module*
  GNRT as the main module computes the GPS solution from all available information. It can be run in base or mobile station mode. If running as base station, it takes GPS observations and known base position as input and computes DGPS corrections. If running as mobile station, it takes GPS observations and DGPS corrections as input and calculates the mobile position.
- *Real time kinematics module*
  The GNRT−K module solves all ambiguities of carrier phase observations as far as possible. It starts multiple threads for optimum ambiguity search algorithms.
- *User interface*
  The GNRT system presents itself in various numerical and graphical status and control windows. It is able to run without keyboard, i.e. on pen driven notebooks in the field. The GNRT base sta− tion is remotely operable through modem or network connections.

2.4 GNRT Configurations

The GNRT modules may be combined to many different DGPS systems.

- *A Standard base station*
  operates as a local temporary DGPS reference station.
- *A Precise base station*
  adds carrier phase corrections to standard base station.
- *A Mobile station*
  allows sub−meter accuracy in real time.
- *A Precise mobile station*
  allows sub−centimeter accuracy in real time.
- *A Permanent reference station*
  called GNREF, adds RINEX data logging capabilities and integrity monitor function to precise base station.
- *A Node in reference station network*
  adds a GNREF network module to permanent reference station.
- *An Inverse or Reverve DGPS station pair*
  does all computation of mobile position on base station. Only a receiver and a radio link are re− quired on the mobile station.
- *A Relative DGPS station pair*
  allows positioning of mobile station relative to moving base station, i.e. for an helicopter landing on a aircraft carrier.

Other approaches are possible and easy to implement due o the modular system. Even existing user or third company programs on the same platform with standard input/output channels may commu−nicate with the GNRT system in real−time using pipes.

3 Examples and Results

The time needed to fix the initial ambiguities, often called the initialization time, depends on the available signals and the distance from the reference station. GNRT−K is able to fix the ambiguities "On−The−Way", no static initialization mode is required.

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Fig.1: Required Time to Fix Ambiguities (TTFA) for single and dual frequency receivers, in relation to the distance from reference station.

Some first tests showed (see Fig. 1), that for dual frequency receivers the time to fix ambiguities (TTFA) is nearly independent from the distance (tested up to 35 km) and normally better than one minute. For single frequency receivers the TTFA is acceptable only for short distances maybe up to 5 or 10 km. For longer distances the required time grows exponentially and, much worse, the esti−mated ambiguities tend to be unreliable. This will improve if reference station networks become available.

In hydrographic surveying GPS derived heights are of special importance for squat and wake deter−mination to improve the results from echo soundings. An example for real−time applications is given in Fig. 2. The precision of the height component is better than 2−3 cm. The typical wave and squat effects in the order of 10 cm are recognizable.

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Fig.2. Height Determination with GNRT−K for hydrographic surveying.

4 Conclusions

Today it is possible to get cm accuracy within a few (ten) seconds with dual frequency receivers over 30 or more kilometers in real time. Single frequency results are still restricted to short baselines (<10 km) and require less than 1 minute to get the centimeter accuracy. Future enhancements as the establishment of reference station networks will reduce the station dependent errors so that cm accuracy will be possible over more than 10 or 20 km, even with single frequency receivers.

5 References

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