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Locator One

Technical literature about monitoring precision.

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Basetime
PRECISION MONITORING

Abstract

The development of sensors has undergone tremendous development over the past decade including GNSS sensors. Positioning using GNSS sensors has become indispensable in our society thinking of navigation purposes or for tracking objects.

Basetime has developed Locator One over the past year to provide very precise positioning using GNSS sensors, among others. During development, a number of large appealing global companies were included in the development of the product to incorporate their requirements and wishes into the final product.

This paper describes the technical background including the data quality of the Locator One when using these devices for monitoring assets in relation to precision. With launching the Locator One, Basetime sets a new standard for autonomous precise and reliable monitoring of assets using GNSS in an attractive price range.

Introduction

The Locator One is an autonomous Multi-band GNSS-based precision measuring device designed for construction companies, surveyors, maritime corporations, geotechnical and structure engineers, and asset managers with complex motion monitoring tasks. By mounting the devices directly on an asset to monitor, or on a settlement rod in case of subsidence, we deliver sub-centimetre monitoring precision in 3D.

Locator One includes sensors like a.o. Multi-band GNSS, thermometer, and RADAR to monitor every horizontal and/or vertical movement of an asset or ground.

The position determination is based on calculate post-processed baselines using one or more reference stations or using virtual reference networks (VRS).

Productivity & User Experience

Our customers install the devices themselves on a project. A Measurement Management System (MMS) is being used to configure the devices as desired and set up a project environment to present final results in a data dashboard. Our customers will use our back end database including developed algorithms to calculate and adjust the measurements.

Installation:

A fleet of Locator One devices is mounted on settlement rods to determine the height of the baseplates, which are positioned at the original ground level. A radar sensor in the Locator One will measure the distance to the actual ground/sand below the settlement rod. For building or structure monitoring the device can be mounted directly on an asset. The Locator can be configurate manually remote to let them measure until 24 times per day.

Connectivity:

The Locator One send its raw geodetic observations and meta data to the Locator One cloud server by using LTE-M connectivity.

Locator One cloud:

Together with the raw data as sent simultaneously by a Locator One used a reference station or a virtual GNSS network, we calculate and adjust precise and reliable baselines to finally obtain absolute coordinates of the monitored assets. Using the differences between these 3D-coordinates, we can accurately deliver the relative and absolute deformation, including the direction of motion.

Data delivery

The results are displayed on the Basetime dashboard, or another preferred environment through an API. In joint consultation, we adapt the data to the contractor's working method.

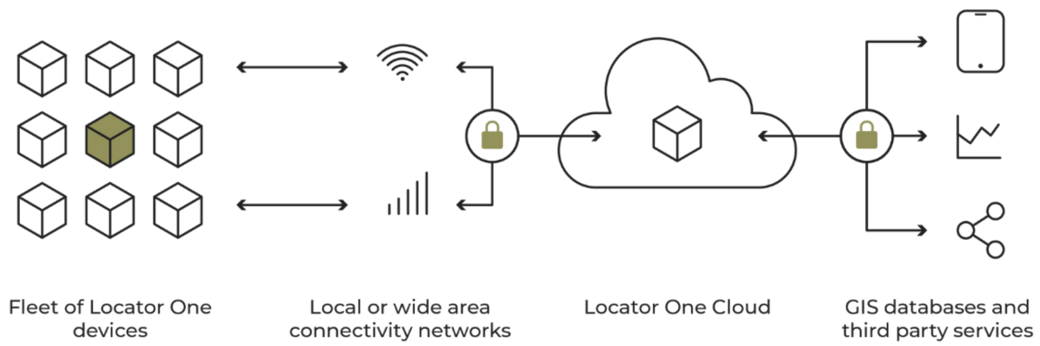


Figure 1 *– Overview of the data flow*

High-performance GNSS-solution

For monitoring assets with Locator One we're calculating the position of the Locator One by using post processed single baselines between the Locator One (mounted on an asset) and a reference station based on star shaped pattern method. The reference station could be a Locator One as well mounted on a stable object or a virtual reference station out of a virtual reference network.

The Locator One is equipped with a multiband GNSS receiver and antenna (186 channels) and it receives and collect the following satellite bands:

GNSS	Bands
GPS	L1C/A and L2C
GLONASS	L1OF and L2OF
Galileo	E1B/C and E5b
BeiDou	B1I and B2I

Table 1 *– GNSS receiver and antenna and it receives and collects the following satellite bands.*

For a standard procedure the device will do an observation with 1Hz of in total of 5 minutes counting from the boot of the Locator One. Between 20 and 30 seconds after the boot of the Locator One, the device will receive all possible and necessary satellite data within an elevation mask of 10 degrees. That means that we will have around 270 epochs to solve the ambiguity and to determine accurate coordinates (reliable and precise).

Performance analysis GNSS

To determine the precision of the processed baselines, we place one Locator One, defined as reference station, at a stable location as standard. For this performance test 20 Locator Ones (rovers) were installed at stable locations at different distances (10 meters and 1, 2, 3 and 4 kilometers) from the reference stations (at every distance four devices were placed).

For 115 days, each of these 21 devices in total did an observation of 5 minutes starting at 00:00 UTC every day, which all devices had a completely free horizon and were able to receive all available satellite data above an elevation mask of 10 degrees.

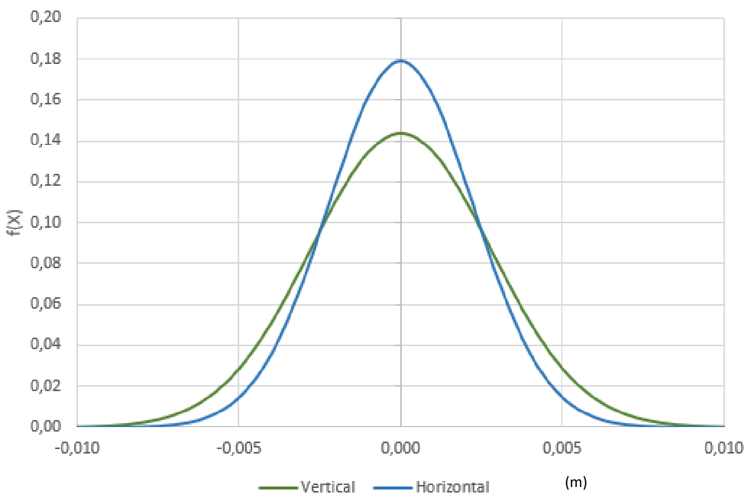
We processed with our algorithms 20 baselines (between reference station and the 20 rovers) for 115 days. To increase the reliability of the determination of the baseline, the ambiguity is determined both forward and backward. Before adjusting the baseline, our processing algorithms will first eliminate epochs with a high signal-noise ratio and/or suspected multipath effect.

In the adjustment of the final baseline, a weighted least-squares adjustment was applied, testing each epoch of an observation epoch to finally obtain the best possible reliable and precise result.

To indicate horizontal and vertical precision, we determined the calculated positions of the rovers in the national datum of the Netherlands (RDNAPTRANS2018). In 'graph 1' is shown the normal distribution horizontal and vertical position bases on rover at 10-meter distance from the reference station. In 'table 2' is shown a comparison of the accuracy (m) of processed locations over 115 days (one measurement a day) using rovers at different distances from the reference station.

Standard deviation (1σ) of X, Y, Hz(Horizontal) en V(Vertical)				
Rover	σX	σY	σHz	σV
10m	0,001	0,001	0,002	0,003
1km	0,001	0,002	0,003	0,004
2km	0,002	0,002	0,003	0,005
3km	0,002	0,003	0,004	0,005
4km	0,003	0,003	0,004	0,006

Table 2 *– Comparison of the precision (m) of processed locations over 115 days (one measurement a day) of rovers at different distances from the reference station.*



Graph 1 *– Normal distribution horizontal and vertical position based on rover at 10-meter distance from the reference station for 115 days (measurement once a day)*

Based on the results presented in table 2, we can conclude that we achieve at least the following precision (1σ) for the post processed baselines with the Locator One with a maximal length of 4 kilometer:

- Horizontal precision: 2mm + 0,5 ppm
- Vertical precision: 4mm + 0,5 ppm

The precision described above was achieved under the following conditions:

- Daily measurement on 00:00 UTC in The Netherlands.
- GNSS observation duration between 4:30 and 4:40 minutes.
- Completely clear horizon (no obstacles above an elevation mask of 10 degrees).
- GNSS-observations of 1Hz.

Any changes of the conditions will have an impact on the quality of the results where a free horizon has the greatest impact overall. To increase the reliability and thus the quality of the result, the number of measurements per day can be increased and thus get a better understanding about the natural movement of the asset and the measurement noise.

Radar distance sensor

On the bottom of the device is a radar distance sensor that can measure a distance from the device to ground level. This distance sensor was added to the Locator One during device development mainly for settlement rod measurement. This way we can measure not only the subsidence of the original ground level but also the settlement of the raised sand package.

The radar distance sensor measures a conical distance downward at an angle of 15° (see Figure 2). At 2 meters from the ground, we measure a representative distance based on a footprint (circle) with a diameter of 54 centimeters. As the distance from the ground increases, so does the footprint.

A radar measurement from the radar sensor consists of a total of 64 distance measurements where the final distance is determined by using the least squares adjustment. Before the distance is determined, any erroneous distances are eliminated by an intelligently developed algorithm. This includes distances that reflect on other objects, for example, the enlargement plate of a settlement rod (a settlement rod does have fixes enlargements lengths).

To determine the quality of the radar distance sensor in this test, we measured the distance from the length of the settlement rod daily for 115 days on four different settlement rods with Locator One. This involved measuring the distance from the head of the pocket beacon to the top of the footplate. This footplate was metal and completely flat and free of sand etc. As a result, based on these datasets, this gives a precision (1σ) of 1mm.

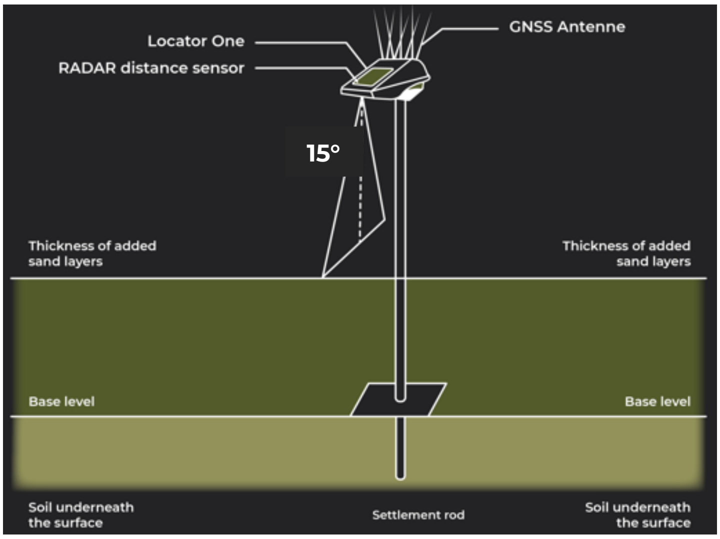
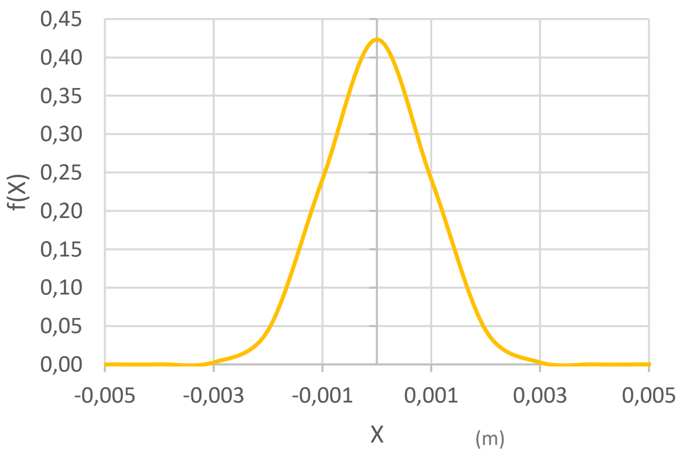


Figure 2 *- Radar distance with 15° cone shape*

Standard deviation (1σ) of radar distance sensor		
Radar	σDistance	Mean measured distance
Rover 1	0,001	1,992
Rover 2	0,001	2,009
Rover 3	0,001	2,012
Rover 4	0,001	1,997

Table 2 *– Comparison of the precision (m) and mean measured distance (m) of processed locations over 115 days (one measurement a day).*



Graph 2 *– Normal distribution radar measurement*

What is noticeable here is that the measured lengths of the settlement rods differ. The contractor assumes that in principle the lengths of the settlement rods should be fixed 2,000 meters but these vary, and Locator One is able to determine the distance with a standard deviation of 1mm. We see differences of up to 2.0 cm in practice.

The distance sensor reflects on all possible substrates such as sand, clay and peaty soil. The distance sensor can also reflect on water. The final reliability of the measured distance of the distance sensor also depends on the degree of flatness of the ground. Our smart algorithm ultimately searches for the most representative height of the surface under the Locator One within the footprint and considers the surface type specified by the user.

Power supply

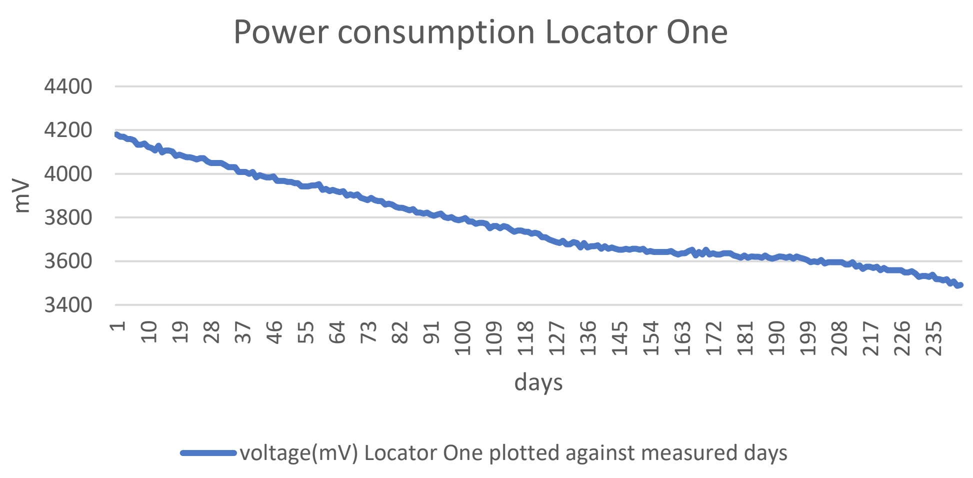
For the power supply, we use a solar panel (4 watts) and a supercapacitor (4.0v DC) for the Locator One. The solar panel is used to charge the supercapacitor. For optimal charging of the solar panel, Locator One should be pointed towards the equator. The supercapacitor can be charged to at least 4000 mV, in practice it will be even higher. The Locator One will remain operational down to 3500mV. If the Locator One hits this threshold, it will no longer take measurements. Locator One's supercapacitor will have to be refilled to at least 3700mV to start measuring again if it went below the threshold of 3500mV.
Between measurements, Locator One falls into a deep sleep to reduce the loss of energy to a minimum. The charging can be done autonomously by the sun or using a charging cable. This charging cable can also be used as external power input during operation when power supply is available.

Performance Power supply

To determine the energy consumption of a measurement (5-minute GNSS measurement and radar measurement (64 times and send data), we performed a measurement with a full supercapacitor for 243 days until it was under the threshold of 3500mV (minimum operation level). During these 243 days we had temperatures between -5°C and 30°C.While doing so, we switched off the solar panel.

On day 1, the voltage was 4180mV and the Locator One performed a daily measurement as described above for 243 days before reaching the threshold of 3500mV. For consumption, this amounts to an average of 2.8mV per measurement ((4180mV-3500mV) / 243 = 2,8mV).

To minimize this consumption, the GNSS measurement can be shortened and possibly the radar measurement switched off if not needed.



Graph 3 *- Power consumption Locator One over 243 days with one measurement a day*