EGNOS-Based GNSS Receiver for Precise Positioning in Restricted Areas

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Positioning accuracy is very important in many areas, whereas the typical GPS receiver accuracy is often not sufficient. The European Geostationary Navigation Overlay Service (EGNOS), Europe's first venture into satellite navigation, improves the open public service offered by the Global Positioning System (GPS). As a satellite navigation augmentation system, EGNOS improves the accuracy of GPS by providing a positioning accuracy to within 3 meters. In this paper we present GNSS receivers based on EGNOS, dedicated for precise positioning in restricted areas of continental shelf performance. The article presents some results regarding position accuracy, obtained for a few receivers in that context.

Keywords: EGNOS, GNSS, positioning accuracy

1. Introduction

Typical GPS receiver accuracy on a low-cost mobile device is not sufficient. It is worsened further by unfavorable urban surroundings, as pedestrians are usually walking near high buildings, which obstruct satellite signal reception. In that context, the Voice Maps project is worth mentioning. The project was carried out as a national project in the scheme of the Polish National R&D Center – NCBR *ZPB/37/67901/IT2/10*. It ended with a prototype system for the blind and visually impaired users, in order to improve their comfort in everyday life, by navigating them in the urban areas. The system includes a client application for Android mobile devices, and a server with a dedicated spatial data and pathfinding module.

The Voice Maps [1, 2] project solved most of the currently basic problems of navigation in urban terrain; i.e., appropriate digital mapping, navigation algorithms, and timeliness of topography data including the effective spatial data acquisition methods, the efficiency of pathfinding methods, and the appropriate design of the user interface - employing voice recognition, speech synthesis mechanisms, and the touch screens of the modern mobile devices.

The application uses a multimodal user interface, which combines voice recognition, dedicated software keyboards, touch-driven menus and speech synthesis mechanisms. The client application calculates the optimal route for the users, and then guides them to the selected target along the route. User's geographical position, and current azimuth, are continuously monitored. Wrong or dangerous behaviour causes appropriate voice messages to be triggered, along with information on nearby objects/addresses (Points of Interest, POI), near obstacles and potential dangers (Points of Attention, POA). Geospatial data is acquired by the community, and aggregated on the web portal, allowing preview and editing.

The community portal is hosted in the OPEGIEKA datacenter. The portal consists of a server backend of the Voice Maps system, and a frontend web solution that allows for viewing, editing, and quality inspection of the data. The solution provides the mobile application with fragments of data that describe the area in the closest surroundings of their current location. Provided data dynamically changes when users move to a different location, so the application always contains only information that is needed to guide users toward their current destination. The frontend solution consists of:

- data editor, that allows for editing spatial database of the system using only the web browser. Voice Maps as a system created for the navigational assistance of the blind or visually impaired, requires a different data set than the typical navigation systems (i.e. purposed for cars). So OSM (Open Street Map) data structure was supplemented by additional features ie: accurate spatial information about sidewalks and pedestrian crossings,
- community forum,
- data viewer.

However, these key problems were solved concurrently with the mobile system development; with one exception, which constitutes the insufficient accuracy of positioning in the urbanized areas. It results in the unstable and unreliable performance of the system in difficult urban conditions. Therefore, the achievement of reliable performance of the system, assuring accurate positioning, and subsequent navigation of pedestrians, became the main objective of the new proposal.

By using the GPS receiver on a smartphone, along with EGNOS services, we expect to achieve precise positioning with a maximal error of 2 meters. Complementing this with our dedicated mobile navigation application, which will use the EDAS service and filtering algorithms (map-matching and others), we assume to reduce the horizontal positioning error. This article proves it is possible, but with some limitations.

2. EGNOS

EGNOS is an SBAS (Satellite-Based Augmentation Systems) system. Both GPS and EGNOS service, thanks to their interoperable and compatible signal baselines, can be relatively easily integrated and processed, even by civilian-user low-cost equipment. Using this kind of integrated solution offers remarkable benefits to a broad range of user communities. Most of the modern smartphones are able to receive EGNOS messages [3][4].

The preferable solution is to use the built-in GPS/EGNOS receiver provided by the mobile phone manufacturer. If the accuracy of the built-in receiver is insufficient, or it is not EGNOS-ready, then it is also possible to use external GNSS receivers.

The European Geostationary Navigation Overlay Service, Europe's first venture into satellite navigation, improves the open public service offered by the Global Positioning System (GPS). EGNOS improves the accuracy of GPS by providing improved positioning accuracy. More than 40 ground stations are linked together to create the EGNOS network which consists of:

- **34 RIMS** (**R**anging and **I**ntegrity **M**onitoring **S**tations): receiving signals from satellites,
- **4 MCC** (**M**ission **C**ontrol **C**enters): data processing and differential corrections counting,
- **6 NLES** (**N**avigation **L**and **E**arth **S**tations): accuracy and reliability data **sending to three geostationary satellite transponders** to allow end-user devices to receive them,
- **2** control and monitoring stations: **DVP** (**D**evelopment **V**erification **P**latform) and **ASQF** (**A**pplication **S**pecific **Q**ualification **F**acility) in Torrejón near Madrid, **PACF** (**P**erformance **A**ssessment and **C**heck-out **F**acility) in Toulouse.

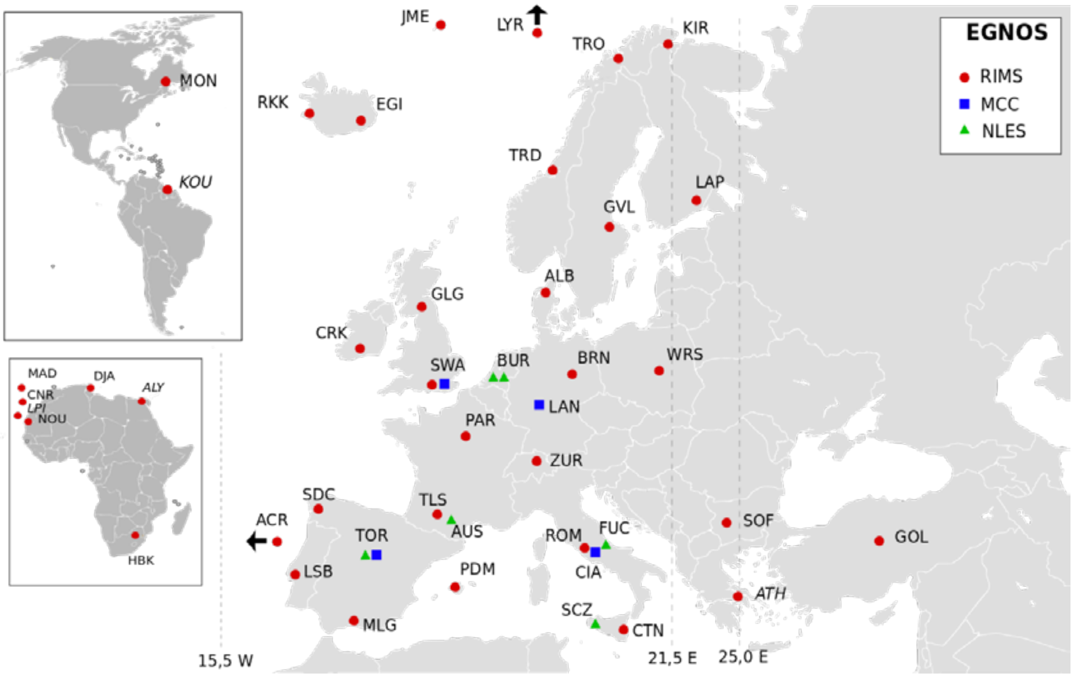


Fig. 1. EGNOS network.

The very important advantage of combined GPS/EGNOS PND, alongside improved accuracy of positioning, is integrity. The integrity is the measure of the trust that can be placed in the correctness of the information supplied by a navigation system; and includes the ability of the system to provide timely warnings to users when the system should not be used for navigation. This is especially important in exposed circumstances, exposed to surrounding environmental hazards in the event of a positioning error.

Moreover, EGNOS additionally provides a terrestrial data service, called the EGNOS Data Access Service (EDAS), e.g. through an internet connection. EDAS disseminates EGNOS data in real-time without relying on the signals from the three EGNOS satellites. EDAS is the single point of access for the data collected and generated by the EGNOS infrastructure. It supports the multimodal use of EGNOS (and later-on Galileo) by disseminating advanced EGNOS services in real-time, and within guaranteed performance boundaries [4]. It is available through a ground network, without requiring direct access to an EGNOS satellite. It can therefore be used in constrained environments, such as when signals are blocked, not visible, or are disturbed by interference. For example, in the northern areas of the EU, the geostationary satellites hovering above the equator will not be sufficiently visible. EDAS delivers two main types of data in real-time, via ground transmission systems:

- EGNOS augmentation messages, as normally received by users via the EGNOS geostationary satellites,
- Raw GPS data collected by the EGNOS monitoring reference network.

The use of EDAS compensates for the EGNOS reception problem in urbanized areas, such as ports. This kind of environment generates a lot of multipath errors, whose effects can only be dealt with using receiver-level techniques.

3. EGNOS Accuracy Measurements & Results

A few types of measurements were carried-out; using typical Garmin, u-blox, and Smart GPS low-cost receivers. RTK measurements were carried-out as well. Figure 3 summarizes all carried-out measurements for urban and open area circumstances. The open area is defined as the area with opened, clear, sky view, when 12 satellites were visible and there is an unobstructed line of sight from the receiver to the satellite.

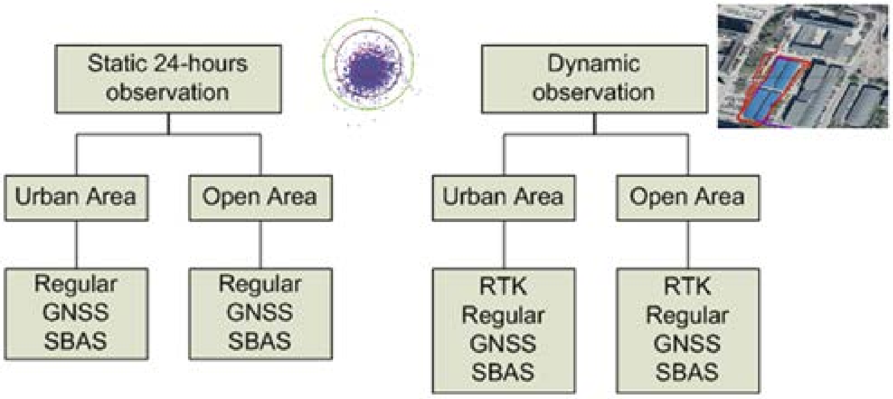


Fig. 3. Tests plan.

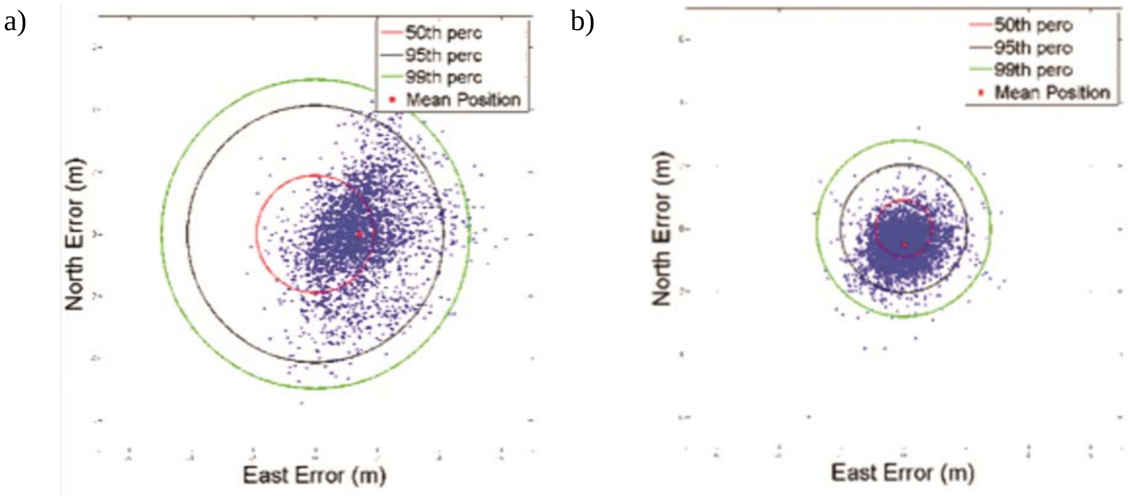

a)
b)

Fig. 4. Results of accuracy for static measurements of a) stand-alone GNSS and b) EGNOS-enabled GNSS .

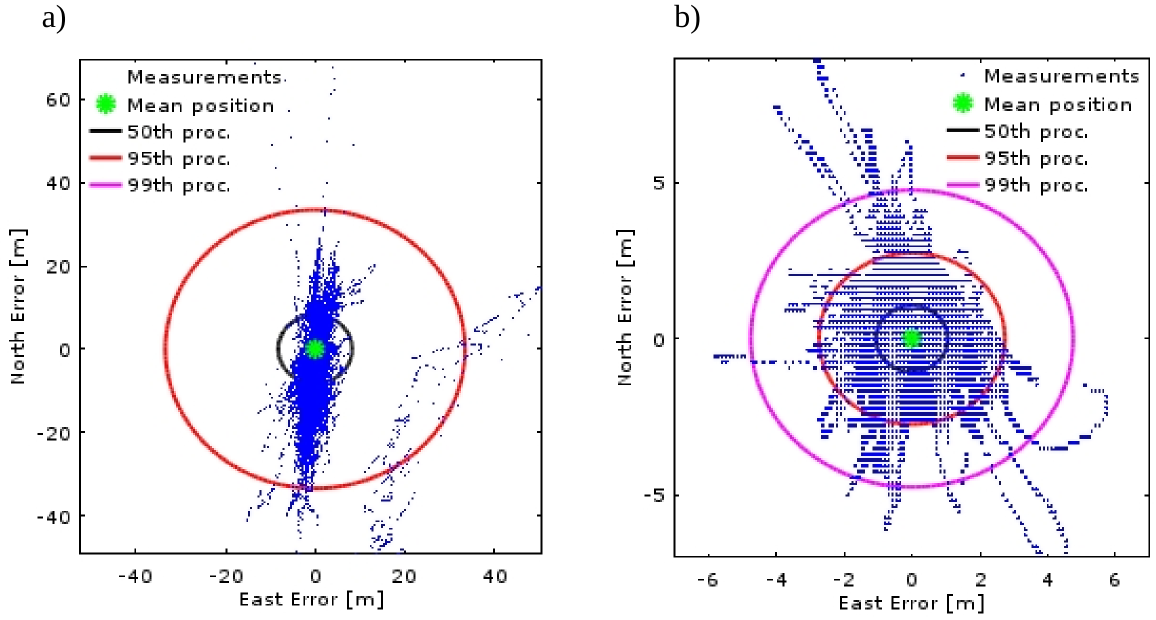


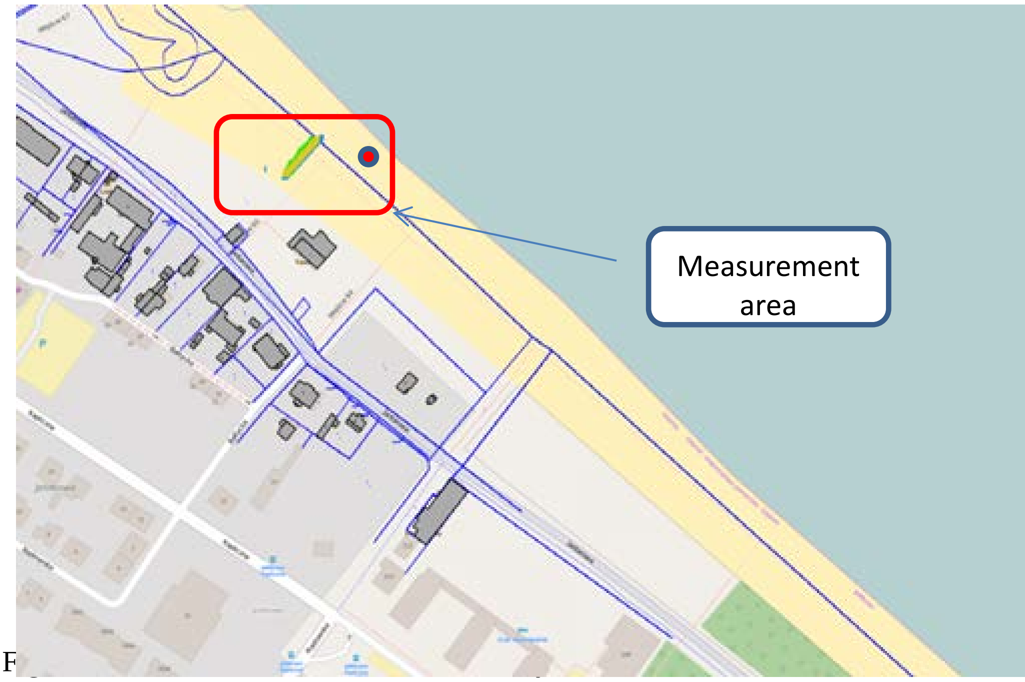
Fig. 5. Results for static measurements EGNOS-enabled GNSS in (a: urbanized and (b: open area.

The urbanized area, as ports are defined, as an area where the so-called urban canyons are present and << 10 satellites are in view.

The Table 1 summarizes results for static measurements performed for the open area only, because the results for urbanized (area)are not satisfied Fig.5a. These measurements were carried out on the shelf water, or the shelf water vicinity, as presented in Fig. 5. The overall accuracy is almost two times better for EGNOS mode performance.

Tab.1. Results for static stand-alone GNSS and EGNOS-enabled GNSS measurements.

Types	Horizontal	Accuracy	[m]
	Mean	Sigma	R95
GNSS	2.07	1.11	4.17
GNSS+EGNOS	1.0	0.57	2.04



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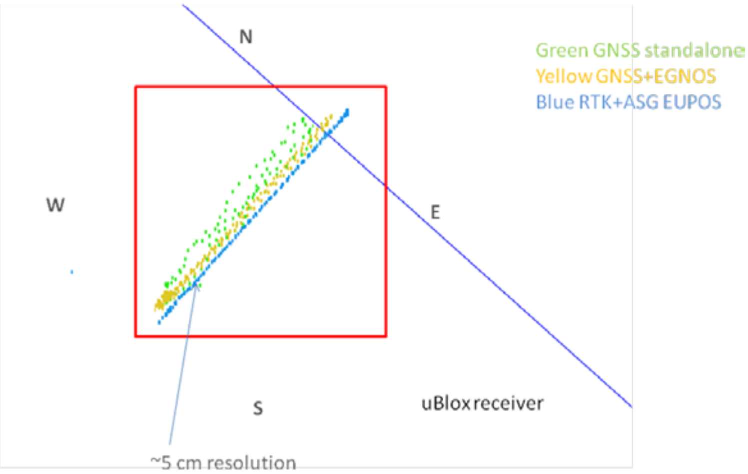

Fig. 7. Dynamic measurement carried out in the shelf water area using a u-blox receiver.

In Fig. 7, the details of Fig. 6 were presented. The measurement was performed using a u-blox receiver with EGNOS mode-enabled (yellow dots) and disabled (green). Blue footprints from RTK –ASG EUPOS were presented as a reference as well. It is clear from the observation that the EGNOS-enabled receiver is almost two times better, which corresponds to the results obtained for the static measurements summarized in Table 1. Figs. 8 and 9 present dynamic measurements carried out using a Garmin receiver. The measurement confirms the maximum error does not exceeds 0.7 meters for the EGNOS-enabled Garmin GNSS receiver, and these results confirm a clear GNSS EGNOS-enabled improvement in the shelf water opened area.

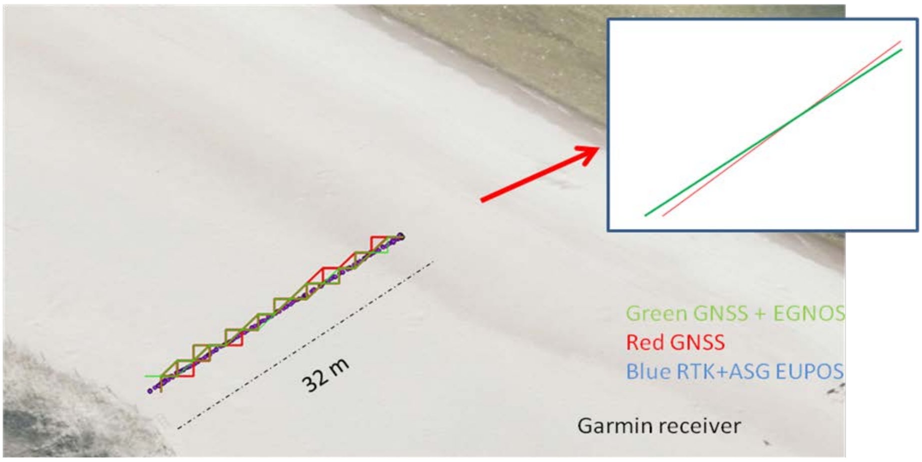

Fig. 8. Dynamic measurement carried out in the shelf water area using a Garmin receiver.

The results obtained for the urbanized area are completely different. Figs. present static (Fig. 5a) and dynamic (Fig. 9, 10) measurements area with the buildings in the vicinity, and urban canyons presence. The true route was depicted in black, close to the buildings (Fig.10). In violet, RTK ASG-EUPOS measurements were overlaid.

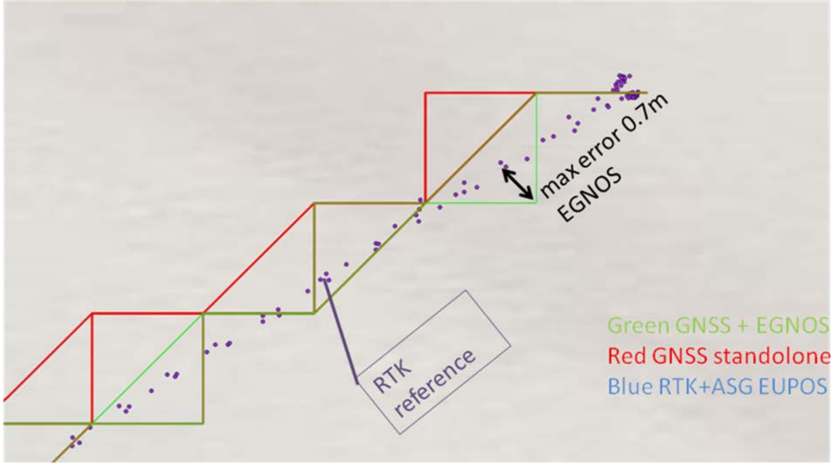

Fig. 9. Dynamic measurement carried out in the shelf water area using a Garmin receiver.

The error exceeds 10 meters for the Garmin receiver Fig. 9, and for the u-blox receiver Fig.10. RTK ASG-EUPOS did not manage in the case as well, but in the last case positions are not calculated at all.

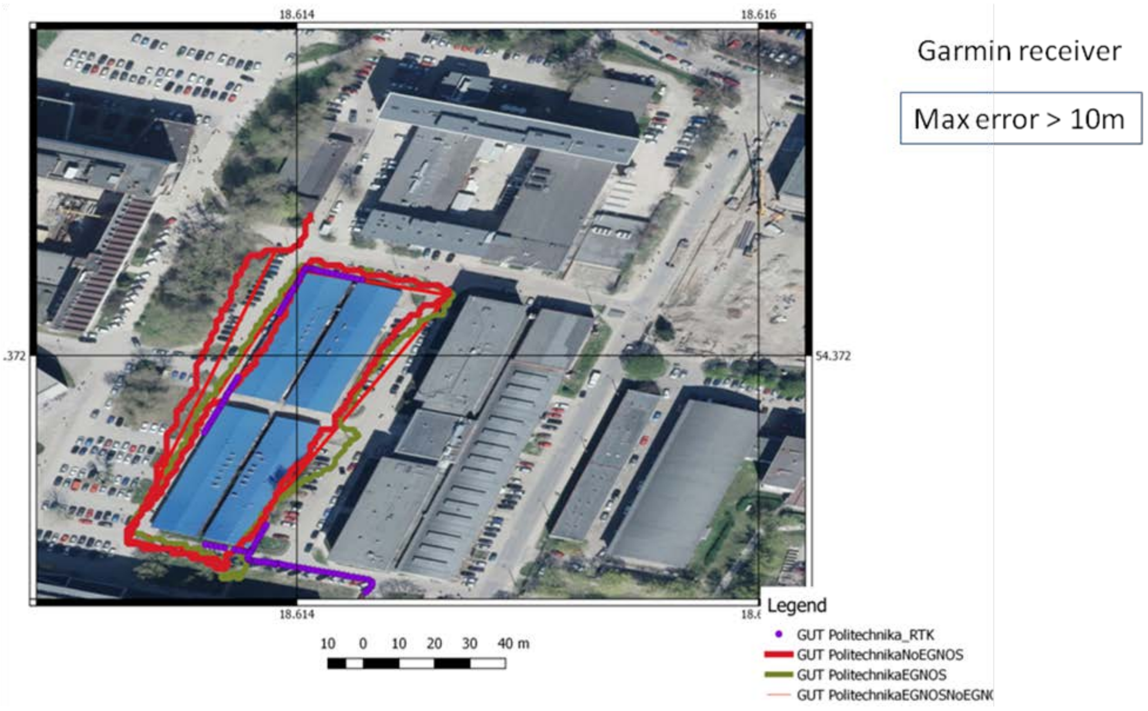

Fig. 10. Dynamic measurement carried out in urbanized area, using a Garmin receiver.

EGNOS-enabled GNSS receivers obviously significantly improve position accuracy, but for the open area in static and dynamic measurement campaign only, and that was proved by some authors already [3], [4], but the urbanized area is still the challenge.

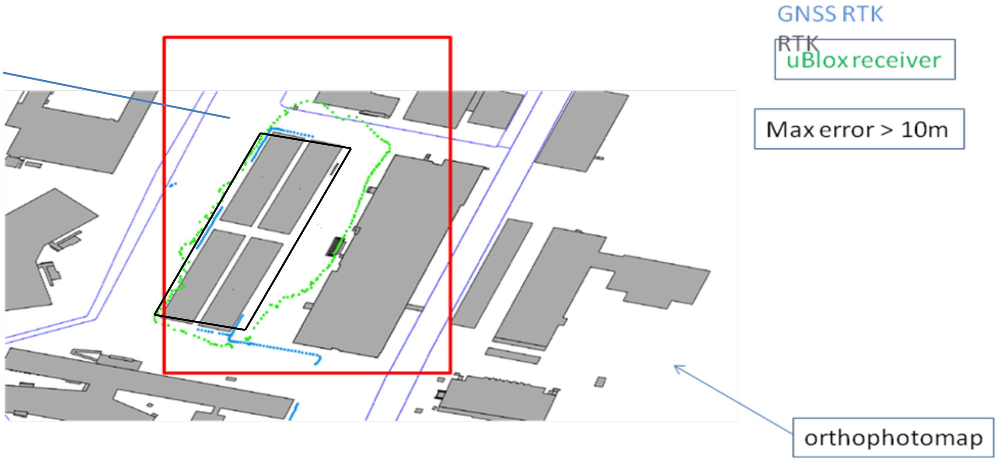

Fig. 11. Dynamic measurement carried out in urbanized area, using a u-blox receiver.

4. Conclusions

Operational EGNOS measurement for different areas was carried out using different GNSS EGNOS-enabled receivers from a u-blox, Garmin, Smart GPS and RTK-ASG EUPOS receiver measurement was carried out as a reference as well. The measurements prove that besides EGNOS integrity, continuity and availability, an accuracy better than << 1m in Opened Areas/Shelf Water in the Gdansk Gulf Area can be obtained. However, urbanized areas like ports etc. degrade the position accuracy, and error may exceed >>10m, and, in that very demanding case, RTK + ASG EUPOS did not supply correct positions as well. Finally, that leads to the conclusion that the urbanized area is still demanding, and remains the main error factor in GNSS observations; because of an obstructed line of sight from the receiver to the satellite, and strong multipath impact.

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