Geolocation Accuracy Test Description

To assess the geolocation accuracy of AFC devices, Sporton Lab has developed a comprehensive field trial test plan. This plan employs a standard reference point with a precisely known location to gauge the geolocation accuracy of AFC devices. The measurements were conducted at 5000 sample points, utilizing GPS data, which was recorded during the trial test. Subsequently, 5000 location data points were collected, and the horizontal and vertical location uncertainty was calculated at a 95% confidence level. Horizontal location uncertainty is calculated using both circle (R95) and ellipse (E95) methods. Manufacturers can choose one for their application.

1. Standard Reference Point:

Taiwan Class 1 Level Reference Net was provided by Taiwan Satellite Survey Center, Depart of Land Administration. M.O.I. [1] and the class 1 grade 1 level reference net horizontal results at latitude, longitude and height direction deviation average values are ±1.4 cm, ±1.3 cm, and ±10.9 cm, respectively.

Reference Point Number: 6017
Coordinate System: TWD97
Easting (E): 249570
Northing (N): 2743380
Orthometric Height: 40m

Converted the coordinate TWD97 to WGS84 DD:

Longitude: 120.995747
Latitude: 24.797783
Above Mean Sea Level (AMSL) Height: 40.52m (Test table height: 0.52m)

控制點號	6017	控制點名	
控制點等級	一等水準點		
控制點所在位置	新竹市新竹市		
註明			

111年臺灣一等水準網水準測量成果

公告機關：內政部

測量坐標系統	TWD97
測量坐標分帶	121
測量坐標X	249570
測量坐標Y	2743380
高程	40

2. GPS Measurement Data:

Sporton only captures GPS data and does not use GNSS, SABS, Galileo, Quasi-Zenith and BeiDou. Examples of source material are provided below. $GPGGA is the GPS log output. Sporton captures that the second through fifth digits represent horizontal position and the 9th digit represents altitude.

```
$GPGGA,032511.000,2447.8727,N,12059.7463,E,1,8,0.95,71.6,M,15.0,M,,*6E
$GPGLL,2447.8727,N,12059.7463,E,032511.000,A,A*5B
$GNGSA,A,3,25,24,32,18,15,12,23,10,,,,,1.29,0.95,0.87*1B
$GPRMC,032511.000,A,2447.8727,N,12059.7463,E,0.00,0.00,131123,,,A*6F
$GPVTG,0.00,T,,M,0.00,N,0.00,K,A*3D
$GPGGA,032512.000,2447.8727,N,12059.7463,E,1,8,0.95,71.6,M,15.0,M,,*6D
$GPGLL,2447.8727,N,12059.7463,E,032512.000,A,A*58
$GNGSA,A,3,25,24,32,18,15,12,23,10,,,,,1.29,0.95,0.87*1B
$GPRMC,032512.000,A,2447.8727,N,12059.7463,E,0.00,0.00,131123,,,A*6C
$GPVTG,0.00,T,,M,0.00,N,0.00,K,A*3D
$PGTOP,3,AXN 5.1.1,8513,012-11-2017,GNSS EXTRF 115200,011-13-2023,032513*22
$GPGGA,032513.000,2447.8727,N,12059.7463,E,1,7,0.95,71.6,M,15.0,M,,*63
```

3. 5000 Samples:

Referring to [2], errors were analyzed for series comprising 600 measurements (over a 10-minute duration) up to 44,500 measurements (over a 12-hour duration). Position radius errors converged after capturing 4,800 samples during an 80-minute measurement period. For the Sporton test report, 5,000 samples were chosen with a measurement duration of 120 minutes.

k	$\sqrt{k}$	σ_z	σ_λ	CEP	DRMS	Δ_R
-	-	m	m	m	m	m
600	24,5	1,98	2,01	2,36	2,82	1,85
1200	34,6	2,88	2,97	3,45	4,14	1,28
1800	42,4	2,97	3,55	3,86	4,63	1,36
2400	49,0	3,45	3,62	4,18	5,00	1,26
3000	54,8	3,16	3,35	3,85	4,61	1,31
3600	60,0	2,95	3,76	3,98	4,78	1,87
4200	64,8	2,86	3,95	4,05	4,88	0,98
4800	69,3	3,21	4,46	4,56	5,50	1,13
5400	73,5	3,36	4,52	4,68	5,63	1,15
6000	77,5	3,61	4,68	4,92	5,91	1,22
43200	207,8	3,82	4,84	5,14	6,17	1,15

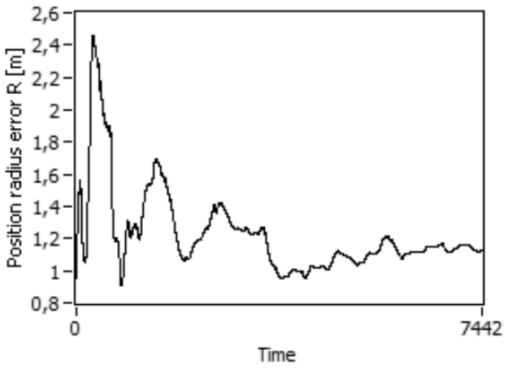


Fig. 10. Position radius error Δ_R in meters versus time of measurement in seconds

4. Radius of the 95% Probability Circle (R95) Error (XY):

R95 Error represents the radius of the circle encompassing 95% of the position-determining results.
Calculation of R95 Error is performed using the following formula:

R95 Error = 2.08 × (0.56σx + 0.62σy) [2]

Where σx and σy are the standard deviations from the known position in the directions of the coordinate axes.
At a 95% confidence level:

95% Confidence Level = R95 Error + Mean Error

Mean Error is calculated as Mean Point – Standard Point.

5. Confidence 95% Ellipse (E95) Error (XY):

E95 Error, which is the ellipse error comprising 95% of the position determining results is following formula:
In our case, the length of the axes are defined by the standard deviations σx and σy of the data such that the equation of the error ellipse becomes:

$$\left(\frac{x}{\sigma_x}\right)^2 + \left(\frac{y}{\sigma_y}\right)^2 = s = 5.991 \quad [3]\ [4]\ [5]$$

where s defines the scale of the ellipse chi-square distribution number.
Thus, the 95% confidence ellipse can be defined similarly to the axis-aligned case, with the major axis of length $2\sqrt{s\lambda_1}$ and the minor axis of length $2\sqrt{s\lambda_2}$, Where λ1 and λ2 represent the eigenvalues of the covariance matrix.
To obtain the ellipse orientation:

$$\alpha = \arctan\frac{\mathrm{V1(y)}}{\mathrm{V1(x)}}$$

where V1 is the eigenvector of the covariance matrix that corresponds to the largest eigenvalue.

95% confidence level= E95 Error + Mean Error

Mean Error = Mean point – Standard point

6. 95% Probability Height Error (Z):

Height Error represents the range encompassing 95% of the position-determining results in the Z-axis.
Calculation of Z Error is performed using the following formula:

Z Error = 1.96 × σz [6]

Where σz is the standard deviation from the known position in the Z-axis.
At a 95% confidence level:

95% Confidence Level = Z Error + Mean Error

Mean Error is calculated as Mean Point – Standard Point.

References:

[1] Class 1 Level Reference Net by Satellite Survey Center, Depart of Land Administration. M.O.I. https://gps.moi.gov.tw/sscenter/Introduce_E/IntroducePage_E.aspx?Page=GPS_E8
[2] AN EXPERIMENTAL INVESTIGATION INTO THE POSITIONING ACCURACY OF LOW-COST GPS RECEIVERS

IN LABVIEW ENVIRONMENT by Politechnika Gdańska Wydział Elektrotechniki i Automatyki Gdańsk 2015
[3] https://www.visiondummy.com/2014/04/draw-error-ellipse-representing-covariance-matrix/
[4] Two-Dimensional Measures of Accuracy in Navigational Systems by Gerald.Y. Chin Transportation Systems Center Cambridge, MA 02142
[5] BORG, F, 2002. The Confidence 95 Ellipse [online]. Finland [cit. 2017-01-07].
[6] Normal Distribution | Examples, Formulas, & Uses by Pritha Bhandari.
https://www.scribbr.com/statistics/normal-distribution/

Geolocation Accuracy Test Report

Equipment	:	**GPS Module**
Brand Name	:	**Ublox**
Model Name	:	**ZOE-M8G**
Applicant	:	**Cisco Systems Inc** **125 West Tasman Drive San Jose California United States 95134-1706**
Manufacturer	:	**Cisco Systems Inc** **125 West Tasman Drive San Jose California United States 95134-1706**
Sample Received	:	**Oct. 25, 2023**
Start Test Date	:	**Dec. 25, 2023**
Final Test Date	:	**Dec. 26, 2023**
Standard	:	**FCC KDB 987594 D01v02**

Table of Contents

History of this test report

Report No.	Version	Description	Issued Date
F2281101-12	01	Initial issue of report	Jan. 31, 2024

Summary of Test Result

Conformance Test Specifications				
Report Clause	**Description**	**Radius 95%+ Uncertainty+ Error (m)**	**Ellipse 95%+Error X (m) / Y (m) / Orientation(°)**	**Probability 95%+ Uncertainty+ Error Z (m)**
2.1.3	Field Trial Test Result	11.19	10.19 / 6.98 / 40.34	21.26

Note: There are additional cables between the GPS antenna and the product, GPS cable length is not taken into account in the test results and should be evaluated by the manufacturer.

1 General Description

1.1 Information

1.1.1 General Information

General Description	
GPS Type:	
☒	Build-in GPS is part of the device certification
	GPS Chip Manufacturers: u-blox
☐	Independent GPS is not part of the device certification
	GPS Provider: ☐ Single Provider; ☐ Multi Provider
	GPS Manufacturers:
	GPS chip manufacturers:
	GPS Models:
	Types of GPS devices: USB Dongle / handsets / tablets
Installation Environment:	
☐	Indoor
☒	Outdoor
Altitude Definition:	
☒	The altitude is determined and entered by the professional installer.
☐	The altitude is determined by GPS Altitude.
Supported Software Product IDs	
IW9167EH-B - Industrial Wireless 9167 AP IW9167EH-B-AP - Wi-Fi mode IW9167EH-B-URWB - URWB mode IW9167EH-B-WGB - WGB mode IW9167EH-ROW - Industrial Wireless 9167 AP IW9167EH-ROW-AP - Wi-Fi mode IW9167EH-ROW-URWB - URWB mode IW9167EH-ROW-WGB - WGB mode IW9165E-B-WGB IW9165E-B-URWB IW9165E-B-AP IW9165DH-URWB IW9165DH-B-AP	

1.1.2 GPS Antenna Information

Antenna Category	
☐	Integral antenna (antenna permanently attached)
☒	External antenna (dedicated antennas)

Ant.	CISCO's Brand Name	CISCO's Model Name	Antenna Type	Connector	Gain (dBi)
	Manufacturer's Brand Name	Manufacturer's Model Name			
1	CISCO	ANT-GNSS-OUT-TNC=	Patch Antenna	TNC Male	2.5
	Pulse	W4053T4572			

Note: The above information was declared by manufacturer.

1.1.3 Table for Multiple Listing of Host

The EUT (GPS Module) will be installed on the host following.

The differences in host model names are listed in the following table.

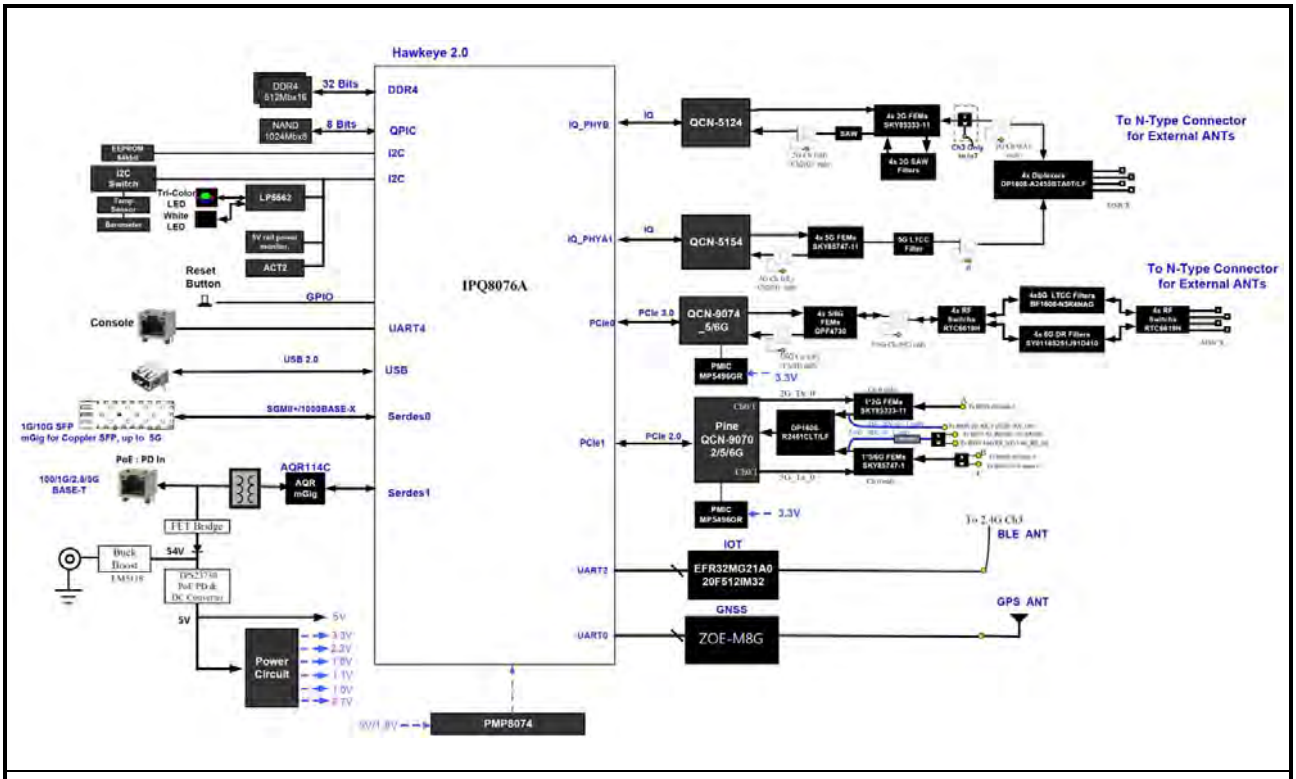
Host Brand Name	Host Model Name	Description for GPS
CISCO	IW9167EH-B	Using the same GPS Chip and GPS Antenna.
	IW9167EH-ROW	
	IW9165E-B	
	IW9165DH-B	

Note 1: From the above models, host model: IW9167EH-B was selected as representative model for the test and its data was recorded in this report.

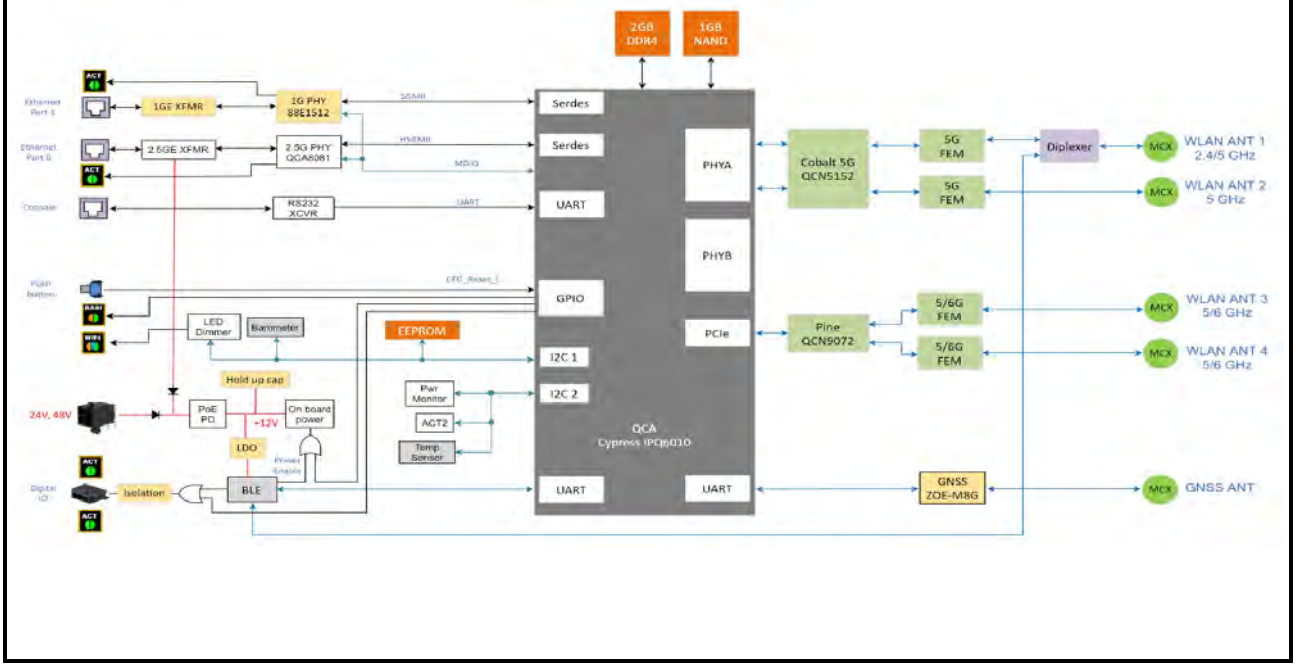
Note 2: The above information was declared by manufacturer.

1.1.4 Geolocation System Block Diagram

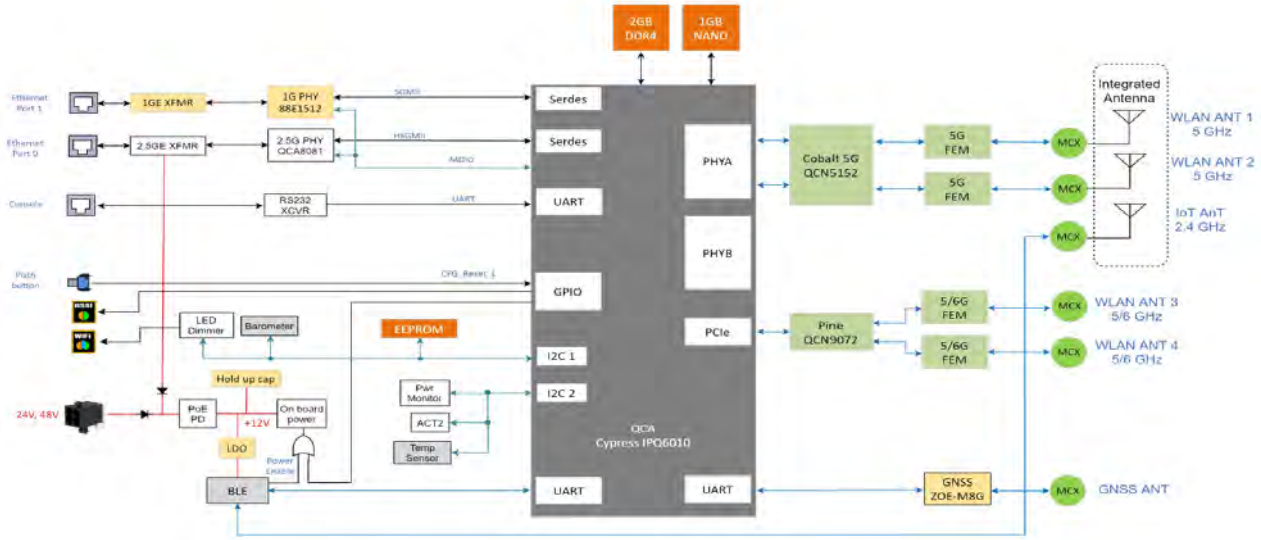
System Block
Host Model Name: IW9167EH-B and IW9167EH-ROW



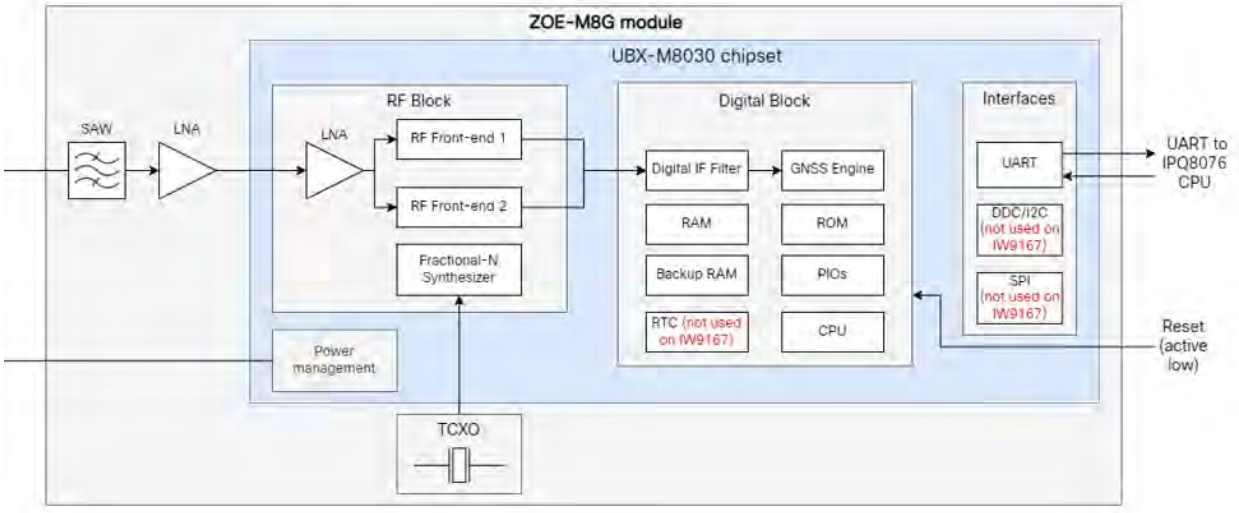
Host Model Name: IW9165E-B



Host Model Name: IW9165DH-B



GPS Block



1.2 Testing Location Information

Testing Location Information	
Test Lab.：Sporton International Inc. Hsinchu Laboratory	
Hsinchu	ADD: No.8, Ln. 724, Bo'ai St., Zhubei City, Hsinchu County 302010, Taiwan (R.O.C.)
	TEL: 886-3-656-9065 FAX: 886-3-656-9085

Test Condition	Test Site No.	Test Engineer	Test Environment (°C / %)	Test Date
Radiated (Field Trial Test)	-	Jeff Wu	21.6~22.1 / 65~68	Dec. 25, 2023~ Dec. 26, 2023

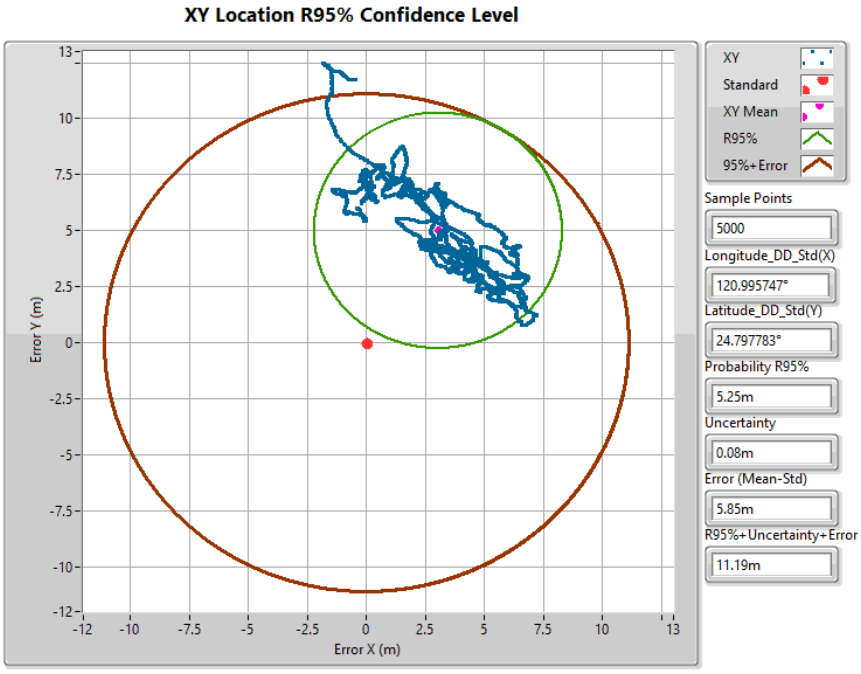
1.3 Support Equipment

Support Equipment				
No.	**Equipment**	**Brand Name**	**Model Name**	**FCC ID**
A	Notebook	DELL	E4300	N/A
B	AC adapter	LITEON	PA-1600-1C	N/A

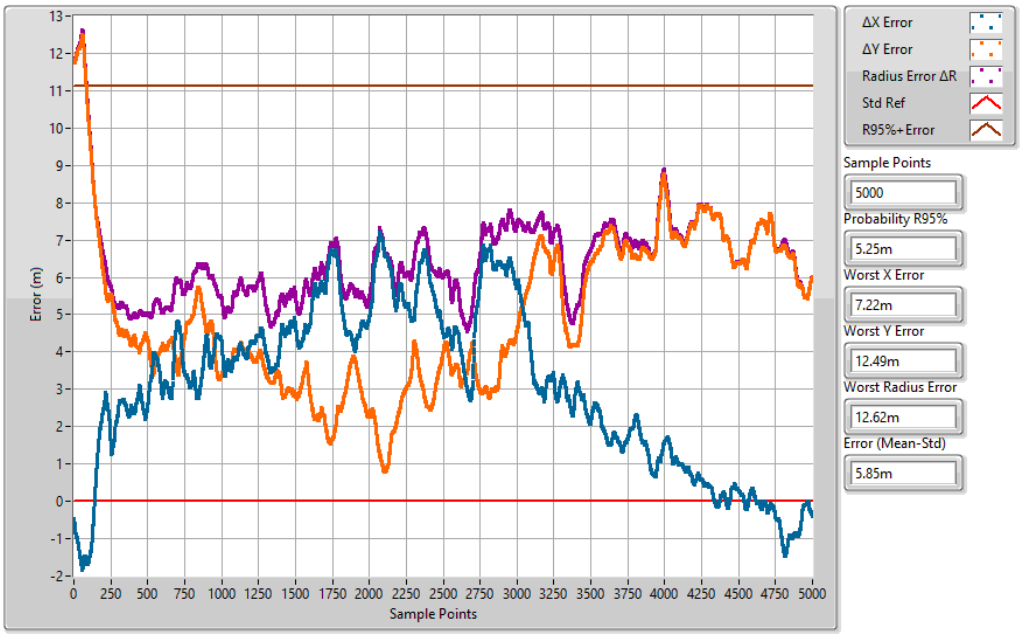
2 Test Result

2.1 Field Trial Test Result

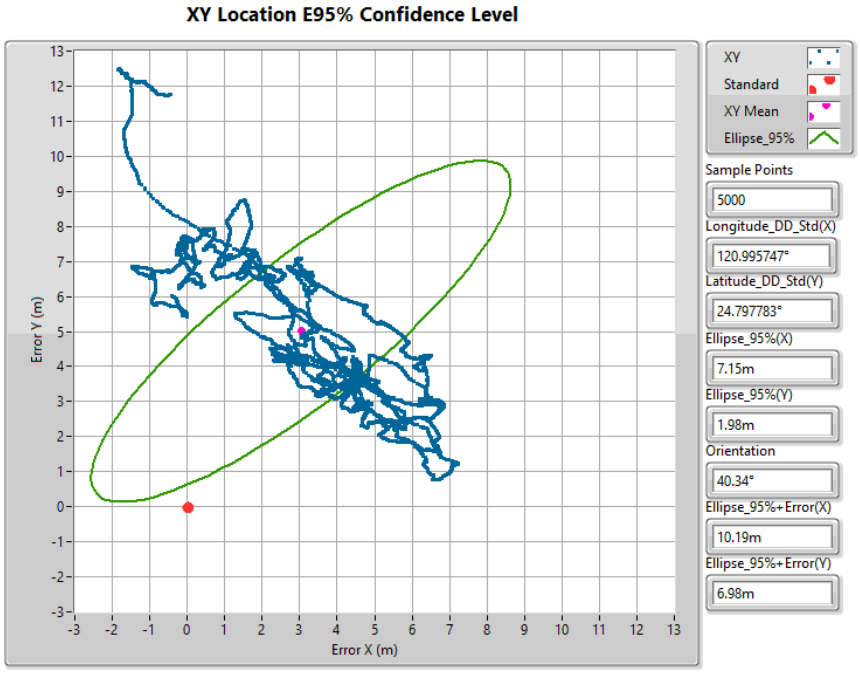
Radius XY 95% Confidence Level



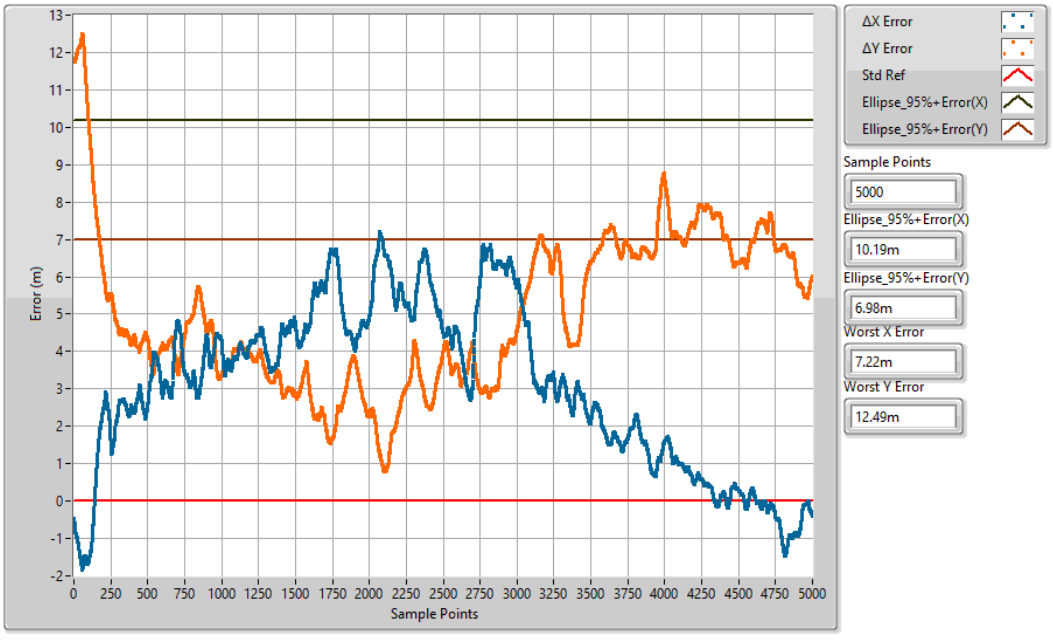
Radius XY Error vs Sample Time



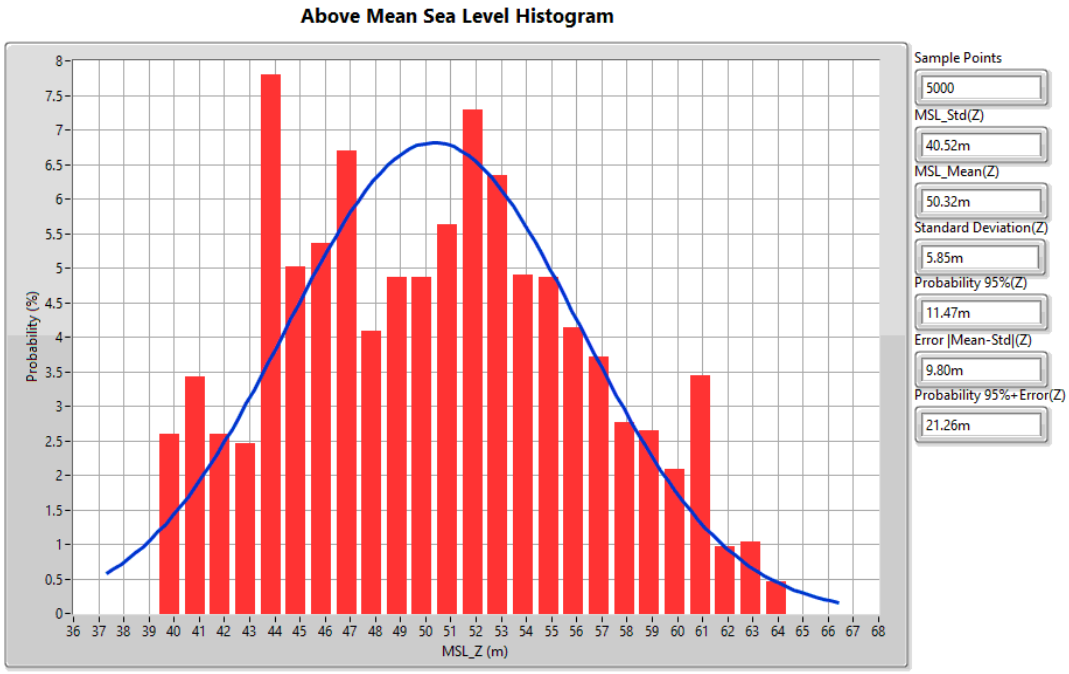
Ellipse XY 95% Confidence Level



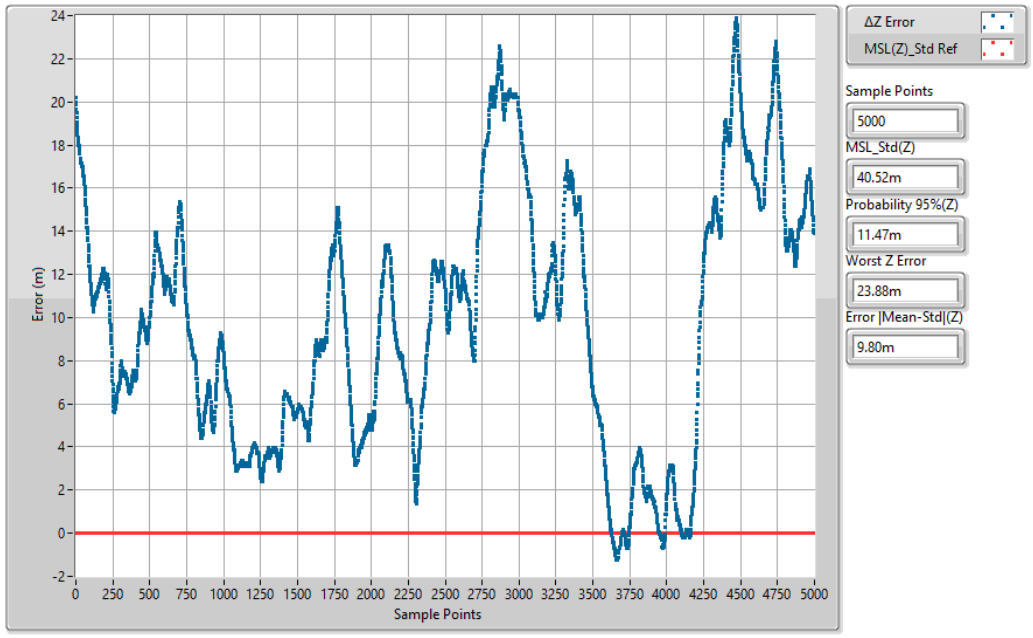
Ellipse XY Error vs Sample Time



Z 95% Confidence Level



Z Error vs Sample Time



3 Test Equipment and Calibration Data

Instrument	Manufacturer	Model No.	Serial No.	Spec.	Calibration Date	Calibration Until	Remark
Test software	SPORTON	SENSE-GPS XYZ	V1.3	N/A	N.C.R.	N.C.R.	Radiation

Note: NCR means Non-Calibration required.

4 Test Photo

FRONT VIEW

———THE END———