AN5317
Application note

Teseo-LIV3F - Low Power Report

Introduction

Purpose of this document is to provide information on the Low Power Management implemented in the Teseo-LIV3F, and power measures against accuracy achieved on Teseo-LIV3F.

Contents

List of tables

List of figures

1 Overview introduction

The Teseo-LIV3F supports different Low Power Mode as shown in *Table 1*

Table 1. Low power mode supported on Teseo-LIV3F

Low Power Mode	Description	Note
Adaptive	Dynamic constellation switching and dynamic channels switching (numbers of satellites used)	Can be mixed with Cyclic mode
Cyclic	Dynamic change the duty cycle of every channels in the RF part and the Base-Band (i.e.: the internal MCU)	Can be mixed with Adaptive mode
Periodic	Report a fix at a given periodicity	Cannot be mixed
On demand	Report a fix on demand	Cannot be mixed

The choice between the different modes is driven by the required fix periodicity and acceptable accuracy degradation. *Table 2* reports a general guideline.

Table 2. Low power mode versus fix periodicity and accuracy degradation

Fix Periodicity	Appropriate mode	Accuracy
0.1s-1s	None	No degradation
1s-10s	Adaptive and Cyclic modes	Very limited degradation
10s-30min	Periodic mode	There could be degradation
Asynchronous	Fix On Demand	

2 Adaptive and cyclic low power mode

Adaptive Low Power mode, using the Estimated Horizontal Position Error (EHPE), implements a dynamic constellation switching, in this way the device is able to optimize the usage of multi-constellation satellites allowing the customer to select the proper compromise between accuracy performance and power consumption.

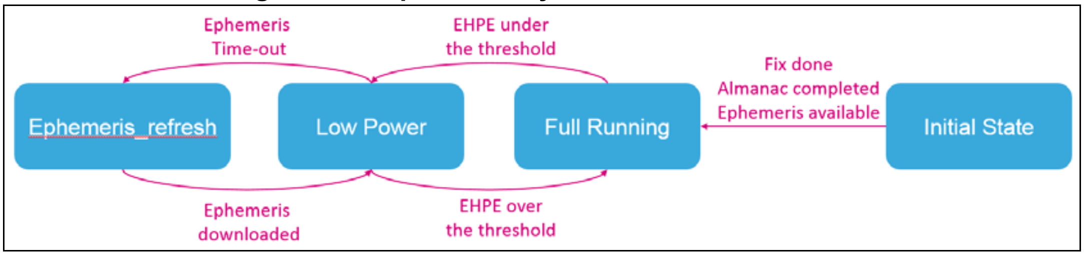
Cyclic Low power mode allows changing the duty cycles of all RF channels and the Base-Band (the internal MCU) which are maintained in standby for ~70% of each second. The duty cycle period dynamically changes using the Estimated Horizontal Position Error (EHPE).

EHPE is a measure of the error in a GNSS position on the horizontal plane. This value can be monitored in the NMEA sentences $GPGST.

The Adaptive and Cyclic Low Power algorithm are scheduled every second.

Figure 1 shows the algorithm's finite state machine.

Figure 1. Adaptive and cyclic finite state machine



Initial state is achieved only after the steady state has been reached. The steady state in GNSS mode is a particular condition in which the software turns off the acquisition engine.

Generally, at first start up (Full Cold Mode) this condition, in full sky, is reached in 12.5 minutes.

Table 3. Adaptive and cyclic finite states machine descriptions

State	Description	Next State
INITIAL_STATE		FULL_CONST only when all the three conditions are taken: – position fix available – almanac completely downloaded – ephemeris available (4 for GPS, 4 for GLONASS);
FULL_CONST	– All the GNSS constellations enabled in the firmware-configuration are active during the runtime – System fully running.	LOW_POWER_STATE only if EHPE average is less than EHPE threshold (good sky condition)

Table 3. Adaptive and cyclic finite states machine descriptions (continued)

State	Description	Next State
LOW_POWER	– Only one GNSS constellation is enabled available (Adaptive constellation ON/OFF) – Only the first N GPS/GLONASS satellites (with higher elevation) are used for the position calculation (Adaptive tracked satellites) – Duty cycle for every channels enabled and Base-Band enabled (if configured) – Turn-on the ephemeris-refresh timer	FULL_CONST only if EHPE average is greater than EHPE threshold (bad sky condition)
		EPHEMERIS_REFRESH only if the ephemeris-refresh timeout fires (30 minutes timeout)
EPHEMERIS_REFRESH	– Turn on all constellations to download the updated ephemeris-data	LOW_POWER_STATE only when the ephemeris are downloaded

The Adaptive low power management can operate even in the case in which the constellations enabled are GPS only and GLONASS only. In this case, the low power state only consists in reducing the GPS/GLONASS used satellites.

Mixing Adaptive Low power and Cyclic Low power four modes can be generated as shown in *Table 4*.

Table 4. Adaptive and cyclic low power modes

LOW POWER MODES	Features
Adaptive and Cyclic Low power mode	– Adaptive Constellation enabled (constellation switching based on estimated EHPE) – Adaptive tracked satellites (only better elevation used) – Duty Cyclic enable – Duty Cyclic switching (based on estimated EHPE) – Ephemeris refresh enabled
Adaptive Only mode	– Adaptive Constellation enabled (constellation switching based on estimated EHPE) – Adaptive tracked satellites (only better elevation used) – Ephemeris refresh enabled

Table 4. Adaptive and cyclic low power modes (continued)

LOW POWER MODES	Features
Duty Cyclic Only mode	– Duty Cyclic enable – Duty Cyclic switching (based on estimated EHPE) – Ephemeris refresh enabled
Duty Cyclic mode with reduced satellites	– Adaptive tracked satellites (only better elevation used) – Duty Cyclic enable – Duty Cyclic switching (based on estimated EHPE) – Ephemeris refresh enabled

3 Periodic low power mode

The periodic mode has different settings to control the FIX reporting, and other settings to control the low power hardware state.

3.1 State machine

The periodic mode has basically two parts in its state machine - one to handle the fix and one to handle the case of no fix. Obviously, there are transitions between in case of fix loss or recovery.

Figure 2. Periodic mode state diagram

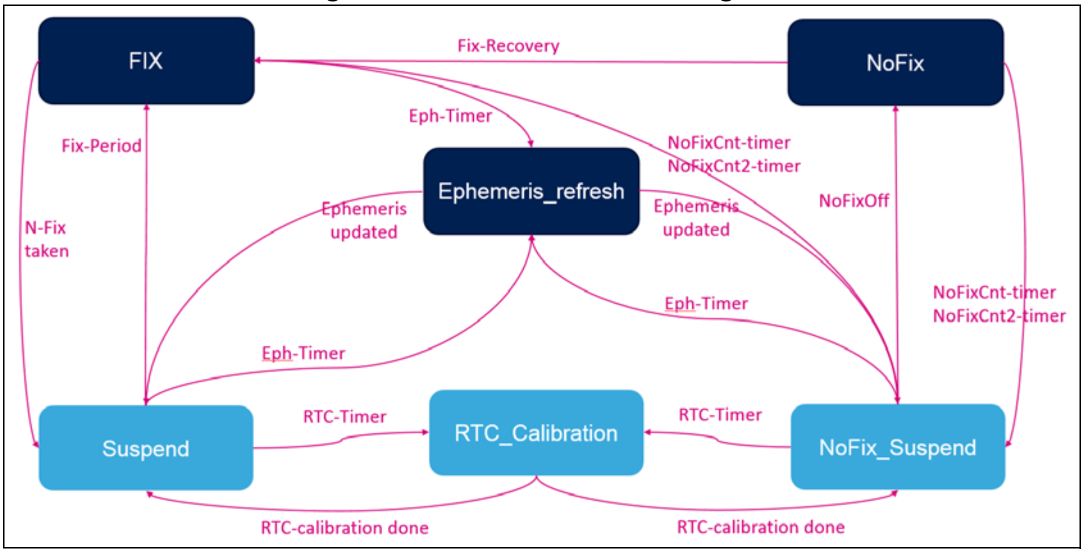


Table 5 details the different states:

Table 5. Periodic mode finite state machine description

State	Description	Next State
SUSPEND	GNSS system sleeping. CPU in idle. System running at low frequency. Three timers running: – FixPeriod timer – EphRefresh timer – RTC_clb timer	FIX when FixPeriod timer fires EPH_REFRESH when EphRefresh timer fires (32 minutes timer) RTC_CALIB when RTC_clb timer fires (5 minutes timer)

Table 5. Periodic mode finite state machine description (continued)

State	Description	Next State
FIX	GNSS system running to acquire a series of N fixes. CPU running Three timers running: – NoFixCnt timer – NoFixCnt2 timer – EphRefresh timer	SUSPEND when the N fixes are acquired
		NOFIX_SUS when the N fixes serie cannot be completed and NoFixCnt timers fire (in HOT(1) conditions)
		NOFIX_SUS when the N fixes serie cannot be completed and NoFixCnt2 timer fire (in NOT-HOT(2) conditions)
		EPH_REFRESH when EphRefresh timer fires (32 minutes timer)
EPH_REFRESH	GNSS system running for 40/60s to download new ephemeris. CPU running Two timers running: – NoFixCnt timer – NoFixCnt2 timer	SUSPEND when ephemeris download completes
		NOFIX_SUS when ephemeris download doesn't complete and NoFixCnt timers fire (in HOT(1) conditions)
		NOFIX_SUS when ephemeris download doesn't complete and NoFixCnt2 timer fire (in NOT-HOT(2) conditions)
NOFIX_SUS	GNSS system sleeping due to No satellites signal or no fix acquired CPU in idle. System running at low frequency. Three timers running: – EphRefresh timer – NoFixCnt timer – NoFixCnt2 timer	EPH_REFRESH when EphRefresh timer fires (32 minutes timer)
		NOFIX when NoFixCnt timer fires (in HOT(1) conditions)
		NOFIX when NoFixCnt2 timer fires (in NOT-HOT(2) conditions)
NOFIX	GNSS system running but unable to acquire a fix. Two timers running: – NoFixCnt timer – NoFixCnt2 timer	FIX if a fix is acquired
		NOFIX_SUS when fix is not acquired and NoFixCnt timer fires (in HOT(1) conditions)
		NOFIX_SUS when fix is not acquired and NoFixCnt2 timer fires (in NOT-HOT(2) conditions)
RTC Calibration	GNSS system sleeping. CPU running for rtc_calibration; calibration is performed at higher frequency settings	SUSPEND when calibration completes

1. HOT conditions: Number of ephemeris and RTC are OK
2. NOT-HOT conditions: start-up cases, obsolete ephemeris

4 Test environment

4.1 Platform parameters

Table 6. Teseo-LIV3F platform parameter

Parameters	Value
Hardware platform	EVB-LIV3F board (LIV_EVB_B0_V1)
Firmware version	$PSTMVER,GNSSLIB_8.4.13.20_ARM

4.2 Tools

The following tools have been used:

- Teseo-Suite Pro available online on www.st.com
- LABSAT2 is used for dynamic tests.
- GSS6700 and Roof Antenna are used for static and power consumption test.

4.3 Position accuracy tests

For Static cases, position accuracy is checked with available automation tool (24 hours scenario on GSS6700)

4.4 Power measurement tests

Board is powered through USB.

The measure is acquired on jumper J503.

Figure 3. EVB-LIV3F PCB layout

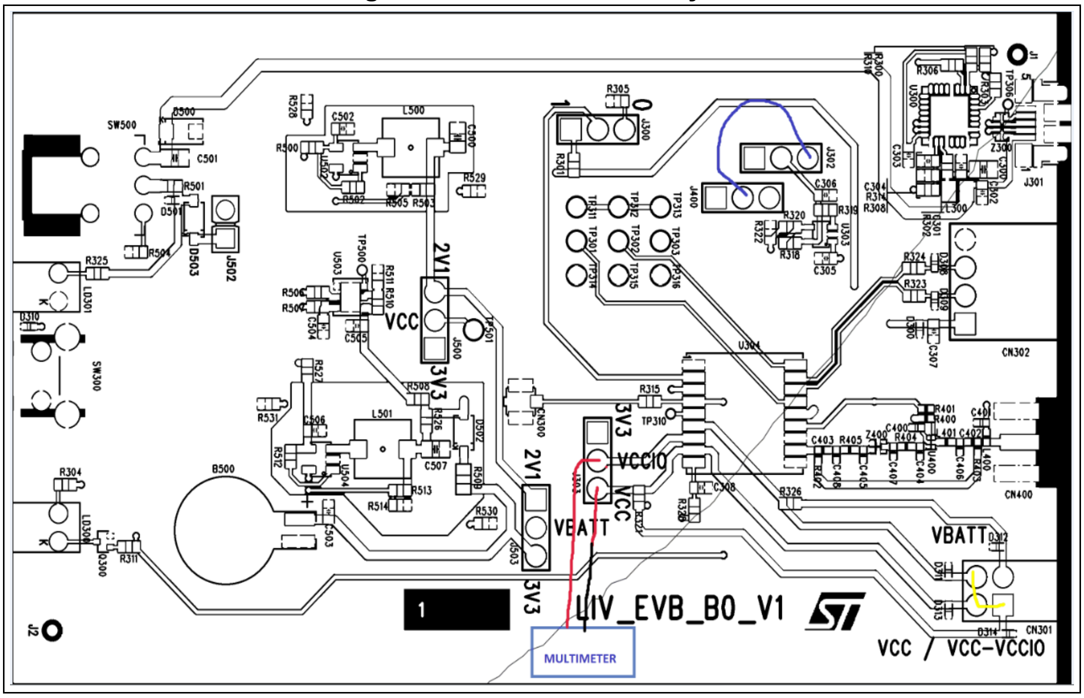
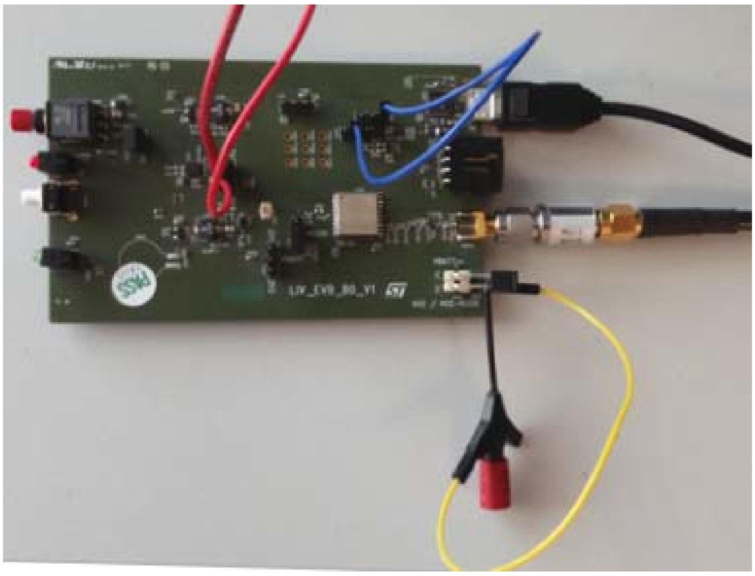


Figure 4. EVB-LIV3F board



A multimeter is set in serial way and is remote controlled from Teseo-Suite (use of HP-34401A).

The control is done using a PROLOGIV-GPIB -USB controller.

Figure 5. Multimeter setup

Using the Teseo-Suite test script, multimeter has been programmed to acquire measurement from the removed interface using the following steps:

1. Place the multimeter in a known state (the reset state)
2. Change the multimeter's setting to achieve the desired configuration
3. Setup the triggering conditions
4. Initiate or arm the multimeter for measurement
5. Trigger the multimeter to make measurement
6. Retrieve the reading from the output buffer or internal memory
7. Read the measured data into the bus controller

5 Position accuracy tests

Table 7. Parameters for all accuracy tests

Parameters	Value
GNSS	GPS only
Position	Static
Sky view	Full
SBAS	OFF
Duration	22 h 13 m 20 s
Ref Position	102.0833333 ◦ 24.0333333 ◦ 87.646 m

5.1 Standard mode (no low power mode)

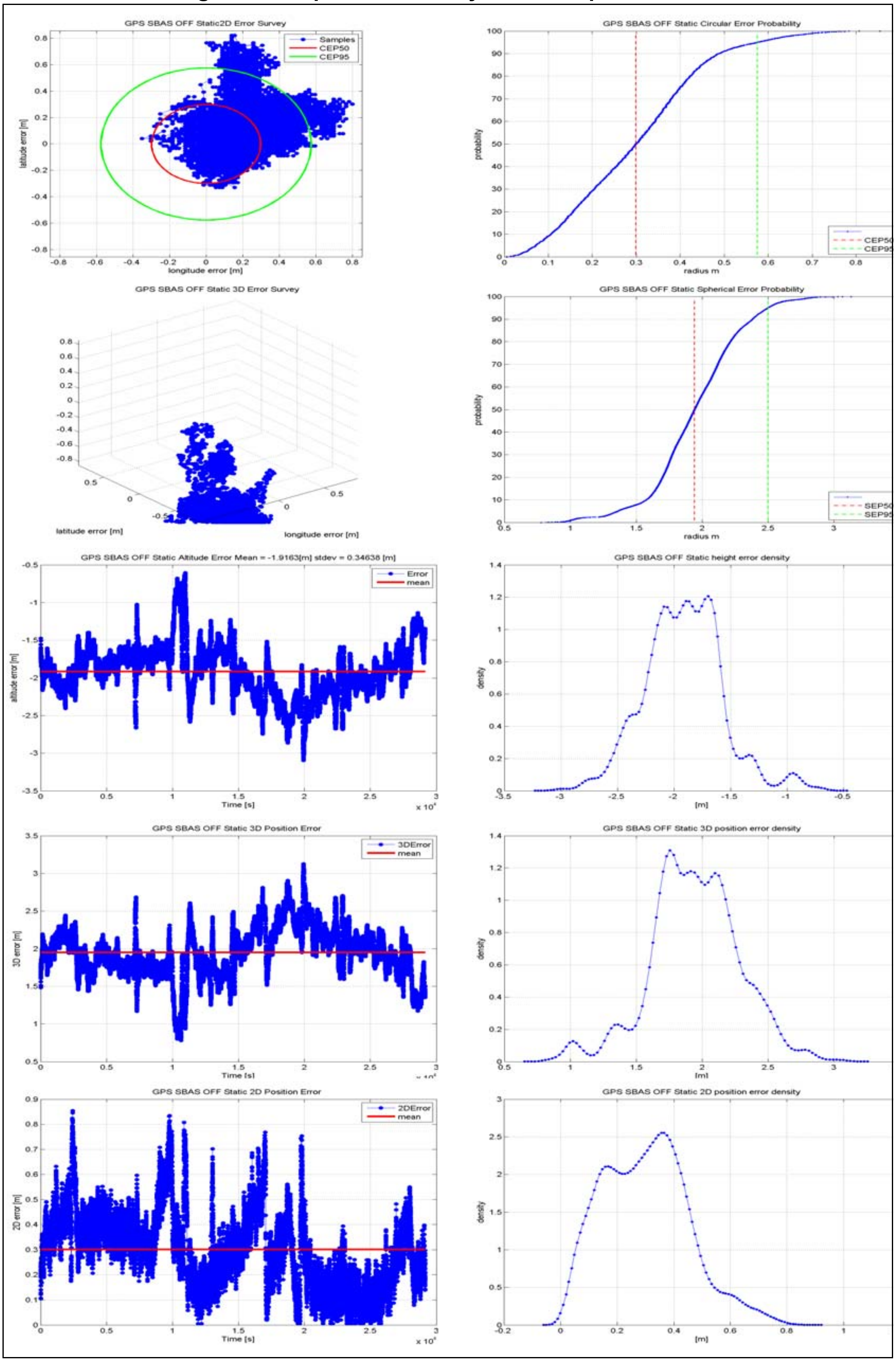
Table 8. Parameters in standard mode (no low power mode)

Parameters	Value
NMEA command	No command sent by the Host
CDB-ID	No CDB-ID modified

Table 9. Measure of accuracy in case of no low power mode

% of accuracy	CEP METERS	SEP METERS
50	0.29914	1.942
68 (1 σ)	0.37196	2.1027
90	0.48741	2.381
95 (2 σ)	0.57557	2.4983
99 (2 σ)	0.70273	2.769

Figure 6. Graphs of accuracy in no low power mode



5.2 Adaptive and cyclic low power mode

Fix period = 1 second, Fix number = 1

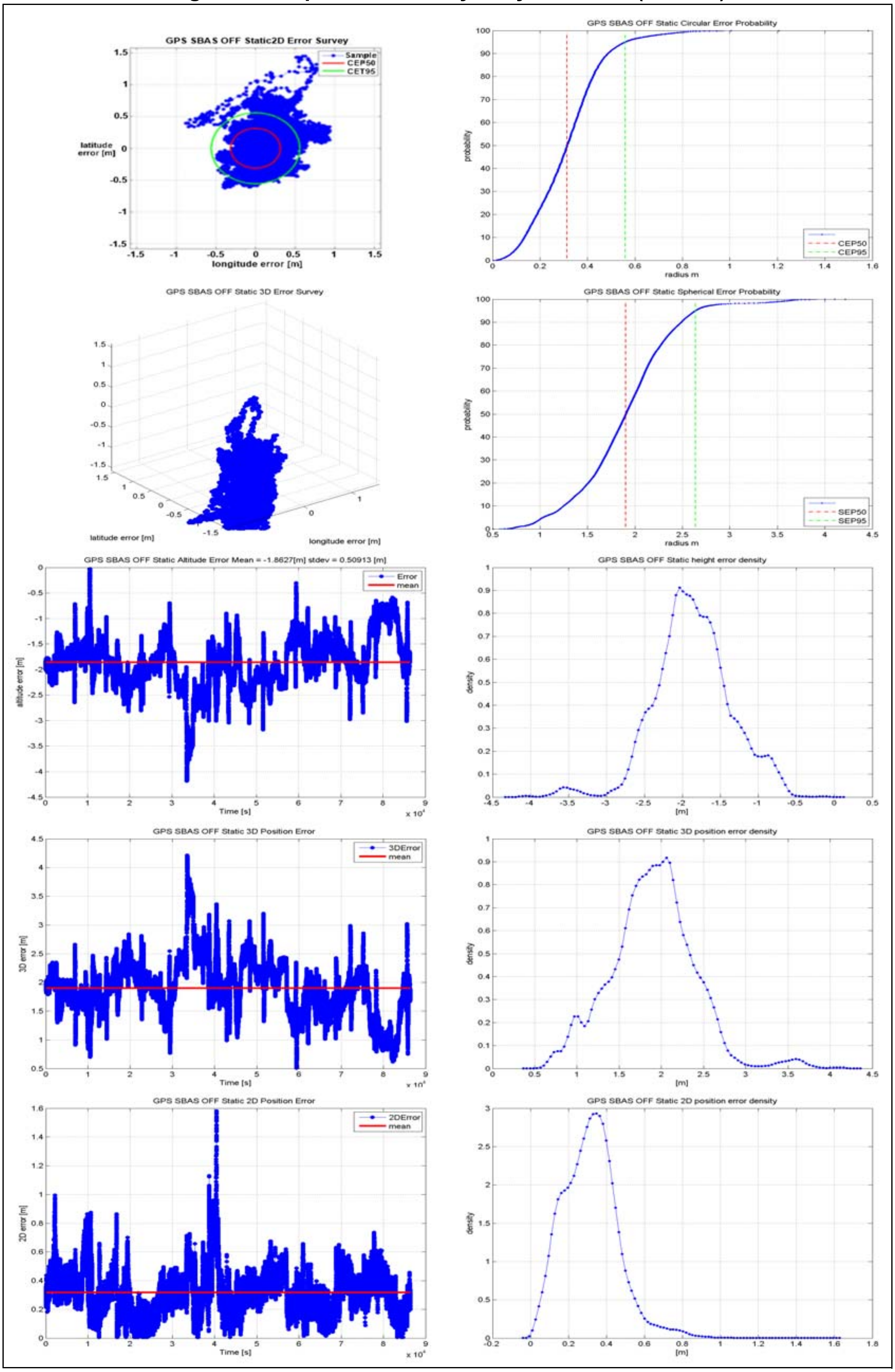
Table 10. Parameters in cyclic mode (1s, 1nb)

Parameters	Value
NMEA command	$PSTMLOWPOWERONOFF,1,1,0,32,0,1,1,0,0,0,0,0,0,0
CDB-ID: xxx	$PSTMSETPAR,1200,81000014,2 $PSTMSETPAR,1220,ffffffff,2 $PSTMSETPAR,1257,ffffffff,2 PSTMSETPAR,1258,ffffffff,2 PSTMSETPAR,1200,80000000,1 $PSTMSETPAR,1220,100002,1 $PSTMSETPAR,1257,2000a0c,1 $PSTMSETPAR,1258,5a0b40f,1

Table 11. Measure of accuracy in cyclic mode (1s, 1nb)

% of accuracy	CEP METERS	SEP METERS
50	0.31385	1.9044
68 (1 σ)	0.37647	2.1021
90	0.48535	2.4878
95 (2 σ)	0.55884	2.6375
99 (3 σ)	0.7684	3.5336

Figure 7. Graphs of accuracy in cyclic mode (1s, 1nb)



Fix period = 3 seconds, Fix number = 1

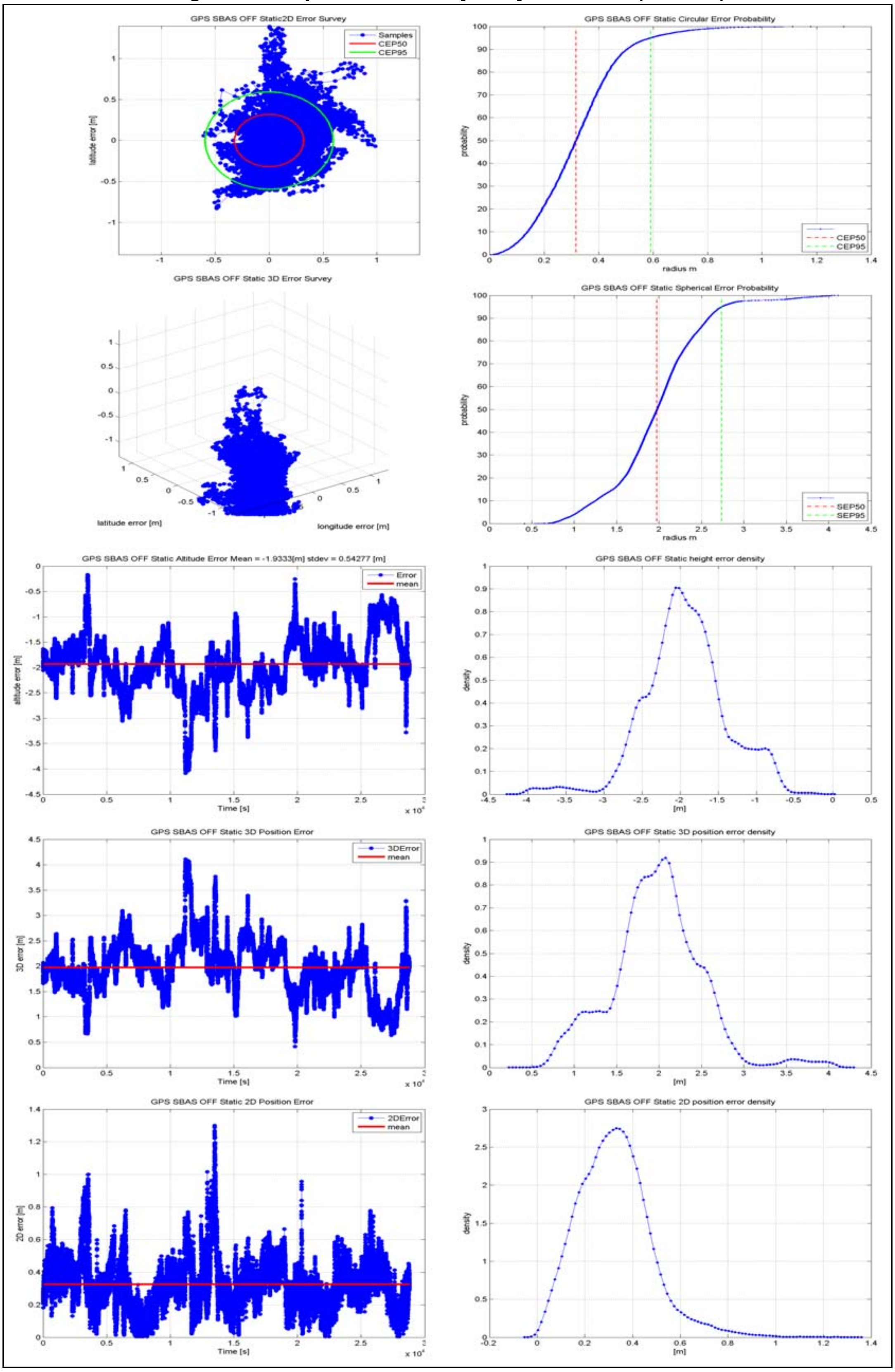
Table 12. Parameters in cyclic mode (3s, 1nb)

Parameters	Value
NMEA command	$PSTMLOWPOWERONOFF,1,1,0,32,0,1,3,0,0,0,0,0,0,0
CDB-ID: xxx	$PSTMSETPAR,1200,81000014,2 $PSTMSETPAR,1220,ffffffff,2 $PSTMSETPAR,1257,ffffffff,2 $PSTMSETPAR,1258,ffffffff,2 $PSTMSETPAR,1220,300002,1 $PSTMSETPAR,1257,2000a0c,1 $PSTMSETPAR,1258,5a0b40f,1

Table 13. Measure of accuracy in cyclic mode (3s, 1nb)

% of accuracy	CEP METERS	SEP METERS
50	0.32061	1.92215
68 (1 σ)	0.38416	2.1334
90	0.51195	2.5608
95 (2 σ)	0.59507	3.6095
99 (3 σ)	0.8295	7.235

Figure 8. Graphs of accuracy in cyclic mode (3s, 1nb)



Fix period = 5 seconds, Fix number = 1

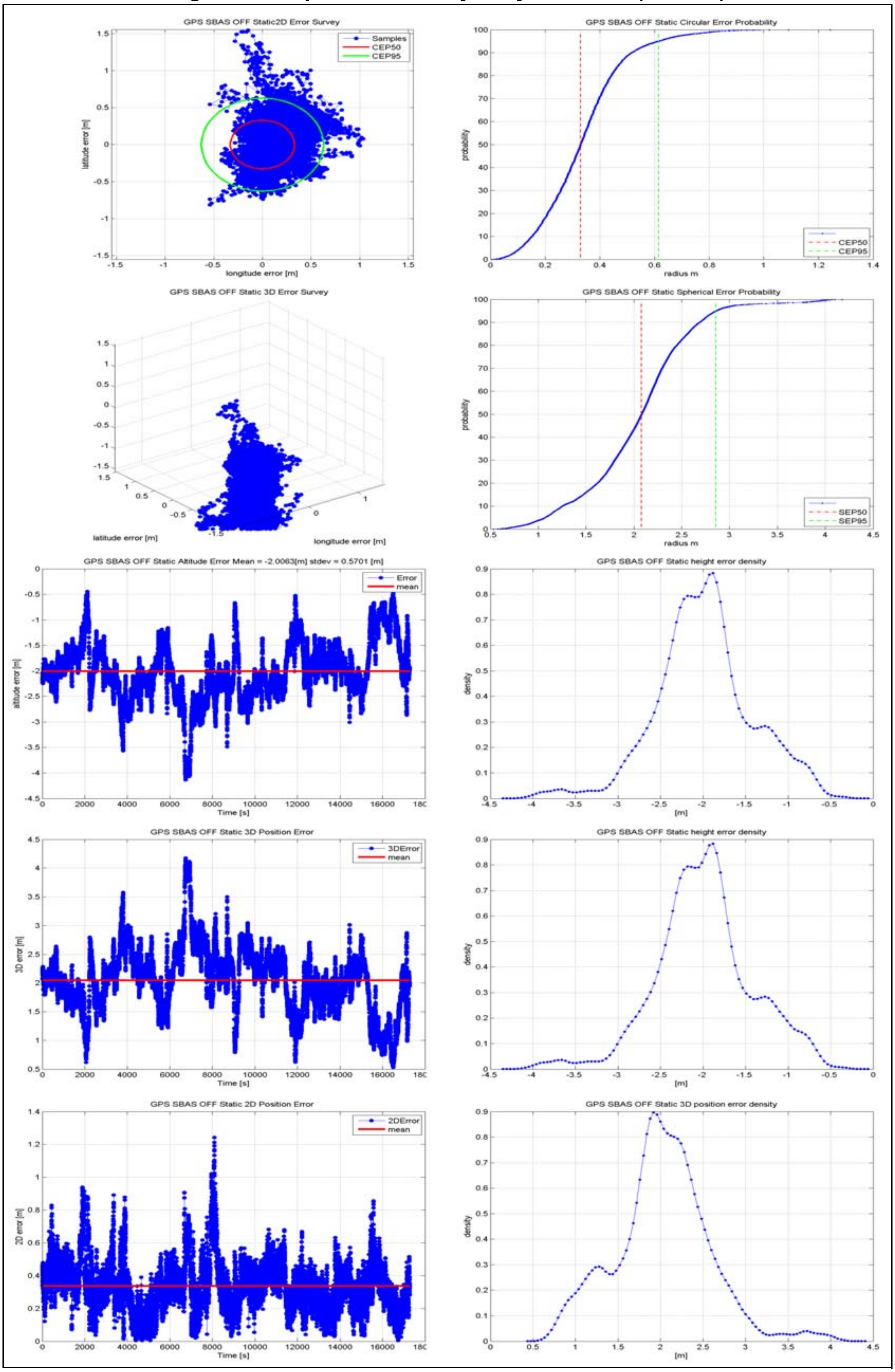
Table 14. Parameters in cyclic mode (5s, 1nb)

Parameters	Value
NMEA command	$PSTMLOWPOWERONOFF,1,1,0,32,0,1,5,0,0,0,0,0,0,0
CDB-ID: xxx	PSTMSETPAR,1200,81000014,2 $PSTMSETPAR,1220,ffffffff,2 $PSTMSETPAR,1257,ffffffff,2 $PSTMSETPAR,1258,ffffffff,2 $PSTMSETPAR,1200,80000000,1 $PSTMSETPAR,1220,500002,1 $PSTMSETPAR,1257,2000a0c,1 $PSTMSETPAR,1258,5a0b40f,1

Table 15. Measure of accuracy in cyclic mode (5s, 1nb)

% of accuracy	CEP METERS	SEP METERS
50	0.32915	2.0269
68 (1 σ)	0.39375	2.251
90	0.53451	2.6788
95 (2 σ)	0.62794	2.9035
99 (3 σ)	0.86478	3.7294

Figure 9. Graphs of accuracy in cyclic mode (5s, 1nb)



5.3 Periodic low power mode

Fix period = 10 seconds, Fix number = 1

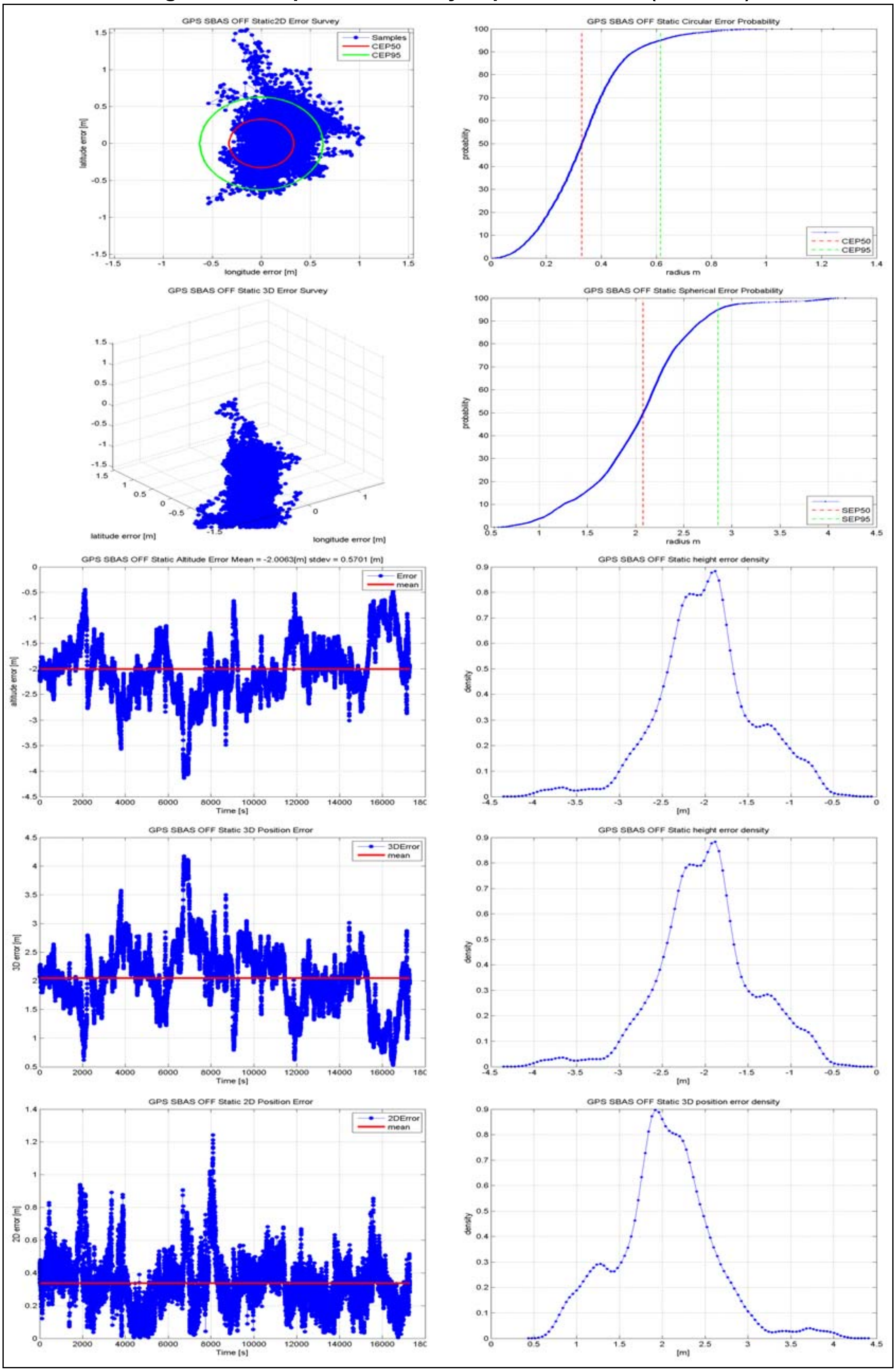
Table 16. Parameters in periodic mode (10s, 1nb)

Parameters	Value
NMEA command	$PSTMLOWPOWERONOFF,1,0,0,0,0,0,0,3,10,1,1,1,15,180
CDB-ID: xxx	$PSTMSETPAR,1200,81000014,2 $PSTMSETPAR,1220,ffffffff,2 $PSTMSETPAR,1257,ffffffff,2 $PSTMSETPAR,1258,ffffffff,2 $PSTMSETPAR,1200,80000000,1 $PSTMSETPAR,1220,100000,1 $PSTMSETPAR,1257,2000a0f,1 $PSTMSETPAR,1258,5a0b40f,1

Table 17. Measure of accuracy in periodic mode (10s, 1nb)

% of accuracy	CEP METERS	SEP METERS
50	0.66587	2.1751
68 (1 σ)	0.93408	2.773
90	1.5268	4.1506
95 (2 σ)	1.9408	5.0518
99 (3 σ)	3.2989	7.235

Figure 10. Graphs of accuracy in periodic mode (10s, 1nb)



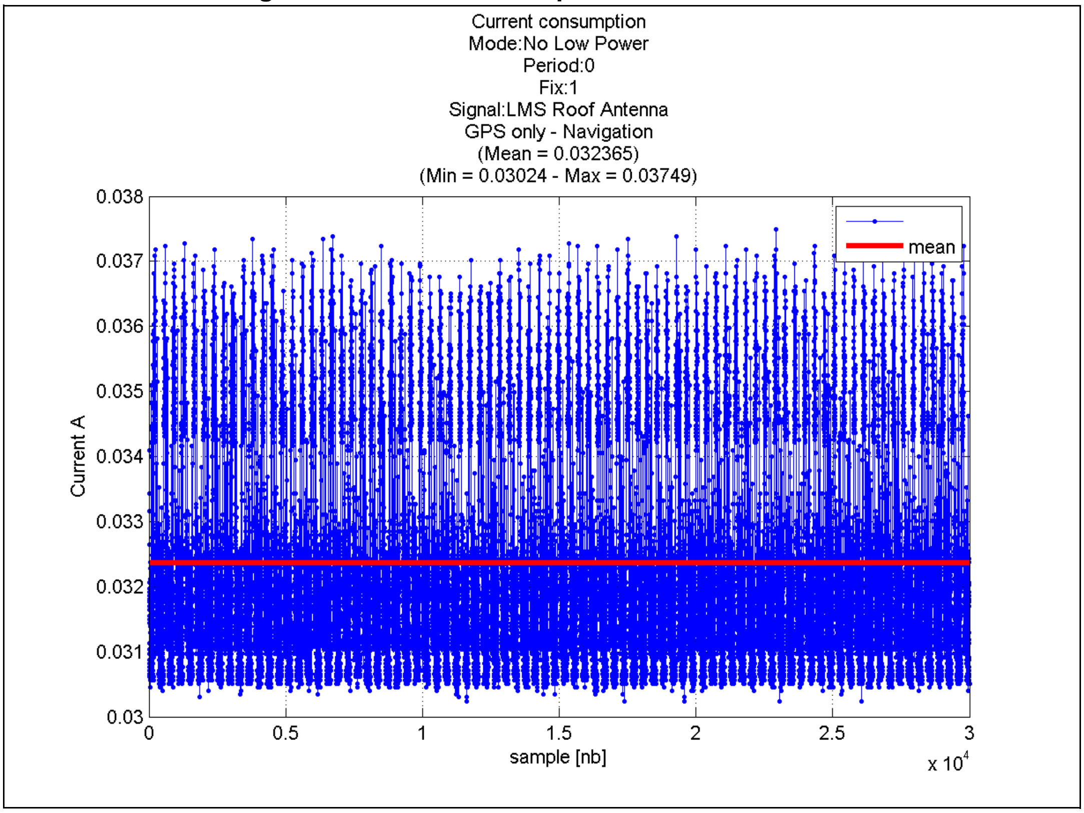
6 Power measurement tests

6.1 Standard mode (no low power mode)

Table 18. Power consumption results in standard mode

Current consumption	Value (A)
Min	0.03024
Average	0.032365
Max	0.03749

Figure 11. Power consumption in standard mode



6.2 Adaptive and cyclic low power mode

Fix period = 1 second, Fix number = 1

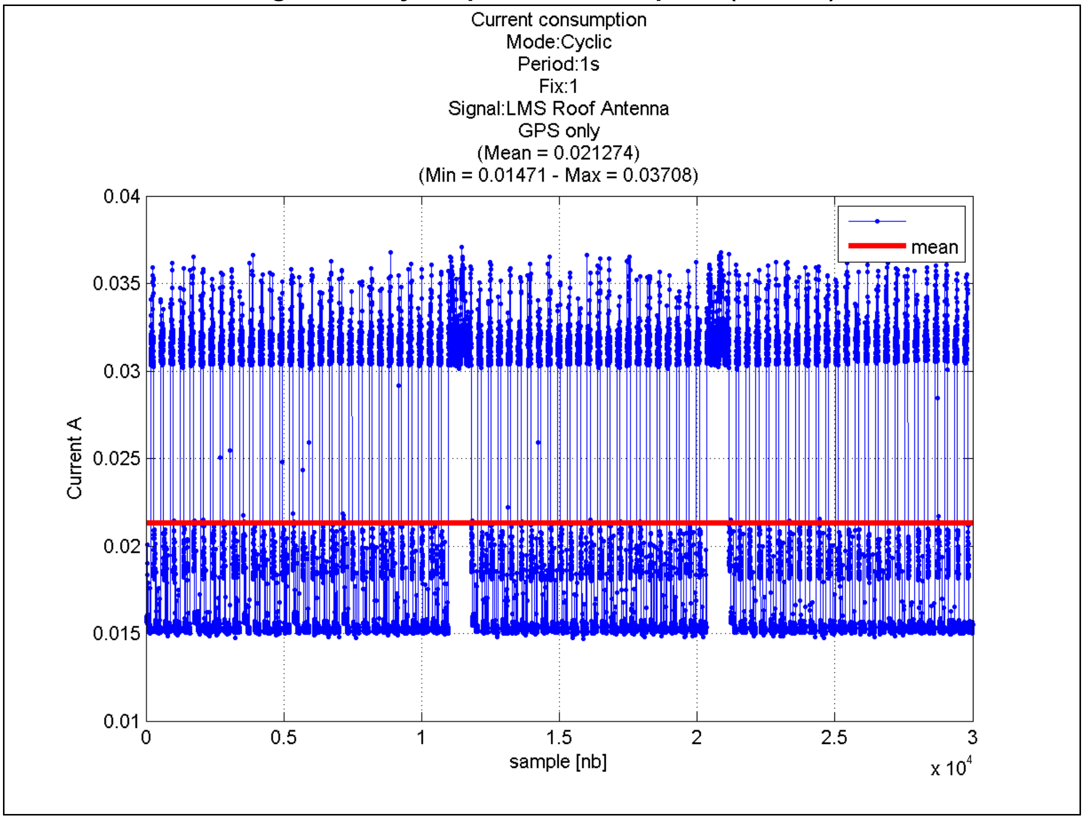
Table 19. Power consumption results in cyclic power mode (1s, 1nb)

Current consumption	Value (A)
Min	0.01471

Table 19. Power consumption results in cyclic power mode (1s, 1nb) (continued)

Current consumption	Value (A)
Average	0.021274
Max	0.03708

Figure 12. Cyclic power consumption (1s, 1nb)

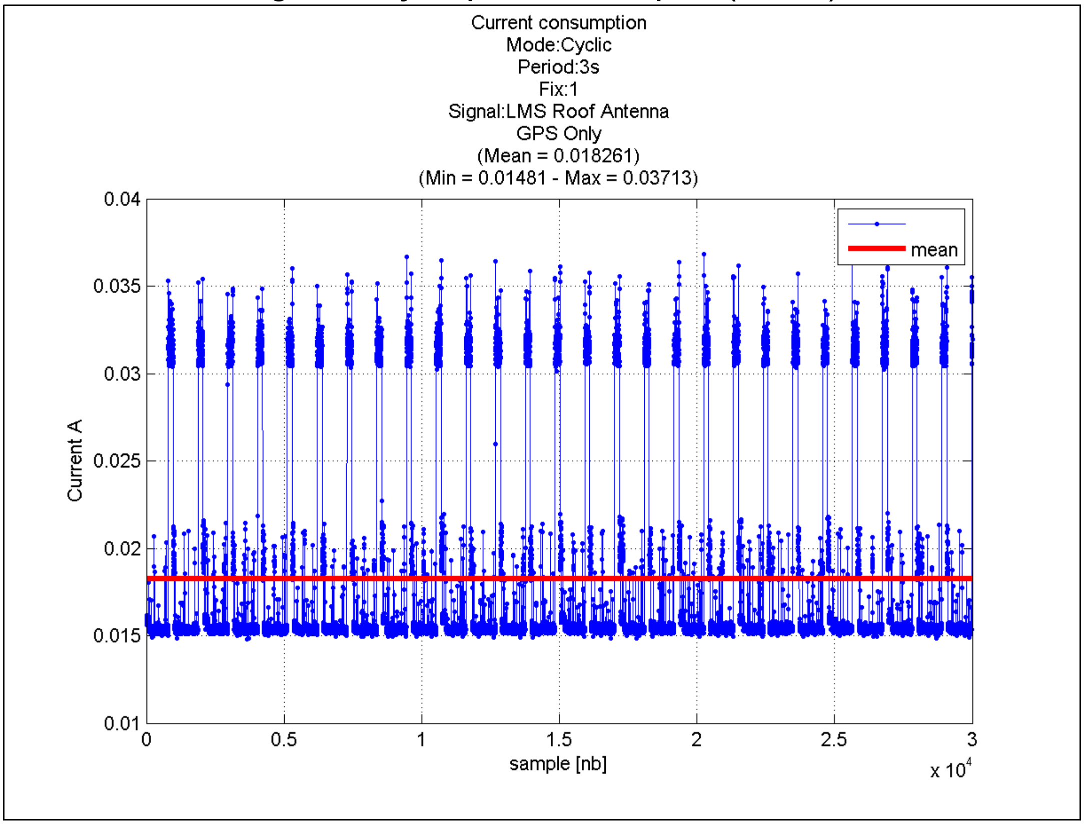


Fix period = 3 seconds, Fix number = 1

Table 20. Power consumption results in cyclic power mode (3s, 1nb)

Current consumption	Value (A)
Min	0.01481
Average	0.018261
Max	0.03713

Figure 13. Cyclic power consumption (3s, 1nb)

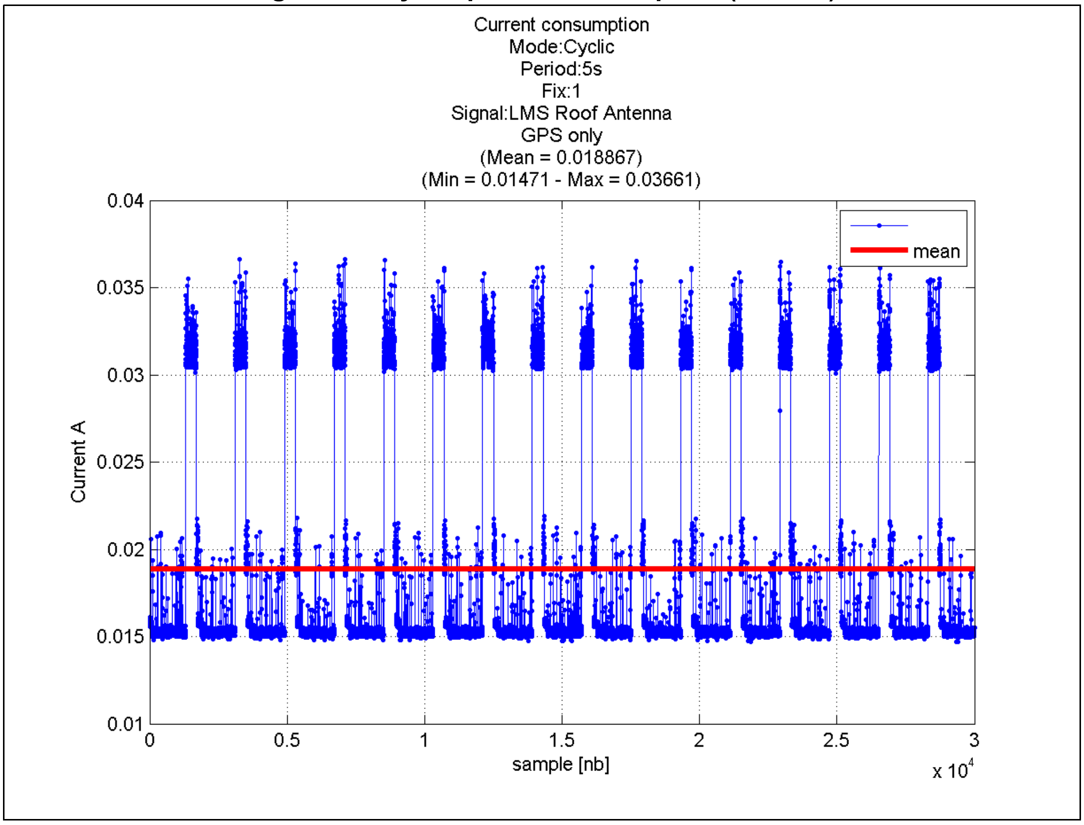


Fix period = 5 seconds, Fix number = 1

Table 21. Power consumption results in cyclic power mode (5s, 1nb)

Current consumption	Value (A)
Min	0.01471
Average	0.018867
Max	0.03661

Figure 14. Cyclic power consumption (5s, 1nb)



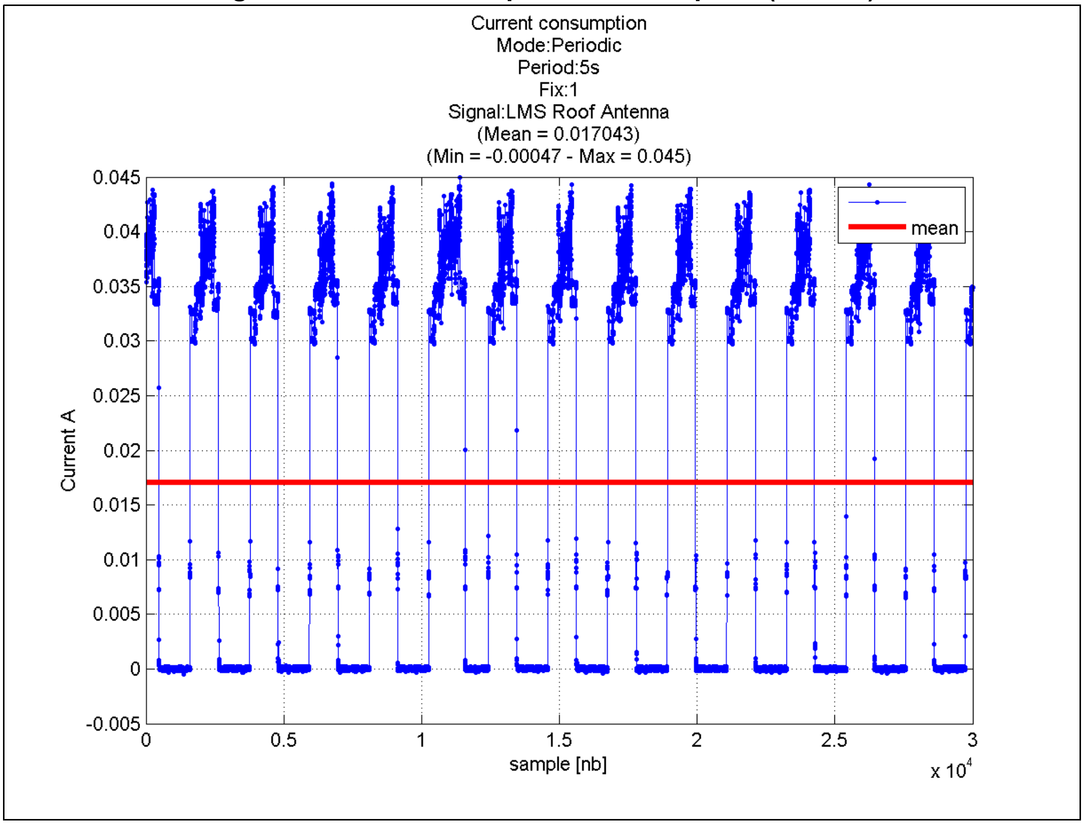
6.3 Periodic low power mode

Fix period = 5 seconds, Fix number = 1

Figure 15. Power consumption results in periodic power mode (5s, 1nb)

Current consumption	Value (A)
Min	0.00047
Average	0.017043
Max	0.045

Figure 16. Periodic low power consumption (5s, 1nb)

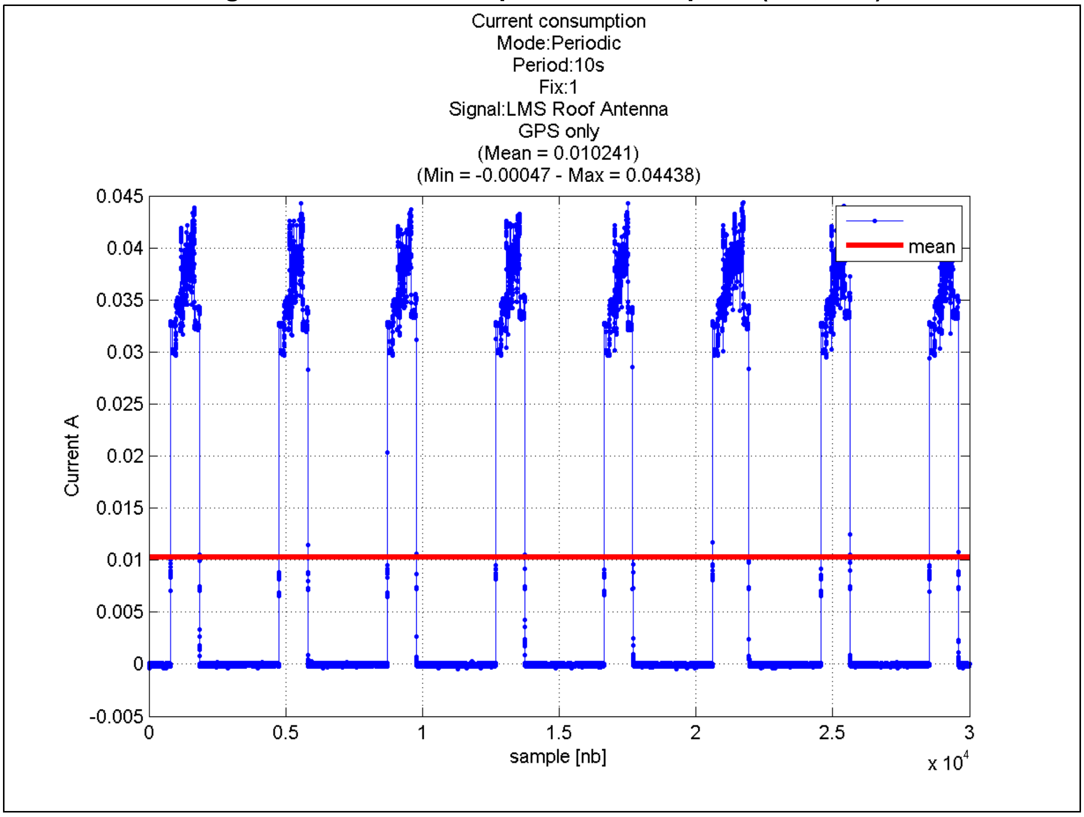


Fix period = 10 seconds, Fix number = 1

Table 22. Power consumption results in periodic low power mode (10s, 1nb)

Current consumption	Value (A)
Min	0.00047
Average	0.010241
Max	0.04438

Figure 17. Periodic low power consumption (10s, 1nb)



Fix period = 999 seconds, Fix number = 1

Table 23. Power consumption results in periodic low power mode with ephemeris refresh (999s, 1nb)

Current consumption	Value (A)
Min	0.00052
Average	0.0077346
Max	0.04406

Figure 18. Periodic low power consumption (999s, 1nb and ephemeris refresh)

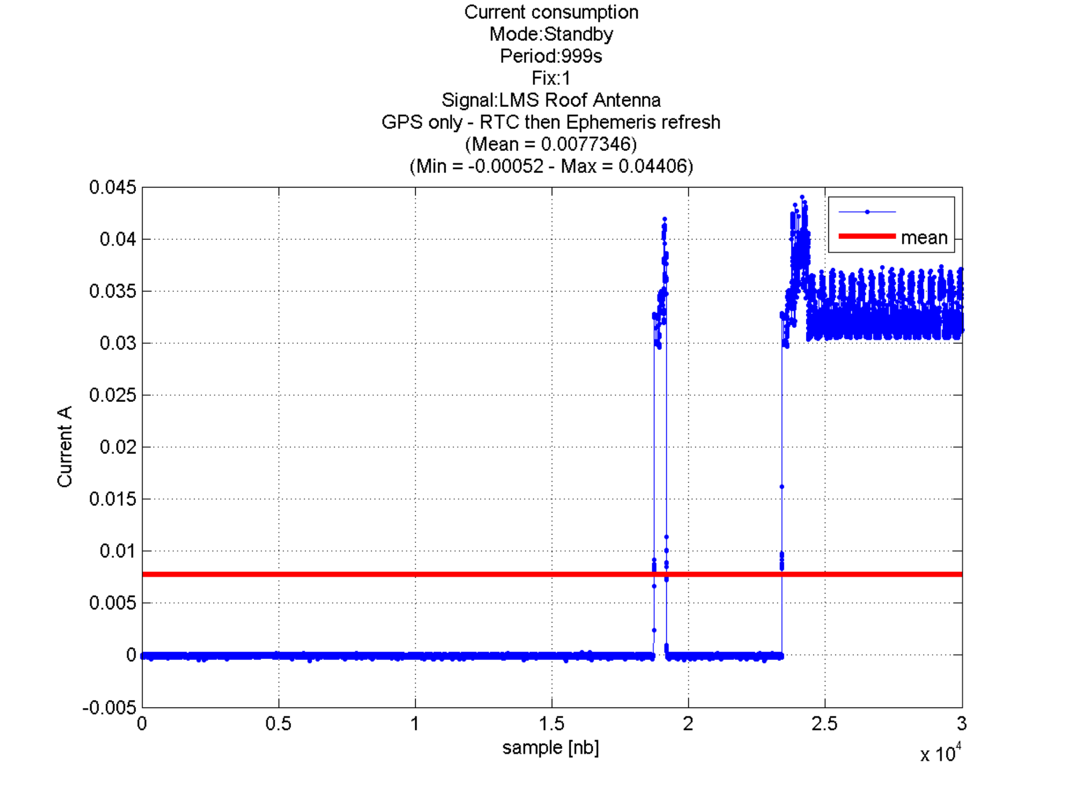
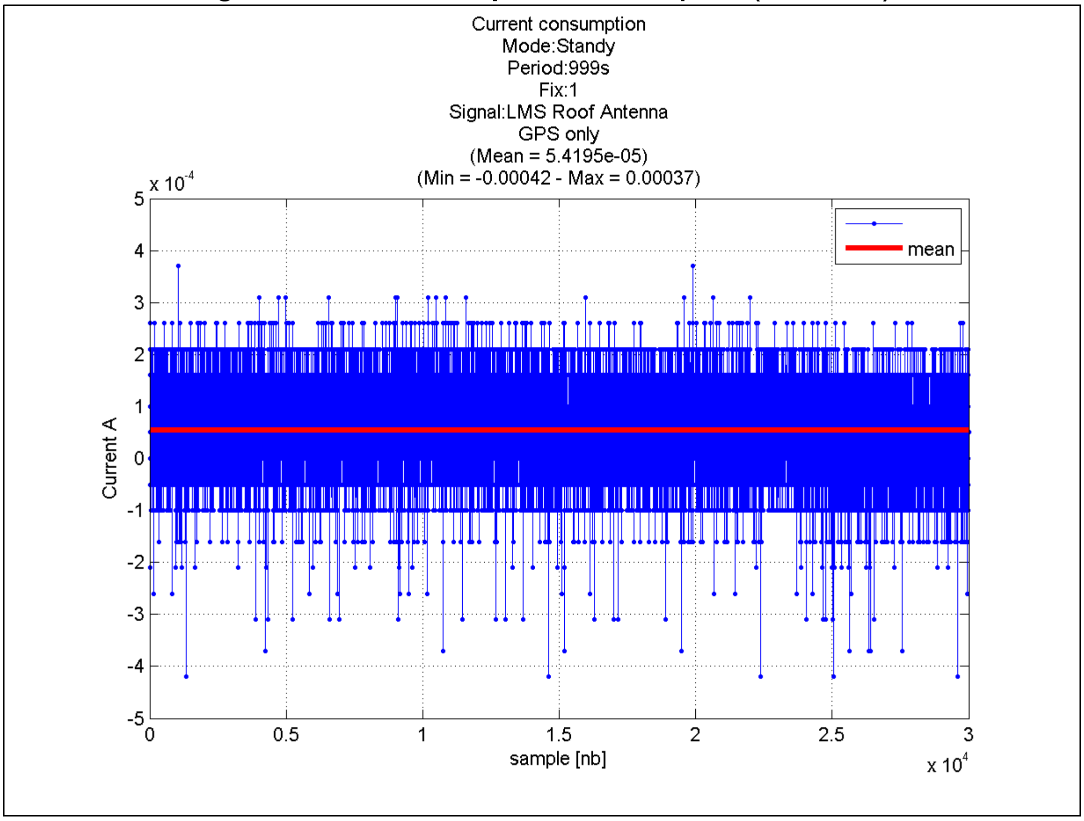


Table 24. Power consumption results in periodic low power mode (999s, 1nb)

Current consumption	Value (A)
Min	0.00042
Average	5.4195e-05
Max	0.00037

Figure 19. Periodic low power consumption (999s, 1nb)

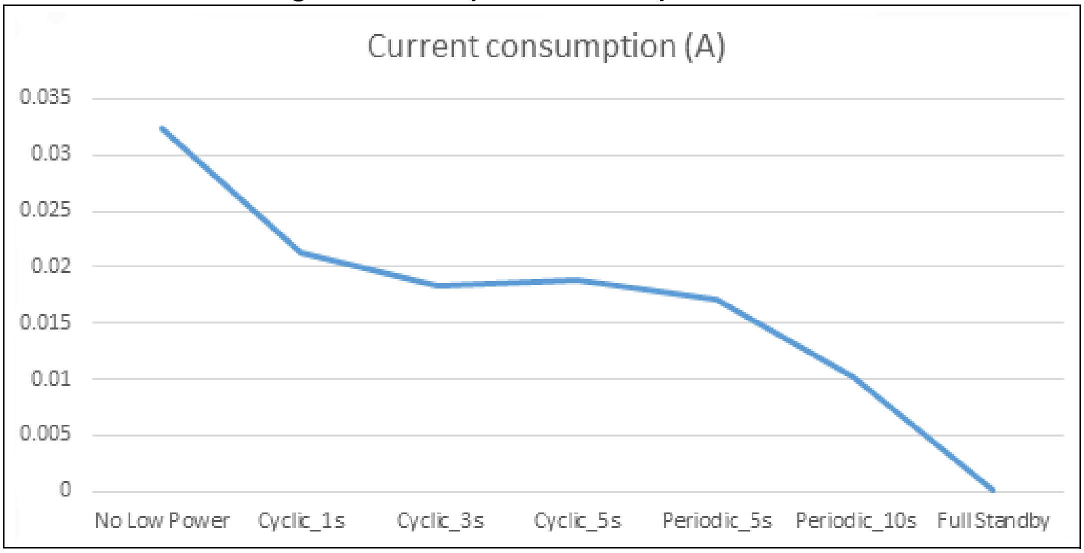


7 Final results

Table 25. Final power consumption results

Mode	Average current consumption (A)	Max current consumption (A)
No low power	0.032635	0.03749
Cyclic 1s, 1nb	0.021274	0.03708
Cyclic 3s, 1nb	0.018261	0.03713
Cyclic 5s, 1nb	0.018867	0.03661
Periodic 5s, 1nb	0.017043	0.045
Periodic 10s, 1nb	0.010241	0.04438
Full standby	0.000054195	0.00037

Figure 20. Final power consumption results



8 Revision history

Table 26. Document revision history

Date	Revision	Changes
01-Apr-2019	1	Initial release.
27-Nov-2019	2	Updated *Table 10: Parameters in cyclic mode (1s, 1nb)*, *Table 12: Parameters in cyclic mode (3s, 1nb)*, *Table 13: Measure of accuracy in cyclic mode (3s, 1nb)*, *Table 14: Parameters in cyclic mode (5s, 1nb)* and *Table 15: Measure of accuracy in cyclic mode (5s, 1nb)*.

IMPORTANT NOTICE – PLEASE READ CAREFULLY

STMicroelectronics NV and its subsidiaries ("ST") reserve the right to make changes, corrections, enhancements, modifications, and improvements to ST products and/or to this document at any time without notice. Purchasers should obtain the latest relevant information on ST products before placing orders. ST products are sold pursuant to ST's terms and conditions of sale in place at the time of order acknowledgement.

Purchasers are solely responsible for the choice, selection, and use of ST products and ST assumes no liability for application assistance or the design of Purchasers' products.

No license, express or implied, to any intellectual property right is granted by ST herein.

Resale of ST products with provisions different from the information set forth herein shall void any warranty granted by ST for such product.

ST and the ST logo are trademarks of ST. For additional information about ST trademarks, please refer to *www.st.com/trademarks*. All other product or service names are the property of their respective owners.

Information in this document supersedes and replaces information previously supplied in any prior versions of this document.

© 2019 STMicroelectronics – All rights reserved