GNSS/RFID Active Transponder Design

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Abstract. *The paper describes a design of global navigation satellite system (GNSS)/Radio frequency identification (RFID) active transponder which is primarily designed for localization of objects as a part of localization system designated for efficient handling of situations with mass casualties. The precise localization is improved by differential GNSS. The block diagram of such GNSS/RFID active transponder is described including main operation procedures of the firmware. Measurement of the localization by algorithms of RTKLIB library and by algorithms of GNSS module is compared. Dynamic tests, i.e. GNSS/RFID active transponder placed in the moving car (50 kmph), and static tests, i.e. GNSS/RFID active transponder placed in the position for 15 min, are performed.*

Keywords

GNSS, IoT, localization, RFID, transponder.

1. Introduction

Efficient and reliable communication, navigation and identification (CNI) technologies form the basics in crisis management and handling of difficult situations on site of the disasters and can significantly contribute to many tasks of the personnel involved [1]. At the disaster scene, multiple and very different units are likely to operate with different CNI needs and requirements. Most of it is related to efficient management of expensive assets, localization and identification of people on site or even for example in case of serious disasters the identification and localization of body remains [2].

Many papers propose a solution trying to improve present disaster management processes. The authors in [3] describe patient tracking and local air temperature monitoring based on ZigBee sensor network and received signal strength indicator (RSSI) localization technique without global navigation satellite system (GNSS) technology. The focus on identification of the scene before and after mass disaster is presented in [4]. The system of active RFID triage transponders and mobile anchor points, represented by a Smartphone with Global Positioning System (GPS) and Radio frequency identification (RFID) reader, carried by paramedics in a mass casualty incident is described in [5]. The authors in [6] present autonomous mobile platform mounted on a robot for enhancement rescue process during mass casualty incidents. An active RFID transponder is tagged to each patient and responder carries an Android Smartphone with GPS and an active RFID reader. The disaster management processes are mainly improved by tagging of patient of active RFID transponder and using GNSS technology as a part of responder device, i.e. Smartphone.

Given the benefits described in this article, it is more than advisable to integrate RFID and GNSS technologies to provide a solution leading to seamless acquisition of the position of an asset or personnel and its proper identification. In this setting, the GNSS technology provides the answers to the “where” and “when” questions, because it is capable of delivering not only precise geo-location, but also precise time. RFID on the other hand answers the “what” question, ensuring proper and reliable identification. The benefit of the fusion of the RFID and GNSS technologies is described for supply chain in [7], for navigation system in [8] and for instance for human resources in [9].

In this paper, we present a design of GNSS/RFID active transponder, a short-range radio device (SRD) capable to receive and transmit data [10]. Primarily, the GNSS/RFID active transponder is determined for mass casualty incidents as a part of a complex RFID localization system [11]. It is designed for identification and localization of casualties with expected accuracy about 1 m in defined area of 1 square kilometer in order to identify human bodies in the area. Secondarily, the GNSS/RFID active transponder can serve as the Internet of Things (IoT) device worldwide. For the purpose of improved accuracy, the described solution uses Differential GNSS (DGNSS). The used GNSS module, type NV08C-CSM, is capable to track GPS, GLONASS and GALILEO satellite networks. However, for the tests, only GPS satellite system is performed. Moreover, producer‘s algorithms of the GNSS module is compared with open source solution called RTKLIB. Tests are performed for GNSS/RFID active transponder placed in a specific position with no movements and also for the movement of a car speed. The results show precise localization by producer‘s algorithms for the speed of a moving car. However, static tests show better performance of logarithms of RTKLIB library.

2. Design of GNSS/RFID Active Transponder

The main purpose of a design of GNSS/RFID active transponder is an accurate localization joint with identification. Therefore differential GNSS, which uses other reference coordinates on the known position, is proposed. Moreover, logging of GNSS coordinates and its further processing is required. Obviously, the designed active transponder has to be able to send a standard bit sequence and its ID as well as standard RFID device. It is designed to be able to receive and transmit data. Therefore it is classified as a short-range radio device, which is generally marked as RFID device.

2.1. Requirements

Designed GNSS/RFID active transponder has to fulfill following requirements:

- support for DGNSS module,
- support for LNA with the gain from 20 dB to 30 dB,
- support for active GNSS antenna,
- antenna power supply (5 VDC or 3.3 VDC) is connected with RF path,
- generate and transmit localization sequence identical with RFID tag sequence,
- battery power supply,
- connection of charging battery,
- long term record of localization data for subsequent data processing.

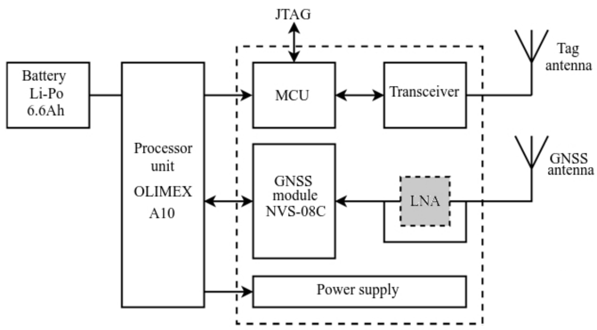


Fig. 1: Block diagram of designed GNSS/RFID active transponder with connected tag and GNSS antenna and battery.

2.2. Technical Description

The prototype of GNSS/RFID active transponder is designed from components depicted in Fig. 1. Processor unit Olimex A10-OlinuXino LIME is a standard embedded board for development purposes [12]. This type is based on the Cortex A8 processor with 512 MB DDR3 RAM memory. Moreover, it supports UART serial ports and GPIO ports, Debian OS Linux and external battery. Micro SD card serves as data disk for OS Linux and also for recorded GNSS data. Li-Po battery 6.6 Ah is able to supply the GNSS/RFID tag about 10 hours. The GNSS module NV08C-CSM is a navigation receiver of GLONASS (with SBAS), GPS, Beidou and GALILEO navigation satellite systems [13]. It supports 32 GNSS tracking channels, NMEA 0183 (IEC 1162), BINR, RTCM SC 104 data protocols, coordinate systems WGS-84, PZ-90 SK-42 and SK-95, two independent serial ports and support for RTKLIB library and it is designed for low power consumption. A radiofrequency input of the GNSS NV08C-CSM module is universally designed, i.e. it is possible to assembly it by:

- input from SMA connector with support of active GPS antenna supplied in the range of 2–5 VDC (chosen configuration),

- input from SMA or U.FL connector with support of GNSS antenna supplied by 2.65 VDC from GNSS NV08C-CSM module,
- input from U.FL connector and possibility of passive GNSS antenna connection.

Both serial ports and GPIO signals of GNSS module are connected to Olimex A10-OlinuXino LIME, which enables RESET function and a change of configuration between BINR and NMEA communication protocols.

The designed GNSS/RFID active transponder obviously has to operate as a standard RFID tag. Therefore it is equipped by appropriate circuits taken over the RFID tag. It is mainly radiofrequency transceiver EM9209 from the producer EM Microelectronics. It is controlled by microcontroller of the family MSP430. The transceiver operates in ISM 2.4 GHz frequency band with FSK modulation. It is configured to non-standard operational mode enabling a short bit sequence of 28 bits length to be sent. The output power of the transceiver is in the range of −20 dBm to +10 dBm according to settings in registers. A RFID antenna is a standard rod antenna in ISM 2.4 GHz frequency band.

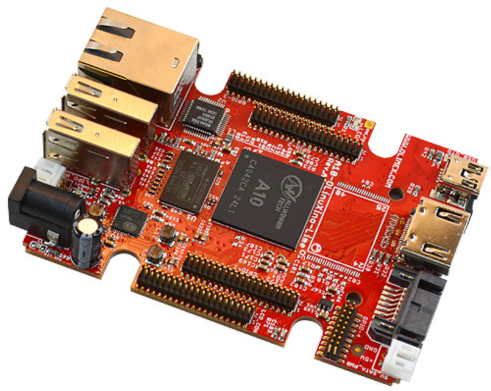


Fig. 2: A10-OLinuXino-LIME [11].

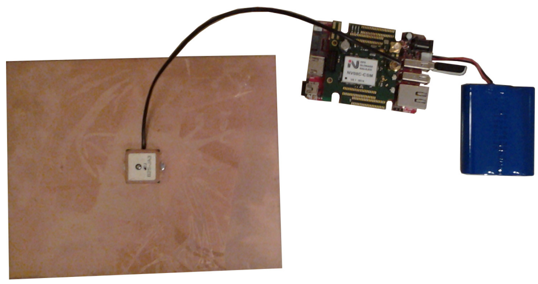


Fig. 3: Assembled GNSS/RFID active transponder prototype in the configuration of the GPS navigation satellite network.

2.3. Assembled Prototype

As described above, A10-OLinuXino LIME is the processor unit of the GNSS/RFID active transponder. It is shown in Fig. 2. The assembled prototype of the GNSS/RFID active transponder corresponds to the block diagram shown in Fig. 1. The active GPS antenna, a battery, the processor unit A10-OLinuXino LIME and realized printed circuit board, which contains LNA, MCU, transceiver, power supply and GNSS NV08C-CSM module, is depicted in Fig. 3.

However, NV08C-CSM module supports GLONASS, GPS, Beidou and GALILEO navigation satellite systems the GPS is chosen for further measurement. Therefore GPS antenna is chosen to be connected to the developed board of GNSS/RFID active transponder.

2.4. Firmware Description

An operating system Debian is installed on the processor unit Olimex A10-OlinuXino LIME. Two of its serial ports (TTYS3 and TTYS4) are connected to the GNSS module NV08C-CSM. The serial port TTYS3 is configured to use communication protocol NMEA with 115200 kb/s bitrate on the GNSS module. The second serial port TTYS4 is configured to use communication protocol BINR with 115200 kb$\cdot$s^{-1} bitrate.

The communication protocol NMEA uses text messages for data transmission. It is readable in terminal program. The GNSS module sends information about location and visible satellites in regular interval (adjustable in the range 100 ms to 10 s). This information is recorded by the script programmed in the command interpret BASH. By inserting a USB flash memory into the port of processor unit, the USB flash memory is automatically connected, a logging of NMEA information starts and it is saved. A file name includes time stamp of record start.

The communication protocol NVS BINR is binary and information is not readable by common terminal program. It however enables, in comparison with NMEA protocol, a possibility of periodical transmission of “RAW” satellites information. It uses RTKLIB library for precise location determination. The library is compiled in versions 2.4.2 and 2.4.3 in the processor unit. The record of information from BINR protocol is saved in the USB flash memory as well as NMEA information.

The RTKLIB library is a file compound of several programs, which enable for example conversion between communication protocols, data recording, transmission of localization data via Ethernet, location determination and processing of “RAW” satellites information.

3. Measurement of GNSS/RFID Active Transponder

Several tests are performed in order to verify expected accuracy and sensitivity of the GNSS receiver in the configuration of the GPS satellite system. The records are processed by two different ways. Firstly, the records of coordinates are processed by algorithms in the NV08C-CSM module and directly displayed in a map. Secondly, the records are processed by algorithms of the RTKLIB library in the processor unit Olimex.

3.1. Position Comparison – Dynamic Tests

This test compares accuracy of localization processed by algorithms of NV08C-CSM module and by RTKLIB library for the 50 km·h^{-1} speed of designed GNSS/RFID active transponder. It is comparable with a car movement of a speed 50 km·h^{-1}.

The data are recorded in STOREGIS program which is recommended by producer for visualization of data received from navigation receiver. The location of GNSS/RFID active transponder is subsequently depicted in maps of application called Google Earth.

At first, number of satellites is controlled in order to obtain sufficient Signal-to-noise ratio (SNR) value, Fig. 4. It shows the SNR values for GPS (blue), SBAS (green) and for GLONASS (red). Ten satellites of GPS, nine satellites of GLONASS and two SBAS stations are clearly visible. However, the GPS signal is characterized by the highest values of SNR for all visible satellites.

Secondly, the location is measured for the speed of a car for localization processed by algorithms of NV08C-CSM module, Fig. 5, Fig. 6, Fig. 7, Fig. 8 and by algorithms of RTKLIB library, Fig. 9 and Fig. 10. The first route is from the city Pardubice to Orel village. Detail of the route is depicted in Fig. 5 and with waypoints in Fig. 6. The second and third ones, chosen for comparison of localization accuracy, are in the city Chrudim and Orel village. The records logged up in Chrudim for algorithms of the NV08C-CSM module are depicted in Fig. 7 and for algorithms for RTKLIB library in Fig. 9. A comparison in Orel village is shown in Fig. 8 and Fig. 10.

The results show precise localization of algorithms of NV08C-CSM module in comparison with inaccurate localization results of algorithms of RTKLIB library considering a speed 50 km·h^{-1} of the designed GNSS/RFID active transponder.

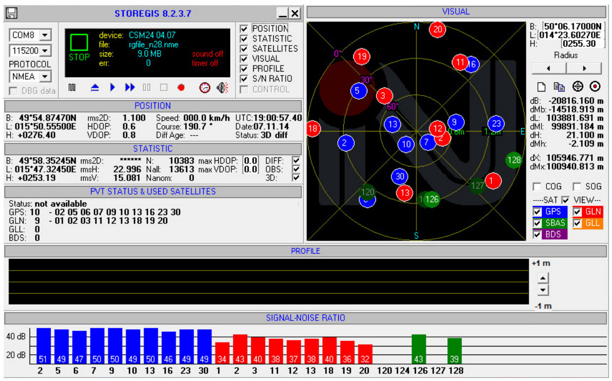


Fig. 4: The visible satellites and SNR values of GPS (blue) and GLONASS (red) satellite systems and SBAS (green) stations.

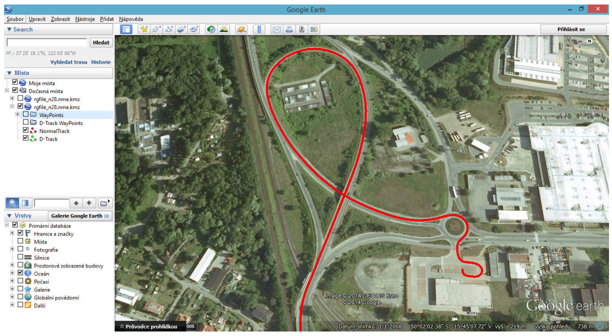


Fig. 5: The location record of NV08C-CSM module in the route between Pardubice and Orel.

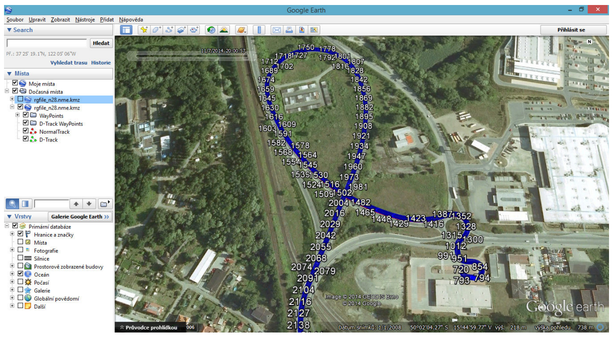


Fig. 6: The location record of NV08C-CSM module in the route between Pardubice and Orel with depicted waypoints.

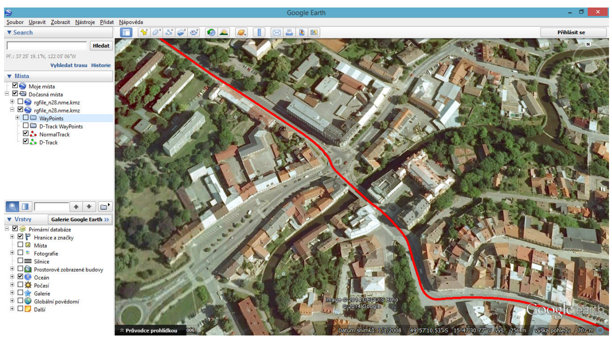


Fig. 7: The location record of NV08C-CSM module in Chrudim.

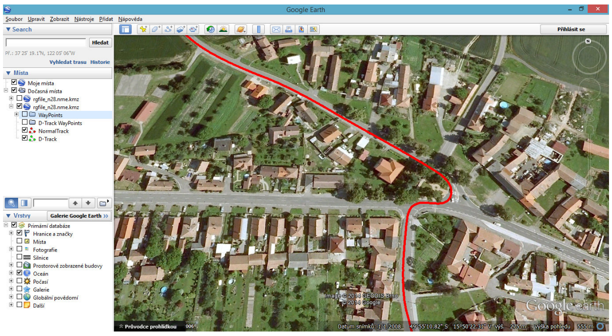


Fig. 8: The location record of NV08C-CSM module in Orel.

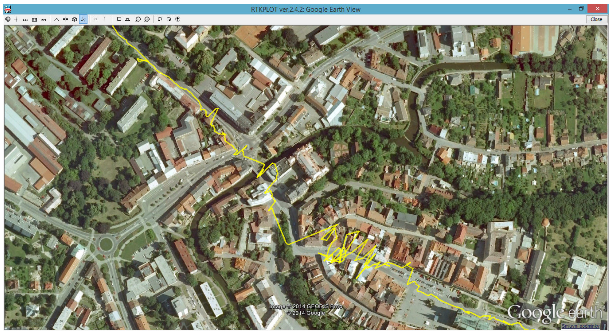


Fig. 9: The location record of RTKLIB library in Chrudim.

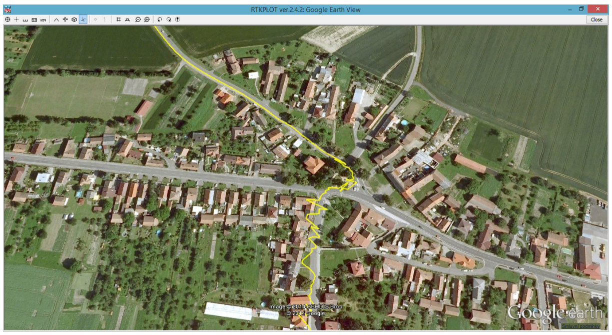
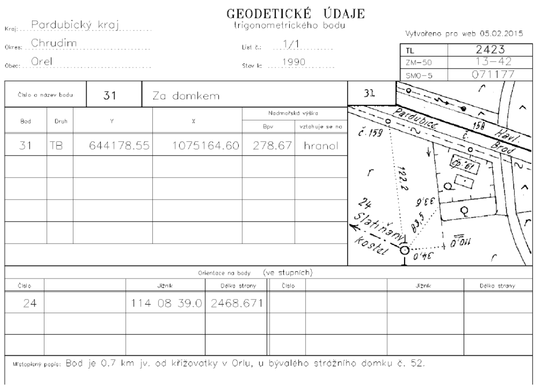


Fig. 10: The location record of RTKLIB library in Orel.



GEODETICKÉ ÚDAJE
trigonometrického bodu

Kraj: Pardubický kraj
Okres: Chrudim
Obec: Orel
List č.: 1/1
Stav k: 1990
Vytvořeno pro web 05.02.2015

TL	2423
ZM-50	13-42
SM0-5	071177

Číslo a název bodu: 31 Za domkem

Bod	Druh	Y	X	Nadmořská výška Bpv	vztahuje se na
31	TB	644178.55	1075164.60	278.67	hranol

Orientace na body (ve stupních)

Číslo		Jižník	Délka strany	Číslo		Jižník	Délka strany
24		114 08 39.0	2468.671				

Místopisný popis: Bod je 0.7 km jv. od křižovatky v Orlu, u bývalého strážního domku č. 52.

Fig. 11: Geodetic point in the Orel village — x and y coordinates (only Czech version available [14]).

Tab. 1: Results obtained after 15 min of gathering satellite data.

	x coordinate	y coordinate
Reference point	1075164.60	644178.55
NV08C-CSM	1075163.95	644176.60
Deviation	0.65	1.95
RTKLIB	1075164.37	644177.47
Deviation	0.23	1.08

3.2. Position Comparison – Static Tests

This test compares localization accuracy of both algorithms previously described for static tests, i.e. the designed GNSS/RFID active transponder is placed in defined location. Precise location of reference points can be found on the official web page of State Administration of Land Surveying and Cadastre, Czech Republic [14]. It offers precise x and y coordinates, altitude and method of specific geodetic point determination (available for some geodetic points). The point number 31 of the village Orel is chosen and depicted in Fig. 11 (only Czech version is available at [14]). The most important information is the value of x and y coordinates. The comparison of coordinates for geodetic reference point and the points obtained by algorithms of NV08C-CSM module and RTKLIB library are depicted in Tab. 1. The records are written down after 15 min of gathering satellite data and their processing. The maximal deviation of x and y coordinates for the NV08C-CSM module is 1.95 m in y coordinates in comparison with RTKLIB library, which is 1.08 m in the same coordinate. As a consequence, position obtained by NV08C-CSM module is 2.964 m far from the reference point and the obtained position by RTKLIB library is 1.104 m far from the reference position.

The results show algorithms of RTKLIB library calculate more accurate static position in comparison with algorithms of NV08C-CSM module considering the designed GNSS/RFID active transponder is placed in defined location for period of time 15 min. The patients, who are tagged in mass casualty incidents, and receiving stations as a part of complex RFID localization system [11] can be seen as such static points.

4. Conclusion

The paper describes a design of GNSS/RFID active transponder, a short-range radio device capable to receive and transmit data. Basic circuit diagram of a standard RFID transponder is extended by GNSS module NV08C-CSM capable to track GLONASS (with SBAS), GPS, Beidou and GALILEO navigation satellite systems. However, GPS satellite system is chosen for tests. The circuit diagram of designed

GNSS/RFID active transponder is described including procedures in firmware. Two sets of measurement are performed. The first one corresponds to a location change of a speed of a moving car in the city. The second one is measured for static position compared to reference position of geodetic point. The results show better performance of algorithms of NV08C-CSM module for a moving car and algorithms of RTKLIB library for static tests.

Acknowledgment

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Tomas KORINEK was born in Jicin, the Czech Republic, in 1979. He received the M.Sc. degree and the Ph.D. degree in radio electronics from the Czech Technical University in Prague, the Czech Republic, in 2005 and 2012 respectively. From 2007 to 2008, he was a research and designer engineer at RFspin s.r.o., where he was engaged in antennas and microwave circuits. He is currently an Assistant Professor and the head of laboratories at the Department of Electromagnetic Field at the Czech Technical University in Prague. His research interests include the area of measurements in EMC and antennas.

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Daniel LOPOUR is an experienced project manager with special focus on market development in the area of transportation and telecommunication. After graduating from the Faculty of Transportation Sciences of the Czech Technical University in Prague (CVUT), he joined GS1 a not-for-profit organization providing the most widely used identification and communication standards for retail and fast moving consumer goods industry as a Project manager for Electronic data interchange and Radio-frequency identification. Between 2010 and 2012, he managed a large RFID infrastructure upgrade project at CTU in Prague and has been representing Czech Republic in the Internet of Things expert group of the European Commission. In September 2012, Daniel joined European GNSS Agency of the European Commission as Market development officer, where he is directing multiple R&D projects and managing market innovation activities in the area of Rail and Logistics. Additionally, he is teaching Information technology in Logistics in double-degree EU-US programme Atlantis.