SDL User Manual

Release 1.0

Embention

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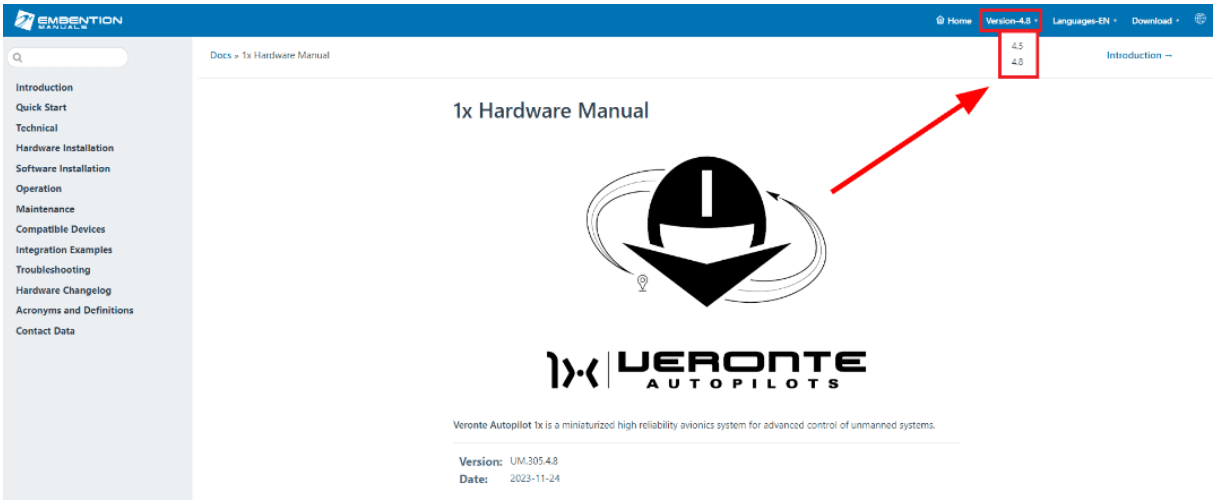
CONTENTS

SDL is a LOS datalink for UAV communications, with bidirectional RS-232 communication.

Warning: Select your version before reading any user manual. The following image shows where to select a version from any Embention user manual.



CHAPTER

ONE

INTRODUCTION

Fig. 1: **SDL**

SDL is a radio module for devices with RS-232, such as **Veronte BCS** with **Autopilots 1x** or **4x**. It establishes wireless serial communications with high performance and reliability. This product can be employed to build *point to point* and *multipoint* applications.

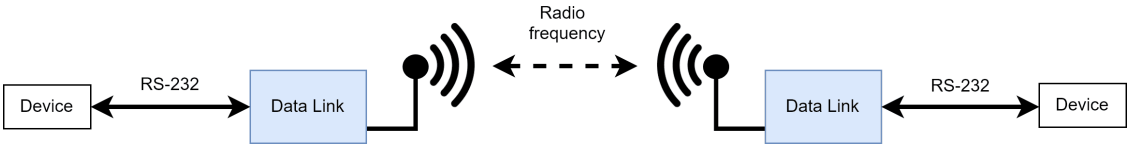


Fig. 2: **Point to point diagram**

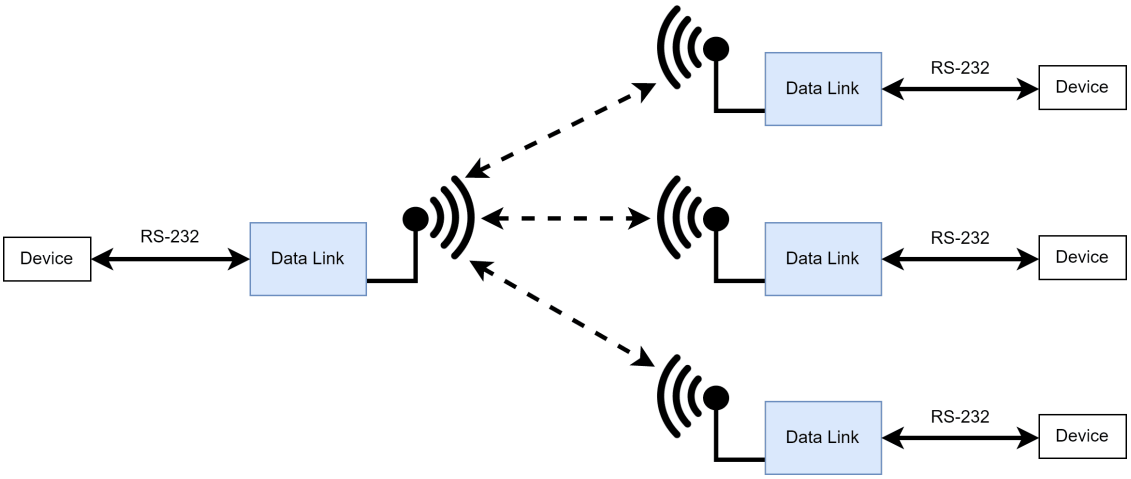


Fig. 3: **Multipoint diagram**

Repeaters can extend the operating range.

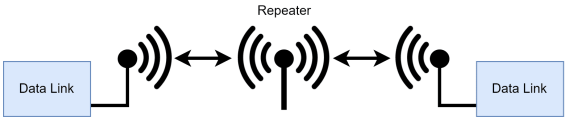


Fig. 4: **Repeater diagram**

CHAPTER

TWO

QUICK START

SDL connects devices with RS-232 ports to RF communications through external antennas. In addition, **SDL** sends RSSI to monitorize the RF signal strength.

Fig. 1: **Connection diagram**

Read the *Software Installation* section of this manual to configure **SDL**. After that, follow the *Hardware Installation* section. To use the radio with other specific devices, read *Integration Examples*.

2.1 Warnings

- Users must not power on a **SDL** without a suitable antenna or **load 50**Ω connected to the SMA.

Danger: This may damage the **SDL** unit.

- The power supply must be in the following range: 6.5 - 36V.
- The installation, removal, or maintenance of any antenna system components must be undertaken only by qualified and experienced personnel.
- Never work on an antenna system when there is lightning in the area.

2.2 Requirements

- Power supply of 6.5 - 36V DC.
- Computer with RS-232 connection. If it does not have RS-232 connector, an USB to RS232 converter can be employed.
- A communication terminal (such as Kitty or Putty).
- Antenna. Recommended antennas are listed in *Operating antennas* section of this manual.

CHAPTER

THREE

TECHNICAL

3.1 Variants

SDL is sold with three variants. They have two main differences: frequency and *operating antennas*.

SDL variant	Frequency
SDL04	400 MHz
SDL09	900 MHz
SDL24	2.4 GHz

3.2 Part List

This product includes the following devices:

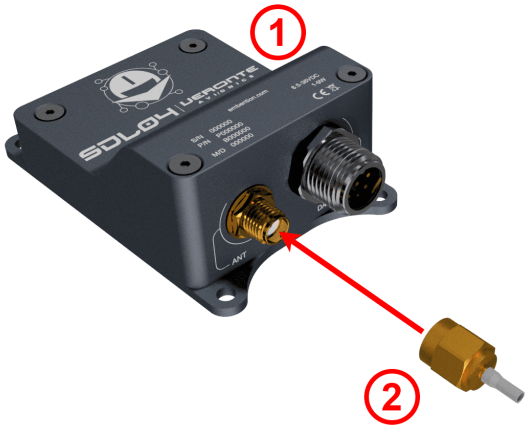


Fig. 1: 1- Veronte SDL.
2- Plug SMA for RF antenna.

3.3 Mechanical Specifications

Specification	Value
Operation temperature	-40 °C to 85 °C (internal)
Humidity	5 % to 95 % (non condensing)
Weight	68 g

3.3.1 Dimensions

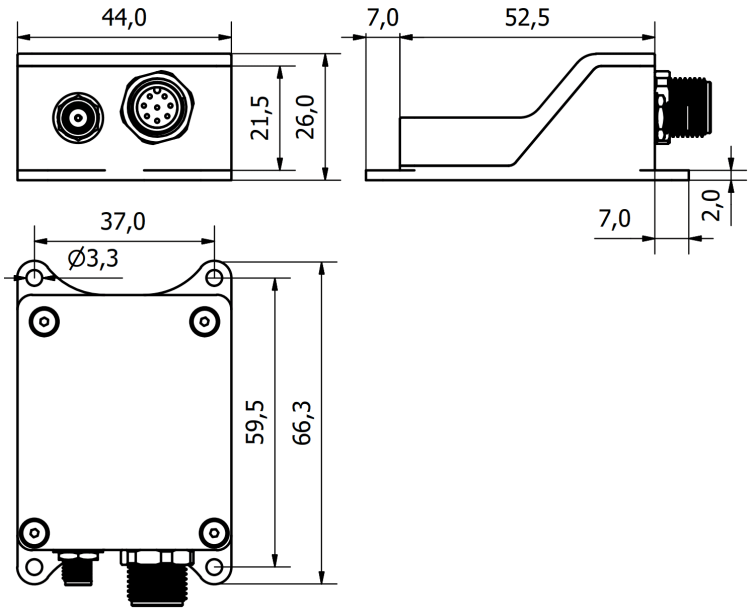


Fig. 2: **SDL dimensions (mm)**

3.4 Electrical

3.4.1 SDL04

Specification	Value
Supported Frequency	410 - 480 MHz
Spreading method	Frequency Hopping, GMSK, 2GFSK, 4GFSK, QPSK
Error detection	32 bits of CRC, ARQ
Range	Depends on the antenna employed and on the user's setup.
Output power	Up to 2 W
Link rate	Up to 345 kbps
Serial Baud Rate	250 to 230.4 kbps

3.4.2 SDL09

Specification	Value
Supported Frequency	902 - 928 MHz
Spreading method	Frequency Hopping
Band Segments	Selectable via Freq. Zones
Error detection	32 bits of CRC, ARQ
Range	Depends on the antenna employed and on the user's setup.
Output power	100 mW to 1 W
Link rate	Up to 276 kbps
Serial Baud Rate	Up to 230.4 kbps

3.4.3 SDL24

Specification	Value
Supported Frequency	2.400 - 2.4835 GHz
Spreading method	Frequency Hopping, DTS
Error detection	32 bits of CRC, ARQ
Range	Depends on the antenna employed and on the user's setup.
Output power	Up to 1 W
Link rate	19.2 to 345 kbps
Serial Baud Rate	250 to 230.4 kbps

3.5 Interfaces

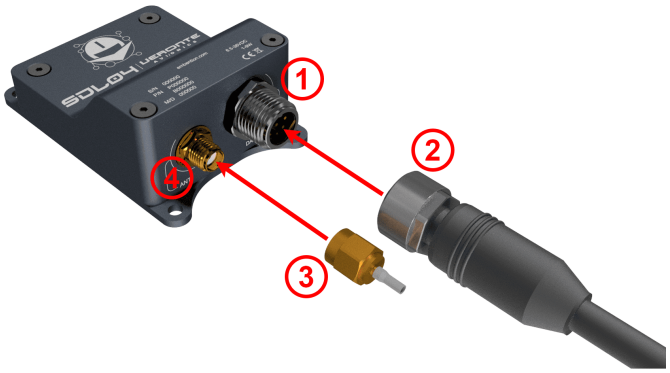


Fig. 3: **Mating connectors**

1. Female circular connector with commercial reference **T4144015081-000**.
2. Male circular connector with 1.5 meters of cable and Embention reference **P007440**. In case of using a commercial connector, there are several recommended options:
   - 21033192801: Straight option, with screw termination.
   - 1522875: Straight option, 24 AWG 3 meters cables already assembled.

- 21033194801: Right angle option, with screw termination.
- 1522639: Right angle option, 24 AWG 3 meters cables already assembled.

3. Male plug SMA. Low-loss cable is recommended for optimum performance.
4. Jack Female SMA for RF atennna.

CHAPTER

FOUR

HARDWARE INSTALLATION

4.1 Assembly

M3 screws are recommended for mounting. In saline environments such as coastal and oceanic, the screw material must be stainless steel.

4.1.1 Vibration Isolation

There might be situations where external isolation of vibrations might be needed.

SDL can be mounted in different ways in order to reject the airframe vibration. The simplest way could be achieved by just using double-sided tape on the bottom side. Other ways may use some external structure which could be rigidly attached to the airframe and softly attached to **SDL** (e.g. foam, silent blocks, aerogel, etc).

The user should take into account that wiring should be loose enough so vibrations may not be transmitted to **SDL**.

In cases where mechanical isolation is not viable, it is possible to use soft engine mounts. It is also recommended when there are other sensible payloads like video cameras or for high vibration engines.

4.2 Antenna Integration

The system uses different kinds of antennas to operate that must be installed on the airframe. Here you can find some advice for obtaining the best performance and for avoiding antenna interferences.

Antenna Installation
Maximize separation between antennas as much as possible.
Keep them far away from alternators or other interference generators.
Always isolate antenna ground panel from the aircraft structure.
Make sure the antenna is securely mounted.
Always use high-quality RF wires minimising the wire length.
Always follow the antenna manufacturer manual.
SMA connections shall be tightened applying 1Nm of torque.
For all-weather aircrafts, insert SMA lightning protectors.

4.2.1 Take into account

The recommended protection against lightnings is to install a surge arrestor at the antenna and another one at the interface. Surge arrestors should be fully interconnected with all the electrical system to have a commond ground.

SDL may only operate using an antenna which type and power are approved by the transmitter. To prevent radio interferences to other users, the antenna type must be chosen and sized to not beam more than the necessary EIRP.

The number of antennas employed on a single network has an effect on the performance of the link rate, since it is shared by all nodes.

The physical distance between antennas (transmitter and receiver) dictates their performance and required lengths. To choose the antenna type, consider the directivity (omnidirectional or directional) of the antennas being used.

Terrain is also an important consideration for antenna height sizing, since antennas should have a LOS, (they need to "see" each other). Nonetheless, LOS is not enough to completely satisfy RF path requirements for a robust communications link. LOS requires a clear path denominated "Fresnel Zone".

The fade margin is the difference between the supposed receive signal level and the minimum required. Usually, a desired fade margin is approximately 20 dB, but 10 dB may work properly.

Radio frequencies are not affected by rain. Frequency ranges penetrate through foliage and around small obstacles. Then, some may scrimp on physical equipments, specially antenna heights.

FHSS is a method to transmit radio signals by rapidly changing the frequency to different frequencies, occupying a large spectral band. It allows to work well in an environment with sources of interferences at certain bands.

4.2.2 Antenna types

An omni directional antenna spreads its energy in all directions (hence the name 'omnidirectional'), with a donut as energy field shape and vertical polarization.

A yagi antenna has a focused energy shape with a greater gain, since it has the shape of a raindrop moving along the antenna direction. If the poles of the yagi are perpendicular to the ground, the signal will be vertically polarized; if they are parallel, the signal will be horizontally polarized.

4.2.3 Operating antennas

This device has been designed to operate with the antennas *listed below* with a gain lower than 13.2 dBi. Different antennas are strictly prohibited. The required antenna impedance should be 50 ohms to prevent potential interferences to other users, the antenna type and its gain should be chosen that the EIRP is not more than required for communication.

4.2.3.1 Operating antennas list for SDL04 and SDL09

Type	Commercial reference	Description
Rubber Ducky	MHS031000	2dBi, 900MHz Rubber Ducky Antenna RPTNC Swivel
	MHS031070	2dBi, 900MHz Rubber Ducky Antenna Reverse SMA Swivel
	MHS031080	2dBi, 900MHz Rubber Ducky Antenna Reverse SMA Straight
Transit antennas	MHS031210	3dBd, 900 MHz Transit Antenna with Ground Plane
	MHS031220	3dBd, 900MHz Transit Antenna No Ground Plane
	MHS031230	3dBd, 900MHz Transit Antenna Permanent Mount GP
	MHS031240	3dBd, 900MHz Transit Antenna Permanent Mount NGP
Yagi Antennas	MHS031311	6dBd, 900MHz Yagi Directional Antenna Antenex, RPTNC Pigtail
	MHS031431	6.5dBd, 900MHz Yagi Directional Antenna Bluewave, RPTNC Pigtail
	MHS031501	9dBd, 900MHz Yagi Directional Antenna Antenex, RPTNC Pigtail
	MHS031441	10dBd, 900 MHz Yagi Directional Antenna Bluewave, RPTNC Pigtail
	MHS031451	11dBd, 900 MHz Yagi Directional Antenna Bluewave, RPTNC Pigtail
Patch Antennas	MHS031440	8dBi, 900 MHz, Patch Antenna, RPTNC Pigtail
Omni Directional	MHS031251	3dBd, 900MHz Omni Directional Antenna Antenex, RPTNC Pigtail
	MHS031461	3dBd, 900 MHz Omni Directional Antenna Bluewave, RPTNC Pigtail
	MHS031321	6dBd, 900MHz Omni Directional Antenna Antenex, RPTNC Pigtail
	MHS031471	6dBd, 900 MHz Omni Directional Antenna Bluewave, RPTNC Pigtail

Note: Mounts for Transit Antennas have a RPTNC Pigtail.

4.2.3.2 Operating antennas list for SDL24

Type	Commercial reference	Description
Rubber Ducky	MHS031100	2 dBi,2.4 GHz Rubber Ducky Antenna RPTNC Swivel
	MHS031110	2 dBi, 2.4 GHz Rubber Ducky Antenna Reverse SMA Swivel
		2.5 dBi, Shenzhen Norminson Technology CO.LTD. - 2.4 GHz Rubber Ducky Antenna
	NW001	Reverse SMA Straight
	WCP2400-MMCX4	2.5 dBi, Laird Technologies - 2.4 GHz Rubber Ducky MMCX
Yagi antennas	MHS034100	9 dBi, 2.4 GHz Yagi Directional Antenna RPTNC Pigtail
	MHS034000	12 dBi, 2.4 GHz Yagi Directional Antenna RPTNC Pigtail
	MHS034120	14 dBi, 2.4 GHz Yagi Directional Antenna RPTNC Pigtail
	MHS034150	14.5 dBi, 2.4 GHz Yagi Directional Antenna RPTNC Pigtail
Patch antennas	MHS034200	8 dBi, 2.4 GHz Mini Flat Patch Directional Antenna RPTNC Pigtail
	MHS034210	14 dBi, 2.4 GHz Flat Patch Directional Antenna RPTNC Pigtail
Omni Directional	MHS031260	5 dBi, Omni Directional Antenna RPTNC Pigtail
	MHS034000	6 dBi, 2.4 GHz Omni Directional Antenna RPTNC Pigtail
	MHS031340	8 dBi, Omni Directional Antenna RPTNC Pigtail
	MHS034020	10.5 dBi, 2.4 GHz Omni Directional Antenna RPTNC Pigtail
	MHS034030	12 dBi, 2.4 GHz Omni Directional Antenna RPTNC Pigtail
	MHS034040	15 dBi, 2.4 GHz Omni Directional Antenna RPTNC Pigtail

4.3 Pinout

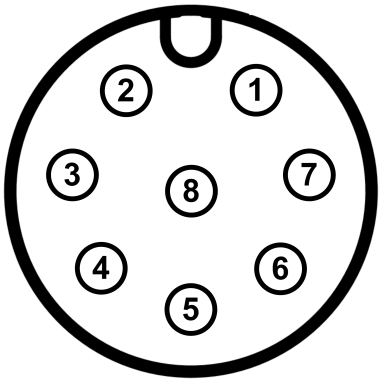
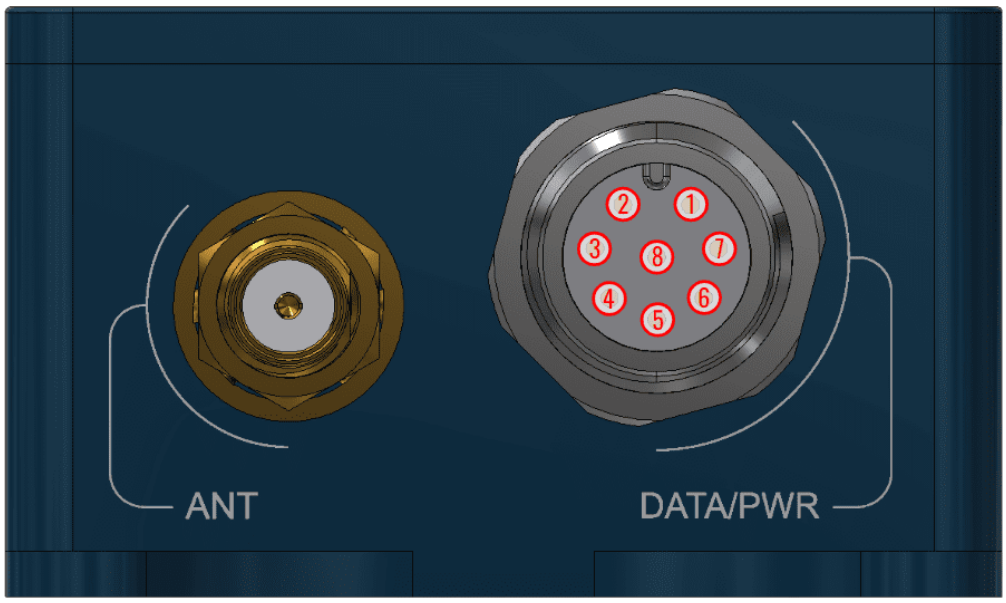


Fig. 1: **Connector pinout**

Clarification

Corresponds to the connector on the radio module side (commercial reference **T4144015081-000**):



Number	Name	Function	Description
1	Vin	Power	Voltage supply 6.5-36V
2	GND	Power	Ground for logic, radio, and I/O pins
3	RS232-RX	Input	Receive Data
4	RS232-TX	Output	Transmit Data
5	GND	Power	Ground for logic, radio, and I/O pins
6	RSSI1	Output	Received Signal Strength Indicator 1. 0 V for low / 3.3 V for high
7	RSSI2	Output	Received Signal Strength Indicator 2. 0 V for low / 3.3 V for high
8	RSSI3	Output	Received Signal Strength Indicator 3. 0 V for low / 3.3 V for high

RSSI pins are digital output signals that indicate RF connection quality.

Signal strength according to RSSI pins			
Pin 6 - RSSI1	Pin 7 - RSSI2	Pin 6 - RSSI3	Signal strength
HIGH	HIGH	HIGH	Strong
HIGH	HIGH	LOW	Medium
HIGH	LOW	LOW	Weak
LOW	LOW	LOW	Lost

4.4 Connections

After configuring **SDL** it has to be connected to the rest of the devices according to the following diagram, where each pin is refered in the *Pinout* section of this manual.

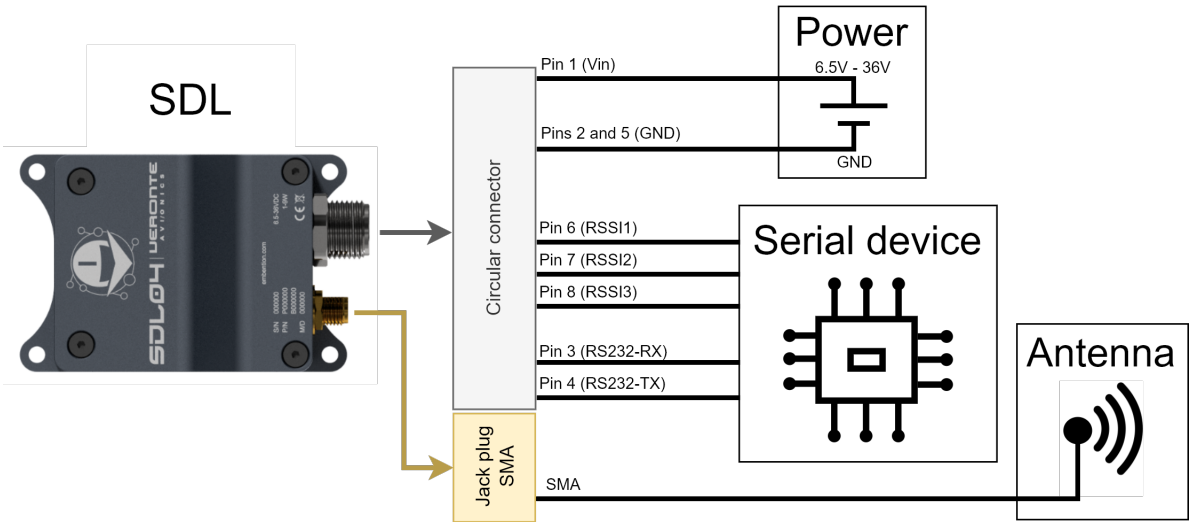


Fig. 2: **Electrical assembly diagram**

An **Autopilot 1x** can be used as serial device employed. To know how to do it, read Veronte SDL - Integration examples section of **1x Hardware Manual**.

CHAPTER

FIVE

SOFTWARE INSTALLATION

To configure **Veronte SDL**, first of all, it must be connected to a computer. This connection can be established in two ways: directly to a computer or through a tunnel with **Veronte Autopilot 1x**.

Tunnel connection is recommended for basic configuration if a **1x** is available, since the interface is more friendly user. Nonetheless, to change advanced parameters the user will have to send AT commands (as messages with the same interface).

5.1 Direct Connection

The following diagram summarizes how to connect a computer to **SDL**, so it can be configured.

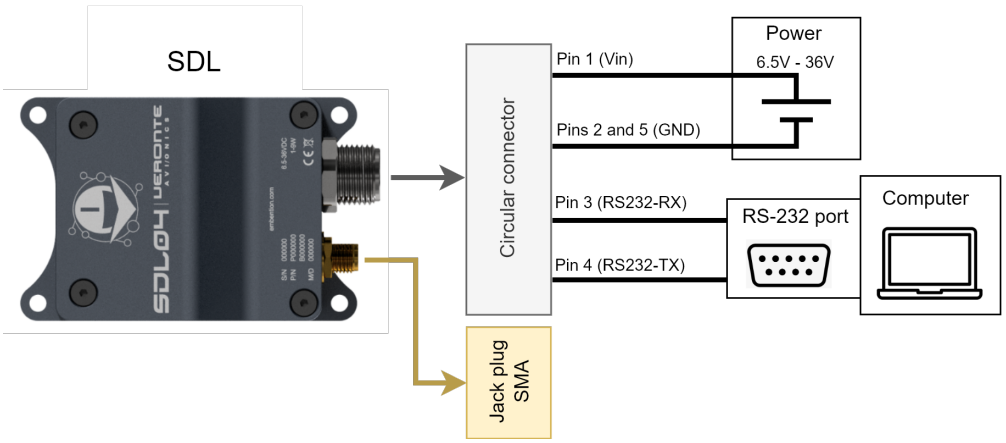


Fig. 1: **Direct connection to computer**

In case of not having a RS-232 port, a RS-232 to USB converter can be used.

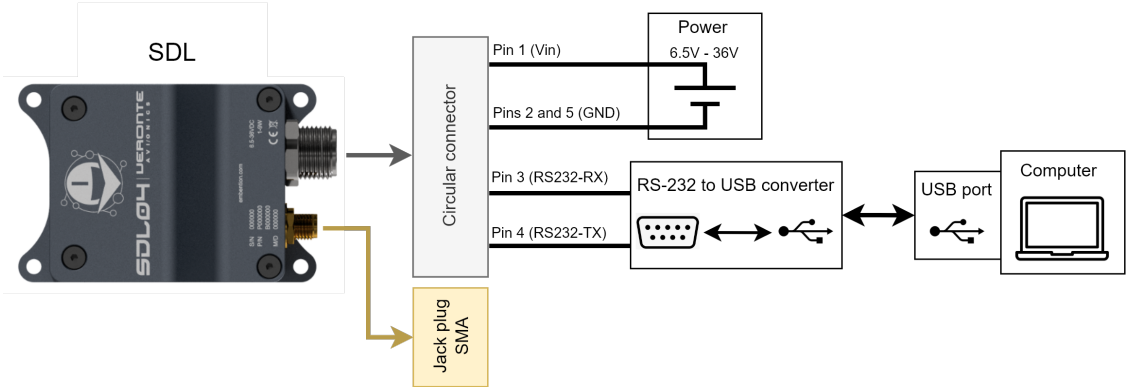


Fig. 2: **Direct connection to computer with USB converter**

5.2 Tunnel Connection

The following diagram shows a way of connecting an **SDL** to a computer through a **1x** tunnel.

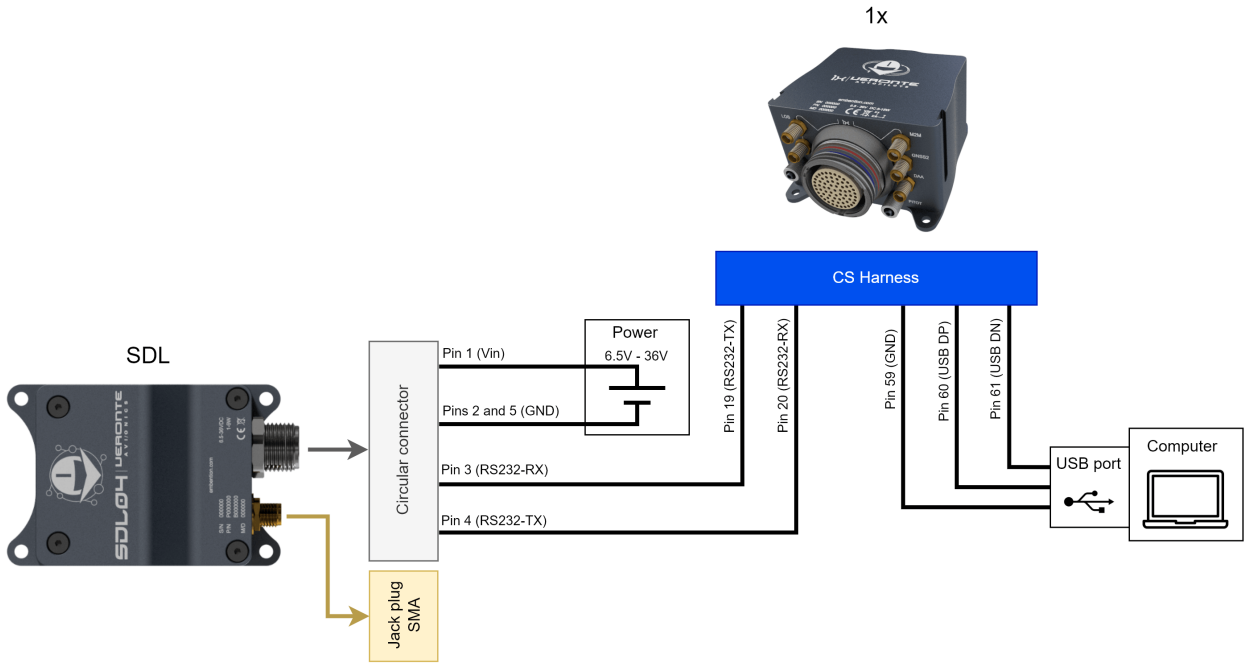


Fig. 3: **Tunnel connection to computer**

5.3 How to configure SDL

Once the electrical connection has been made (in the previous sections), **SDL** can be configured. The configuration method changes according to the connection type (direct or tunnel). Read the subsection which corresponds to the built connection.

5.3.1 Configuration for Tunnel Connection

First of all, initialize the communication between computer and **1x** using **Veronte Link**, to know more, read its user manual. Then, configure the **1x** terminal manager to establish tunnel communication through RS-232. This configuration is explained in the Terminal - Operation section of **1x PDI Calibration** user manual. Finally, the interface will be simillar to the following window.

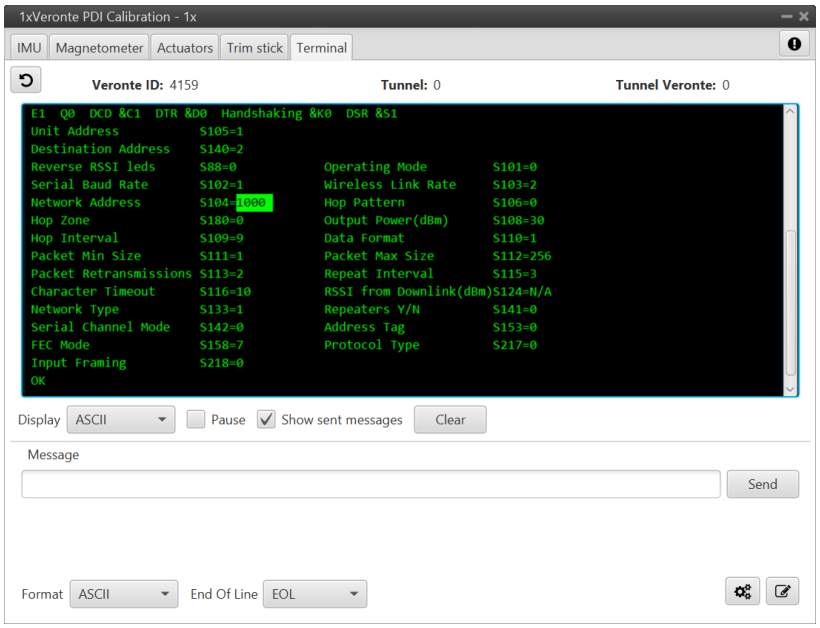


Fig. 4: **Terminal manager configured for SDL**

Note: The referenced section of **1x PDI Calibration** user manual includes a Microhard Setup Helper subsection. This subection shoud be read when configuring **SDL**, since this wizard also works with **SDL**.

Note that **SDL** is configured with AT registers and AT commands that terminal sends. For advanced configuration, send AT commands to change AT registers as "messages". To know more, read the **SDL configuration** subsection of the used variant:

- `SDL 04:` *click here.*
- `SDL 09:` *click here.*
- `SDL 24:` *click here.*

5.3.2 Configuration for Direct Connection

SDL is set as repeater by default, it can be configurated with AT commands. Therefore, a communication terminal (such as Kitty or Putty) is required to send these commands to the device.

Important: If Putty communication terminal is used, ensure that the Flow Control is configured as *None*.

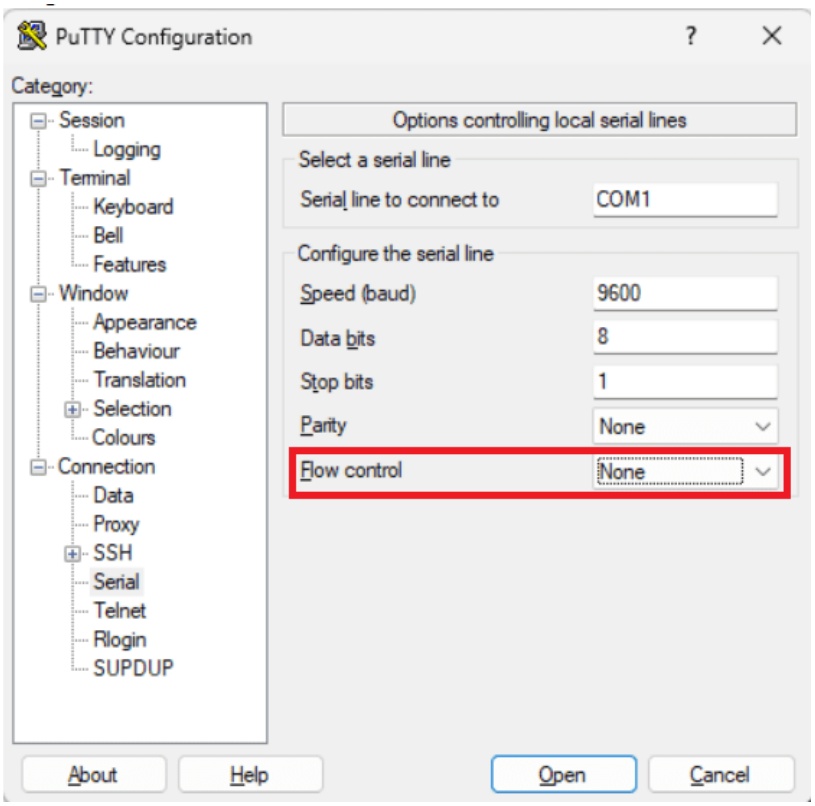


Fig. 5: Flow Control Configuration

SDL is delivered with the following configuration as default:

Register	Default value	Description
S101	2	Operating mode: 2 sets the slave mode, usully employed for air units.
S104	1234567890	Network address.
S107	7	Serial baud rate: 7 establishes 9600 bps.

To know more about registers, read the **AT Registers** subsection of each **SDL** variant:

- `SDL 04:` *click here.*
- `SDL 09:` *click here.*
- `SDL 24:` *click here.*

To configure the module, read the following steps:

1- Once **SDL** is connected to a computer, open a communication terminal.

2- Set 9600 bps as baudrate, serial as communication type and The COM port where **SDL** is connected. To know which port is using the computer, open the Device Manager from Windows.

3- Open the communication.

4- Write "+++" and press enter in the terminal to establish the communication.

5- Write "at" and press enter to check that communication is established. The terminal should respond with "ok".

6 (optional step)- To know more about the device configuration, type "at&v", then a message like the following one will be displayed.

```
at&v
p900
900MHz Mesh Radio Microhard Systems, Inc.
v1.33 build 1.2232 Sep 27 2017 11:50:19
MAC: 00:F0:49:01:67:84

E1  Q0  DCD &C1  DTR &D0  Handshaking &K0  DSR &S1
Destination Address    S140=FF:FF:FF:FF:FF:FF
Tx Profile             S80=0            CS threshold           S81=20
Reverse RSSI leds      S88=0            Operating Mode         S101=2
Serial Baud Rate       S102=7           Wireless Link Rate     S103=0
Network Address        S104=1234567890  Hop Pattern            S106=0
Hop Zone               S180=0           Output Power(dBm)      S108=30
Data Format            S110=1           Packet Min Size        S111=1
Packet Max Size        S112=256         Packet Retransmissions S113=3
Repeat Interval        S115=5           Character Timeout      S116=10
Average RSSI(dBm)      S123=N/A         Attempts b4 re-route   S126=9
Network Type           S133=2           Serial Channel Mode    S142=0
Sleep mode             S143=0           Address Tag            S153=0
FEC Mode               S158=7           Num of aloha slots     S214=60
Num of mesh sync slots S215=1           Protocol Type          S217=0
Input Framing          S218=0           Routing Request TTL    S219=10
Mesh Roaming Mode      S222=1           Routing                S223=0
Standby trip level     S224=20          Ch Access Mode         S244=1
Cost of hop in mesh    S245=100
OK
```

7- Send AT commands typing on terminal to configure **SDL**. These commands are different according to the desired configuration. Remember that parameter "S104" (destination address) must be the same for all radios that communicate in the same network.

Tip: If the connection is lost due to a change in baudrate. Restart the communication terminal and use the new baudrate.

5.3.2.1 Configuration for Each Variant

To configure each **SDL** variant, read the **SDL configuration** subsection of each one:

- `SDL 04:` *click here.*
- `SDL 09:` *click here.*
- `SDL 24:` *click here.*

5.3.2.1.1 SDL04 configuration

5.3.2.1.1.1 AT commands

- ATA: sets the device into online/data mode.
- ATg or ATG: defines whether interfering RF signals are present. **SDL** sweeps the operating band and provide a display of mean and peak signal levels, in dBm.
- ATN: provides a detailed scrutiny of the RF environment. The specific start and stop frequencies, along with step size and dwell time are definable. An ATN command example is ATN 905.250 908.500750 25 100, where:
  - 905.250 is the start frequency in MHz up to 6 decimal digits.
  - 908.500750 is the stop frequency in MHz up to 6 6 decimal digits.
  - 25 is the step increment in kHz, it can be from 1 to 1000.
  - 100 is the dwell time in ms, it can be from 1 to 1000.
- AT&Fn: where "n" is a number, it establishes a default configuration.
  - AT&F1 FH Master Fast PMP
  - AT&F2 FH Slave Fast PMP
  - AT&F3 FH Repeater Fast PMP
  - AT&F4 FH Master Slow PMP
  - AT&F5 FH Slave Slow PMP
  - AT&F6 FH Master Fast PP
  - AT&F7 FH Slave Fast PP
  - AT&F8 FH Master Slow PP
  - AT&F9 FH Slave Slow PP
  - AT&F10 FH Master Fast PMP no Time ACK
  - AT&F11 FH Master Fast P2P no Time ACK
  - AT&F12 FH Master Fast PP no Time ACK
  - AT&F15 FH Master WL
  - AT&F16 FH Slave WL
  - AT&F18 FH Master Fast TDMA
  - AT&F19 FH Slave Fast TDMA

Note:

- Mesh Primary Coordinator - Each Mesh network must have a primary coordinator. The primary coordinator provides the synchronization for the network.
- Mesh Secondary Coordinator - Secondary coordinators can be deployed to extend the range of the Mesh network. Each device on a Mesh network must have LOS (Line of Sight) with either a Primary or Secondary Coordinator.
- Mesh Remote (Slave) - Any device on the network that is not a Primary or Secondary Coordinator, generally attached to end devices. Can also be used to perform routing tasks if enabled.

  - Master (PMP/PP) - Only one per network. In PP/PMP network types (see S133) data either originates at, is destined to, or passes through the Master.
  - Repeater (PMP/PP) - May act simply as a 'Repeater' to store and forward data to/from an upstream unit to/from a downstream unit (e.g. when there is a long distance between units), or, may act as a Repeater/Slave in which case the above function is performed AND the unit may also exchange data as a Slave within the network.
  - Slave (PMP/PP) - Interfaces with remote devices and communicates with Master either directly or via Repeater(s).

- AT&V: displays all visible S registers and their current values.
- AT&W: writes configuration into non-volatile memory
- ATSxxx?: displays the xxx register.
- ATSxxx=yyy: writes value yyy in register xxx.
- ATSxxx /?: displays the xxx register settings (if they are available).
- ATIn: where n is one of the following numbers.
  - 1 Product Code.
  - 3 Product Identification (Firmware Version).
  - 4 Firmware Date.
  - 5 Firmware Copyright.
  - 6 Firmware Time.
  - 255 Factory-Configured Options listing.
- ATlogin: enables a password to access command mode.
- ATM: provides information about mesh, such as the current routing table, routing logs and errors.
- ATP0: allows a user to edit the primary frequency table channel by channel. The user can press ESC to exit from editing mode. Any valid frequencies typed will be saved into the table automatically. The BACKSPACE key can be used to correct mistakes when typing a frequency. Once ENTER is pressed, the value will be accepted if it has the right format. An accepted value can NOT be modified with the BACKSPACE key. If changing is desired, the table has to be entered.
- ATP1: allows a user to edit the secondary frequency table channel by channel. This command is employed like ATP0.
- ATP0?: shows the primary available frequencies and bandwidth for each channel, as well as the direction of communication allowed on that channel.
- ATP1?: shows the secondary available frequencies and bandwidth for each channel, similar to ATP0.

5.3.2.1.1.2 AT registers

The most of configurations is defined by registers, which are compound of the letter "S" and a number.

- S0: selects the mode that the device will haVve when starting up.

  Values:

  - 0 - command mode
  - 1 - Data mode (default)

- S2: ascii value for the character that will be used for escape detection.

  - It can be from 0 to 255. 0 disables the scape detection.
  - 43 (character "+") is the default value.

- S101: operating mode. Function that **SDL** will do.

  - 0 - Master. Data originates or passes trhought the master. Only one master can exist in a PP/PMP network.
  - 1 - Repeater. **SDL** sends data received from RF, it can also exchange data as a slave.
  - 2 - Slave. The device communicates with the master (directly or through repeaters).

- S102: serial baud rate for serial communications. The data rate must be the same for the serial device connected to **SDL**. When forcing to Command Mode, the data port will temporarily communicate at the default value.

  Values (bps):

  - 0 - 230400
  - 1 - 115200
  - 2 - 57600
  - 3 - 38400
  - 4 - 28800
  - 5 - 19200
  - 6 - 14400
  - 7 - 9600 (default)
  - 8 - 7200
  - 9 - 4800
  - 10 - 3600
  - 11 - 2400
  - 12 - 1200
  - 13 - 600
  - 14 - 300

- S103: Wireless Link rate at which RF communications will occur. All radios within a particular network must be configured with the same wireless link rate. Faster link rates sacrifice sensitivity.

  Values (bps):

  - 0 - 172800 (default)
  - 1 - 230400

  - 2 - 276480
  - 3 - 57600
  - 4 - 115200

- S104: Network address as ID. All modems in a given network must have the same address.
- S105: Unit address. Unique identifier for each radio in a network. It can be from 1 to 65534.
  - 1 - Address for master.
  - 65535 - Broadcast address.
- S108: Output power. Trasmission power for the antenna in dBm, it should be as low as possible while the fade margin is appropiate. It can be from 20 to 30.
  - 30 is the default value (equivalent to 1 W).
- S109 (only for masters with PP or PMP configuration): Hop interval. It defines the rate to change frequency for all radios in the same network. Long intervals have large throughput. Short intervals have low latency and are more reliable to interferences. It can be from 0 to 61, with 20 as default.
- S110: Data format on the serial port. The value must match with the serial device. When forcing to command mode, **SDL** will temporarily communicate at the default value. When returning to Data Mode, the configuration will take again the values from S102 and S110.

Values	Parity	Stop bits	Data bits
1	No	1	8
2	No	2	
3	Even	1	
4	Odd	1	
5	No	1	7
6	No	2	
7	Even	1	
8	Odd	1	
9	Even	2	
10	Odd	2	

- S111: Packet minimum size. This is the minimum number of collected bytes in one buffer, before the buffer can be closed by the character timeout (timer controlled by S116). It can be from 1 to 225, with 1 as default.

> **Warning:** It is STRONGLY advised not to modify this parameter, since changing S111 may prevent the **SDL** from detecting the escape sequence.

- S112: Packet maximum size. It defines the number of bytes from the connected device that will be encapsulated into a packet, unless the timer S116 expires. Large packets produce better data throughput; however, small packets are less likely to become corrupted, with less impact in that case. It can be from 1 to 256, with 256 as default.
- S113: This register determines the maximum number of times that a packet will be retransmitted (in addition to the initial transmission). Retransmissions provide system robustness and ensure data delivery. Retransmissions create additional traffic. It can be from 0 to 254, with 254 as default.
- S115 (with mesh configuration): Repeat interval. It defines the difficulty to access the RF channel. The bigger the number, less attempts are required to access, but the latency will be larger. It can be from 0 to 255, with 5 as default.

- S115 (with PP or PMP configuration): Repeat interval. It defines the number of slots which are available within a window of opportunity for remote units to submit channel requests to the Master. Remotes will randomly contend for the ability to access the channel request slots. For a small number of Remotes, it is advisable to keep S115 closer to the default value so as to not 'waste bandwidth' by maintaining a relatively large window housing a greater-than-necessary number of channel reservation request slots. It can be from 0 to 255, with 3 as default.
- S116: Character Timeout in quarters of character time. It can be from 10 to 255, with 10 as default (2.5 character time). **Radio Link** will accumulate data in buffers from the serial port, until one of the following conditions occur:
  - The Maximum Packet Size (S112) has been accumulated.
  - Minimum Packet Size (S111) has been accumulated AND the Character timeout (S116) has expired.

  After that, the message is sent through RF.
- S118 (with PP or PMP configuration): synchronization with master or repeater. The default value is 1.

  Values.
  - 65535: **SDL** will synchronize with an upstream unit which has the same network address (S104). If that upstream unit fails, it will attempt to synchronize with another upstream.
  - From 1 to 65534: specific address to synchronize.
- S119: Quick Enter to Command Mode.

  Values:
  - 1 - Enabled. A delay of 5 seconds is introduced at powerup before the modem will go into data mode. If during these 5 seconds, the user enters 'mhx' the modem will instead go into Command Mode and reply with 'OK'. The terminal baud rate must be set to 9600bps. If an incorrect character is entered, the modem will immediately go into data mode.
  - 0 (default) - The radio will promptly go into data mode upon power-up.
- S123: average signal strength received over the previous 8 hop intervals, from -110 to -55 dBm.
- S124: average signal strength received over the previous 8 hop intervals from a slave or repeater. It can be from -110 to -55 dBm.

Tip: The "ATS124 /?" command will show the RSSI statistics (minimum, maximum, average, channel and frequency).

- S130: synchronization intake. It defines if the modem will accept data when/if the remote has become unsynchronized from the master.

  Values:
  - 1 - Enabled. The modem will accept data and buffer it until the unit is synchronized.
  - 0 - Disabled (default). Any data received will be ignored.
- S133: Network Type. This register must be set to the same value on every unit in the RF system.

  Values:
  - 0 - Point to Multipoint (PMP).
  - 1 - Point to Point (PP).
  - 2 - Peer to Peer or Everyone to Everyone.
  - 3 - Reserved.

  - 4 - PMP with acks.

Note:

  - Point to Multipoint - The Master broadcasts data to all units, and all remote units send data back to the Master.
  - Point to Point - Point to point traffic between a master and a slave (with 0 or more Repeaters in between).
  - Peer to Peer - involves either communication between 2 (typically remote) units (P2P) or between all units (Everyone-2-Everyone - E2E).

- S139: Compatible_21 at 345.

  Values:

  - 1 - Enabled: **SDL** will be compatible with the MHX2421 operating at a link rate of 345kbps.
  - 0 (default) - Disabled.

- S140: Destination address. Ultimate destination for a radio.

  In PP or PMP, the value can be from 1 to 65535, where 65535 is broadcast.

  - PMP - Master S140=65535 and remote S140=1.
  - PTP - Master S140=UA of remote, remote S140=1 (Master).
  - P2P - Master S140=65535, S140 of each (of 2 / pair) remote modem is the UA of the other.
  - E2E - S140 of all modems=65535 (broadcast).

- S141 (for master): registers the presence of repeaters in the network.

  - 0 - No repeater
  - 1 - 1 or more repeaters.

Note: with one or more repeaters in the system, a networks throughput is divided in half.

- S142: Serial channel mode for the data port.

  - 0 - RS-232 (default)
  - 1 - RS-485 half duplex
  - 2 - RS-485 full duplex

> **Warning:** The radio module of **SDL** is able to transmit through RS-485, but **SDL** itself is not built to operate with RS-485. The register S142 must not be changed and keep as 0.

- S150 (only for master radio): it dictates which synchronitation mode will be used when it initially goes online. Quick synchronization mode results in the master hopping very quickly, which will enable a downstream unit to become synchronized faster.

  Values:

  - 0 - Normal synchronitation.

  - 1 - (Only for PTP configuration). The Master will stay in quick synchronization mode until such time as it receives an acknowledgement from its associated slave, it will then remain hopping quickly for the number of hop intervals (8-255) defined by S152 (Fast Sync Hold on Ack), after which time it will go into normal sync mode.
  - 2 - The master will go into quick synchronization mode when it initially comes online, then it will remain in that mode for the time specified in S151 and finally return to normal synchronization mode.

- S151: This register settings applies only to a Master modem. Effective only when S150=2. It defines how long, a master modem will stay in fast synchronization mode after it initially goes online.

  Values in ms: from 100 to 6500, with 200 as default.

- S153: address tag. If this register is enabled with 1, the radio prepends 4 extra bytes to the data (in the same order):
  - First byte =0x00.
  - Second = 0xFF.
  - Third = source unit address (high byte) .
  - Fourth = source unit address (low byte).

  By default, this register is set as 0 - disable.

- S158: FEC method. FEC consumes significant bandwidth: depending on which coding rate is chosen, a number of coding bits are transmitted along with the data bits. In noisy or long-range communications environments, FEC may effectively increase throughput by decreasing the amount of packet retransmissions which would otherwise be required. FEC may extend RF communications range: at a certain distance where data would otherwise be unacceptably corrupted, employing FEC may be all that is required to maintain the integrity of that data at that distance.

  Values:

Value	Name	Information rate	Number of corrected bits
0	No FEC	/	/
1	Hamming(7,4)	0.5	1 out of 7
2	Hamming (15,11)	0.66	1 out of 15
3	Hamming (31,24)	0.75	1 out of 31
5	Binary BCH (47,36)	0.75	2 bits
6	Golay (23, 12, 7)	0.5	3 bits
7	Reed-Solomon (15,11)	0.687	2 nibbles

- S163: it enables CRC checking of received data on local diagnostic port. Note that even if disabled, the incoming data must have two dummy bytes transmitted in place of crc bytes.
  - 0 - Disable.
  - 1 - Enable (default).

> **Warning:** Disabling CRC check is only advisable during troubleshooting of the user's diagnostic requests.

- S167: Tx enable. Enables RF emission.

  Values:
  - 0 - Disable. The radio will never transmit data, it will be in a listen only mode.
  - 1 - Enable (default). The radio will be able to send data.

- S213: packet retry limit. Valid only from child to parent.

  Values: from 0 to 254, with 5 as default.

- S214: number of retransmission of diagnostic packets.

  Values: from 0 to 254, with 0 as default.

- S215 (with mesh configuration): defines the number of synchronization slots available in a Mesh Frame. In systems with many coordinators, additional slots may be required to avoid collisions. Register S216 can also be used to provide randomness in sending sync packets to avoid collisions. S215 must be set to the same value for each modem on the network or the unit will not synchronize. The value can be from 1 to 10, with 1 as default.

- S216 (with mesh configuration): defines how often the coordinator transmits synchronization packets. After each synchronization packet transmission the coordinator picks a random number from 1 to the value in S216 and transmits the next packet in this slot. 1 - every synchronization slot, 2 — on average once every 1.5 slots, 3 - on average once every 2 slots etc.

- S217: Protocol type. Defines how data is sent as output on the local serial port. When Modbus RTU is enabled, there is a delay between the packets coming out of the serial port. The register S146 defines the delay between individual packets.

  Values:

  – 0 - Transparent Serial (default)

  – 1 - Modbus RTU

- S218 (with mesh configuration): Input framing type. Controls how the radio treats data coming to serial port. It allows the destination address to be embedded into the data stream, which is automatically stripped by the **SDL** before transmitting the packet.

  Values:

  – 0 - Transparent Serial (Default)

  – 1 - Destination Address (DA) is in the first six bytes (high byte first) of the packet. The radio strips these six bytes and doesn't transmit them. For example, if the DA is 01:23:45:67:89:AB then the high byte is 0x01,the lowest byte is 0xAB. Note that the max size of the data itself in this case is S112 minus 6. If S112 = 256 then the max data size is 250 bytes.

- S217: protocol type.

  Values:

  – 0 (default)- Transparent operation. For most applications this value will be maintained in this register.

  – 1 - MODBUS operation. The radio will frame the output data to comply with MODBUS specifications.

  – 2 - DF1 filtering. In this mode, the PLC's address must match the unit address of the modem. Data not intended for a specific PLC/Modem pairing will be blocked from passing through the modem to the attached PLC.

- S238: Hopping mode register, preset by manufacturer. It is a readonly register for the end user. S238 controls the modem either hopping on pattern or on frequency table.

  Values:

  – 0 - Hopping on pattern.

  – 1 - Hopping on frequency table.

  – 2 - Hopping on channel.

  – 3 - Hopping on frequency.

- S244: channel request mode.

  Values:

  - 0 (default) - Channel request. It allows a Remote modem which has data to send to request from the Master permission to do so. When granted, the Remote will be allowed to transmit all of its data (no other Remotes may transmit during this period), upon completion of which it will release the channel. This feature eliminates collisions which would otherwise occur if a number of Remotes were all trying to transmit at the same time.
  - 1 - TDMA mode. It relates to channel requests where, in TDMA mode, the Master does not allow such requests from remotes; the master sequences through a list of remotes, giving each one in turn an opportunity to transmit.

- S248: synchronitation timeout. This register defines how many hop intervals where the slave does not receive a synchronization packet from the master, before it will become unsynchronized and begins to search for a master.

  Values: from 1 to 65534, with 512 as default.

- S251: in TDMA mode (see S244) this register determines how long, in hop intervals, the Master will wait for a Remote to either (a) begin to send data or (b) indicate that it has completed sending all of its data, prior to the Master sequencing to the next Remote to be given permission to transmit.

  Values (in hops): from 1 to 254, with 10 as default.

5.3.2.1.2 SDL09 configuration

5.3.2.1.2.1 AT commands

- ATA: sets the device into online/data mode.
- ATg or ATG: defines whether interfering RF signals are present. **SDL** sweeps the operating band and provide a display of mean and peak signal levels, in dBm.
- ATN: provides a detailed scrutiny of the RF environment. The specific start and stop frequencies, along with step size and dwell time are definable. An ATN command example is ATN 905.250 908.500750 25 100, where:
  - 905.250 is the start frequency in MHz up to 6 decimal digits.
  - 908.500750 is the stop frequency in MHz up to 6 6 decimal digits.
  - 25 i the step increment in kHz, it can be from 1 to 1000.
  - 100 is the dwell time in ms, it can be from 1 to 1000.
- AT&Fn: where “n” is a number, it establishes a default configuration.
  - AT&F1 - Mesh Primary Coordinator
  - AT&F2 - Mesh Remote
  - AT&F3 - Mesh Secondary Coordinator
  - AT&F7 - PMP Master
  - AT&F8 - PMP Slave
  - AT&F9 - PMP Repeater
  - AT&F10 - PP Master
  - AT&F11 - PP Slave
  - AT&F12 - PP Repeater

- AT&F13 - PMP Master 57k
- AT&F14 - PMP Slave 57k

Note:

- Mesh Primary Coordinator - Each Mesh network must have a primary coordinator. The primary coordinator provides the synchronization for the network.
- Mesh Secondary Coordinator - Secondary coordinators can be deployed to extend the range of the Mesh network. Each device on a Mesh network must have LOS (Line of Sight) with either a Primary or Secondary Coordinator.
- Mesh Remote (Slave) - Any device on the network that is not a Primary or Secondary Coordinator, generally attached to end devices. Can also be used to perform routing tasks if enabled.
- Master (PMP/PP) - Only one per network. In PP/PMP network types (see S133) data either originates at, is destined to, or passes through the Master.
- Repeater (PMP/PP) - May act simply as a 'Repeater' to store and forward data to/from an upstream unit to/from a downstream unit (e.g. when there is a long distance between units), or, may act as a Repeater/Slave in which case the above function is performed AND the unit may also exchange data as a Slave within the network.
- Slave (PMP/PP) - Interfaces with remote devices and communicates with Master either directly or via Repeater(s).

- AT&V: displays all visible S registers and their current values.
- AT&V1: displays the complete set of user parameters (for advanced users).
- AT&W: writes configuration into non-volatile memory
- AT&WA: writes configuration into non-volatile memory and sets the device in online mode.
- ATSxxx?: displays the xxx register.
- ATSxxx=yyy: writes value yyy in register xxx.
- ATSxxx /?: displays the xxx register settings (if they are available).
- ATIn: where n is one of the following numbers.
  - 0 User string. Use ATI0=<string> to save the string.
  - 1 Product Code
  - 2 Firmware CRC check
  - 3 Product Identification (Firmware Version)
  - 4 Firmware Date
  - 5 Firmware Copyright
  - 6 Firmware Time
  - 7 MAC Address
  - 11 Statistics
  - 18 Error log
  - 19, 20 Mesh Timing information.
  - 255 Factory-Configured Options listing.

- ATlogin: enables a password to access command mode.
- ATM: provides information about mesh, such as the current routing table, routing logs and errors.

5.3.2.1.2.2 AT registers

The most of configurations is defined by registers, which are compound of the letter "S" and a number.

- S0: selects the mode that the device will hace when starting up.

  Values:

  - 0 - command mode
  - 1 - Data mode

- S2: ascii value for the character that will be used for escape detection.

  - It can be from 0 to 255. 0 disables the scape detection.
  - 43 (character "+") is the default value.

- S80 (with mesh configuration): TX profile. In a mesh configuration where multiple repeaters are transmitting, it is required to establish a ranking system for areas to decide connections and avoid overlappings.

  The first transmitting area is ranked as 1, the second as 2 (repeating 1), the third as 3 (repeating 2), the fourth as 0 (repeating 3) and the following one starts again as 1, repeating the cycle ad infinitum.

  Values:

  - 0 - It disables TX Profiling, so any radio can send data. This is the default configuration, since TX profiling is generally only useful in partially overlapping coverage areas where collision rates are high.
  - 1 - It allows the bandwidth to be split equally between the Primary Coordinator and all rank 1 units. This may be useful in system where there are no secondary coordinators, as there are no frames assigned to any units other than the Primary Coordinator and associated units
  - 2 - It allows rank 1 units to have 1/2 of the bandwidth. The rest of the bandwidth is split between rank 2 and rank 3 modems. This profile is used when the primary Coordinator is generally located in a location that provides the greatest coverage, meaning it generally has the most units associated with it.
  - 3 - Allocates most of the bandwidth to Rank 1 units. This profile is used in systems with no additional coordinators, where the units send data the majority of the time, with the occasional transmission from the primary.

- S81 (with mesh configuration): threshold to assess whether a channed is signal or noise. It is expressed in dBm.

  - 60 is the default value.

- S83: is the 'Time to Live' in seconds. **SDL** averages the last 8 measurements, but if they are not renewed in this time, they are deleted. This time can be from 10 to 65535.

  - 30 is the default value.

- S85 (with PP or PMP configuration): distance from master repeater to slave repeater (in kilometers) to take into account delays. It can be from 0 to 255.

  - 3 is the default value.

- S86 (with PP or PMP configuration): distance from master repeater to furthest repeater (in kilometers). It can be from 0 to 255.

  - 3 is the default value.
  - 255 means no slaves will be transmitting any packets.

- S87 (with mesh configuration): enables using S105 as modem's units address in Mesh.
  - 0 - Disable. Default value.
  - 1 - Enable.
- S101 (with mesh configuration): function that **SDL** will do.
  - 2 - Remote. The device will not act as coordinator.
  - 4 - Primary coordinator. The device will manage the network to synchronize it.
  - 5 - Secondary coordinator. The device will extend the network range.
  - 6 - Stanby coordinator. The device can take over the primary coordinator.
- S101 (with PP or PMP configuration): function that **SDL** will do.
  - 0 - Master. Data originates or passes trhought the master. Only one master can exist in a PP/PMP network.
  - 1 - Repeater. **SDL** sends data received from RF, it can also exchange data as a slave.
  - 2 - Slave. The device communicates with the master (directly or through repeaters).
- S102: serial baud rate for serial communications. The data rate must be the same for the serial device connected to **SDL**. When forcing to Command Mode, the data port will temporarily communicate at the default value.

  Values (bps):
  - 0 - 230400
  - 1 - 115200
  - 2 - 57600
  - 3 - 38400
  - 4 - 28800
  - 5 - 19200
  - 6 - 14400
  - 7 - 9600 (default)
  - 8 - 7200
  - 9 - 4800
  - 10 - 3600
  - 11 - 2400
  - 12 - 1200
  - 13 - 600
  - 14 - 300
- S103: Wireless Link rate at which RF communications will occur. All radios within a particular network must be configured with the same wireless link rate. Faster link rates sacrifice sensitivity.

  Values (bps):
  - 0 - 172800 (default)
  - 1 - 230400
  - 2 - 276480
  - 3 - 57600

  - 4 - 115200

- S104: Network address as ID. All modems in a given network must have the same address.
- S105: Unit address. Unique identifier for each radio in a network. It can be from 1 to 65534.
  - 1 - Address for master.
  - 65535 - Broadcast address.
- S106: Hop pattern. It defines the pattern that **SDL** will follow to change frequency. The pattern must be the same for master or repeater linked (except for roaming). This register can be from 0 to 49, with 0 as default.
- S108: Output power. Trasmission power for the antenna in dBm, it should be as low as possible while the fade margin is appropiate. It can be from 20 to 30.
  - 30 is the default value (equivalent to 1 W).
- S109 (only for masters with PP or PMP configuration): Hop interval. It defines the rate to change frequency for all radios in the same network. Long intervals have large throughput. Short intervals have low latency and are more reliable to interferences. It can be from 0 to 61, with 20 as default.
- S110: Data format on the serial port. The value must match with the serial device. When forcing to command mode, **SDL** will temporarily communicate at the default value. When returning to Data Mode, the configuration will take again the values from S102 and S110.

Values	Parity	Stop bits	Data bits
1	No	1	8
2	No	2	
3	Even	1	
4	Odd	1	
5	No	1	7
6	No	2	
7	Even	1	
8	Odd	1	
9	Even	2	
10	Odd	2	

- S111: Packet minimum size. This is the minimum number of collected bytes in one buffer, before the buffer can be closed by the character timeout (timer controlled by S116). It can be from 1 to 225, with 1 as default.

> **Warning:** It is STRONGLY advised not to modify this parameter, since changing S111 may prevent the **SDL** from detecting the escape sequence.

- S112: Packet maximum size. It defines the number of bytes from the connected device that will be encapsulated into a packet, unless the timer S116 expires. Large packets produce better data throughput; however, small packets are less likely to become corrupted, with less impact in that case. It can be from 1 to 256, with 256 as default.
- S113: This register determines the maximum number of times that a packet will be retransmitted (in addition to the initial transmission). Retransmissions provide system robustness and ensure data delivery. Retransmissions create additional traffic. It can be from 0 to 254, with 254 as default.
- S115 (with mesh configuration): Repeat interval. It defines the difficulty to access the RF channel. The bigger the number, less attempts are required to access, but the latency will be larger. It can be from 0 to 255, with 5 as default.
- S115 (with PP or PMP configuration): Repeat interval. It defines the number of slots which are available within a window of opportunity for remote units to submit channel requests to the Master. Remotes will randomly

contend for the ability to access the channel request slots. For a small number of Remotes, it is advisable to keep S115 closer to the default value so as to not 'waste bandwidth' by maintaining a relatively large window housing a greater-than-necessary number of channel reservation request slots. It can be from 0 to 255, with 3 as default.

- S116: Character Timeout in quarters of character time. It can be from 10 to 255, with 10 as default (2.5 character time). **Radio Link** will accumulate data in buffers from the serial port, until one of the following conditions occur:
  - The Maximum Packet Size (S112) has been accumulated.
  - Minimum Packet Size (S111) has been accumulated AND the Character timeout (S116) has expired.

  After that, the message is sent through RF.
- S118 (with PP or PMP configuration): synchronization with master or repeater. The default value is 1.

  Values.
  - 65535: **SDL** will synchronize with an upstream unit which has the same network address (S104). If that upstream unit fails, it will attempt to synchronize with another upstream.
  - From 1 to 65534: specific address to synchronize.
- S123: average signal strength received over the previous 8 hop intervals, from -110 to -55 dBm.
- S124 (master with PP or PMP configuration): average signal strength received over the previous 8 hop intervals from a slave or repeater. It can be from -110 to -55 dBm.
- S126 (with mesh configuration): Attempt before routing again. Number of failed transmissions bofre trying to route again. It can be from 1 to 255, with 9 as default.
- S130: if it is enabled, it allows to receive and keep data from serial port while the modem is searching for synchronization. This setting does not apply to master and primary coordinator. Should normally be disabled to prevent accumulation of stale data inside a modem.

  Values:
  - 0 - Disabled (default).
  - 1 - Enabled.
- S133: Network Type. This register must be set to the same value on every unit in the RF system.

  Values:
  - 0 - Point to Multipoint. A single master radio broadcasts data to all units, and all remote units send data to the master.
  - 1 - Point to point. Communication between a Master and a Slave. One or more repeaters can be employed.
  - 2 - Mesh. Radios can communicate with each other directly or through another mesh node, without all data being routed through a master.
  - 3 - Mesh with Roaming. Similar to option 2 (mesh), with a difference: a remote radio may join networks with different S106 and S180.
- S140: Destination address. Ultimate destination for a radio.
  - In a Mesh system, the destination address is entered in MAC address format.
    - For broadcast operation, use the value FF:FF:FF:FF:FF:FF.
    - For unicast operation, the factory assigned MAC address of the destination device must be used, or S105 if S87 = 1.
  - In PP or PMP, the value can be from 1 to 65535, where 65535 is broadcast.

    - PMP - Master S140=65535 and Remote S140=1
    - PP - Master S140=UA of Remote and Remote S140=1 (Master)

- S141 (mater with PP or PMP configuration): registers the presence of repeaters in the network.
  - 0 - No repeater
  - 1 - 1 or more repeaters.
- S142: Serial channel mode for the data port.
  - 0 - RS-232 (default)
  - 1 - RS-485 half duplex
  - 2 - RS-485 full duplex

> **Warning:** The radio module of **SDL** is able to transmit through RS-485, but **SDL** itself is not built to operate with RS-485. The register S142 must not be changed and keep as 0.

- S143: Sleep mode. Values:
  - 0 - The radio is always active.
  - 1 (only on remotes) - **SDL** stays on for at least S145 seconds. After that, it goes to sleep if all data including over the air is sent. The radio will wake up in S144 seconds. Upon wake up the modems will be out on sync with the network and need time to re-synchronize
- S144: Sleep time in seconds. If Sleep mode is enabled in S143, the radio will go to sleep for S144 seconds. It can be from 2 to 65535, with 60 as default.
- S145: Wake time in seconds. If Sleep mode is enabled in S143, the modem will stay awake for S145 seconds if all conditions of S143 are met. It can be from 1 to 65535, with 10 as default.
- S146: Tx Done timeout in quarter of chart. This register along with Modbus RTU setting of S217 can be used to insert a gap between individual packet coming out of the serial port. It can be from 0 to 255, with 14 as default (3.5 characters).
- S151 (with mesh configuration): when coordinators first come online, they send out a number of quick sync packets, defined by S151, used to quickly attain network synchronization. Each quick sync packet is sent on a random channel listed in the hop pattern. The more sync packets sent, the quicker network synchronization occurs, but at a cost of delayed data transmission. The lower the number of packets sent, the less likely the entire network will synchronize during the quick sync process, resulting in slower overall synchronization. It can be from 5 to 65534, with 500 as default.
- S153: if this register is enabled with 1, the radio will prepend each packet received from RF with 10 bytes of the following data (in the same order):
  - First 2 bytes - size (high byte first)
  - One byte - RSSI
  - One reserved byte (0x00)
  - Last six bytes - source unit address (high byte first).

  By default, this register is set as 0 - disable.
- S158: FEC method. FEC consumes significant bandwidth: depending on which coding rate is chosen, a number of coding bits are transmitted along with the data bits. In noisy or long-range communications environments, FEC may effectively increase throughput by decreasing the amount of packet retransmissions which would otherwise be required. FEC may extend RF communications range: at a certain distance where data would otherwise be

unacceptably corrupted, employing FEC may be all that is required to maintain the integrity of that data at that distance.

Values:

Value	Name	Information rate	Number of corrected bits
0	No FEC	/	/
1	Hamming(7,4)	0.5	1 out of 7
2	Hamming (15,11)	0.66	1 out of 15
3	Hamming (31,24)	0.75	1 out of 31
5	Binary BCH (47,36)	0.75	2 bits
6	Golay (23, 12, 7)	0.5	3 bits
7	Reed-Solomon (15,11)	0.687	2 nibbles

- S163: it enables CRC16 checking of received data on local diagnostic port. Note that even if disabled, the incoming data must have two dummy bytes transmitted in place of crc bytes.
  - 0 - Disable.
  - 1 - Enable (default).

Warning: Disabling CRC check is only advisable during troubleshooting of the user's diagnostic requests.

- S180: Hop zone. This register allows the use of hopping zones to restrict the hopping table to a specific segment of the 900 MHz ISM band. The default is to populate the hopping pattern/table using channels or frequencies from the entire 900MHz ISM band.

  Values:
  - 0 - Use the entire ISM band (default).
  - 1 to 10 - Use the band according to register S180.

Tip: Additional zones can be seen by displaying help for the S180 register.

- S181 (with PP or PMP configuration): allows the use of hopping zones to restrict the secondary hopping pattern to specific segments of the 900 MHz ISM band. Any downstream units connected to this will need to have their S180 (Primary Hop Zone) set to same value as the Secondary Hop Zone of the Repeater they are connected to.

  0 - Use the entire ISM band (default). 1 to 10 - Use the band according to register S181.

Tip: Additional zones can be seen by displaying help for the S181 register.

- S183 (with PP or PMP configuration): The period of DCD pulses on synchronized slaves in &C3 mode.

  Values:
  - Minimum: 1
  - Maximum: number of channels in a hop pattern minus one
  - Default: 5

S183 = 1 - will pulse every hop interval, if S183 = 3 - every third, etc. The counter starts at hop index 0. It is used in some applications to generate common synchronization on many slaves. With the default setting of 5 and the hop interval of 20ms, each slave will synchronously generate a pulse of approximately 3ms every 100ms. * S184 (with

mesh configuration): is used to age data in mesh networks in 10 ms ticks. It can be from 1 to 65535. The default is 65535 (never age). * S206 (with PP or PMP configuration): Secondary Hop Pattern. This register, together with the Network ID and the Secondary Hop Zone, determines the secondary hopping pattern that a **SDL** repeater will use to synchronize and communicate with downstream units. The S106 (Primary Hop Pattern) register must be set to the same value on each repeater/slave that is downstream of this unit. It can be from 0 to 49, with 1 as default. * S214 (with mesh configuration): defines the number of aloha slots available in a Mesh Frame. A slot is a set period of time required to transmit the shortest packet (RTS, CTS, ACK). Increasing the number of aloha slots allows more time for a modem to transmit data during a Mesh Frame. The number of aloha slots directly impacts the hop interval, the more aloha slots, the more time to transmit data, but also the longer the system sits on a single frequency. Reducing the number of aloha slots creates a shorter hop interval which results in a system more immune to interference, but too short an interval may disable communication if devices do not have time to transmit.

It can be from 1 to 255, with 60 as default.

Note: Aloha slots are used for all data communication. When the channel access mode is set to Aloha, the transmitting modem randomly selects a Aloha slot within any frame to begin its data transmission.

- S215 (with mesh configuration): defines the number of synchronization slots available in a Mesh Frame. In systems with many coordinators, additional slots may be required to avoid collisions. Register S216 can also be used to provide randomness in sending sync packets to avoid collisions. S215 must be set to the same value for each modem on the network or the unit will not synchronize. The value can be from 1 to 10, with 1 as default.
- S216 (with mesh configuration): defines how often the coordinator transmits synchronization packets. After each synchronization packet transmission the coordinator picks a random number from 1 to the value in S216 and transmits the next packet in this slot. 1 - every synchronization slot, 2 — on average once every 1.5 slots, 3 - on average once every 2 slots etc.
- S217: Protocol type. Defines how data is sent as output on the local serial port. When Modbus RTU is enabled, there is a delay between the packets coming out of the serial port. The register S146 defines the delay between individual packets.

  Values:

  - 0 - Transparent Serial (default)
  - 1 - Modbus RTU
- S218 (with mesh configuration): Input framing type. Controls how the radio treats data coming to serial port. It allows the destination address to be embedded into the data stream, which is automatically stripped by the **SDL** before transmitting the packet.

  Values:

  - 0 - Transparent Serial (Default)
  - 1 - Destination Address (DA) is in the first six bytes (high byte first) of the packet. The radio strips these six bytes and doesn't transmit them. For example, if the DA is 01:23:45:67:89:AB then the high byte is 0x01,the lowest byte is 0xAB. Note that the max size of the data itself in this case is S112 minus 6. If S112 = 256 then the max data size is 250 bytes.
- S219 (with mesh configuration): Routing request TTL. Routing Request Timeout in 10 ms ticks. (1-10000). The default is 10, which is 100 msec. This defines how long a unit will wait for a Routing Request to provide possible routes. During this time no other data may be sent from the unit. Setting this value too low may not give the system enough time to report the best path, alternately, a value too high may create latency in the system as it waits for the TTL to expire before allowing data transmission, although it has already received the best path. It can be from 1 to 10000, with 10 as default (which lasts 100 ms).
- S220 (with mesh configuration): Mesh coordinator rank. Used with Tx Profiles. It can be set from 0 to 3 or 255. Value of 255 (default) is for automatic ranking.

- S221 (with mesh configuration): Aloha slot number in mesh TDMA (Time-Division Multiple Access), where the radio will start its transmission in Tx On Slot channel access mode S244 = 2. It can be from 1 to 255, with 1 as default.

Note: When register S244 = 2, the Channel Access Mode is set to TDMA. In this mode each radio in the system starts its transmission on an assigned slot number within the frame. The slot number is defined by S221.

- S222 (with mesh configuration): Roaming mode.

  Values:

  - 0 - Disabled. A mesh radio will synchronize only to a coordinator with the matching set of S106 and S180.
  - 1 - Roaming on Zone/Pattern.The radio will synchronize with any valid coordinator.

- S223 (with mesh configuration): Routing. This register is used to enable or disable the Mesh Routing function of the radio. Whenever coordinators are added to a system, routers are typically required in a network. Any unit in a Mesh network can be used to perform routing tasks. Although it is a good idea to have more than a single router, too many routers may create unnecessary traffic in the system.

  Values:

  - 0 - Disabled - Disabled by default
  - 1 - Enabled - Routing can be enable on any unit, but the more units performing routing tasks, the more routing traffic generated.

Note: For Mesh Networking to be an effective networking topology, routing functions must be performed to discover paths within the network to each destination, to ensure the best path is chosen. All units in a Mesh Network, including remotes, can be configured to provide routing capabilities by setting register S223.

- S224 (with mesh configuration): Standby trip level. Synchronization level of mesh standby coordinator to become the primary coordinator. This register works with the syncrhonization timeout (S248) on the primary coordinator to monitor the synchronization level to determine when the Primary Coordinator has failed. The synchronization timeout sets a counter (set by S248 on the Primary coordinator and propagated in synchronization packets) that counts down each time a frame is received that does not contain synchronization data from a coordinator. If the unit receives synchronization data the counter is reset, if the counter reaches zero the unit will lose synchronization.

  Values: from 0 to 255, with 20 as default.

Note: The standby trip level (S224) is designed to be able to transition a standby coordinator to a primary coordinator before the network loses synchronization. This is accomplished by watching the counter set by S248 and triggering at the level set by S224.

- S225: Compression. Using compression may improve overall performance of the modem.

  Values:

  - 0 - Disabled.
  - 1 - Enabled (default).

- S232: Maximum number of buffers from the local communications port. It is used to limit the amount of storage that the modem will allocate to incoming user's data. Each buffer is S112 number of bytes. With S112=256 (default) and S232=200 (default) the modem can store up to 51200 bytes.

Values: from 1 to 255, with 200 as default.

- S234 (with PMP configuration): after the master releases the channel, it will wait for the S234 number of hop intervals to allow the slaves to send channel requests before the master arbitrates the channel.

Note: When many slaves want to request the channel at the same time, setting this register to a bigger number will help to ensure that the channel arbiter in the master will allocate the channel fairly (new modems will be given higher priority over modems that were recently allocated the channel).

Values: 1 to 254, with 1 as default.

- S235 (with PP configuration): routing time to live in seconds. It defines the aging interval for routing information in PP Mode.

  Values: from 1 to 65535.

  - 65535 — Never aging.
  - 30- default.

- S236: maximum buffer out storage. It limits the number of buffers waiting to be output to the user on COM1.

  Values: from 1 to 65535.

Warning: Normally this register should not be changed.

- S244 (with mesh configuration): channel access mode. This register defines how devices access the channel when they have data to transmit.

  Values:

  - 0 - Aloha: units use Carrier Sense Multiple Access (CSMA) to access the channel, if available, and send data. Register S115 can be set to configure the randomness at which devices access the channel to avoid collisions. Default for coordinator.
  - 1 - RTS/CTS: when units wish to transmit, they request a channel (RTS) from the associated coordinator. The Coordinator will respond immediately (CTS) if the channel is successfully allocated. Default for secondary coordinators and remotes.
  - 2 - TDMA: transmission on slot. See S221.

- S245 (with mesh configuration): cost of one hop in mesh routing. When choosing the best route, the cost of each route must be considered. Cost of Hop allows a user to influence the relationship between the cost of RSSI and the Cost of Each hop.

  Values: from 0 to 255, with 100 as default.

Note: For Mesh Networking to be an effective networking topology, routing functions must be performed to discover paths within the network to each destination, to ensure the best path is chosen. Routing is a key element in Mesh network design that can have a profound impact on overall system performance.

- S248: synchronization timeout. To remain synchronized to the network, a unit must receive synchronization data occasionally from a coordinator or master. The synchronization timeout defines the number of frames (Mesh) or hops (PMP or PTP), before losing synchronization completely.

  Values: from 4 to 65534.

  - 100 is default for mesh.

- 512 is default for PP and PMP.

Note: In mesh topology, 248 is only set on primary coordinator and propagated in synchronization packets.

- S249 (with PMP or PP configuration): it limits the number of packets that a radio can send in one hop interval.

  Values: from 1 to 255, with 255 as default. 255 represents unlimited packets.

  Warning: Normally S249 should be left unchanged.

- S250 (with PMP configuration): It sets a limit on bandwidth available to the master when the channel is allocated to a slave. Its is represented as %.

  Values: from 0 to 100, with 50 as default.

- S251 (with PMP configuration): it defines the channel release timeout in hop intervals. Normally a slave must release the channel by sending a channel release packet. If slave stopped communicating with master and didn't release the channel, the master will wait for S251 hop intervals before de-allocating the channel.

  Values: from 1 to 255, with 10 as default.

Warning: Normally S251 should be left unchanged.

- S252 (with PMP configuration): it defines a number of packets a slave can transmit before releasing the channel.

  Values: from 1 to 255, with 10 as default and 255 disables that restriction.

5.3.2.1.3 SDL24 configuration

5.3.2.1.3.1 AT commands

- ATA: sets the device into online/data mode.
- ATg or ATG: defines whether interfering RF signals are present. **SDL** sweeps the operating band and provide a display of mean and peak signal levels, in dBm.
- ATN: provides a detailed scrutiny of the RF environment. The specific start and stop frequencies, along with step size and dwell time are definable. An ATN command example is ATN 905.250 908.500750 25 100, where:
  - 905.250 is the start frequency in MHz up to 6 decimal digits.
  - 908.500750 is the stop frequency in MHz up to 6 6 decimal digits.
  - 25 i the step increment in kHz, it can be from 1 to 1000.
  - 100 is the dwell time in ms, it can be from 1 to 1000.
- AT&Fn: where "n" is a number, it establishes a default configuration.
  - AT&F1 FH Master Fast PMP
  - AT&F2 FH Slave Fast PMP
  - AT&F3 FH Repeater Fast PMP
  - AT&F4 FH Master Slow PMP
  - AT&F5 FH Slave Slow PMP

  - AT&F6 FH Master Fast PP
  - AT&F7 FH Slave Fast PP
  - AT&F8 FH Master Slow PP
  - AT&F9 FH Slave Slow PP
  - AT&F10 FH Master Fast PMP no Time ACK
  - AT&F11 FH Master Fast P2P no Time ACK
  - AT&F12 FH Master Fast PP no Time ACK
  - AT&F15 FH Master WL
  - AT&F16 FH Slave WL
  - AT&F18 FH Master Fast TDMA
  - AT&F19 FH Slave Fast TDMA
  - AT&F100 - Reset Hopping Modes

Note:

  - Mesh Primary Coordinator - Each Mesh network must have a primary coordinator. The primary coordinator provides the synchronization for the network.
  - Mesh Secondary Coordinator - Secondary coordinators can be deployed to extend the range of the Mesh network. Each device on a Mesh network must have LOS (Line of Sight) with either a Primary or Secondary Coordinator.
  - Mesh Remote (Slave) - Any device on the network that is not a Primary or Secondary Coordinator, generally attached to end devices. Can also be used to perform routing tasks if enabled.
  - Master (PMP/PP) - Only one per network. In PP/PMP network types (see S133) data either originates at, is destined to, or passes through the Master.
  - Repeater (PMP/PP) - May act simply as a 'Repeater' to store and forward data to/from an upstream unit to/from a downstream unit (e.g. when there is a long distance between units), or, may act as a Repeater/Slave in which case the above function is performed AND the unit may also exchange data as a Slave within the network.
  - Slave (PMP/PP) - Interfaces with remote devices and communicates with Master either directly or via Repeater(s).

- AT&V: displays all visible S registers and their current values.
- AT&V1: displays the complete set of user parameters (for advanced users).
- AT&W: writes configuration into non-volatile memory
- AT&WA: writes configuration into non-volatile memory and sets the device in online mode.
- ATSxxx?: displays the xxx register.
- ATSxxx=yyy: writes value yyy in register xxx.
- ATSxxx /?: displays the xxx register settings (if they are available).
- ATIn: where n is one of the following numbers.
  - 1 Product Code.
  - 3 Product Identification (Firmware Version).

  - 4 Firmware Date.
  - 5 Firmware Copyright.
  - 6 Firmware Time.
  - 255 Factory-Configured Options listing.

- ATlogin: enables a password to access command mode.
- ATM: provides information about mesh, such as the current routing table, routing logs and errors.
- AT&H0: by default, **SDL** will hop on frequencies across the entire 2.4 GHz ISM band. For some applications or within certain operating environments, it may be desired to prohibit the modem from operating on specific frequencies or range(s) of frequencies. The radio will not allow too many frequencies to be restricted; it requires a certain amount of bandwidth within which to operate to comply with regulations.

  The modem responds with a prompt for the Unit Address. (Enter the Unit Address for the Master (1) and all Repeaters in the network into each modem in the network.) Having entered '1', the modem prompts for the first restricted frequency to be entered.

  Press [Esc] key to escape the entry process, then, a summary at left/bottom will be displayed. Pressing [Esc] again saves and exits the process. To modify an existing restriction, simply overwrite it. To remove a restriction, overwrite it with 000.000.

- AT&H1: repeater registration. When more than one Repeater exists in a network, the Unit Address of each Repeater should be registered within every modem in the network. The reason for doing this is to enable the modems to create hopping patterns which will be orthogonal to each other, thereby minimizing possible interference between network segments.

  Upon entering the AT&H1 command, the radio prompts as follows:

  - A to add a Repeater (this is done by entering the Unit Address of the Repeater).
  - R to remove a Repeater.
  - C to clear all registered Repeaters.

  Pressing the [Esc] key saves and exits the process.

5.3.2.1.3.2 AT registers

The most of configurations is defined by registers, which are compound of the letter "S" and a number.

- S0: selects the mode that the device will hace when starting up.

  Values:

  - 0 - command mode
  - 1 - Data mode

- S2: ascii value for the character that will be used for escape detection.
  - It can be from 0 to 255. 0 disables the scape detection.
  - 43 (character "+") is the default value.

- S101: function that **SDL** will do.
  - 0 - Master. Data originates or passes trhought the master. Only one master can exist in a PP/PMP network.
  - 1 - Repeater. **SDL** sends data received from RF, it can also exchange data as a slave.

  - 2 - Slave. The device interfaces with remote devices and communicates with the master (directly or through repeaters).

- S102: serial baud rate for serial communications. The data rate must be the same for the serial device connected to **SDL**. When forcing to Command Mode, the data port will temporarily communicate at the default value.

  Values (bps):

  - 0 - 230400
  - 1 - 115200
  - 2 - 57600
  - 3 - 38400
  - 4 - 28800
  - 5 - 19200
  - 6 - 14400
  - 7 - 9600 (default)
  - 8 - 7200
  - 9 - 4800
  - 10 - 3600
  - 11 - 2400
  - 12 - 1200
  - 13 - 600
  - 14 - 300

- S103: Wireless Link rate at which RF communications will occur. All radios within a particular network must be configured with the same wireless link rate. Faster link rates sacrifice sensitivity.

  Values (bps):

  - 0 - 19200
  - 1 - 115200
  - 2 - 172800
  - 3 - 230000
  - 4 - 276000
  - 5 - 340000
  - 6 - 24700
  - 8 - 57600

- S104: Network address as ID. All modems in a given network must have the same address.

  Values: from 0 to 4,000,000,000, with 1234567890 as default.

- S105: Unit address. Unique identifier for each radio in a network. It can be from 1 to 65534.

  - 1 - Address for master.
  - 65535 - Broadcast address.

- S107: this mask is applied to the transmitted data, and removed from the received data. It is an added form of security for a network.

Tip: Change S107 to something unique for your network.

- S108: Output power. Trasmission power for the antenna in dBm, it should be as low as possible while the fade margin is appropiate. It can be from 20 to 30.
  - 30 is the default value (equivalent to 1 W).
- S109: Hop interval. It defines the rate to change frequency for all radios in the same network. Long intervals have large throughput. Short intervals have low latency and are more reliable to interferences. It can be from 0 to 61, with 20 as default.

Tip: The default setting of 20 ms is satisfactory for most applications. If adjustment of S109 is being considered, also consider the serial baud rate, wireless link rate, and maximum packet size (S102, S103, and S112).

- S110: Data format on the serial port. The value must match with the serial device. When forcing to command mode, **SDL** will temporarily communicate at the default value. When returning to Data Mode, the configuration will take again the values from S102 and S110.

Values	Parity	Stop bits	Data bits
1	No	1	8
2	No	2	
3	Even	1	
4	Odd	1	
5	No	1	7
6	No	2	
7	Even	1	
8	Odd	1	
9	Even	2	
10	Odd	2	

- S111: Packet minimum size. This is the minimum number of collected bytes in one buffer, before the buffer can be closed by the character timeout (timer controlled by S116). It can be from 1 to 225, with 1 as default.
- S112: Packet maximum size. It defines the number of bytes from the connected device that will be encapsulated into a packet, unless the timer S116 expires. Large packets produce better data throughput; however, small packets are less likely to become corrupted, with less impact in that case. It can be from 1 to 256, with 256 as default.
- S113: This register determines the maximum number of times that a packet will be retransmitted (in addition to the initial transmission). Retransmissions provide system robustness and ensure data delivery. Retransmissions create additional traffic. It can be from 0 to 254, with 254 as default.

Tip: In a PMP system, set S113 to the minimum value required as, effectively, the data throughput from Master to Remote is divided by 1 plus the number stored in S113.

- S115 (with PP or PMP configuration): Repeat interval. It defines the number of slots which are available within a window of opportunity for remote units to submit channel requests to the Master. Remotes will randomly contend for the ability to access the channel request slots. For a small number of Remotes, it is advisable to keep S115 closer to the default value so as to not 'waste bandwidth' by maintaining a relatively large window housing a greater-than-necessary number of channel reservation request slots.

Values: from 0 to 255, with 3 as default.

Note: In a TDMA type system, S115 may be set to 1 as the Remotes are not able to request a transmission channel: the master polls each Remote for data.

- S116: Character Timeout in quarters of character time. It can be from 10 to 255, with 10 as default (2.5 character time). **Radio Link** will accumulate data in buffers from the serial port, until one of the following conditions occur:
  - The Maximum Packet Size (S112) has been accumulated.
  - Minimum Packet Size (S111) has been accumulated AND the Character timeout (S116) has expired.

  After that, the message is sent through RF.
- S118 (with PP or PMP configuration): synchronization with master or repeater. The default value is 1.

  Values:
  - 65535: **SDL** will synchronize with an upstream unit which has the same network address (S104). If that upstream unit fails, it will attempt to synchronize with another upstream.
  - From 1 to 65534: specific address to synchronize.
- S119: Quick Enter to Command Mode.

  Values:
  - 1 - Enabled. A delay of 5 seconds is introduced at powerup before the modem will go into data mode. If during these 5 seconds, the user enters 'mhx' the modem will instead go into Command Mode and reply with 'OK'. The terminal baud rate must be set to 9600bps. If an incorrect character is entered, the modem will immediately go into data mode.
  - 0 (default) - The radio will promptly go into data mode upon power-up.
- S123: average signal strength received over the previous 8 hop intervals, from -110 to -55 dBm.
- S124 (master with PP or PMP configuration): average signal strength received over the previous 8 hop intervals from a slave or repeater. It can be from -110 to -55 dBm.
- S126 (with mesh configuration): Attempt before routing again. Number of failed transmissions bofre trying to route again. It can be from 1 to 255, with 9 as default.
- S130: if it is enabled, it allows to receive and keep data from serial port while the modem is searching for synchronization. This setting does not apply to master and primary coordinator. Should normally be disabled to prevent accumulation of stale data inside a modem.

  Values:
  - 0 - Disabled (default).
  - 1 - Enabled.
- S133: Network Type. This register must be set to the same value on every unit in the RF system.

  Values:
  - 0 - Point to Multipoint. A single master radio broadcasts data to all units, and all remote units send data to the master.
  - 1 - Point to point. Communication between a Master and a Slave. One or more repeaters can be employed.
  - 2 - Mesh. Radios can communicate with each other directly or through another mesh node, without all data being routed through a master.

  - 3 - Mesh with Roaming. Similar to option 2 (mesh), with a difference: a remote radio may join networks with different S106 and S180.

- S140: Destination address. Ultimate destination for a radio.
  - In a Mesh system, the destination address is entered in MAC address format.
    - For broadcast operation, use the value FF:FF:FF:FF:FF:FF.
    - For unicast operation, the factory assigned MAC address of the destination device must be used, or S105 if S87 = 1.
  - In PP or PMP, the value can be from 1 to 65535, where 65535 is broadcast.
    - PMP - Master S140=65535 and Remote S140=1
    - PP - Master S140=UA of Remote and Remote S140=1 (Master)
- S141 (mater with PP or PMP configuration): registers the presence of repeaters in the network.
  - 0 - No repeater
  - 1 - 1 or more repeaters.
- S142: Serial channel mode for the data port.
  - 0 - RS-232 (default)
  - 1 - RS-485 half duplex
  - 2 - RS-485 full duplex

> **Warning:** The radio module of **SDL** is able to transmit through RS-485, but **SDL** itself is not built to operate with RS-485. The register S142 must not be changed and keep as 0.

- S143: Sleep mode. Values:
  - 0 - The radio is always active.
  - 1 (only on remotes) - **SDL** stays on for at least S145 seconds. After that, it goes to sleep if all data including over the air is sent. The radio will wake up in S144 seconds. Upon wake up the modems will be out on sync with the network and need time to re-synchronize
- S144: Sleep time in seconds. If Sleep mode is enabled in S143, the radio will go to sleep for S144 seconds. It can be from 2 to 65535, with 60 as default.
- S145: Wake time in seconds. If Sleep mode is enabled in S143, the modem will stay awake for S145 seconds if all conditions of S143 are met. It can be from 1 to 65535, with 10 as default.
- S146: Tx Done timeout in quarter of chart. This register along with Modbus RTU setting of S217 can be used to insert a gap between individual packet coming out of the serial port. It can be from 0 to 255, with 14 as default (3.5 characters).
- S151 (with mesh configuration): when coordinators first come online, they send out a number of quick sync packets, defined by S151, used to quickly attain network synchronization. Each quick sync packet is sent on a random channel listed in the hop pattern. The more sync packets sent, the quicker network synchronization occurs, but at a cost of delayed data transmission. The lower the number of packets sent, the less likely the entire network will synchronize during the quick sync process, resulting in slower overall synchronization. It can be from 5 to 65534, with 500 as default.
- S153: if this register is enabled with 1, the radio will prepend each packet received from RF with 10 bytes of the following data (in the same order):
  - First 2 bytes - size (high byte first)

  - One byte - RSSI
  - One reserved byte (0x00)
  - Last six bytes - source unit address (high byte first).

  By default, this register is set as 0 - disable.

- S158: FEC method. FEC consumes significant bandwidth: depending on which coding rate is chosen, a number of coding bits are transmitted along with the data bits. In noisy or long-range communications environments, FEC may effectively increase throughput by decreasing the amount of packet retransmissions which would otherwise be required. FEC may extend RF communications range: at a certain distance where data would otherwise be unacceptably corrupted, employing FEC may be all that is required to maintain the integrity of that data at that distance.

  Values:

Value	Name	Information rate	Number of corrected bits
0	No FEC	/	/
1	Hamming(7,4)	0.5	1 out of 7
2	Hamming (15,11)	0.66	1 out of 15
3	Hamming (31,24)	0.75	1 out of 31
5	Binary BCH (47,36)	0.75	2 bits
6	Golay (23, 12, 7)	0.5	3 bits
7	Reed-Solomon (15,11)	0.687	2 nibbles

- S163: it enables CRC16 checking of received data on local diagnostic port. Note that even if disabled, the incoming data must have two dummy bytes transmitted in place of crc bytes.
  - 0 - Disable.
  - 1 - Enable (default).

Warning: Disabling CRC check is only advisable during troubleshooting of the user's diagnostic requests.

- S180: Hop zone. This register allows the use of hopping zones to restrict the hopping table to a specific segment of the 900 MHz ISM band. The default is to populate the hopping pattern/table using channels or frequencies from the entire 900MHz ISM band.

  Values:

  0 - Use the entire ISM band (default). 1 to 10 - Use the band according to register S180.

Tip: Additional zones can be seen by displaying help for the S180 register.

- S181 (with PP or PMP configuration): allows the use of hopping zones to restrict the secondary hopping pattern to specific segments of the 900 MHz ISM band. Any downstream units connected to this will need to have their S180 (Primary Hop Zone) set to same value as the Secondary Hop Zone of the Repeater they are connected to.

  0 - Use the entire ISM band (default). 1 to 10 - Use the band according to register S181.

Tip: Additional zones can be seen by displaying help for the S181 register.

- S183 (with PP or PMP configuration): The period of DCD pulses on synchronized slaves in &C3 mode.

Values:

- Minimum: 1
- Maximum: number of channels in a hop pattern minus one
- Default: 5

S183 = 1 - will pulse every hop interval, if S183 = 3 - every third, etc. The counter starts at hop index 0. It is used in some applications to generate common synchronization on many slaves. With the default setting of 5 and the hop interval of 20ms, each slave will synchronously generate a pulse of approximately 3ms every 100ms. * S184 (with mesh configuration): is used to age data in mesh networks in 10 ms ticks. It can be from 1 to 65535. The default is 65535 (never age). * S206 (with PP or PMP configuration): Secondary Hop Pattern. This register, together with the Network ID and the Secondary Hop Zone, determines the secondary hopping pattern that a **SDL** repeater will use to synchronize and communicate with downstream units. The S106 (Primary Hop Pattern) register must be set to the same value on each repeater/slave that is downstream of this unit. It can be from 0 to 49, with 1 as default. * S214 (with mesh configuration): defines the number of aloha slots available in a Mesh Frame. A slot is a set period of time required to transmit the shortest packet (RTS, CTS, ACK). Increasing the number of aloha slots allows more time for a modem to transmit data during a Mesh Frame. The number of aloha slots directly impacts the hop interval, the more aloha slots, the more time to transmit data, but also the longer the system sits on a single frequency. Reducing the number of aloha slots creates a shorter hop interval which results in a system more immune to interference, but too short an interval may disable communication if devices do not have time to transmit.

It can be from 1 to 255, with 60 as default.

Note: Aloha slots are used for all data communication. When the channel access mode is set to Aloha, the transmitting modem randomly selects a Aloha slot within any frame to begin its data transmission.

- S215 (with mesh configuration): defines the number of synchronization slots available in a Mesh Frame. In systems with many coordinators, additional slots may be required to avoid collisions. Register S216 can also be used to provide randomness in sending sync packets to avoid collisions. S215 must be set to the same value for each modem on the network or the unit will not synchronize. The value can be from 1 to 10, with 1 as default.
- S216 (with mesh configuration): defines how often the coordinator transmits synchronization packets. After each synchronization packet transmission the coordinator picks a random number from 1 to the value in S216 and transmits the next packet in this slot. 1 - every synchronization slot, 2 — on average once every 1.5 slots, 3 - on average once every 2 slots etc.
- S217: Protocol type. Defines how data is sent as output on the local serial port. When Modbus RTU is enabled, there is a delay between the packets coming out of the serial port. The register S146 defines the delay between individual packets.

  Values:

  - 0 - Transparent Serial (default)
  - 1 - Modbus RTU
- S218 (with mesh configuration): Input framing type. Controls how the radio treats data coming to serial port. It allows the destination address to be embedded into the data stream, which is automatically stripped by the **SDL** before transmitting the packet.

  Values:

  - 0 - Transparent Serial (Default)
  - 1 - Destination Address (DA) is in the first six bytes (high byte first) of the packet. The radio strips these six bytes and doesn't transmit them. For example, if the DA is 01:23:45:67:89:AB then the high byte is 0x01,the lowest byte is 0xAB. Note that the max size of the data itself in this case is S112 minus 6. If S112 = 256 then the max data size is 250 bytes.

- S219 (with mesh configuration): Routing request TTL. Routing Request Timeout in 10 ms ticks. (1-10000). The default is 10, which is 100 msec. This defines how long a unit will wait for a Routing Request to provide possible routes. During this time no other data may be sent from the unit. Setting this value too low may not give the system enough time to report the best path, alternately, a value too high may create latency in the system as it waits for the TTL to expire before allowing data transmission, although it has already received the best path. It can be from 1 to 10000, with 10 as default (which lasts 100 ms).
- S220 (with mesh configuration): Mesh coordinator rank. Used with Tx Profiles. It can be set from 0 to 3 or 255. Value of 255 (default) is for automatic ranking.
- S221 (with mesh configuration): Aloha slot number in mesh TDMA (Time-Division Multiple Access), where the radio will start its transmission in Tx On Slot channel access mode S244 = 2. It can be from 1 to 255, with 1 as default.

Note: When register S244 = 2, the Channel Access Mode is set to TDMA. In this mode each radio in the system starts its transmission on an assigned slot number within the frame. The slot number is defined by S221.

- S222 (with mesh configuration): Roaming mode.

  Values:

  - 0 - Disabled. A mesh radio will synchronize only to a coordinator with the matching set of S106 and S180.
  - 1 - Roaming on Zone/Pattern.The radio will synchronize with any valid coordinator.

- S223 (with mesh configuration): Routing. This register is used to enable or disable the Mesh Routing function of the radio. Whenever coordinators are added to a system, routers are typically required in a network. Any unit in a Mesh network can be used to perform routing tasks. Although it is a good idea to have more than a single router, too many routers may create unnecessary traffic in the system.

  Values:

  - 0 - Disabled - Disabled by default
  - 1 - Enabled - Routing can be enable on any unit, but the more units performing routing tasks, the more routing traffic generated.

Note: For Mesh Networking to be an effective networking topology, routing functions must be performed to discover paths within the network to each destination, to ensure the best path is chosen. All units in a Mesh Network, including remotes, can be configured to provide routing capabilities by setting register S223.

- S224 (with mesh configuration): Standby trip level. Synchronization level of mesh standby coordinator to become the primary coordinator. This register works with the syncrhonization timeout (S248) on the primary coordinator to monitor the synchronization level to determine when the Primary Coordinator has failed. The synchronization timeout sets a counter (set by S248 on the Primary coordinator and propagated in synchronization packets) that counts down each time a frame is received that does not contain synchronization data from a coordinator. If the unit receives synchronization data the counter is reset, if the counter reaches zero the unit will lose synchronization.

  Values: from 0 to 255, with 20 as default.

Note: The standby trip level (S224) is designed to be able to transition a standby coordinator to a primary coordinator before the network loses synchronization. This is accomplished by watching the counter set by S248 and triggering at the level set by S224.

- S225: Compression. Using compression may improve overall performance of the modem.

  Values:

  - 0 - Disabled.
  - 1 - Enabled (default).

- S232: Maximum number of buffers from the local communications port. It is used to limit the amount of storage that the modem will allocate to incoming user's data. Each buffer is S112 number of bytes. With S112=256 (default) and S232=200 (default) the modem can store up to 51200 bytes.

  Values: from 1 to 255, with 200 as default.

- S234 (with PMP configuration): after the master releases the channel, it will wait for the S234 number of hop intervals to allow the slaves to send channel requests before the master arbitrates the channel.

  Note: When many slaves want to request the channel at the same time, setting this register to a bigger number will help to ensure that the channel arbiter in the master will allocate the channel fairly (new modems will be given higher priority over modems that were recently allocated the channel).

  Values: 1 to 254, with 1 as default.

- S235 (with PP configuration): routing time to live in seconds. It defines the aging interval for routing information in PP Mode.

  Values: from 1 to 65535.

  - 65535 — Never aging.
  - 30- default.

- S236: maximum buffer out storage. It limits the number of buffers waiting to be output to the user on COM1.

  Values: from 1 to 65535.

  Warning: Normally this register should not be changed.

- S244 (with mesh configuration): channel access mode. This register defines how devices access the channel when they have data to transmit.

  Values:

  - 0 - Aloha: units use Carrier Sense Multiple Access (CSMA) to access the channel, if available, and send data. Register S115 can be set to configure the randomness at which devices access the channel to avoid collisions. Default for coordinator.
  - 1 - RTS/CTS: when units wish to transmit, they request a channel (RTS) from the associated coordinator. The Coordinator will respond immediately (CTS) if the channel is successfully allocated. Default for secondary coordinators and remotes.
  - 2 - TDMA: transmission on slot. See S221.

- S245 (with mesh configuration): cost of one hop in mesh routing. When choosing the best route, the cost of each route must be considered. Cost of Hop allows a user to influence the relationship between the cost of RSSI and the Cost of Each hop.

  Values: from 0 to 255, with 100 as default.

Note: For Mesh Networking to be an effective networking topology, routing functions must be performed to discover paths within the network to each destination, to ensure the best path is chosen. Routing is a key element in Mesh network design that can have a profound impact on overall system performance.

- S248: synchronization timeout. To remain synchronized to the network, a unit must receive synchronization data occasionally from a coordinator or master. The synchronization timeout defines the number of frames (Mesh) or hops (PMP or PTP), before losing synchronization completely.

  Values: from 4 to 65534.

  - 100 is default for mesh.
  - 512 is default for PP and PMP.

Note: In mesh topology, 248 is only set on primary coordinator and propagated in synchronization packets.

- S249 (with PMP or PP configuration): it limits the number of packets that a radio can send in one hop interval.

  Values: from 1 to 255, with 255 as default. 255 represents unlimited packets.

Warning: Normally S249 should be left unchanged.

- S250 (with PMP configuration): It sets a limit on bandwidth available to the master when the channel is allocated to a slave. Its is represented as %.

  Values: from 0 to 100, with 50 as default.

- S251 (with PMP configuration): it defines the channel release timeout in hop intervals. Normally a slave must release the channel by sending a channel release packet. If slave stopped communicating with master and didn't release the channel, the master will wait for S251 hop intervals before de-allocating the channel.

  Values: from 1 to 255, with 10 as default.

Warning: Normally S251 should be left unchanged.

- S252 (with PMP configuration): it defines a number of packets a slave can transmit before releasing the channel.

  Values: from 1 to 255, with 10 as default and 255 disables that restriction.

CHAPTER

SIX

MAINTENANCE

Apart from cleaning, no extra maintenance is required to guarantee the correct operation of the **SDL**.

In order to clean **SDL** properly follow the next recommendations.

- Turn off the device before cleaning.
- Use a clean, soft, damp cloth to clean the unit.
- Do not immerse the unit in water to clean it.

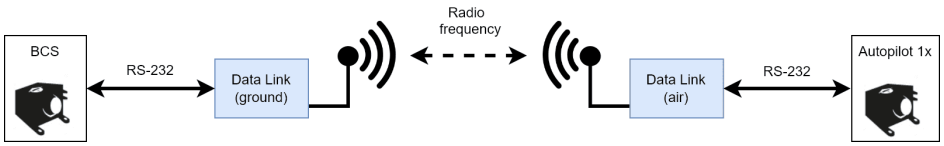
CHAPTER

SEVEN

INTEGRATION EXAMPLES

7.1 Veronte Autopilot 1x and Veronte BCS

An **Autopilot 1x** can communicate with a **BCS** or another **Autopilot 1x**. Usually, **BCS** are used as ground stations to control autopilots.



"Ground" stations manage remote communications with "air" stations, which are mounted in an aircraft.

An **SDL** configured as "ground" sends continuosly messages to establish connection with "air" stations, "air" stations do not send any message until they receive messages from "ground", then they start to send and receive data each other.

To establish communication between an **SDL** and an **Autopilot 1x** (or a **BCS**), both devices require configuration. This configuration for an **Autopilot 1x** (or a **BCS**) can be read on the External radios - Integration examples section from the **1x PDI Builder user manual**. The **SDL** is configured with AT commands (read the *How to configure SDL* section to know more). Click on the links of the following table and use the listed AT commands according to the application requirements.

Variant	Ground	Air
SDL04	*Commands for ground SDL04*	*Commands for air SDL04*
SDL09	*Commands for ground SDL09*	*Commands for air SDL09*
SDL24	*Commands for ground SDL24*	*Commands for air SDL24*

CHAPTER

EIGHT

ACRONYMS AND DEFINITIONS

ARQ	Automatic Repeat-reQuest
AT command	ATtention command
AWG	American Wire Gauge
BCS	Basic Contol Station
bps	Bits Per Second
COM	COMmunications
CRC	Cyclic Redundancy Check
DC	Direct current
dBd	DeciBel relative to Dipole
dBi	DeciBel relative to Isotropic
dBm	DeciBel per Milliwatt
FHSS	Frequency Hopping Spread Spectrum
EIRP	Effective Isotropic Radiated Power
GFK	Gaussian Frequency Shift Keying
GMSK	Gaussian Minimum Shift Keying
GND	GrouND
I/O	Input / Output
LOS	Line Of Sight
PSK	Phase-Shift Keying
RSSI	Received Signal Strength Indicator
SDL	Standard Data Link
SMA	SubMiniature version A
SSMA	Miniature-SMA
PMP	Point to Multipoint
PP	Point to Point
QPSK	Quadrature Phase Shift Keying
RF	Radio Frequency
RPTNC	Reverse Polarity Threaded Neill-Concelman
RS-485	Recommended Standard 485
RX	Receiver
TX	Trasmiter
UAV	Unmanned Aerial Vehicle
USB	Universal Serial Bus

CHAPTER

NINE

CONTACT DATA

You can contact Embention if you need further help and support.

Embention contact data is as follows:

Email: support@embention.com

Telephone: (+34) 965 421 115

Address: Polígono Industrial Las Atalayas, C/ Chelín, Nº 16, CP 03114, Alicante (España).

CHAPTER

TEN

ANNEXES

10.1 Annex 1: commands for ground SDL04

AT&F6 (Factory defaults for a PP master)

ATS128=2 (400 MHz Frequency Hopping)

ATS108=30 (1 W to transmit power)

ATS104=1893 (Network Address. All radios in a given network must have the same Network Address, but different networks must have different address)

ATS105=1 (Unit address, masters must have 1)

ATS102=1 (Serial baud rate for serial port. It must be the same for the connected device: 115200 bps for this case)

ATS113=2 (Maximum number of times that a packet will be retransmitted)

ATP0= (Set available primary frequencies for the radio)

411.000000

472.000000

443.000000

464.000000

415.000000

436.000000

467.000000

478.000000

419.000000

460.000000

421.000000

472.000000

443.000000

464.000000

445.000000

426.000000

427.000000

468.000000

429.000000

440.000000

431.000000

412.000000

433.000000

464.000000

445.000000

436.000000

437.000000

478.000000

429.000000

410.000000

461.000000

452.000000

443.000000

454.000000

465.000000

416.000000

427.000000

418.000000

449.000000

470.000000

431.000000

452.000000

433.000000

414.000000

465.000000

476.000000

437.000000

428.000000

419.000000

480.000000

ATP1= (Set available secondary frequencies for the radio)

411.000000

472.000000

443.000000
464.000000
415.000000
436.000000
467.000000
478.000000
419.000000
460.000000
421.000000
472.000000
443.000000
464.000000
445.000000
426.000000
427.000000
468.000000
429.000000
440.000000
431.000000
412.000000
433.000000
464.000000
445.000000
436.000000
437.000000
478.000000
429.000000
410.000000
461.000000
452.000000
443.000000
454.000000
465.000000
416.000000
427.000000
418.000000

449.000000

470.000000

431.000000

452.000000

433.000000

414.000000

465.000000

476.000000

437.000000

428.000000

419.000000

480.000000

AT&W (Store active configuration into the non-volatile memory)

ATA (Set the device to online mode)

10.2 Annex 2: commands for air SDL04

AT&F7 (Factory defaults for a Point to Point slave)

ATS128=2 (400 MHz Frequency Hopping)

ATS108=30 (1 W to transmit power)

ATS104=1893 (Network Address. All radios in a given network must have the same Network Address, but different networks must have different address)

ATS105=2 (Unit address, each unit must have a unique identifier in a network).

ATS102=1 (Serial baud rate for serial port. It must be the same for the connected device: 115200 bps for this case)

ATS113=2 (Maximum number of times that a packet will be retransmitted)

ATP0= (Set available primary frequencies for the radio)

411.000000

472.000000

443.000000

464.000000

415.000000

436.000000

467.000000

478.000000

419.000000

460.000000

421.000000

472.000000
443.000000
464.000000
445.000000
426.000000
427.000000
468.000000
429.000000
440.000000
431.000000
412.000000
433.000000
464.000000
445.000000
436.000000
437.000000
478.000000
429.000000
410.000000
461.000000
452.000000
443.000000
454.000000
465.000000
416.000000
427.000000
418.000000
449.000000
470.000000
431.000000
452.000000
433.000000
414.000000
465.000000
476.000000
437.000000

428.000000

419.000000

480.000000

ATP1= (Set available secondary frequencies for the radio)

411.000000

472.000000

443.000000

464.000000

415.000000

436.000000

467.000000

478.000000

419.000000

460.000000

421.000000

472.000000

443.000000

464.000000

445.000000

426.000000

427.000000

468.000000

429.000000

440.000000

431.000000

412.000000

433.000000

464.000000

445.000000

436.000000

437.000000

478.000000

429.000000

410.000000

461.000000

452.000000

443.000000

454.000000

465.000000

416.000000

427.000000

418.000000

449.000000

470.000000

431.000000

452.000000

433.000000

414.000000

465.000000

476.000000

437.000000

428.000000

419.000000

480.000000

AT&W (Store active configuration into the non-volatile memory)

ATA (Set the device to online mode)

10.3 Annex 3: commands for ground SDL09

AT&F10 (Factory defaults for a PP master)

ATS108=30 (1 W to transmit power)

ATS104=1000 (Network Address. All radios in a given network must have the same Network Address, but different networks must have different address)

ATS105=1 (Unit address. Every unit in a PP Network must have a unique unit address. Masters must have 1 as address)

ATS102=1 (Serial baud rate for serial port. It must be the same for the connected device: 115200 bps for this case)

ATS113=2 (Maximum number of times that a packet will be retransmitted)

ATS103=2 (RF link rate. All radio within a particular network must be configured with the same one, 276480 bps for this case)

AT&W (Store active configuration into the non-volatile memory)

ATA (Set the device to online mode)

10.4 Annex 4: commands for air SDL09

AT&F11 (Factory defaults for a PP slave)

ATS108=30 (1 W to transmit power)

ATS104=1000 (Network Address. All radios in a given network must have the same Network Address, but different networks must have different address)

ATS105=2 (Unit address. Every unit in a PP Network must have a unique unit address)

ATS102=1 (Serial baud rate for serial port. It must be the same for the connected device: 115200 bps for this case)

ATS113=2 (Maximum number of times that a packet will be retransmitted)

ATS103=2 (RF link rate. All radio within a particular network must be configured with the same one, 276480 bps for this case)

AT&W (Store active configuration into the non-volatile memory)

ATA (Set the device to online mode)

10.5 Annex 5: commands for ground SDL24

AT&F6 (Sets the factory defaults for a PP master)

ATS108=30 (1 W to transmit power)

ATS104=2397 (Network Address. All radios in a given network must have the same Network Address, but different networks must have different address)

ATS105=1 (Unit address, masters must have 1)

ATS102=1 (Serial baud rate for serial port. It must be the same for the connected device: 115200 bps for this case)

ATS113=2 (Maximum number of times that a packet will be retransmitted)

ATS103=2 (RF link rate. All radio within a particular network must be configured with the same one, 276480 bps for this case)

AT&W (Store active configuration into the non-volatile memory)

ATA (Set the device to online mode)

10.6 Annex 6: commands for air SDL24

AT&F7 (Sets the factory defaults for a PP slave)

ATS108=30 (1 W to transmit power)

ATS104=2397 (Network Address. All radios in a given network must have the same Network Address, but different networks must have different address)

ATS105=2 (Unit address. Every unit in a PP Network must have a unique unit address)

ATS102=1 (Serial baud rate for serial port. It must be the same for the connected device: 115200 bps for this case)

ATS113=2 (Maximum number of times that a packet will be retransmitted)

ATS103=2 (RF link rate. All radio within a particular network must be configured with the same one, 276480 bps for this case)

AT&W (Store active configuration into the non-volatile memory)

ATA (Set the device to online mode)