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Libor SEIDL[1]
Pavel KOVÁŘ[2]
Martin VIČAN[3]
Petr KAČMAŘÍK[4]
František VEJRAŽKA[5]

EXPERIMENTAL GNSS RECEIVER

At the Czech Technical University in Prague the Experimental GNSS Receiver based on Software Defined Radio Architecture has been developed. The receiver is determined for research and development of new GNSS signal processing algorithms including massive parallel processing for navigation in urban area with low quality signal coverage and for the study of new forms of the GNSS signals during the early phase of the GALILEO mission. As a first step the ability of weak signal processing in indoor environment was tested.

EKSPERYMENTALNY ODBIORNIK GNSS

Na Politechnice Czeskiej w Pradze opracowano Doświadczalny Odbiornik GNSS oparty na Zdefiniowanej Komputerowo Architekturze Radiowej. Odbiornik jest przeznaczony do badania i opracowania nowych algorytmów przetwarzania sygnałów GNSS, włącznie z masowym przetwarzaniem równoległym do nawigacji w obszarach miejskich, w zasięgu sygnału niskiej jakości oraz do opracowania nowych form sygnałów GNSS w czasie wczesnych etapów prac nad GALILEO. Jako pierwszy krok przetestowano możliwość przetwarzania słabego sygnału w zamkniętych pomieszczeniach.

[1] Czech Technical University, Faculty of Electrical Engineering, Technická 2, 166 27 Praha 6, Czech Republic, seidl@feld.cvut.cz
[2] Czech Technical University, Faculty of Electrical Engineering, Technická 2, 166 27 Praha 6, Czech Republic, kovar@fel.cvut.cz
[3] Czech Technical University, Faculty of Electrical Engineering, Technická 2, 166 27 Praha 6, Czech Republic, vicanm@fel.cvut.cz
[4] Czech Technical University, Faculty of Electrical Engineering, Technická 2, 166 27 Praha 6, Czech Republic, kacmarp@fel.cvut.cz
[5] Czech Technical University, Faculty of Electrical Engineering, Technická 2, 166 27 Praha 6, Czech Republic, vejrazka@fel.cvut.cz

1. INTRODUCTION

Global Navigation Satellite Systems (GNSS) represent an essential part of typical telematic system – localisation sensor. The GPS system is the most widespread Global Navigation Satellite System, it is the only one fully applicable global satellite position determination system on the world at present. Availability and reliability of the GPS measurement is affected by the GPS signal propagation conditions in the neighbourhood of the user equipment.

The direct radio-visibility of satellites is unreachable or problematic for many of terrestrial GPS applications, mainly for indoor or highly urbanized area and under vegetation cover. Additional GPS signal attenuation is about 10-15 dB typically in dense forest; the attenuation measured in indoors exceeds 20-35 dB. The GPS weak signal receiving and processing becomes very difficult in such environments and it requires special construction of radio-frequency part, frequency base and mainly DSP part. The significant advance of the GNSS usability in the difficult environment is expected from integration of the GPS with the other GNSS systems. The new European GNSS system GALILEO is planed to be usable in 2008 and presents an extension of the current GPS satellite segment to the 54-60 satellites. The integrated GNSS system GPS+GALILEO will be more reliable due to better signal coverage and the safety and integrity improvement.

Development of the new European GNSS system GALILEO, modernization of the GPS, and implementation of augmented systems WAAS and EGNOS require new approach to investigation of the signal processing in the receiver. At the Czech Technical University in Prague the Experimental GNSS Receiver based on Software Defined Radio (SDR) Architecture has been developed. The receiver is determined for research and development of new GNSS signal processing algorithms including massive parallel processing for indoor navigation and for the study of new forms of the GNSS signals transmitted during the early phase of the GALILEO mission.

2. RECEIVER ARCHITECTURE OVERVIEW

The receiver architecture is based on the Software Defined Radio philosophy because of its versatility, easy modification of implemented algorithms and ability to fit to changes in the signal structure during the development phase of the navigation system.

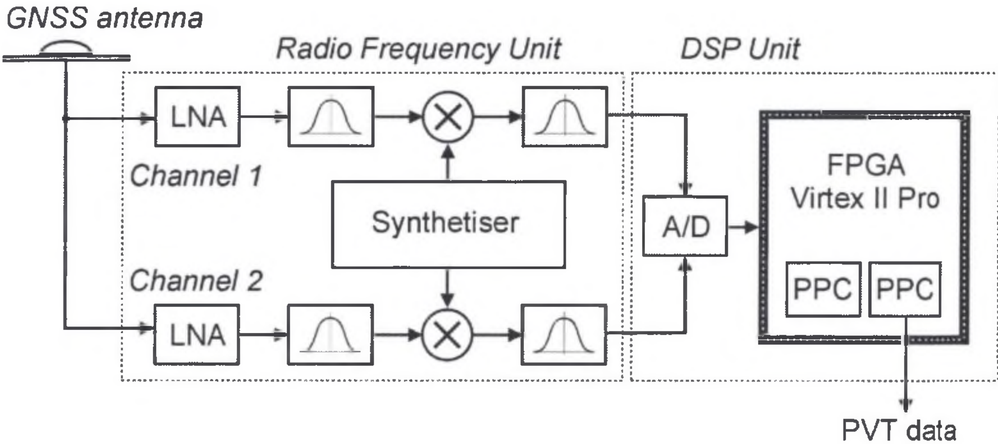

Fig.1. Experimental GNSS Receiver architecture

The receiver consists of two units: the Radio Frequency Unit (RFU) and the Digital Signal Processing Unit (DSP). The RFU contains two independent equivalent channels; each channel can operate at any frequency in the frequency band from 1 to 2 GHz. The bandwidth of each channel is adjustable. The gain of the receiver can be controlled either by AGC (Automatic Gain Control) loop, or via external input signal by DSP. The output immediate-frequency wide-band signal (122-158 MHz) is sampled by 8-bit A/D converter with very low jitter.

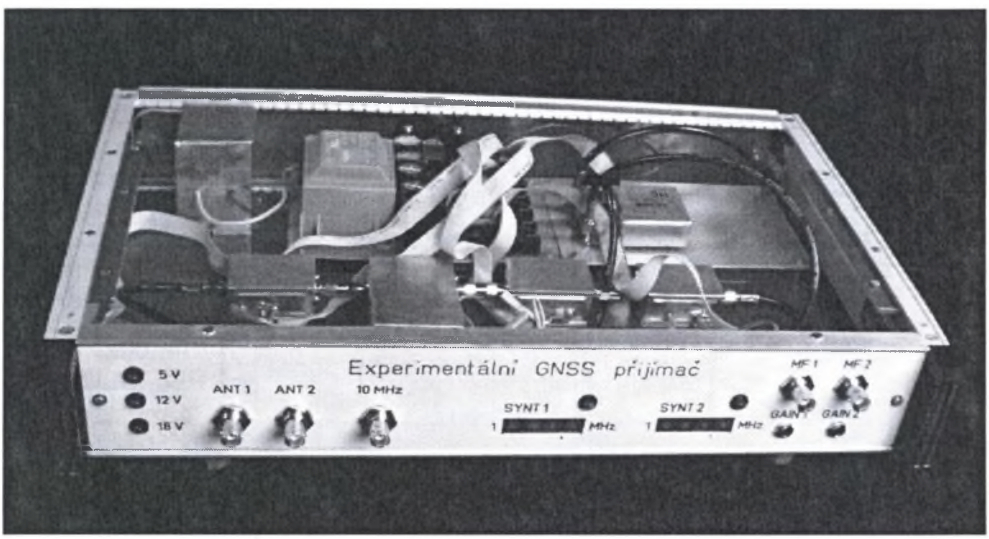

Fig.2. Radio Frequency Unit in 19" rack

The DSP unit is based on the on the FPGA Virtex-II Pro. This solution presents integration of very powerful gate array with two or more processor cores PowerPC (PPC 405E) on 300 MHz and other support circuits such as set of multipliers for parallel algorithm realization or 200 to 600 kilobytes of in-chip memory. The concentration of these circuits in one chip device allows compact solution of complicated DSP unit. The used FPGA platform enables single chip integration of all digital processing parts of the GNSS receiver, i.e. correlators and signal filtering, signal tracking tasks and finally position-velocity-timing (PVT) resolving, system integrity monitoring, navigation and other related tasks. The FPGA is fully programmable and one iteration of design procedure takes several tens of minutes only. Therefore, many variants of DSP algorithm solution can be verified and tested on the real signal in suitable time duration.

The described DSP unit version is a follow-up to an earlier one based on the FPGA Virtex-II without internal PowerPC cores. This DSP unit was used for several early experiments in our laboratory and for weak parts inquiry of the receiver design.

3. RECEIVER VERIFICATION AND TESTING

As the first step, the simple GPS receiver was implemented into the Experimental GNSS receiver. The suitability of the design scheme was verified on the real GPS signal. Results of this step was published in the [3].

Consequently the receiver sensitivity was verified on the series of experiments with the very weak GPS signal receiving under the indoor environment. The non-attenuated outdoor signal was engaged to second channel for easy synchronization of locally generated reference signal by PLL and DLL loops (see Fig.3). The measured signal was processed by the advanced GPS correlation technique (strobe correlator). The cross-correlation processing between measured signal and reference signal was provided. The second time difference of the discrete time replica of the transmitted GPS signal was used as the reference signal. The precise frequency and time synchronization was obtained by the auxiliary high-quality outdoor GPS signal processed by the second channel of the receiver.

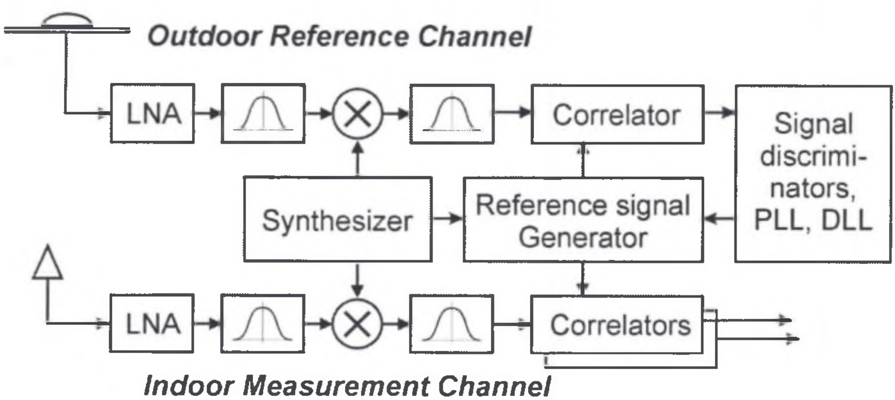

Fig.3. Scheme of experimental indoor signal measurement

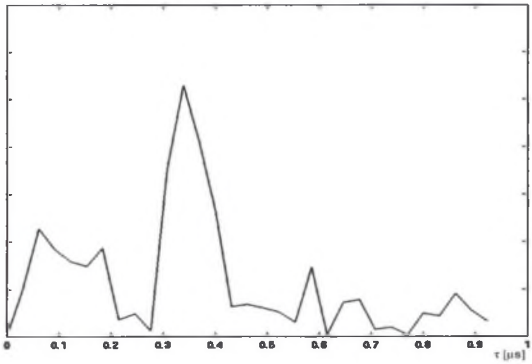

Fig.4. Typical measured envelope of impulse response of the indoor environment (GPS L1/CA, attenuation 25-30 dB)

The estimation of characteristic of indoor GPS signal is a main result of the experiment. Attenuation of indoor GPS signal was estimated and the signal propagation delay profile was evaluated. The typical profile of estimated impulse response envelope for received GPS L1/CA signal in typical indoor environment is presented in Fig.4. However, range of provided experiments up to now was limited and can not characterize arbitrary environment, but the results can be used for preliminary mathematical modelling of indoor GNSS signal spreading.

4. CONCLUSION

The described experiment examined the Experimental GNSS Receiver concept and realisation. The tested receiver has suitable sensitivity for weak GNSS signal processing. The measured characteristic of indoor GPS signal is the useful but minor result if these experiments. We assume extend the measurements to prepare fundament for modelling of GNSS signal spreading in the indoor and difficult outdoor environments.

The next planed test will verify the receiver dynamics, resistance to signal interference, phase noise and other significant receivers characteristics.

We assume the receiver will be prepared for research and development of new GNSS signal processing algorithms including massive parallel processing for navigation in urban area with low quality signal coverage and for the study of new forms of the GNSS signals transmitted during the early phase of the GALILEO mission.

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Reviewer: Prof. Ryszard Wawruch