L26-DR Application Note

GNSS Module Series

Rev. L26-DR_Application_Note_V1.0

Date: 2019-07-26

Status: Released

Our aim is to provide customers with timely and comprehensive service. For any assistance, please contact our company headquarters:

Quectel Wireless Solutions Co., Ltd.
Building 5, Shanghai Business Park Phase III (Area B), No.1016 Tianlin Road, Minhang District, Shanghai, China 200233
Tel: +86 21 5108 6236
Email: info@quectel.com

Or our local office. For more information, please visit:
http://www.quectel.com/support/sales.htm

For technical support, or to report documentation errors, please visit:
http://www.quectel.com/support/technical.htm
Or email to: support@quectel.com

GENERAL NOTES

QUECTEL OFFERS THE INFORMATION AS A SERVICE TO ITS CUSTOMERS. THE INFORMATION PROVIDED IS BASED UPON CUSTOMERS' REQUIREMENTS. QUECTEL MAKES EVERY EFFORT TO ENSURE THE QUALITY OF THE INFORMATION IT MAKES AVAILABLE. QUECTEL DOES NOT MAKE ANY WARRANTY AS TO THE INFORMATION CONTAINED HEREIN, AND DOES NOT ACCEPT ANY LIABILITY FOR ANY INJURY, LOSS OR DAMAGE OF ANY KIND INCURRED BY USE OF OR RELIANCE UPON THE INFORMATION. ALL INFORMATION SUPPLIED HEREIN IS SUBJECT TO CHANGE WITHOUT PRIOR NOTICE.

COPYRIGHT

About the Document

History

Revision	Date	Author	Description
1.0	2019-07-26	Jenn XIANG/ Berton PENG	Initial

Contents

Table Index

Figure Index

1 Introduction

This document provides an overview on automotive DR function of L26-DR module and introduces the configuration of module mounting. Also, the operating modes to acquire vehicle data and the module calibration procedure are elaborated.

2 Overview on Automotive DR

Automotive Dead-Reckoning (DR) refers to the capability of a GNSS receiver to continuously navigate on an automotive platform when there is an insufficient number of GNSS satellite signals available. To realize this function, the receiver uses the information provided by external sensors concerning the state of the vehicle in order to propagate the navigation solution.

The L26-DR module supports such automotive DR function to complement GNSS navigation. Moreover, the function enables the module to combine vehicle state information with the GNSS navigation to provide improved navigation during periods when difficult operating conditions could negatively impact the accuracy of the GNSS solution alone.

The module's DR function is supported by an MEMS Inertial Measurement Unit (IMU) sensor which is a 6-axis sensor, a combination of a 3-axis gyroscope and a 3-axis accelerometer.

Automotive DR requires information regarding the change in heading of the vehicle, which is provided by a three-axis digital gyroscope.

Also, the DR function requires information about speed and direction of the vehicle. Speed information can be provided by an odometer (wheel tick) count, which is input into the module as a train of pulses on a GPIO pin. A high/low level voltage input on a second GPIO pin indicates whether the vehicle's direction of motion is forward or reverse. A logic high level indicates reverse direction.

Moreover, L26-DR module accepts data from a three-axis digital accelerometer, which provides information that can be used to determine the orientation of the gyroscope when it is installed at a tilt angle. This information is also used to estimate elevation.

3 Frames Conventions

This chapter introduces the reference frames used by the automotive DR function and L26-DR module's IMU sensor frame.

3.1. Vehicle Reference Frame

Algorithms of DR function assume that sensors are mounted in such a way that IMU axes can achieve a specific alignment with the vehicle reference frame.

- X points at the vehicle's travel direction.
- Y points at the right side and it is perpendicular to the travel direction.
- Z points up and it is perpendicular to road surface.

The vehicle reference frame is illustrated as below:

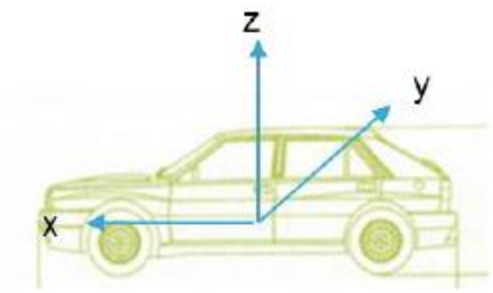

Figure 1: Vehicle Reference Frame

The vehicle frame is used to define pitch, roll and yaw installation angles, which will be discussed in ***Chapter 5***.

3.2. Sensor Reference Frame

The DR algorithms of L26-DR operate on the assumption that the sensors are placed in a correct orientation.

3.2.1. Accelerometer Reference Frame

The accelerometer reference frame matches the vehicle frame:

- X points at the vehicle's travel direction.
- Y points at the right side and it is perpendicular to the travel direction.
- Z points up and it is perpendicular to road surface.

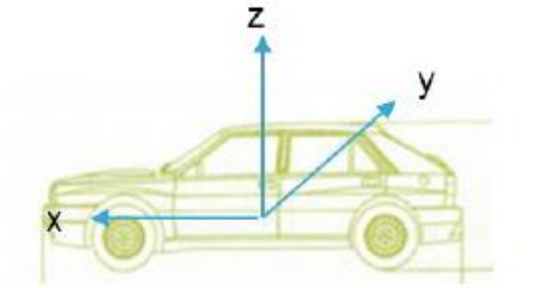

Figure 2: Accelerometer Reference Frame

3.2.2. Gyroscope Reference Frame

The gyroscope reference frame matches the vehicle frame but with X axis reversed polarity:

- X aligned with the vehicle's travel direction, points backwards.
- Y points at the right side and it is perpendicular to the travel direction.
- Z points up and it is perpendicular to road surface.

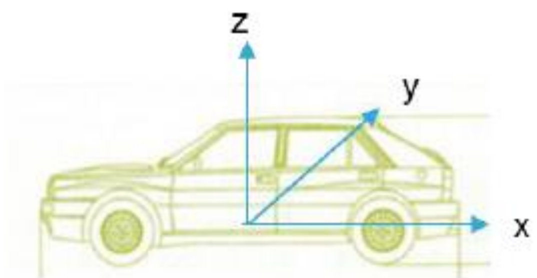

Figure 3: Gyroscope Reference Frame

3.3. IMU Sensor Frame of L26-DR

L26-DR is equipped with a 6-axis sensor which contains a 3-axis accelerometer and a 3-axis gyroscope, and the two sensors inside have the same direction. The IMU sensor frame is shown as below.

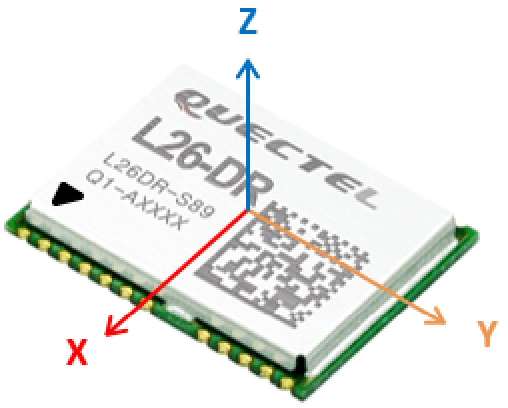

Figure 4: IMU Sensor Frame of L26-DR

NOTE

The IMU sensor frame of L26-DR shown in the figure above is applicable to both the gyroscope and the accelerometer within the IMU.

4 Mounting Orientation Configuration

4.1. Recommended Module Mounting

L26-DR module should be mounted horizontally with the vertical axis upward (as illustrated in Figure 4 above, Z-axis points upward) and mounted on a stable part of the vehicle. The "PIN 1" indicator marked in the following figure should face the forward direction of the vehicle.

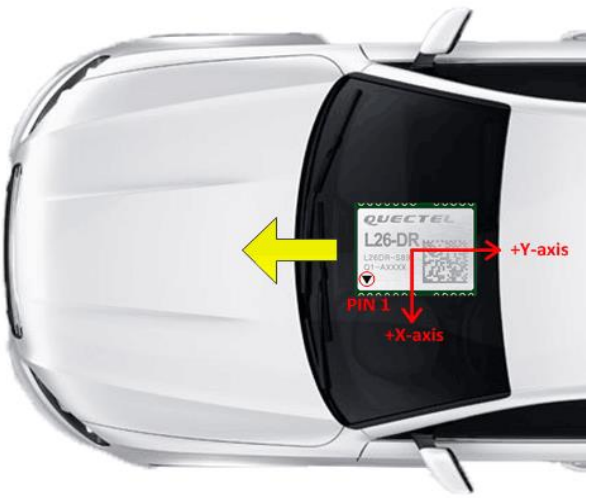

Figure 5: Recommended Module Mounting

4.2. Mounting Orientation Setting

To ensure DR function works properly, a matching between physical IMU axes (sensor frame) and expected vehicle axes (vehicle frame) should be established. This is achieved through parameters called "axes masks", which can be configured through CDB[1)] -ID 669. The axes masks are appointed to address all the possible "orthogonal" installations. Orthogonal installation means an installation which assumes that at least one axis is perpendicular to vehicle horizontal motion plane and at least one axis is pointing at the vehicle's forward direction exactly.

NOTE

1) means Configuration Data Block (CDB). Parameters used for receiver configuration are grouped in it.

4.2.1. Axes Masks

CDB-ID 669 contains two axes masks, one for gyroscope and the other for accelerometer. Each axis mask is a set of three integer elements. A generic axis mask is given for example:

Mask = [a, b, c]

- Element **a** indicates the actual sensor X axis should be ported to match the reference sensor frame introduced in ***Chapter 3.2***.
- Element **b** indicates the actual sensor Y axis should be ported to match the reference sensor frame introduced in ***Chapter 3.2***.
- Element **c** indicates the actual sensor Z axis should be ported to match the reference sensor frame introduced in ***Chapter 3.2***.

Each element can assume one of the following values:

- 1 or -1, indicates the X or -X axis in reference sensor frame.
- 2 or -2, indicates the Y or -Y axis in reference sensor frame.
- 3 or -3, indicates the Z or -Z axis in reference sensor frame.

For example:

If a gyroscope mask is shown as below:

Gyro mask = [2, -3, 1]

This setting shall have the following effect:

- a = 2, DR algorithm will use X axis of the gyroscope as Y axis of the reference frame.
- b = -3, DR algorithm will use Y axis of the gyroscope as Z axis of the reference frame. Its sign shall be changed.
- c = 1, DR algorithm will use Z axis of the gyroscope as X axis of the reference frame.

4.2.2. Module Mounting Example

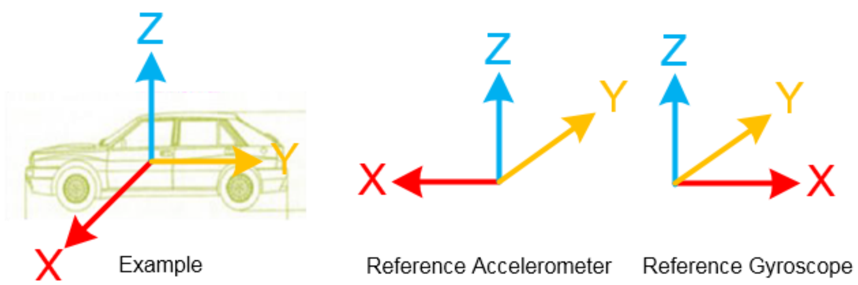

Figure 6: Module Mounting VS. Reference Sensor Frame

The following are the mask identification procedure.

Accelerometer mask identification procedure:

- The X axis of mounted module sensor should be regarded as Y axis in the reference frame, and needs to invert sign, hence [-2, x, x]
- The Y axis of mounted module sensor should be regarded as X axis in the reference frame, and needs to invert sign, hence [-2, -1, x]
- The Z axis of mounted module sensor should be maintained as Z axis in the reference frame, and the sign is right, hence [-2, -1, 3]

Gyroscope mask identification procedure:

- The X axis of mounted module sensor should be regarded as Y axis in the reference frame, and needs to invert sign, hence [-2, x, x]
- The Y axis of mounted module sensor should be regarded as X axis in the reference frame, and the sign is right, hence [-2, 1, x]
- The Z axis of mounted module sensor should be maintained as Z axis in the reference frame, and the sign is right, hence [-2, 1, 3]

4.2.3. Axes Masks Parameter Setting

CDB-ID 669 is used to set the value of axes masks. Users can set it through the following command:

```
$PSTMSETPAR,1669,<value>
```

Each bit of the 32-bit value is defined as follows:

Bits	Description
0-3	Gyroscope Z axis mask element ***c***
4-7	Gyroscope Y axis mask element ***b***
8-11	Gyroscope X axis mask element ***a***
12-15	Accelerometer Z axis mask element ***c***
16-19	Accelerometer Y axis mask element ***b***
20-23	Accelerometer X axis mask element ***a***
24-31	For L26-DR, this filed is fixed as 0xB.

The axes mask element field can only be 0x01, 0x02, 0x03 0x0F(-1), 0x0E(-2) and 0x0D(-3). The complete parameter value for the recommended module mounting should be set as 0x0BEF3E13.

For L26-DR which has a 6-axis sensor inside, the accelerometer and the gyroscope have the same direction. Users can ignore gyroscope mask value and keep it as 0, so the value should be 0x0BEF3000 and the following command should be sent:

```
$PSTMSETPAR,1669,0BEF3000
```

NOTE

GNSS receiver will change its current configuration in RAM immediately after receiving the configuration message. Such change will be lost in case either of hardware or software reset. $PSTMSAVEPAR command can be sent to save the configuration into NVM, and then a module reset is necessary to make the configuration take effect.

5 Mounting Angles Configuration

The mounting angles of L26-DR can be configured when there are misalignments between the module and the ideal “orthogonal mounting”. The premise is that the axes masks have been set correctly.

The mounting angles include 3 angles, and they are:

- Pitch, describing the mismatch between X axis and the horizontal plane
- Roll, describing the mismatch between Y axis and the horizontal plane
- Yaw, describing the mismatch between X axis and the forward direction

These angles shall be previously determined by the users with sufficient accuracy (1-2 degree tolerance), in order to maximize navigation and integrity performance.

If axes masks are configured correctly, the actual pitch, roll and yaw misalignment should not exceed ±45°.

5.1. Angles Convention

5.1.1. Pitch Angle

The pitch angle represents the mismatch between the horizontal plane and X axis of the gyroscope sensor.

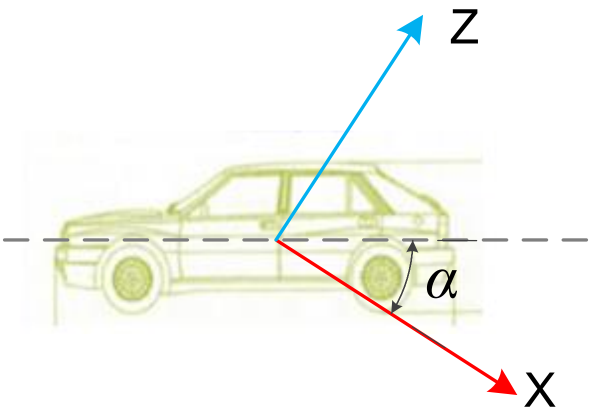

Figure 7: Positive Pitch Angle ($\alpha > 0$)

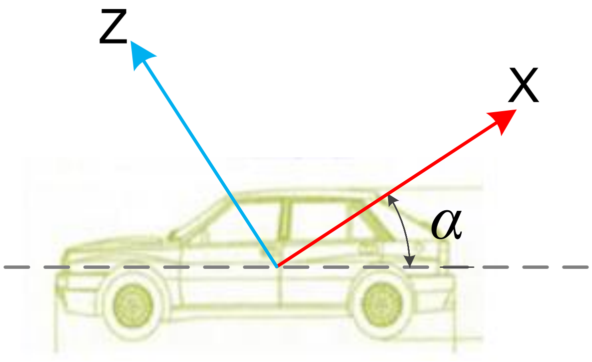

Figure 8: Negative Pitch Angle (*α* < 0)

5.1.2. Roll Angle

The roll angle represents the mismatch between the horizontal plane and Y axis of the gyroscope sensor.

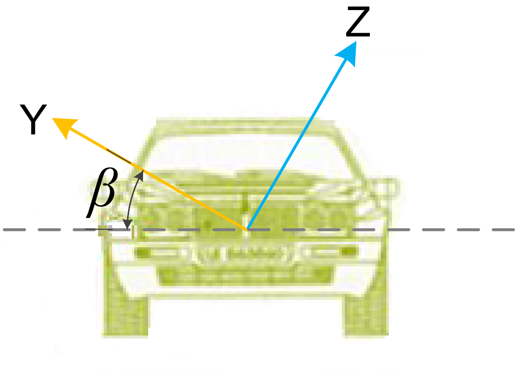

Figure 9: Positive Roll Angle (*β* > 0)

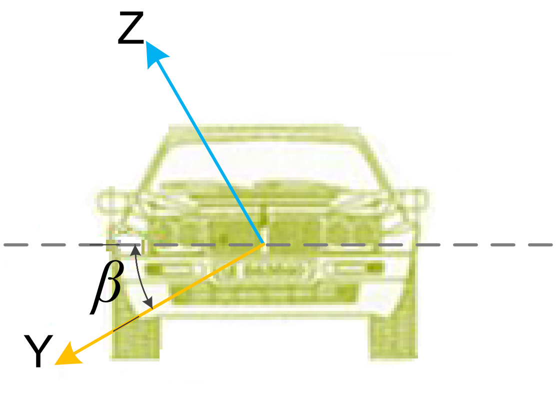

Figure 10: Negative Roll Angle (*β* < 0)

5.1.3. Yaw Angle

The yaw angle represents the mismatch between the vehicle forward direction and X axis of the accelerometer sensor.

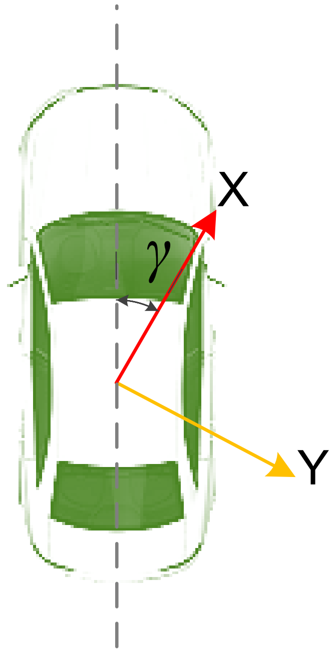

Figure 11: Positive Yaw Angle (γ > 0)

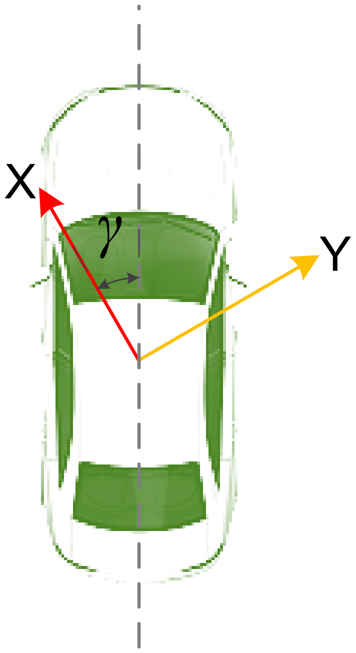

Figure 12: Negative Yaw Angle (γ < 0)

5.2. Automatic Mounting Angles Determination

L26-DR employs an auto-tilt compensation algorithm which can automatically detect tilt angles (pitch and roll angles) without configuring CDB-ID 668. It is important to underline that the algorithm is not able to detect axes masks automatically. If the recommended module mounting is not being used, CDB-ID 669 needs to be configured correctly by users.

5.3. Mounting Yaw Angles Setting

As for L26-DR, tilt angles (pitch and roll) are automatically detected (if CDB-ID 669 has been set correctly). For this reason, there is no need to configure tilt angles in CDB-ID 668. It should be noted that currently there is no automatic estimation procedure for the yaw misalignment. So, it shall be correctly configured in CDB-ID 668.

The default mounting yaw angle is set to be 0 degree. Users can configure the yaw value using the command below.

```
$PSTMSETPAR,1668,<value>
```

Each bit of the 32-bit value is defined as follows:

Bits	Description
0-8	Mounting yaw angle, resolution is 1 deg/LSB, range is 0-359 degrees
9-17	Mounting roll angle, resolution is 1 deg/LSB, range is 0-359 degrees
18-26	Mounting pitch angle, resolution is 1 deg/LSB, range is 0-359 degrees
27-31	Reserved

NOTE

When the axes masks are properly configured, the range in which each mounting angle can be changed is ±45 degrees. However the range of values accepted by the parameter is 0 to 359, so negative angles should be expressed as 360-modulo.

Example:
If the yaw angle is 2 degrees, the parameter should be set as follows:

```
$PSTMSETPAR,1668,2
```

If the yaw angle is -30 degrees, the parameter should be set as follows:

```
$PSTMSETPAR,1668,14A
```

NOTE

GNSS receiver will change its current configuration in RAM immediately after receiving the configuration message. Such change will be lost in case either of hardware or software reset. $PSTMSAVEPAR command can be sent to save the configuration into NVM, and then a module reset is necessary to make the configuration take effect.

5.4. Module Mounting Angles Detection Procedure

L26-DR features an alignment algorithm capable of computing the module's mounting angles. The angles determine the rotation matrix that describes the relationship between the vehicle frame and the sensors frame (dependent on how the module is placed in the vehicle). The purpose of this section is to describe the detection process of the installation angles.

The detection process comprises the following steps:

Step 1: Install L26-DR module on a vehicle.

Step 2: Start the vehicle and turn on the module.

Step 3: Stop the vehicle for at least 20 seconds on a flat section of road (1-2 degree tolerance in respect to gravity direction).

Step 4: Drive the vehicle for 1 minute.

Step 5: Stop the vehicle for at least 5 seconds. The software will save calculated installation angles to flash memory.

NOTES

1. This process above is based on the precondition that users have placed the module in a fixed way, and no displacements or rotations of the module will happen.
2. The process above is required only when:
   - The module installation is changed.
   - During a DR cold start and when the NVM is blank or invalid.

   If the installation information is correctly stored in NVM, next time there will be no need to repeat the process.
3. Please follow the steps above to finish the angle detection process as improper operation may affect the module calibration.

6 DR Operating Modes (Speed & Reverse Data Acquisition)

The module's DR function can't work properly in the absence of the vehicle's speed information. There are three modes to acquire speed information: CAN Bus Mode, Analog Odometer Mode (through WHEELTICK pin) and UART Mode.

6.1. CAN Bus Mode (Default)

In this mode, the module gets speed data via CAN bus. Users can connect the module to OBDII interface of the vehicle. The default setting of CAN bus follows ISO15765 standard protocol.

PSTM Command Used for Switching to CAN Bus Mode:

$PSTMSETPAR,1600,8001050E

Result:

If the module gets speed data via CAN bus successfully, the following sentence will be output.

$PSTMDRSENMSG,14,<cpu_timestamp>,<vehicle_speed>*<checksum><cr><lf>

Parameter	Format	Description
message_id	Decimal, 2 digits	Data type, here the value is 14.
cpu_timestamp	Decimal, 10 digits	Microseconds
vehicle_speed	Decimal, 5 digits	1 km/h resolution
checksum	Hexadecimal, 2 digits	Checksum of the message bytes between but not including "$" and "*" characters

NOTE

In CAN Bus Mode, reverse signal is not supported.

6.2. Analog Odometer Mode

In this mode, the module uses WHEELTICK pin to obtain speed data from analog odometer. The reverse gear signal should be connected to module's FWD pin in order to obtain reverse data.

The default initial value of the odometer's scale factor supported by the module's DR function is 0.2 meters per pulse. If the nominal scale factor value is significantly different from the default value, for example by a factor of 10 or more, then reconfiguration of the initial value can be considered to shorten the calibration time of odometer scale factor. However, the reconfiguration is not a requirement as the scale factor will be eventually calibrated automatically regardless of the initial value.

PSTM Command Used for Odometer Scale Factor Configuration:

```
$PSTMSETPAR,1656,<value>
```

<value> is an integer expressed in hexadecimal and is equal to the odometer scale factor multiplied by 100000.

For example, to set the default scale factor to 0.2 meters per pulse, multiply 0.2 by 100000 and get 20000. The command would be:

```
$PSTMSETPAR,1656,4E20
```

PSTM Command Used for Switching to Analog Odometer Mode:

```
$PSTMSETPAR,1600,80010106
```

Result:

In this mode, the message about odometer count and reverse will be output:

```
$PSTMDRSENMSG,3,<cpu_timestamp>,<odometer>,<reverse>*<checksum><cr><lf>
```

Parameter	Format	Description
message_id	Decimal, 2 digits	Data type, here the value is 3.
cpu_timestamp	Decimal, 10 digits	Microseconds
odometer	Decimal, 5 digits	Unsigned odometer count
reverse	Enum	0 = forward 1 = reverse
checksum	Hexadecimal, 2 digits	Checksum of the message bytes between but not including "$" and "*" characters

6.3. UART Mode

6.3.1. UART Odometer Mode

In this mode, the module gets odometer count and reverse data via the module's UART interface.

PSTM Command Used for Switching to UART Odometer Mode:

```
$PSTMSETPAR,1600,80010306
```

If the nominal scale factor value of the odometer input is significantly different from the default value, the odometer scale factor needs to be reconfigured. For more details, please refer to ***Chapter 6.2***.

The odometer count sent to L26-DR module via UART is as follows:

```
$PSTMDRSENMSG,1,0,<odometer>*<checksum><cr><lf>
```

Parameter	Format	Description
message_id	Decimal, 2 digits	Data type, here the value is 1.
cpu_timestamp	Decimal, 10 digits	Microseconds, here the value must be 0.
odometer	Decimal, 5 digits	Unsigned odometer count
checksum	Hexadecimal, 2 digits	Checksum of the message bytes between but not including "$" and "*" characters

The reverse data sent to L26-DR module via UART is as follows:

```
$PSTMDRSENMSG,2,0,<reverse>*<checksum><cr><lf>
```

Parameter	Format	Description
message_id	Decimal, 2 digits	Data type, here the value is 2.
cpu_timestamp	Decimal, 10 digits	Microseconds, here the value must be 0.
reverse	Enum	0 = forward 1 = reverse
checksum	Hexadecimal, 2 digits	Checksum of the message bytes between but not including "$" and "*" characters

Results:

In this mode, the message about odometer count and reverse data will be added with CPU timestamp and then be output:

```
$PSTMDRSENMSG,1,<cpu_timestamp>,<reverse>*<checksum><cr><lf>
$PSTMDRSENMSG,2,<cpu_timestamp>,<reverse>*<checksum><cr><lf>
```

Besides, the message about vehicle speed will be output too:

$PSTMDRSTATE,<cpu_timestamp>,<lat>,<lon>,<heading>,<speed>,<gyro_offset>,<gyro_gain>,<odo_scale>,<gyro_ovst>,<acc_offset>,<height>*<checksum><cr><lf>

Parameter	Format	Description
cpu_timestamp	Decimal, 10 digits	Microseconds
lat	Double, 5 significant digits	Decimal degrees
lon	Double, 5 significant digits	Decimal degrees
heading	Double, 5 digits	Degrees, -180 to +180
speed	Double, 5 digits	Meters/second
gyro_offset	Double, 4 significant digits	Volts
gyro_gain	Double, 4 significant digits	(Radians/s)/Volt
odo_scale	Double, 5 significant digits	Meters/pulse
gyro_ovst	Double, 6 significant digits	Volt/°C
acc_offset	Double, 6 significant digits	g
height	Double, 1 significant digit	Meters
checksum	Hexadecimal, 2 digits	Checksum of the message bytes between but not including “$” and “*” characters

6.3.2. UART Speed Mode

In this mode, the module gets speed data via the module’s UART interface.

PSTM Command Used for Switching to UART Speed Mode:

$PSTMSETPAR,1600,80010506

The speed data sent to L26-DR module via UART is as follows:

$PSTMDRSENMSG,14,0,<vehicle_speed>*<checksum><cr><lf>

Parameter	Format	Description
message id	Decimal, 2 digits	Data type, here the value is 14.
cpu_timestamp	Decimal, 10 digits	Microseconds, here the value must be 0.

vehicle_speed	Decimal, 5 digits	1 Kph resolution
checksum	Hexadecimal, 2 digits	Checksum of the message bytes between but not including “$” and “*” characters

Results:

In this mode, the message about speed data will be added with CPU timestamp and be output:

$PSTMDRSENMSG,14,<cpu_timestamp>,<vehicle_speed>*<checksum><cr><lf>

Besides, the message about vehicle speed will be output too:

$PSTMDRSTATE,<cpu_timestamp>,<lat>,<lon>,<heading>,<speed>,<gyro_offset>,<gyro_gain>,<odo_scale>,<gyro_ovst>,<acc_offset>,<height>*<checksum><cr><lf>

NOTES

1. In UART speed mode, the recommended speed data input rate is at least 10 Hz
2. GNSS receiver will change its current configuration in RAM immediately after receiving the configuration message. Such change will be lost in case either of hardware or software reset. $PSTMSAVEPAR command can be sent to save the configuration into NVM, and then a module reset is necessary to make the configuration take effect.

7 Calibration Procedure

Once the module has been correctly initialized and installed on a target vehicle, the following steps should be executed in order to fine tune the calibration accurately.

Step 1: Start the vehicle, turn on the module and connect an antenna.

Step 2: Drive the vehicle for about 1 minute and stop it, then start it again. In this way the yaw rate offset is automatically initialized with a reliable value.

Step 3: Drive in straight road sections (speed>30 km/h) for at least 5 minutes.

Step 4: Drive in areas rich of curves (speed>30 km/h). This process is needed to calibrate the yaw rate gain. It is important to underline that tight turns (with narrow radius of curvature) are required. Examples of turns that allow this step to be performed properly are roundabouts, corners, and in general sections in which road direction changes of 90 degrees or more in few seconds. Large turns (e.g. highway ones, lane changes, etc.) do not have any effect on calibration.

Please note that the success of this operation does not depend on its duration, but the number of valid turns that the module is subjected to. In order to have a fine-tuned yaw rate gain, it is suggested that the first-boot calibration route should include at least 10 examples of the tight curves described above. During this procedure, the same curve can be repeated for more times.

It is of the utmost importance that all these operations are fulfilled under benign GNSS signal conditions. This means that the antenna must have maximum sky visibility. In order to fulfil this condition, the calibration should be performed in open areas, i.e. avoiding urban scenarios, forests, tunnels and any form of signal blockage or reflection.

NOTE

It is important to note that the hybrid GNSS/DR navigation mode will not be entered until a valid calibration becomes available. Prior to that point, only GNSS-standalone navigation will be provided.

8 Appendix A References

Table 1: Related Documents

SN	Document Name	Remark
[1]	Quectel_L26-DR_Hardware_Design	L26-DR Hardware Design
[2]	Quectel_L26-DR_GNSS_Protocol_Specification	L26-DR GNSS Protocol Specification

Table 2: Terms and Abbreviations

Abbreviation	Description
CDB	Configuration Data Block
DR	Dead Reckoning
GNSS	Global Navigation Satellite System
GPIO	General Purpose Input/Output
IMU	Inertial Measurement Unit
MEMS	Micro-Electro-Mechanical System
NVM	Non-volatile Memory
OBDII	On-Board Diagnostics II
UART	Universal Asynchronous Receiver/Transmitter