II INTERNATIONAL CONFERENCE
TRANSPORT SYSTEMS TELEMATICS TST`02

ZESZYTY NAUKOWE
POLITECHNIKI ŚLĄSKIEJ 2002
TRANSPORT z.45, nr kol. 1570

GPS, DGPS, IGDGPS, accuracy requirements, data transfer, internet

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DATA TRANSFER FOR HIGH PRECISION USERS IN THE SEA, ROAD AND RAIL TRANSPORT

Telematics can be defined as the branch of information technology, which deals with the long-distance transmission of computerized information. The accuracy of position obtained from satellite navigation systems depends on the mode of data transfer also. In the new solution, IGDGPS (Internet-based Global Differential Global Positioning System) the data and corrections to the GPS broadcast ephemeris to authorized users are transmitted over the internet.

TRANSFER PRECYZYJNYCH DANYCH DO UŻYTKOWNIKÓW W TRANSPORCIE MORSKIM, LĄDOWYM I KOLEJOWYM

Telematyka może być zdefiniowana jako część technologii informacyjnych, które zajmują się transmisją komputerowych danych. Dokładność miejsca otrzymanego z systemu satelitarnej nawigacji zależy również od sposobu przesyłu danych. W nowym rozwiązaniu, IGDGPS (system oparty na internetowym globalnym różnicowym pozycjonowaniu) dane i poprawki do transmisji GPS są przekazywane do uprawnionych użytkowników przez internet.

1. INTRODUCTION

The continuous information of user's position is one of the most important elements, which determines the safety of the user in the transport. Safety of sea transport consists of safety of navigation, people, cargo and environment. The information about position is obtained the most frequently from specialised electronic position–fixing systems, in particular satellite navigation systems – American GPS (Global Positioning System – Navstar) and Russian Glonass. The new system GNSS (Global Navigation Satellite System), the system of the future will be used in aviation, sea transport and rail and road transport also [2].

Accuracy requirements of the user's position depend upon various factors which include three different levels of coverage (global, regional and local) as well as safety performance:

– essential use – safety of life,
– essential use – other applications,
– non essential use.

The user applications summary is presented in the table 1, the summary of accuracy requirements in the table 2. It is recognized that the categorisation are some what subjectively

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based on current capabilities and may change, particularly if dependence on GNSS increases, the applications may move from Non–essential to Essential. Also the distinction between local and regional is not always clear [7].

2. DATA TRANSFER IN DIFFERENTIAL MODE OF GPS

Differential GPS (DGPS) services have been developed in response to inherent and previously imposed limitations of GPS (horizontal circular error with 95% confidence level – 22.5 meters). In the sea transport for the civil users (receiver L1, code C/A only) it is not sufficiently accurate to meet the stringent requirements of navigation in harbours and their approaches. The fundamental principle of DGPS technology is the comparison of the position of a surveyed point, referred to as the reference position, with absolute positions obtained from GPS receiver at that point.

Table 1

User applications summary

Coverage	Safety criticality		
	Essential		Non essential
	Safety of life	Other	
Global	Aviation Marine: Oceanic SAR	Timing and frequency Fisheries – deep sea	Recreational
Regional	Aviation Marine: Coastal phase Road: Safety and security Collision avoidance Rail: Train location and control	Rail: management information Road: Fleet management Land survey Marine survey	Road: Information services Navigation Demand management Rail: Passenger information
Local	Aviation Marine: Harbours Inland waterways Rail: Train location and control	Marine: Dredging Hydrography Tracking personel and containers	Road: Traffic control

Table 2

Summary of accuracy requirements [m]

Coverage	Essential		Non essential
	Safety of life	Other	
Global	10 – 100	10 – 100	10 – 100
Regional	1 – 10	1 –10	1 –10
Local	0.1 – 10	0.01 – 10	0.03

The pseudorange technique used in DGPS receivers for the sea users involves computing a unique correction (Pseudo Range Correction – PRC) to the range of each satellite observed at the reference station but does not necessarily require all of the same satellites to be ones used by the mobile observer. Investigations of transmitting the pseudoranges corrections to the user, identified medium frequency marine radiobeacons operating in the 283.5 – 325 kHz (MF band) as the most suitable terrestrial method for use within the coastal zone. An American correction message format known as RTCM SC 104 has become the internationally standard for encoding DGPS corrections [1].

The results of measurements of several hundred thousands DGPS positions fixed by several different types of DGPS receivers with different reference stations performed in Gdynia (on Baltic Sea) in different ports in Europe and America are demonstrated in [4].

DGPS secures the continuos positions with accuracy of few metres for the mariner users. The results of using of DGPS with or without S.A were practically the same in maritime navigation. By chance, the measurements were realised during the last days of April 2000 and during the first days of May 2000, i.e. with and without Selective Availability (S.A. was switched off 2 May 2000). As a result we can say univocally, that the accuracy of DGPS positions obtained during all this period was the same.

Accuracy of DGPS position depends on the parameters of the receiver (its antenna and cable), the distance from the reference station, the "quality" of this station, the DGPS correction type number (1 or 9), the age of corrections and the suppleness of the user's receiver to electromagnetic interference and radio noise. In each port the user must take the probability of disturbances in the reception of signals from satellites and reference station into consideration.

As the DGPS position accuracy decreases with the distance from the reference station, the effective range of these stations is 100 ÷ 200 nautical miles only. That's why the new DGPS systems using geostationary satellites have also been developed. A network of reference stations provides the pseudorange corrections, which are transmitted to the satellites for broadcasting to users. The coverage of the satellite broadcast is very much greater than MF radiobeacons and the "range" of the system is only constrained by the distance from the reference station over which the derived corrections remain valid.

For land navigation and transport (cars, railway etc.) the satellite navigation systems as GPS, Glonass or Galileo are (at present) or will be (in the future) an additional positioning system only. The position of trucks and trains can be obtained from few other method; uninterrupted information about latitude and longitude of these vehicles is not one of the most important elements of the safety, on the contrary to the safety of navigation in the sea transport [3]. The information about actual position of the vehicle obtained from satellite system can be immediately transmitted to the center, to the master control station etc.

3. DATA TRANSFER OVER INTERNET – IGDGPS

Many commercial, civilian, scientific and military applications require precise (decimetre accuracy or better) real–time, onboard knowledge of receiver's position and velocity as a critical component. Real–time kinematic (RTK) techniques have enabled decimetre–level (and better) real–time GPS–based positioning, but with a few kilometres local range scale only. For regional applications satellite–based augmentations systems as Wide Area Differential GPS (WADGPS) and various commercial differential systems can be used. But global (ground and airborne) real-time positioning at the decimetre level has never been attempted nor achieved due to the perceived technical and cost challenges.

The solution of this problem – two parameters at the same time – very high position accuracy and global coverage, is new system – IGDGPS (Internet-based Global Differential GPS). This is a uniquely powerful and flexible C-language software package that provides a complete end-to-end system capability for GPS-based real-time positioning and orbit determination. The features of IGDGPS are [8]:

- 10 cm horizontal and 20 cm vertical real time positioning accuracy with dual frequency GPS receivers,
- 5 cm – level real time orbit determination for low Earth satellites carrying dual frequency GPS receivers,
- the most precise and complete set of geodetic, satellite dynamics, and GPS measurements models for uncompromising accuracy,
- dual mode application: dedicated software used to compute GPS orbit and clock corrections and, embedded, for user positioning/orbit determination,
- valid corrections anywhere in the world or in space,
- Internet-based correction dissemination,
- software proven operationally in a number of critical.

The fundamental tenet of the Global Differential GPS (GDGPS) is a "state-space" approach in which the orbits of the GPS satellites are precisely modeled and the satellite epoch states, thus guaranteeing that the corrections will be global and uniformly valid. In contrast, at present most differential systems employ a "measurement-space" approach, where the estimated parameters are the user local range errors. These errors depend on the user's position local relatively to the reference network.

IGDGPS is geared toward users carrying dual-frequency receivers. These high-end users typically require high-accuracy positioning. Having eliminated the ionosphere as an error source using dual-band receivers, these users are still susceptible to errors in the GPS ephemeris and clocks. Ground-based users (marine, rail and road transport) and aircraft (aviation) must also deal with errors due to the troposphere. At present (July 2002) there is one civil GPS frequency (L1 = 1575.42 MHz) only. The situation will improve in 2003 with launch of the first IIR-M satellite with the new civil signal on L2 (1227.6 MHz). When the first satellite IIF satellite is launched in 2005, the number of civil signals will increase to three by addition the L5 (1176.45 MHz) [5].

3.1. DATA PROCESSING

Accurate correction for the GPS ephemeris and clock errors requires a network of GPS reference sites. With Global Differential GPD architecture, a well distributed global network of about a dozen sites is sufficient for continuously providing GPS ephemeris and clock corrections for GPS satellites. For this purpose NASA Global GPS Network (GGN), which is operated and maintained by Jet Propulsion Laboratory (JPL), was used. The GGN consists of approximately 60 dual-frequency GPS geodetic reference stations, operates as a component of the International GPS Service's GPS network. Data from the GGN are normally downloaded in batch mode, but to support a variety of NASA missions with low data latency requirements, the GGN is being upgraded to provide GPS data in real time over the open internet. That's why a subset of the GGN is equipped with computers and internet connection.

Internet-based data communications were chosen over the more conventional telephony-based communications primarily for reason of its significant economical advantage.

IGDGPS has been designed to return all GPS data in real time from remove receivers. IGDGPS collects, edits and compresses the raw GPS observable at the remote site. It then transmits the packetized data over the open internet (227 bytes/second) to the processing center – the central data daemon. A daemon is a computer program that runs continuously and exists for the purpose of handling periodic service requests. At this center the global data is analysed by IGDGPS to produce precise GPS orbits and clocks. These are formatted as global differential corrections to the GPS broadcast ephemeris, encoded and are provided over the internet (560 bit/sec message) to authorized users.

In addition to produce the differential corrections, IGDG supports the end user with a module for onboard, autonomous user positioning and orbit determination. In this mode IGDG combines the correction message and the user GPS observables to provide precise estimates of the user position, tropospheric delay and the receiver's clock estimates. For users with known dynamics (spacecraft) IGDG performs precise orbit determination constrained by the platform's dynamics through a form of Kalman filtering. For the users with unknown dynamics (vehicles, airplanes) IGDG provides unconstrained kinematic positioning [6].

The GDGPS system has been operated at JPL since November 1999 with automated distribution to approved users via the Internet.

The comparison of capability of GPS and its two modes – WADGPS and IGDGPS is presented in the table 3.

Table 3

Comparison of GPS, WADGPS and IGDGPS

Capability		**GPS**	**WADGPS**	**IGDGPS**
Coverage	Global	+	–	+
	Seamless	+	–	+
	Space	+	–	+
Accuracy	Kinematic applications	5 m	> 1 m	0.2 m (demonstrated 0.1 m (projected)
	Orbit determination	1 m	–	0.01 – 0.05 m (projected)
Dissemination method		Broadcast	Broadcast	Internet/broadcast
Targeted users		Dual frequency	Single frequency	Dual/frequency

4. CONCLUSIONS

The new generation of GPS satellites (IIR–M and IIF) with the second and third civil frequency permit the users to profit from dual-frequency receivers. The global differential corrections will be transmitted over open internet, to provide very high position accuracy and global coverage, which (IGDGPS) will be accessible in aviation, sea transport and rail or road applications.

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