



---

## ERINOME-II USER MANUAL

---

2614021137000

VERSION 1.5

AUGUST 26, 2021

\*\*\*\*\*

## MUST READ

### Check for firmware updates

Before using the product make sure you use the most recent firmware version, data sheet and user manual. This is especially important for Wireless Connectivity products that were not purchased directly from Würth Elektronik eiSos. A firmware update on these respective products may be required.

We strongly recommend to include in the customer system design, the possibility for a firmware update of the product.

## Revision history

Manual version	FW version	HW version	Notes	Date
1.0	1.0	1.0	<ul style="list-style-type: none"> <li>Initial release of the manual</li> </ul>	February 2020
1.1	1.0	1.0	<ul style="list-style-type: none"> <li>Corrected version of harmonized norm EN 303 413 according to test reports: Chapter 16.5</li> </ul>	May 2020
1.2	1.0	1.0	<ul style="list-style-type: none"> <li>Extended description of I<sup>2</sup>C host connection: Chapter 9.2</li> <li>Added default UART baud rate to Table 33</li> </ul>	July 2020
1.3	1.0	1.0	<ul style="list-style-type: none"> <li>Added description of SPI host connection and interface: Chapter 8.3 and 9.3</li> <li>Updated Chapter 6 with recommendation for baud rate selection</li> <li>Corrected operating temperature in Table 30</li> <li>Added Chapter 7.3.1.2</li> </ul>	October 2020
1.4	1.0	1.0	<ul style="list-style-type: none"> <li>Added reference to SPI interface, where missing</li> <li>Updated ordering information with Extended EV-Kit: Table 1</li> </ul>	March 2021
1.5	1.0	1.0	<ul style="list-style-type: none"> <li>Updated Desing In Guide and layout recommendation (Chapter 7.1)</li> <li>Added References chapter (Chapter 15)</li> <li>Updated Chapter 3.1</li> </ul>	August 2021

# Abbreviations

Abbreviation	Name	Description
CEP	Circular Error Probability	Radius of a circle including accuracy measurements data with a given probability
CS	Chip Select	
CTS	Clear To Send	
ECEF	Earth-Centered Earth-Fixed	Coordinate system
EEPROM	Electrically Erasable Programmable Read-Only Memory	
EHE	Estimated Heading Error	
EHPE	Estimated Horizontal Position Error	
EHVE	Estimated Velocity Error	
ESD	Electrostatic Discharge	
FCC	Federal Communications Commission	
FIFO	First In First Out	
GDOP	Geometric Dilution Of Precision	
GLONASS	Global Navigation Satellite System	Russian satellite navigation system
GNSS	Global Navigation Satellite System	
GPIO	General Purpose Input/Output	
GPS	Global Positioning System	American satellite navigation system
HDOP	Horizontal Dilution of Precision	
I <sup>2</sup> C	Inter-Integrated Circuit	
IC	Integrated Circuit	
LNA	Low-Noise Amplifier	
LSB	Least Significant Bit	
LPM	Low Power Mode	
MID	Message Identifier	OSP sentence identifier
MISO	Master In Slave Out	
MOSI	Master Out Slave In	
MSL	Mean Sea Level	

Abbreviation	Name	Description
µC	Microcontroller	
NMEA	National Marine Electronics Association	Standard communication protocol for navigation
OSP	One Socket Protocol	Qualcomm-proprietary communication protocol
PDOP	Position Dilution of Precision	
PPS	Pulse per Second	Pulse signal sent by the GNSS module once a fix with at least 5 SVs is obtained
PRN	Pseudo-Random Noise	SV-specific codes used for ranging and as satellite identifiers
PVT	Position, Velocity, and Time	
QZSS	Quasi-Zenith Satellite System	Satellite-based augmentation system for the Asia-Oceania regions
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals	
RED	Radio Equipment Directive	Regulatory framework for radio equipment
RF	Radio Frequency	Describes everything relating to the wireless transmission
RNSS	Regional Navigation Satellite System	
RoHS	Restriction of Hazardous Substances	
RTC	Real-Time Clock	
RTS	Ready To Send	
SBAS	Satellite-Based Augmentation System	Satellite systems enhancing GNSS
SCL	Serial Clock Line	
SCLK	Serial Clock	
SDA	Serial Data Line	
SPI	Serial Peripheral Interface	
SV	Space Vehicle	
SWDCLK	Serial Wire Debug Clock	
TCXO	Temperature-Compensated Crystal Oscillator	
TDOP	Time Dilution Of Precision	
TOW	Time Of Week	
TP	Trickle Power	Self-managed low power mode
TTFF	Time To First Fix	Time required by the GNSS receiver to obtain first valid position fix

Abbreviation	Name	Description
UART	Universal Asynchronous Receiver Transmitter	
UTC	Coordinated Universal Time	24-h primary time standard
VDOP	Vertical Dilution of Precision	
XTAL	Crystal Oscillator	
WGS84	World Geodetic System 1984	Earth model and reference system

# Contents

<b>1 Introduction</b>	<b>8</b>
1.1 Block diagram . . . . .	9
1.2 Ordering information . . . . .	9
<b>2 Electrical specifications</b>	<b>10</b>
2.1 Recommended operating conditions . . . . .	10
2.2 Absolute maximum ratings . . . . .	10
2.3 Current consumption . . . . .	11
2.4 Radio characteristics . . . . .	11
2.5 Pin characteristics . . . . .	12
<b>3 GNSS performances</b>	<b>13</b>
3.1 Satellite constellations supported . . . . .	13
3.2 Accuracy . . . . .	14
3.2.1 Position Accuracy . . . . .	14
3.2.2 Velocity Accuracy . . . . .	14
3.2.3 Heading Accuracy . . . . .	14
3.2.4 Time Accuracy . . . . .	14
3.3 Time To First Fix . . . . .	15
3.4 Sensitivity . . . . .	15
3.5 Dynamic constraints . . . . .	16
<b>4 Pinout</b>	<b>17</b>
4.1 ON_OFF pin . . . . .	18
4.2 WAKE_UP pin . . . . .	19
4.3 /RESET pin . . . . .	19
4.4 1PPS pin . . . . .	19
4.5 /RTS and /CTS pins . . . . .	19
<b>5 Quick start guide</b>	<b>20</b>
5.1 External GNSS antenna . . . . .	20
5.2 Minimal pin configuration . . . . .	20
5.3 Power up . . . . .	20
5.4 Acquisition, first fix, and tracking . . . . .	22
5.5 Quick start example . . . . .	24
<b>6 Functional description</b>	<b>25</b>
6.1 Cold, warm, and hot start . . . . .	26
6.2 Low power modes . . . . .	27
6.2.1 Host-controlled low power mode . . . . .	27
6.2.2 Self-managed low power modes . . . . .	28
6.2.3 Push To Fix . . . . .	28
6.2.4 Trickle Power mode . . . . .	29
6.2.5 SiRFSmartGNSS . . . . .	30
<b>7 Design in guide</b>	<b>31</b>
7.1 Advice for schematic and layout . . . . .	31
7.1.1 Footprint . . . . .	32
7.1.2 Module Footprint on PCB . . . . .	33
7.1.3 PCB Stackup . . . . .	34

7.1.4	Module's placement . . . . .	35
7.2	Dimensioning of the micro strip antenna line . . . . .	36
7.3	Antenna solutions . . . . .	37
7.3.1	Antennas provided by Würth Elektronik eiSos . . . . .	38
7.3.1.1	2600130016 - GNSS Active antenna . . . . .	38
7.3.1.2	7488920157 - GNSS multilayer chip antenna . . . . .	39
<b>8</b>	<b>Reference design</b>	<b>40</b>
8.1	Schematic . . . . .	41
8.2	Layout . . . . .	44
8.3	Interface Selection for SPI . . . . .	45
<b>9</b>	<b>Host connection</b>	<b>46</b>
9.1	UART . . . . .	47
9.2	I <sup>2</sup> C multi master . . . . .	48
9.2.1	General characteristics . . . . .	48
9.2.2	SDA and SCL logic levels . . . . .	49
9.2.3	Addressing the GNSS module . . . . .	49
9.2.4	GNSS communication protocol . . . . .	49
9.2.5	I <sup>2</sup> C timing parameters . . . . .	49
9.2.6	I <sup>2</sup> C communication between Erinome-II and a generic Microcontroller	50
9.3	SPI Slave . . . . .	52
9.3.1	General characteristics . . . . .	52
9.3.2	Addressing the GNSS module . . . . .	53
9.3.3	SPI timing parameters . . . . .	53
9.3.4	GNSS communication protocol . . . . .	53
9.3.5	SPI communication between Erinome-II and a generic Microcontroller	54
<b>10</b>	<b>Erinome-II communication protocols</b>	<b>58</b>
10.1	NMEA sentences . . . . .	58
10.1.1	NMEA sentences overview . . . . .	61
10.1.2	NMEA output sentences . . . . .	62
10.1.3	NMEA input sentences . . . . .	73
10.2	OSP sentences . . . . .	78
10.2.1	OSP sentences overview . . . . .	79
10.2.2	OSP output sentences . . . . .	80
10.2.3	OSP input sentences . . . . .	88
<b>11</b>	<b>UserSettings</b>	<b>95</b>
11.1	Default Settings . . . . .	95
<b>12</b>	<b>Manufacturing information</b>	<b>96</b>
12.1	Moisture sensitivity level . . . . .	96
12.2	Soldering . . . . .	96
12.2.1	Reflow soldering . . . . .	96
12.2.2	Cleaning . . . . .	98
12.2.3	Potting and coating . . . . .	98
12.2.4	Other notations . . . . .	98
12.3	ESD handling . . . . .	98
12.4	Safety recommendations . . . . .	99

<b>13 Physical dimensions</b>	<b>100</b>
13.1 Dimensions . . . . .	100
13.2 Weight . . . . .	100
13.3 Module drawing . . . . .	101
13.4 Footprint . . . . .	102
<b>14 Marking</b>	<b>103</b>
14.1 Lot number . . . . .	103
14.2 General labeling information . . . . .	104
<b>15 References</b>	<b>105</b>
<b>16 Regulatory compliance information</b>	<b>106</b>
16.1 Important notice EU . . . . .	106
16.2 Important notice FCC . . . . .	106
16.3 Conformity assessment of the final product . . . . .	106
16.4 Exemption clause . . . . .	106
16.5 EU Declaration of conformity . . . . .	107
16.6 FCC conformity . . . . .	108
<b>17 Important notes</b>	<b>109</b>
17.1 General customer responsibility . . . . .	109
17.2 Customer responsibility related to specific, in particular safety-relevant applications . . . . .	109
17.3 Best care and attention . . . . .	109
17.4 Customer support for product specifications . . . . .	109
17.5 Product improvements . . . . .	110
17.6 Product life cycle . . . . .	110
17.7 Property rights . . . . .	110
17.8 General terms and conditions . . . . .	110
<b>18 Legal notice</b>	<b>111</b>
18.1 Exclusion of liability . . . . .	111
18.2 Suitability in customer applications . . . . .	111
18.3 Trademarks . . . . .	111
18.4 Usage restriction . . . . .	111
<b>19 License terms</b>	<b>113</b>
19.1 Limited license . . . . .	113
19.2 Usage and obligations . . . . .	113
19.3 Ownership . . . . .	114
19.4 Disclaimer of warranty . . . . .	114
19.5 Limitation of liability . . . . .	114
19.6 Applicable law and jurisdiction . . . . .	114
19.7 Severability clause . . . . .	114
19.8 Miscellaneous . . . . .	115

# 1 Introduction

Based on Qualcomm SirfStar V 5e B02 chipset, it supports four major GNSS constellations (GPS, GLONASS, Galileo, and BeiDou) for fast and accurate positioning.

Ultra-compact 7mm x 7mm design allows the module to fit in small-size applications. UART, I<sup>2</sup>C and SPI interfaces are available. Connection of external antenna through RF pad is required for module operation. This manual provides design guidelines for hardware integration.

The module can be operated through one of two available communication protocols:

- NMEA (standard) and
- OSP (Qualcomm-proprietary).

Each of these protocols defines a set of commands for module's configuration.

Module's evaluation board [9] (see Table 1) and PC tool [8] allow getting started with the module and testing its functionalities. The evaluation board also represents our reference design. For further information, please refer to the evaluation board manual [3].

The module is RED, RoHS, and REACH certified.



Figure 1: Erinome-II module

## 1.1 Block diagram

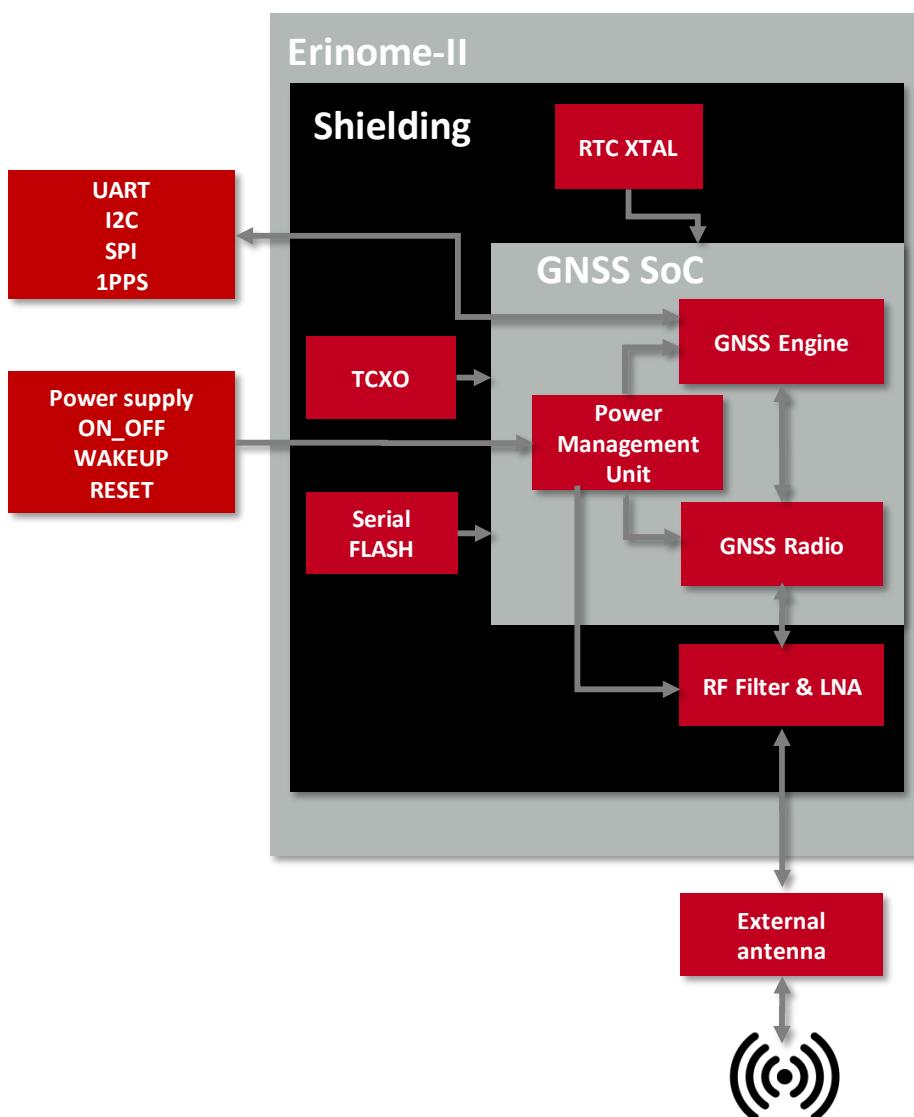


Figure 2: Erinome-II Block diagram

## 1.2 Ordering information

WE order code	Description
2614021137000	Erinome-II GNSS module in T&R packaging
2614029237001	Erinome-II Standard EV-Kit
2614029237011	Erinome-II Extended EV-Kit (with Thyone-I RF interface)

Table 1: Ordering information

## 2 Electrical specifications

Unless otherwise stated, all the values given in the manual were measured on the Erinome-II evaluation board under the following conditions: T=25 °C and VCC=1.8V.

### 2.1 Recommended operating conditions

Description	Min.	Typ.	Max.	Unit
Supply voltage	1.71	1.8	1.89	V
Operating temperature	-40	25	85	°C

Table 2: Recommended operating conditions

1.8 V regulated power supply must be provided to the VCC pin of the module. Inrush current is up to 150 mA for about 20 µs. Reduction of system noise and voltage ripples is essential to preserve module performances. LC filters, output and ESR capacitors are recommended in order to maximize stability. Please refer to our reference design.

### 2.2 Absolute maximum ratings

Description	Min.	Max.	Unit
Supply voltage	-0.3	2.2	V
Supply current		150	mA
GPIO Voltage		3.60	V
GPIO Current	-4	4	mA
Power dissipation		350	mW
RF Input power		10	dBm

Table 3: Absolute maximum ratings

## 2.3 Current consumption

Parameter	State	Mode	Value	Unit
Current consumption	Acquisition	GPS-only	44	mA
		GPS-GLO	55	mA
	Tracking	GPS-only	43	mA
		GPS-GLO	54	mA
	Hibernate		30	µA
	Standby (within TP mode)		200	µA
Push To Fix	GPS-GLO	4.11	mA	
		11.76	mA	
Trickle Power	GPS-GLO			

Table 4: Current consumption



Current consumption changes according to the received signal strength as well as the GNSS systems. Measurements of the table refer to an average signal strength of -130 dBm.



Push To Fix and Trickle Power mode measurements refer to an average value over a 15 minutes test with 30s rate for Push To Fix and 1s rate for Trickle Power. For details about these low power modes refer to chapter 6

## 2.4 Radio characteristics

Module performance is based on the quality of the RF link from GNSS satellites to the module. End product design shall foresee:

- external GNSS antenna for signal reception from GNSS satellites
- RF trace delivering the signal from the external antenna to the RF pad of the the GNSS module

A wide range of GNSS antennas exists, varying in dimensions and characteristics. Active antennas have in general higher gain and are the best solution in weak-signal environments. Passive antennas have the advantage that no dedicated power supply is needed. Module EV-Board shows the integration of an active and a passive antenna and serves as reference design. On the EV-board, it is possible to select either external SMA connection to an active antenna or to an integrated passive antenna. This allows comparing module's behavior with different antenna variants.

Also, please refer to our application note on GNSS antennas [1], which provides extensive recommendations and guidelines to select the right antenna solution.

Following factors and tasks are critical for the performance of the GNSS module:

- GNSS antenna selection, integration and matching
- Quality of the RF design from the GNSS antenna to Erinome-II
- Minimization of external and environmental effects

Please refer to our hardware layout recommendations (chapter 7).



In the same perspective, be aware that the external antenna shall foresee the freest possible view of GNSS satellites.

Description	Value
Antenna Connector Type	RF pad

Table 5: Antenna connector Type

Description	Min	Typ.	Max	Unit
Input Frequency	1560		1620	MHz
Impedance at 1575.5 MHZ		50		$\Omega$
Return Loss at 1575.5 MHZ	-7			dB

Table 6: Radio characteristics

## 2.5 Pin characteristics

Property	Min	Typ.	Max	Unit
GPIO Voltage Input high	$0.70 \times VCC$		3.6	V
GPIO Voltage Input low	-0.3		0.4	V
GPIO Voltage Output high	$0.75 \times VCC$			V
GPIO Voltage Output low			0.4	V
Internal Pull-down resistor	110	1000	2800	$\Omega$
Input Leakage Current	-10		10	$\mu A$
Output Leakage Current	-10		10	$\mu A$
Input Capacitance		5		pF

Table 7: Pin characteristics

### 3 GNSS performances

This chapter describes the GNSS behavior of the module. Several GNSS performance indicators are statistical in nature, which intends that the given values are obtained as mean value over a large number of measurements under laboratory conditions.

#### 3.1 Satellite constellations supported

Position calculation is based on one-way signal transmission from navigation satellites flying at around 20000 km altitude from ground. These satellites compose global (GNSS) and regional (RNSS) constellations.

Currently existing GNSS are GPS (US), GLONASS (Russia), Galileo (Europe), and BeiDou (China). These systems are interoperable: satellites from different constellations can be tracked simultaneously by the GNSS module (multi-GNSS). This increases robustness and overall performance of GNSS positioning, and becomes particularly important in obstructed environments (e.g. urban canyons).

Erinome-II supports GPS, GLONASS, Galileo, and BeiDou.

Supported GNSS	Frequency Band	Center Frequency	Active by default
GPS	L1	1575.42 MHz	Yes
GLONASS	L1	1602 MHz	Yes
Galileo	E1	1575.42 MHz	Yes
BeiDou	B1	1561.098 MHz	No

Table 8: GNSS constellations supported



The GNSS module cannot use GLONASS and BeiDou simultaneously. Maximum three systems can be used concurrently.

Additional ranging signals are provided by the Japanese regional system QZSS, which serves as enhancement of GPS in the Asia-Oceania region, with focus on Japan. SBAS also provides additional ranging signals, together with correction data.

Supported system	Frequency Band	Function	Active by default
QZSS	L1	Ranging	Yes
SBAS	L1	Corrections and ranging	Yes

Table 9: Additional systems supported

GPS, GLONASS and Galileo, as well as QZSS and SBAS, are active by default. Changing the set of active systems can be done through software command (refer to MID 222,16 of the OSP protocol, described in chapter 10).

## 3.2 Accuracy

### 3.2.1 Position Accuracy

Parameter	Mode	Value	Unit	Test conditions
Horizontal Position Accuracy	GPS-only	2.5	m	Static, VCC = 1.8V, power level = -130 dBm, T=25°C, CEP(50%)
	GPS-GLO	1.5	m	

Table 10: Horizontal Position Accuracy

Parameter	Mode	Value	Unit	Test conditions
Vertical Position Accuracy	GPS-only	4	m	Static, VCC = 1.8V, power level = -130 dBm, T=25°C, 50% of trials
	GPS-GLO	2.5	m	

Table 11: Vertical Position Accuracy

### 3.2.2 Velocity Accuracy

Parameter	Value	Unit	Test conditions
Speed Over Ground Accuracy	0.1	m/s	VCC = 1.8V, power level = -130 dBm, T=25°C, v<30 m/s, 50% of trials

Table 12: Velocity Accuracy

### 3.2.3 Heading Accuracy

Parameter	Value	Unit	Test conditions
Heading Accuracy	0.3	°(from North)	VCC = 1.8V, power level = -130 dBm, T=25°C,

Table 13: Heading Accuracy

### 3.2.4 Time Accuracy

Best time synchronization is obtained using the PPS signal (see section 4). The accuracy defined here is the delay between the PPS pulse and the UTC epoch. In case a software message is used for synchronization, the delay between the PPS signal and sending out the message should also be taken into account.

Parameter	Value	Unit	Test conditions
Timing Accuracy	30	ns	VCC = 1.8V, power level = -130 dBm, T=25 °C

Table 14: Time Accuracy

### 3.3 Time To First Fix

The Time To First Fix (TTFF) is the time needed by the module to achieve the first valid position fix, once the module is powered up or returns from a period of signal blockage.

Depending on the type of start (hot, warm, cold, see chapter 6), different TTFF performance is given.

Parameter	Start Type	Mode	Value	Unit	Test conditions
Time To First Fix	Hot start		1	s	Static, VCC = 1.8V, power level = -130 dBm, T=25 °C, average or 50% of trials
	Warm start	GPS-only	30	s	
		GPS-GLO	27.5	s	
	Cold start	GPS-only	32	s	
		GPS-GLO	28	s	

Table 15: Time To First Fix

### 3.4 Sensitivity

Module sensitivity is the weakest signal level the receiver can work with and it depends on the state of the module.

- Acquisition sensitivity is the minimum power required by the module to acquire satellites and perform first fix.
- Navigation sensitivity is the minimum power required by the module maintain a position fix.
- Tracking sensitivity is the minimum power required by the module to keep in track of at least one satellite, regardless of the position fix.
- Reacquisition sensitivity is the minimum power required by the module to reobtain the position fix after a temporary RF blockage.



The ultra-high sensitivity of the module increases robustness to obstructed environments. On the other hand, please note that optimal performance are obtained under open sky conditions (no obstacles).

Parameter	Mode	Value	Unit
Acquisition sensitivity	GPS	-147	dBm
Reacquisition sensitivity	GPS	-160	dBm
Navigation sensitivity	GPS	-161	dBm
Tracking sensitivity	GPS	-167	dBm

Table 16: Sensitivity

### 3.5 Dynamic constraints

The following table describes limits and constraints which apply to Erinome-II module.

Parameter	min	max	Unit	Test condition
Altitude	-500	60000	m	velocity < 514 m/s
		18000	m	velocity > 514 m/s
Velocity		600	m/s	altitude < 18288 m
		514	m/s	altitude > 18288 m
Acceleration		4	g	
Jerk		5	m/s <sup>3</sup>	

Table 17: Dynamic Constraints

## 4 Pinout

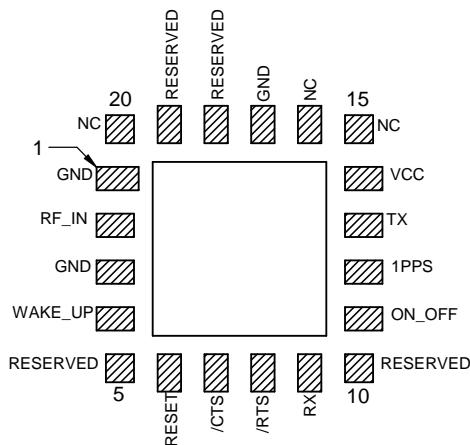


Figure 3: Pinout (top view)

No	Designation	I/O	Description
1	GND	Supply	Negative supply voltage
2	RF_IN	Input	RF Signal Input
3	GND	Supply	Negative supply voltage
4	WAKE_UP	Output	Operation mode status
5	RESERVED	Input/Output	See manual for more details
6	/RESET	Input	Reset
7	/CTS	Input/Output	Clear to send signal
8	/RTS	Input/Output	Request to send signal
9	RX	Input/Output	Receive
10	RESERVED	Input/Output	See manual for more details
11	ON_OFF	Input	Power State Control
12	1PPS	Output	UTC Time Mark
13	TX	Input/Output	Transmit
14	VCC	Supply	Positive supply voltage
15	NC	—	Not connected
16	NC	—	Not connected
17	GND	Supply	Negative supply voltage
18	RESERVED	Input/Output	See manual for more details
19	RESERVED	Input/Output	See manual for more details
20	NC	—	Not connected

Table 18: Pinout

Specific pin connection for UART and I<sup>2</sup>C interfaces is described in the tables below.

Pin number	Designation	I/O	Description
7	/CTS	Input	UART Clear to send signal
8	/RTS	Output	UART Request to send signal
9	RX	Input	UART Receive
13	TX	Output	UART Transmit

Table 19: Pinout - UART communication

Pin number	Designation	I/O	Description
9	RX	Input/Output	I <sup>2</sup> C data
13	TX	Input/Output	I <sup>2</sup> C clock

Table 20: Pinout - I<sup>2</sup>C Multi Master communication

Pin number	Designation	I/O	Description
7	/CTS	Input	SPI Clock
8	/RTS	Input	SPI Chip Select
9	RX	Input	MOSI, SPI Data In
13	TX	Output	MISO, SPI Data Out

Table 21: Pinout - SPI slave communication

## 4.1 ON\_OFF pin

Connection of *ON\_OFF* pin to host is mandatory for module operation. *ON\_OFF* pin allows changing of module's power state according to the following table.

Initial state	Final state
Hibernate	Full Power
Full Power	Hibernate
Push To Fix	Full power (until position fix is obtained)
Trickle Power	Full Power

Table 22: ON\_OFF pin function

Until new logic level is applied, module stays in the corresponding state. *ON\_OFF* pin low state corresponds to hibernate state, while high state to full power state.

## 4.2 WAKE\_UP pin

Connection of *WAKE\_UP* pin is not mandatory for module operation. It indicates module's operating power state according to the following table.

Logic level	Power state
Low	Hibernate
High	Full Power

Table 23: *WAKE\_UP* pin function

*WAKE\_UP* output is LVCMOS 1.8V compatible and can be used to control external devices, provided the logic level and GPIO current are supported. Connecting *WAKEUP* to *ON\_OFF* enables autonomous start to Full Power state.

Do not connect if not used.

## 4.3 /RESET pin

Connection of */RESET* pin is not mandatory for module operation. It is triggered by applying a low level pulse, has internal pull-up resistor of  $1\text{ M}\Omega$ , and signal shall be applied for at least  $1\text{ }\mu\text{s}$ . Power-On-Reset (POR) sequence is generated internally.

Please do not perform any of the following actions:

- do not drive high
- do not connect if not used

## 4.4 1PPS pin

Connection of *1PPS* pin is not mandatory for module operation. It provides a pulse signal for precise timing, as it is synchronized with the UTC time epoch with 30 ns accuracy. It starts once the module obtains a 3D position fix based on at least 5 GNSS satellites. If this condition is lost, PPS output stops.

After pulse is generated, UTC time is reported in the NMEA ZDA message. This message is the one sent with shortest time delay with respect to the real UTC time and should be used whenever software-based time synchronization is foreseen in the application.

*1PPS* is LVCMOS 1.8V compatible and pulse length is 200 ms with rising edge of less than 30ns.

Do not connect if not used.

## 4.5 /RTS and /CTS pins

*/CTS* and */RTS* states are active low and define the interface used for communication (see chapter 9).

## 5 Quick start guide

The Erinome-II GNSS module comes pre-flashed, tested and ready-to-use out-of-the-box. This chapter describes the steps to quickly build a prototype system and test the capabilities of the module.

### 5.1 External GNSS antenna

The Erinome-II has a RF pad for connection of an external GNSS antenna. Module EV-Board includes two ready-to-use selectable antenna options allowing getting started with Erinome-II without previous effort for RF design.

### 5.2 Minimal pin configuration

The following pins must be connected as described in the following table for correct operation. Remaining pins can be left unconnected. With this configuration the UART will be selected as communication interface and will be running in 4800 Baud 8n1 as default.

Pin Number	Pin Function	Pin connection
1	<i>GND</i>	<i>GND</i>
7	<i>/CTS</i>	external pull-up required, UART flow control during application
8	<i>/RTS</i>	UART flow control during application
9	<i>RX</i>	Host TX
11	<i>ON_OFF</i>	Host GPIO for power state selection
13	<i>TX</i>	Host RX
14	<i>VCC</i>	Power supply

Table 24: Minimal pin configuration, UART mode

Use of */CTS* and */RTS* defines the interface (UART, I<sup>2</sup>C or SPI) for communication with the host (see chapter 9).

For further information about pin configuration, refer to chapter 4.

### 5.3 Power up

After first power up, module boots to hibernate state. If */RESET* is left unconnected, it is asserted to high level automatically after power up. In order for RTC to start and for WAKE\_UP pulse to occur, */RESET* pin must be in high level. WAKE\_UP pulse indicates that the module is in ready-to-start state.

From ready-to-start state, the module can be driven to full power state by applying a high state to the *ON\_OFF* pin.

Once transition to full power state is complete, Ok-To-Send message \$PSRF150,1\*3E is sent out by the module (refer to chapter 10).



If *WAKE\_UP* and *ON\_OFF* pins are connected, the module goes by default into full power state, without action on *ON\_OFF* pin needed.

Further details are shown in the picture and table below.

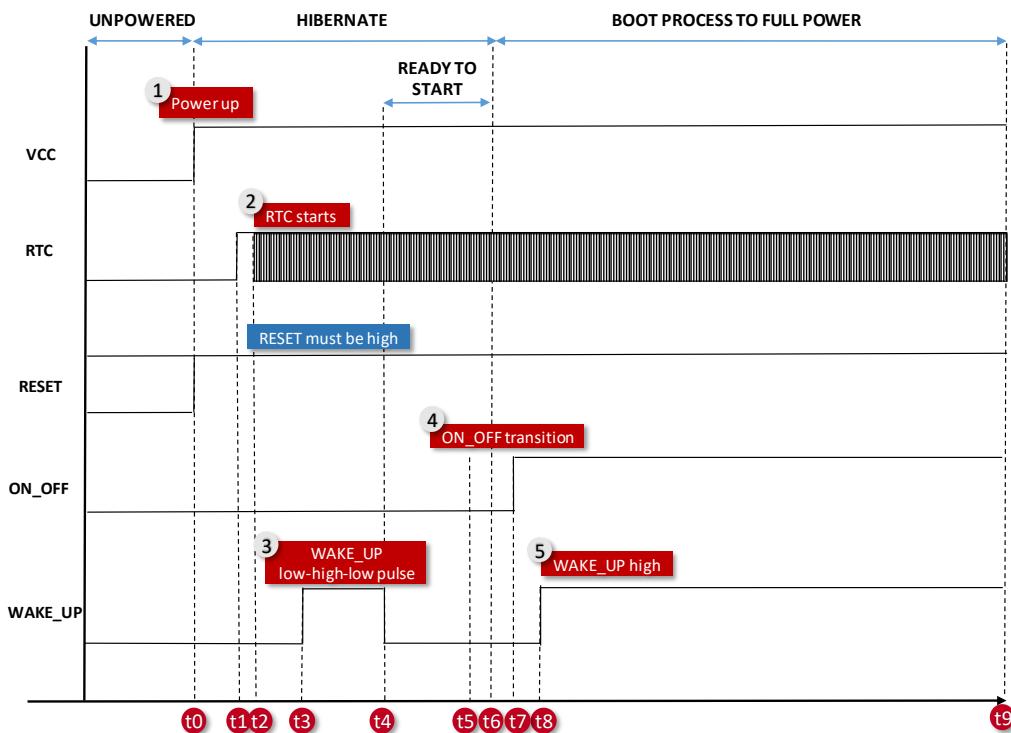


Figure 4: Power up

Symbol	Event/parameter	Value	Unit
$f_{RTC}$	RTC frequency	32768	Hz
$t_{RTC}$	RTC Tick	30.5176	$\mu s$
$t_2-t_1$	RTC startup time	300 (typ)	ms
$t_2-t_0$	Power stabilization	$7 * t_{RTC} + (t_2-t_1)$	$\mu s$
$t_4-t_3$	<i>WAKE_UP</i> pulse	10 (typ)	$t_{RTC}$
$t_7-t_5$	<i>ON_OFF</i> transition	6 (min)	$t_{RTC}$
$t_8-t_6$	<i>ON_OFF</i> to <i>WAKE_UP</i> high	6 (typ)	$t_{RTC}$
$t_9-t_6$	boot process to full power	2130 (typ)	$t_{RTC}$

Table 25: Startup timing

## 5.4 Acquisition, first fix, and tracking

When powered up, the module enters hibernate state by default.

In this state the module:

- does not track navigation signals;
- does not compute position;
- is not able to receive or send commands to the host

For applications where infrequent positioning is required, this state can be set to achieve minimum power consumption for the module, until new position fix is needed.

When brought to full power through the *ON\_OFF* pin, the module starts searching for GNSS satellite signals (acquisition) on its available channels in order to compute the first position. Only satellites corresponding to the default constellation settings (GPS, GLONASS) are searched. In full power state, the module sends out messages automatically according to the default protocol (NMEA) and update rate (1 Hz) and is able to receive messages from the host and react. This phase corresponds to the maximum power consumption of the module.

Once at least 3 GNSS satellites are tracked, the receiver returns the first position fix (2D). Once at least 4 GNSS satellites are tracked, 3D position fix is achieved. The time needed to provide first valid position (2D or 3D) is called Time To First Fix (see section 3.3).

After first fix, the receiver enters tracking conditions. In this phase, navigation as well as communication with the module are possible. The receiver keeps searching for GNSS satellites to acquire. A higher number of tracked satellites improves accuracy and stability of the positioning.



During tracking, further information about the satellite constellations (almanac) are downloaded from the GNSS satellites . This leads to a higher power consumption. At the end of the download phase (that takes approximately 15 minutes), a drop in the current consumption can be observed.

After stable tracking conditions are achieved, low power modes can be activated through software commands.



Application of a a low logic level to the *ON\_OFF* pin brings the module back from full power to hibernate state.

Mode of Operation	Tracking Navigation Signals	Compute Position	Receive/Send Command from/to host	Power Consumption
Hibernate	NO	NO	NO	LOW
Full Power	YES	YES	YES	HIGH

Table 26: Module Mode of Operation

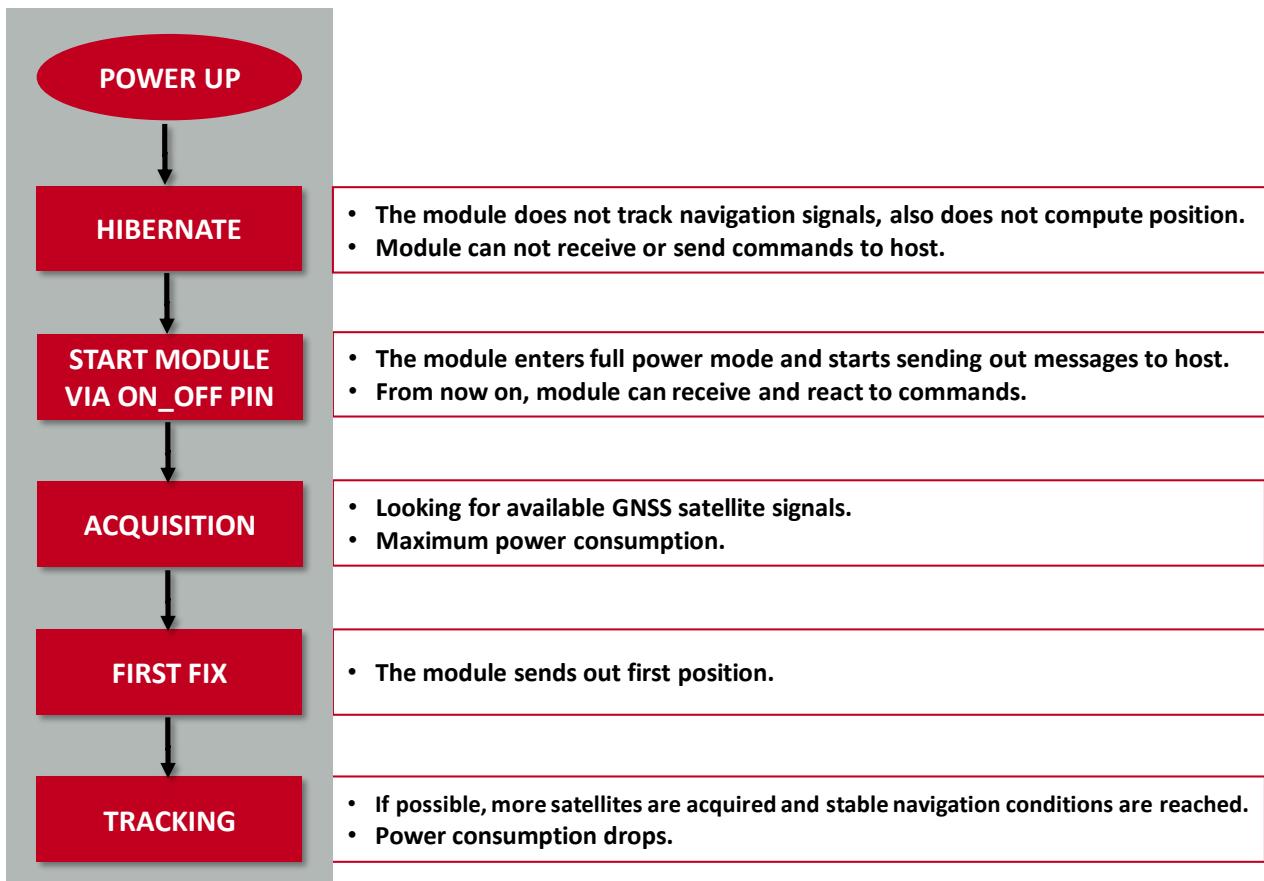


Figure 5: Erinome-II (Module Start-up)

## 5.5 Quick start example

It is recommended to use the Erinome-II evaluation kit [9] and WENSS PC tool for putting the GNSS module into operation. Passive and active antenna options are available for antenna connection. Please refer to the evaluation board [3] and WENSS PC tool user manual for detailed information.

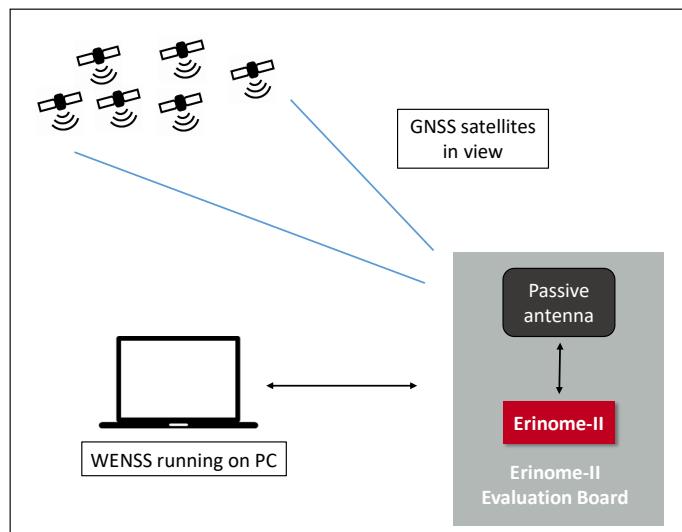


Figure 6: Erinome-II - Quick start setup (passive antenna)

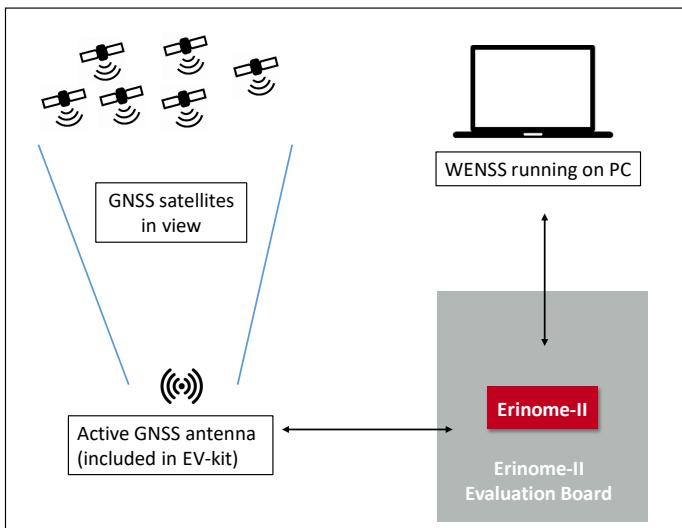


Figure 7: Erinome-II - Quick start setup (active antenna)



Be sure that GNSS satellites are in view. Typically this is not possible inside buildings!

## 6 Functional description

Erinome-II GNSS module is meant to be integrated in systems where position, velocity, and time information are needed. When in full power mode, the module sends out sentences containing this information to the host. Validity and accuracy of these data depends on the quality of the link established with the GNSS satellites.

Use and/or further path of these data has to be built-up and configured on host side.

Information	Values
Position	Latitude
	Longitude
	Altitude (MSL and WGS84)
Time	Coordinated Universal Time (UTC)
Motion	Course (heading from North)
	Speed over ground

Table 27: PVT data

These messages are sent from the module according to the following communication parameters:

Parameter	Value
Communication interface	UART, I <sup>2</sup> C, SPI
Communication protocol	<b>NMEA</b> or OSP
Baud rate	<b>4800</b> , 9600, 19200, 38400, 57600, 115200, 230400, 460800, 921600, 1228800
Update rate	<b>1 Hz</b> , 5 Hz, and 10 Hz
Single message rate	1 to 255 seconds

Table 28: Communication Settings

The data rate used must be larger than the amount of data sent out by the module. This depends on the protocol, the active messages and the update rate. In Erinome-II typical configuration (UART 4800 baud, NMEA) the amount of messages was selected according to the communication interface speed. In general, when working with OSP and/or with update rates greater than 1 Hz, switching from the default data rate to a higher data rate is mandatory in order to avoid loss of data.



Communication interface and data rate between the host and module must comply with each other



Default communication parameters values are defined in the firmware. After power up or factory reset, module returns to these settings

## 6.1 Cold, warm, and hot start

Different types of start are defined for GNSS receivers. They are performed according to available data which might support and shorten acquisition phase until first fix. The type of start depends on the following data.

- satellite ephemeris:  
set of data containing prediction of GNSS satellites orbit, valid for max. 4 hours.
- valid position estimate  
(within 100 km from true position)
- valid time estimate

These data result from user injection or from previous tracking conditions.

- **Cold start**

Module needs to perform a sky search to acquire GNSS satellites without any known information or estimate. Complete re-learning of satellite data and ephemeris download is needed in order to compute first position.

- **Warm Start**

In warm start conditions, valid position and time estimates are known. Complete re-learning of satellite data and ephemeris download is needed.

- **Hot Start**

In hot start, position and time estimates, as well as satellite ephemeris, are available.

	Valid position estimate	Valid time estimate	Valid satellite ephemeris
Cold Start	Not known	Not known	Not known
Warm Start	Known	Known	Not known
Hot Start	Known	Known	Known

Table 29: Cold, Warm and Hot Start

## 6.2 Low power modes

Power saving in Erinome-II is accomplished by setting the module in hibernate state during time slots when a new position fix is not required. Therefore, all power saving modes are based on scheduling low and full power states for the GNSS module at variable rates.

When in hibernate, the module maintains configuration and critical data (f.e. clock synchronization) which are used for faster reacquisition once the module returns to full power state. If the module stays in hibernate for more than 4 hours, satellite ephemeris expires and a new download is needed at wake up for position fix.

If the module is not needed for a longer phase, complete un-powering of the module shall be considered to achieve zero power consumption. In this case, all critical data and settings are lost. Complete re-learning of satellite data, time and location is needed at power up.

### 6.2.1 Host-controlled low power mode

The module can be set to hibernate state by triggering a low logic level on the ON\_OFF pin or by software command (see chapter 10). Triggering a high logic level sets the module back to full power. This means that a schedule of hibernate and full power time slots can be defined on host side according to the application. Alternatively, the host can wake up the module when a specific event occurs. If needed, this mechanisms have to be implemented on host side.

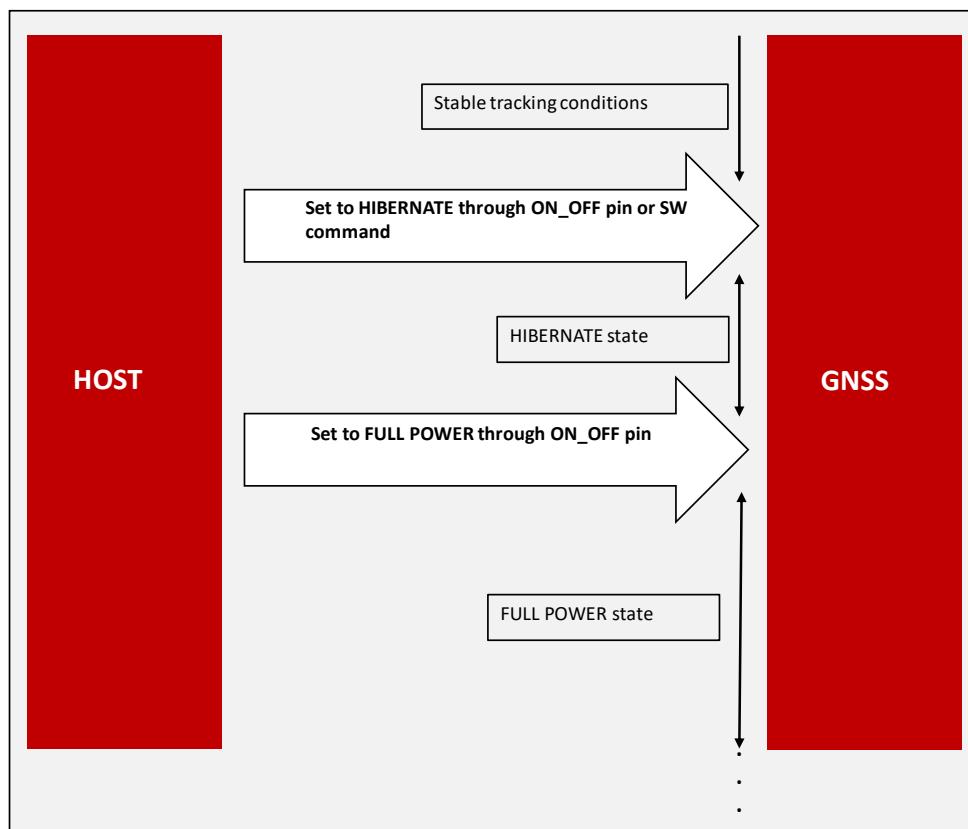


Figure 8: Host Based Low Power Mode

### 6.2.2 Self-managed low power modes

The module offers different self managed low power modes, which automatically switch between hibernate and full power according to a configurable time schedule. Please note that:

- self managed low power modes shall be activated from stable tracking conditions, since update of the position has to be performed in a short full power time slot;
- in general, degradation of position accuracy has to be expected when using low power modes.

### 6.2.3 Push To Fix

Push To Fix is the recommended low power mode when infrequent navigation solution is required.

It consists of alternating longer sleep times (PTF period) and short acquisition attempts (maximum duration defined by MAX\_SEARCH\_TIME). If a position fix could not be obtained during MAX\_SEARCH\_TIME, the module goes to hibernate for a time defined by MAX\_OFF\_TIME, before waking up and trying again. During sleep time, a new acquisition attempt can be requested by triggering a high and then a low level on the ON/OFF pin.

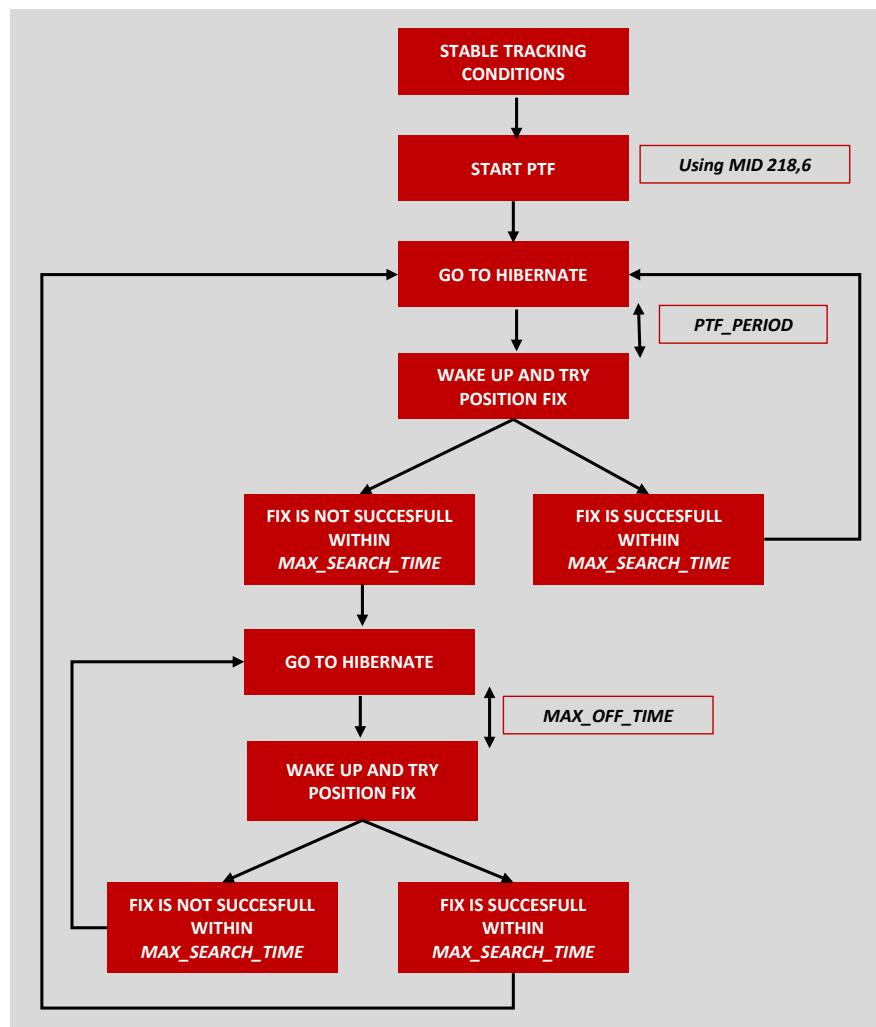


Figure 9: Push To Fix

Figure 10 shows a diagram of Push To Fix current consumption profile.

Please see chapter 10 (MID 218,6) for configuration of PTF.

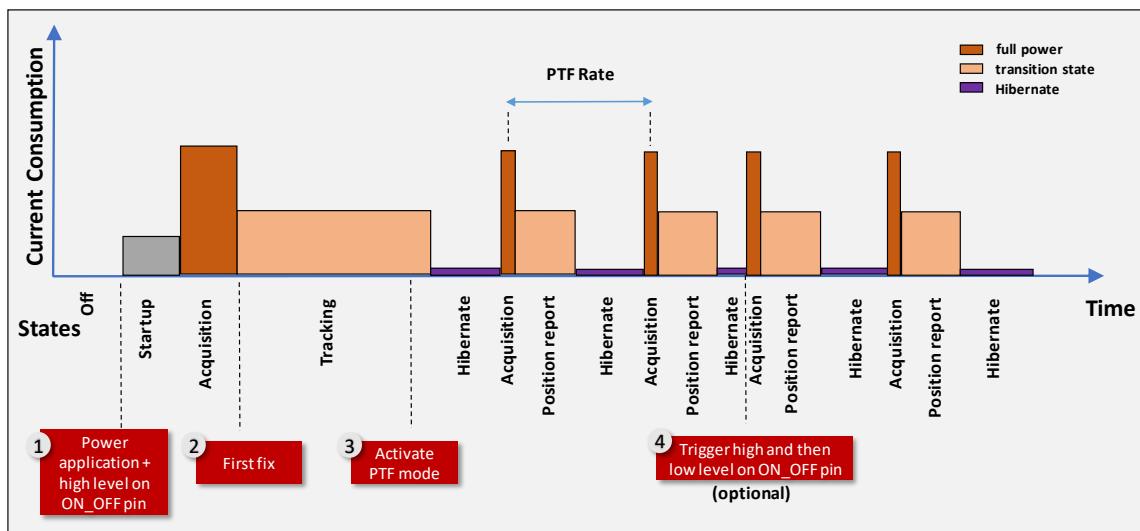


Figure 10: Push-To-Fix Current Consumption Profile

#### 6.2.4 Trickle Power mode

Trickle power is the recommended state when positioning is required:

- at a fixed rate;
- with low power consumption
- with the ability to track weak signals retained

In Trickle Power mode, the receiver cycles between full power (RF and CPU on), CPU-only mode, and STANDBY according to a configurable rate. At wake up, GNSS signals are recorded (RF on), then position fix is computed during CPU-only state. Similarly to PTF, the parameter MAX\_SEARCH TIME defines how long the receiver tries to compute position during the full power time slots. MAX\_OFF\_Time defines how long the receiver stays in sleep mode, if no position fix could be computed during MAX\_SEARCH\_TIME.



In weak-signal environment, the receiver switches to full power automatically.

Figure 11 shows a diagram of Trickle Power current consumption profile.

Please refer to section chapter 10 (MID 218,6) for configuration of Trickle Power mode.

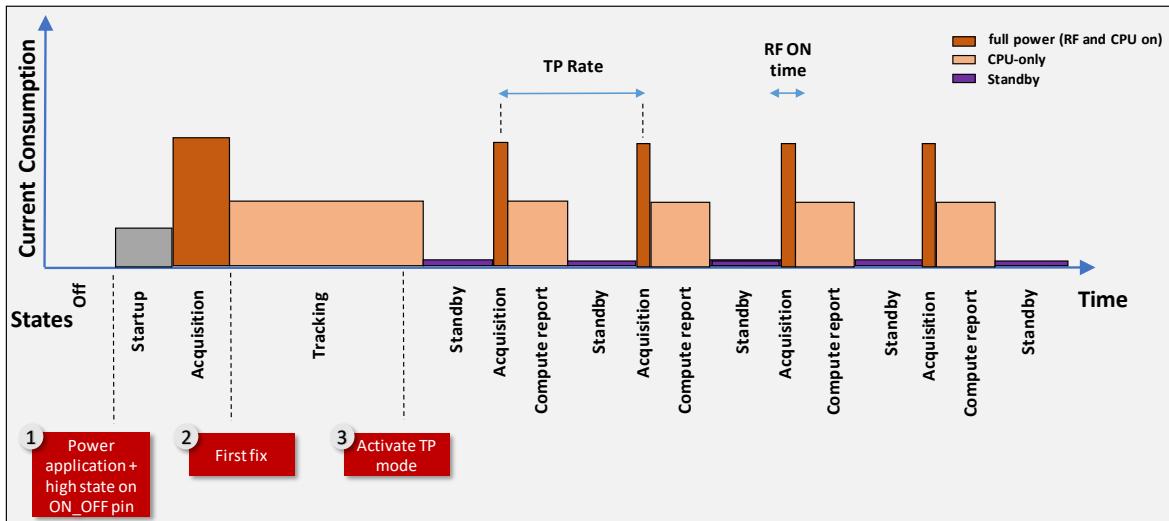


Figure 11: Trickle Power Mode Current Consumption Profile

### 6.2.5 SiRFSmartGNSS

In addition to the self-managed low power modes, SiRFStar V 5e B02 chipset introduces two further energy-saving modes: SiRFSmartGNSS I and SiRFSmartGNSS II.

Module's behavior and functionality is similar to full power mode, as the receiver tracks signals and reports position at the configured rate and without interruptions. Power saving is obtained through internal management of system resources based on RF conditions and on minimal performance degradation.

Please refer to chapter 10 (MID 218,6) for configuration of SiRFSmartGNSS modes.

- **SiRFSmartGNSS I**

SiRFSmartGNSS I autonomously manages usage of system resources according to available GNSS signal levels. More resources are used in weak-signal conditions, fewer in strong-signal conditions. The criteria to enter and remain in SiRFSmartGNSS I is a valid position fix with 6 or more satellites above 24 dB-Hz (Carrier-To-Noise Ratio). If this condition is not fulfilled, the module switches back to full power state.

- **SiRFSmartGNSS II**

SiRFSmartGNSS II autonomously manages constellation usage based on satellite availability in order to save power. In particular, usage of a secondary GNSS constellation is minimized, in case of strong-signal conditions with the primary system. SiRFSmartGNSS II is only applicable to multi-constellation operation. The criteria to enter and remain in SiRFSmartGNSS II is a valid position fix with 4 or more satellites. If this condition is not fulfilled, the module switches back to full power state.

## 7 Design in guide

### 7.1 Advice for schematic and layout

For users with less RF experience it is advisable to closely copy the related evaluation board [3] with respect to schematic and layout, as it is a proven reference design. The layout should be designed with particular care, because even small deficiencies could affect the radio performance and its range or even the conformity.

The following general advice should be taken into consideration.

#### Power Supply

- A clean, stable power supply is strongly recommended. Interference, especially oscillation can severely restrain range and conformity.
- Variations in voltage level should be avoided.
- A dedicated LDO should be used to power the module and placed close to the VCC pad.
- Blocking capacitors (e.g. WCAP-CGSP product family) and a ferrite bead (e.g. WE-CBF product family) in the power supply line can be included to filter and smoothen the supply voltage when necessary. These devices should be placed as close as possible to the VCC pad.



No specific blocking capacitors and ferrite bead values can be recommended, as these depend on the types of interferences, ripples or disturbances.



The use of an external reset IC should be considered if one of the following points is relevant:



- The slew rate of the power supply exceeds the electrical specifications.
- The effect of different current consumptions on the voltage level of batteries or voltage regulators should be considered. The module draws higher currents in certain scenarios which might lead to a voltage drop on the supply. In such scenarios, the reset IC voltage should be chosen as high as the static (battery) voltage from which it is known to break down below the module's minimum supply voltage (VCCmin). This would avoid events like module improper start up, voltage break down and restarting.
- Voltage levels below the minimum recommended voltage level may lead to malfunction. The /Reset pin of the module shall be held on LOW logic level whenever the VCC is not stable or below the minimum operating voltage.
- Special care must be taken in case of battery powered systems.

# ESD Protection

- Elements for ESD protection should be placed on all pins that are accessible from the outside and should be placed close to the accessible area. For example a voltage suppression diode (e.g. WE-TVS product family) should be implemented near the USB connector for ESD protection.
  - ESD protection for the antenna connection must be chosen such as to have a minimum effect on the RF signal. For example, a protection diode with low capacitance (e.g. WE-VE femtoF product family) connecting the RF-line to ground give good results.
  - ESD protection device should be placed on the pins that may influence the module's operation. For example, an accidental trigger on the *ON\_OFF* and */RESET* may cause a module reset. It could be avoided by placing 1nF blocking capacitor.



No specific values can be recommended, as they depend on the influencing circumstances of the application (antenna, interferences etc.).

### 7.1.1 Footprint

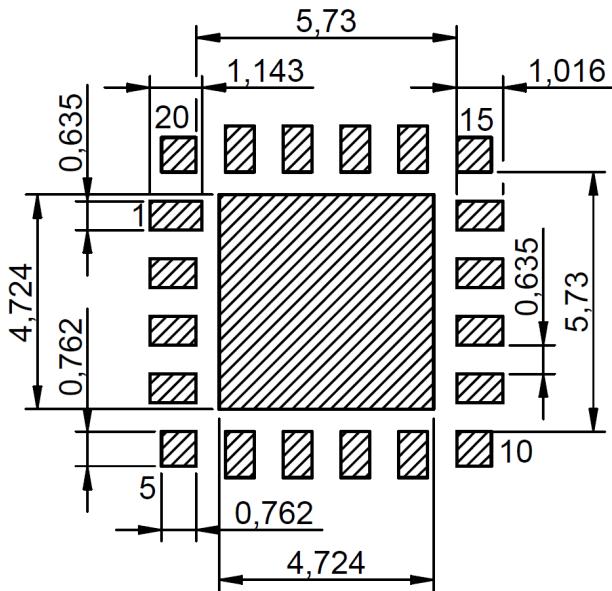


Figure 12: Footprint Design

On the top layer directly underneath the module, a GND paddle is placed in the footprint. It is covered with solder resist.

The GND paddle shall be connected to the extensive GND plane on the second layer with 9 x 0.8 mm drill ground plane vias, shown as green circles on Figure 13.

The whole footprint area below the GNSS module, except for the module's pads, shall be solder masked. The footprint implemented on a PCB is shown in Figure 13.

It is recommended to use the libraries from Würth Elektronik eiSos for hardware design as they already include the necessary implementation [6] [7].

### 7.1.2 Module Footprint on PCB

It is recommended to design a keep out area of minimum 3mm around the module. It is highly recommended to avoid placing other components in the keep out area as shown in Figure 13.

Blocking capacitors should be placed close to the VCC pin of the module, which is an exception to the keep out area.

Filter and decoupling capacitors should be placed directly in the tracks without stubs, to achieve the best effect.

Any component having a ground connection should be directly connected to the ground plane. So it is recommended to use a separate via connection to ground plane by placing the via close to the components.

The antenna path should be kept as short as possible.

Antenna matching elements should be placed close to the antenna / connector.

Place holders for optional antenna matching or additional filtering are recommended.

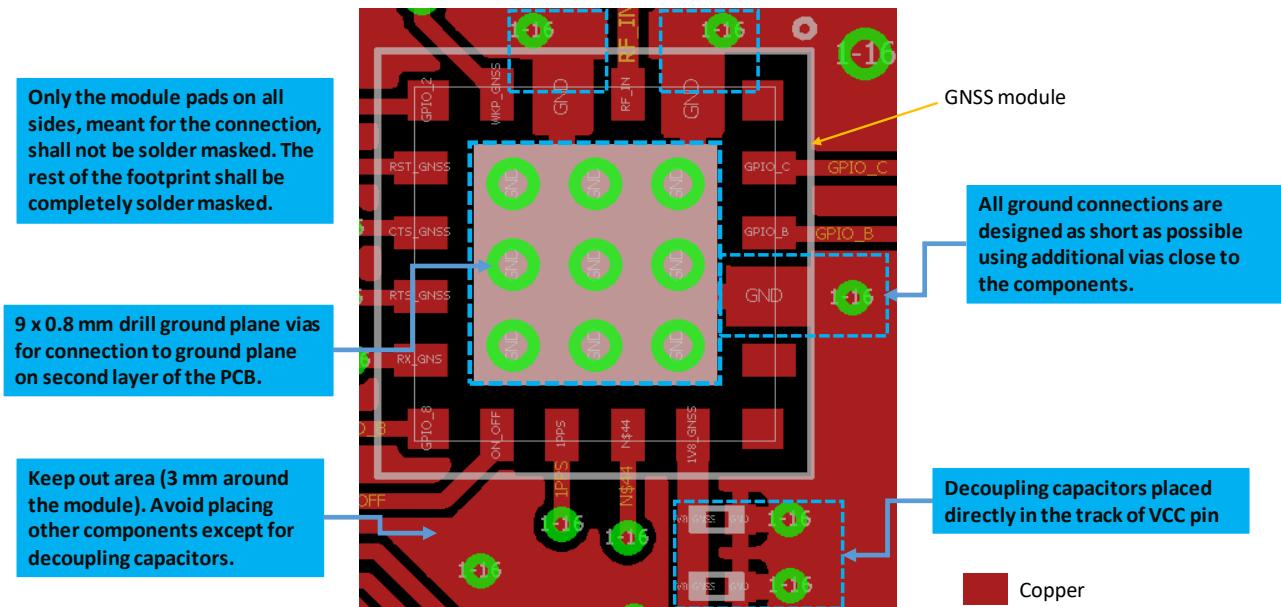


Figure 13: Layout Design

### 7.1.3 PCB Stackup

On the top layer, signal routing is recommended. On the third layer, signal as well as power routing can be designed.

On the second and bottom layer, a ground plane is recommended, to provide good grounding and shielding to any adjacent layers as well as application environment. The bottom layer functions as the main ground plane which has to be connected to the second layer using vias.

The ground plane on second layer should at least cover the filter and blocking devices and has to be connected to the main ground layer using vias.

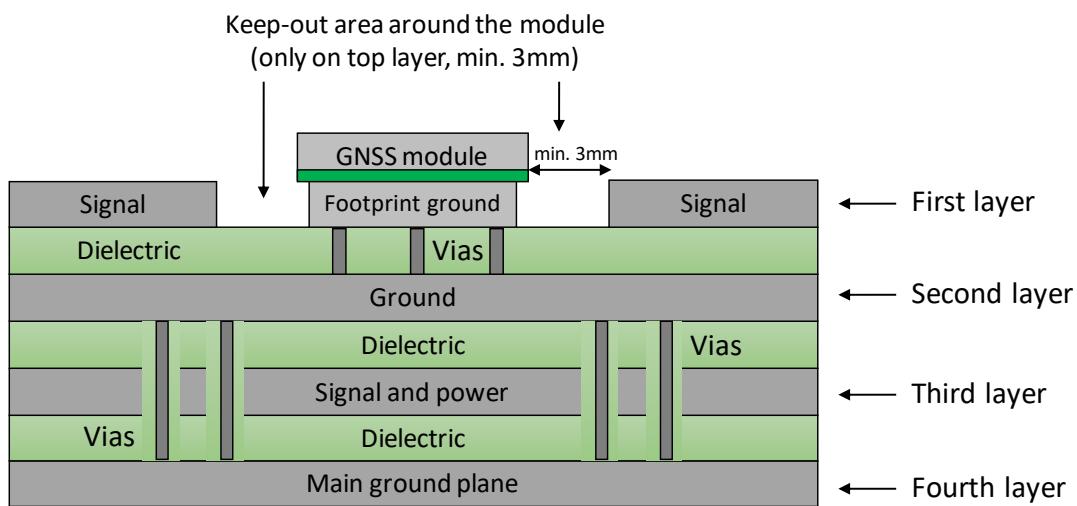


Figure 14: Stackup

#### 7.1.4 Module's placement

The GNSS module should be positioned in the center of the board to have symmetrical or nearly symmetrical ground distribution as shown in the Figure 15.



Figure 15: Placement of the module

## 7.2 Dimensioning of the micro strip antenna line

The antenna track has to be designed as a  $50\Omega$  feed line. In the following, calculation of the type "micro strip line" is described. An other possibility would be to use a coplanar line.

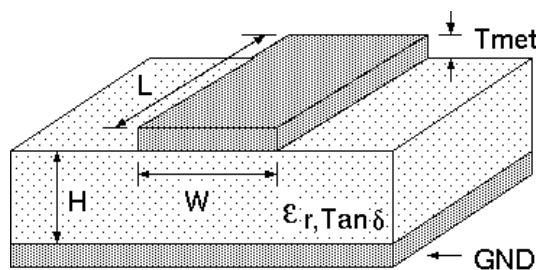


Figure 16: Dimensioning the antenna feed line as micro strip

The width  $W$  for a micro strip can be calculated using the following equation:

$$W = 1.25 \times \left( \frac{5.98 \times H}{e^{\frac{50 \times \sqrt{\epsilon_r} + 1.41}{87}}} - T_{met} \right) \quad (1)$$

Example:

A FR4 material with  $\epsilon_r = 4.3$ , a height  $H = 1000 \mu\text{m}$  and a copper thickness of  $T_{met} = 18 \mu\text{m}$  will lead to a trace width of  $W \sim 1.9 \text{ mm}$ . To ease the calculation of the micro strip line (or e.g. a coplanar) many calculators can be found in the internet.

- As rule of thumb a distance of about  $3 \times W$  should be observed between the micro strip and other traces / ground.
- The micro strip refers to ground, therefore there has to be the ground plane underneath the trace.
- Keep the feeding line as short as possible.

### 7.3 Antenna solutions

There exist several kinds of antennas, which are optimized for different needs. Chip antennas are optimized for minimal size requirements but at the expense of range, PCB antennas are optimized for minimal costs, and are generally a compromise between size and range. Both usually fit inside a housing.

Higher received signal strength is in general at the expense of space. Antennas that are bigger in size, which would probably not fit in a small housing, are usually equipped with a RF connector. A benefit of this connector may be to used to lead the RF signal through a metal plate (e.g. metal housing, cabinet).

As a rule of thumb a minimum distance of  $\lambda/10$  (which is 1.9 cm @ 1.575 GHz) from the antenna to any other metal should be kept. Metal placed further away will not directly influence the behaviour of the antenna, but will anyway produce shadowing.



Keep the antenna as far as possible from large metal objects to avoid electromagnetic field blocking.

Please refer to our application note [1] for further information and recommendations on GNSS antenna selection.

GNSS antennas from Würth Elektronik are described in the following chapters.

### 7.3.1 Antennas provided by Würth Elektronik eiSos

#### 7.3.1.1 2600130016 - GNSS Active antenna



Figure 17: GNSS Active antenna

Specification	Value
Frequency range [MHz]	1575.42MHz ± 5MHz 1610MHz ± 10MHz
Impedance [ $\Omega$ ]	50
VSWR	$\leq 2$
Peak Gain [dBiC]	5 (min)
Axial Ratio [dB]	2 (max)
Polarization	R.H.C.P.
LNA Gain [dB]	30 (typ)
LNA Noise Figure [dB]	1.5 (max)
Cable insertion loss [dB/m]	1.2 (typ)
DC Voltage [V]	3 - 5
DC Current [mA]	11.5 (typ) @ 3V
Dimensions (L x W x H) [mm]	48.6 x 39.2 x 15.2
Weight [g]	106
Mounting	Magnet Base
Cable type	RG-174
Cable Length [m]	5
Connector	SMA plug
Operating Temp. [°C]	-40 to +80

Table 30: 2600130016 - antenna specifications

Further information and datasheet of the this antenna can be found on our website [5].

### 7.3.1.2 7488920157 - GNSS multilayer chip antenna



Figure 18: GNSS multilayer chip antenna

Specification	Value
Frequency range [MHz]	1550 MHz - 1600 MHz
Impedance [ $\Omega$ ]	50
VSWR	$\leq 2$
Peak Gain [dBi]	3.4 (typ.)
Dimensions (L x W) [mm]	5.2 x 3.7
Operating Temp. [°C]	-40 to +85

Table 31: 7488920157 - antenna specifications

Further information and datasheet of the this antenna can be found on our website [4].

## 8 Reference design

Erinome-II was tested and certified on the corresponding Erinome-II evaluation board, which serves as reference design. For the compliance with the EU directive 2014/53/EU Annex I, the evaluation board serves as reference design.

This is no discrepancy due to the fact that the evaluation board itself does not fall within the scope of the EU directive 2014/53/EU Annex I as the module is tested on the evaluation board, which is also the recommended use.

Further information concerning the use of the evaluation board can be found in the manual of the Erinome-II evaluation board [3].

## 8.1 Schematic

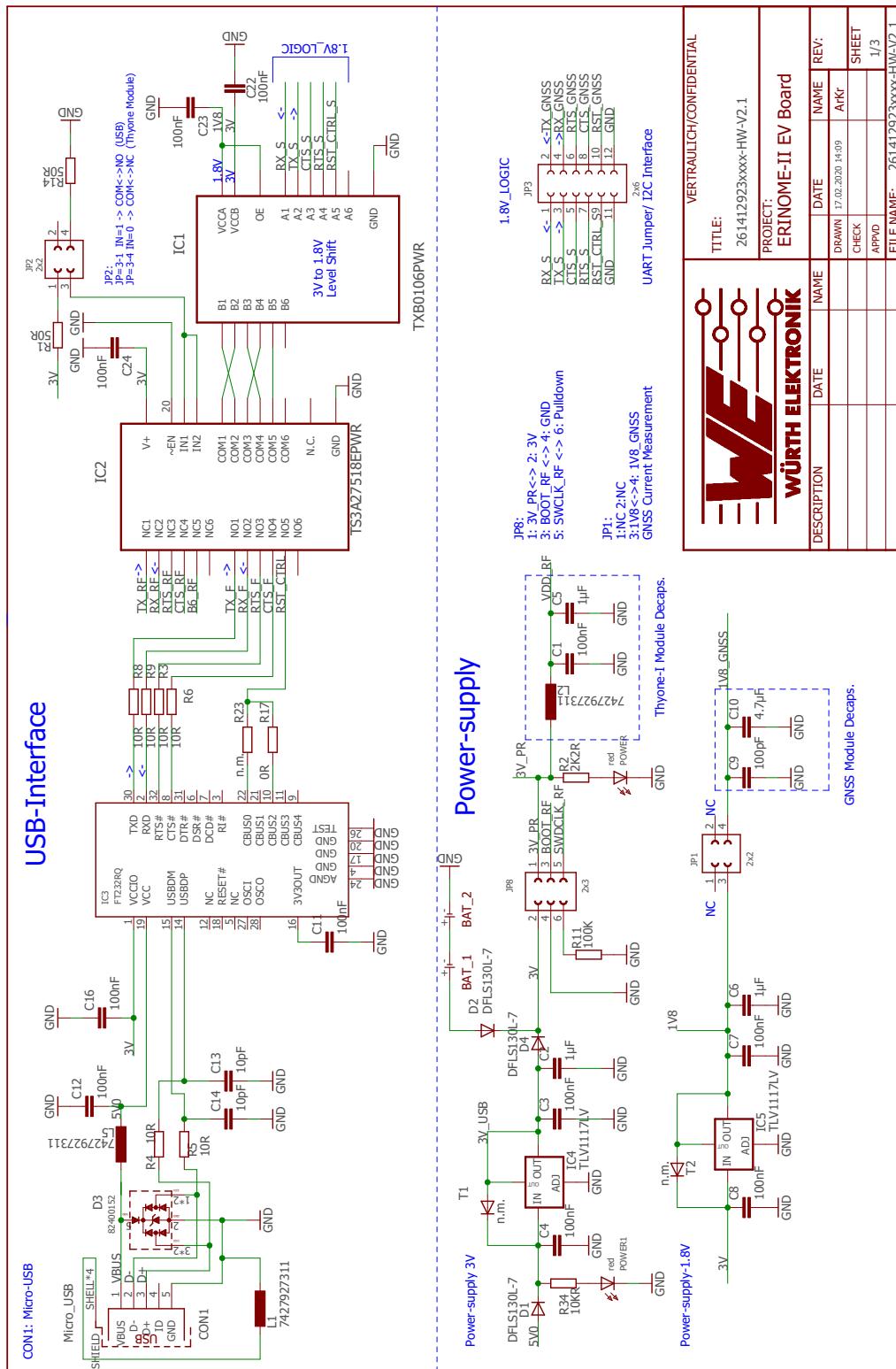


Figure 19: Reference design: Schematic sheet-1

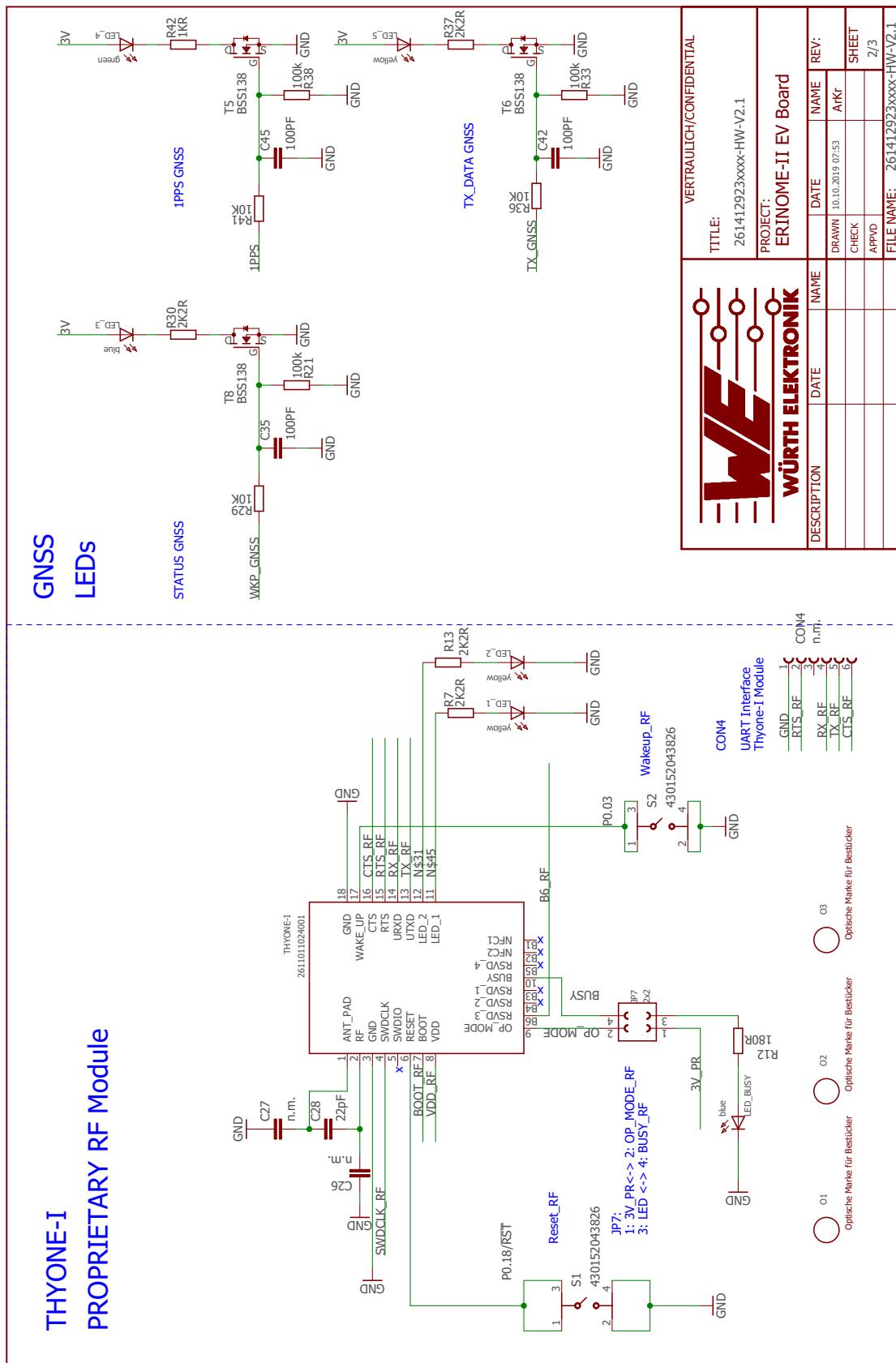


Figure 20: Reference design: Schematic sheet-2

ERINOME\_II  
GNSS Module

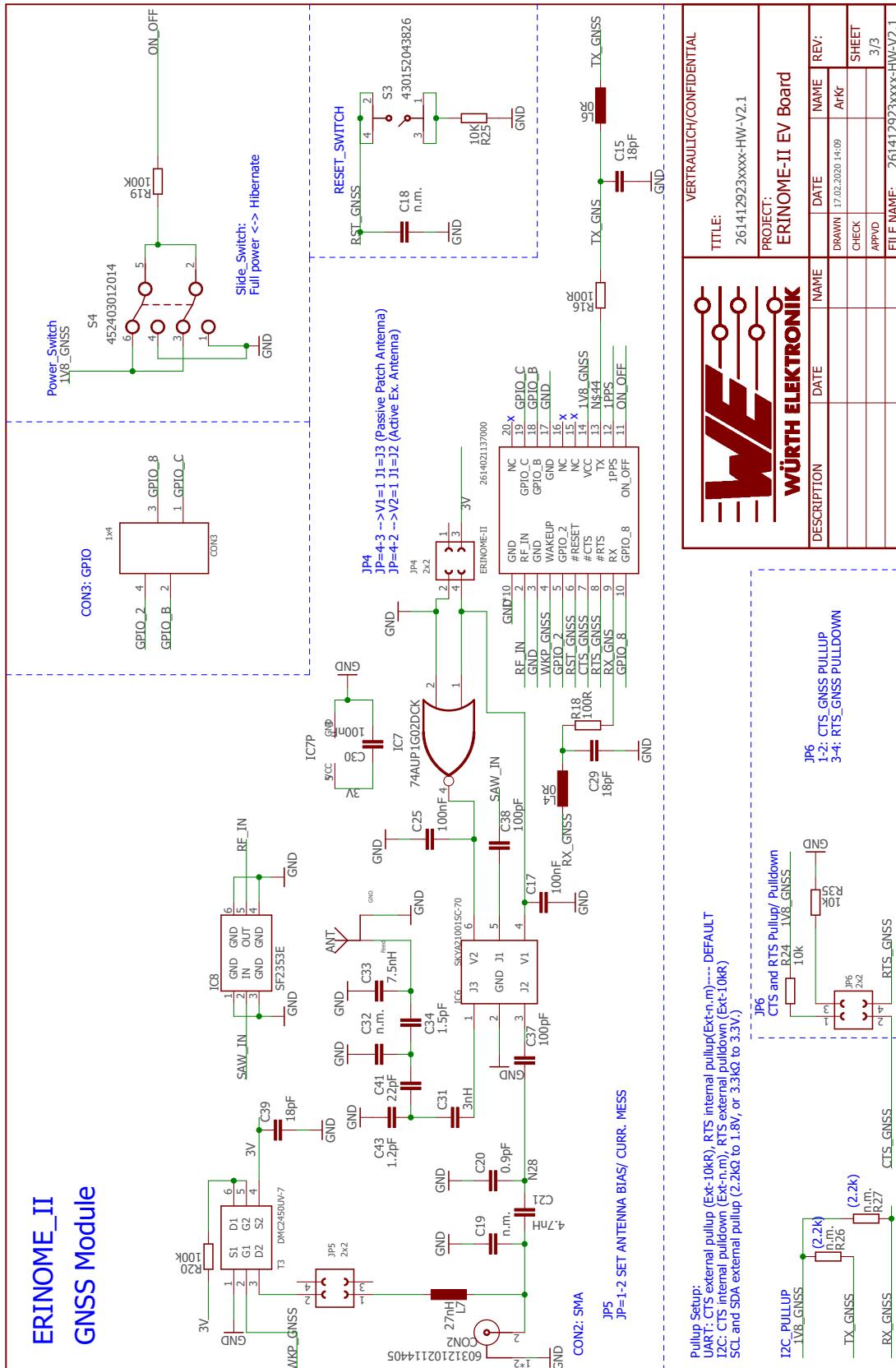


Figure 21: Reference design: Schematic sheet-3

## 8.2 Layout

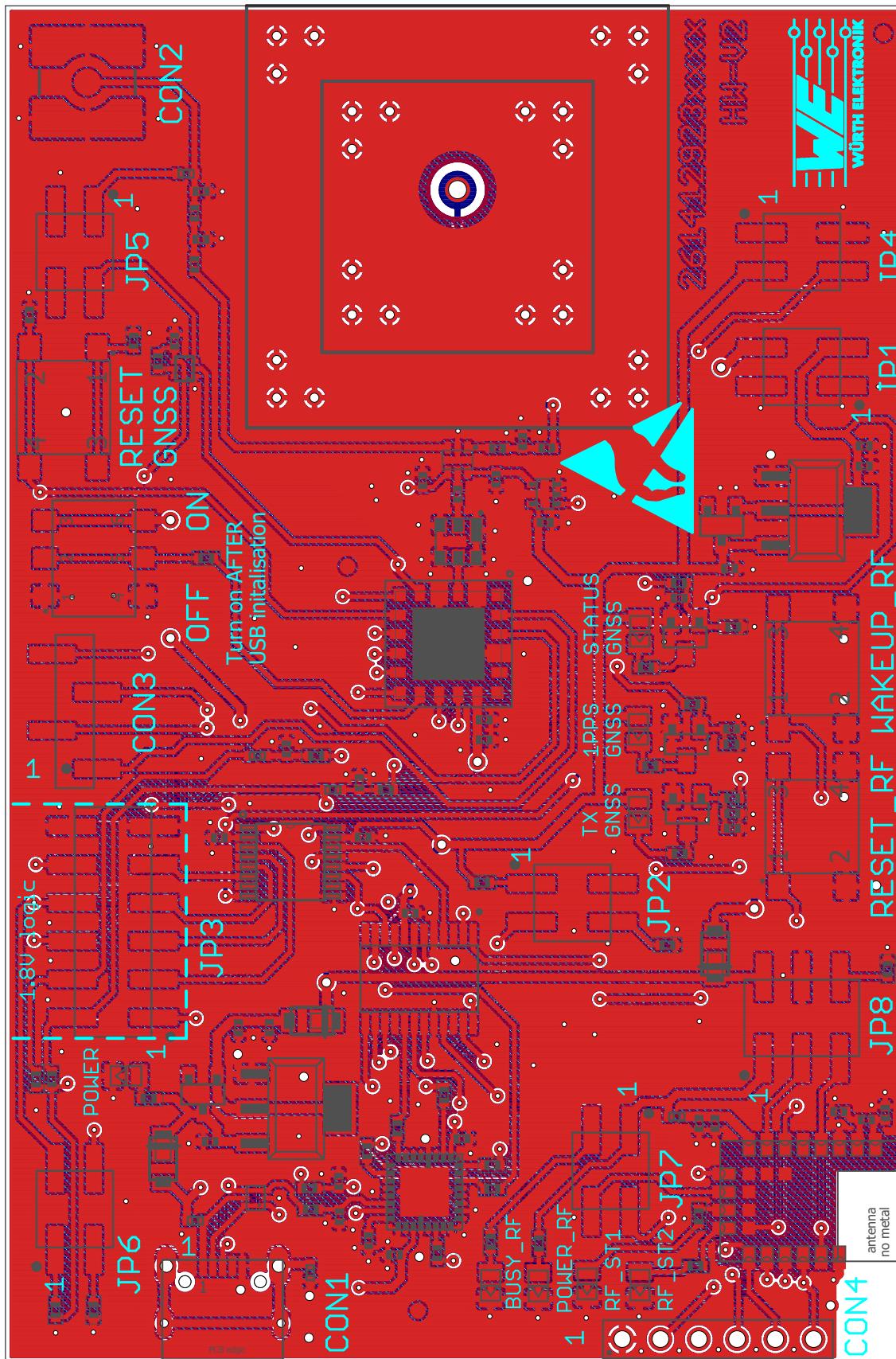


Figure 22: Reference design: Layout

### 8.3 Interface Selection for SPI

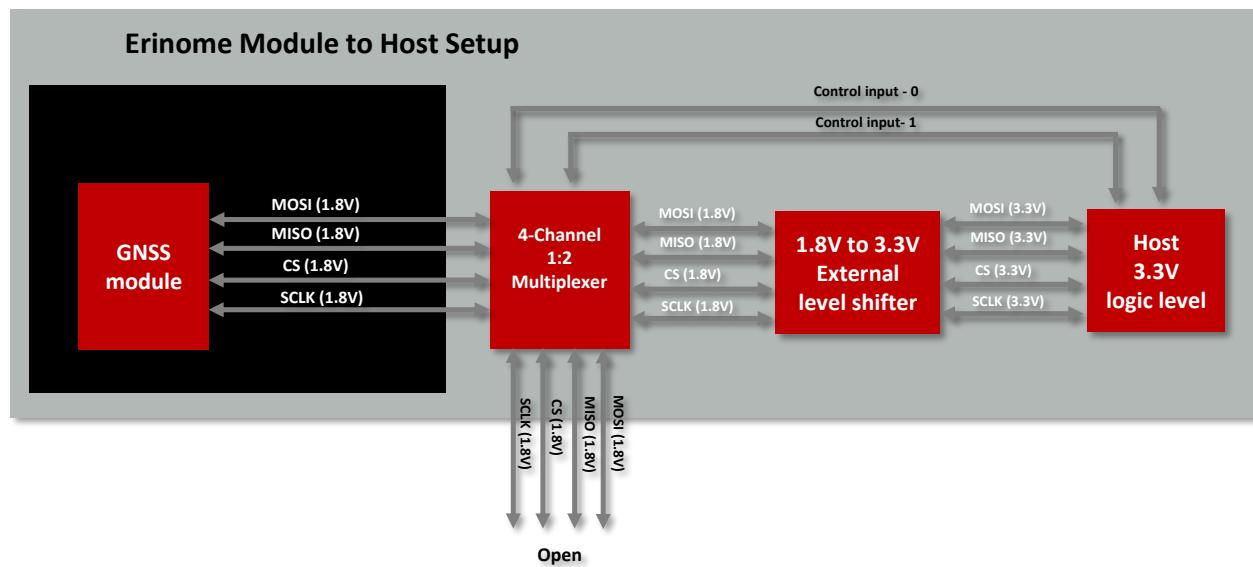


Figure 23: Interface Selection for SPI

## 9 Host connection

Erinome-II is intended to be used as GNSS module in a system, interfaced with a host micro-controller. Connection to host is possible via UART, I<sup>2</sup>C or SPI interfaces on the same set of pads. /CTS and /RTS lines are used by the module to recognize the interface at module power up. UART is implemented in Erinome-II evaluation board as reference design.

Interface	/CTS	/RTS
UART	External pull-up	Open
I <sup>2</sup> C	Open	External pull-down
SPI	Open	Open

Table 32: Interface selection

- external resistor of 10kΩ is recommended
- pull-up resistor is referenced to 1.8V

## 9.1 UART

Erinome-II implements the standard UART interface with following properties.

Item	Property
TX line	Output logic high voltage level: 1.8V compatible
RX line	Input logic high voltage level: min 1.45V, max 3.6V
Flow control	Default: disabled
Baud rate (default)	4800 baud

Table 33: UART properties

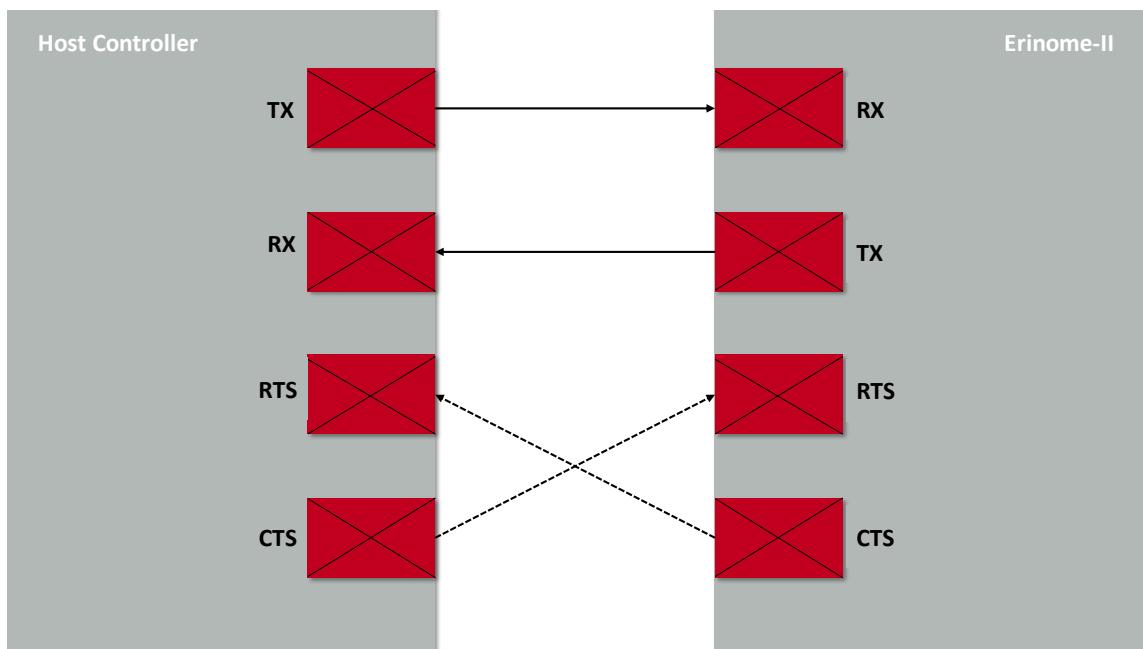


Figure 24: UART host interface

## 9.2 I<sup>2</sup>C multi master

Erinome-II supports standard I<sup>2</sup>C (Inter-IC) bus interface as an alternative to the UART interface.

I<sup>2</sup>C is a serial 8-bit protocol with two-wire interface, which supports communication between different ICs. For example between the µC and other peripheral devices such as a GNSS module or sensors.

### 9.2.1 General characteristics

The GNSS module supports the role of I<sup>2</sup>C multi-master which means it will act as a I<sup>2</sup>C master and send data to a specific slave address whenever it has data available and the bus is idle. In case the GNSS module has no data to send, it will switch into the I<sup>2</sup>C slave role to be able to receive data from another master that addresses the GNSS module via the bus.

Item	Property
I <sup>2</sup> C mode	Multi Master
I <sup>2</sup> C clock (GNSS role = master)	400 kHz (fast mode)
I <sup>2</sup> C clock (GNSS role = slave)	up to 400 kHz (normal mode, fast mode)
Supported addressing type	7-bit addressing
Erinome-II RX	address 0x60
Erinome-II TX	address 0x62
FIFO length	64 bytes
SCL, SDA	pseudo open-drain lines, external pull-up resistors needed: 2.2kΩ to 1.8V

Table 34: I<sup>2</sup>C properties

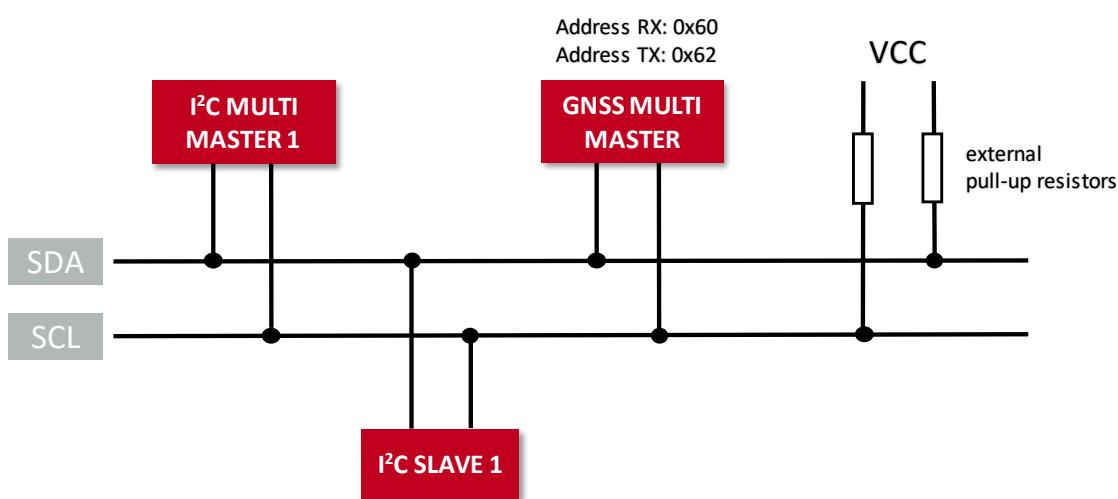


Figure 25: I<sup>2</sup>C host interface

## 9.2.2 SDA and SCL logic levels

The Erinome-II supports specified logic levels which must be either used by every device on the I<sup>2</sup>C bus or a logic level conversion must be implemented in-between the GNSS module and the other bus participants. This conversion IC must be selected in a manner that it supports the requirements of I<sup>2</sup>C set by the GNSS module, i.e. open-drain / open-collector and at least 400kHz clock speed.

## 9.2.3 Addressing the GNSS module

The GNSS module supports 7-bit addressing. Users must make sure that each device on the I<sup>2</sup>C bus has a unique address. The master selects the slave by sending a slave address after each START condition.

When the GNSS module takes the role of a master/transmitter it will always try to send data to a fixed 7-bit slave address 1100010b (0x62).

The 7-bit slave/receiving address of the GNSS module is 1100000b (0x60). This address is used by the GNSS module only to receive data from a master.

The R/W bit determines the data direction. A '0' (LOW logic level) indicates a write operation (transmission from master to slave) and a '1' (HIGH) indicates a read operation (data request from slave).

In the master role the GNSS module only uses "write" operation as indicated by the R/W bit in the first byte of a transfer. In the slave role it only supports "write" operations from the master that is sending data to the GNSS module.

The GNSS module does not support I<sup>2</sup>C messages indicating "read" in the R/W bit.

## 9.2.4 GNSS communication protocol

The GNSS module uses the NMEA protocol (default) or the OSP binary protocol (optional, can be enabled temporarily by the user). This is valid for any of its host communication interfaces. Details regarding the protocols can be found in 10. The first protocol byte is directly following the 7-bit address and 1 R/W bit.

Users need to ensure that the bus capacity is adequate for the bus data transfer load peaks and that resulting latencies are not detrimental to system performance. This means that only a limited number of participants can be part of the shared bus.

Depending on the enabled messages, the GNSS module will send more or less data to the slave that is addressed by the 0x62 address.

## 9.2.5 I<sup>2</sup>C timing parameters

The clock is fixed to 400 kHz during master operation of the module and sending data (fast mode). During slave mode (receiving data from a master) fast mode (400kHz) as well as normal mode (100kHz) are supported by the GNSS module. The bus contention/arbitration

timeout is 30 ms and cannot be changed.

Old data in the GNSS module buffer is discarded when a slave is not acknowledging the reception of the messages from the GNSS module. For optimal operation, the GNSS module assumes unrestricted outflow of serial messages and no periodic inflow of serial messages into the GNSS module.

When a message is sent to the GNSS module the reaction to this message may be delayed until all pending messages in the buffer are sent by the GNSS module and acknowledged by a slave.

### 9.2.6 I<sup>2</sup>C communication between Erinome-II and a generic Microcontroller

Figure 26 shows the principle that needs to be implemented into the µC firmware to allow a communication with the GNSS module over the I<sup>2</sup>C interface and the protocol used in the GNSS module.

The protocol used by the GNSS module is typically different to common sensor protocols. Therewith many existing drivers or hardware abstraction layers are not matching the requirements of the GNSS protocol. It may be necessary to modify existing drivers or write new drivers.

A µC host driver for use with the GNSS module is required to support at least 400kHz clock, slave mode, 7-bit addressing with the own address 0x62 and a variable I<sup>2</sup>C transfer length.

The application in the host is also required to support concatenating and parsing NMEA messages that will be sent by the GNSS module.

This scheme assumes that the GNSS module was started into I<sup>2</sup>C mode and has been woken up from hibernate mode.

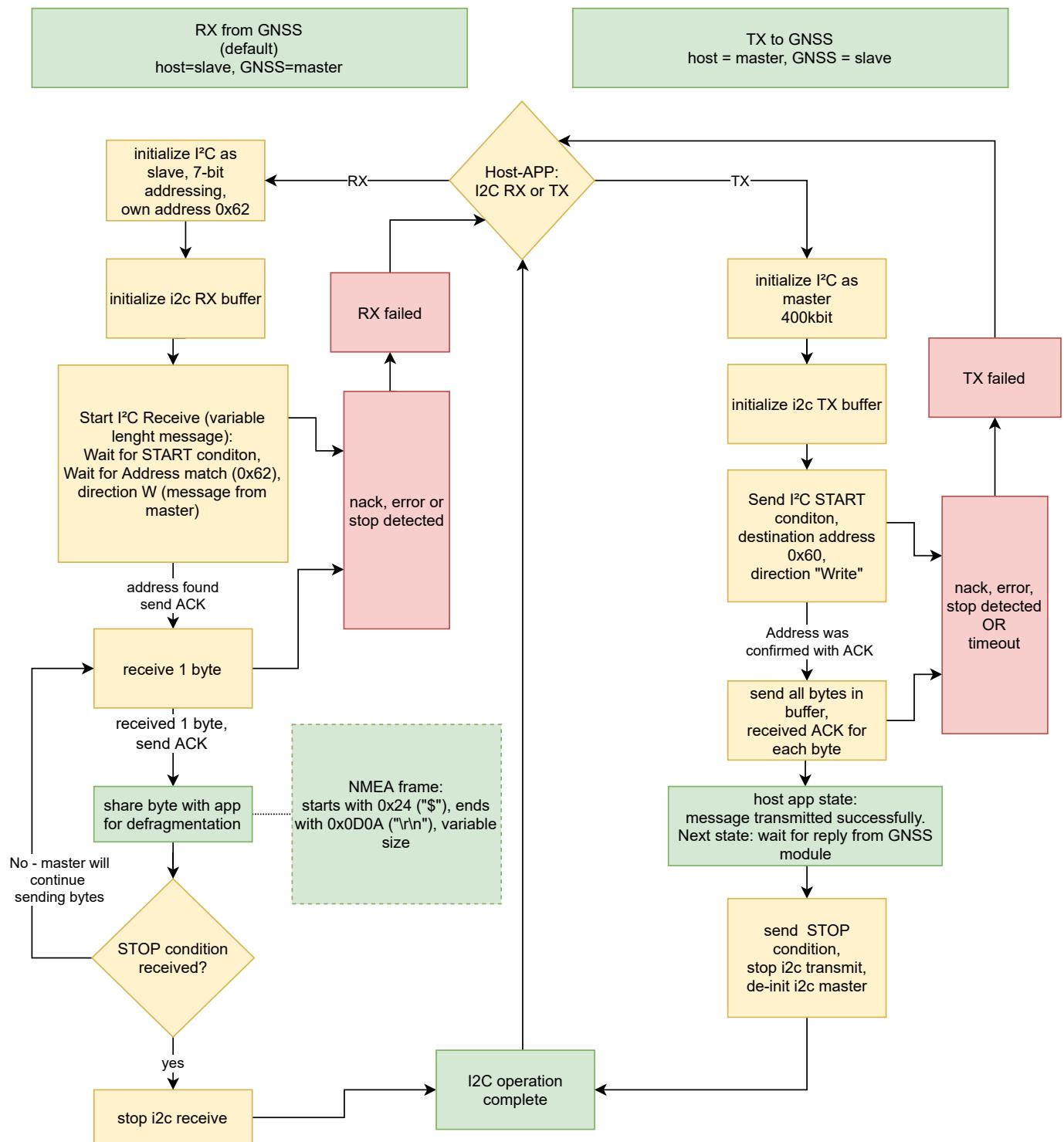


Figure 26: Flowchart for host implementation

For further information about I<sup>2</sup>C communication with the Erinome-II, including description of the hardware setup and taking into operation, please refer to our dedicated application note [2].

## 9.3 SPI Slave

Erinome-II supports standard SPI (Serial Peripheral Interface) bus interface as an alternative to the UART interface. The Erinome-II will take the role of a SPI Slave.

SPI, as used by the GNSS module, is a serial 8-bit protocol with 4-wire interface, which supports communication between different ICs. It operates in full duplex mode, which means Master and Slave can send data at the same time to each other. For example between the µC and other peripheral devices such as a GNSS module or sensors.

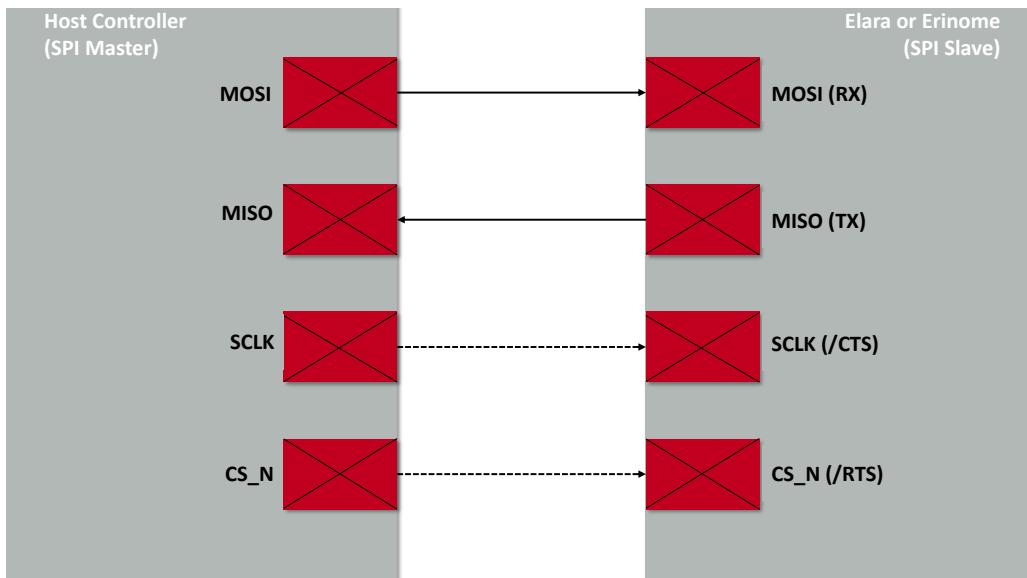


Figure 27: SPI interface

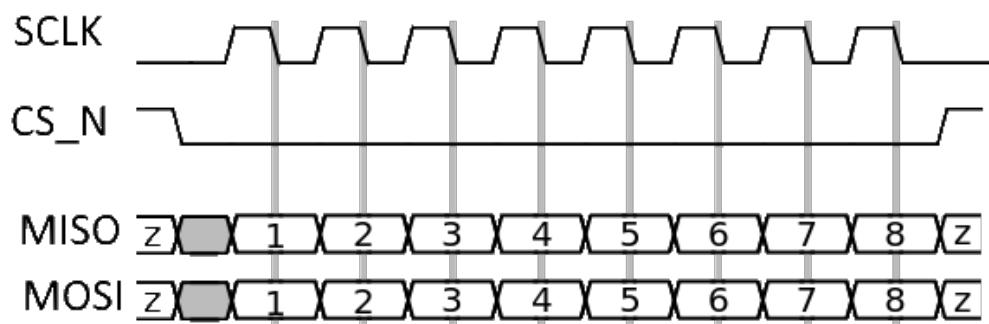


Figure 28: SPI Mode 1 (CPHA=1, CPOL=0)

### 9.3.1 General characteristics

The GNSS module supports the role of SPI Slave. That means a SPI Master needs to be connected to the GNSS module and readout the FIFO content of the GNSS module whenever data is available. This process is called polling. The SPI Master needs to select the SPI Slave device by signaling CS\_N (chip select) LOW towards the Slave.

The SPI Master has to provide the clock signal for the bit sampling.

In case the FIFO of the GNSS module is empty, it will indicate that by sending GNSS FIFO idle bytes. This means the Master may stop the current transmission by ending the pending byte and signaling CS\_N HIGH. A later transmission session will be signaled by CS\_N LOW by the Master again.

Any traffic on the SPI data lines goes directly into or comes out from the respective rx or tx FIFO of the two devices. There is no additional register mapping or addressing in case of SPI communication with the Erinome-II.

Item	Property
SPI role	Slave
SPI clock, max	6.8 MHz
SPI Mode	Mode 1 (CPHA=1, CPOL=0)
GNSS FIFO size	1024 Byte
GNSS FIFO idle bytes	0xA7B4
SPI Master idle bytes	0xFFFF
SPI MOSI, SCLK, CS_N	input for GNSS
SPI MISO	output for GNSS
SPI bit order	MSB first (most significant bit first)

Table 35: SPI properties of GNSS module

### 9.3.2 Addressing the GNSS module

The GNSS module is addressed by a LOW signal on the CS\_N line. Any byte received is directly handed over to the receive FIFO and vice versa.

### 9.3.3 SPI timing parameters

The maximum clock speed supported by the Erinome-II is 6.8 MHz. Depending on the user's hardware layout, the SPI clock must be adopted (i.e. be reduced) to ensure clean edges of the level changes. This is very important, since the change of the edges is used for sampling data.

### 9.3.4 GNSS communication protocol

The GNSS module uses the NMEA protocol (default) or the OSP binary protocol (optional, can be enabled temporarily by the user). This is valid for any of its host communication interfaces. Details regarding the protocols can be found in Chapter 10.

Users need to ensure that the bus capacity is adequate for the bus data transfer load peaks and that resulting latencies are not detrimental to system performance. The SPI Master is required to poll any available data from the GNSS module to prevent malfunction and data loss.

Depending on the enabled messages, a different amount of data will be available in the Slave's FIFO buffer per time interval. Any data in the GNSS module FIFO has to be read ("polled") by the SPI Master.

### 9.3.5 SPI communication between Erinome-II and a generic Microcontroller

The following figures show the principle that needs to be implemented into the µC firmware to allow a communication with the GNSS module over the SPI interface.

The SPI protocol used by the GNSS module is different to common sensor protocols. Therewith many existing drivers or hardware abstraction layers are not matching the requirements of the GNSS module SPI communication handling. It may be necessary to modify existing drivers or write new drivers for the SPI Master in the host.

A µC host driver for use with the Erinome-II is required to support:

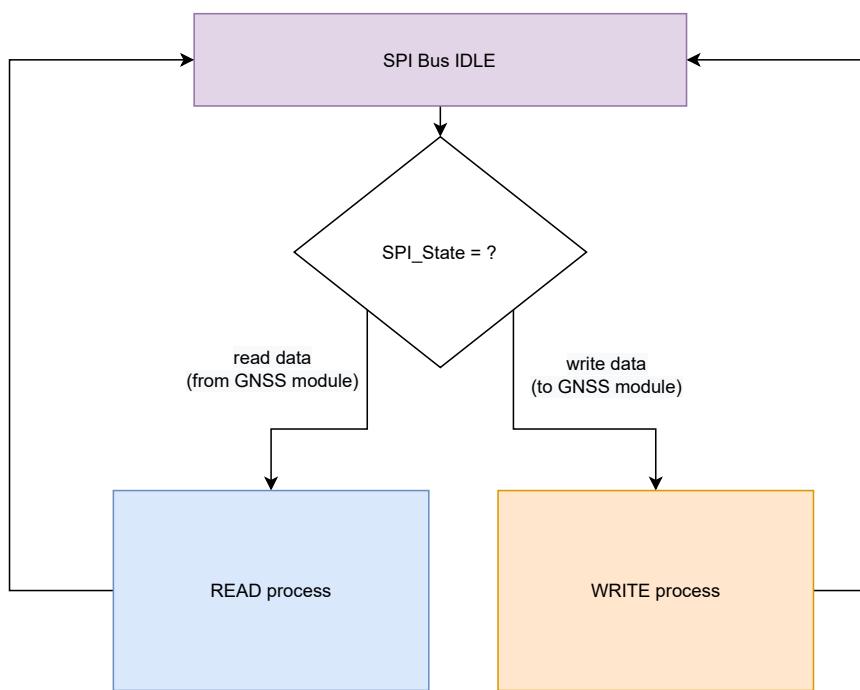
- SPI Master role
- SPI Mode 1 (CPHA=1, CPOL=0)
- handling of variable SPI transfer lengths
- receiving of at least 1024 byte in one SPI transfer
- configuring the GNSS module interface select lines (/RTS and /CTS) in the state "open" while GNSS boot-up
- configuring the GNSS module interface select lines (/RTS and /CTS) for SPI Clock and Chip Select (CS\_N) during the normal operation

The application in the host is required to support concatenating and parsing NMEA messages that will be sent by the GNSS module. The OSP protocol must be implemented when the end-application is required to use it.

The following schemes assume that the GNSS module was started properly into SPI Slave mode and has been woken up from hibernate mode.

The host has no possibility to check if the SPI boot-up was proper until communication with the module can or cannot be established by performing the "READ process" shown below.

After a re-boot the first message from the GNSS module will be the "OK\_TO\_SEND" message (\$PSRF150,1\*3E followed by one byte carriage return 0x0D and one byte line feed 0x0A).



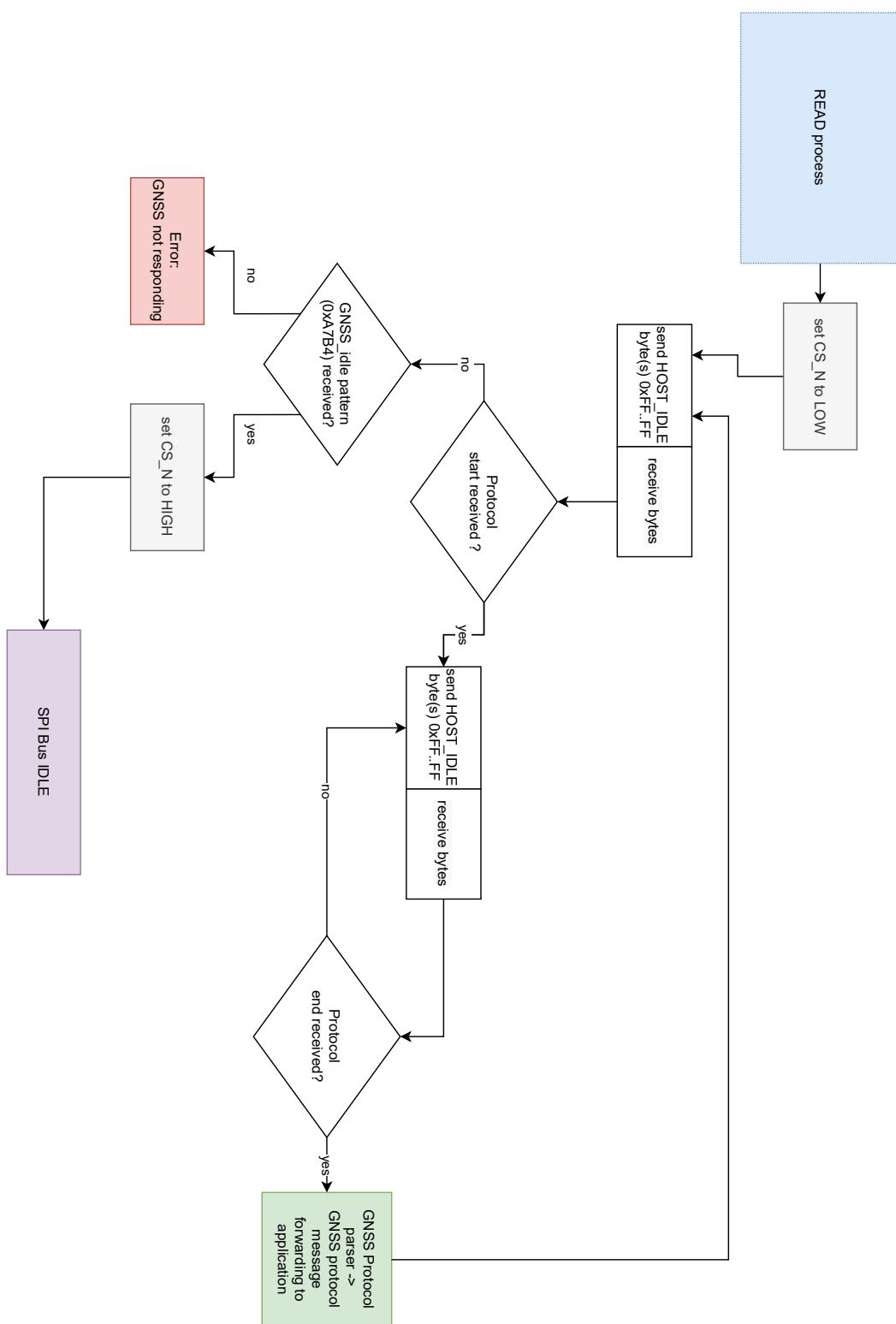


Figure 29: Flowchart Read for SPI Master implementation

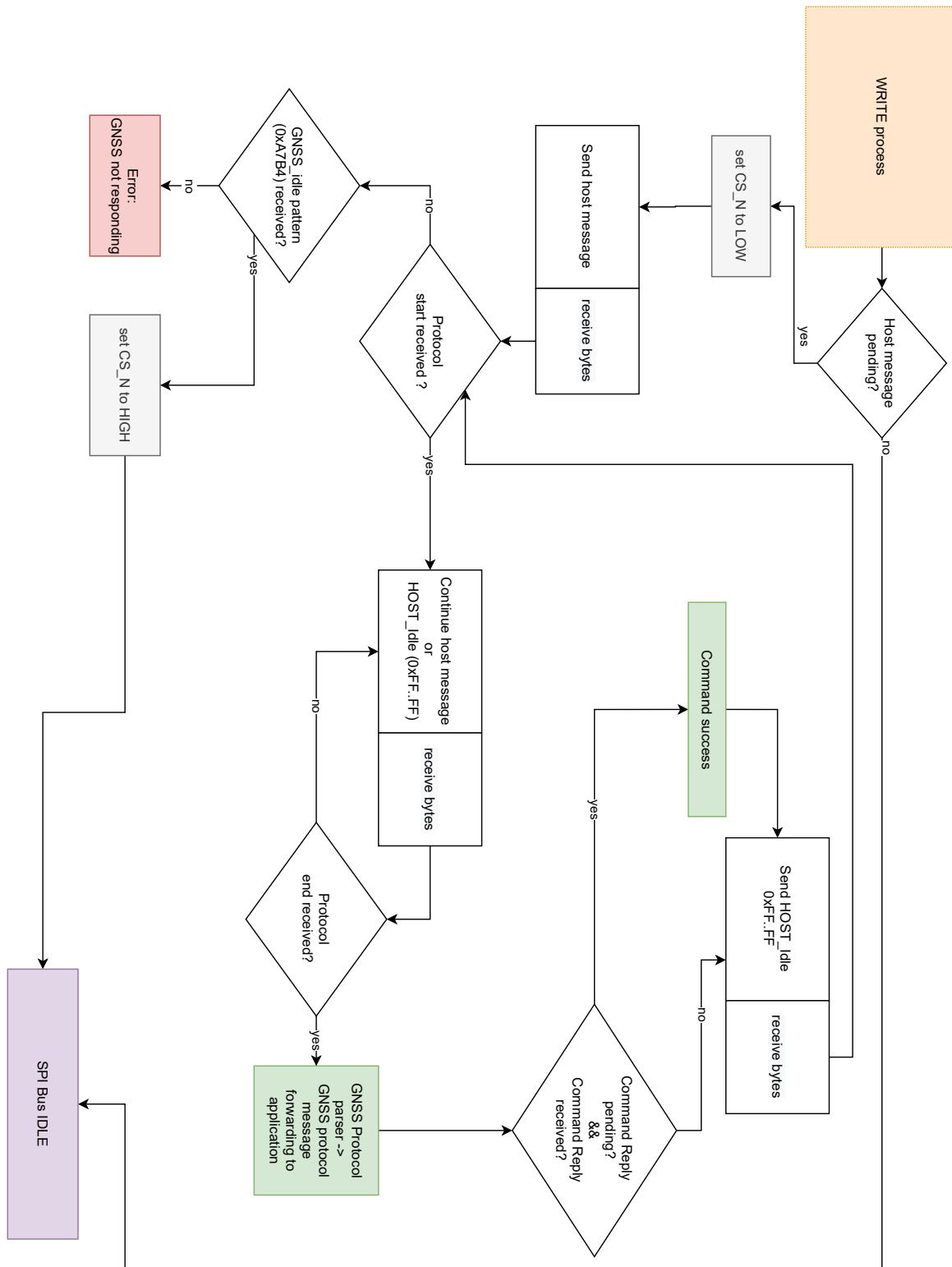


Figure 30: Flowchart Write for SPI Master implementation

## 10 Erinome-II communication protocols

The Erinome-II module can communicate with the host through two available protocols: NMEA and OSP. OSP is the Qualcomm proprietary protocol. NMEA protocol foresees standard compliant as well as product-specific sentences.

While NMEA is simpler than OSP, some of the module functions can be activated only via OSP. Both NMEA and OSP protocols include input messages (commands sent from host) and output messages (messages sent from the module to host). Scope of the input commands is changing module configuration settings and modes of operation.

In end applications, relevant information (e.g. position and time) can be extracted from the output messages through parsing of the messages.

This chapter contains the description of a selection of NMEA and OSP messages and commands which are relevant for module's operation. This chapter will be revised with additional information in future manual revisions.

Our proprietary PC tool (WENSS) [8], together with the EV-board [9], can be used to understand and test communication with Erinome-II. It supports the user in getting familiar with NMEA and OSP protocols. It implements parsing of NMEA and OSP messages, pre-defined commands, and a utility for checksum calculation.

Communication Protocol	Description
NMEA	- standard sentences (start with Talker ID) - product-specific sentences (start with protocol header \$PSRFMessageNumber)
OSP	product-specific

Table 36: Communication Protocol

### 10.1 NMEA sentences

NMEA is a protocol originally used for communication between marine electronics and is widely used in GNSS receivers. It is simpler than OSP and widely documented. It is extended with product-specific sentences with a slightly different message structure.

Overall NMEA message structure is represented here below and is the basis for understanding all sentences and commands. NMEA messages are encoded in human readable ASCII characters 0-9, a-z, A-Z, and some special ASCII characters like \$,\*. All fields are comma-separated. All messages are completed by the checksum. NMEA messages are sent as ASCII data.

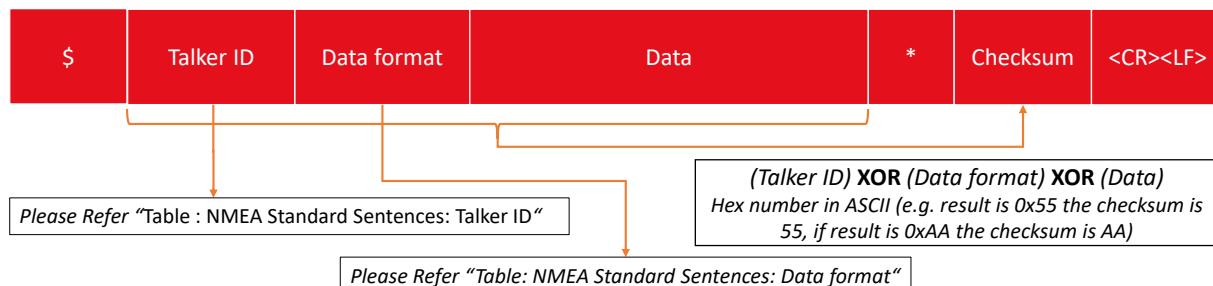


Figure 31: NMEA Standard Sentences for Erinome-II

Field	Description
GP	GPS satellites
GL	GLONASS satellites
GN	Satellites from multiple constellations
GA	Galileo satellites
GB	BeiDou satellites

Table 37: NMEA Standard Sentences: Talker ID

Field	Description
GGA	Time, position and fix type data for GPS constellations
GLL	Latitude, longitude, UTC time of position fix and status
GNS	Time, position and fix type date for all constellations
GSA	GPS receiver operating mode, satellites used in the position solution and DOP values
GSV	Number of GPS satellites in view, satellite ID numbers, elevation, azimuth and SNR values
RMC	Time, date, position, course and speed data
VTG	Course and speed information relative to the ground
ZDA	PPS timing message, synchronized to PPS

Table 38: NMEA Standard Sentences: Data format

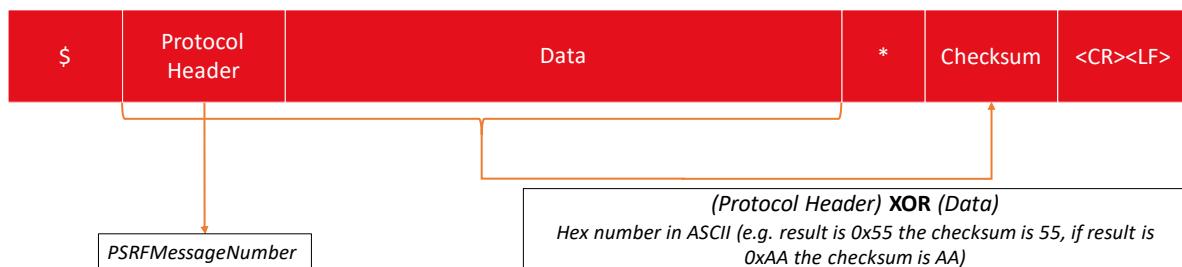


Figure 32: NMEA Product-Specific Sentences for SiRFStar V

For standard compliant sentences, checksum is calculated with the following formula, where conversion to HEX is needed before XOR operation.

#### Talker ID XOR Data format XOR Data

Example sentence:

\$GNZDA,204519.000,25,12,2019,\*4D

In this example, checksum 4D is obtained as following:

- HEX(G) XOR HEX(N) XOR HEX(Z) XOR HEX(D) XOR HEX(A) XOR HEX(,) XOR HEX(2) XOR ... XOR (,) =  $0x4D_{hex}$
- ASCII [ $0x4D_{hex}$ ] = 4D

For non-compliant sentences, checksum is calculated with the following formula:

#### Protocol Header XOR Data

Example:

\$PSRF100,0,115200,8,1,0,\*04

In this command, checksum 04 is obtained as following:

Checksum = Protocol Header XOR Data =

ASCII [HEX(P) XOR HEX(S) XOR HEX(R) XOR ... XOR HEX(,)] = 04

### 10.1.1 NMEA sentences overview

Data Format	Input/Output	Short description	Link to description
GGA	Output	Time, position, and fix type data	GGA
GLL	Output	Latitude, longitude, time, and status	GLL
GNS	Output	Time, position, and fix type data	GNS
GSA	Output	GNSS receiver operating mode, satellites used in the position solution and DOP values	GSA
GSV	Output	Number of GPS satellites in view, satellite ID numbers, elevation, azimuth and SNR values	GSV
RMC	Output	Time, date, position, course and speed data	RMC
VTG	Output	Course and speed information relative to the ground	VTG
ZDA	Output	Timing message, synchronized to PPS pulse	ZDA
PSRFEPE	Output	Navigation data	PSRFEPE
PSRF150	Output	Module status. Indicates if host can communicate with the module	PSRF150
PSRF195	Output	Software version. Response to PSRF125	PSRF195
PSRGNSSTART	Output	GNSS start	PSRGNSSTART
PSRGNSSTOP	Output	GNSS stop	PSRGNSSTOP
PSRF103	Input	Change message rate	PSRF103
PSRF100	Input	Switch protocol and baud rate	PSRF100
PSRF125	Input	Poll software version	PSRF125
PSRF101	Input	Restart the module	PSRF101
PSRF117	Input	System turn off	PSRF117
PSRF132	Input	Factory reset	PSRF132

Table 39: Message overview

### 10.1.2 NMEA output sentences

Most relevant NMEA output messages are the ones containing position, time and related information about the position fix. If the module is in full power mode, these are sent automatically with the configured update rate. Other NMEA output messages are product specific and sent from the module in response to specific commands or events.

Most relevant NMEA output message types and corresponding data fields are described in the following pictures and table.

- **GGA Data Format:**

Field	Description
UTC Time	hhmmss.sss (Hours Minutes Seconds)
Latitude	ddmm.mmmm (Degree Minutes)
N/S	N: North S: South
Longitude	Ddmm.mmmm (Degree Minutes)
E/W	E: East W: West
Position Fix Indicator	0: Fix not available or invalid 1: Fix valid
Satellites used	In fix: 0-12
HDOP	Horizontal Dilution of Precision
MSL Altitude	In meters
Units	M (meters)
Geoid Separation	Geoid-to-ellipsoid separation Ellipsoid altitude = Geoid MSL altitude + Geoid separation
Units	M (meters)
Empty field	Empty field
Null field	0000

Table 40: GGA Data Format

An example of GGA sentence is:

\$GPGGA,153219.000,4809.0013,N,01135.0012,E,1,08,0.8,457.7,M,47.6,M,,0000\*57

- **GLL Data Format:**

Field	Description
Latitude	Ddmm.mmmm (Degree Minutes)
N/S	N: North S: South
Longitude	Ddmmmmmm (Degree Minutes)
E/W	E: East W: West
UTC Time	Hhmmss.sss (Hours Minutes Seconds)
Status	A: Data Valid V: Data not Valid
Mode	A: Autonomous N: Output Data Not Valid R: Coarse Position (SV states based on almanac, not ephemeris)

Table 41: GLL Data Format

An example of GLL sentence is:

\$GNGLL,4809.0009,N,01135.0008,E,153450.000,A,A\*43

- **GNS Data Format:**

Field	Description
UTC of position	hhmmss.sss (Hours Minutes Seconds)
Latitude	ddmm.mmmm (Degree Minutes)
N/S	N: North S: South
Longitude	ddmm.mmmm (Degree Minutes)
E/W	E: East W: West
Mode Indicator	A: Autonomous (satellite system used in standard mode) E: Estimated M: Manual Input N: No fix Variable length: Galileo or GLONASS enabled: 4 characters, order GPS-GLO-GAL-BDS Otherwise: 2 characters, order: GPS-GLO
Satellites used	In fix: 0-99
HDOP	Horizontal Dilution of Precision
MSL Altitude	In meters
Geoid Separation	Geoid-to-ellipsoid separation Ellipsoid altitude = Geoid MSL altitude + Geoid separation
Empty field	Empty field
Null field	0000

Table 42: GNS Data Format

An example of GNS sentence is:

\$GNGNS,152715.000,4809.0010,N,01134.9989,E,AA,08,1.2,467.7,47.6,,0000\*63

- **GSA Data Format:**

Field	Description
Mode 1	A: Automatic. Enabled to automatically switch 2D/3D
Mode 2	1: Fix not available 2: 2D (<4 SVs used) 3: 3D (>4 SVs used)
Satellite used [1...12]	1 to 32: GPS (PRN code) 33 to 51: SBAS (PRN-87) 52 to 61: QZSS 65 to 96: GLONASS (Slot#+64) 121 to 147: BeiDou (PRN + 110) 148 to 157: BeiDou (PRN + 147) 205 to 254: Galileo (PRN + 204)
PDOP	Position Dilution of Precision
HDOP	Horizontal Dilution of Precision
VDOP	Vertical Dilution of Precision

Table 43: GSA Data Format

An example of GSA sentence is:

\$GNGSA,A,3,06,21,29,19,18,31,27,05,,,1.5,0.8,1.2\*2E

- **GSV Data Format:**

Field	Description
Number of Messages	Total number of GSV messages to be sent in this group
Message Number	Message number in this group of GSV messages
Satellites in View	Number of satellites in view
Satellite ID	1 to 32: GPS (PRN code) 33 to 51: SBAS (PRN-87) 52 to 61: QZSS 65 to 96: GLONASS (Slot#+64) 121 to 147: BeiDou (PRN + 110) 148 to 157: BeiDou (PRN + 147) 205 to 254: Galileo (PRN + 204)
Elevation angle	0 to 90 degrees
Azimuth angle	0 to 359 degrees clockwise from North
C/N <sub>O</sub>	Carrier-to-Noise density: 0 to 99 dB-Hz, null when not tracking
...	Satellite ID, elevation, azimuth and C/N <sub>O</sub> are repeated for three additional satellites

Table 44: GSV Data Format

An example of GSV sentence is:

```
$GPGSV,3,1,10,21,54,218,40,06,40,286,40,19,35,279,40,29,54,079,40*7B
$GPGSV,3,2,10,18,33,135,40,31,29,251,40,05,35,074,40,27,32,283,40*75
$GPGSV,3,3,10,57,17,303,,07,04,337,*78
```

- **RMC Data Format:**

Field	Description
UTC Time	hhmmss.sss (Hours Minutes Seconds)
Status	A: Data Valid V: Data not Valid
Latitude	ddmm.mmmm (Degree Minutes)
N/S	N: North S: South
Longitude	ddmm.mmmm (Degree Minutes)
E/W	E: East W: West
Speed Over Ground	in Knots
Course Over Ground	in Degrees
Date	ddmmyy (Day Month Year)
Empty field	Empty field
Empty field	Empty field
Mode	A: Autonomous (standard) N: Output Data Not Valid R: Coarse Position (SV states based on almanac, not ephemeris)

Table 45: RMC Data Format

An example of RMC sentence is:

\$GNRMC,155401.000,A,4809.0000,N,01135.0002,E,0.00,0.00,251219,,A\*79

- **VTG Data Format:**

Field	Description
Course	Measured heading (degrees)
Reference	True
Empty field	Empty field
Reference	Magnetic
Speed	Measured horizontal speed (knots)
Units	In knots
Speed	Measured horizontal speed (km/h)
Units	In km/hour
Mode	A: Autonomous (standard) N: Output Data Not Valid R: Coarse Position (SV states based on almanac, not ephemeris)

Table 46: VTG Data Format

An example of VTG sentence is:

\$GNVTG,0.00,T,M,0.00,N,0.0,K,A\*13

- **ZDA Data Format:**

Field	Description
UTC Time	hhmmss.sss (Hours Minutes Seconds)
Day	Day of the month (range 1 to 31)
Month	Month of the year (range 1 to 12)
Year	Year
Empty field	Empty field
Empty field	Empty field

Table 47: ZDA Data Format

An example of ZDA sentence is:

\$GNZDA,163101.000,25,12,2019,,\*42

- **\$PSRFEPE:** If activated through command \$PSRF103, \$PSRFEPE is sent from the receiver together with standard output messages with the configured rate.

Field	Description
\$PSRFEPE	Protocol header
UTC	Hhmmss.sss (Hours Minutes Seconds)
HDOP	Horizontal Dilution Of Precision
EHPE	Estimated Horizontal Position Error (meters)
EVPE	Estimated Vertical Position Error (meters)
EHVE	Estimated Velocity Error (m/s)
EHE	Estimated Heading Error (degrees)

Table 48: Estimated Position Error

An example of EPE sentence is:

\$PSRFEPE,163910.000,A,0.6,2.65,2.56,0.0,180.0\*19

- **\$PSRF150:** \$PSRF150 is sent from the receiver to indicate status and if communication with host is possible.

Field	Description
\$PSRF150	Protocol header
OkToSend	0: CPU is about to go Off and stay in Hibernate. 1: CPU has just come On in Full Power Mode. 2: Receiver initialization is complete in full power state (after restart or hibernate). Ok to Send 4: Low Power Mode enabled. CPU is about to go off. Not Ok to Send 5: Low Power Mode enabled. Receiver is on. 6: Low Power Mode enabled. Receiver initialization is complete (after hibernate). Ok to Send.

Table 49: Ok To Send

This sentence is sent as last message when transitioning from full power to hibernate state (not ok to send) and as first message when transitioning from hibernate to full power (ok to send)

Two examples of this sentence are:

\$PSRF150,0\*3F

\$PSRF150,1\*3E

- **\$PSRF195:** \$PSRF195 is sent from the receiver in response to the "poll SW version" command (\$PSRF125).

Field	Description
\$PSRF195	Protocol header
Version String	SW version string

Table 50: Response to Poll SW version

An example of this sentence is:

\$PSRF195,5xp\_5.5.2-R32+5xpt\_5.5.2-R32\*06

- **\$PSRGNSSTART and \$PSRGNSSTOP:** These messages are sent in sequence from the receiver in response to restart execution. Fields after protocol header are identical for both messages.

Field	Description
\$PSRGNSSTOP or \$PSRGNSSTART	Protocol header
Start mode	Bit [3:0]: start mode: 1: Hot start 2: Warm start (no init) 3: Warm start (with init) 4: Cold start 5: Factory reset Bit 6: start reason: 0: External command 1: Internal reason 2: Push-To-Fix mode 4: Initial Bit 7: Restart type 0: GPS-only restart 1: System restart
Status	Bit 0: RTC status 0: Invalid RTC status 1: Valid RTC status Bit 1: Storage status: 0: Invalid data in storage 1: Valid data in storage Bit 2: Flash storage: 0: Invalid data in storage 1: Valid data in storage

Field	Description
Not Supported	Not Supported
Off Time	Time GPS is off (seconds)
GPS Week	GPS week number. Week 0 starts on 6th January 1980
Time of Week	Measured in seconds (scaled by $10^3$ )
UTC year	UTC year
UTC month	UTC month, 1 to 12
UTC day	UTC day of month, 1 to 31
UTC hour	UTC hour, 0 to 23
UTC minute	UTC minute, 0 to 59
UTC second	UTC second, 0 to 59.999 in s, scaled by $10^3$
Latitude	Positive value indicates North, degrees, scaled by $10^7$
Longitude	Positive value indicates East, degrees, scaled by $10^7$
Alt_ellips	Altitude relative to the WGS-84 ellipsoid, meters, scaled by $10^2$
Not supported	Not supported
Almanac week	Week number of the collected almanac
Not supported	Not supported
Not supported	Not supported

Table 51: GNSS Start and Stop

Examples of these sentences are:

```
$PSRFGNSSTOP,1,0,0,0,2093,67115000,2020,2,16,18,38,35,481827222,  
115666029,57083,0,0,0,2093,95834,13 *63
```

```
$PSRFGNSSTART,1,0,0,0,2093,67146000,2020,2,16,18,39,6,481827222,  
115666029,57083,0,0,0,2093,95835,14 *0A
```

### 10.1.3 NMEA input sentences

Most relevant NMEA input message types and corresponding data fields are described in the following pictures and table. All NMEA input messages are manufacturer or even IC specific.

- **\$PSRF103:**

NMEA command \$PSRF103 allows selecting which NMEA output message types are sent out from the module and at which rate. 5 and 10 Hz update rate (5 messages/second) support applications where a finer grid of navigation points is needed (ex. high speed). If enabled, 5 and 10 Hz update rates apply to all standard compliant NMEA output messages, unless deactivated.

Field	Description
\$PSRF103	Protocol header
Message to control	0: GGA / Update rate > 1 Hz 1: GLL 2: GSA 3: GSV 4: RMC 5: VTG 7: EPE 8: ZDA 9: GNS
Action	0: set rate 1: query one time 6: activate 5 Hz update rate 7: deactivate 5 Hz update rate 14: activate 10 Hz update rate 15: deactivate 10 Hz update rate
Rate	0: deactivate message / Update Rate > 1Hz 1-255: seconds between messages
En. Checksum	1: checksum enabled (do not change)

Table 52: Message rate selection

If overflow causes delay in delivering the NMEA messages, this message can be used to reduce the number of messages sent from the module in the time unit.

Example: change rate of output message GLL to 5 seconds.

\$PSRF103,1,0,5,1\*3D

Example: enable 5 Hz navigation.

\$PSRF103,0,6,0,1\*22

Example: query GSV message once.

\$PSRF103,3,1,0,1\*26



When 5 or 10 Hz navigation is active, baud rate has to be increased in order to support the higher data flow

The different update rates (1 msg/sec, 5 msg/sec, 10 msg/sec) can be observed along the time stamps of the single messages. See an example from WENSS PC tool here below.

```
[06:40:40.119] $GNGNS,195648.000,4808.9996,N,01135.0004,E,AA,18,0,6,462,8,47,6,,0000*64
[06:40:41.120] $GNGNS,195649.000,4808.9996,N,01135.0004,E,AA,18,0,6,462,8,47,6,,0000*65
[06:40:42.104] $GNGNS,195650.000,4808.9996,N,01135.0004,E,AA,18,0,6,462,8,47,6,,0000*6D
[06:40:43.104] $GNGNS,195651.000,4808.9996,N,01135.0004,E,AA,18,0,6,462,8,47,6,,0000*6C
[06:40:44.120] $GNGNS,195652.000,4808.9996,N,01135.0004,E,AA,18,0,6,462,8,47,6,,0000*6F
[06:40:45.104] $GNGNS,195653.000,4808.9996,N,01135.0004,E,AA,18,0,6,462,8,47,6,,0000*6E
[06:40:46.104] $GNGNS,195654.000,4808.9996,N,01135.0004,E,AA,18,0,6,462,8,47,6,,0000*69
[06:40:47.105] $GNGNS,195655.000,4808.9996,N,01135.0004,E,AA,18,0,6,462,8,47,6,,0000*68
[06:40:48.136] $GNGNS,195656.000,4808.9996,N,01135.0004,E,AA,18,0,6,462,8,47,6,,0000*6B
[06:40:49.105] $GNGNS,195657.000,4808.9996,N,01135.0004,E,AA,18,0,6,462,8,47,6,,0000*6A
[06:40:50.089] $GNGNS,195658.000,4808.9996,N,01135.0004,E,AA,18,0,6,462,8,47,6,,0000*65
[06:40:51.152] $GNGNS,195659.000,4808.9996,N,01135.0004,E,AA,18,0,6,462,8,47,6,,0000*64
[06:40:52.074] $GNGNS,195700.000,4808.9996,N,01135.0004,E,AA,18,0,6,462,8,47,6,,0000*69
[06:40:53.043] $GNGNS,195701.000,4808.9996,N,01135.0004,E,AA,18,0,6,462,8,47,6,,0000*68
```

Figure 33: Example of 1 Hz navigation

```
[06:44:03.062] $GNGNS,200011.000,4808.9996,N,01135.0004,E,AA,18,0,6,462,8,47,6,,0000*61
[06:44:03.249] $GNGNS,200011.200,4808.9996,N,01135.0004,E,AA,18,0,6,462,8,47,6,,0000*63
[06:44:03.436] $GNGNS,200011.400,4808.9996,N,01135.0004,E,AA,18,0,6,462,8,47,6,,0000*65
[06:44:03.811] $GNGNS,200011.600,4808.9996,N,01135.0004,E,AA,18,0,6,462,8,47,6,,0000*67
[06:44:03.929] $GNGNS,200011.800,4808.9996,N,01135.0004,E,AA,18,0,6,462,8,47,6,,0000*69
[06:44:04.070] $GNGNS,200012.000,4808.9996,N,01135.0004,E,AA,18,0,6,462,8,47,6,,0000*62
[06:44:04.242] $GNGNS,200012.200,4808.9996,N,01135.0004,E,AA,18,0,6,462,8,47,6,,0000*60
[06:44:04.430] $GNGNS,200012.400,4808.9996,N,01135.0004,E,AA,18,0,6,462,8,47,6,,0000*66
[06:44:04.645] $GNGNS,200012.600,4808.9996,N,01135.0004,E,AA,18,0,6,462,8,47,6,,0000*64
[06:44:04.880] $GNGNS,200012.800,4808.9996,N,01135.0004,E,AA,18,0,6,462,8,47,6,,0000*6A
[06:44:05.067] $GNGNS,200013.000,4808.9996,N,01135.0004,E,AA,18,0,6,462,8,47,6,,0000*63
[06:44:05.255] $GNGNS,200013.200,4808.9996,N,01135.0004,E,AA,18,0,6,462,8,47,6,,0000*61
[06:44:05.442] $GNGNS,200013.400,4808.9996,N,01135.0004,E,AA,18,0,6,462,8,47,6,,0000*67
[06:44:05.629] $GNGNS,200013.600,4808.9996,N,01135.0004,E,AA,18,0,6,462,8,47,6,,0000*65
[06:44:05.817] $GNGNS,200013.800,4808.9996,N,01135.0004,E,AA,18,0,6,462,8,47,6,,0000*6B
[06:44:06.020] $GNGNS,200014.000,4808.9996,N,01135.0004,E,AA,18,0,6,462,8,47,6,,0000*64
```

Figure 34: Example of 5 Hz navigation

```
[11:06:22.719] $GNGNS,220428.000,4810.9624,N,01133.9936,E,NNAA,15.0,7.523.5,47.6.,0000
[11:06:22.836] $GNGNS,220428.100,4810.9624,N,01133.9936,E,NNAA,15.0,7.523.5,47.6.,0000
[11:06:22.977] $GNGNS,220428.200,4810.9624,N,01133.9936,E,NNAA,15.0,7.523.5,47.6.,0000
[11:06:23.093] $GNGNS,220428.300,4810.9624,N,01133.9936,E,NNAA,15.0,7.523.5,47.6.,0000
[11:06:23.213] $GNGNS,220428.400,4810.9624,N,01133.9936,E,NNAA,15.0,7.523.5,47.6.,0000
[11:06:23.347] $GNGNS,220428.500,4810.9624,N,01133.9936,E,NNAA,15.0,7.523.5,47.6.,0000
[11:06:23.461] $GNGNS,220428.600,4810.9624,N,01133.9936,E,NNAA,15.0,7.523.5,47.6.,0000
[11:06:23.585] $GNGNS,220428.700,4810.9624,N,01133.9936,E,NNAA,15.0,7.523.5,47.6.,0000
[11:06:23.703] $GNGNS,220428.800,4810.9624,N,01133.9936,E,NNAA,15.0,7.523.5,47.6.,0000
[11:06:23.823] $GNGNS,220428.900,4810.9624,N,01133.9936,E,NNAA,15.0,7.523.5,47.6.,0000
[11:06:23.957] $GNGNS,220429.000,4810.9624,N,01133.9936,E,NNAA,15.0,7.523.5,47.6.,0000
[11:06:24.083] $GNGNS,220429.100,4810.9624,N,01133.9936,E,NNAA,15.0,7.523.5,47.6.,0000
[11:06:24.198] $GNGNS,220429.200,4810.9624,N,01133.9936,E,NNAA,15.0,7.523.5,47.6.,0000
[11:06:24.311] $GNGNS,220429.300,4810.9624,N,01133.9936,E,NNAA,15.0,7.523.5,47.6.,0000
[11:06:24.439] $GNGNS,220429.400,4810.9624,N,01133.9936,E,NNAA,15.0,7.523.5,47.6.,0000
[11:06:24.575] $GNGNS,220429.500,4810.9624,N,01133.9936,E,NNAA,15.0,7.523.5,47.6.,0000
[11:06:24.693] $GNGNS,220429.600,4810.9624,N,01133.9936,E,NNAA,15.0,7.523.5,47.6.,0000
[11:06:24.819] $GNGNS,220429.700,4810.9624,N,01133.9936,E,NNAA,15.0,7.523.5,47.6.,0000
[11:06:24.945] $GNGNS,220429.800,4810.9624,N,01133.9936,E,NNAA,15.0,7.523.5,47.6.,0000
[11:06:25.073] $GNGNS,220429.900,4810.9624,N,01133.9936,E,NNAA,15.0,7.523.5,47.6.,0000
[11:06:25.202] $GNGNS,220430.000,4810.9624,N,01133.9936,E,NNAA,15.0,7.523.5,47.6.,0000
[11:06:25.346] $GNGNS,220430.100,4810.9624,N,01133.9936,E,NNAA,15.0,7.523.5,47.6.,0000
[11:06:25.467] $GNGNS,220430.200,4810.9624,N,01133.9936,E,NNAA,15.0,7.523.5,47.6.,0000
[11:06:25.584] $GNGNS,220430.300,4810.9624,N,01133.9936,E,NNAA,15.0,7.523.5,47.6.,0000
[11:06:25.707] $GNGNS,220430.400,4810.9624,N,01133.9936,E,NNAA,15.0,7.523.5,47.6.,0000
[11:06:25.827] $GNGNS,220430.500,4810.9624,N,01133.9936,E,NNAA,15.0,7.523.5,47.6.,0000
[11:06:25.958] $GNGNS,220430.600,4810.9624,N,01133.9936,E,NNAA,15.0,7.523.5,47.6.,0000
```

Figure 35: Example of 10 Hz navigation

- **\$SPRF100:**

NMEA command \$SPRF100 can be used to switch protocol and to select baud rate.

Field	Description
\$PSRF100	Protocol header
Protocol	0: OSP 1: NMEA
Baud rate	4800, 9600, 19200, 38400, 57600, 115200, 230400, 460800, 921600, 12288001
DataBits	8
StopBits	1
Parity	0

Table 53: Baud rate selection

Example: switch to OSP at 115200 bd

\$PSRF100,0,115200,8,1,0\*04

Example: switch to NMEA at 921600 bd

\$PSRF100,1,921600,8,1,0\*0E

- **\$PSRF101:**

Hot, warm and cold start can be performed using NMEA command \$PSRF101. Initialization data (position and time) can be injected through the corresponding parameters.

Field	Description
\$PSRF101	Protocol header
ECEF X	X position (ECEF coordinate system, meters)
ECEF Y	Y position (ECEF coordinate system, meters)
ECEF Z	Z position (ECEF coordinate system, meters)
ClkDrift	Clock drift: 0 (Hz) for last saved value
Time Of Week	GPS time of week (seconds)
Week number	GPS week number
Channel count	12
Reset Configuration	1: Hot Start 2: Warm start with no initialization data (fields ECEF X, ECEF Y, ECEF Z) 3: Warm start with initialization data (fields ECEF X, ECEF Y, ECEF Z) 4: Cold start

Table 54: Navigation initialization

Example: Execute hot start (without initialization data)

\$PSRF101,0,0,0,0,0,12,1\*15

Example: Execute cold start (without initialization data)

\$PSRF101,0,0,0,0,0,12,4\*10

Example: Execute warm start (with initialization data)

\$PSRF101,-2686700,-4304200,3851624,96000,497260,921,12,3\*1C

- **\$PSRF117:**

\$PSRF117 allows system turn off and transition to hibernate state. The complete command is:

\$PSRF117,16\*0B

- **\$SPRF132:**

NMEA command \$SPRF132 performs a factory reset. All data and memory content is deleted and module performs a cold start.

Field	Description
\$PSRF132	protocol header
Clear type	17: clear all / NMEA 4800 33: clear all / OSP 115200
Erase data type	0
Reserved	0

Table 55: Factory reset

Example: factory reset with NMEA 4800 Bd

\$PSRF132,17,0,0\*0D

Example: factory reset with OSP 115200 Bd

\$PSRF132,33,0,0\*0B



Configuration is lost after Factory Reset or power cycle, not after turn off

- **\$PSRF125:**

\$PSRF125 allows polling SW version string. The complete command is simply:

\$PSRF125\*21

Module responds with NMEA output message \$PSRF195.

## 10.2 OSP sentences

Overall OSP message structure is represented here below. It is the basis for understanding all OSP input and output messages. All messages start with the sequence A0 A2 and end with the sequence B0 B3. The start sequence is followed by payload length, payload, and payload checksum fields. Data format is HEX.

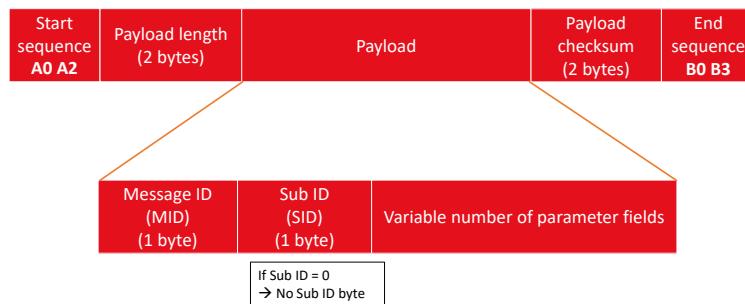


Figure 36: OSP Sentences for Erinome-II

The checksum is calculated through the following formula:

$$(\text{Payload\_byte1} + \text{Payload\_byte2} + \dots + \text{Payload\_byteN}) \text{ AND } (0x7FFF)$$

If not differently specified, MSB comes first in all OSP data fields.

Example message with following payload:

- ID 56 (HEX 38) , SubID 95 (HEX 5F)

- 4 bytes of data (all zeros): total payload length (including ID and SubID): 6 bytes (HEX 00 06)

$$\text{Checksum} = (38 + 5F + 00 + 00 + 00 + 00 + 00) \text{ AND } (7FFF) = 00\ 97$$

Completing with start and end sequence we obtain:

A0 A2 00 06 38 5F 00 00 00 00 00 97 B0 B3

Data types are indicated in the descriptions through following symbols.

Data Type	Description
n U	Unsigned value of byte length n
n S	Signed value of byte length n
n D	Discrete, bitmapped values occupying n bytes
n F	Floating point number, n is either 4 or 8

Table 56: Data types

### 10.2.1 OSP sentences overview

MID	Input/Output	Short description	Link to description
MID 67,1	Output	Multiconstellation navigation data	MID67,1
MID 67,16	Output	Multiconstellation satellite data	MID67,16
MID 2	Output	Measure navigation data indication	MID2
MID 66	Output	DOP values indication	MID66
MID 51,01	Output	Navigation cycle complete	MID51,1
MID 6	Output	Software version. Response to MID 132	MID6
MID18	Output	Indicates module status	MID18
MID 11	Output	Positive acknowledgement. Indicates successful request.	MID11
MID 12	Output	Negative acknowledgement. Indicates unsuccessful request.	MID12
MID 129	Input	Switch protocol and baud rate.	MID129
MID 134	Input	Switch baud rate.	MID134
MID 132	Input	Poll software version	MID132
MID 222,16	Input	Manage constellation settings	MID222,16
MID 136	Input	Enable/Disable 5 Hz navigation	MID136
MID 218,6	Input	Configure power modes	MID218,6

Table 57: Message overview for OSP messages

## 10.2.2 OSP output sentences

Most relevant OSP output messages are the ones containing position, time and related information about the position fix. If the module is in full power mode, these are sent automatically with the configured update rate. Other OSP output messages are sent in response to specific commands or events. OSP output message types and corresponding payload fields are explained in the following pictures and table.

- **MID 67,1- Multiconstellation Navigation Data:**

Field	Bytes	Description
ID, optional SubID	2 U	67,1 (HEX 43 01)
Navigation valid	4 D	00 00 00 00: Navigation valid else: Navigation not optimal (<5 SV)
Not supported	4 D	-
GPS Week	2 U	GPS week number. Week 0 starts on 6th January 1980
Time of Week	4 U	Measured in seconds (scaled by $10^3$ )
Not supported	8 U	-
UTC year	2 U	UTC year
UTC month	1 U	UTC month, 1 to 12
UTC day	1 U	UTC day of month, 1 to 31
UTC hour	1 U	UTC hour, 0 to 23
UTC minute	1 U	UTC minute, 0 to 59
UTC second	2 U	UTC second, 0 to 59.999 in s, scaled by $10^3$
UTC offset	1 U	Integer offset between UTC and GPS time (sec)
Model	1 U	21 (HEX 15): WGS84
Not supported	20 U	-
Latitude	4 S	Position Latitude. Positive value indicates North, degrees, scaled by $10^7$
Longitude	4 S	Position Longitude. Positive value indicates East, degrees, scaled by $10^7$
Altitude (WGS 84)	4 S	Altitude relative to the WGS-84 ellipsoid, meters, scaled by $10^2$
Altitude (MSL)	4 S	Altitude from mean sea level: altitude using geoid model, meters, scaled by $10^2$
Speed Over Ground	2 U	Speed Over Ground (horizontal component of velocity), m/s, scaled by $10^2$
Course Over Ground	2 U	Course over ground, clockwise from true north, degrees, scaled by $10^2$

Field	Bytes	Description
Climb rate	2 S	Vertical component of velocity, m/s, scaled by $10^2$
Heading rate	2 S	Rate of change of course over ground, deg/sec, scaled by $10^2$
Distance traveled	4 U	Distance traveled since reset (m)
Heading error	2 U	Estimate of error in course over ground (COG), degrees, scaled by $10^2$
Distance traveled error	2 U	Estimate of error in distance (m)
EHPE	4 U	Estimated Horizontal Position Error (m), scaled by $10^2$
EVPE	4 U	Estimated Vertical Position Error (m), scaled by $10^2$
EHVE	2 U	Estimated Horizontal Velocity Error (m/s), scaled by $10^2$
GDOP	1 U	Geometric Dilution Of Precision, scaled by 5
PDOP	1 U	Position Dilution Of Precision, scaled by 5
HDOP	1 U	Horizontal Dilution Of Precision, scaled by 5
VDOP	1 U	Vertical Dilution Of Precision, scaled by 5
TDOP	1 U	Time Dilution Of Precision, scaled by 5
Satellites used	1 U	Number of satellites used in solution
SV List (1)	4 D	List of GPS satellites used in solution (Bits 0-31: PRNs 1-31)
SV List (2)	4 D	List of SBAS satellites used in solution (Bits 0-18: PRNs 1-18)
SV List (3)	4 D	List of GLONASS satellites used in solution (Bits 0-23: Slot Numbers 1-24)
SV List (4)	4 D	List of QZSS and BeiDou satellites used in solution. Bits [0:4] Slot Numbers 193-197 Bits [5:9] future QZSS satellites 198-202 Bits [10:14] BeiDou PRN 150 - 154
SV List (5)	4 D	BeiDou satellites used in solution Bits [0:4]: BeiDou PRN 155 - 159 Bits [5:31]: BeiDou PRN 38 - 64
Not supported	4 D	-

Table 58: MID 67,1 - Multiconstellation Navigation Data

An example of this message is:

```
A0 A2 00 7E 43 01 00 00 00 00 00 00 04 08 25 12 C7 F0 07 00 0F 41 DF 00
00 02 01 07 E3 0C 19 0F 1F 42 10 15 E1 00 00 00 41 B8 03 48 00 00 00 00 00 00 1B 7B
24 00 00 00 00 1C B3 1C 9A 06 E7 7A 42 00 00 D4 8A 00 00 C1 F7 00 00 60 22 00
00 00 00 00 00 00 00 00 00 00 00 00 02 DC 00 00 05 C2 00 02 0E OC 06 0B 07 09
54 16 00 30 00 00 00 00 00 02 00 00 00 00 00 00 00 00 00 00 03 08 11 B1 B0
B3
```

- **MID 67,16 - Multiconstellation Satellite Data:**

Field	Bytes	Description
ID, optional SubID	2 U	67,16 (HEX 43 10)
GPS Week	2 U	GPS week number. Week 0 starts on 6th January 1980
Time of Week	4 U	Measured in seconds (scaled by $10^3$ )
Not supported	8	-
Messages info	1 U	Bits 7 - 4: number of messages in this group Bits 3 - 0: message number within the group
Number of sats	1 U	Total number of satellites reported in this group of messages (range 1-15)
Satellite	[15] × 12	Repetitions of data pattern described in table 60: MID 67,16 - Satellite information

Table 59: MID 67,16 - Multiconstellation Satellite Data

Field	Bytes	Description
Satellite info	2 U	<p>Satellite information and status, packed as follows:</p> <p>Bits [15:13]: Constellation type enumeration      0 = GPS/QZSS      1 = SBAS      2 = GLONASS      3 = Galileo      4 = BeiDou</p> <p>Bits [12:8] : Other info      For GLONASS, frequency channel -7 to 6.      For SBAS      0 = WAAS      1 = EGNOS      2 = MSAS      3 = GAGAN      other: reserved</p> <p>Bits [7:0] : ID      For GPS and SBAS, this field reports PRN.      For GLONASS, Slot Number 1-24      For BeiDou, PRN</p>
Azimuth	2 U	SV azimuth, deg, clockwise from true north, scaled by 10
Elevation	2 U	SV elevation above horizon, deg, scaled by 10
Carrier-to-noise	2 U	Average Carrier-to-noise ratio, dB-Hz, scaled by 10
Status	4 D	<p>Satellite status. Following description of each bit is effective when the specified bit is set.</p> <p>Bit 0: successful acquisition/re-acquisition      Bit [1-5]: not supported      Bit 6: reserved      Bit 7: ephemeris data is available.      Bits [8-14]: reserved      Bit 15: satellite used in solution.      Bits [16-31]: reserved</p>

Table 60: MID 67,16 - Satellite information

An example of this message is:

```
A0 A2 00 C6 43 10 08 25 13 0E E7 FF 00 0F 41 FC 00 00 02 01 21 1A 00 15 09 3A
03 36 01 92 00 00 82 BF 00 06 0B B1 02 94 01 90 00 00 82 BF 00 13 0B A9 02 61 01
91 00 00 82 BF 00 1B 0B AA 02 41 01 91 00 00 82 BF 00 12 04 0F 01 FA 01 91 00 00
82 BF 00 1D 03 F3 01 31 01 91 00 00 82 BF 00 05 01 D8 00 F3 01 91 00 00 82 BF 00
16 06 F7 00 E0 01 90 00 00 82 BF 00 20 06 AC 00 D8 01 8B 00 00 82 BF 00 10 0C
61 00 CC 01 91 00 00 82 BF 00 07 0C 5C 00 88 01 92 00 00 82 BF 00 1F 09 0B 00
57 01 91 00 00 82 BF 00 0F 02 06 00 4F 01 92 00 00 82 BF 00 C1 0B AF 00 B2 00 00
00 00 00 00 00 1A 01 5C 00 2B 00 00 00 00 00 00 2D BB B0 B3
```

- **MID 2 - Measure Navigation Data Indication:**

Field	Bytes	Description
ID	1 U	2 (HEX 02)
ECEF X	4 S	X position (ECEF system), meters
ECEF Y	4 S	Y position (ECEF system), meters
ECEF Z	4 S	Z position (ECEF system), meters
ECEF vel X	2 S	X velocity (ECEF system), m/s, scaled by 8
ECEF vel Y	2 S	Y velocity (ECEF system), m/s, scaled by 8
ECEF vel Z	2 S	Z velocity (ECEF system), m/s, scaled by 8
Not supported	1	-
HDOP	1 U	Horizontal Dilution Of Precision, scaled by 5
Not supported	1	-
GPS Week	2 U	GPS week number. Week 0 starts on 06.01.1980
Time of Week	4 U	Measured in seconds (scaled by $10^3$ )
Satellites used	1 U	Number of satellites used in solution, 0 to 18
SV used	[18]	Satellite ID (see table 62: for PRN mapping)

Table 61: MID 2 - Measure Navigation Data Indication

Value	Constellation	Description
0	None	No report
1-32	GPS	Satellite PRN code
38-64	BeiDou	PRN+27
65-88	GLONASS	Channel (-7 to +6) + 77
120-138	GPS SBAS	SBAS PRN code
150-159	BeiDou	PRN+149
173-187, 193-202	QZSS	Satellite PRN code
205-254	Galileo	PRN+204

Table 62: Satellite PRN mapping

An example of this message is:

A2 00 2F 02 00 55 F8 C6 00 1F 4A 89 00 21 13 92 00 00 00 00 00 00 04 04 02 00 23  
02 35 8D 40 0A 17 11 01 13 0D 1F 0B 14 03 20 00 00 00 00 00 00 00 05 B2 B0 B3

- **MID 66 - DOP Values Indication:**

Field	Bytes	Description
ID	1 U	66 (HEX 42)
Time of Week	4 U	Measured in seconds (scaled by $10^3$ )
GDOP	2 U	Geometric Dilution Of Precision (scaled by 10)
PDOP	2 U	Position Dilution Of Precision (scaled by 10)
HDOP	2 U	Horizontal Dilution Of Precision (scaled by 10)
VDOP	2 U	Vertical Dilution Of Precision (scaled by 10)
TDOP vel Z	2 U	Time Dilution Of Precision (scaled by 10)

Table 63: MID 66 - DOP Values Indication

An example of this message is:

A0 A2 00 0F 42 04 F8 18 40 00 0D 00 0C 00 06 00 0A 00 06 01 C5 B0 B3

- **MID 51,1:**

MID 51,1 is sent at the end of every navigation cycle and indicates that all messages for this cycle have been sent.

Field	Bytes	Description
ID, optional SubID	2 U	51,01 (HEX 33 01)
Reserved	1 U	Reserved (set to 0)

Table 64: MID 51,1 - Navigation Cycle Complete

The complete sentence is:

A0 A2 00 03 33 01 00 00 34 B0 B3

- MID 6:**

MID 6 is sent from the receiver in response to poll SW version command

Field	Bytes	Description
ID	1 U	6 (HEX 06)
Length SiRF SW Version	1 U	Size of SiRF SW version field including terminating 0x00
Length Customer SW Version	1 U	Size of Customer SW version field including terminating 0x00
SiRF SW Version	specified in field Length SiRF SW Version	SiRF SW version as ASCII. Terminated by 0x00
Customer SW Version	specified in field Length Customer SW Version	Customer SW version as ASCII (optional). Terminated by 0x00

Table 65: MID 6 - SW Version

An example of this message with SiRF software version "5xp\_5.5.2-R32+5xpt\_5.5.2-R32" and undefined Customer SW Version: An example of this message is:

A0 A2 00 22 06 1E 01 35 78 70 5F 5F 35 2E 35 2E 32 2D 52 33 32 2B 35 78 70  
74 5F 35 2E 35 2E 32 2D 52 33 32 00 00 07 D3 B0 B3

- MID 18:**

MID 18 is sent from the receiver to indicate status and if communication with host is possible.

Field	Bytes	Description
ID	1 U	18 (HEX 12)
Send indicator	1 U	0: Receiver is about to be in sleep mode (HEX 00) 1: Receiver is not in sleep mode (HEX 01)

Table 66: MID 18 - Ok To Send

Example of Ok To Send at module start-up:

A0 A2 00 02 12 01 00 13 B0 B3

- **MID 11:**

MID 11 is sent from the receiver to indicate that a request from host was accepted and successfully executed (ACK).

Field	Bytes	Description
ID	1 U	11 (HEX 0B)
Send indicator	1 U	ID of the successful request
Send indicator	1 U	SubID of the successful request

Table 67: MID 11 - Command Acknowledgment Response

Example of ACK for poll SW version request (MID 132, HEX 84):

A0 A2 00 03 0B 84 00 8F B0 B3

- **MID 12:**

MID 12 is sent from the receiver to indicate that a request from host failed (NACK).

Field	Bytes	Description
ID	1 U	12 (HEX 0C)
Send indicator	1 U	ID of the failed request
Send indicator	1 U	SubID of the failed request

Table 68: MID 12 - Command Negative Acknowledgment Response

Example of NACK for poll SW version request (MID 132, HEX 84):

A0 A2 00 03 0C 84 00 90 B0 B3

### 10.2.3 OSP input sentences

Most relevant OSP input message types and corresponding payload fields are described in the following pictures and table.

- **MID 129:**

MID 129 switches the protocol to NMEA with the desired baud and messages rate configuration.

Field	Bytes	Description
ID	1 U	129 (HEX 81)
Mode	1 U	0: Enable NMEA debug messages 1: Disable NMEA debug messages
NMEA config	[10] × 2U	Array specifying output rate for each NMEA message. Mapping inside the array: GGA, GLL, GSA, GSV, RMC, VTG, MSS, EPE, ZDA, unused. Entry (2 bytes) for each message: 1 U: number of seconds between reports. If 0 (HEX 00): no reports. 1 U: 1 (HEX 01)
Baud rate	2 U	Valid baud rates: 4800, 9600, 19200, 38400, 57600

Table 69: MID 129 - Switch NMEA protocol request

Example: switch to NMEA, with: baud rate 4800, GGA, GLL, GSA, GSV, RMC, VTG messages active at 1 Hz (1 msg/sec)

Start sequence: A0 A2

Length: 24 (HEX 00 18)

ID: 129 (HEX 81)

Mode: 0 (HEX 00)

NMEA config: 0101 0101 0101 0101 0101 0101 0001 0001 0001 0101

baud rate: 4800 (HEX 12C0)

Checksum: 0164

End sequence: B0B3

The complete message is therefore:

A0 A2 00 18 81 00 01 01 01 01 01 01 01 01 01 01 01 00 01 00 01 01 01 12 C0 01 64 B0 B3

- **MID 134:**

MID 134 switches the baud rate without changing the protocol.

Field	Bytes	Description
ID	1 U	134 (HEX 86)
Mode	4 U	0: Valid baud rates: 4800 9600 19200 38400 57600 115200 230400 460800 921600 1228800
Data bits	1 U	Valid bits per byte: 8 (HEX 08)
Stop bits	1 U	Valid number of stop bits: 1 (HEX 01)
Parity	1 U	0: none (HEX 00)
Reserved	1 U	0 (HEX 00)

Table 70: MID 134 - Baud rate selection

Example: set baud rate 4800

A0 A2 00 09 86 00 00 12 C0 08 01 00 00 01 61 B0 B3

- **MID 132:**

MID 132 request software version. Module responds with MID 6.

Field	Bytes	Description
ID	1 U	132 (HEX 84)
Reserved	1 U	Reserved (set to 0)

Table 71: MID 132 - SW version request

Full sentence is:

A0 A2 00 02 84 00 00 84 B0 B3

- **MID 222,16:**  
MID 222,16 manages constellation settings.

Field	Bytes	Description
ID	2 U	222,16 (HEX 0xDE,0x10)
Reserved	3 U	Reserved (set to 0)
PrimConst.	1 U	Primary GNSS constellation 0: GPS 1: GLONASS 2: Galileo 3: BeiDou
TechSet	2 U	GNSS technologies (enabled when set to 1) Bits [15:8]: Reserved (set to 0) Bit 7: GPS L1C Bit 6: QZSS-IMES Bit 5: QZSS Bit 4: SBAS Bit 3: BeiDou Bit 2: Galileo Bit 1: GLONASS Bit 0: GPS Bit 1 (GLONASS) and bit 3 (BeiDou) cannot be enabled at the same time.
Not supported	2 U	Not supported (set to 0)
Reserved	4 U	Reserved (set to 0)

Table 72: MID 222,16 - Location Technology Constraints Request



GLONASS and BeiDou cannot be used simultaneously

Example: set GPS-GLONASS mode

A0 A2 00 0E DE 10 00 00 00 00 00 03 00 00 00 00 00 00 F1 B0 B3

Example: set GLONASS-only mode

A0 A2 00 0E DE 10 00 00 00 01 00 02 00 00 00 00 00 00 F1 B0 B3

Example: set GPS-only mode

A0 A2 00 0E DE 10 00 00 00 00 00 01 00 00 00 00 00 00 EF B0 B3

- **MID 128:**

This message forces Erinome-II to perform a restart according to command settings

Field	Bytes	Description
ID	1 U	128 (HEX 80)
ECEF_x	4 S	X position (ECEF coordinate system, meters)
ECEF_y	4 S	Y position (ECEF coordinate system, meters)
ECEF_z	4 S	Z position (ECEF coordinate system, meters)
clk_offset	4 S	Set to 0 (Hz)
TOW	4 U	GPS TOW of the measurement Units: seconds, scaled by 100 Range: 0 to 604,799.999 s
GPS_week	2 U	Week number
Chnl_cnt	1 U	Number of channels: 12 (HEX 0C)
Restart_flags	1 U	Restart configuration: 3A: factory reset 04: cold start 02: warm start (no initialization data) 03: warm start (with initialization data) 00: hot start

Table 73: MID 128 - Initialize Data Source Request



if a factory reset is executed, the module switches to NMEA protocol with 4800 baud.

Example: execute factory reset

## Example: execute cold start

Example: execute warm start (no init)

- MID 136:**

This message enables and disables 5 Hz navigation

Field	Bytes	Description
ID	1 U	136 (HEX 88)
Reserved	2 U	Reserved (set to 0)
Degraded mode	1 U	Disabled: 04
Pos. Mode	1 D	5 Hz navigation enabled: 0x04 10 Hz navigation enabled: 0x20 5 Hz or 10 Hz navigation disabled: 0x00
Reserved	7 U	Reserved ( set to 0)
TimeOut	1 U	Range: 1 to 120 s (default 5 s). If signal is lost, last computed position continues to be reported after this time.
AcqAndTrack	1 D	<p>Bit [7:5]: Reserved</p> <p>Bit [4:3]: Channel usage: provides a means to control power used during acquisition and tracking (navigation). "Full" uses all resources available and the most power. "Limited" uses less power and restricts usage to the minimum necessary to find satellites.</p> <p>00 = Acquisition and navigation are full</p> <p>01 = Acquisition is limited, navigation is full</p> <p>10 = Acquisition is full, navigation is limited</p> <p>11 = Acquisition and navigation are limited</p> <p>Bit 2: High sensitivity tracking loop. If this bit is disabled, power usage is reduced while trading high sensitivity.</p> <p>0 = Enable tracking loop</p> <p>1 = Disable tracking loop</p> <p>Bit 1: Smoothed measurements</p> <p>0 = Use raw measurements</p> <p>1 = Use smooth measurements</p> <p>Bit 0: Track smoothing</p> <p>0 = Disable track smoothing</p> <p>1 = Enable track smoothing</p>

Table 74: MID 136 - Mode control

Example: enable 5 Hz navigation (no track smoothing, smoothed measurements active, tracking loop disabled, acquisition and navigation limited)

A0 A2 00 0E 88 00 00 04 04 00 00 00 00 00 00 0F 1A 00 B9 B0 B3

- MID 218,6:**

This message can be used to activate and configure available low power modes.

Field	Bytes	Description
ID, optional SubID	2 U	218,6 (HEX 0xDA 0x06)
PowerMode	1 U	Power mode selection 0: Full Power Mode 1: Low Power Mode
Feature list	1 U	0x00: SiRFSmartGNSS disabled 0x02: Enable SiRFSmartGNSS I 0x06: Enable SiRFSmartGNSS II
Version	1 U	Set to 0
LPM rate (upper)	1 U	Upper byte of LPM rate in seconds The value for the LPM rate is computed by combining the value in this field multiplied by $2^{16}$ and adding to LPM rate (upper).
LPM rate (lower)	2 U	Lower 2 bytes of the LPM rate in seconds Special values of the LPM rate indicate: - If useMask bit 2 is 0: Trickle Power. - If useMask bit 2 is 1: Push-To-Fix - 1 to 29: Value is rounded to a multiple of 6 - 30 to 86400: Value is rounded to a multiple of 30
UseMask	2 D	Use mask bitmap bit 0: 0: Use LPM defaults 1: Use LPM settings of corresponding fields below bit 1: Reserved (set to 0) bit 2: 0: Use Trickle Power 1: Enable PTF at 6s Bit [3-15]: Reserved (set to 0)
MAX_SEARCH_TIME (TP and PTF)	2 U	Max Search Time of acquisition attempts (sec) Valid for both TP and Push-to-Fix. Rounded to a multiple of 30 seconds for PTF. Default: 120 s
MAX_OFF_TIME (TP and PTF)	2 U	Max Off Time when the search fails (sec) Valid for both TP and Push-to-Fix. Rounded to a multiple of 30 seconds for PTF. Default: 30 s
Not supported	6 U	Not supported (set to 0)
RF ON Time (TP only)	2 U	Amount of time for RF to be on for signal acquisition Units: ms, range: 100 to 800 ms (100 ms intervals), recommended 200 ms
Reserved	20 U	Reserved (set to 0)

Table 75: MID 218,6 - Low Power Mode Request



Only 1 to 3 seconds Trickle Power rate is allowed. Recommended value for RF ON time is 200 ms.

Example: set Trickle Power mode with:

```
rate = 10 s
RF ON time = 200 ms
MAX_OFF_TIME = 30 s
MAX_SEARCH_TIME = 120 s
```

```
A0 A2 00 2A DA 06 01 00 00 00 00 0A 00 01 00 78 00 1E 00 00 00 00 00 00
C8 00 00 00 04 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 02 4E B0 B3
```

Example: set Push To Fix with:

```
rate = 10 s
RF ON time = 200 ms
MAX_OFF_TIME = 30 s
MAX_SEARCH_TIME = 120 s
```

```
A0 A2 00 2A DA 06 01 00 00 00 00 1E 00 05 00 5A 00 3C 00 00 00 00 00 00
00 00 00 00 04 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 01 9E B0 B3
```

The sleep times and the LPM rates can be verified through:

- the flow of messages from the module: no messages during sleep times, flow starts again during full power time slots
- Ok To Send and Not Ok To Send messages: sent from the module at every transition full power/sleep
- LEDs on module EV-Board (if used)

Example: set SiRFStarGNSS I:

```
A0 A2 00 2A DA 06 00 02 00 00 00 0A 00 05 00 78 00 1E 00 00 00 00 00 00
C8 00 00 00 04 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 02 53 B0 B3
```

# 11 UserSettings

Default configuration of the module is stored in module's flash memory. Changing default settings is possible by flashing a new firmware version on the unit (action is not open to customers). New firmware versions might be provided in the future after prior notice. All changes to settings made during runtime are volatile.

While in full power mode, software commands described in this manual allow partial changing of this configuration. Power cycling the module, as well as performing a factory reset, causes the loss of these volatile changes and returning to the default settings as shown below.

## 11.1 Default Settings

Setting	State
Power On State	Hibernate
Data Format	NMEA
UART Settings	4800 bps, 8 data bits, no parity, one stop bit
I <sup>2</sup> C Settings	Multi-Master, 400 kbps
SPI Settings	Slave, up to 6.8 MHz
Satellite Constellation	GPS, GLONASS, Galileo (+SBAS)
NMEA Messages	\$GPGGA, \$GNGNS, \$GNGSA, \$GNRMC: 1 msg/1 sec; \$GPGSV, \$GLGSV: 1 msg/5 sec

Table 76: Default firmware Settings

## 12 Manufacturing information

### 12.1 Moisture sensitivity level

This wireless connectivity product is categorized as JEDEC Moisture Sensitivity Level 3 (MSL3), which requires special handling.

More information regarding the MSL requirements can be found in the IPC/JEDEC J-STD-020 standard on [www.jedec.org](http://www.jedec.org).

More information about the handling, picking, shipping and the usage of moisture/reflow and/or process sensitive products can be found in the IPC/JEDEC J-STD-033 standard on [www.jedec.org](http://www.jedec.org).

### 12.2 Soldering

#### 12.2.1 Reflow soldering

Attention must be paid on the thickness of the solder resist between the host PCB top side and the modules bottom side. Only lead-free assembly is recommended according to JEDEC J-STD020.

Profile feature		Value
Preheat temperature Min	$T_{S\ Min}$	150 °C
Preheat temperature Max	$T_{S\ Max}$	200 °C
Preheat time from $T_{S\ Min}$ to $T_{S\ Max}$	$t_S$	60 - 120 seconds
Ramp-up rate ( $T_L$ to $T_P$ )		3 °C / second max.
Liquidous temperature	$T_L$	217 °C
Time $t_L$ maintained above $T_L$	$t_L$	60 - 150 seconds
Peak package body temperature	$T_P$	see table below
Time within 5 °C of actual peak temperature	$t_P$	20 - 30 seconds
Ramp-down Rate ( $T_P$ to $T_L$ )		6 °C / second max.
Time 20 °C to $T_P$		8 minutes max.

Table 77: Classification reflow soldering profile, Note: refer to IPC/JEDEC J-STD-020E

Package thickness	Volume mm <sup>3</sup> <350	Volume mm <sup>3</sup> 350-2000	Volume mm <sup>3</sup> >2000
< 1.6 mm	260 °C	260 °C	260 °C
1.6 mm - 2.5 mm	260 °C	250 °C	245 °C
> 2.5 mm	250 °C	245 °C	245 °C

Table 78: Package classification reflow temperature, PB-free assembly, Note: refer to IPC-/JEDEC J-STD-020E

It is recommended to solder this module on the last reflow cycle of the PCB. For solder paste use a LFM-48W or Indium based SAC 305 alloy (Sn 96.5 / Ag 3.0 / Cu 0.5 / Indium 8.9HF / Type 3 / 89%) type 3 or higher.

The reflow profile must be adjusted based on the thermal mass of the entire populated PCB, heat transfer efficiency of the reflow oven and the specific type of solder paste used. Based on the specific process and PCB layout the optimal soldering profile must be adjusted and verified. Other soldering methods (e.g. vapor phase) have not been verified and have to be validated by the customer at their own risk. Rework is not recommended.

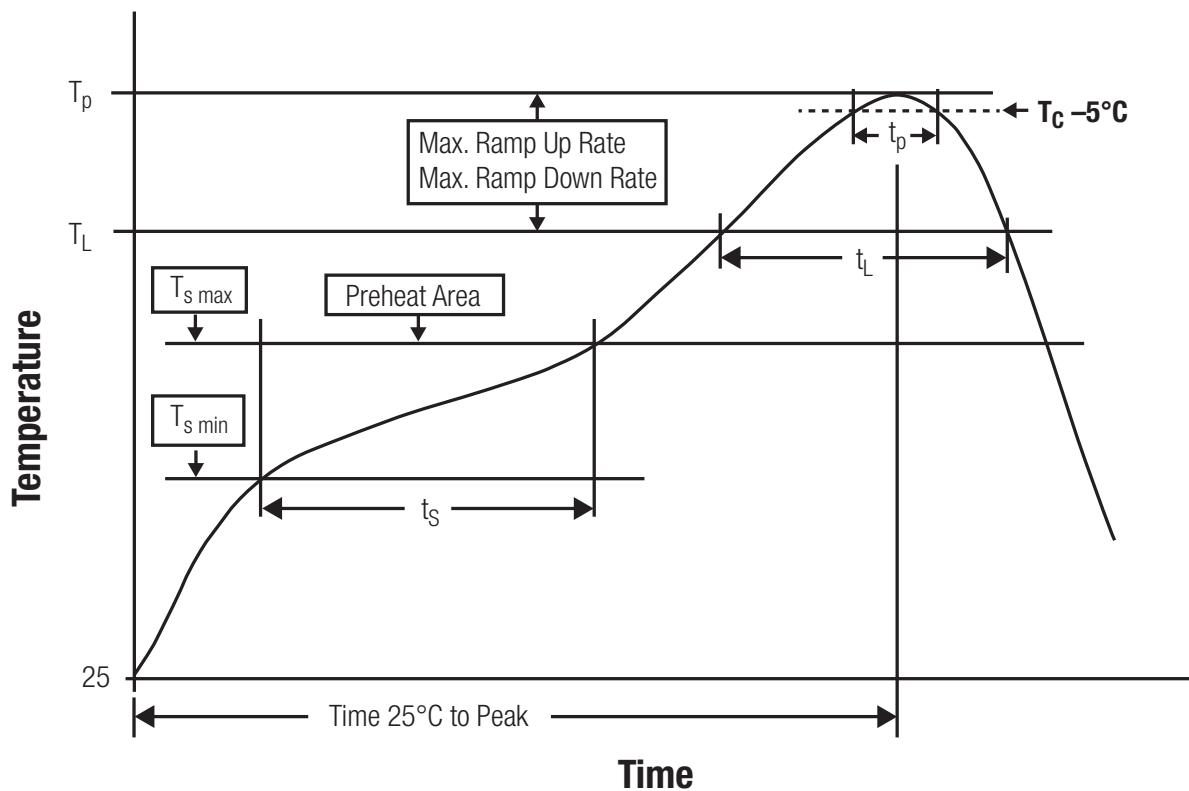


Figure 37: Reflow soldering profile

After reflow soldering, visually inspect the board to confirm proper alignment

## 12.2.2 Cleaning

Do not clean the product. Any residue cannot be easily removed by washing. Use a "no clean" soldering paste and do not clean the board after soldering.

- Do not clean the product with water. Capillary effects can draw water into the gap between the host PCB and the module, absorbing water underneath it. If water is trapped inside, it may short-circuit adjoining pads. The water may also destroy the label and ink-jet printed text on it.
- Cleaning processes using alcohol or other organic solvents may draw solder flux residues into the housing, which won't be detected in a post-wash inspection. The solvent may also destroy the label and ink-jet printed text on it.
- Do not use ultrasonic cleaning as it will permanently damage the part, particularly the crystal oscillators.

## 12.2.3 Potting and coating

- If the product is potted in the customer application, the potting material might shrink or expand during and after hardening. Shrinking could lead to an incomplete seal, allowing contaminants into the component. Expansion could damage components. We recommend a manual inspection after potting to avoid these effects.
- Conformal coating or potting results in loss of warranty.
- The RF shield will not protect the part from low-viscosity coatings and potting. An undefined amount of coating and potting will enter inside the shielding.
- Conformal coating and potting will influence the parts of the radio front end and consequently influence the radio performance.
- Potting will influence the temperature behaviour of the device. This might be critical for components with high power.

## 12.2.4 Other notations

- Do not attempt to improve the grounding by forming metal strips directly to the EMI covers or soldering on ground cables, as it may damage the part and will void the warranty.
- Always solder every pad to the host PCB even if some are unused, to improve the mechanical strength of the module.
- The part is sensitive to ultrasonic waves, as such do not use ultrasonic cleaning, welding or other processing. Any ultrasonic processing will void the warranty.

## 12.3 ESD handling

This product is highly sensitive to electrostatic discharge (ESD). As such, always use proper ESD precautions when handling. Make sure to handle the part properly throughout all stages of production, including on the host PCB where the module is installed. For ESD ratings, refer to the module series' maximum ESD section. For more information, refer to the relevant chapter 2. Failing to follow the aforementioned recommendations can result in

severe damage to the part.

- the first contact point when handling the PCB is always between the local GND and the host PCB GND, unless there is a galvanic coupling between the local GND (for example work table) and the host PCB GND.
- Before assembling an antenna patch, connect the grounds.
- While handling the RF pin, avoid contact with any charged capacitors and be careful when contacting any materials that can develop charges (for example coaxial cable with around 50-80 pF/m, patch antenna with around 10 pF, soldering iron etc.)
- Do not touch any exposed area of the antenna to avoid electrostatic discharge. Do not let the antenna area be touched in a non ESD-safe manner.
- When soldering, use an ESD-safe soldering iron.

## 12.4 Safety recommendations

It is your duty to ensure that the product is allowed to be used in the destination country and within the required environment. Usage of the product can be dangerous and must be tested and verified by the end user. Be especially careful of:

- Use in areas with risk of explosion (for example oil refineries, gas stations).
- Use in areas such as airports, aircraft, hospitals, etc., where the product may interfere with other electronic components.

It is the customer's responsibility to ensure compliance with all applicable legal, regulatory and safety-related requirements as well as applicable environmental regulations. Disassembling the product is not allowed. Evidence of tampering will void the warranty.

- Compliance with the instructions in the product manual is recommended for correct product set-up.
- The product must be provided with a consolidated voltage source. The wiring must meet all applicable fire and security prevention standards.
- Handle with care. Avoid touching the pins as there could be ESD damage.

Be careful when working with any external components. When in doubt consult the technical documentation and relevant standards. Always use an antenna with the proper characteristics.



Würth Elektronik eiSos radio modules with high output power of up to 500 mW, as for example the radio module Thebe-II, generate a high amount of warmth while transmitting. The manufacturer of the end device must take care of potentially necessary actions for his application.

# 13 Physical dimensions

## 13.1 Dimensions

Dimensions
7.00 * 7.00 * 1.6 mm

Table 79: Dimensions

Tolerances: see chapter 13.3

## 13.2 Weight

Weight
0.2 g

Table 80: Weight

Tolerance:  $\pm 0.03$  g

### 13.3 Module drawing

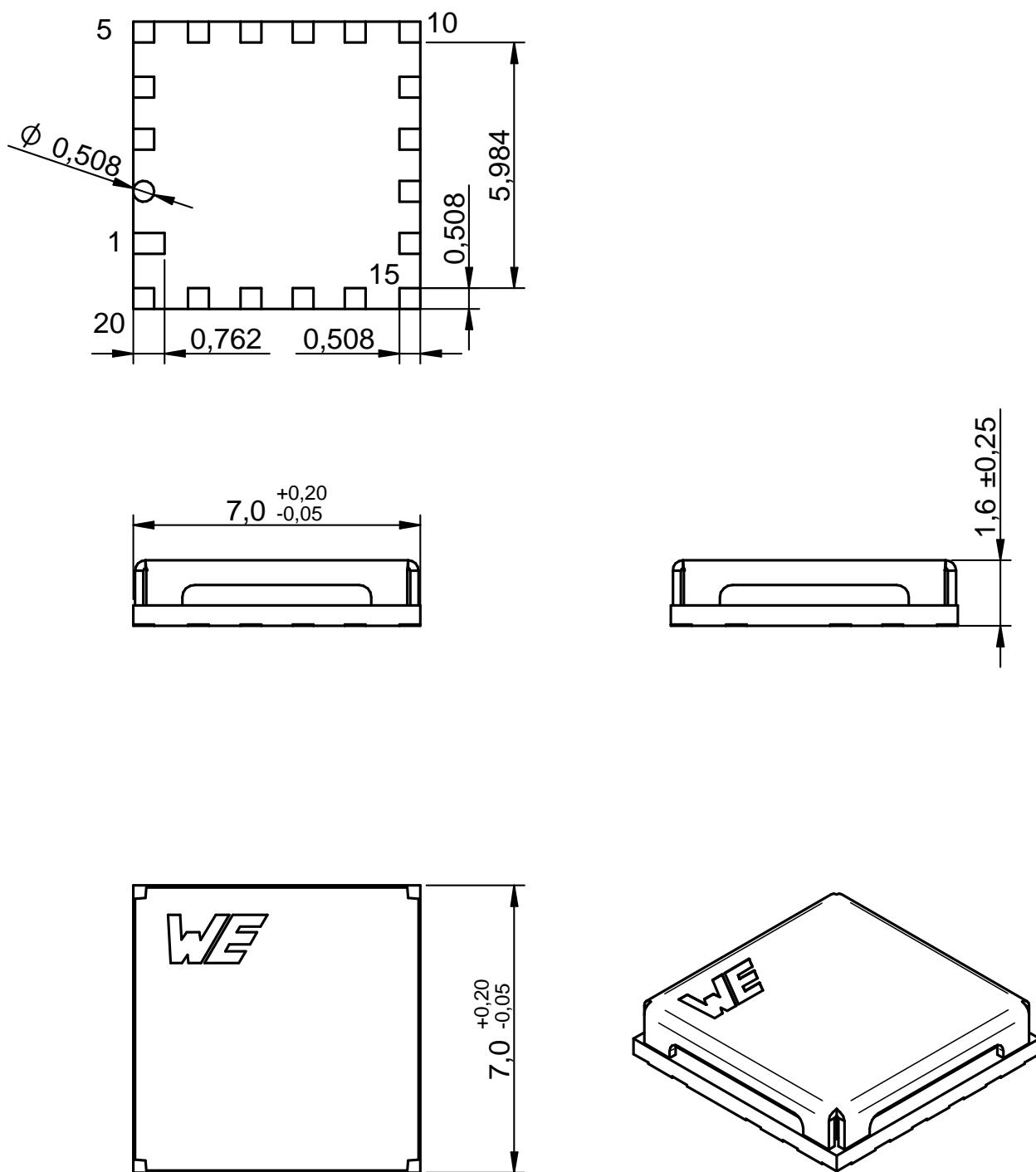


Figure 38: Module dimensions [mm]

### 13.4 Footprint

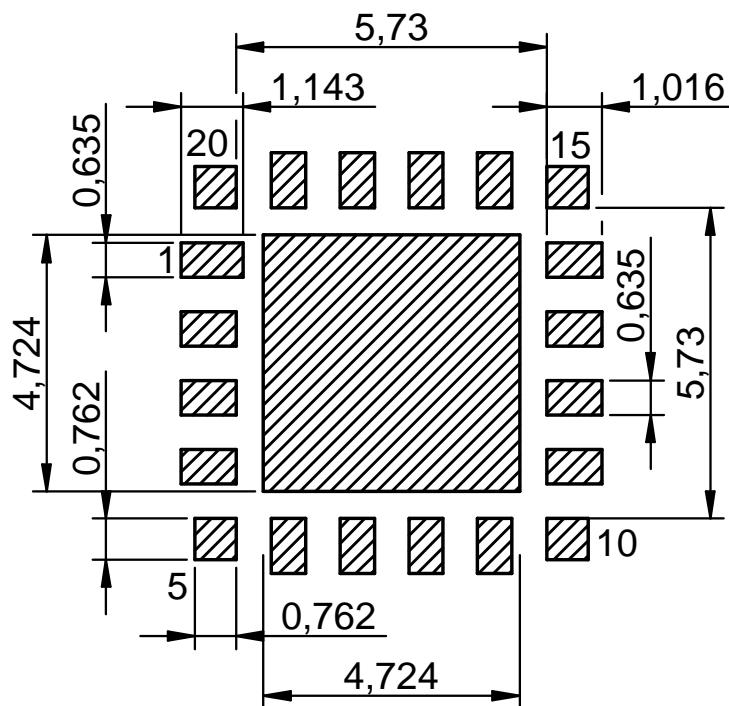


Figure 39: Footprint and dimensions [mm]

## 14 Marking

### 14.1 Lot number

The 15 digit lot number is printed in numerical digits as well as in form of a machine readable bar code. It is divided into 5 blocks as shown in the following picture and can be translated according to the following table.

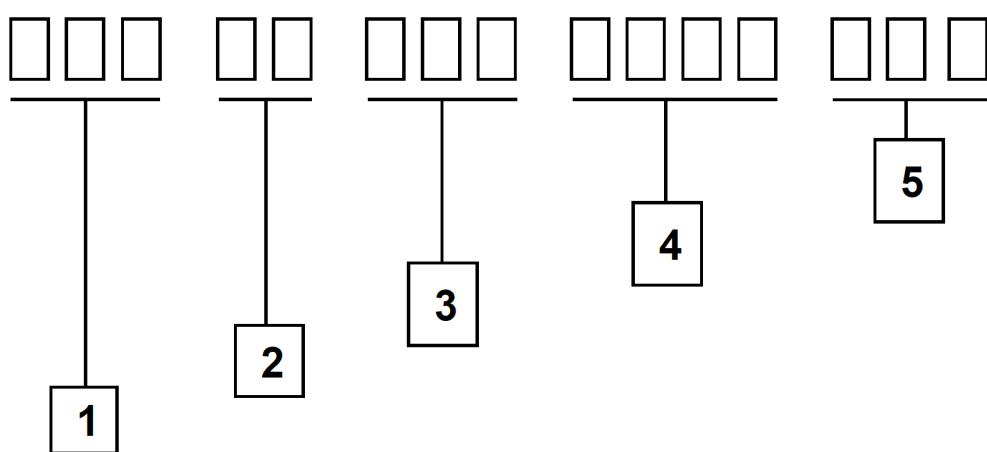


Figure 40: Lot number structure

Block	Information	Example(s)
1	WE eiSos internal, 3 digits	439
2	WE eiSos internal, 2 digits	01
3	Hardware version, 3 digits	V2.4 = 024, V12.2 = 122
4	Date code, 4 digits	1703 = week 03 in year 2017, 1816 = week 16 in year 2018
5	Firmware version, 3 digits	V3.2 = 302, V5.13 = 513

Table 81: Lot number details

## 14.2 General labeling information

The module labels include the following fields.

Field example (see picture below)	Description
WE	Company logo
CE	CE certification
19	Date code YY (Year Year)
50	Date code WW (Week Week)
2614021137000	Article number
Erinome-II	Product name

Table 82: Label of the Erinome-II



Figure 41: Label of the Erinome-II

## 15 References

- [1] Würth Elektronik. Application note "GNSS Antenna Selection". <https://www.we-online.com/ANR017>.
- [2] Würth Elektronik. Application note "GNSS I2C Communication". <https://www.we-online.com/ANR018>.
- [3] Würth Elektronik. Erinome-II evaluation board user manual. <https://we-online.de/katalog/en/manual/2614029237001>.
- [4] Würth Elektronik. GNSS antenna 7488920157. <https://www.we-online.de/catalog/en/WE-MCA#7488920157>.
- [5] Würth Elektronik. GNSS antenna Halimedede-I. <https://www.we-online.de/katalog/en/HALIMED-E-I>.
- [6] Würth Elektronik. RF Modules Altium library. <https://www.we-online.com/WCO-ALTIUM>.
- [7] Würth Elektronik. RF Modules Eagle library. <https://www.we-online.com/WCO-EAGLE>.
- [8] Würth Elektronik. WENSS PC tool. <https://www.we-online.com/WENSS>.
- [9] Würth Elektronik. Würth Elektronik eiSos GNSS Evaluation Kits. <https://www.we-online.com/EVAL-GNSS>.

# 16 Regulatory compliance information

## 16.1 Important notice EU

The use of RF frequencies is limited by national regulations. The Erinome-II has been designed to comply with the R&TTE directive 1999/5/EC and the RED directive 2014/53/EU of the European Union (EU).

The Erinome-II can be operated without notification and free of charge in the area of the European Union. However, according to the R&TTE / RED directive, restrictions (e.g. in terms of duty cycle or maximum allowed RF power) may apply.



Since the module itself is not fused the voltage supply shall be fed from a power source which is class PS2 according to EN 62368-1.

## 16.2 Important notice FCC

The use of RF frequencies is limited by national regulations. The Erinome-II has been designed to comply with the FCC Part 15.

The Erinome-II can be operated without notification and free of charge in the area of the United States of America. However, according to the FCC Part 15, restrictions (e.g. in terms of maximum allowed RF power and antenna) may apply.

## 16.3 Conformity assessment of the final product

The Erinome-II is a subassembly. It is designed to be embedded into other products (products incorporating the Erinome-II are henceforward referred to as "final products").

It is the responsibility of the manufacturer of the final product to ensure that the final product is in compliance with the essential requirements of the underlying national radio regulations.

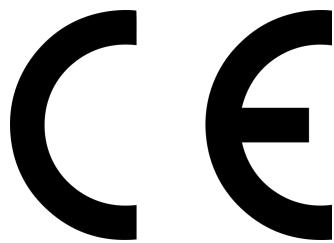
The conformity assessment of the subassembly Erinome-II carried out by Würth Elektronik eiSos does not replace the required conformity assessment of the final product.

## 16.4 Exemption clause

Relevant regulation requirements are subject to change. Würth Elektronik eiSos does not guarantee the accuracy of the before mentioned information. Directives, technical standards, procedural descriptions and the like may be interpreted differently by the national authorities. Equally, the national laws and restrictions may vary with the country. In case of doubt or uncertainty, we recommend that you consult with the authorities or official certification organizations of the relevant countries. Würth Elektronik eiSos is exempt from any responsibilities or liabilities related to regulatory compliance.

Notwithstanding the above, Würth Elektronik eiSos makes no representations and warranties of any kind related to their accuracy, correctness, completeness and/or usability for customer applications. No responsibility is assumed for inaccuracies or incompleteness.

## 16.5 EU Declaration of conformity



### EU DECLARATION OF CONFORMITY

**Radio equipment:** 2614021137000

**Product name:** Erinome-II

**Receiver module for GPS, GLONASS, Galileo and Beidou signals**

**Lot number:** 497 01 04 1950 001 and all more recent lots

**The manufacturer:** Würth Elektronik eiSos GmbH & Co. KG  
Max-Eyth-Straße 1  
74638 Waldenburg

This declaration of conformity is issued under the sole responsibility of the manufacturer.

#### **Object of the declaration: 2614021137000**

The object of the declaration described above is in conformity with the relevant Union harmonisation legislation: Directive 2014/53/EU and 2011/65/EU.

Following harmonised norms or technical specifications have been applied:

EN 303 413 V1.1.1 (2017-06)  
EN 301 489-1 V2.2.3 (2019-11)  
EN 301 489-19 V2.1.1 (2019-04)  
EN 62368-1: 2014/AC: 2015/A11: 2017

*A. Eschenb*

Trier, 13th of January 2020

Place and date of issue

## 16.6 FCC conformity

The Erinome-II is a pure receiver without any transmitting capability. Therefore, no applicable certification exists. Nevertheless, the end device has to be tested for the requirements as per FCC CFR Title 47 chapter I sub chapter A Part 15 Subpart B, unintentional radiators.

Due to the fact, that the Erinome-II is intended to receive non-U.S.-licensed space stations §25.137 of CFR Title 47 chapter I sub chapter B Part 25 Subpart B has to be considered. The FCC Form 312 has to be submitted to the international Bureau Filing System.

[https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=b5653e2553e10fdf141e336593203a6d&mc=true&n=pt47.2.25&r=PART&ty=HTML#se47.2.25\\_1137](https://www.ecfr.gov/cgi-bin/retrieveECFR?gp=&SID=b5653e2553e10fdf141e336593203a6d&mc=true&n=pt47.2.25&r=PART&ty=HTML#se47.2.25_1137)

In case of non-federal U.S. receive-only earth stations operating with specific Galileo signals, a waiver permits the use of E1 and E5 bands without license or grant of market access.

<https://docs.fcc.gov/public/attachments/FCC-18-158A1.pdf>

It is the integrator's responsibility to configure the GNSS module in such a way, that only permitted bands are used.

## 17 Important notes

The following conditions apply to all goods within the wireless connectivity product range of Würth Elektronik eiSos GmbH & Co. KG:

### 17.1 General customer responsibility

Some goods within the product range of Würth Elektronik eiSos GmbH & Co. KG contain statements regarding general suitability for certain application areas. These statements about suitability are based on our knowledge and experience of typical requirements concerning the areas, serve as general guidance and cannot be estimated as binding statements about the suitability for a customer application. The responsibility for the applicability and use in a particular customer design is always solely within the authority of the customer. Due to this fact, it is up to the customer to evaluate, where appropriate to investigate and to decide whether the device with the specific product characteristics described in the product specification is valid and suitable for the respective customer application or not. Accordingly, the customer is cautioned to verify that the documentation is current before placing orders.

### 17.2 Customer responsibility related to specific, in particular safety-relevant applications

It has to be clearly pointed out that the possibility of a malfunction of electronic components or failure before the end of the usual lifetime cannot be completely eliminated in the current state of the art, even if the products are operated within the range of the specifications. The same statement is valid for all software sourcecode and firmware parts contained in or used with or for products in the wireless connectivity and sensor product range of Würth Elektronik eiSos GmbH & Co. KG. In certain customer applications requiring a high level of safety and especially in customer applications in which the malfunction or failure of an electronic component could endanger human life or health, it must be ensured by most advanced technological aid of suitable design of the customer application that no injury or damage is caused to third parties in the event of malfunction or failure of an electronic component.

### 17.3 Best care and attention

Any product-specific data sheets, manuals, application notes, PCN's, warnings and cautions must be strictly observed in the most recent versions and matching to the products firmware revisions. This documents can be downloaded from the product specific sections on the wireless connectivity homepage.

### 17.4 Customer support for product specifications

Some products within the product range may contain substances, which are subject to restrictions in certain jurisdictions in order to serve specific technical requirements. Necessary information is available on request. In this case, the field sales engineer or the internal sales person in charge should be contacted who will be happy to support in this matter.

## 17.5 Product improvements

Due to constant product improvement, product specifications may change from time to time. As a standard reporting procedure of the Product Change Notification (PCN) according to the JEDEC-Standard, we inform about major changes. In case of further queries regarding the PCN, the field sales engineer, the internal sales person or the technical support team in charge should be contacted. The basic responsibility of the customer as per section 17.1 and 17.2 remains unaffected. All wireless connectivity module driver software "wireless connectivity SDK" and its source codes as well as all PC software tools are not subject to the Product Change Notification information process.

## 17.6 Product life cycle

Due to technical progress and economical evaluation we also reserve the right to discontinue production and delivery of products. As a standard reporting procedure of the Product Termination Notification (PTN) according to the JEDEC-Standard we will inform at an early stage about inevitable product discontinuance. According to this, we cannot ensure that all products within our product range will always be available. Therefore, it needs to be verified with the field sales engineer or the internal sales person in charge about the current product availability expectancy before or when the product for application design-in disposal is considered. The approach named above does not apply in the case of individual agreements deviating from the foregoing for customer-specific products.

## 17.7 Property rights

All the rights for contractual products produced by Würth Elektronik eiSos GmbH & Co. KG on the basis of ideas, development contracts as well as models or templates that are subject to copyright, patent or commercial protection supplied to the customer will remain with Würth Elektronik eiSos GmbH & Co. KG. Würth Elektronik eiSos GmbH & Co. KG does not warrant or represent that any license, either expressed or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, application, or process in which Würth Elektronik eiSos GmbH & Co. KG components or services are used.

## 17.8 General terms and conditions

Unless otherwise agreed in individual contracts, all orders are subject to the current version of the "General Terms and Conditions of Würth Elektronik eiSos Group", last version available at [www.we-online.com](http://www.we-online.com).

## 18 Legal notice

### 18.1 Exclusion of liability

Würth Elektronik eiSos GmbH & Co. KG considers the information in this document to be correct at the time of publication. However, Würth Elektronik eiSos GmbH & Co. KG reserves the right to modify the information such as technical specifications or functions of its products or discontinue the production of these products or the support of one of these products without any written announcement or notification to customers. The customer must make sure that the information used corresponds to the latest published information. Würth Elektronik eiSos GmbH & Co. KG does not assume any liability for the use of its products. Würth Elektronik eiSos GmbH & Co. KG does not grant licenses for its patent rights or for any other of its intellectual property rights or third-party rights.

Notwithstanding anything above, Würth Elektronik eiSos GmbH & Co. KG makes no representations and/or warranties of any kind for the provided information related to their accuracy, correctness, completeness, usage of the products and/or usability for customer applications. Information published by Würth Elektronik eiSos GmbH & Co. KG regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof.

### 18.2 Suitability in customer applications

The customer bears the responsibility for compliance of systems or units, in which Würth Elektronik eiSos GmbH & Co. KG products are integrated, with applicable legal regulations. Customer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of Würth Elektronik eiSos GmbH & Co. KG components in its applications, notwithstanding any applications-related information or support that may be provided by Würth Elektronik eiSos GmbH & Co. KG. Customer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences lessen the likelihood of failures that might cause harm and take appropriate remedial actions. The customer will fully indemnify Würth Elektronik eiSos GmbH & Co. KG and its representatives against any damages arising out of the use of any Würth Elektronik eiSos GmbH & Co. KG components in safety-critical applications.

### 18.3 Trademarks

AMBER wireless is a registered trademark of Würth Elektronik eiSos GmbH & Co. KG. All other trademarks, registered trademarks, and product names are the exclusive property of the respective owners.

### 18.4 Usage restriction

Würth Elektronik eiSos GmbH & Co. KG products have been designed and developed for usage in general electronic equipment only. This product is not authorized for use in equipment where a higher safety standard and reliability standard is especially required or where a failure of the product is reasonably expected to cause severe personal injury or death,

unless the parties have executed an agreement specifically governing such use. Moreover, Würth Elektronik eiSos GmbH & Co. KG products are neither designed nor intended for use in areas such as military, aerospace, aviation, nuclear control, submarine, transportation (automotive control, train control, ship control), transportation signal, disaster prevention, medical, public information network etc. Würth Elektronik eiSos GmbH & Co. KG must be informed about the intent of such usage before the design-in stage. In addition, sufficient reliability evaluation checks for safety must be performed on every electronic component, which is used in electrical circuits that require high safety and reliability function or performance. By using Würth Elektronik eiSos GmbH & Co. KG products, the customer agrees to these terms and conditions.

## 19 License terms

This License Terms will take effect upon the purchase and usage of the Würth Elektronik eiSos GmbH & Co. KG wireless connectivity products. You hereby agree that this license terms is applicable to the product and the incorporated software, firmware and source codes (collectively, "Software") made available by Würth Elektronik eiSos in any form, including but not limited to binary, executable or source code form.

The software included in any Würth Elektronik eiSos wireless connectivity product is purchased to you on the condition that you accept the terms and conditions of this license terms. You agree to comply with all provisions under this license terms.

### 19.1 Limited license

Würth Elektronik eiSos hereby grants you a limited, non-exclusive, non-transferable and royalty-free license to use the software and under the conditions that will be set forth in this license terms. You are free to use the provided Software only in connection with one of the products from Würth Elektronik eiSos to the extent described in this license terms. You are entitled to change or alter the source code for the sole purpose of creating an application embedding the Würth Elektronik eiSos wireless connectivity product. The transfer of the source code to third parties is allowed to the sole extent that the source code is used by such third parties in connection with our product or another hardware provided by Würth Elektronik eiSos under strict adherence of this license terms. Würth Elektronik eiSos will not assume any liability for the usage of the incorporated software and the source code. You are not entitled to transfer the source code in any form to third parties without prior written consent of Würth Elektronik eiSos.

You are not allowed to reproduce, translate, reverse engineer, decompile, disassemble or create derivative works of the incorporated Software and the source code in whole or in part. No more extensive rights to use and exploit the products are granted to you.

### 19.2 Usage and obligations

The responsibility for the applicability and use of the Würth Elektronik eiSos wireless connectivity product with the incorporated Firmware in a particular customer design is always solely within the authority of the customer. Due to this fact, it is up to you to evaluate and investigate, where appropriate, and to decide whether the device with the specific product characteristics described in the product specification is valid and suitable for your respective application or not.

You are responsible for using the Würth Elektronik eiSos wireless connectivity product with the incorporated Firmware in compliance with all applicable product liability and product safety laws. You acknowledge to minimize the risk of loss and harm to individuals and bear the risk for failure leading to personal injury or death due to your usage of the product.

Würth Elektronik eiSos' products with the incorporated Firmware are not authorized for use in safety-critical applications, or where a failure of the product is reasonably expected to cause severe personal injury or death. Moreover, Würth Elektronik eiSos' products with the incorporated Firmware are neither designed nor intended for use in areas such as military, aerospace, aviation, nuclear control, submarine, transportation (automotive control, train control, ship control), transportation signal, disaster prevention, medical, public information network etc. You shall inform Würth Elektronik eiSos about the intent of such usage before design-in stage. In certain customer applications requiring a very high level of safety and in which the malfunction or failure of an electronic component could endanger human life or

health, you must ensure to have all necessary expertise in the safety and regulatory ramifications of your applications. You acknowledge and agree that you are solely responsible for all legal, regulatory and safety-related requirements concerning your products and any use of Würth Elektronik eiSos' products with the incorporated Firmware in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by Würth Elektronik eiSos. YOU SHALL INDEMNIFY WÜRTH ELEKTRONIK EIROS AGAINST ANY DAMAGES ARISING OUT OF THE USE OF WÜRTH ELEKTRONIK EIROS' PRODUCTS WITH THE INCORPORATED FIRMWARE IN SUCH SAFETY-CRITICAL APPLICATIONS.

### **19.3 Ownership**

The incorporated Firmware created by Würth Elektronik eiSos is and will remain the exclusive property of Würth Elektronik eiSos.

### **19.4 Disclaimer of warranty**

THE FIRMWARE IS PROVIDED "AS IS". YOU ACKNOWLEDGE THAT WÜRTH ELEKTRONIK EIROS MAKES NO REPRESENTATIONS AND WARRANTIES OF ANY KIND RELATED TO, BUT NOT LIMITED TO THE NON-INFRINGEMENT OF THIRD PARTIES' INTELLECTUAL PROPERTY RIGHTS OR THE MERCHANTABILITY OR FITNESS FOR YOUR INTENDED PURPOSE OR USAGE. WÜRTH ELEKTRONIK EIROS DOES NOT WARRANT OR REPRESENT THAT ANY LICENSE, EITHER EXPRESS OR IMPLIED, IS GRANTED UNDER ANY PATENT RIGHT, COPYRIGHT, MASK WORK RIGHT, OR OTHER INTELLECTUAL PROPERTY RIGHT RELATING TO ANY COMBINATION, MACHINE, OR PROCESS IN WHICH THE WÜRTH ELEKTRONIK EIROS' PRODUCT WITH THE INCORPORATED FIRMWARE IS USED. INFORMATION PUBLISHED BY WÜRTH ELEKTRONIK EIROS REGARDING THIRD-PARTY PRODUCTS OR SERVICES DOES NOT CONSTITUTE A LICENSE FROM WÜRTH ELEKTRONIK EIROS TO USE SUCH PRODUCTS OR SERVICES OR A WARRANTY OR ENDORSEMENT THEREOF.

### **19.5 Limitation of liability**

Any liability not expressly provided by Würth Elektronik eiSos shall be disclaimed.

You agree to hold us harmless from any third-party claims related to your usage of the Würth Elektronik eiSos' products with the incorporated Firmware, software and source code. Würth Elektronik eiSos disclaims any liability for any alteration, development created by you or your customers as well as for any combination with other products.

### **19.6 Applicable law and jurisdiction**

Applicable law to this license terms shall be the laws of the Federal Republic of Germany. Any dispute, claim or controversy arising out of or relating to this license terms shall be resolved and finally settled by the court competent for the location of Würth Elektronik eiSos' registered office.

### **19.7 Severability clause**

If a provision of this license terms is or becomes invalid, unenforceable or null and void, this shall not affect the remaining provisions of the terms. The parties shall replace any such

provisions with new valid provisions that most closely approximate the purpose of the terms.

## 19.8 Miscellaneous

Würth Elektronik eiSos reserves the right at any time to change this terms at its own discretion. It is your responsibility to check at Würth Elektronik eiSos homepage for any updates. Your continued usage of the products will be deemed as the acceptance of the change. We recommend you to be updated about the status of new firmware and software, which is available on our website or in our data sheet and manual, and to implement new software in your device where appropriate.

By ordering a wireless connectivity product, you accept this license terms in all terms.

## List of Figures

1	Erinome-II module . . . . .	8
2	Erinome-II Block diagram . . . . .	9
3	Pinout (top view) . . . . .	17
4	Power up . . . . .	21
5	Erinome-II (Module Start-up) . . . . .	23
6	Erinome-II - Quick start setup (passive antenna) . . . . .	24
7	Erinome-II - Quick start setup (active antenna) . . . . .	24
8	Host Based Low Power Mode . . . . .	27
9	Push To Fix . . . . .	28
10	Push-To-Fix Current Consumption Profile . . . . .	29
11	Trickle Power Mode Current Consumption Profile . . . . .	30
12	Footprint Design . . . . .	32
13	Layout Design . . . . .	33
14	Stackup . . . . .	34
15	Placement of the module . . . . .	35
16	Dimensioning the antenna feed line as micro strip . . . . .	36
17	GNSS Active antenna . . . . .	38
18	GNSS multilayer chip antenna . . . . .	39
19	Reference design: Schematic sheet-1 . . . . .	41
20	Reference design: Schematic sheet-2 . . . . .	42
21	Reference design: Schematic sheet-3 . . . . .	43
22	Reference design: Layout . . . . .	44
23	Interface Selection for SPI . . . . .	45
24	UART host interface . . . . .	47
25	I <sup>2</sup> C host interface . . . . .	48
26	Flowchart for host implementation . . . . .	51
27	SPI interface . . . . .	52
28	SPI Mode 1 (CPHA=1, CPOL=0) . . . . .	52
29	Flowchart Read for SPI Master implementation . . . . .	56
30	Flowchart Write for SPI Master implementation . . . . .	57
31	NMEA Standard Sentences for Erinome-II . . . . .	59
32	NMEA Product-Specific Sentences for SiRFStar V . . . . .	60
33	Example of 1 Hz navigation . . . . .	74
34	Example of 5 Hz navigation . . . . .	74
35	Example of 10 Hz navigation . . . . .	75
36	OSP Sentences for Erinome-II . . . . .	78
37	Reflow soldering profile . . . . .	97
38	Module dimensions [mm] . . . . .	101
39	Footprint and dimensions [mm] . . . . .	102
40	Lot number structure . . . . .	103
41	Label of the Erinome-II . . . . .	104

## List of Tables

1	Ordering information . . . . .	9
2	Recommended operating conditions . . . . .	10
3	Absolute maximum ratings . . . . .	10
4	Current consumption . . . . .	11

5	Antenna connector Type . . . . .	12
6	Radio characteristics . . . . .	12
7	Pin characteristics . . . . .	12
8	GNSS constellations supported . . . . .	13
9	Additional systems supported . . . . .	13
10	Horizontal Position Accuracy . . . . .	14
11	Vertical Position Accuracy . . . . .	14
12	Velocity Accuracy . . . . .	14
13	Heading Accuracy . . . . .	14
14	Time Accuracy . . . . .	15
15	Time To First Fix . . . . .	15
16	Sensitivity . . . . .	16
17	Dynamic Constraints . . . . .	16
18	Pinout . . . . .	17
19	Pinout - UART communication . . . . .	18
20	Pinout - I <sup>2</sup> C Multi Master communication . . . . .	18
21	Pinout - SPI slave communication . . . . .	18
22	ON_OFF pin function . . . . .	18
23	WAKE_UP pin function . . . . .	19
24	Minimal pin configuration, UART mode . . . . .	20
25	Startup timing . . . . .	21
26	Module Mode of Operation . . . . .	23
27	PVT data . . . . .	25
28	Communication Settings . . . . .	25
29	Cold, Warm and Hot Start . . . . .	26
30	2600130016 - antenna specifications . . . . .	38
31	7488920157 - antenna specifications . . . . .	39
32	Interface selection . . . . .	46
33	UART properties . . . . .	47
34	I <sup>2</sup> C properties . . . . .	48
35	SPI properties of GNSS module . . . . .	53
36	Communication Protocol . . . . .	58
37	NMEA Standard Sentences: Talker ID . . . . .	59
38	NMEA Standard Sentences: Data format . . . . .	59
39	Message overview . . . . .	61
40	GGA Data Format . . . . .	62
41	GLL Data Format . . . . .	63
42	GNS Data Format . . . . .	64
43	GSA Data Format . . . . .	65
44	GSV Data Format . . . . .	66
45	RMC Data Format . . . . .	67
46	VTG Data Format . . . . .	68
47	ZDA Data Format . . . . .	69
48	Estimated Position Error . . . . .	70
49	Ok To Send . . . . .	70
50	Response to Poll SW version . . . . .	71
51	GNSS Start and Stop . . . . .	72
52	Message rate selection . . . . .	73
53	Baud rate selection . . . . .	75
54	Navigation initialization . . . . .	76
55	Factory reset . . . . .	77

56	Data types . . . . .	78
57	Message overview for OSP messages . . . . .	79
58	MID 67,1 - Multiconstellation Navigation Data . . . . .	81
59	MID 67,16 - Multiconstellation Satellite Data . . . . .	82
60	MID 67,16 - Satellite information . . . . .	83
61	MID 2 - Measure Navigation Data Indication . . . . .	84
62	Satellite PRN mapping . . . . .	84
63	MID 66 - DOP Values Indication . . . . .	85
64	MID 51,1 - Navigation Cycle Complete . . . . .	85
65	MID 6 - SW Version . . . . .	86
66	MID 18 - Ok To Send . . . . .	86
67	MID 11 - Command Acknowledgment Response . . . . .	87
68	MID 12 - Command Negative Acknowledgment Response . . . . .	87
69	MID 129 - Switch NMEA protocol request . . . . .	88
70	MID 134 - Baud rate selection . . . . .	89
71	MID 132 - SW version request . . . . .	89
72	MID 222,16 - Location Technology Constraints Request . . . . .	90
73	MID 128 - Initialize Data Source Request . . . . .	91
74	MID 136 - Mode control . . . . .	92
75	MID 218,6 - Low Power Mode Request . . . . .	93
76	Default firmware Settings . . . . .	95
77	Classification reflow soldering profile, Note: refer to IPC/JEDEC J-STD-020E . . . . .	96
78	Package classification reflow temperature, PB-free assembly, Note: refer to IPC/JEDEC J-STD-020E . . . . .	97
79	Dimensions . . . . .	100
80	Weight . . . . .	100
81	Lot number details . . . . .	103
82	Label of the Erinome-II . . . . .	104



# more than you expect



**Internet  
of Things**



**Monitoring  
& Control**



**Automated Meter  
Reading**

## Contact:

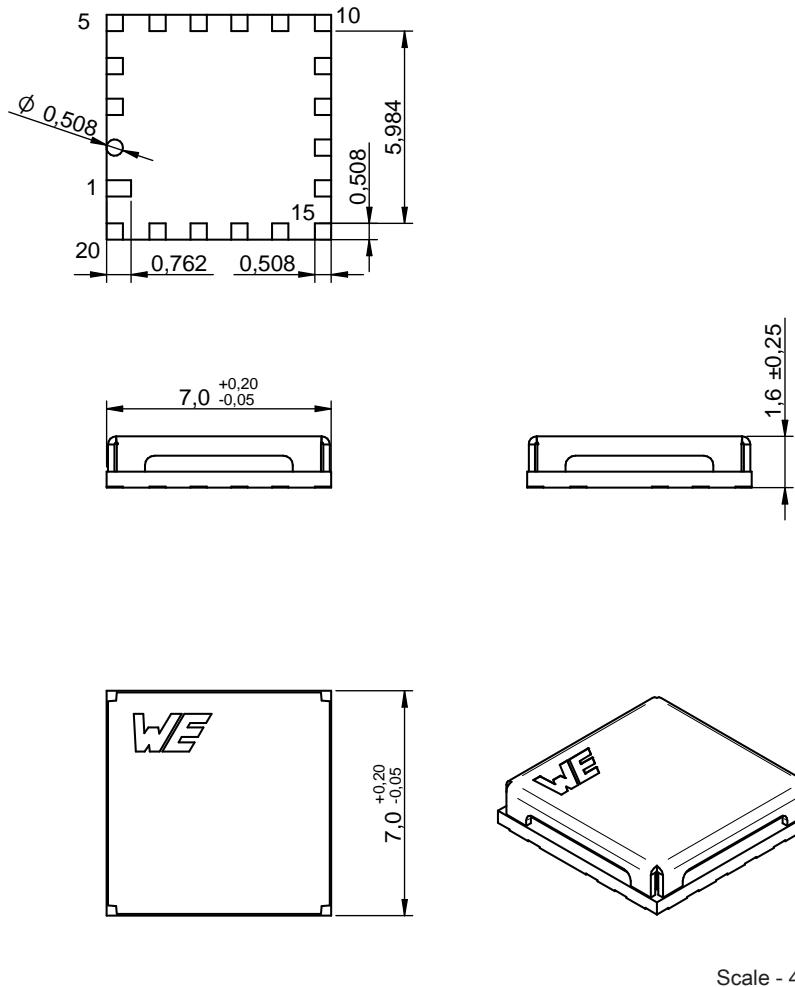
Würth Elektronik eiSos GmbH & Co. KG  
Division Wireless Connectivity & Sensors

Max-Eyth-Straße 1  
74638 Waldenburg  
Germany

Tel.: +49 651 99355-0  
Fax.: +49 651 99355-69  
[www.we-online.com/wireless-connectivity](http://www.we-online.com/wireless-connectivity)

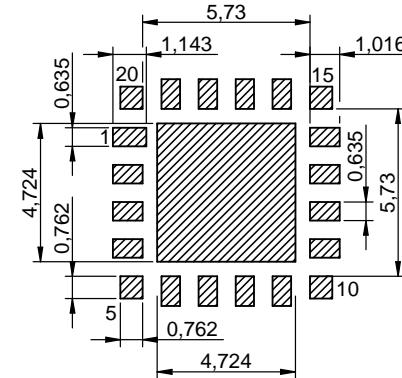


## Dimensions: [mm]



Scale - 4:1

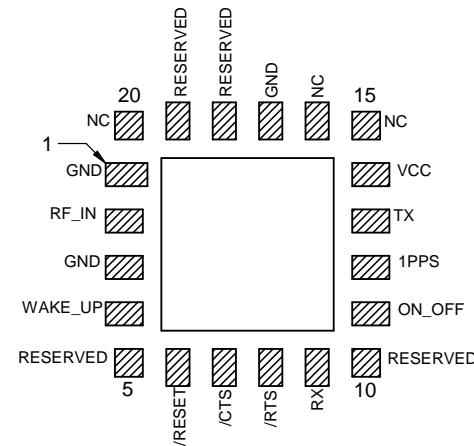
## Recommended Land Pattern: [mm]



Please refer to the user manual for hardware layout recommendations

Scale - 4:1

## Product Specific Pinning:



CHECKED	REVISION	DATE (YYYY-MM-DD)	GENERAL TOLERANCE	PROJECTION METHOD
LuSe	002.000	2020-11-02	DIN ISO 2768-1m	
DESCRIPTION				ORDER CODE
<b>WIRL-POSI Erinome-II GPS-GLO-GAL-BDS GNSS module T&amp;R</b>				<b>2614021137000</b>
BUSINESS UNIT	STATUS	PAGE		
eSmart	Valid	1/7		

This electronic component has been designed and developed for usage in general electronic equipment only. This product is not authorized for use in equipment where a higher safety standard and reliability standard is especially required or where a failure of the product is reasonably expected to cause severe personal injury or death, unless the parties have executed an agreement specifically governing such use. Moreover Würth Elektronik eiSos GmbH & Co KG products are neither designed nor intended for use in areas such as military, aerospace, aviation, nuclear control, submarine, transportation (automotive control, train control, ship control), transportation signal, disaster prevention, medical, public information network etc.. Würth Elektronik eiSos GmbH & Co KG must be informed about the intent of such usage before the design-in stage. In addition, sufficient reliability evaluation checks for safety must be performed on every electronic component which is used in electrical circuits that require high safety and reliability functions or performance.

## General Properties:

Properties		Value	Unit
Antenna Connector Type	ANT Conn	RF pad	
Microcontroller	µC	Soc	
Radio Chipset	RF-IC	SiRFstar V 5e B02	
Update rate <sub>max.</sub>		10	Hz
Communication Protocol/ Standard		NMEA, OSP	
Communication interface		UART, I <sup>2</sup> C, SPI	
Channels		52	
Memory Type		Flash-based	

## Electrical Properties:

Properties		Value	Unit
Operating Supply Voltage Min.	V <sub>DD min.</sub>	1.71	V
Operating Supply Voltage Max.	V <sub>DD max.</sub>	1.89	V
Recommended Supply Voltage	V <sub>DD typ.</sub>	1.8	V
Current Consumption <sub>Hibernate</sub>		30	µA

## General Information:

It is recommended that the temperature of the component does not exceed +85°C under worst case conditions	
Operating Temperature	-40 up to +85 °C
Storage Conditions (in original packaging)	< 40 °C ; < 90 % RH
Moisture Sensitivity Level (MSL)	3

## Certification:

RoHS Approval	Compliant [2011/65/EU&2015/863]
REACH Approval	Conform or declared [(EC)1907/2006]

## RF-Electrical Properties:

Properties		Test conditions	Value	Unit
Rx Sensitivity (Tracking)		GPS	-167	dBm
Rx Sensitivity (Acquisition)		GPS	-147	dBm
Frequency min.	f <sub>min.</sub>		1560	MHz
Frequency max.	f <sub>max.</sub>		1620	MHz
Impedance	Z	Input Frequency = 1575.42 MHz	50	Ω
Return Loss	RL	Input Frequency = 1575.42 MHz	-7	dB
Current Consumption <sub>Acquisition</sub>		VDD = 1.8 V, Temperature = 25°C, power level = -130dBm, GPS-GLO	55	mA
Current Consumption <sub>Tracking</sub>		VDD = 1.8 V, Temperature = 25°C, power level = -130dBm, GPS-GLO	54	mA

## GNSS Performances:

Properties	Test conditions	Value	Unit
GNSS Constellations Supported	GPS L1 (1575.42 MHz), GLONASS L1 (1602 MHz), Galileo E1 (1575.42 MHz), BeiDou B1 (1561.1 MHz)	GPS, GLONASS, Galileo, BeiDou	
Position Accuracy (GPS & GLO)	Static, VDD = 1.8 V, Temperature = 25°C, power level = -130dBm, Circular Error Probability (50%)	1.5	m
Position Accuracy (GPS)	Static, VDD = 1.8 V, Temperature = 25°C, power level = -130dBm, Circular Error Probability (50%)	2.5	m
Time To First Fix (Cold Start)	Static, VDD = 1.8 V, Temperature = 25°C, power level = -130dBm, GPS-GLO	28	s
Time To First Fix (Hot Start)	Static, VDD = 1.8 V, Temperature = 25°C, power level = -130dBm, GPS-GLO	1	s

## Product Specific Pinning:

Pin	Pad	Description	I/O
GND	1	Negative supply voltage	Supply
RF_IN	2	RF Signal Input	Input

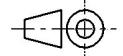


 <b>WÜRTH ELEKTRONIK</b>	CHECKED LuSe	REVISION 002.000	DATE (YYYY-MM-DD) 2020-11-02	GENERAL TOLERANCE DIN ISO 2768-1m	PROJECTION METHOD 
	DESCRIPTION	<b>WIRL-POSI Erinome-II GPS-GLO-GAL-BDS GNSS module T&amp;R</b>			ORDER CODE <b>2614021137000</b>
				BUSINESS UNIT eiSmart	STATUS Valid
				PAGE 2/7	

This electronic component has been designed and developed for usage in general electronic equipment only. This product is not authorized for use in equipment where a higher safety standard and reliability standard is especially required or where a failure of the product is reasonably expected to cause severe personal injury or death, unless the parties have executed an agreement specifically governing such use. Moreover Würth Elektronik eiSos GmbH & Co KG products are neither designed nor intended for use in areas such as military, aerospace, aviation, nuclear control, submarine, transportation (automotive control, train control, ship control), transportation signal, disaster prevention, medical, public information network etc.. Würth Elektronik eiSos GmbH & Co KG must be informed about the intent of such usage before the design-in stage. In addition, sufficient reliability evaluation checks for safety must be performed on every electronic component which is used in electrical circuits that require high safety and reliability functions or performance.

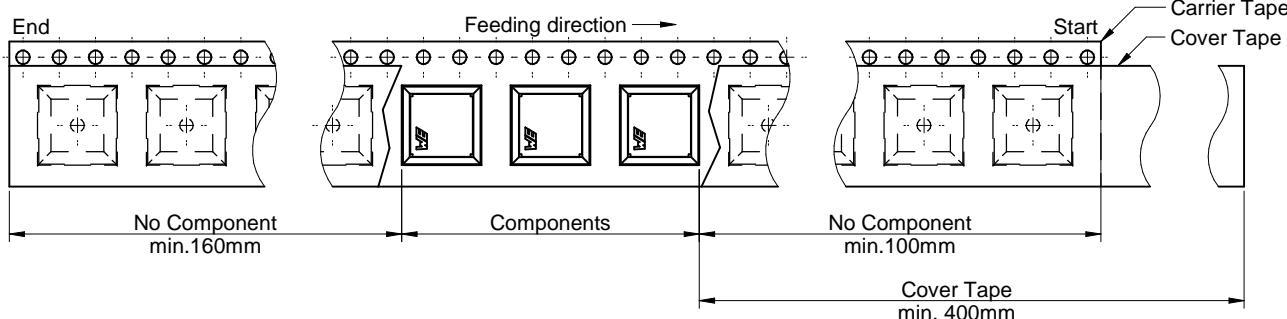
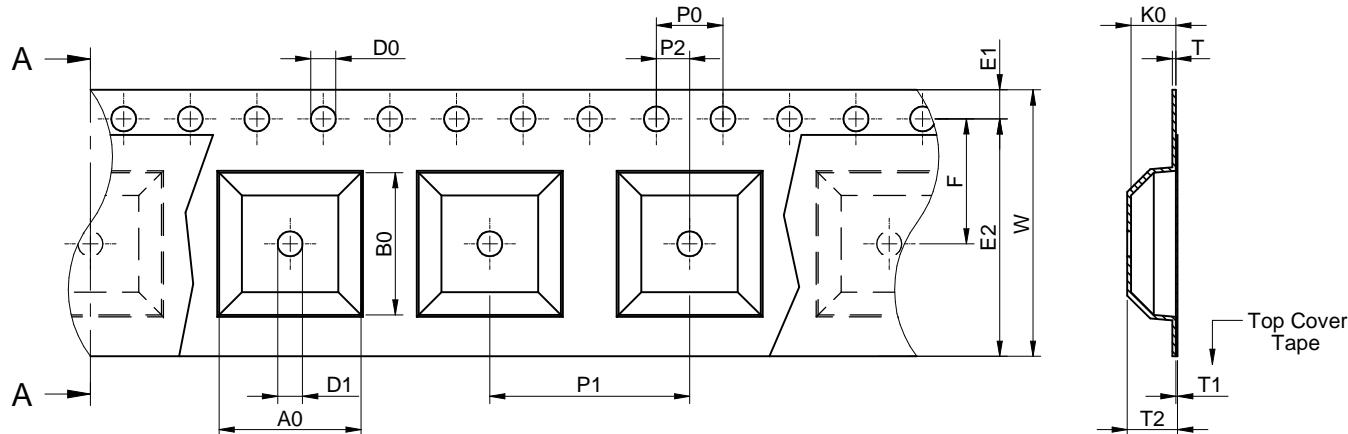
## Product Specific Pinning:

Pin	Pad	Description	I/O
GND	3	Negative supply voltage	Supply
WAKE_UP	4	Operation mode status	Output
RESERVED	5	See manual for more details	Input/Output
/RESET	6	Reset	Input
/CTS	7	Clear to send signal	Input/Output
/RTS	8	Request to send signal	Input/Output
RX	9	Receive	Input/Output
RESERVED	10	See manual for more details	Input/Output
ON_OFF	11	Power State Control	Input
1PPS	12	UTC Time Mark	Output
TX	13	Transmit	Input/Output
VCC	14	Positive supply voltage (VDD)	Supply
NC	15	Not connected	--
NC	16	Not connected	--
GND	17	Negative supply voltage	Supply
RESERVED	18	See manual for more details	Input/Output
RESERVED	19	See manual for more details	Input/Output
NC	20	Not connected	--

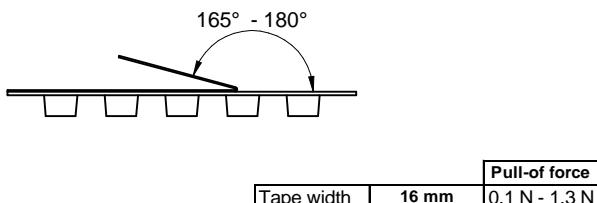
  	CHECKED LuSe	REVISION 002.000	DATE (YYYY-MM-DD) 2020-11-02	GENERAL TOLERANCE DIN ISO 2768-1m	PROJECTION METHOD 
	DESCRIPTION	<b>WIRL-POSI Erinome-II GPS-GLO-GAL-BDS GNSS module T&amp;R</b>			ORDER CODE <b>2614021137000</b>
			BUSINESS UNIT eISmart		STATUS Valid
				PAGE 3/7	

This electronic component has been designed and developed for usage in general electronic equipment only. This product is not authorized for use in equipment where a higher safety standard and reliability standard is especially required or where a failure of the product is reasonably expected to cause severe personal injury or death, unless the parties have executed an agreement specifically governing such use. Moreover Würth Elektronik eiSos GmbH & Co KG products are neither designed nor intended for use in areas such as military, aerospace, aviation, nuclear control, submarine, transportation (automotive control, train control, ship control), transportation signal, disaster prevention, medical, public information network etc.. Würth Elektronik eiSos GmbH & Co KG must be informed about the intent of such usage before the design-in stage. In addition, sufficient reliability evaluation checks for safety must be performed on every electronic component which is used in electrical circuits that require high safety and reliability functions or performance.

## Packaging Specification - Tape and Reel: [mm]



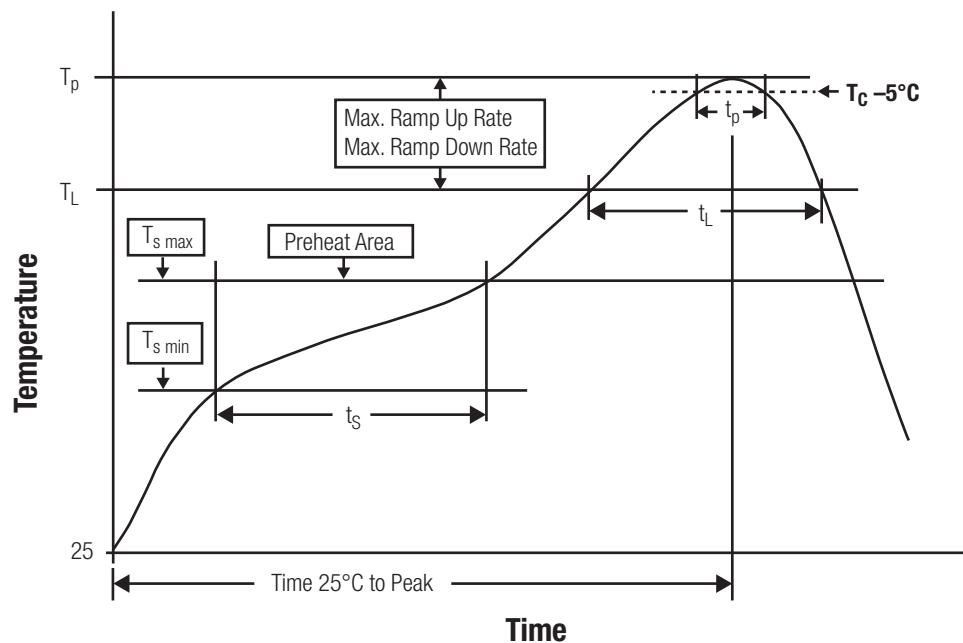
Tape Type	A0 (mm)	B0 (mm)	W (mm)	T (mm)	T1 (mm)	T2 (mm)	K0 (mm)	P0 (mm)	P1 (mm)	P2 (mm)	D0 (mm)	D1 (mm)	E1 (mm)	E2 (mm)	F (mm)	Material	Qty. (pcs.)
	±0,1	±0,1	±0,3	±0,05	ref.	typ.	±0,1	±0,1	±0,1	±0,1	+0,1/-0,0	min.	±0,1	min.	±0,1		
2a	8,30	8,30	16,00	0,30	0,10	2,95	2,70	4,00	12,00	2,00	1,50	1,50	1,75	14,25	7,50	Polystyrene	500



 <b>WÜRTH ELEKTRONIK</b>	CHECKED LuSe	REVISION 002.000	DATE (YYYY-MM-DD) 2020-11-02	GENERAL TOLERANCE DIN ISO 2768-1m	PROJECTION METHOD 
	DESCRIPTION <b>WIRL-POSI Erinome-II GPS-GLO-GAL-BDS GNSS module T&amp;R</b>	ORDER CODE <b>2614021137000</b>			
	BUSINESS UNIT eiSmart	STATUS Valid		PAGE 4/7	

This electronic component has been designed and developed for usage in general electronic equipment only. This product is not authorized for use in equipment where a higher safety standard and reliability standard is especially required or where a failure of the product is reasonably expected to cause severe personal injury or death, unless the parties have executed an agreement specifically governing such use. Moreover Würth Elektronik eiSos GmbH & Co KG products are neither designed nor intended for use in areas such as military, aerospace, aviation, nuclear control, submarine, transportation (automotive control, train control, ship control), transportation signal, disaster prevention, medical, public information network etc.. Würth Elektronik eiSos GmbH & Co KG must be informed about the intent of such usage before the design-in stage. In addition, sufficient reliability evaluation checks for safety must be performed on every electronic component which is used in electrical circuits that require high safety and reliability functions or performance.

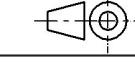
## Classification Reflow Profile for SMT components:



## Classification Reflow Soldering Profile:

Profile Feature	Value
Preheat Temperature Min	T <sub>s min</sub> 150 °C
Preheat Temperature Max	T <sub>s max</sub> 200 °C
Preheat Time t <sub>s</sub> from T <sub>s min</sub> to T <sub>s max</sub>	t <sub>s</sub> 60 - 120 seconds
Ramp-up Rate (T <sub>L</sub> to T <sub>p</sub> )	3 °C/ second max.
Liquidous Temperature	T <sub>L</sub> 217 °C
Time t <sub>L</sub> maintained above T <sub>L</sub>	t <sub>L</sub> 60 - 150 seconds
Peak package body temperature	T <sub>p</sub> 260°C
Time within 5°C of actual peak temperature	t <sub>p</sub> 20 - 30 seconds
Ramp-down Rate (T <sub>p</sub> to T <sub>L</sub> )	6 °C/ second max.
Time 25°C to peak temperature	8 minutes max.

refer to IPC/ JEDEC J-STD-020E

 <b>RoHS</b> COMPLIANT	 <b>REACH</b> COMPLIANT	 <b>WE</b> <b>WÜRTH ELEKTRONIK</b>	CHECKED LuSe	REVISION 002.000	DATE (YYYY-MM-DD) 2020-11-02	GENERAL TOLERANCE DIN ISO 2768-1m	PROJECTION METHOD 		
			DESCRIPTION <b>WIRL-POSI Erinome-II GPS-GLO-GAL-BDS GNSS module T&amp;R</b>				ORDER CODE <b>2614021137000</b>		
						BUSINESS UNIT eSmart	STATUS Valid		
						PAGE 5/7			

## Cautions and Warnings:

### The following conditions apply to all goods within the product series of wireless connectivity of Würth Elektronik eISOS GmbH & Co. KG:

#### General:

- This electronic component is designed and developed with the intention for use in general electronic equipment.
- Würth Elektronik must be asked for written approval (following the PPAP procedure) before incorporating the components into any equipment in fields such as military, aerospace, aviation, nuclear control, submarine, transportation (automotive control, train control, ship control), transportation signal, disaster prevention, medical, public information network, etc. where higher safety and reliability are especially required and/or if there is the possibility of direct damage or human injury.
- Electronic components that will be used in safety-critical or high-reliability applications, should be pre-evaluated by the customer.
- The component is designed and manufactured to be used within the datasheet specified values. If the usage and operation conditions specified in the datasheet are not met, the wire insulation may be damaged or dissolved.
- Do not drop or impact the components, the component may be damaged.
- Würth Elektronik products are qualified according to international standards, which are listed in each product reliability report. Würth Elektronik does not guarantee any customer qualified product characteristics beyond Würth Elektroniks' specifications, for its validity and sustainability over time.
- The responsibility for the applicability of the customer specific products and use in a particular customer design is always within the authority of the customer. All technical specifications for standard products also apply to customer specific products.

#### Product specific:

#### Soldering:

- The solder profile must comply with the technical product specifications. All other profiles will void the warranty.
- All other soldering methods are at the customer's own risk.

#### Cleaning and Washing:

- Washing agents used during the production to clean the customer application might damage or change the characteristics of the component. Washing agents may have a negative effect on the long-term functionality of the product.
- Using a brush during the cleaning process could break the module. Therefore, we do not recommend using a brush during the PCB cleaning process.

#### Potting and Coating:

- If the product is potted in the customer application, the potting material might shrink or expand during and after hardening. Shrinking could lead to an incomplete seal, allowing contaminants into the component. Expansion could damage components. We recommend a manual inspection after potting to avoid these effects.

- Conformal coating may affect the product performance.

#### Storage Conditions:

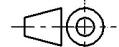
- A storage of Würth Elektronik products for longer than 12 months is not recommended. Within other effects, the terminals may suffer degradation, resulting in bad solderability. Therefore, all products shall be used within the period of 12 months based on the day of shipment.
- Do not expose the components to direct sunlight.
- The storage conditions in the original packaging are defined according to DIN EN 61760-2.
- If there is a moisture sensitive component, the storage condition in the original packaging is defined according to IPC/JEDEC-J-STD-033. It is also recommended to return the component to the original moisture proof bag and reseal the moisture proof bag again.
- ESD prevention methods need to be followed for manual handling and processing by machinery.
- The storage conditions stated in the original packaging apply to the storage time and not to the transportation time of the components.

#### Handling:

- Violation of the technical product specifications such as exceeding the nominal rated current, will void the warranty.
- Violation of the technical product specifications such as but not limited to exceeding the absolute maximum ratings will void the conformance to regulatory requirements.
- The edge castellation is designed and made for prototyping, i.e. hand soldering purposes only.
- Non-antenna modules must be equipped with a proper antenna having specific characteristics.
- The applicable country regulations and specific environmental regulations must be observed.
- Do not disassemble the product. Evidence of tampering will void the warranty.
- The temperature rise of the component must be taken into consideration. The operating temperature is comprised of ambient temperature and temperature rise of the component. The operating temperature of the component shall not exceed the maximum temperature specified.

These cautions and warnings comply with the state of the scientific and technical knowledge and are believed to be accurate and reliable. However, no responsibility is assumed for inaccuracies or incompleteness.

All topics are described in a more detailed manner in the manual for each product.

 RoHS COMPLIANT	 REACH COMPLIANT	 <b>WÜRTH ELEKTRONIK</b>	CHECKED LuSe	REVISION 002.000	DATE (YYYY-MM-DD) 2020-11-02	GENERAL TOLERANCE DIN ISO 2768-1m	PROJECTION METHOD 
DESCRIPTION <b>WIRL-POSI Erinome-II GPS-GLO-GAL-BDS GNSS module T&amp;R</b>						ORDER CODE <b>2614021137000</b>	
			BUSINESS UNIT eISmart	STATUS Valid		PAGE 6/7	

## Important Notes

**The following conditions apply to all goods within the product range of Würth Elektronik eiSos GmbH & Co. KG:**

### 1. General Customer Responsibility

Some goods within the product range of Würth Elektronik eiSos GmbH & Co. KG contain statements regarding general suitability for certain application areas. These statements about suitability are based on our knowledge and experience of typical requirements concerning the areas, serve as general guidance and cannot be estimated as binding statements about the suitability for a customer application. The responsibility for the applicability and use in a particular customer design is always solely within the authority of the customer. Due to this fact it is up to the customer to evaluate, where appropriate to investigate and decide whether the device with the specific product characteristics described in the product specification is valid and suitable for the respective customer application or not.

### 2. Customer Responsibility related to Specific, in particular Safety-Relevant Applications

It has to be clearly pointed out that the possibility of a malfunction of electronic components or failure before the end of the usual lifetime cannot be completely eliminated in the current state of the art, even if the products are operated within the range of the specifications. In certain customer applications requiring a very high level of safety and especially in customer applications in which the malfunction or failure of an electronic component could endanger human life or health it must be ensured by most advanced technological aid of suitable design of the customer application that no injury or damage is caused to third parties in the event of malfunction or failure of an electronic component. Therefore, customer is cautioned to verify that data sheets are current before placing orders. The current data sheets can be downloaded at [www.we-online.com](http://www.we-online.com).

### 3. Best Care and Attention

Any product-specific notes, cautions and warnings must be strictly observed. Any disregard will result in the loss of warranty.

### 4. Customer Support for Product Specifications

Some products within the product range may contain substances which are subject to restrictions in certain jurisdictions in order to serve specific technical requirements. Necessary information is available on request. In this case the field sales engineer or the internal sales person in charge should be contacted who will be happy to support in this matter.

### 5. Product R&D

Due to constant product improvement product specifications may change from time to time. As a standard reporting procedure of the Product Change Notification (PCN) according to the JEDEC-Standard inform about minor and major changes. In case of further queries regarding the PCN, the field sales engineer or the internal sales person in charge should be contacted. The basic responsibility of the customer as per Section 1 and 2 remains unaffected.

### 6. Product Life Cycle

Due to technical progress and economical evaluation we also reserve the right to discontinue production and delivery of products. As a standard reporting procedure of the Product Termination Notification (PTN) according to the JEDEC-Standard we will inform at an early stage about inevitable product discontinuance. According to this we cannot guarantee that all products within our product range will always be available. Therefore it needs to be verified with the field sales engineer or the internal sales person in charge about the current product availability expectancy before or when the product for application design-in disposal is considered. The approach named above does not apply in the case of individual agreements deviating from the foregoing for customer-specific products.

### 7. Property Rights

All the rights for contractual products produced by Würth Elektronik eiSos GmbH & Co. KG on the basis of ideas, development contracts as well as models or templates that are subject to copyright, patent or commercial protection supplied to the customer will remain with Würth Elektronik eiSos GmbH & Co. KG. Würth Elektronik eiSos GmbH & Co. KG does not warrant or represent that any license, either expressed or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, application, or process in which Würth Elektronik eiSos GmbH & Co. KG components or services are used.

### 8. General Terms and Conditions

Unless otherwise agreed in individual contracts, all orders are subject to the current version of the "General Terms and Conditions of Würth Elektronik eiSos Group", last version available at [www.we-online.com](http://www.we-online.com).

  	CHECKED LuSe	REVISION 002.000	DATE (YYYY-MM-DD) 2020-11-02	GENERAL TOLERANCE DIN ISO 2768-1m	PROJECTION METHOD 
DESCRIPTION <b>WIRL-POSI Erinome-II GPS-GLO-GAL-BDS GNSS module T&amp;R</b>					ORDER CODE <b>2614021137000</b>
		BUSINESS UNIT eISmart	STATUS Valid		PAGE 7/7



---

# ANR017 GNSS ANTENNA SELECTION

---

VERSION 1.1

JULY 31, 2020

## Revision history

Manual version	Notes	Date
1.0	Initial Version	March 2020
1.1	Effective dielectric constant formula corrected	July 2020

## Abbreviations and abstract

Abbreviation	Description
AR	Axial Ratio
BDS	BeiDou navigation System
CP	Circular Polarization
FR4	Flame Retardant 4
GLONASS	Global Navigation Satellite System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
LHCP	Left Hand Circular Polarization
LNA	Low Noise Amplifier
RF	Radio frequency
RHCP	Right Hand Circular Polarization
SAW	Surface Acoustic Wave
SMD	Surface Mounted Device
THT	Through Hole Technology
TM	Transverse Magnetic
VSWR	Voltage Standing Wave Ratio

# Contents

<b>1 Introduction</b>	<b>5</b>
<b>2 Basic Antenna Theory</b>	<b>6</b>
2.1 Antenna Radiation Pattern . . . . .	6
2.2 Efficiency . . . . .	7
2.3 Directivity . . . . .	7
2.4 Antenna gain . . . . .	8
2.5 Bandwidth . . . . .	8
2.6 Input impedance and VSWR . . . . .	8
2.7 Polarization and Axial ratio . . . . .	10
<b>3 General Antenna Consideration</b>	<b>12</b>
3.1 Passive Antenna Types . . . . .	13
3.1.1 Wire Antennas . . . . .	14
3.1.2 Loop Antennas . . . . .	15
3.1.3 Helix Antennas . . . . .	17
3.1.4 Spiral Antennas . . . . .	18
3.1.5 Microstrip Patch Antenna . . . . .	19
3.1.6 Slot Antenna . . . . .	23
3.1.7 Ceramic Antenna . . . . .	24
3.1.7.1 Ceramic Chip Antenna . . . . .	24
3.1.7.2 Ceramic Patch Antenna . . . . .	25
<b>4 Ceramic Patch Antenna Analysis</b>	<b>27</b>
<b>5 Practical Implementation</b>	<b>30</b>
<b>6 Summary</b>	<b>35</b>
<b>7 References</b>	<b>36</b>
<b>8 Important notes</b>	<b>37</b>
8.1 General customer responsibility . . . . .	37
8.2 Customer responsibility related to specific, in particular safety-relevant applications . . . . .	37
8.3 Best care and attention . . . . .	37
8.4 Customer support for product specifications . . . . .	37
8.5 Product improvements . . . . .	38
8.6 Product life cycle . . . . .	38
8.7 Property rights . . . . .	38
8.8 General terms and conditions . . . . .	38
<b>9 Legal notice</b>	<b>39</b>
9.1 Exclusion of liability . . . . .	39
9.2 Suitability in customer applications . . . . .	39
9.3 Trademarks . . . . .	39
9.4 Usage restriction . . . . .	39

<b>10 License terms</b>	<b>41</b>
10.1 Limited license . . . . .	41
10.2 Usage and obligations . . . . .	41
10.3 Ownership . . . . .	42
10.4 Firmware update(s) . . . . .	42
10.5 Disclaimer of warranty . . . . .	42
10.6 Limitation of liability . . . . .	43
10.7 Applicable law and jurisdiction . . . . .	43
10.8 Severability clause . . . . .	43
10.9 Miscellaneous . . . . .	43

# 1 Introduction

This application note provides an understanding of antenna theory, antenna design considerations and implementation for GNSS solutions. The first chapter of the document covers basic antenna theory to provide better understanding of the following chapters. The later chapters of the document focus on

- Types of antenna
- Design considerations
- Requirements and specifications
- Simulated analysis
- Practical implementation

Information provided in this application note are intended for GNSS solutions.

## 2 Basic Antenna Theory

An antenna can be described as a device used to radiate and absorb electromagnetic waves. It transforms the electromagnetic waves from the free space into electrical voltages and currents in conductors and vice versa. The antenna is an essential component in any RF communication system.

In GNSS applications, signals from satellites have very low power level at the earth surface. This imposes a significant importance in selection, design and implementation of an antenna.

### 2.1 Antenna Radiation Pattern

The radiation pattern is simply defined as the representation of the electromagnetic field or energy radiated from the antenna. All radiation characteristics of an antenna can be represented by a function in 2D or 3D coordinate systems. These patterns are created by measuring the fields radiated from the antenna. They are commonly used to investigate the radiation field characteristics of the antenna in detail.

The radiation patterns vary based on the antenna types and specification such as isotropic, omnidirectional and directional.

Isotropic radiation is exhibited by an ideal antenna that radiates equally on all directions, however these antennas do not practically exist. Omnidirectional and directional are commonly found radiation patterns. Omnidirectional antennas radiate equally in all directions perpendicular to an axis. They exhibit a radiation pattern shaped like a donut in three dimensional representation.

Antennas radiating in a specific direction apart from omnidirectional antennas are referred as directional antennas. The radiation pattern of a directional antenna varies according to the power distribution in different directions.

The radiation pattern is used to describe most antenna parameters in graphical representation for better understanding and interpretation.

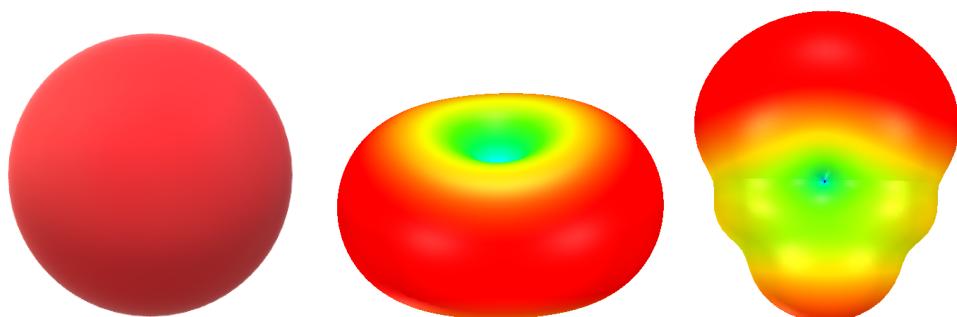


Figure 1: Isotropic, Omnidirectional and Unidirectional radiation pattern

The radiation performance of antenna can be described through some important antenna parameters as follows:

- Efficiency
- Directivity
- Gain
- Bandwidth
- Polarization
- Axial ratio

Some of these parameters are further explained below.

## 2.2 Efficiency

Antenna efficiency is defined as a combination of radiation, conduction and reflection. The radiation efficiency is simply the ratio of the total power transmitted into space to the input power of the antenna provided by the source. The non-radiated input power accepted by the antenna is lost in form of heat dissipation, dielectric and ohmic losses.

$$\eta = \frac{P_{rad}}{P_{in}} \quad (1)$$

$$P_{in} = P_{rad} + P_l \quad (2)$$

$P_{rad}$  = Radiated power

$P_{in}$  = Input power accepted by the antenna

$P_l$  = Power loss

$\eta$  = Radiation efficiency

The total efficiency takes the power losses as well as the effect of impedance matching into account. Both total and radiation efficiency can be used to express antenna gain.

## 2.3 Directivity

Directivity of an antenna is given by the ratio of radiation field density of an antenna in a given direction to the average field density in all other directions.

Depending on the antenna design, direction of the radiation changes. In some cases the antenna radiation is high in one direction relative to other directions. The front to back ratio

of the radiation also varies depending on the antenna design. Similar to Gain, the directivity of an antenna is expressed in dB and it can be also expressed in dBi if it is defined relative to an isotropic radiator.

## 2.4 Antenna gain

Antenna gain is one of the important parameters used to describe antenna performance. In general, antennas are passive components and do not possess gain by itself similar to an amplifier power gain. Antenna gain can also be stated as a factor of radiation efficiency multiplied by directivity. In practice, no antenna can transfer input power completely into radiated output power resulting in radiation efficiency always less than a hundred percent. This results in the antenna gain being always lower than directivity. Gain of an antenna is expressed in dB and it can be also expressed in dBi if it is defined relative to an isotropic radiator.

$$G = D \times \eta \quad (3)$$

$G$  = Antenna gain

$D$  = Directivity

$\eta$  = Radiation efficiency

## 2.5 Bandwidth

Bandwidth is defined as a range of frequencies in which the antenna characteristics meets certain specification. These specification are defined based on the end application.

Each characteristic of an antenna varies over the frequency in a different manner. This results in several bandwidth definitions depending on antenna characteristics like Efficiency bandwidth, polarization bandwidth, directivity bandwidth, gain bandwidth and impedance bandwidth. Commonly the antenna bandwidth is referred to impedance bandwidth or return loss bandwidth. The specification is to achieve pure resistive impedance at antenna resonant frequency and to get a minimum of -10dB return loss for the specified bandwidth.

As all the satellites signals are circularly polarized, GNSS application requires maintaining a axial ratio below 3dB in the operating bandwidth of an antenna.

## 2.6 Input impedance and VSWR

As already discussed an efficient antenna radiates most of its power and has minimum loss to provide better efficiency. Some of the reasons for power loss include reflection of the waves and impedance mismatch in the transmission line.

To maximize power transfer in an antenna, output impedance of the transmission line should match the input impedance of the antenna. In this way, the transmission line maintains the same level of impedance, which is usually the characteristic impedance of the transmission line. This is achieved by the process called impedance matching. In practice, the

input impedance of an antenna is affected by many external factors like nearby objects, conducting materials and other antennas. In theory, for purposes of simplification, an isolated antenna composed of real and imaginary parts is considered.

$$Z_{in} = R_{in} + X_{in} \quad (4)$$

$R_{in}$  = Input Resistance

$X_{in}$  = Capacitive or Inductive reactance

The characteristic impedance widely used in the coaxial cables is  $50\Omega$ , which provides best trade-off between loss dissipation and power handling in RF systems. For this reason RF systems commonly work with  $50\Omega$  transmission line.

Transmission lines with improperly matched impedance results in loss of power. Reflection in the transmission line and related phenomena are further defined by some parameters such as reflection coefficient, Voltage Standing Wave Ratio (VSWR) and return loss.

Reflection Coefficient is defined as the ratio of reflected wave voltage to the incident wave voltage.

$$\Gamma = \frac{(Z_{in} - Z_{out})}{(Z_{in} + Z_{out})} \quad (5)$$

$Z_{in}$  - Input impedance of the antenna

$Z_{out}$  - Characteristic impedance of the transmission line

Return loss of the antenna is given by

$$RL = 20 \log_{10}(|\Gamma|) \quad (6)$$

VSWR is the ratio of maximum voltage to the minimum voltage on the transmission line.

$$VSWR = \frac{(1 + |\Gamma|)}{(1 - |\Gamma|)} \quad (7)$$

## 2.7 Polarization and Axial ratio

Unlike other parameters, polarization is one of the least explained parameters in antenna characteristics. It is used to describe the vectorial nature of the electric fields radiated by an antenna. Based on the orientation of the electric field expressed by the antennas, the polarization of an antenna is classified into linear and circular and elliptical polarization.

In linear polarization, the electric and magnetic field vectors do not change their direction during wave propagation. If the electric field vectors are perpendicular to earth surface, the wave is vertically polarized. If the electric field vectors are parallel to earth surface, then the wave is horizontally polarized. Figure 2 shows the linear vertically polarized wave propagating in the direction Z. The electric field vectors are represented in straight lines and the magnetic field vectors are represented in dashed lines. Figure 3 shows the direction of the electric field vectors in horizontal and vertically polarized waves respectively. In figure 3, direction of propagation is away from the reader.

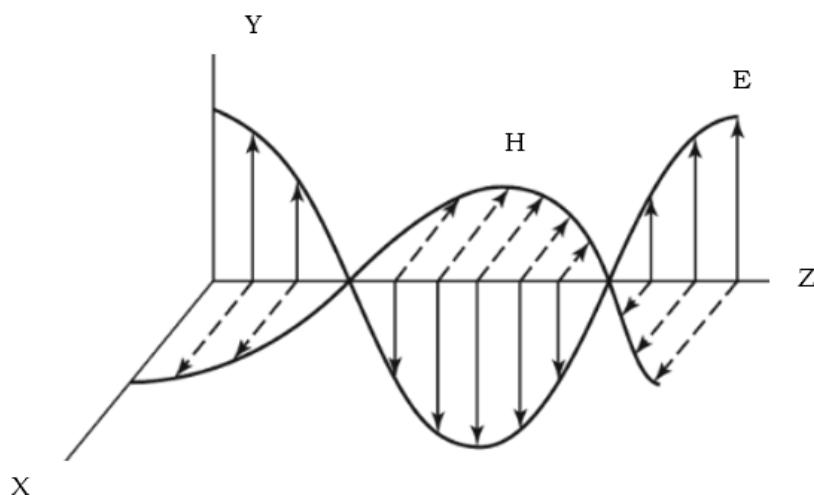


Figure 2: Linear polarization

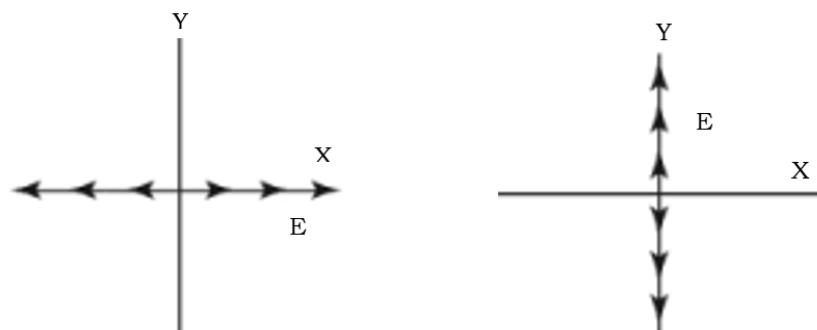


Figure 3: Horizontal and vertical linear polarization

In circular polarization the electric and magnetic vectors do not point in the same direction. They rotate 360° per wavelength during wave propagation. The rotation is achieved by the specific excitation of the orthogonal modes. If the phase delay between the two orthogonal modes is 90°, then circular polarization is achieved. Depending on the direction of rotation, right hand or left hand circular polarization is determined. Figure 4 shows the right hand circular polarized wave propagating in the direction Z. Figure 5 shows the direction of electric field vector rotation in left and right hand circular polarized waves respectively. In the figure 5, direction of propagation is away from the reader.

Due to the relative antenna orientation and high to multipath interference, satellite communication applications tend to use circular polarization.

In practice, it is impossible to obtain a perfect circular polarization, which mostly results elliptical polarization. The ratio of major to minor axis of the ellipse is called the axial ratio. In case of proper circular polarization, the minor and major axis are equal which gives an axial ratio of unity or 0dB. Therefore, it is recommended to design an antenna with an axial ratio as close as possible to 0dB. Depending on the type of antennas various methods are used to achieve circular polarization.

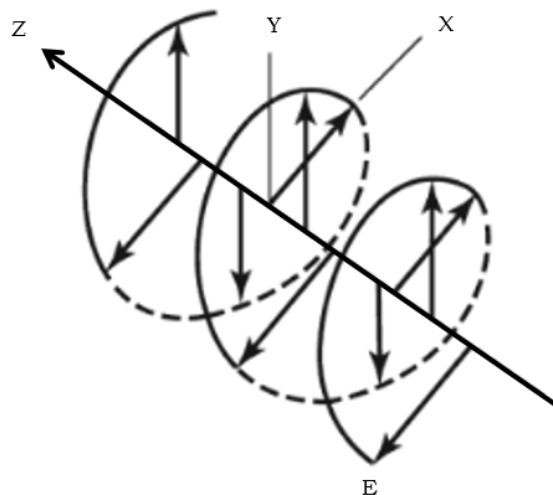


Figure 4: Circular polarization

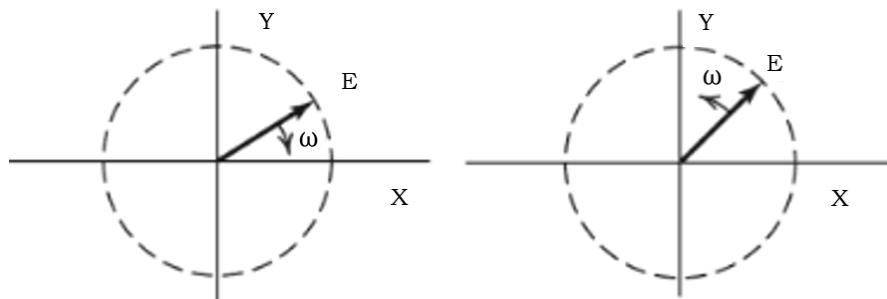


Figure 5: Left hand and right hand circular polarization

### 3 General Antenna Consideration

Based on the antenna theory described in the previous section, important antenna parameters influencing the performance of the antennas can be understood. The requirements for antenna design and selection are defined by those parameters. In addition to the technical requirements derived from antenna parameters, other factors have to be taken into account in the antenna selection process, such as

- Antenna placement
- Ground plane size and design
- Interference on the application board
- Impedance matching to the system
- Antenna exposure to sky
- Noise factor
- Power consumption
- End application

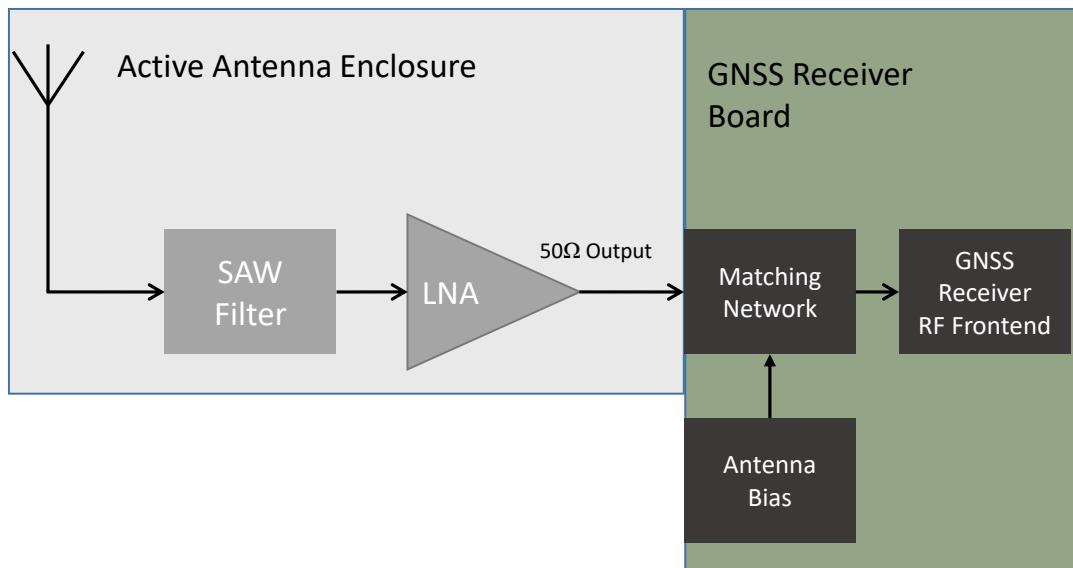


Figure 6: Active antenna implementation

Different GNSS systems are used worldwide for positioning and navigation applications. In general, the GNSS signal has a signal power level of -120dBm to -140dBm at the earth surface, which implies that the GNSS receiver needs minimum carrier to noise ratio approximately in the range from 35dBHz to 50dBHz for optimal performance.

A standard active antenna used for GNSS purpose commonly integrated with a LNA, SAW filter along with  $50\Omega$  matched input connection. So it provides higher gain, sensitivity and reduced noise figure for an optimal performance to the receiver.

However, integration of an active antenna might be critical in applications with low power consumption requirements. A proper gain selection of an active antenna is also necessary as an antenna gain higher than receiver input specification might overload some GNSS receivers.

In the following chapters, this application note focuses on passive antenna types and related considerations.

### 3.1 Passive Antenna Types

The typical technical antenna requirements of a passive antenna preferred for GNSS application include

- High Gain towards zenith
- Low Noise Figure
- Axial Ratio close to unity
- LHCP signal rejection
- RHCP signal susception
- Properly matched impedance

As the GNSS signals are circular polarized, only circularly polarized antennas are described. It is important for the passive antenna to use circular polarization. This demands RF expertise for design and implementation. The circulation polarization can be obtained in passive antennas through different methods based on the types of antenna.

Common passive antenna types which can provide circular polarization and can be used in GNSS applications are

- Wire Antenna
- Loop Antenna
- Helix Antenna
- Spiral Antenna
- Slot Antenna
- Microstrip Patch Antenna
- Ceramic Antenna

Antennas listed here are originally linearly polarized. Their base designs can be modified to achieve circular polarization.

### **3.1.1 Wire Antennas**

Basic form of commonly used wire antennas are dipole wire antennas which support linear polarization.

Designing a crossed dipole antenna using normal dipole wire antenna is a common method used to obtain circular polarization. The crossed dipole is created by placing two dipole antennas perpendicular to each other. Each dipole antenna is fed with  $90^\circ$  phase shift which results in circular polarization. The crossed dipole antenna is large in size and radiation pattern of the antenna is mostly omnidirectional due to the dipole antenna behaviour.

A crossed dipole to operate at frequency of 1.575GHz has the dimension:

- Dipole length = 71.2mm
- Width = 1.8mm
- Feed gap = 1.8mm
- Ground plane = 142mm x 142mm

It has a RHCP gain of -0.6dBi and Return loss of -13.4dB. Because of the omnidirectional radiation and large dimension of the antenna, it is commonly not preferred for GNSS application.

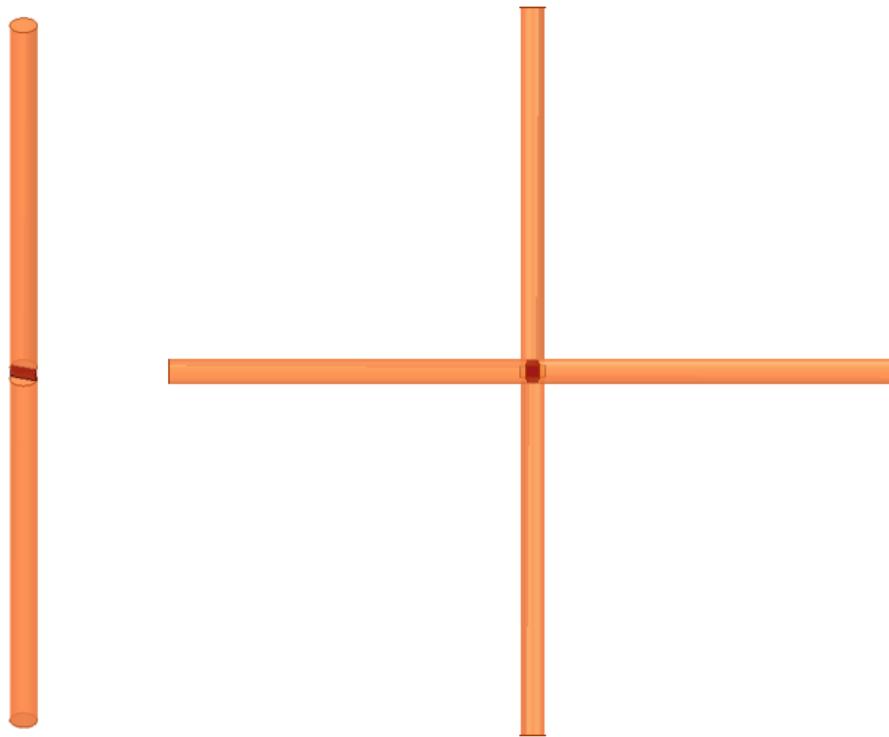


Figure 7: Normal dipole and cross dipole wire antenna

### 3.1.2 Loop Antennas

A loop antenna is implemented generally by a bent metallic conductor to form different shapes. Depending on the shapes, number of turns in the loop, structures as well as feeding techniques the performance can be altered to achieve circular polarization.

Loop antennas are commonly used for its directional radiation pattern. The circular polarization in loop antennas is achieved using different methods such as parasitic loop, dual loops and different types of feeds.

Figure 8 shows a circular loop antenna with two concentric circular loops, among which the inner loop is parasitic loop and the outer loop is a driven loop which is excited by a probe feed. There are gaps in the loops, gap1 and gap2 placed at an angle 45° and 60° respectively. Gap1 of outer loop produces circular polarized fields which is coupled with the inner loop to provide circular polarization. The antenna is designed on an 40x40mm<sup>2</sup> ground plane at a height of 13mm and provides unidirectional radiation pattern. The gain of this antenna is about 7 to 8dBi and VSWR of 3 over the operating frequency at 1.5GHz.

All the parameters of the antenna can be altered to manipulate the antenna characteristics to achieve best performance.

In case of figure 9, a dual rectangular loop antenna is designed on a ground plane of 200mm x 150mm at an height of 53mm excited at the middle through dipole antenna in series. The gaps in the loops are situated symmetrically with respect to the feed. In comparison with single loop antennas, a dual loop antenna significantly increases the AR Bandwidth.

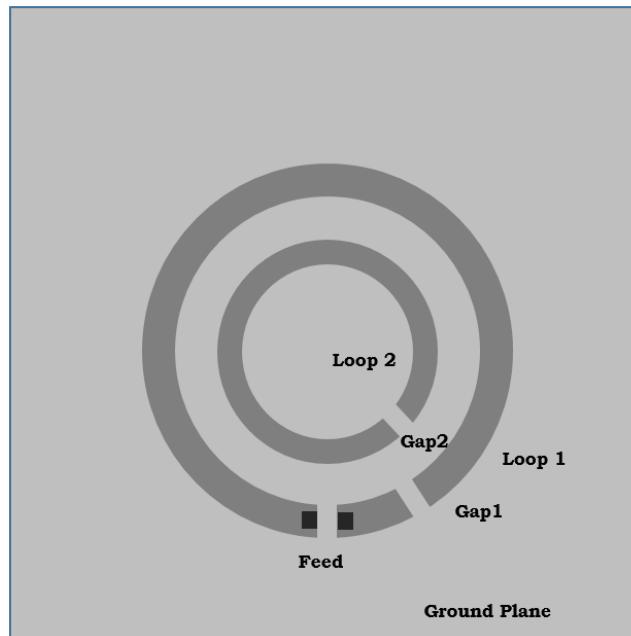


Figure 8: Parasitic loop antenna

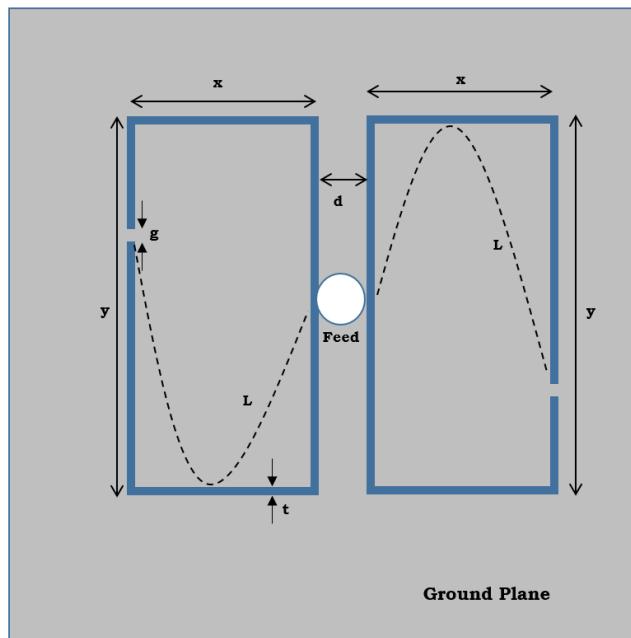


Figure 9: Dual rectangular loop antenna

Similar to parasitic loop, all antenna parameters can be optimized for specific performance. The optimized parameters values are  $x=48.3\text{mm}$ ,  $y=96.7\text{mm}$ ,  $g=5.9\text{mm}$ ,  $L=157.4\text{mm}$ ,  $d=10\text{mm}$  and  $t=2\text{mm}$ .

At the operating frequency of 1.5GHz and with the optimized parameters the VSWR is 1.07, with minimum AR of 0.03dB and similar gain as parasitic loop antenna.

### 3.1.3 Helix Antennas

Helix Antenna is a widely preferred antenna structure for the circular polarization. It is designed by a metallic wire wound to form a screw thread like structure. The major parameters to design the helix antenna which significantly influences the antenna performance are

- Number of turns (N)
- Pitch angle ( $\alpha$ )
- Separation between turns (S)
- Diameter (D)
- Length of the antenna (L)
- Circumference of one turn (C)

The circumference of the turns defines the mode of operation. If the circumference of one turn (C) is small compared to the wavelength then the mode of operation is referred as normal mode. In normal mode the antenna exhibits linear polarization. If the circumference of one turn is same or nearly equal to the wavelength then the mode of operation is referred as Axial mode.

Axial mode is the preferred operation mode because of its circular polarization and unidirectional gain. One other mode of operation called higher-order radiation mode occurs when the circumference exceeds the wavelength. This results in splitting the major lobe of the radiation pattern.

For optimal performance in axial mode, the design equations of the key parameters are given by

$$\frac{3}{4} < C < \frac{4}{3}\lambda \quad (8)$$

$$S \approx \frac{1}{4} \quad (9)$$

$$12^\circ \leq \alpha \leq 14^\circ \quad (10)$$

An axial mode helical antenna with minimal possible dimension to operate at 1.575GHz is given as: L=19.3cm, C=21.2cm, D=6cm, S=4.2cm and N=4. The antenna is designed on a ground plane of 21.5cm x 21.5cm. It has a RHCP gain of 11.6dBi and return loss of -13.8dB. Despite having good characteristics, these antennas have some limitations such as high dimension and complex integration. Ceramic helical antenna are also designed in order to reduce antenna size.

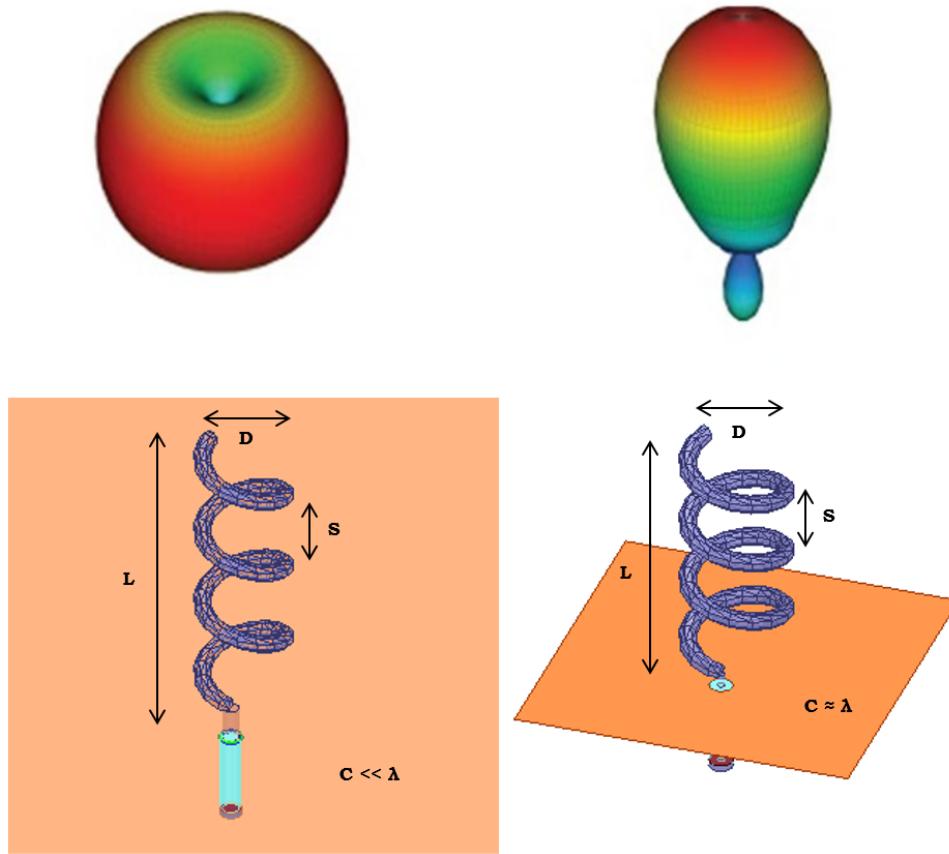


Figure 10: Helix antenna normal and axial mode

### 3.1.4 Spiral Antennas

Spiral antennas provide frequency-independent performance in terms of radiation pattern, impedance and polarization which is independent of frequency. This behaviour allows to operate over a wide range of frequencies.

Figure 11 shows different types of planar spiral antennas like sinusoidal log and archimedean spiral antenna respectively. The antenna has two conducting arms flaring outwards from the center. The structure of the arms flaring out depends on the type of spiral. For instance a typical planar archimedean spiral antenna arm is defined by the equation

$$r = r_0 a \phi \left( \frac{1}{b} \right) \quad (11)$$

r - Inner radius

a - Expansion Coefficient

b - Spiral Coefficient

$\phi$  - Angle at radius linearly increase

The arms are excited in balanced mode with equal amplitude and with phase difference of  $180^\circ$ . This design results in the radiation of circularly polarized waves.

The characteristics of different planar spiral antenna types with minimum possible dimension to operate at frequency 1.575GHz are displayed in the Table 1.



Figure 11: Different types of spiral antenna

Patch type	RHCP Gain(dBi)	Return Loss(dB)	Antenna Dimension
Planar Spiral-Log	2.1	-5.56	90mm x 90mm
Planar Spiral-Archimedean	0.92	-2.86	70mm x 70mm
Planar Spiral-Sinuous	4.8	-3.92	120mm x 120mm

Table 1: Spiral antenna characteristics

### 3.1.5 Microstrip Patch Antenna

Microstrip patch is one of the popular PCB antennas. It is well known for its low profile, low cost, compact design and easy implementation. Patch antennas provide many design possibilities to manipulate antenna behaviour. The required performance of the antenna can be achieved by modifying the

- Structure
- Feed technique
- Patch design

During the design process, very common shapes of patch considered are rectangular and circular patches. Depending on the dimensions of base patch, the shape further changes. Some of basic shapes are shown in the figure 12

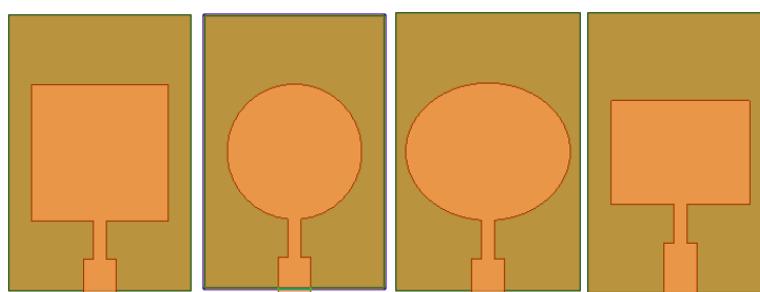


Figure 12: Microstrip patch antenna shapes

Once the shape of the patch is decided, the next important step is the feeding type to be used. Generally, there are four types of feeds used for the excitation. These feed types are

1. Edge feed
2. Inset feed
3. Probe feed
4. Slot Feed

The above listed feed types are shown in the figure 13 respectively.

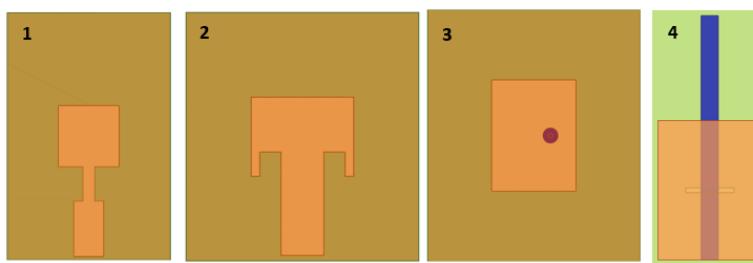


Figure 13: Feed types in microstrip patch antenna

A specific performance can be achieved using different designs, producing different patch antenna solutions. During the design process, all requirements of the end application shall be taken into account. Design considerations relevant to circular polarization shall also be taken into account. Centre operating frequency depends on the dimension of the patch.

The width of the patch is determined approximately by the equation.

$$W \approx \frac{c}{2fc\sqrt{\frac{\varepsilon_r + 1}{2}}} \quad (12)$$

The effective dielectric constant is given by the equation

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \left( \frac{1}{\sqrt{1 + \frac{12h}{W}}} \right) \quad (13)$$

Effective length of the patch is given as

$$L_{eff} \approx \frac{c}{2fc\sqrt{\varepsilon_{eff}}} \quad (14)$$

Actual length of the patch is

$$L = L_{eff} - 2\Delta L \quad (15)$$

From the equation it can be seen that the length and width of the patch are inversely proportional to the relative permittivity of the substrate. If size of the patch decreases, the relative permittivity increases.

In case of circular patch the approximate radius is given by the equation

$$r \approx \frac{F}{\sqrt{1 + \frac{200h}{\pi\epsilon_r F} [\ln(\frac{\pi h}{200h}) + 1.7726]}} \quad (16)$$

$$F = \frac{8.791 \times 10^9}{fc\sqrt{\epsilon_r}} \quad (17)$$

c - Velocity of light in vacuum

$fc$  - Centre operating frequency

$\epsilon_r$  - Relative Permittivity of the substrate

h - Thickness of substrate

$\Delta L$  - Length extension of patch during operation

r - Radius of the Patch

Even though the circular patch antenna has the advantage of wider bandwidth compared to rectangular patch, the fabrication of circular patch is more challenging compared to the rectangular patch. Therefore rectangular patch is preferred in practical application.

Antenna characteristics of different Microstrip patch antenna types with minimal possible patch dimension without optimization to operate at frequency of 1.575GHz are given in the Table 2. Further optimization and impedance matching is possible in the end application.

Patch type	RHCP Gain(dBi)	Return Loss(dB)	Patch Dimension	Ground Dimension
Rectangular-Probe fed	2.7	-6.26	58mm x 45mm	97mm x 77mm
Rectangular-Inset fed	1.87	-10.32	58mm x 45mm	97mm x 138.7mm
Rectangular-Edge fed	1.7	-3.25	58mm x 45mm	97mm x 196.2mm
Circular-Probe fed	0.1	-0.3	45mm x 45mm	55mm x 55mm
Elliptical-Inset fed	-4.2	-0.72	58mm x 45mm	97mm x 138.7mm
Elliptical-Edge fed	-4.3	-0.74	58mm x 45mm	97mm x 196.2mm

Table 2: Microstrip patch antenna characteristics

After creating the basic design, the tuning of an antenna to achieve optimal performance is made by further detailed design process. This tuning optimizes the antenna characteristics. As already discussed, the basic concept of circular polarization is the excitation of two orthogonal modes (TM01,TM10) equally but with a 90° phase difference. In case of microstrip patch antenna, circular polarization phenomena is obtained by means of several feeding techniques and combinations. One important condition to be always considered is to maintain  $50\Omega$  impedance microstrip lines in the feed networks.

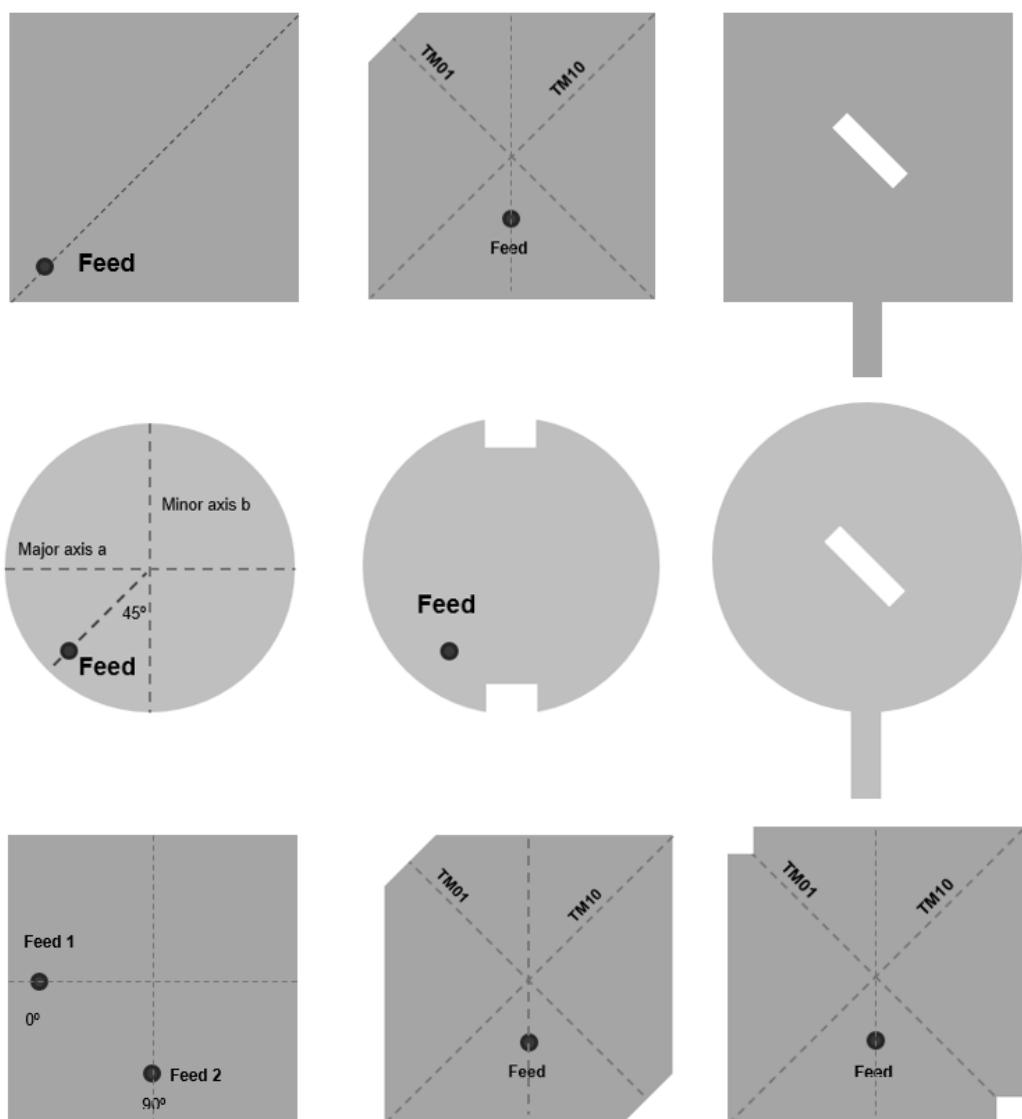


Figure 14: Circular polarization feed techniques

The feeding techniques include

- Single feed with different excitations
- Excitation at specific angles
- Combination with slots
- Corner truncation
- Perturbation
- Dual or multi feeds
- Different feed network

Few of these feed techniques are shown in figure 14

### 3.1.6 Slot Antenna

Slot antennas are very simple PCB-based antennas. Their design is based on the concept of microstrip patch antenna. Generally the slot antenna has a microstrip feed on bottom layer of the PCB and a slot above on the top layer. The electromagnetic energy is coupled to the slot through micro strip which enables the slot to radiate as an antenna. They are simpler to design and can be easily integrated along with other active and passive devices. A broader bandwidth relative to a normal microstrip patch can be achieved.

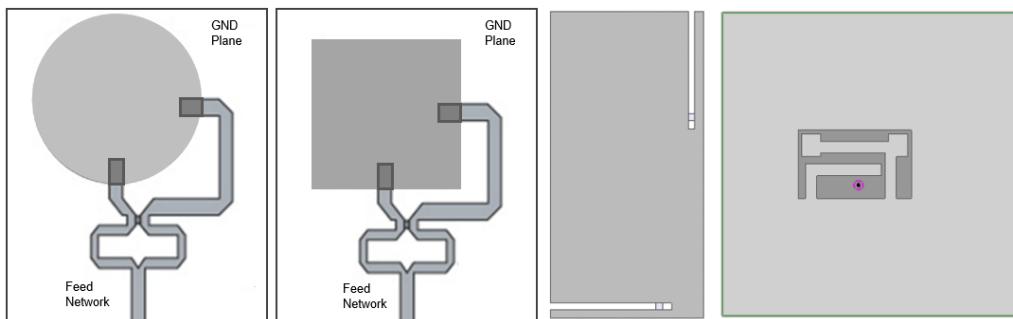


Figure 15: Different types of slot antennas

Circular polarization in the slot antenna is achieved by modifying the feed. Typical feed technique is to design a power divider in the microstrip line, so that two feeds with a quarter wavelength excited at two orthogonal modes with a phase shift of 90°. To operate at 1.575GHz, a microstrip fed slot antenna has a length=89mm, width=4.5mm and designed

on a 134mm x 178mm ground plane. It provides a RHCP Gain of 2.1dBi and Return loss of -17.6dB.

The slots and feed shapes as well as structures can be varied in numerous ways to achieve circular polarization. Some of such slot antenna types are shown in the figure 15

### 3.1.7 Ceramic Antenna

Ceramic antenna as indicated by the name itself, is an antenna created using ceramic as its core material. The main reason of using ceramic material is strict size requirements in some applications. As ceramic has higher relative permittivity compared to commonly used FR4 PCB substrate, size of the ceramic antenna is relatively small. The size reduction also results in reduced gain, directivity and bandwidth of the antenna. Nevertheless, comparing to the similar antenna design in FR4 substrates of same dimension, ceramic antennas provide the better gain and directivity.

There are three major types of ceramic antennas. The first is the ceramic resonator or dielectric resonator antenna which is commonly a ceramic cuboid or cylinder block used to radiate energy. A single ceramic block cannot produce efficient results in all required antenna applications, they need to be adapted to the end application.

The second type is the ceramic patch antenna which is widely used for GNSS application

The third type is ceramic chip antenna which is well known for the small size and high efficiency.

#### 3.1.7.1 Ceramic Chip Antenna

Ceramic chip antenna presents advantages in size, high gain and ease of implementation. It is therefore one of the good choices of antenna for GNSS solutions. This type of antenna is mostly used in relatively small like mobile applications.

Ceramic chip antenna provides relatively high gain in comparison to other antennas of similar size, but does not provide optimal circular polarization and its performance is highly affected by the ground plane. Commonly chip antenna comes under the monopole antenna classification. In this classification, antenna together with the ground plane exhibit a dipole antenna characteristic. The high gain of the chip antenna is achieved by a sufficiently large ground plane. Some ceramic chip antenna manufacturers represent antennas with no ground plane requirement which is not exactly true.

The linear polarization characteristics, ground plane influence, design consideration like isolation distance, footprint and mounting of ceramic chip antenna shall be always taken into consideration during design. To achieve much higher performance, the size of the antenna is relatively increased which leads to further increase in ground plane size. Due to these difficulties, chip antennas are only considered for suitable applications.

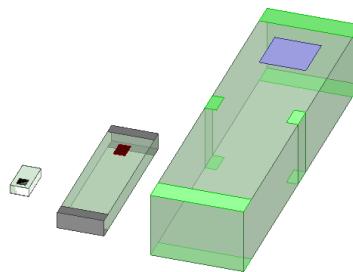


Figure 16: Ceramic chip antenna

Some of the ceramic chip antennas available in the market and their typical characteristics are given in the Table 3. All antennas listed in the table are linearly polarized and have own specific layout recommendations. Impedance matching is possible in the end application.

Dimension	Gain(dBi)	Bandwidth(MHz)	Return Loss(dB)	Ground Plane
3.2x1.6x0.5mm	-2	10	< -10	80mm x 40mm
10x3.2x1.5mm	-1.6	20	< -10	80mm x 37mm
10x10x0.9mm	1.2	45	< -10	70mm X 40mm
12x3mm x 2.4mm	1.6	45	< -10	70mm x 50mm
15x4mm x 3.2mm	1.6	45	< -9.5	100mm x 50mm

Table 3: Ceramic chip antenna characteristics

### 3.1.7.2 Ceramic Patch Antenna

Ceramic patch antenna is a patch antenna designed on ceramic substrate instead of the common printed circuit board. Due to nature of the ceramic material and flexible design solution of microstrip patch antenna, Ceramic patch antennas provide optimal performance and are suitable for GNSS application. As discussed in the section 3.1.5, possible microstrip patch antenna designs apply to ceramic patch antennas as well. Because of the implementation of the patch design on the ceramic substrate, the size of antenna can be reduced depending on the ceramic material.

A typical dimension of microstrip patch for GNSS application is approximately 60mm x 40mm, whereas ceramic patch antennas are available from dimension of 10mm x 10mm. Although the characteristics change depending on size, they can be optimized by tuning the antenna. Usage of ceramic substrate supports size reduction of the antenna.

If properly implemented, a ceramic patch antenna is circularly polarized and possess a hemispherical radiation pattern. This leads to directivity almost twice the directivity of omnidirectional antenna.

The high directivity from radiation pattern allows higher antenna visibility to sky and reduces the interference from other devices nearby. Although the peak gain of the antenna even with small ground plane would be high, the bandwidth reduces and also the Axial ratio gets affected. The flexible design possibilities of the patch allow fine tuning of the antenna.

As of a very small ceramic patch, the performance reduces considerably. The typical preferred size of the ceramic patch antenna range from 10 to 35mm.

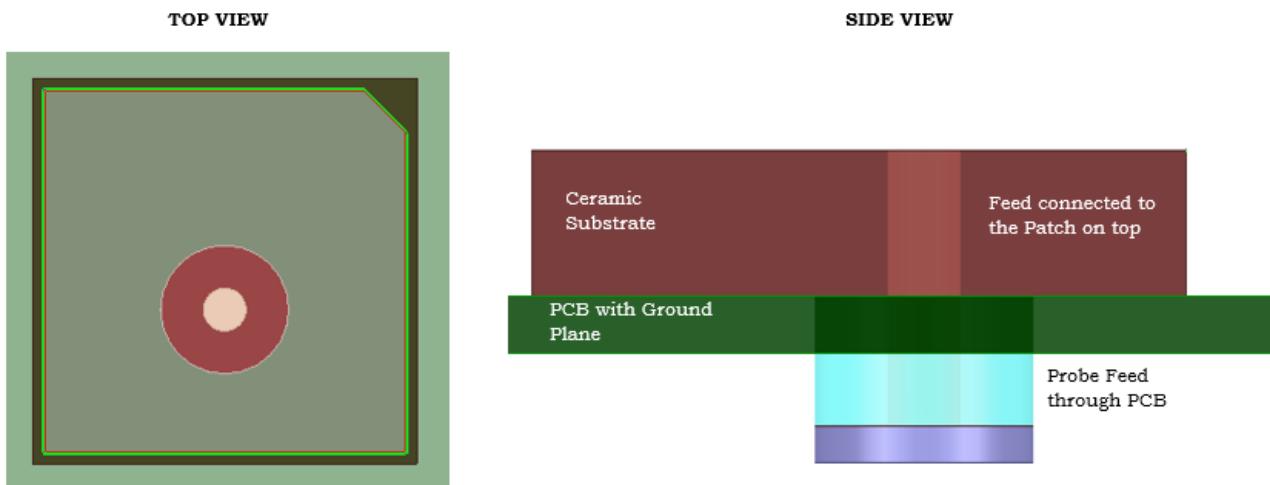


Figure 17: Ceramic patch antenna

Some of the typical characteristics of ceramic chip antennas for different sizes are given in Table 4. All antennas listed in the table are right hand circularly polarized with an axial ratio of 1-2.5 dB and the characteristics are displayed for the ground plane size of 75mm x 75mm.

The antenna tuning and impedance matching can be done in the end application for further improvement in the characteristics.

Dimension	RHCP Gain(dBi)	Bandwidth(MHz)	Return Loss(dB)	Efficiency
10x10x4mm	2	10	< -10	45%
13x13x4mm	3	15	< -10	50%
15x15x4mm	3-4	15	< -10	70%
18x18mm x 4mm	4.5-5.5	20	< -10	70%
25x25mm x 4mm	5.5	25	< -9.5	80%

Table 4: Ceramic patch antenna characteristics

## 4 Ceramic Patch Antenna Analysis

As described in the previous section, the ceramic patch antenna is one of the most suitable antenna for GNSS application and provides flexible designing to optimize the antenna performance. This section allows to understand the antenna behaviour and design considerations to be taken care before implementation of the antenna in practical application.

The smallest and most suitable ceramic patch antenna dimension is 18mm x 18mm, as this antenna size has a bandwidth to provide required performance at all the interested frequency of the GNSS application with the same design optimization. If the size of the antenna is smaller, complex optimization is needed for different operating frequency.

There are two types of common mountings used in the ceramic patch antenna: SMD and THT. The typical ground plane size of the 18mm x 18mm ceramic patch antenna for optimal performance is 75mm x 75mm. Although by designing the patch the antenna performance can be tuned, it has to be done by antenna design engineers and requires RF expertise. For an already designed antenna the performance can also be manipulated by the ground plane size, positioning and impedance matching.

To get a general overview and observe the behaviour of the already designed antenna, an 18mm x 18mm through hole mount antenna is simulated with two different conditions.

Firstly the antenna ground plane is varied from  $20\text{ mm}^2$  to  $75\text{ mm}^2$  throughout the simulation. In the second setup, the position of the antenna is varied based on distance between the edge of the ceramic patch antenna and the edge of the ground plane.

For a  $75\text{ mm}^2$  standard ground plane shown in figure 18 the value of L is varied from 0mm to 28.5mm, moving the antenna in a diagonal path from the corner to the center of the ground plane.

The antenna is already tuned to the center frequency of 1576MHz and due to the change in the size of the ground plane, the center frequency is shifted which results in detuning of antenna. Although results for the antenna with different dimensions are subjected to change, the behaviour of the antenna remains similar.

The analysis shows the importance of understanding the behaviour, design consideration and implementation of the ceramic patch antenna. Figure 19 shows that, if the condition of antenna implementation changes, the characteristics like center frequency, bandwidth, gain and axial ratio change as well. The size of the ground plane is modified by the parameter G.

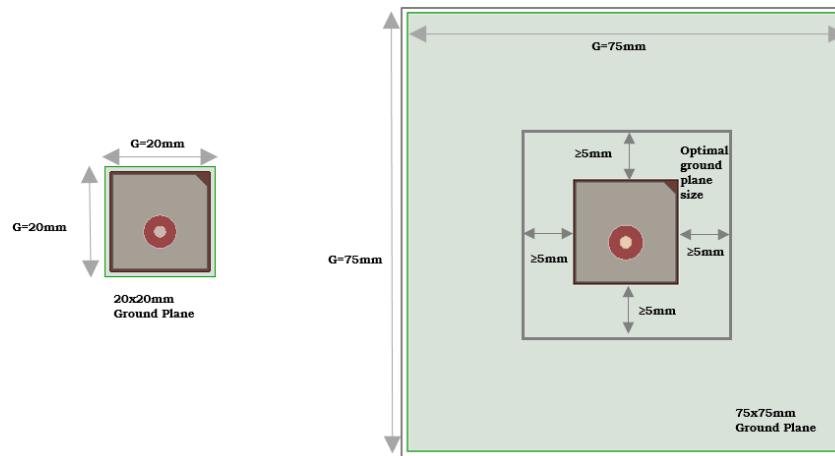


Figure 18: Ceramic patch antenna simulation - different ground plane

As from the results, it can be observed that the change in the ground plane influences all the important parameters. Once the ground plane size decreases from the required size  $G=75\text{mm}$  to  $20\text{mm}$ , the antenna gets detuned to lower frequency. The rapid drop in center frequency occurs around  $G=28\text{mm}$ , when the ground plane size becomes very small. On a typical ceramic patch antenna implementation, it is better to have at least a ground size  $10\text{mm}$  larger than the antenna size, so that all sides of the antenna edge have distance of  $5\text{mm}$  to the edge of the ground plane.

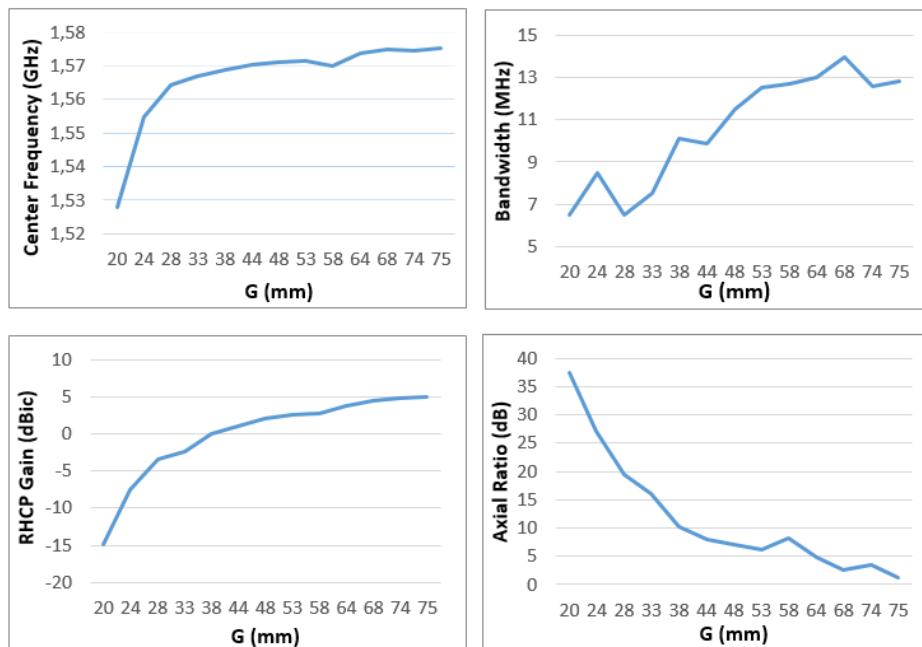


Figure 19: Antenna performance for different ground plane



Design or implementation of other components in the near  $5\text{mm}$  distance around the antenna can affect the antenna performance. So generally, a minimum of  $5\text{mm}$  keep out distance from antenna to other components is recommended in layout design

The bandwidth becomes narrower with reduction in ground size reduction. The most affected parameters are the RHCP Gain and Axial ratio, as seen in the results there is a phenomenal change by the ground plane size reduction.

Similar to the size of the ground, the position of antenna on the ground plane also changes the antenna characteristics. This is due to the change in the asymmetrical distribution of the ground plane created by the change in antenna position. To observe the changes in antenna characteristics in response to the change in antenna position on ground plane, a simulation is executed. On the standard ground plane of  $75 \times 75 \text{ mm}^2$  size, the position of the antenna is moved from the corner to the center of the ground plane in a diagonal path by varying the value of the parameter L from 28.5mm to 0mm. This setup can be seen in figure 20. The simulation results are shown in figure 21.

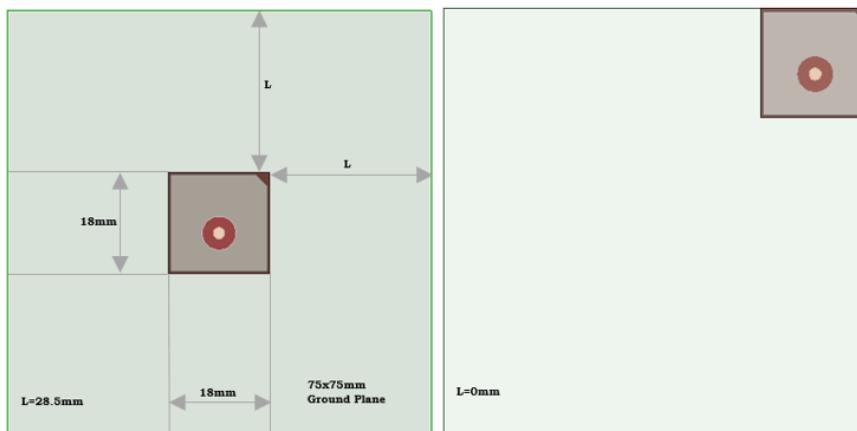


Figure 20: Ceramic patch antenna simulation - different antenna position

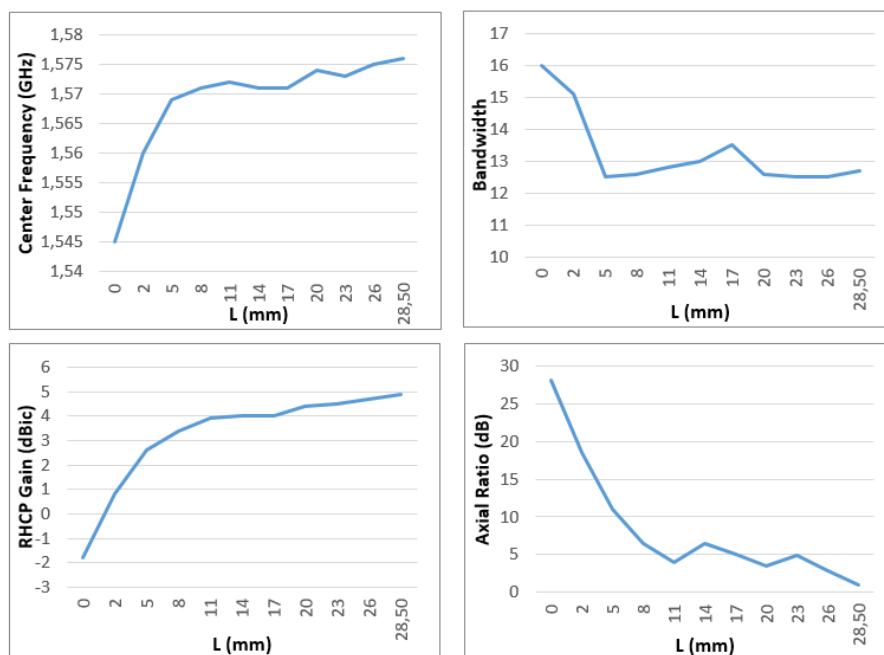


Figure 21: Antenna performance for different antenna position

In the results, the center frequency, bandwidth and RHCP gain show small variation until the antenna approaches the corner of the ground plane. Once the antenna moves very near approximately 5mm to the corner, the center frequency and RHCP gain are affected significantly which is seen by the reduced antenna performance. Although the bandwidth increases approaching the corner, other parameters are drastically affected with the antenna positioned near the corner of the ground plane. Most significantly the axial ratio is affected with the change in position resulting in depolarization. This indicates that during the design process, the antenna shall not be positioned near the edges or corner of the ground plane, as it results in antenna performance degradation.

## 5 Practical Implementation

From the previous chapters, it can be understood that to implement the ceramic patch antenna on a printed circuit board, certain design considerations should be taken into account. In order to understand the antenna behaviour in real life scenario, the practical implementation of a ceramic patch antenna is further explained in this section.

A ceramic patch antenna of size 18mm x 18mm with the through hole mount is designed on two different Boards. PCB-A is a four layer PCB with dimension 60mm x 90mm. The ground plane in PCB-A is distributed on layer 2 and layer 4. Layer 1 and layer 3 of the PCB are dedicated for signal and power traces. Antenna feed is connected to the coplanar stripline on the bottom layer.

PCB-B is also a four layer PCB with dimension 60mm x 118mm. The ground plane in PCB-B is separated between the antenna and main ground plane. The main ground plane of the PCB has a dimension of 60mm x 90mm distributed on the layer 2 and layer 4. Layer 1 and layer 3 of the PCB are dedicated for signal and power plane. The ceramic patch antenna has a dedicated ground plane underneath on all the four layers with a dimension of 24mm x 24mm. The antenna ground plane is connected to the main ground plane on layer 3 and layer 4. This connection also supports the coplanar strip line feed connection to the antenna pin on the bottom layer.

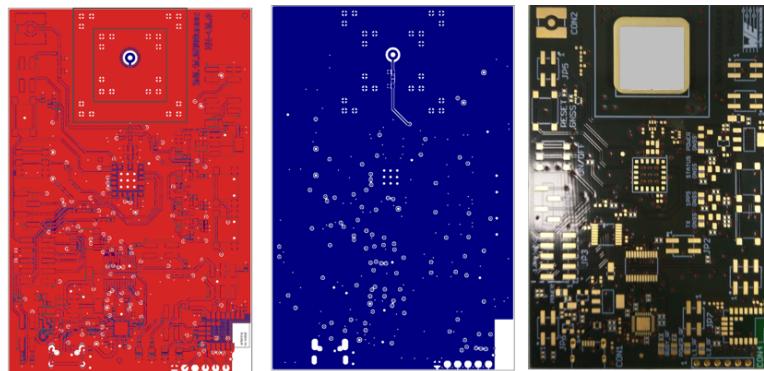


Figure 22: PCB-A

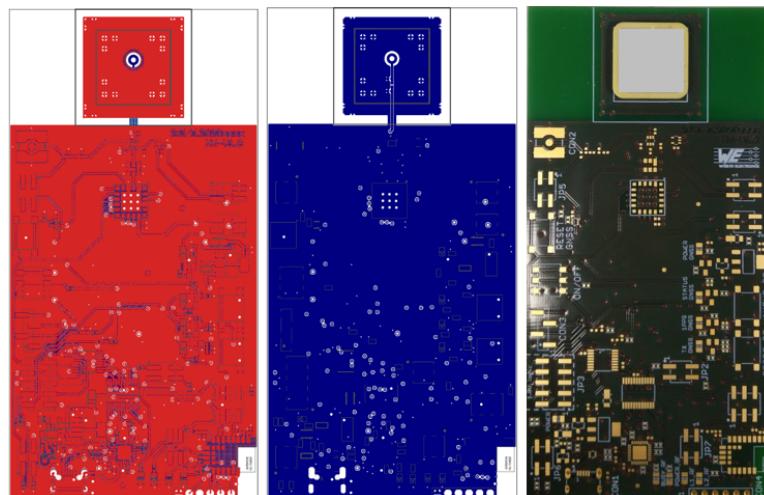


Figure 23: PCB-B

As described already, tuning an antenna for a specified ground can be done on the ceramic patch antenna through the modification handled on the patch. Apart from tuning the antenna through the patch modification, the impedance matching method is the most commonly used tuning method which allows to set the antenna in optimal performance for certain frequency range. Impedance matching allows to match the antenna input impedance to a characteristic impedance of the transmission line. Using impedance matching the antenna can be set into resonance at operating frequency, achieve low return loss and better signal reception.

To have a  $50 \Omega$  impedance matched coplanar line from the receiver output to antenna input, the input impedance of the antenna should be known. It can be seen from figure 24 that four different through hole ceramic patch antennas (A1, A2, A3, A4) of dimension 18mm x 18mm are soldered on both PCB-A and PCB-B.

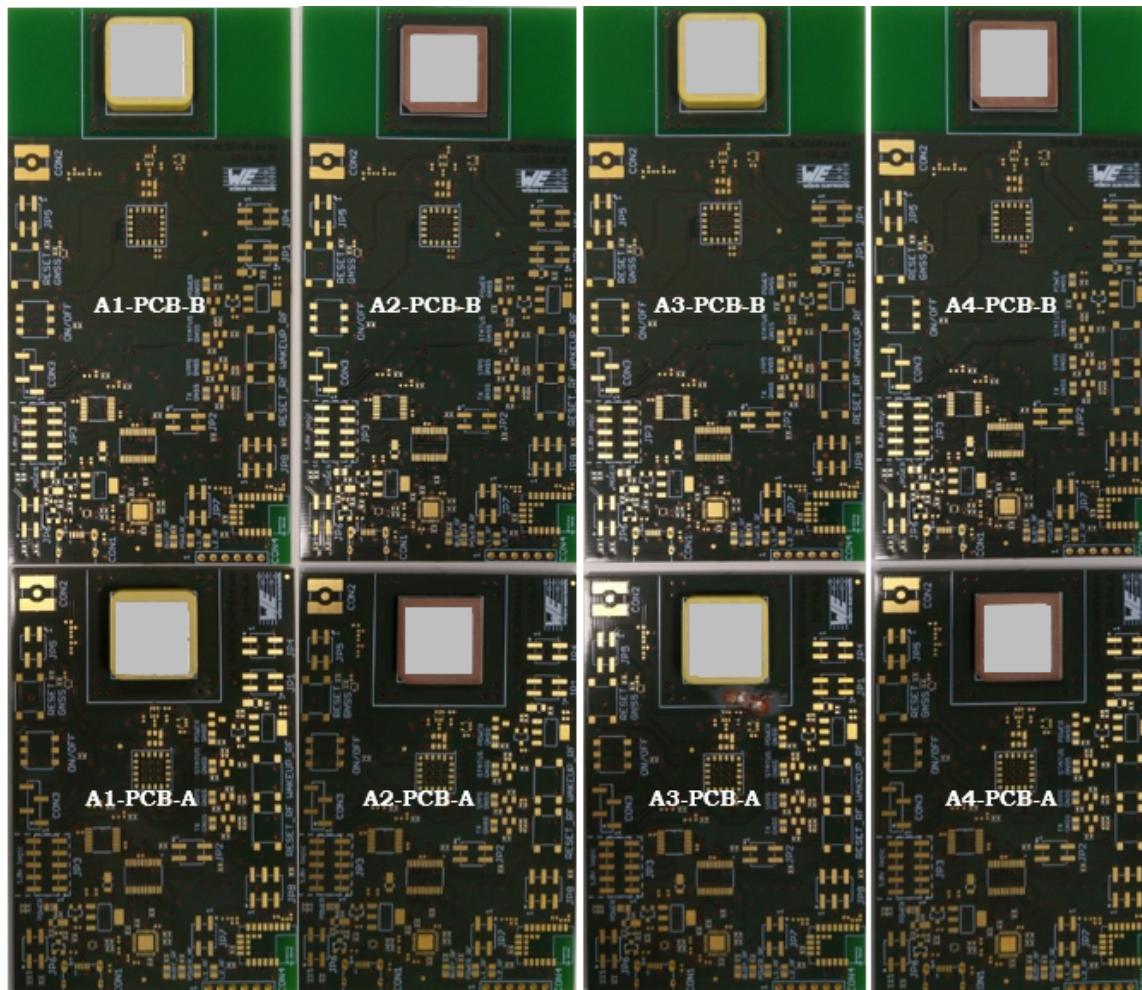


Figure 24: Antennas assembled on PCB-A and PCB-B

The antennas are from different manufacturers and have similar characteristics. Firstly, the impedance characteristics and return loss of the antenna on two PCB variants are observed using a network analyzer which is shown in the figure 25.

In figure 25, there can also be seen the markers are placed on the frequencies representing the important GNSS systems as GPS, Galileo, GLONASS and BeiDou.

- Marker 1: 1.561 GHz (BeiDou)
- Marker 5: 1.609 GHz (GLONASS)
- Marker 6: 1.575 GHz (GPS, Galileo)

The green markers are used in the impedance trace and the yellow markers are used in return loss trace.

As per the technical data from manufacturers, the antennas have an input impedance of  $50\Omega$ . However, the input impedance varies according to the ground plane which can be observed from network analyzer measurement in figure 25. It can be seen the green markers in figure 25 changes between PCB-A and PCB-B, exhibiting different input impedance.

PCB-A provides input impedance close to  $50\Omega$ . PCB-A is also less susceptible to external influence than PCB-B.

Figure 25 also denotes that the operating frequency range of the different GNSS systems vary and not all the frequencies can be covered for the optimal performance, thus resulting in a trade-off between the performance and operating frequency. Based on the navigation system on the end application, impedance matching is done for a particular system or favouring some systems over other.

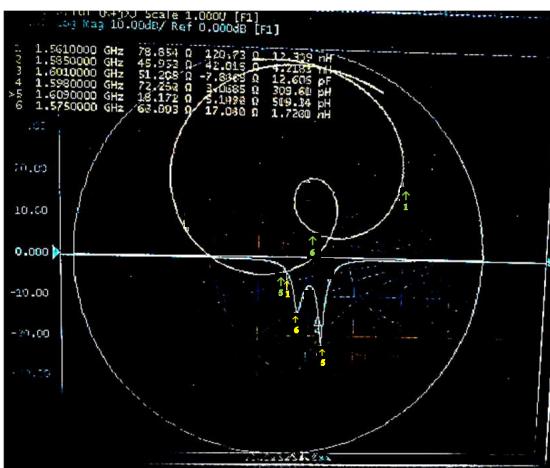
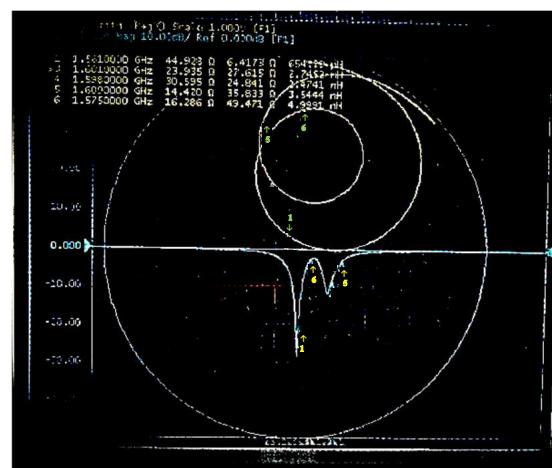
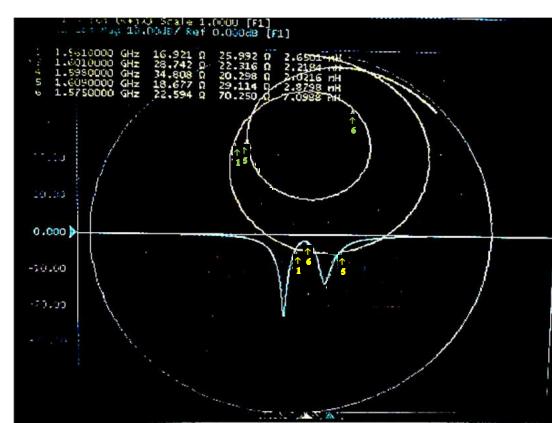
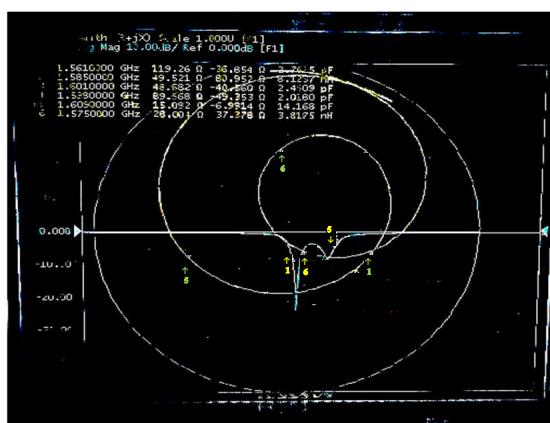
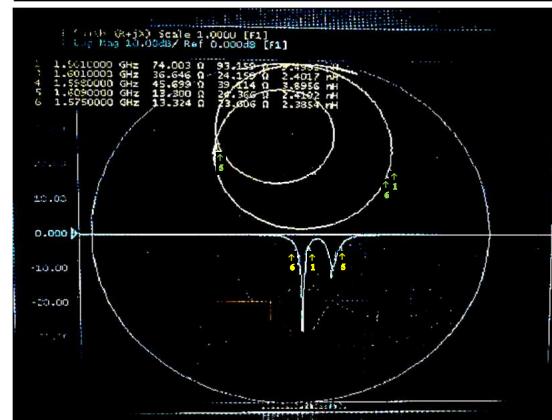
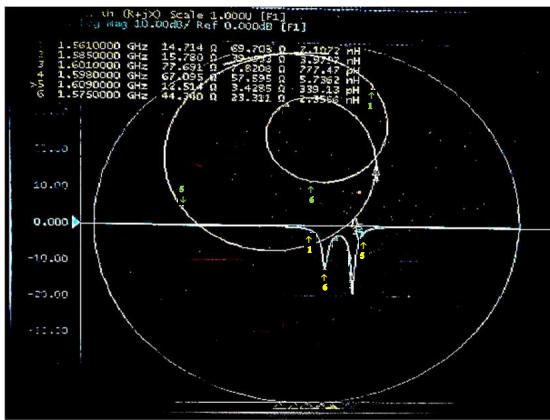
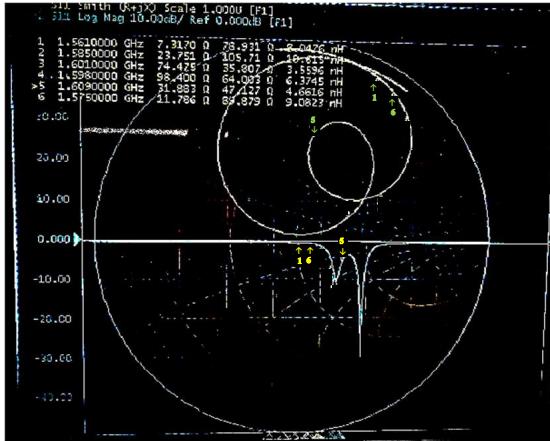
**PCB-A****PCB-B****A1****A2****A3****A4**

Figure 25: Input impedance of antennas on PCB-A and PCB-B

Impedance matching can be done using different methods. Most common method is using II-filter matching circuit composed of capacitive and inductive elements. Along with the help of the Smith chart, the values of components in the pi filter are modified to determine the proper impedance matching circuit. On both PCB-A and PCB-B, a pi filter circuit is designed using a coplanar strip on the bottom layer where the components can be assembled to provide  $50\Omega$  matched output for the antenna feed pin.

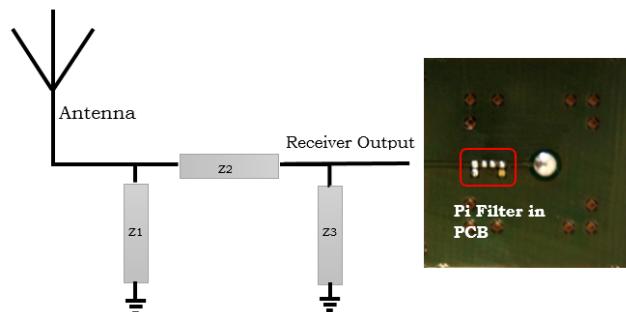
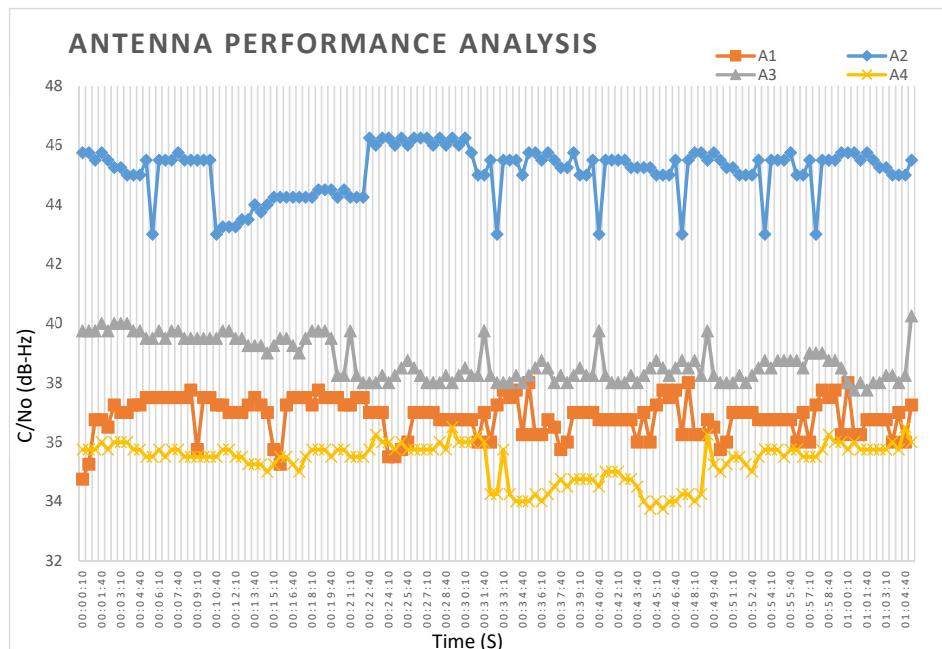


Figure 26: Pi-filter on PCB

PCB-A providing the better antenna input impedance is used for further experimentation. The antennas along with the other circuitry are assembled on PCB-A and taken into operation. All the boards are tuned to have optimal  $50\Omega$  matched impedance from output of the GNSS receiver to antenna input. To compare antenna performance, the GNSS signals which are received by the GNSS receiver through the implemented antenna are analysed and the mean carrier to noise ratio of four strong satellite signals are plotted over time, which can be seen in the figure 27.

The antenna A2 shows better signal reception for all the important frequencies and systems in comparison to other antennas. Based on the result from the figure 27, antenna variant 'A2', an 18mm x 18mm through hole ceramic patch antenna from the manufacturer Abracon, is selected as the most suitable option for implementation on our GNSS Evaluation boards.



## 6 Summary

This application note provides recommendations and guidelines for GNSS antenna selection as well as implementation.

An introduction section covers fundamentals of antenna theory (Chapter 2). Chapter 2 provides the necessary basics to understand concepts, terms and details of the rest of the analysis.

Followed by that, challenges of antenna selection, design and implementation for GNSS antennas are discussed. Advantages and disadvantage of the different antenna solutions are highlighted.

Critical steps of the integration, such as:

- Tuning the patch
- Optimized antenna dimension
- Implementation

and their impact on the end application are explained in detail and shown with several examples. Provided examples also shows the change in characteristics for different antenna implementations of same type.

Being one of the most used antennas, a simulated analysis of ceramic patch antennas was performed and described for different test conditions. The results explains the effect of external influence on the ceramic patch antenna implementation. The guidelines for practical implementation are also discussed based on analysis.

Discussing the practical implementation of different ceramic patch antennas in real life scenarios emphasized major design challenges, such as:

- Antenna detuning
- Influence of ground plane
- Influence of antenna position
- Change in performance

In the last part of the application note, the performance analysis of the different antennas are represented graphically. The results display the signal reception capabilities of the antenna. Although the antennas used have similar characteristics, the performance on the implemented PCB is different. Based on the performance of the antennas, the antenna with best signal reception is selected for the end application. The end application in this case is the evaluation boards of our GNSS modules *Elara – II* and *Erinome – II*.

Considerations and outcomes of this work concerning antenna selection, design, and integration are decisive for the performance of the GNSS end application.

## 7 References

1. Antenna Theory and Design By Warren L. Stutzman, Gary A. Thiele
2. Understanding GPS/GNSS: Principles and Applications, Third Edition
3. Circularly Polarized Antennas By Steven Shichang Gao, Qi Luo, Fuguo Zhu
4. Antenna Design for Mobile Devices By Zhijun Zhang
5. Multifunctional Operation and Application of GPS edited by Rustam B. Rustamov, A.M. Hashimov
6. Broadband Planar Antennas: Design and Applications By Zhi Ning Chen, Michael Yan Wah Chia

For detailed information related to impedance matching please look into our application note below.

[https://www.we-online.com/web/en/electronic\\_components/produkte\\_pb/application\\_notes/we\\_mca\\_multilayer\\_chipantenne\\_platzierung\\_und\\_anpassung.php](https://www.we-online.com/web/en/electronic_components/produkte_pb/application_notes/we_mca_multilayer_chipantenne_platzierung_und_anpassung.php)

## 8 Important notes

The following conditions apply to all goods within the wireless connectivity product range of Würth Elektronik eiSos GmbH & Co. KG:

### 8.1 General customer responsibility

Some goods within the product range of Würth Elektronik eiSos GmbH & Co. KG contain statements regarding general suitability for certain application areas. These statements about suitability are based on our knowledge and experience of typical requirements concerning the areas, serve as general guidance and cannot be estimated as binding statements about the suitability for a customer application. The responsibility for the applicability and use in a particular customer design is always solely within the authority of the customer. Due to this fact, it is up to the customer to evaluate, where appropriate to investigate and to decide whether the device with the specific product characteristics described in the product specification is valid and suitable for the respective customer application or not. Accordingly, the customer is cautioned to verify that the documentation is current before placing orders.

### 8.2 Customer responsibility related to specific, in particular safety-relevant applications

It has to be clearly pointed out that the possibility of a malfunction of electronic components or failure before the end of the usual lifetime cannot be completely eliminated in the current state of the art, even if the products are operated within the range of the specifications. The same statement is valid for all software sourcecode and firmware parts contained in or used with or for products in the wireless connectivity and sensor product range of Würth Elektronik eiSos GmbH & Co. KG. In certain customer applications requiring a high level of safety and especially in customer applications in which the malfunction or failure of an electronic component could endanger human life or health, it must be ensured by most advanced technological aid of suitable design of the customer application that no injury or damage is caused to third parties in the event of malfunction or failure of an electronic component.

### 8.3 Best care and attention

Any product-specific data sheets, manuals, application notes, PCN's, warnings and cautions must be strictly observed in the most recent versions and matching to the products firmware revisions. This documents can be downloaded from the product specific sections on the wireless connectivity homepage.

### 8.4 Customer support for product specifications

Some products within the product range may contain substances, which are subject to restrictions in certain jurisdictions in order to serve specific technical requirements. Necessary information is available on request. In this case, the field sales engineer or the internal sales person in charge should be contacted who will be happy to support in this matter.

## 8.5 Product improvements

Due to constant product improvement, product specifications may change from time to time. As a standard reporting procedure of the Product Change Notification (PCN) according to the JEDEC-Standard, we inform about major changes. In case of further queries regarding the PCN, the field sales engineer, the internal sales person or the technical support team in charge should be contacted. The basic responsibility of the customer as per section 8.1 and 8.2 remains unaffected. All wireless connectivity module driver software "wireless connectivity SDK" and its source codes as well as all PC software tools are not subject to the Product Change Notification information process.

## 8.6 Product life cycle

Due to technical progress and economical evaluation we also reserve the right to discontinue production and delivery of products. As a standard reporting procedure of the Product Termination Notification (PTN) according to the JEDEC-Standard we will inform at an early stage about inevitable product discontinuance. According to this, we cannot ensure that all products within our product range will always be available. Therefore, it needs to be verified with the field sales engineer or the internal sales person in charge about the current product availability expectancy before or when the product for application design-in disposal is considered. The approach named above does not apply in the case of individual agreements deviating from the foregoing for customer-specific products.

## 8.7 Property rights

All the rights for contractual products produced by Würth Elektronik eiSos GmbH & Co. KG on the basis of ideas, development contracts as well as models or templates that are subject to copyright, patent or commercial protection supplied to the customer will remain with Würth Elektronik eiSos GmbH & Co. KG. Würth Elektronik eiSos GmbH & Co. KG does not warrant or represent that any license, either expressed or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right relating to any combination, application, or process in which Würth Elektronik eiSos GmbH & Co. KG components or services are used.

## 8.8 General terms and conditions

Unless otherwise agreed in individual contracts, all orders are subject to the current version of the "General Terms and Conditions of Würth Elektronik eiSos Group", last version available at [www.we-online.com](http://www.we-online.com).

## 9 Legal notice

### 9.1 Exclusion of liability

Würth Elektronik eiSos GmbH & Co. KG considers the information in this document to be correct at the time of publication. However, Würth Elektronik eiSos GmbH & Co. KG reserves the right to modify the information such as technical specifications or functions of its products or discontinue the production of these products or the support of one of these products without any written announcement or notification to customers. The customer must make sure that the information used corresponds to the latest published information. Würth Elektronik eiSos GmbH & Co. KG does not assume any liability for the use of its products. Würth Elektronik eiSos GmbH & Co. KG does not grant licenses for its patent rights or for any other of its intellectual property rights or third-party rights.

Notwithstanding anything above, Würth Elektronik eiSos GmbH & Co. KG makes no representations and/or warranties of any kind for the provided information related to their accuracy, correctness, completeness, usage of the products and/or usability for customer applications. Information published by Würth Elektronik eiSos GmbH & Co. KG regarding third-party products or services does not constitute a license to use such products or services or a warranty or endorsement thereof.

### 9.2 Suitability in customer applications

The customer bears the responsibility for compliance of systems or units, in which Würth Elektronik eiSos GmbH & Co. KG products are integrated, with applicable legal regulations. Customer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of Würth Elektronik eiSos GmbH & Co. KG components in its applications, notwithstanding any applications-related information or support that may be provided by Würth Elektronik eiSos GmbH & Co. KG. Customer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences lessen the likelihood of failures that might cause harm and take appropriate remedial actions. The customer will fully indemnify Würth Elektronik eiSos GmbH & Co. KG and its representatives against any damages arising out of the use of any Würth Elektronik eiSos GmbH & Co. KG components in safety-critical applications.

### 9.3 Trademarks

AMBER wireless is a registered trademark of Würth Elektronik eiSos GmbH & Co. KG. All other trademarks, registered trademarks, and product names are the exclusive property of the respective owners.

### 9.4 Usage restriction

Würth Elektronik eiSos GmbH & Co. KG products have been designed and developed for usage in general electronic equipment only. This product is not authorized for use in equipment where a higher safety standard and reliability standard is especially required or where

a failure of the product is reasonably expected to cause severe personal injury or death, unless the parties have executed an agreement specifically governing such use. Moreover, Würth Elektronik eiSos GmbH & Co. KG products are neither designed nor intended for use in areas such as military, aerospace, aviation, nuclear control, submarine, transportation (automotive control, train control, ship control), transportation signal, disaster prevention, medical, public information network etc. Würth Elektronik eiSos GmbH & Co. KG must be informed about the intent of such usage before the design-in stage. In addition, sufficient reliability evaluation checks for safety must be performed on every electronic component, which is used in electrical circuits that require high safety and reliability function or performance. By using Würth Elektronik eiSos GmbH & Co. KG products, the customer agrees to these terms and conditions.

## 10 License terms

This License Terms will take effect upon the purchase and usage of the Würth Elektronik eiSos GmbH & Co. KG wireless connectivity products. You hereby agree that this license terms is applicable to the product and the incorporated software, firmware and source codes (collectively, "Software") made available by Würth Elektronik eiSos in any form, including but not limited to binary, executable or source code form.

The software included in any Würth Elektronik eiSos wireless connectivity product is purchased to you on the condition that you accept the terms and conditions of this license terms. You agree to comply with all provisions under this license terms.

### 10.1 Limited license

Würth Elektronik eiSos hereby grants you a limited, non-exclusive, non-transferable and royalty-free license to use the software and under the conditions that will be set forth in this license terms. You are free to use the provided Software only in connection with one of the products from Würth Elektronik eiSos to the extent described in this license terms. You are entitled to change or alter the source code for the sole purpose of creating an application embedding the Würth Elektronik eiSos wireless connectivity product. The transfer of the source code to third parties is allowed to the sole extent that the source code is used by such third parties in connection with our product or another hardware provided by Würth Elektronik eiSos under strict adherence of this license terms. Würth Elektronik eiSos will not assume any liability for the usage of the incorporated software and the source code. You are not entitled to transfer the source code in any form to third parties without prior written consent of Würth Elektronik eiSos.

You are not allowed to reproduce, translate, reverse engineer, decompile, disassemble or create derivative works of the incorporated Software and the source code in whole or in part. No more extensive rights to use and exploit the products are granted to you.

### 10.2 Usage and obligations

The responsibility for the applicability and use of the Würth Elektronik eiSos wireless connectivity product with the incorporated Firmware in a particular customer design is always solely within the authority of the customer. Due to this fact, it is up to you to evaluate and investigate, where appropriate, and to decide whether the device with the specific product characteristics described in the product specification is valid and suitable for your respective application or not.

You are responsible for using the Würth Elektronik eiSos wireless connectivity product with the incorporated Firmware in compliance with all applicable product liability and product safety laws. You acknowledge to minimize the risk of loss and harm to individuals and bear the risk for failure leading to personal injury or death due to your usage of the product.

Würth Elektronik eiSos' products with the incorporated Firmware are not authorized for use in safety-critical applications, or where a failure of the product is reasonably expected to cause severe personal injury or death. Moreover, Würth Elektronik eiSos' products with the incorporated Firmware are neither designed nor intended for use in areas such as military, aerospace, aviation, nuclear control, submarine, transportation (automotive control, train control, ship control), transportation signal, disaster prevention, medical, public information network etc. You shall inform Würth Elektronik eiSos about the intent of such usage before

design-in stage. In certain customer applications requiring a very high level of safety and in which the malfunction or failure of an electronic component could endanger human life or health, you must ensure to have all necessary expertise in the safety and regulatory ramifications of your applications. You acknowledge and agree that you are solely responsible for all legal, regulatory and safety-related requirements concerning your products and any use of Würth Elektronik eisSos' products with the incorporated Firmware in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by Würth Elektronik eisSos. YOU SHALL INDEMNIFY WÜRTH ELEKTRONIK EISOS AGAINST ANY DAMAGES ARISING OUT OF THE USE OF WÜRTH ELEKTRONIK EISOS' PRODUCTS WITH THE INCORPORATED FIRMWARE IN SUCH SAFETY-CRITICAL APPLICATIONS.

## 10.3 Ownership

The incorporated Firmware created by Würth Elektronik eisSos is and will remain the exclusive property of Würth Elektronik eisSos.

## 10.4 Firmware update(s)

You have the opportunity to request the current and actual Firmware for a bought wireless connectivity Product within the time of warranty. However, Würth Elektronik eisSos has no obligation to update a modules firmware in their production facilities, but can offer this as a service on request. The upload of firmware updates falls within your responsibility, e.g. via ACC or another software for firmware updates. Firmware updates will not be communicated automatically. It is within your responsibility to check the current version of a firmware in the latest version of the product manual on our website. The revision table in the product manual provides all necessary information about firmware updates. There is no right to be provided with binary files, so called "Firmware images", those could be flashed through JTAG, SWD, Spi-Bi-Wire, SPI or similar interfaces.

## 10.5 Disclaimer of warranty

THE FIRMWARE IS PROVIDED "AS IS". YOU ACKNOWLEDGE THAT WÜRTH ELEKTRONIK EISOS MAKES NO REPRESENTATIONS AND WARRANTIES OF ANY KIND RELATED TO, BUT NOT LIMITED TO THE NON-INFRINGEMENT OF THIRD PARTIES' INTELLECTUAL PROPERTY RIGHTS OR THE MERCHANTABILITY OR FITNESS FOR YOUR INTENDED PURPOSE OR USAGE. WÜRTH ELEKTRONIK EISOS DOES NOT WARRANT OR REPRESENT THAT ANY LICENSE, EITHER EXPRESS OR IMPLIED, IS GRANTED UNDER ANY PATENT RIGHT, COPYRIGHT, MASK WORK RIGHT, OR OTHER INTELLECTUAL PROPERTY RIGHT RELATING TO ANY COMBINATION, MACHINE, OR PROCESS IN WHICH THE WÜRTH ELEKTRONIK EISOS' PRODUCT WITH THE INCORPORATED FIRMWARE IS USED. INFORMATION PUBLISHED BY WÜRTH ELEKTRONIK EISOS REGARDING THIRD-PARTY PRODUCTS OR SERVICES DOES NOT CONSTITUTE A LICENSE FROM WÜRTH ELEKTRONIK EISOS TO USE SUCH PRODUCTS OR SERVICES OR A WARRANTY OR ENDORSEMENT THEREOF.

## 10.6 Limitation of liability

Any liability not expressly provided by Würth Elektronik eiSos shall be disclaimed. You agree to hold us harmless from any third-party claims related to your usage of the Würth Elektronik eiSos' products with the incorporated Firmware, software and source code. Würth Elektronik eiSos disclaims any liability for any alteration, development created by you or your customers as well as for any combination with other products.

## 10.7 Applicable law and jurisdiction

Applicable law to this license terms shall be the laws of the Federal Republic of Germany. Any dispute, claim or controversy arising out of or relating to this license terms shall be resolved and finally settled by the court competent for the location of Würth Elektronik eiSos' registered office.

## 10.8 Severability clause

If a provision of this license terms is or becomes invalid, unenforceable or null and void, this shall not affect the remaining provisions of the terms. The parties shall replace any such provisions with new valid provisions that most closely approximate the purpose of the terms.

## 10.9 Miscellaneous

Würth Elektronik eiSos reserves the right at any time to change this terms at its own discretion. It is your responsibility to check at Würth Elektronik eiSos homepage for any updates. Your continued usage of the products will be deemed as the acceptance of the change. We recommend you to be updated about the status of new firmware and software, which is available on our website or in our data sheet and manual, and to implement new software in your device where appropriate.

By ordering a wireless connectivity product, you accept this license terms in all terms.

## List of Figures

1	Isotropic, Omnidirectional and Unidirectional radiation pattern . . . . .	6
2	Linear polarization . . . . .	10
3	Horizontal and vertical linear polarization . . . . .	10
4	Circular polarization . . . . .	11
5	Left hand and right hand circular polarization . . . . .	11
6	Active antenna implementation . . . . .	12
7	Normal dipole and cross dipole wire antenna . . . . .	15
8	Parasitic loop antenna . . . . .	16
9	Dual rectangular loop antenna . . . . .	16
10	Helix antenna normal and axial mode . . . . .	18
11	Different types of spiral antenna . . . . .	19
12	Microstrip patch antenna shapes . . . . .	19
13	Feed types in microstrip patch antenna . . . . .	20
14	Circular polarization feed techniques . . . . .	22
15	Different types of slot antennas . . . . .	23
16	Ceramic chip antenna . . . . .	25
17	Ceramic patch antenna . . . . .	26
18	Ceramic patch antenna simulation - different ground plane . . . . .	28
19	Antenna performance for different ground plane . . . . .	28
20	Ceramic patch antenna simulation - different antenna position . . . . .	29
21	Antenna performance for different antenna position . . . . .	29
22	PCB-A . . . . .	30
23	PCB-B . . . . .	30
24	Antennas assembled on PCB-A and PCB-B . . . . .	31
25	Input impedance of antennas on PCB-A and PCB-B . . . . .	33
26	Pi-filter on PCB . . . . .	34
27	Antenna performance analysis . . . . .	34

## List of Tables

1	Spiral antenna characteristics . . . . .	19
2	Microstrip patch antenna characteristics . . . . .	21
3	Ceramic chip antenna characteristics . . . . .	25
4	Ceramic patch antenna characteristics . . . . .	26



# more than you expect



**Internet  
of Things**



**Monitoring  
& Control**



**Automated Meter  
Reading**

## Contact:

Würth Elektronik eiSos GmbH & Co. KG  
Division Wireless Connectivity & Sensors

Max-Eyth-Straße 1  
74638 Waldenburg  
Germany

Tel.: +49 651 99355-0  
Fax.: +49 651 99355-69  
[www.we-online.com/wireless-connectivity](http://www.we-online.com/wireless-connectivity)

