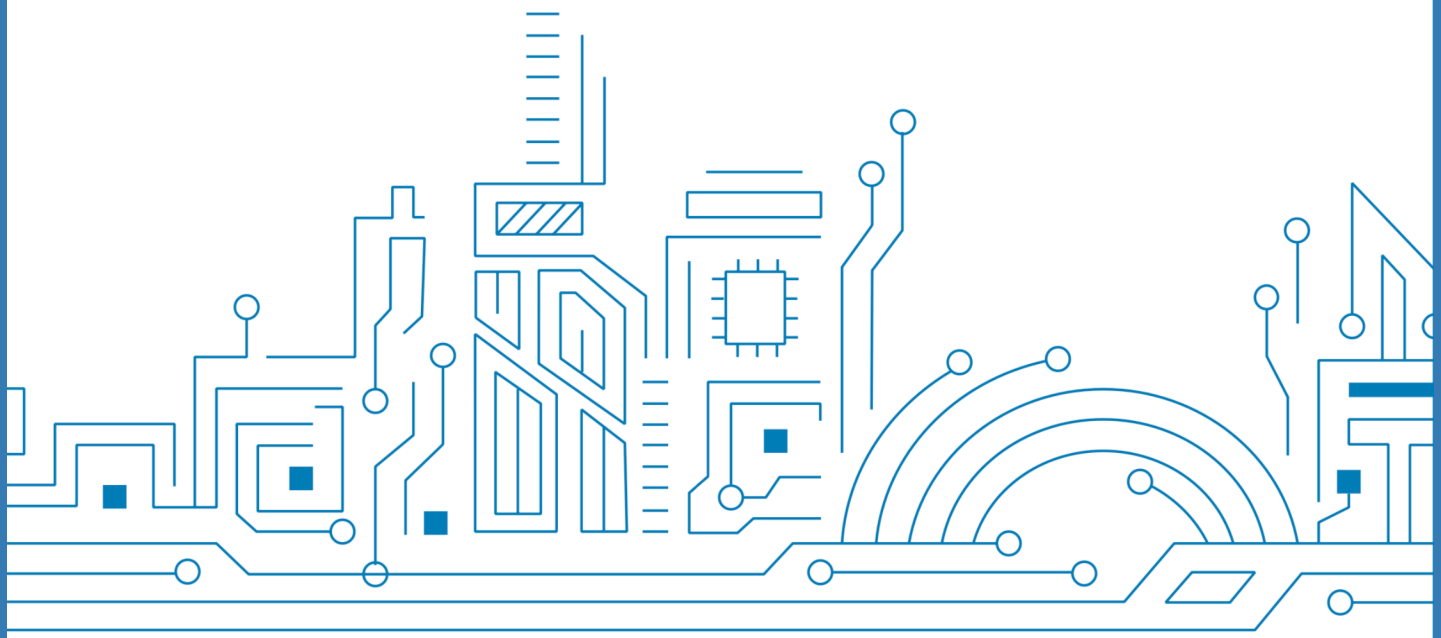
GNSS Positioning Module

GEM1111

Datasheet V1.0



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About the Document

Basic info

Document applies to	GEM1111
Document type	Datasheet
Revision and date	V1.0/2022-09
Product status	Preliminary

Product status description

In development	Objective specification. Revision may be released at later status.
Engineering sample	Product specifications tested early. Revision may be released at later status.
Preliminary	Product specifications come from small producers. Revision may be released at later status.
Mass production	Final product specification to mass market

Table of content

1. SYSTEM OVERVIEW

1.1 General Description

GEM1111 is a high-performance L1 GNSS positioning module with antenna built-in, which is developed on the base of the state-of-the-art Allystar Cynosure III Lite architecture.

It supports global civil navigation systems, including GPS, BDS, GLONASS, Galileo, and QZSS. Featured with SAW and LNA, GEM1111 achieves high positioning accuracy and short TTFF, especially in a rough urban environment. It supports antenna supervisor and auto-switching between the built-in antenna and the external antenna.

With a compact body and high performance, GEM1111 is widely applied to tracking applications, like automotive, consumer, and industrial tracking.

1.2 Features

- Supports GPS, BDS, Galileo, GLONASS, and QZSS systems Built-in LNA & SAW for better sensitivity
- Supports A-GNSS
- Supports geo-fence function
- Ultra-low power consumption around 13 mA in tracking mode
- Supports antenna supervision
- Supports auto-switching between the built-in antenna and the external antenna

P/N	Option	GPS/QZSS	BDS	GLONASS	Galileo
		L1 C/A	B1I	L1	E1
GEM1111	default	●	-	●	●

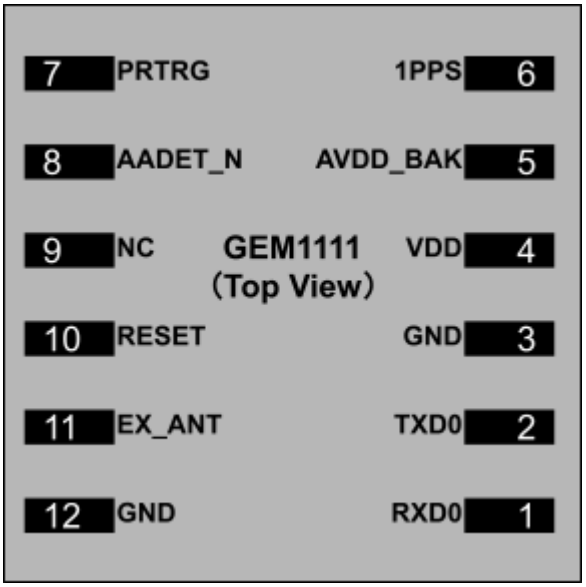
1.3 Module Photo

1.5 Specifications

Parameters	Specification		
GNSS tracking channels	72 channels GPS/QZSS: L1C/A Galileo: E1 GLONASS: L1OF		
Updating rate	1 Hz (Default), up to 5 Hz		
Position accuracy	GNSS	< 1.5 m CEP @ Open Sky	
Velocity & Time accuracy	GNSS	0.1 m/s CEP	
	1PPS	20ns	
Time to First Fix(TTFF)	Hot start	1 s	
	Cold start	28 s	
Sensitivity	Cold start	-149 dBm	
	Reacquisition	-159 dBm	
	Tracking	-163 dBm	
Power supply	VDD	2.0-3.63 V, Typical 3.3 V	
Power consumption	Operating mode	Acquisition	15mA @3.3V
		Tracking	13mA @3.3V
	Standby mode	10uA	
Serial Interface	UART	Adjustable: 9600-460800 bps; Default: 9600 bps	
Protocol	NMEA 0183 Protocol Ver.3.01/4.00 (Default)/4.10		
Operating limit	Velocity	515 m/s	
	Altitude	18,000 m	
Temperature	Operating temperature	-40∘C ~ +85∘C	
	Storage temperature		
Package	Weight: Approx. 7.5 g Dimensions: 16 * 16 * 6.95 mm		
Certification	RoHS & REACH		

2 PIN DESCRIPTION

2.1 Pin Assignment



2.2 Detailed Pin Descriptions

Function	Symbol	No	I/O	Decription
Power	VDD	4	Power	Main power supply voltage input.
	GND	3,12	VSS	Ground
	AVDD_BAK	5	Power	Backup power supply voltage input. Backup power is needed in order to enable warm and hot start features. Backup power is a must for the system to work. If no backup power is available, connect AVDD_BAK to the main power supply.
Antenna	RF_IN	11	I	RF signal input. Use a controlled impedance of 50 for the routing from RF_IN pin to the antenna or the antenna connector.
UART	TXD0	2	O	UARTO serial data Tx.
	RXD0	1	I	UARTO serial data Rx.
Other	PRTRG	7	I	Mode selection or the trigger input in deep sleep mode to wake up the system.
	RESET	10	I	External reset, low active
	1 PPS	6	O	Setting for time pulse output (PPS). Leave it floating if not used.
	AADET_N	8	O	Active antenna detection
	NC	9		Reserved. Leave it floating if not used.

3. ELECTRICAL CHARACTERISTICS

3.1 Absolute Maximum Rating

Symbol	Parameter	Min.	Max.	Unit
VDD	Power input for the main power domain	-0.5	3.6	V
AVDD_BAK	Power input for the backup power domain	-0.5	3.6	V
VI_{max}	Digital I/O pin input voltage	-0.5	3.6	V
$T_{storage}$	Storage temperature	-40	85	°C
T_{solder}	Solder reflow temperature	--	260	°C

3.2 IO Characteristics

3.2.1 PRRSTX and PRTRG

Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit
I_{IZ}	Input leakage current	--	--	--	+/-1	uA
V_{IH}	Input high voltage	--	AVDD_BAK*0. 67	--	AVDD_BAK	V
V_{IL}	Input low voltage	--	0	--	AVDD_BAK*0.27	V
V_{OH}	Output high voltage	I_{OH}=5.3 mA, AVDD_BAK=3.3V	2.64	--	--	V

I_{OH}=1.2 mA, AVDD_BAK=1.8V	1.53	--	--	V		
V_{OL}	Output low voltage	I_{OL}=3.9 mA, AVDD_BAK=3.3V	--	--	0.4	V
I_{OL}=1.9 mA, AVDD_BAK=1.8V	--	--	0.45	V		
C_i	Input capacitancee	--	--	--	11	pF
R_{PU}	Pull-up resistance	--	35	--	84	kΩ

3.2.2 Others

Symbol	Parameter	Condition	Min.	Typ.	Max.	Unit
I_{IZ}	Input leakage current	--	--	--	+/-1	uA
V_{IH}	Input high voltage	--	VDD*0.67	--	VDD	V
V_{IL}	Input low voltage	--	0	--	VDD*0.27	V
V_{OH}	Output high voltage	I_{OH} =5.3 mA, VDD=3.3V	2.64	--	--	V
V_{OL}	Output low voltage	I_{OL} =3.9 mA, VDD=3.3V	--	--	0.4	V
C_i	Input capacitance	--	--	--	11	pF

3.3 DC Characteristics

3.3.1 Operating Conditions

Symbol	Parameter	Min.	Typ.	Max.	Unit
VDD	Power supply voltage	3.0	3.3	3.6	V
AVDD_BAK	Backup battery voltage	1.6	3.3	3.6	V
ICC_{max}	Maximum operating current @ VDD	--	--	200	mA
T_{env}	Operating temperature	-40	--	85	°C

3.3.2 Power Consumption

Parameter	Measure Pin	Typ.	Unit
Average tracking current（GNSS）	VDD[1]	33	mA
Standby mode	AVDD_BAK[2]	14	uA

** [1] Condition: VDD=3.3V@Room Temperature. All Pins Open. GNSS=GPS+Galileo+GLONASS+QZSS+SBAS*

** [2] Condition: AVDD_BAK=3.3V@Room Temperature. All Pins Open.*

4. HARDWARE DESCRIPTION

4.1 Connecting Power

In order to ensure positioning performance, please control the ripple of the module power supply.

It is recommended to use the LDO with a max output current above 100mA.

If the power for the VDD pin is off, the real-time clock (RTC) and battery-backed RAM (BBR) is supplied through the AVDD_BAK pin. Thus, orbit information and time can be maintained and will allow a Hot or Warm start.

Note: If no backup supply is available, connect the AVDD_BAK pin to the main power supply. The floating state is not recommended

4.2 Internal Antenna

GEM1111 module offers an internal patch antenna (18.4 × 18.4 × 4.0mm) with high performance.

4.3 Reset and Mode control

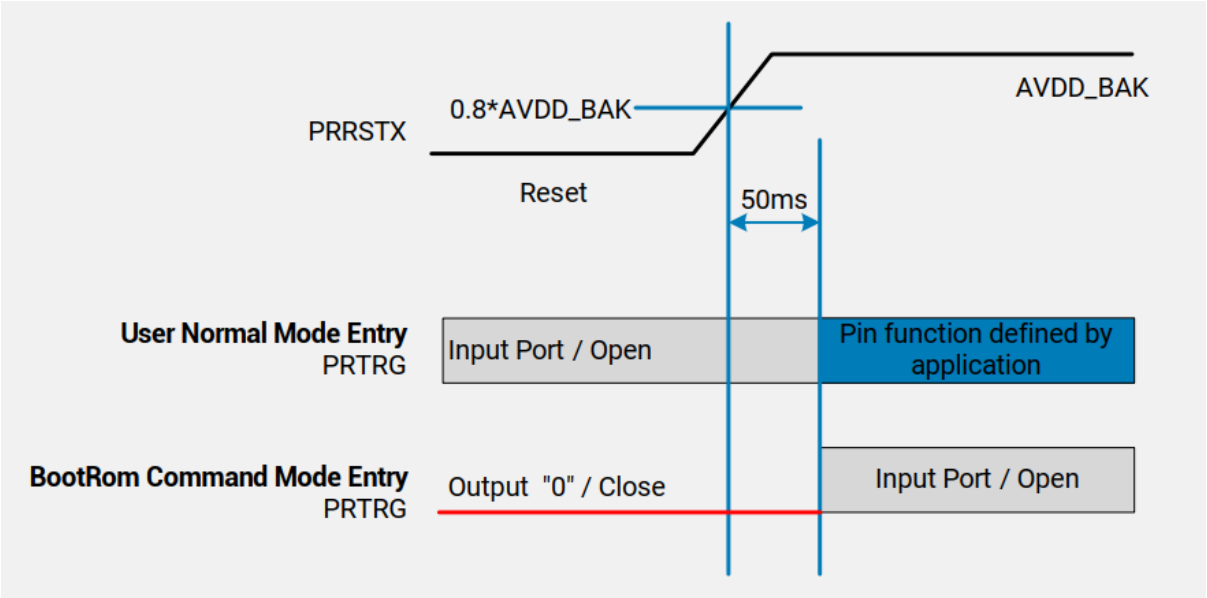
The operation mode of the GNSS module is controlled by PRRSTX (nRESET) and PRTRG (BOOT) pin.

While the module works in normal operation, leave PRRSTX and PRTRG pins floating if there is no upgrading or reset demands, or others.

- Keep PRTRG pin floating during system power-up or the external reset (PRRSTX from low to high), and the module will enter User Normal Mode.
- When the module powers up or PRRSTX from low to high, the module will execute an external reset. (If the power for AVDD_BAK is always on, the external reset will not affect the ephemeris data in the backup domain)
- Drive PRTRG pin to low or connect PRTRG to GND directly (not by pull-down resistance) during system power-up or the external reset (PRRSTX from low to high),

and the system enters BootROM Command Mode at PRTRG pin being released from low to floating state, and ready for firmware upgrading command.

- When connecting PRRSTX and PRTRG to any host IO, DO NOT use the pull-up or pull-down resistance



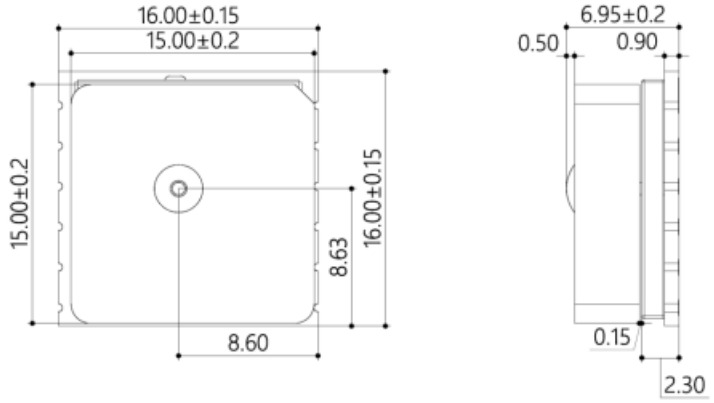
4.4 Default Serial Interfaces

Interface	Settings
UART output	9600 baud, 8 data bits, no parity bit, 1 stop bit. Configured to transmit both NMEA and HD Binary protocols, but only the following NMEA (and no HD Binary sentence) messages have been activated at start-up: GGA, GSA, GSV, RMC, ZDA, TXT-ANT
UART input	9600 baud, 8 data bits, no parity bit, 1 stop bit, autobaud disabled. Automatically accepts the following protocols without the need for explicit configuration: HD binary sentence, NMEA The GNSS receiver supports interleaved HD Binary and NMEA messages.
Timepulse (1Hz Nav)	1 pulse per second, synchronized at the rising edge, pulse length 100ms.

When the module is applied to the specific application, users can shut off the main power in order to further reduce the power consumption. To avoid the high level of serial interface influencing the normal operation, it is highly suggested to cut off the serial port when shutting off the main power.

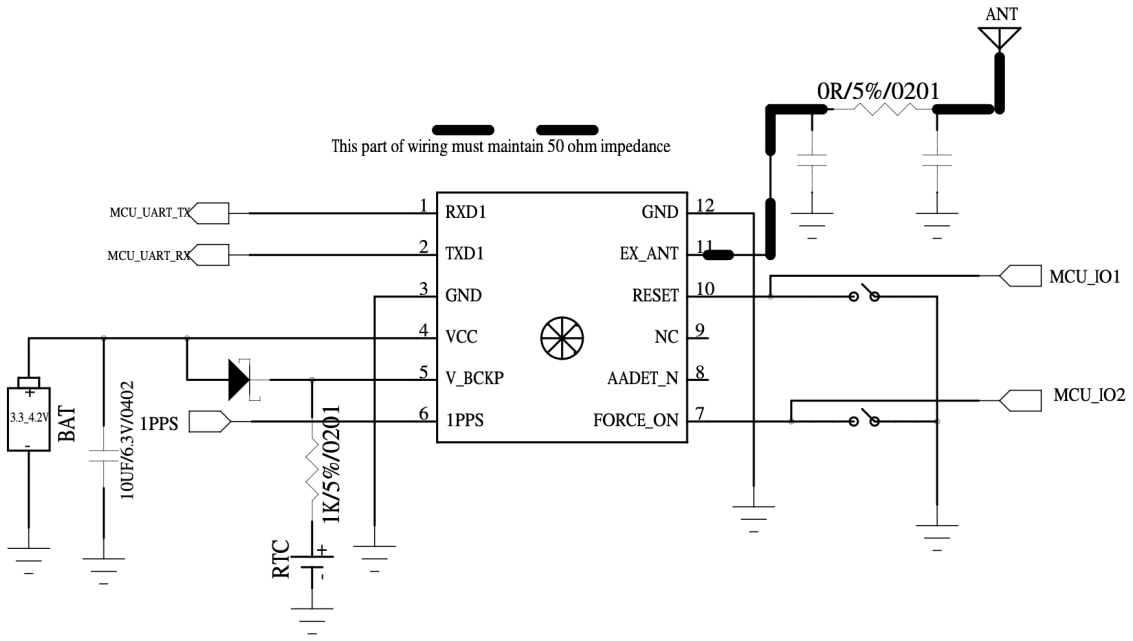
Otherwise, please set the serial port to input mode or high impedance state with a pull-down resistor.

5 MECHANICAL SPECIFICATION



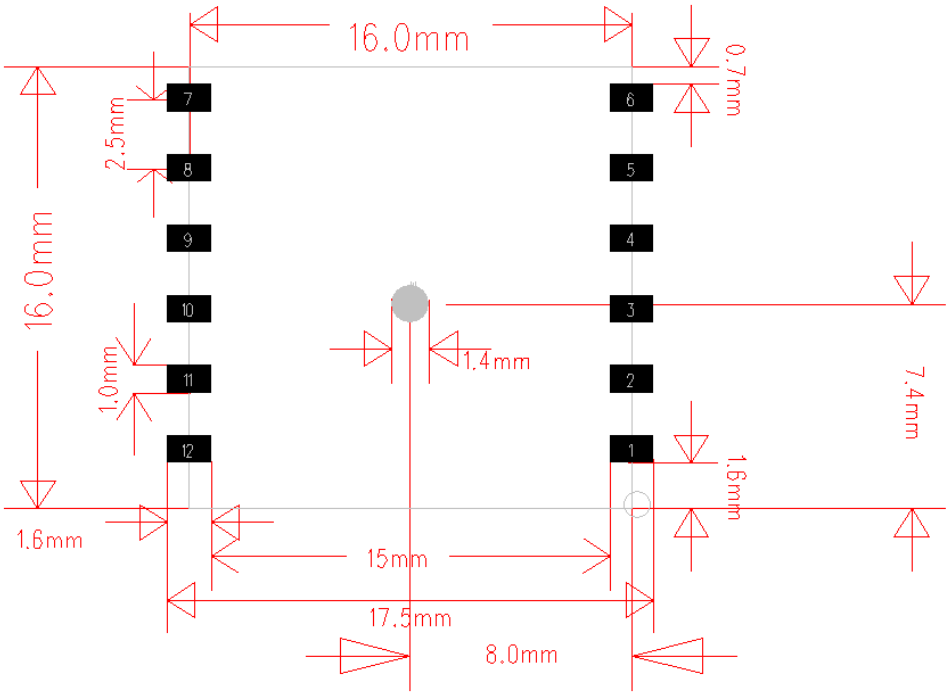
6 REFERENCE DESIGN

6.1 Minimal Design



F6.1.1 Minimal Design

6.2 PCB Footprint Reference



F6.2.1 PCB Footprint Reference

6.3 Layout Notes

(1) A decoupling capacitor should be placed close to the VDD pin of the module, and the width of power routing should be more than 0.5mm.

(2) The width of RF routing between RF port to antenna interface should be wider than 0.2mm. The characteristic impedance of RF routing between RF port to antenna interface should be controlled to 50Ω.

(3) It is recommended that the routing from the RF port to the antenna interface refers to the second layer, and no routing is recommended on the layer.

(4) Do not place the module close to any EMI source, like an antenna, RF routing, DC/DC or power conductor, clock signal or another high-frequency switching signal, etc.

7. SOFTWARE INTERFACE

7.1 NMEA Message Format

NMEA	Sub ID	Description
GGA	0x00	Global positioning system fixed data
GLL	0x01	Geographic position - latitude/longitude
GRS	0x02	GNSS Overall satellite data
GSA	0x03	GNSS Overall satellite data
GSV	0x04	GNSS Detailed satellite data
RMC	0x05	Recommended minimal data for GNSS
VTG	0x06	Course over ground and ground speed
ZDA	0x07	Date and time
GST	0x08	GNSS Pseudorange Error Statistics
TXT	0x20	Antenna status
** The default output of the module is GGA GSA GSV RMC ZDA TXT*		

7.1.1 GGA - Global Positioning System Fix Data

Output example of Table 12 as bellows:
$GNGGA,074144.000,3957.79941,N,11619.02981,E,1,19,0.83,105.5,M,-8.4,M,,*65

Name	Example	Unit	Description
Message ID	$GNGGA		GGA protocol header
UTC Time	074144.000		hhmmss.sss
Latitude	3957.79941		ddmm.mmmmm
N/S indicator	N		N=north or S=south
Longitude	11619.02981		dddmm.mmmmm
E/W Indicator	E		E=east or W=west
Position Fix Indicator	1		See Table 13
Satellites Used	19		Number of satellites in use, 00-24
HDOP	0.83		Horizontal Dilution of Precision (meters)
MSL Altitude	105.5	meters	Antenna Altitude above/below mean-sea-level (geoid) (in meters)
Units	M	meters	Units of antenna altitude, meters
Geoidal Separation	-8.4	meters	
Units	M	meters	Units of geoidal separation, meters
Age of diff. GNSS data		second	Null fields when DGPS is not used
Diff. Ref. Station ID			Differential reference station ID, 0000-1023
Checksum	*65		checksum
<CR><LF>			End of message termination

7.1.2 GLL-Geographic Position – Latitude/Longitude

Output example of Table 14 as bellows:
$GNGLL,2503.71465,N,12138.73922,E,062052.000,A,A*45

Name	Example	Unit	Description
Message ID	$GNGLL	GLL protocol header	
Latitude	2503.71465	ddmm.mmmmm	
N/S indicator	N	N=north or S=south	
Longitude	12138.73922	dddmm.mmmmm	
E/W indicator	E	E=east or W=west	
UTC Time	062052.000	hhmmss.sss	
Status	A	A=data valid or V=data not valid	
Mode	A	A=Autonomous, D=DGPS, N=Data not valid,	
Checksum	*45		
<CR> <LF>	End of message termination		

7.1.3 GSA-GNSS DOP and Active Satellites

Output example of Table 15 as bellows:
$GPGSA,A,3,01,11,18,30,28,07,17,22,03,,,,1.10,0.79,0.77,1*12
$BDGSA,A,3,10,07,08,12,03,13,01,11,02,04,05,,1.10,0.79,0.77,4*0B

Name	Example	Unit	Description
Message ID	$GPGSA	GSA protocol header	
Mode 1	A	See Table 16	
Mode 2	3	See Table 17	
ID of satellite used	1	Sv on Channel 1	
ID of satellite used	11	Sv on Channel 2	
….	….		
ID of satellite used			Sv on Channel 12
PDOP	1.1		Position Dilution of Precision
HDOP	0.79		Horizontal Dilution of Precision
VDOP	0.77		Vertical Dilution of Precision
System ID	1		Satellites used in GPS
			1= GPS
			4=BD
Checksum	*12		
<CR> <LF>			End of message termination

Table 16 Mode 1

Value	Description
M	Manual-forced to operate in 2D or 3D mode
A	Automatic-allowed to automatically switch 2D/3D

Table 17 Mode 2

Value	Description
1	Fix not available
2	2D
3	3D

7.1.4 GSV-GNSS Satellites in View

Output example of Table 18 as bellows:
$GPGSV,4,1,15,193,69,35,39,6,50,28,41,137,50,134,34,129,50,134,34*73
$GPGSV,4,2,15,17,45,137,41,2,42,326,40,5,42,250,40,128,38,243,36*4B
$GPGSV,4,3,15,9,36,65,42,12,26,285,35,127,12,260,32,19,9,137,35*7D
$GPGSV,4,4,15,23,8,41,35,25,4,316,36,28,,,*4F
$BDGSV,3,1,09,8,75,64,39,6,73,237,38,3,58,205,38,1,53,143,38*56
$BDGSV,3,2,09,9,47,224,38,4,38,118,37,2,35,246,33,5,16,259,31*6C
$BDGSV,3,3,09,10,2,210,21*62

Name	Example	Unit	Description
Message ID	$GPGSV		GSV protocol header
Total number of messages	4		Range 1 to 6,Total number of GSV messages to be transmitted in this group
Message number[1]	1		Range 1 to 6 Origin number of this GSV message within current group
Satellites in view	15		Total number of satellites in view
Satellite ID[2]	193		Satellite PRN number
Elevation	69	degrees	Elevation in degrees (Range 00 to 90)
Azimuth	35	degrees	Azimuth in degrees to true north (Range 000 to 359)
SNR (C/No)	39	dB-Hz	SNR in dB (Range 00 to 99, null when not tracking)
…	….		
Satellite ID	129		Satellite PRN number (Range 01 to 196)
Elevation	50	degrees	Elevation in degrees (Range 00 to 90)
Azimuth	134	degrees	Azimuth in degrees to true north (Range 000 to 359)

SNR (C/No)	34	dB-Hz	SNR in dB Channel 4 (Range 00 to 99, null when not tracking)
Checksum	*73		
<CR> <LF>			End of message termination

7.1.5 RMC-Recommended Minimum Specific GNSS Data

Output example of Table 19 as bellows:
$GNRMC,075939.000,A,2225.56166,N,11412.68199,E,0.000,64.79,020589,0.0,E,A*1D
$GNRMC,074458.000,A,3957.79932,N,11619.03010,E,0.005,0.00,280419,,,A*4B

Name	Example	Unit	Description
Message ID	$GNRMC		RMC protocol header
UTC Time	075939.000		hhmmss.sss
Status	A		A=data valid or V=data not valid
Latitude	2225.56166		ddmm.mmmmm
N/S Indicator	N		N=north or S=south
Longitude	11412.68199		dddmm.mmmmm
E/W Indicator	E		E=east or W=west
Speed over ground	0.000	knots	Speed over ground
Course over ground	64.79	degrees	Degrees to true north
Date	020589	ddmmyy	
Magnetic variation	0.0	degrees	(Not shown)
Variation sense	E		E=east or W=west (Not shown)
Mode	A		A=Autonomous, D=DGPS, N=Data not valid,
Checksum	*4B		
<CR> <LF>			End of message termination

7.1.6 VTG-Course over Ground and Ground Speed

Output example of Table 20 as bellows: $GNVTG,0.00,T,0.00,M,0.000,N,0.000,K,A*3D
$GNVTG,0.00,T,,M,0.011,N,0.021,K,A*20

Name	Example	Unit	Description
Message ID	$GNVTG		VTG protocol header
Course over ground	0.00	degrees	Degrees to true north
Reference	T		True north
Course over ground		degrees	Degrees to Magnetic
Reference	M		Magnetic
Speed over ground	0.000	knots	Measured speed
Units	N		Knots
Speed over ground	0.000	km/hr	Measured speed
Units	K		Kilometer per hour
Mode	A		A=Autonomous, D=DGPS, N=Data not valid
Checksum	*3D		
<CR> <LF>			End of message termination

7.1.7 ZDA-Time & Date

Output example of Table 21 as bellows: $GNZDA,033900.000,28,10,2015,,*4C

Name	Example	Unit	Description
Message ID	$GNZDA		ZDA protocol header
UTC Time	033900.000		hhmmss.sss
Day	28		dd (01 to 31)
Month	10		mm (01 to 12)
Year	2015		yyyy (1980 to 2025)
Local zone hours		hour	
Local zone minutes		minute	
Checksum	*4C		
<CR> <LF>			End of message termination

7.1.8 GST- GNSS Pseudorange Error Statistics

Output example of Table 22 as bellows: $GNGST,081119.000,1.2,,,,0.6,0.5,0.5*52

Name	Example	Unit	Description
Message ID	$GNGST		GST protocol header
UTC Time	081119.000		hhmmss.sss
RMS value	1.2		RMS value of the standard deviation of the range inputs to the navigation process. Range inputs include pseudoranges & DGNSS corrections
Standard semi-major axis of error		Meter	Standard deviation of semi-major axis of error ellipse
Standard semi-minor axis of error		Meter	Standard deviation of semi-minor axis of error ellipse
Orientation of semi-major axis of error		Degree	Orientation of semi-major axis of error ellipse (degrees from true north)
latitude error	0.6	Meter	Standard deviation of latitude error
longitude error	0.5	Meter	Standard deviation of longitude error
altitude error	0.5	Meter	Standard deviation of altitude error
Checksum	*52		

7.1.9 TXT-ANT & USR message

Output example of Table 23 as bellows: $GNTXT,01,01,01,ANT_OK*50

Name	Example	Unit	Description
Message ID	$GNTXT		USR message protocol header
Total number	01		Total number of sentences
Sentence Number	01		Sentence number
Identifier	01		Text identifier
Content	ANT_OK		Text message
Checksum	*50	4C	
<CR> <LF>			End of message termination

Table Antenna status NMEA output

Active antenna status	GNSS module output
Short circuit	$GNTXT,01,01,01,ANT_SHORT*06
Normal operating	$GNTXT,01,01,01,ANT_OK*50
Open circuit	$GNTXT,01,01,01,ANT_OPEN*40

7.2 Exclusive Binary Message

The common exclusive commands show as bellows:

Command description	Software[command][1]
Perform a Cold start	F1 D9 06 40 01 00 01 48 22
Perform a Warm start	F1 D9 06 40 01 00 02 49 23
Perform a Hot start	F1 D9 06 40 01 00 03 4A 24
Perform a Factory reset	F1 D9 06 09 08 00 02 00 00 00 FF FF FF FF 15 01
UART configures as 115200bps	F1 D9 06 00 08 00 00 00 00 00 00 C2 01 00 D1 E0
UART configures as 9600bps	F1 D9 06 00 08 00 00 00 00 00 80 25 00 00 B3 07
Enable ZDA message	F1 D9 06 01 03 00 F0 07 01 02 1E
Disable ZDA message	F1 D9 06 01 03 00 F0 07 00 01 1D
Navigate with GPS only	F1 D9 06 0C 04 00 01 00 00 00 17 A0
Navigate with BeiDou system only	F1 D9 06 0C 04 00 04 00 00 00 1A AC
Navigate with GPS+ BeiDou system	F1 D9 06 0C 04 00 05 00 00 00 1B B0
Query firmware version[1]	F1 D9 0A 04 00 00 0E 34

** [1] Add 0D 0A at the end of command*

7.3 Mode Configuration

7.3.1 CFG-SIMPLERST

Configure soft reset (as system command,there is NO ACK);
F1 D9 06 40 01 00 00 47 21
Configure a cold start (as system command, there is NO ACK);
F1 D9 06 40 01 00 01 48 22
Configure a warm start (as system command, there is NO ACK);
F1 D9 06 40 01 00 02 49 23
Configure a hot start (as system command, there is NO ACK);
F1 D9 06 40 01 00 03 4A 24
Configure GNSS stop (if successful, it would return ACK, else return NAK);
F1 D9 06 40 01 00 10 57 31
Configure GNSS start (if successful, it would return ACK, else return NAK);
F1 D9 06 40 01 00 11 58 32

Configure Clear All TRK Channels (if successful, it would return ACK, else return NAK);
F1 D9 06 40 01 00 80 C7 A1
CFG-SLEEP
Set GNSS task to deep sleep for 5000ms;
F1 D9 06 41 05 00 88 13 00 00 01 E8 56 CFG-PWRCTL
Poll message of power control;
F1 D9 06 42 00 00 13 3F
Set receiver into cyclic sleep mode;
F1 D9 06 42 14 00 00 05 00 00 B8 0B 00 00 60 EA 00 00 D0 07 00 00 00 00 00 00 45 F9

8 PRODUCT PACKAGING AND HANDLING

8.1 Packaging

8.1.1 Packaging Notes

GEM1111 GNSS module is a Moisture Sensitive Device (MSD) and Electrostatic Sensitive Device (ESD). During the packing and shipping, it is strictly required to take appropriate MSD handling instructions and precautions. The table below shows the general packing hierarchy for the standard shipment.

8.1.2 Tape and Reel

GEM1111 modules are delivered as hermetically sealed, reeled tapes in order to enable efficient production, production lot set-up, and tear-down. The figure below shows the tape dimension.

The GEM1111 modules are deliverable in quantities of 1000pcs on a reel. The figure below shows the dimensions of the reel for GEM1111.

8.1.3 Shipment Packaging

The reels of GEM1111 are packed in sealed bags and shipped in shipping cartons. Up to five sealed bags (5000pcs in total) can be packed in one shipping carton.

8.2 Storage

In order to prevent moisture intake and protect against electrostatic discharge, GEM1111 is packaged together with a humidity indicator card and desiccant to absorb humidity.

8.3 Handling

8.3.1 ESD Handling Precautions

GEM1111 module which contains susceptible electronic circuitry is an Electrostatic Sensitive Device (ESD). Observe precautions for handling! Failure to observe these precautions may result in severe damage to the GNSS module!

Unless there is a galvanic coupling between the local GND (i.e. the workbench) and the PCB GND, then the first point of contact when handling the PCB must always be between the local GND and PCB GND.

Before mounting an antenna patch, connect the ground of the device.

When handling the RF pin, do not come into contact with any charged capacitors, and be careful

when contacting materials that can develop charges (e.g. patch antenna ~10 pF, coax cable ~50– 80 pF/m, soldering iron ...)

Do not touch any exposed antenna area to prevent electrostatic discharge through the RF input.

If there is any risk that such an exposed antenna area is touched in a non-ESD protected work area, implement proper ESD protection measures in the design.

When soldering RF connectors and patch antennas to the receiver’s RF pin, make sure to use an ESD-safe soldering iron (tip).

8.3.2 ESD Protection Measures

This series of GNSS positioning modules is sensitive to static electricity. Whenever handling the module, particular care must be exercised to reduce the risk of electrostatic charges. In addition to standard ESD safety practices, the following measures should be taken into account.

Adds ESD Diodes to the RF input part to prevent electrostatic discharge.

Do not touch any exposed antenna area.

Adds ESD Diodes to the UART interface.

8.3.3 Moisture Sensitivity Level

The Moisture Sensitivity Level (MSL) of the GNSS modules is MSL4.