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LOCAL AUGMENTATION IN GNSS

GNSS usability and reliability in transport telematics applications can be improved by local augmentation systems. GSM/GPRS or other radio-data network can be utilised. Algorithms of augmentation and integration of current GPS and prepared European Galileo system are developed and tested using the Experimental GNSS receiver based on the SDR principles and FPGA technology.

LOKALNE WZMOCNIENIE GNSS

Użyteczność i niezawodność GNSS w zastosowaniach telematyki transportu może ulec poprawie poprzez lokalne systemy wzmocnienia. Można wykorzystać GSM/GPRS oraz inne sieci danych radiowych. Algorytmy wzmocnienia i integracji bieżących GPS oraz przygotowywanego europejskiego systemu Galileo są opracowywane i testowane za pomocą eksperymentalnego odbiornika GNSS opartego na zasadach SDR i technologii FPGA

1. INTRODUCTION

The global satellite position determination system GPS (NAVSTAR) is well known as the most important global navigation satellite system (GNSS) in the world and it is utilized in many logistic and telematics applications. Modernization of the GPS signal spectrum and services and initiation of European satellite system Galileo improve quality of GNSS services

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in future years. On the other hand, using new signal modulation methods and intersystem integration cause necessity of new signal and data processing methods development.

GNSS usability and reliability in transport telematics applications are limited due to difficult signal propagation mainly in hilly terrain or in urban areas. Therefore, methods for GPS support by local infrastructure are developed. Utilization of GSM/GPRS data channel for GPS/GNSS augmentation techniques and preparation of suitable platform based on FPGA technology for algorithm testing is main aim of the paper.

2. GNSS AUGMENTATION

The reachable GPS (generally - GNSS) performance for most of civil users is limited and not sufficient for some applications. Precision and other performance parameters of the system may be improved by differential measurement methods (DGPS). These improvements arise because the largest measurement errors are strongly correlated over distance and vary slowly with time. The differential system accuracy is limited by residual errors only, i.e., mainly by residual atmospheric signal refraction and multipath effect. The typical precision of determined position varies from sub-centimeter levels to several decimeters or meters depending on type and quality of used DGPS technique and quality of GPS signal receiving and processing.

Reliability and safety of GNSS services in terrain with poor signal coverage can be improved by Assisted GNSS technique, which is based on local transmission of supplementary information (ephemeris, signal samples) that is usable for processing of weak and discontinuous GNSS signal. The differential and augmentation techniques can be combined on common local mobile data channel (e.g. GPRS).

2.1. DGNSS VIA GPRS AND INTERNET

In recent years, several applications for DGPS data transfer via Internet were developed and published but none prevailed because they usually used their own closed proprietary protocols and unique transmission channels.

The concept of common systems can be divided according to the transmission method into two main groups:

- Dedicated connection between DGPS data source and rover (P2P connection)
- Use of data replicators or streaming servers for corrections data

The first solution is based on creation of dedicated direct connection between reference station or DGPS corrections generator and user receiver. This connection is based for example on telnet application or similar peer to peer (P2P) applications. Its limitations are obvious: The separated connection and transmission channel has to be established for each pair reference station – user receiver. Moreover, in case of failure of the reference station operation the user receiver is left without up-to-date corrections. The advantage of this concept lies in its simplicity of realization.

The second concept uses a block in the middle of reference station – rover connection [4, 3]. This block collects DGNSS stream from several reference stations and distributes these streams independently to user receivers. Its philosophy of operation is similar to data and media streaming known from Internet radios. Since data rates for DGNSS corrections are much lower when compared to commonly streamed multimedia data, the concept of Internet radio can be successfully used. Much more user receivers can be provided with the data than in case of dedicated connection. The user can choose from various reference stations and thanks to these multiple sources of DGNSS corrections the data will stay available even after failure of some of reference stations.

Nowadays, the widely used method of streaming DGNSS data seems to be NTRIP (Networked Transport of RTCM via Internet Protocol) developed by Federal Agency for Cartography and Geodesy of Germany (BKG). This protocol is used for DGNSS data streaming in the EUREF-IP network [1]. NTRIP is a generic, stateless protocol based on the Hypertext Transfer Protocol HTTP/1.1 and is enhanced to GNSS data streams. The NTRIP concept consists of three main building blocks: NtripClient, NtripServer and NtripCaster. The NtripCaster operates as a real server or splitter (HTTP) based on the GNU General Public License developed by Icecast software that was originally developed to stream MP3 data. The programs NtripClient and NtripServer act more like clients according to the classical Internet communication that is usually based on the classic server-client principle (one or more servers share resources with users within a network). The NtripServer processes data from reference station and serves them to NtripCaster. NtripClient at the user side provides data from NtripCaster to user receiver. The communication between NtripServer and NtripCaster as well as NtripClient and NtripCaster is fully compatible HTTP 1.1. The transmitted data can be DGNSS corrections, RTK corrections according to the RTCM standard or even raw GNSS data.

The common advantage of DGNSS data transmission via Internet resides in its independence on the physical realization of the reference station – user receiver connection. It can combine solid metallic or optical transmission lines with mobile technologies, e.g. cellular radio (GPRS, EDGE) or UHF channel.

2.2. ASSISTED GNSS

The birth of assisted GPS (AGPS) techniques was be induced by requirement of continuous and reliable position measurement in case of difficult conditions of GPS signal reception. The AGPS techniques are intended for indoor applications (e.g., localization of persons) or difficult outdoor applications (e.g. cars or trains localization and navigation in heavy terrain or highly urbanized areas). These techniques are now used in GPS, but it may be generalized for other systems (Galileo, GLONASS) and they may be called Assisted GNSS (AGNSS).

The AGNSS techniques are based on the cooperation of the specialized user GNSS mobile equipment with a localization server in GNSS reference station. A specialized receiver in the mobile equipment provides sophisticated signal processing of a residual GNSS signal, which is received in cases of indoor or weak signal applications. The residual signal does not contain all the information, which is necessary for the position computing. The required part of the GNSS signal may be received by the GNSS reference station and may be delivered to mobile equipment by appropriate data link. The GSM-GPRS data channel may be used for realization of this interconnection between the mobile equipment and the localization server.

The GNSS signal carries data with satellite ephemeris and other information, which are necessary for the position computing. These data are transmitted by satellite periodically (with the 30-second's period for GPS). Consequently, the time interval from start of receiving to first measured position availability (time to first fix - TTFF) cannot be shorter than several tens of seconds in case of classical GPS techniques. If the GPS signal quality is poor and the reception is inconsequent (this is typical for mobile applications in an urban area), the time of error-free ephemeris acquirement may be prolonged to tens of minutes. However, the ephemeris can be delivered to mobile equipment by GPRS data channel of AGNSS system in the time of several seconds only. The TTFF may be shorted dramatically due to this technique.

The transmission of the ephemeris data is not one and only AGNSS technique. The signal correlation search process, which is typical for GNSS signal processing, may be shorten essentially by the prior signal phase estimation obtained from the reference station or from the location server. Nevertheless, the AGNSS receiver hardware usually contains specially constructed circuits for correlation searching of very weak GNSS signals.

Although assisted GNSS (AGPS) and differential GNSS (DGPS) are superficially similar, since in both technologies signal processing are enhanced using information from terrestrial infrastructure, they differ in the essentials. DGNSS increases the location accuracy of conventional GNSS, but does not increase the sensitivity of GNSS receivers. AGNSS improves the performance of conventional GNSS receivers in low-SNR conditions, and can be combined with DGNSS to increase the position accuracy as well.

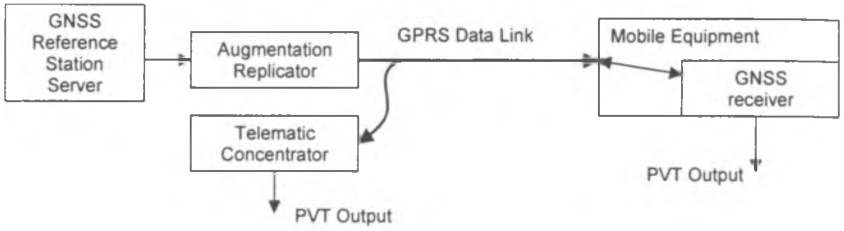

Fig.1. Assisted GNSS concept with position processing at mobile equipment side

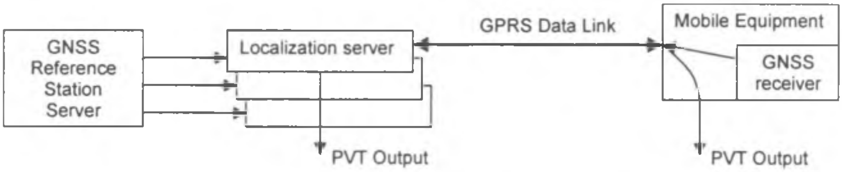

Fig.2. Assisted GNSS concept with position processing at location server side

The AGNSS signal processing presents a complex problem, which requires extreme hardware requirements. This problem can be solved effective by relocating of selected parts of position computation from mobile equipment to terrestrially located server. This relocation may save energy-intensive demands of mobile equipment, especially in case of limited battery sources in this equipment. This disposition (see Fig. 2) is advantageous for experimental and development works, because of easy development and testing possibilities of frame of location server.

2.3. ADAPTATION OF GPRS CHANNEL

The differential techniques are based on processing of measurement records from twice of GNSS receivers – user receiver and reference receiver. Consequently, a data communication channel is a necessary part of each real-time differential application. The Internet or various local networks present a chance of perspective data channels with relative sufficient technical and economical parameters for DGNSS purposes at present. The General Packed Radio Service (GPRS) of GSM network may be used for interconnection between stationary networks and mobile DGNSS users. .

The data stream between location server and mobile equipment is divided into GPRS packet series. The UDP or TCP layers of Internet network model can be used for DGNSS/AGNSS purposes. The TCP layer ensures the reliable deliverance of carried data, however it result in a greater data load and longer latency delay in case of bad transmission conditions. The UDP layer allows to sending separated datagrams. This technique is simple, it is not reliable at all (about 1-10 % of datagrams may be lost typically), but it is preferable in the real-time conditions. The most of existing Internet DGPS systems is based on the UDP layer, although the using of the TCP layer is easy.

The position computation delay T_P is a key parameter of the AGNSS system. It is given as an interval from receiving of the GNSS signals to obtain the corresponding position data. We assume that the AGNSS data is transferred from mobile equipment to location server and the position information is used on the location server side of GPRS channel. The position computation delay T_P can be obtained by equation

$$T_P = t_m + t_{dat} + t_d + t_C$$

The t_m is the delay of measurement process in GNSS receiver. It depends mainly on the size of measurement's window implemented on this receiver (typ. 0.1 s) and on the time for the received signal preprocessing. The t_{dat} is the delay necessary for filling up the outgoing datagram by measurements from several measurement's periods. This delay depends on the required outgoing datagram size. If we will transmit data from each measurement in separate datagram, this delay will be zero, but the data overheads increases and the system economy will be impaired. The computation delay t_C depends on the numerical power of the location server, which provides the position computation (typically < 1 sec).

The t_d presents the delivery delay of the GSM-GPRS network for one UDP packet. This delay depends partly on the length of the datagram, but it depends on the many factors of the GSM network state, too. In the fig 3, the measured results of the delivery delay in the GSM network are presented in dependence on the interval Δt between datagram sending. The delay for $\Delta t < 1.5\,\mathrm{sec}$ is a little worse, mainly in the aspect of variance. Due to, we recommend making the interval between datagram $\Delta t \geq 1.5\,\mathrm{sec}$.

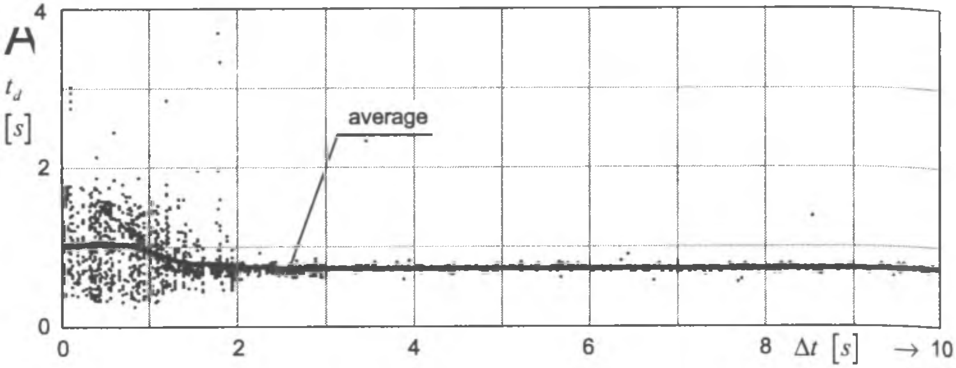

Fig.3. GPRS/UDP delivery delay from mobile unit to server in dependence on datagram transmission period

2.4. INTEGRATION OF GALILEO SYSTEM

The prepared European system Galileo is planned for initial use in telematics applications in the course of 2008. The system will provide additional commercial and others services in comparison to current GPS. The system will be usable independently on GPS, but the Galileo-GPS interconnection in user equipment will be very desirable in transport telematics applications, mainly in rugged signal conditions in high-urbanized areas and mountainous terrain. The main effect of interconnection results from increasing quantity of all usable satellites up to 50-60.

Simple variant of Galileo+GPS receiver usable for undemanding telematics applications will contain standard radio-frequency part for current GPS L1 band comparable with present GPS modules, but it will require significantly reinforced DSP part for Galileo signal processing and for integrated PVT algorithms implementation. Next demand on DSP power will be given by implementation of Assisted algorithms (AGNSS).

3. REALIZATION OF GNSS RECEIVER

Assisted GNSS techniques allow GNSS utilization in poor signal quality condition, but they are very complex and demanding for development and testing. Therefore it is needed special powerful multi-frequency GNSS receiver, which enables effortless access and modifications of low-level signal and data processing algorithms. It is advisable to be prepared for processing of present and future modernized GPS signal, fundamental part of Galileo signal budget and GLONASS signal accessible for civil users. From these reasons the Experimental GNSS receiver has been developed at the Czech Technical University in Prague.

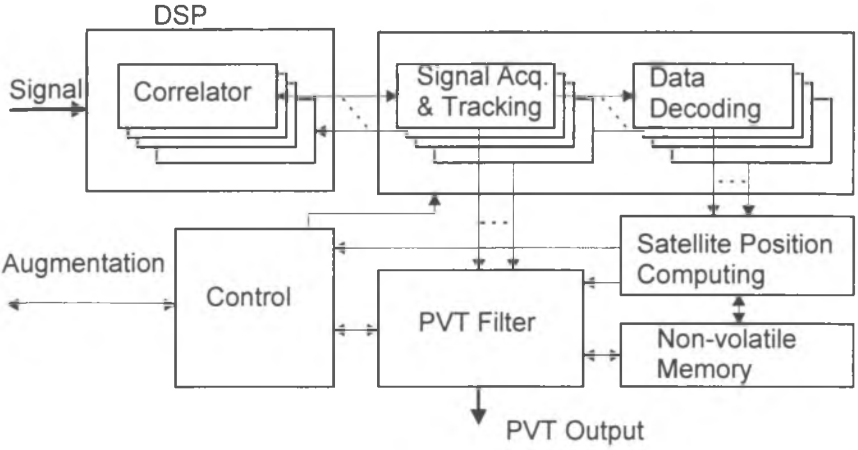

Fig.4. Data flow diagram of designed GNSS receiver

The Software Defined Radio (SDR) concept and embedded processor in FPGA device was chosen for design and development of the receiver. The main aim of the design is to provide flexible and versatile platform for implementation, testing, and verification of GNSS signal processing algorithms. The receiver should serve also as a highly configurable device for GNSS signal measurements and tests. To achieve these requirements the modular concept of the receiver was chosen.

Generally, the receiver consists of two main parts: RF unit and DSP unit. The RF unit consisted of four channels, providing down converting of wide-band analogue signals from L-band to DSP unit. The DSP unit was based on Xilinx FPGA Virtex-II Pro device with two embedded IBM PowerPC PPC–405 cores. That platform enables single chip integration of all digital processing parts, i.e. correlators and computer for tracking and navigation task resolving. For achieving higher reliability of the whole system, the true real time multitasking operating system is chosen.

Moreover, the number of RF channels was increased to four due to expected modernization of the GNSS systems, where the new GPS and GLONASS signals on the new frequencies will be available. The receiver should process these signals simultaneously. The RF channels are unified to keep the simplicity and compactness of the receiver. Each channel is equipped with SAW intermediated frequency (IF) filter of unified bandwidth 24 MHz. The intermediate frequency is increased to 140 MHz. It ensures higher suppression of undesirable signals on the mirror frequency. The resolution of the analogue to digital converters will be 8 bits. The sampling frequency is designed 80 MHz. Such frequency can be easily derived from high-stable 10 MHz normal by frequency multiplication.

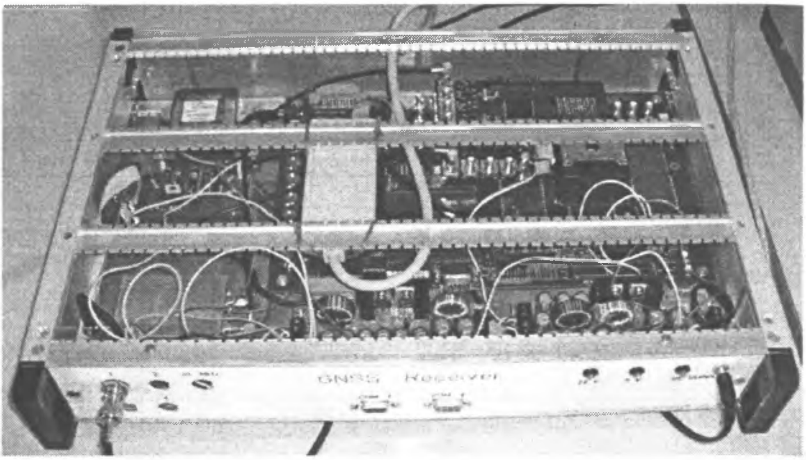

Fig.5. Realization of Experimental GNSS receiver

3.1. RECEIVER DESIGN VALIDATION

Experimental receiver design was successfully tested by project of standard fully parallel GPS receiver for L1 band and C/A code. Projects of GLONASS signal processing and very fast EGNOS signal detection [2] have verified suitability of the platform for untypical applications with huge requirements of signal processing power.

4. CONCLUSION

Differential and Assisted algorithms for GNSS signal processing allow improvement of accuracy, reliability and safety of GNSS in transport telematics applications, mainly in hard condition terrain with poor GNSS signal coverage (high-urbanized zones, mountains). Launch of modernized GPS signal budget and European Galileo systems within several years raises the chance of local augmentation methods and increases requirement on the used data channel for augmentation. The advantage of independent transmission media (Internet) with combination of fixed and mobile transmission technologies (especially GSM-GPRS) can be utilized for the local augmentation and its capacity redundancy is sufficient for requirements in next years.

The Experimental GNSS receiver is developed at the Czech Technical University in Prague. The receiver is suitable for local augmentation algorithms design and testing. This receiver design was based on the SDR concept and Xilinx FPGA Virtex-II Pro device and was successfully tested in the GPS, GLONASS and EGNOS signal processing. The receiver seems to be prepared for future applications associated with launch of European Galileo system in transport telematics applications.

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