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Mobile satellite measurements in designing and exploitation of rail roads

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Abstract

The article presents a summary of several years (2009-2015) of studies on the application of mobile satellite Global Navigation Satellite Systems (GNSS) measurements in the field of designing and operation of railways. These studies have been conducted by an interdisciplinary research team from the Gdansk University of Technology and the Gdynia Maritime University. Mobile satellite GNSS measurements are taken during a ride (through the railroad) by the measuring train consist of motor car with a trailed double axles platform bogies on which the GNSS receivers were installed. The authors described the adopted methodology of the carried out measurements of the rail and tram tracks. The problem of an accuracy of satellite positioning measurements has been discussed.

The authors proposed a method that makes it possible to assess quantitatively the accuracy of the research implemented over years. New concepts were introduced, such as: GNSS positioning networking service availability, reliability and continuity based on the theory of reliability. Using a developed mathematical model they recounted the results of four archival measurement campaigns of years: 2009-2015. The studies have shown that the number of used satellite systems as well as support for GNSS measurements with the inertial system are important from the point of view of the accuracy of the results.

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Keywords: Satellite GNSS measurements; accuracy assessment; availability; reliability; continuity

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1. Introduction

The development of satellite geodetic techniques, together with the increase of GPS (Global Positioning System) surveying precision, leads to taking an effort of application the GPS technology for the purpose of railway track inventory. Start of Polish Active Geodetic Network (ASG-EUPOS) in 2008 and a significant qualitative improvements in the Global Navigation Satellite Systems (GNSS) accuracies (use of integrated GPS/GLONASS receivers, fix rate up to 20 Hz, and implementation of the geoid model in receivers' system) led the interdisciplinary research team to undertake an investigation within attempts to assess the possibility of using GNSS for geodetic service of railways.

Nomenclature

$X_1, X_2, ...$	working times
$Y_1, Y_2, ...$	times of failures
$Z_n^{'} = X_1 + Y_1 + X_2 + Y_2 + ... + Y_{n-1} + X_n$	moments of failures
$Z_n^{*} = Z_n^{'} + Y_n$	moments of renewal
$F(x),\ G(y)$	distribution functions of X_n and Y_n
$\alpha(t)$	binary interpretation of the reliability state
$A_{\exp}(t)$	positioning GNSS networking service availability
$R_{\exp}(t,\tau)$	positioning GNSS networking service reliability
$C_{\exp}(t,\tau)$	positioning GNSS networking service continuity

The first satellite measurements of railway lines were carried out in February 2009 by the Gdansk University of Technology and the Polish Naval Academy scientific team. The research was implemented on the 50 km section of the railway line. The system of four GPS devices located in the parallelogram with the direct measure of the wagon wheels was used in the surveys. Studies have shown that an accuracy of the determination of the coordinates values were mainly determined by the field obstacles (Koc, Specht, 2009; Koc et al., 2009a; Koc et al., 2009b; Koc et al., 2012a).

In 2010, the measurement of the geometric shape of railway track was carried out on the section of the Gdansk - Gdansk Nowy Port railway line. Three receivers Leica System 1200 SmartRover, which consisted of Smart-type controllers RX ATX1230GG and 1250 were deployed on the longitudinal axis of the PWM-15 platform. Dynamic measurements were performed in real-time GPS service (RTK measurement method), with the use of RTK corrections NAVGEO RTCM 3 1 VRS stream. The measurement set used the internet access service via modems GPRS Siemens MC45-mode network NTRIP Simplus (Koc, Specht, 2010; Koc, Specht, 2011; Koc et al., 2012a; Koc et al., 2012b).

In 2012 the satellite measurements of tram line in Gdansk was performed. It was expected that the GNSS signal will be limited by terrain obstacles occurring in the urban area. Therefore, it was decided to verify the research methodology after a detailed analysis of the conditions for the implementation of measurements carried out in previous years. Real Time measurements with the use of ASG-EUPOS were no longer used due to the existing (in the afternoon) network breaks associated with the transmission of GPS pseudo-range corrections. Measurement were carried out in post-processing, so that the analysis of the results gave more opportunities to use signals from different reference stations. It was decided to implement a dual-mode GNSS receivers using the signal of two satellite system: GPS and GLONASS. This resulted in increasing the accuracy of coordinate values survey directly related to the number of available GNSS satellites. Since the ASG-EUPOS network doesn't have the possibility of sending corrections to the dual-mode receivers, the scientific GPS/GLONASS reference station from Gdansk University of Technology was also used. It was located in the area of the measurements (up to 10 km). Two