The possibility of Using the Low-Cost External Antenna with Smartphone for Accurate Surveying Applications by RTX Technology

Omar Ali Ibrahim¹, Luma Khalid Jasim*¹, Raghad Hadi Hassan¹

¹College of Engineering, University of Baghdad, Baghdad
*luma.k@coeng.uobaghdad.edu.iq

Abstract. Real Time Extended (RTX) technology works to take advantage of real-time data comes from the global network of tracking stations together with inventor locating and compression algorithms to calculate and relaying the orbit of satellite, satellite atomic clock, and any other systems corrections to the receivers, which lead to real-time correction with high accuracy. These corrections will be transferred to the receiver antenna by satellite (where coverage is available) and by IP (Internet Protocol) for the rest of world to provide the accurate location on the screen of smartphone or tablet by using specific software. The purpose of this study was to assess the accuracy of Global Navigation Satellite System (GNSS) low-cost external antenna and possibility for using it with a smartphone to measure the points in Real Time Kinematic (RTK) and (RTX) modes, obtaining the same accuracy by using high-cost (GNSS) receiver with same modes. The assessment has applied through comparing the control points measured in static mode (3 to 5 hours) and corrected by Online Positioning User Service (OPUS) web-based processing software with same control points measured in RTX mode by GNSS low-cost external antenna (5 minutes). The results of an assessment were obtained horizontal and vertical location error in real time, by receiver getting the RTX correction data over the satellite link were RMS (east 41cm, north 35 cm, elevation 94 cm), that means it's more suitable for automotive, agriculture, and forestry application. As for the RTK mode, the comparison of the differences in RTK mode between the two antennas were RMS (north 5 cm, east 6 cm, elevation 10). This result indicates that the GNSS low-cost external antenna might be very useful in accurate surveying application.

Key words. RTX, RTK, GNSS, Static, Low-cost, antenna.

1. Introduction
GNSS low-cost external antenna was designed to be, lightweight and portable while still allowing the high-quality signal reception required for high accuracy GNSS that including (GPS) Global Positioning System, (GLONASS) Global Navigation Satellite System, Beidou, Galileo and other local systems. There are two commonly used types of the GNSS external antenna: 1) Leica Zeno GG04 plus antenna. 2) Trimble catalyst DA1 antenna.

Leica Zeno GG04 antenna was rough, elastic and not difficult to use, it was designed to bring centimeter-accurate positioning to consumer android devices utilizes RTK technology and applying Precise Point Positioning (PPP). This makes real-time with high-accuracy data collection probably in the most exacting of locations and no need to use the internet connection. The Zeno antenna can connect with all available Zeno handhleds controller as well as Android, IOS and Windows smart devices by Bluetooth. as shown in Figure 1.[1]
Trimble Catalyst DA1 antenna was a lower price than Leica Zeno GG04 antenna, it offers incredibly reliable reception of satellite signals for accurate positioning on the smartphone screen or tablet. In addition to being the technology that combines a software GNSS receiver, digital antenna, and an on-demand monthly subscription to transform an android device into a highly accurate data collector system. Catalyst antenna DA1 was an insert for standard 5/8" and 1/4" thread pole mount, connected the antenna to a fiber carbon rang pole or standard 2m range pole. The antenna cable wound around the pole then connect to the smartphone over the USB port to digitize the GNSS signal and send them to the catalyst applications running on a smartphone, as shown in Figure 2.

There is five main android software available for the Catalyst DA1 antenna (Trimble Penmap for android, Trimble Terraflex mobile, 3DR GCP, K-mobile and ESRI collector for Arc GIS). These applications integrate directly with Catalyst using Trimble Precise Software Development Kit (TPSDK), opening more advantages and adding greater value and functionality to field workflows with Catalyst technology. These applications were using the Trimble Mobile Manager android application to manage the Catalyst subscription and initiate a connection to the Catalyst soft GNSS engine, monitor the status of the service,
and control how GNSS positions are access or shared with other location-enabled applications running on the phone or tablet. However, depending on the level of integration receiver settings and setup can be customized. The applications are easily configured to use positions from Catalyst instead of the phone's on-board GPS.

Trimble Penmap for Android was optimized to participate with the new Trimble Catalyst facility, a software-defined GNSS receiver that attaches to the small, low-priced plug-and-play antenna, and allows surveyors to select from centimeter to one meter as the level of accuracy will be suit to their applications.[2]

There are four subscription levels of the software differ among them depending on what works type, the prices of these subscription increases according to the accuracy increasing. Both (first and second) Meter and Sub-meter subscriptions make use of Trimble’s RTX service provided by geostationary satellites whereas the (third and fourth) decimeter and precision subscriptions require a reliable internet connection.

The detailed of each subscription as follows: -

- **Meter subscription** delivers code processing utilities the debug data from the RTX service. At the first, tries to obtain code data from the RTX online service when the internet connection is available, if not. it can obtain the data from the GSO L-Band satellites which are transmit RTX corrections. if the others sources are not available, it is possible to use an SBAS solution. The area covered by this service is shown in Figure 3.

![Figure 3. The area coverage by one-meter subscription.](image)

- **Sub-meter subscription** using the same RTX code correction sources with the same method as the meter subscription, but the higher subscription rate opens the precision. When using online code data, it is possible to obtain 30cm-75cm, and by satellite-based code data, it is just less precise (40cm-60cm). The area covered by this service is shown in Figure 4.
• **Decimeter subscription** using RTK or Network RTK sources or both sources. If a surveyor is in an area covered by Trimble’s VRS Now networks (south of the U.S., Western Europe, Australia, etc.), corrections were provided by internet connection and might be included in the subscription. If not, will connect to another real time networks (local, regional, state) which is free in some area and charges in the others or obtain the RTK corrections from base station supported by internet protocol (private or public). This subscription level opens the handling for only decimeter precision. The area covered by this service is shown in Figure 5.

• **Precision subscription** opens in the range of 2cm by handling of full-on RTK/Network RTK. It can use some of RTK formats, like RTCM-3. It is also supporting RTCM-3 MSM (Multi-Service Message) for multiple towers. The area covered by this service as shown in Figure 6.[3]
The RTX positioning solution is the technique producing by the employment of a different set of new technologies, that support users with real time centimeters accuracy location at any position on earth’s excepting the seas and oceans. This innovative technique working on precise satellite information, which produced at processing centers, and broadcasting to users. Utilizing an RTX signal is more useful because it was no more worrying about losing the signal of radio connection since a base station is not necessary while providing the productivity of RTK positioning. [4]

**HOW DOES RTX WORKS**

Trimble RTX technology uses data from a global reference station network distribution consists of more hundred stations, distributed across the globe. These data transmitted by internet to the RTK control center, which contains three parts: 1) Communication servers that utilities to delay network observation data to the data processing servers. 2) Data processing servers that host the network processors that produce precise orbit, clock, and observation biases valid for any place in the world. 3) Networked Transport of RTCM by Internet Protocol (NTRIP) that forwarded the correction to the satellite uplink station in the United States. The RTX correction will be uploaded to the L-band communication satellite by the satellite uplink station, so the GNSS antenna will be easy to access satellite delivery to get the positions with high accuracy in nearly any work environment. The NTRIP Caster can also distribute the data stream into the internet for possible use by all receivers connected to the internet via IP/cellular communication. As shown in Figure 7 [5]
The aim of this study is to achieve a highly accurate positioning corrected by the RTX technology using precision subscription and low-cost external antenna (Catalyst DA1 antenna) with smartphone contains Penmap android application, even if this subscription does not cover the region of Iraq.

2. Case Study Area And Dataset
Al-Jadriya Campus - the University of Baghdad were selected as a study area for this research due to the availability of a large number of the control points distributed in a strong surveying style, which constantly monitors every year. Ten points were selected depend on: 1) the open sky visible and space surround the points. 2) Far away from the artificial obstacles (high voltage electric power transmission lines, communications towers) and natural obstacle that cause reflection of satellite signals such as lakes and high buildings as shown in Figure 8.

![Figure 8. The Position of the ten points.](image)

Each of these selected points was observed four times using different devices (GNSS Topcon GR5, Catalyst DA1 antenna and smartphone) with different surveying positioning techniques (Static, RTK and RTX) as well as mobile software GNSS receiver (Penmap). The comparison between the differences in the coordinates comes from these devices and techniques for the same points employed to assess the accuracy of Catalyst DA1 antenna and the possibility to use it in accurate surveying application.

3. Methodology
The assessment and possibility of using the low-cost external antenna (Catalyst DA1 antenna) in an accurate surveying application are explained in this paper by using the different subscription of the RTX technology.

Regarding fieldwork, The Ten points selected were observed by GNSS device using Static mode. Then it observed by Catalyst DA1 antenna connected to the smartphone with Penmap android application using the sub-meter subscription for RTX correction without using the mobile data connection.

The RMS for easting, northing, and elevation were computed from the differences in coordinates obtained from the two devices to assess the accuracy of Catalyst DA1 antenna for the sub-meter subscription in Iraq. On the other hand, each of these ten points observed by Topcon GR5 using RTK over internet mode. Then observe by Catalyst DA1 antenna with Penmap android application using precision subscription provides...
The differences between the coordinate that comes from the two devices were proved to the possibility of using DA1 antenna for Accurate Surveying Applications by computed the RMS for easting, northing, and elevation as well as the time period to obtain the corrected coordinates.

4. The Processing And Results

The coordinate of the ten points, which observed by GNSS device using static mode (3-5 hours) has been transferred to OPUS web-based processing software to fix ambiguities and mitigate multipath error and provides easy access to high-accuracy. The coordinates were average from three autonomously, single-baseline solutions, each calculated by double-differenced, carrier-phase measurements from one of three nearby Continuously Operating Reference Stations (CORS), and send back to us via mail. These coordinates systems were in The International Terrestrial Reference Frame (ITRF) and the projected system selected was the Universal Transverse Mercator (UTM) as shown in Table [1].

| Point Name | UTM Grid Easting (m) | UTM Grid Northing (m) | Elevation (m) |
|------------|----------------------|-----------------------|---------------|
| GCP 1      | 441850.638           | 3681857.783           | 33.295        |
| GCP 4      | 441923.523           | 3681920.015           | 32.651        |
| GCP 5      | 442120.792           | 3682046.765           | 32.489        |
| GCP 7      | 442218.21            | 3681943.706           | 33.602        |
| GCP 8      | 442316.251           | 3681942.718           | 32.407        |
| GCP 9      | 442037.324           | 3681702.133           | 32.349        |
| GCP 10     | 441883.696           | 3681749.306           | 33.224        |
| GCP 11     | 441844.988           | 3681647.22            | 32.53         |
| GCP 19     | 442056.757           | 3681787.475           | 32.139        |
| GCP 21     | 441907.682           | 3681634.263           | 32.36         |

The coordinates of the same points measuring by Catalyst DA1 antenna has corrected directly by receiving Trimble RTX correction stream from the L-band satellite. Through out the GNSS antenna which tracking the Trimble RTX (L-band) satellite and every other satellite in its field of view (including GPS, GLONASS, Galileo, BeiDou and QZSS. that allows calculating the position in real time with a limited period, not more than three minutes. as shown in Figure 7.

The corrections have been transferred from the antenna along the cable to the Penmap Android application runs on a smartphone, which supports real-time correction source methods including RTK, RTX, and Virtual Reference System (VRS). The project created in the Penmap contains the configuration settings for the raw survey data including coordinate system, map provider and GNSS setting, as shown in Figure 9.
This project was uploaded to Trimble Connect cloud-based collaboration platform, then the corrected coordinates were exported using Penmap project manager office as an Excel sheet. As shown in Table [2].

### Table 2. The coordinate of the ten points measuring in RTX mode by DA1 antenna.

| Point Name | UTM Grid Easting (m) | UTM Grid Northing (m) | Elevation (m) |
|------------|----------------------|-----------------------|---------------|
| GCP 1      | 441850.387           | 3681857.568           | 32.374        |
| GCP 4      | 441923.513           | 3681920.008           | 31.743        |
| GCP 5      | 442120.185           | 3682047.734           | 33.862        |
| GCP 7      | 442217.903           | 3681943.865           | 33.607        |
| GCP 8      | 442316.055           | 3681942.764           | 30.768        |
| GCP 9      | 442036.629           | 3681702.062           | 31.334        |
| GCP 10     | 441883.816           | 3681749.198           | 33.534        |
| GCP 11     | 441845.765           | 3681647.015           | 32.523        |
| GCP 19     | 442056.589           | 3681787.105           | 30.974        |
| GCP 21     | 441907.626           | 3681634.205           | 33.091        |

The comparison between the coordinates comes from the two devices shown in Table [3].

### Table 3. The differences in coordinates.

| Point Name | Delta Easting (cm) | Delta Northing (cm) | Delta Elevation (cm) |
|------------|--------------------|---------------------|----------------------|
| GCP 1      | 25                 | 22                  | 92                   |
| GCP 4      | 1                  | 0.7                 | 91                   |
| GCP 5      | 61                 | -97                 | -137                 |
| GCP 7      | 31                 | -16                 | -0.5                 |
| GCP 8      | 20                 | -5                  | 164                  |
| GCP 9      | 70                 | 7                   | 102                  |
| GCP 10     | -12                | 11                  | -3                   |
| GCP 11     | -78                | 21                  | 0.7                  |
| GCP 19     | 17                 | 37                  | 117                  |
| GCP 21     | 6                  | 6                   | -73                  |

were employed to assess the accuracy of Catalyst DA1 antenna for the sub-meter subscription in Iraq by computing the RMS. The vertical error of 96 cm RMS and the horizontal errors of (41, 35) cm RMS in easting, nothing, respectively, as shown in Figure 10.
On the other hand, the GNSS device used RTK over internet measured the same ten points by connecting to the CORS to receive the real-time corrected coordinates in 2-5 cm accuracy as shown in Table [4].

**Table [4]. The coordinate of the ten points measuring in RTK mode by GNSS GR5**

| Point Name | UTM Grid Easting (m) | UTM Grid Northing (m) | Elevation (m) |
|------------|----------------------|-----------------------|---------------|
| GCP 1      | 441850.593           | 3681857.743           | 33.238        |
| GCP 4      | 441923.483           | 3681919.977           | 32.615        |
| GCP 5      | 442120.880           | 3682046.824           | 32.460        |
| GCP 7      | 442218.171           | 3681943.663           | 33.535        |
| GCP 8      | 442316.202           | 3681942.960           | 32.388        |
| GCP 9      | 442037.270           | 3681702.130           | 32.295        |
| GCP 10     | 441883.668           | 3681749.265           | 33.365        |
| GCP 11     | 441844.920           | 3681647.145           | 32.711        |
| GCP 19     | 442056.714           | 3681787.443           | 32.073        |
| GCP 21     | 441907.548           | 3681634.175           | 32.566        |

Within a few seconds later, the catalyst DA1 antenna using the RTX over the internet measured the same ten points, because there is no satellite coverage for the precise subscription in Iraq provide the accuracy of
RTK method. The corrected coordinates shown in Table [5] have received in a maximum of 5 seconds by the same procedure in Figure 7.

Table 5. The coordinate of the ten points measuring in RTK mode by DA1 antenna

| Point Name | UTM Grid Easting (m) | UTM Grid Northing (m) | Elevation (m) |
|------------|----------------------|-----------------------|---------------|
| GCP 1      | 441850.592           | 3681857.745           | 33.261        |
| GCP 4      | 441923.472           | 3681919.969           | 32.63         |
| GCP 5      | 442120.754           | 3682046.733           | 32.451        |
| GCP 7      | 442218.157           | 3681943.668           | 33.565        |
| GCP 8      | 442316.21            | 3681942.673           | 32.41         |
| GCP 9      | 442037.266           | 3681702.105           | 32.01         |
| GCP 10     | 441883.765           | 3681749.139           | 33.363        |
| GCP 11     | 441844.913           | 3681647.151           | 32.719        |
| GCP 19     | 442056.721           | 3681787.437           | 32.118        |
| GCP 21     | 441907.621           | 3681634.22            | 32.644        |

The accuracy analysis by differencing the two devices shown in Table [6] using the RTK over internet mode solution result in the vertical error of 10 cm RMS and the horizontal errors of (6, 5) cm RMS in easting, nothing, respectively, as shown in Figure 11. [6]

Table 6. The differences in coordinates.

| Point Name | Delta Easting (mm) | Delta Northing (mm) | Delta Elevation (mm) |
|------------|--------------------|---------------------|----------------------|
| GCP 1      | 1                  | -2                  | -23                  |
| GCP 4      | 11                 | 8                   | -15                  |
| GCP 5      | 126                | 91                  | 9                    |
| GCP 7      | 14                 | -5                  | -3                   |
| GCP 8      | -8                 | 17                  | -22                  |
| GCP 9      | 4                  | 25                  | 285                  |
| GCP 10     | -97                | 126                 | 2                    |
| GCP 11     | 7                  | -6                  | -8                   |
| GCP 19     | -7                 | 6                   | -45                  |
| GCP 21     | -73                | -45                 | -78                  |
Figure 11. RMS in easting, northing and elevation in RTK mode

this indicates that the catalyst DA1 antenna can be used for the accurate surveying application.

5. Conclusions
This research based on a precise location through low-cost equipment; this study proved the possibility of utilities RTX in real time depend on different subscriptions where maximum accuracy (mm resolution) is not required. The following conclusions extracted from the results of this study:

- The study has shown that the RTX can be used on the projects that reducing the total cost of the equipment system without affecting the accuracy required.
- The static tests with the sub-meter subscription of RTX correction showed RMS value in easting, northing and elevation are 41, 35, 94 cm, respectively. This indicates that Catalyst DA1 antenna can be used for applications that require a low accuracy such as mapping, agriculture, and forestry.
- RMS in easting, northing, and elevation for the RTK mode tests with the precision subscription of RTX correction showed values of (6, 5, 10) cm easting, northing, and elevation, respectively. This indicates that the Catalyst DA1 antenna can be used for surveying applications that require high accuracy.
- RMS in point 5 was maximum because there is no open sky above this point.
- The positions accuracy in RTK mode comes from high-cost GNSS is not much different from comes by using the low-cost antenna and the measurement time is the same.
References

[1] GNSS I 2017 Leica Zeno GG04 Smart Antenna Aids GNSS Accuracy with RTK, PPP INSIDE GNSS IG Magazine

[2] Barker A 2017 Industry News GEOMATICA, Canadian Science Publishing (CSP) 71 116-8

[3] Schrock G 2017 A groundbreaking new service turns your smartphone into a high-precision, software-defined GNSS receiver.

[4] Agüera Vega J 2014 Comparison of positional accuracy between RTK and RTX GNSS gased on the autonomous agricultural vehicles under field conditions APPLIED ENGINEERING IN AGRICULTURE

[5] Leandro R, H. Landau, M. Nitschke, M. Glocker, S. Seeger, X. Chen, A. Deking, M.B. Tahar, F. Zhang, R. Stolz, N. Talbot, G. Lu, K. Ferguson, M. Brandl, V. Gomez, A. 2011

[6] Leandro R, Landau H, Nitschke M, Glocker M, Seeger S, Chen X, Deking A, BenTahar M, Zhang F, Ferguson K, Stolz R, Talbot N, Lu G, Allison T, Brandl M, Gomez V, Cao W and Kipka A 2011 RTX Positioning: The Next Generation of cm-accurate Real-time GNSS Positioning Proceedings of the 24th International Technical Meeting of the Satellite Division of The Institute of Navigation (ION GNSS 2011) 1460 - 75