AN4967
Application note

Examples of AT commands on I-CUBE-LRWAN

Introduction

The I-CUBE-LRWAN is a LoRaWAN™ software expansion for STM32Cube. This expansion package consists of a set of libraries and application examples for microcontrollers of the STM32L0 Series, STM32L1 Series and STM32L4 Series acting as end devices.

The I-CUBE-LRWAN main features are:

- Easy add-on of the low-power LoRa® solution
- Extremely low CPU load
- No latency requirements
- Small STM32L0 Series memory footprint

This application note describes the set of AT commands for the B-L072Z-LRWAN1 Discovery board embedding the CMWX1ZZABZ-091 LoRa® module.

This document explains how to interface with the LoRaWAN™ to manage the LoRa® wireless link using AT commands.

For more information on the LoRa® embedded expansion software (I-CUBE-LRWAN) implementation on the STM32Lx Series refer to the user manual *STM32 LoRa™ software expansion for STM32Cube* (UM2073), available at *www.st.com*.

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1 Acronyms

Table 1. List of acronyms

Acronym	Definition
LoRa®	Long range radio technology
LoRaWAN™	LoRa® wide-area network
RF	Radio Frequency
RSSI	Received Signal Strength Indicator
SNR	Signal to Noise ratio
OTAA	Over-the-air activation
ABP	Activation by personalization
ETSI	European Telecommunications Standards Institute

2 Reference documents

1. LoRaWAN™ Specification by LoRa Alliance™ (version V1.0, January 2015, released), available at www.lora-alliance.org
2. *STM32 LoRa™ software expansion for STM32Cube* (UM2073), available at *www.st.com*
3. *Description of STM32L0 HAL and Low-layer drivers* (UM1749), available at *www.st.com*

3 Overview

The B-L072Z-LRWAN1 Discovery board embeds the CMWX1ZZABZ-091 LoRa® firmware.

This firmware Implements the AT_Slave module (see document 2) that supports a set of AT commands to drive the LoRaWAN™ communications and the LoRa® RF test.

The following sections contain the Interface description, the AT Commands definition, the description of some use cases and of the embedded software.

4 AT commands

The AT command set is a standard developed by “Hayes” to control modems. AT stands for attention.

The command set consists of a series of short text strings providing operations such as joining, data exchange and parameters setting.

In a context of LoRa® modem, the Hayes command set is a variation of the standard AT Hayes commands.

The AT commands are used to drive the LoRa® module and to send data (refer to document *1*). The AT commands are sent through the UART.

As described in document *2*, the LoRa® modem can be controlled either through a terminal emulation like Tera Term or PuTTY (see *Figure 1*), or through an embedded AT master module (see *Figure 2*).

Figure 1. Terminal emulation mode

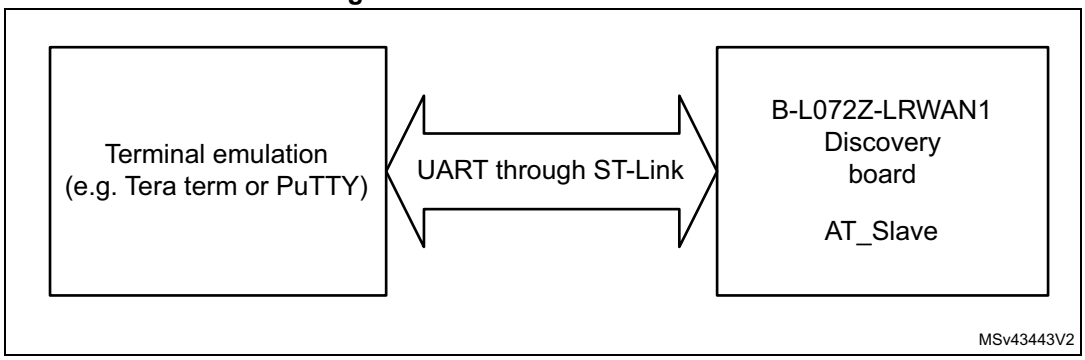
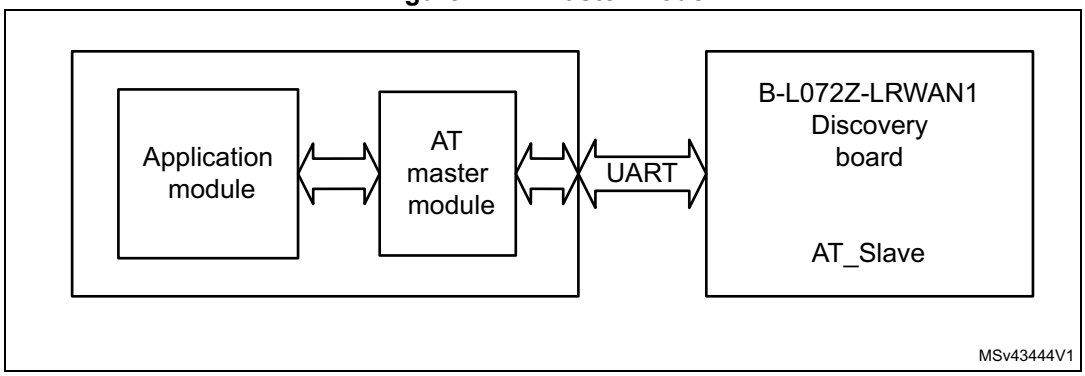


Figure 2. AT master mode



For illustration purposes, the rest of the document is based on the relation “terminal emulation” with the B-L072Z-LRWAN1 Discovery board.

An UART over ST-Link can then be used with standard Windows® software such as Tera Term or PuTTY. The chosen software should be configured with the following parameters:

- Baud rate: 9600
- Data: 8 bit
- Parity: none
- Stop: 1 bit
- Flow control: none

Figure 3 and *Figure 4* show the standard configuration for Tera Term to use the UART over the ST-LINK.

Figure 3. Tera Term port setup example

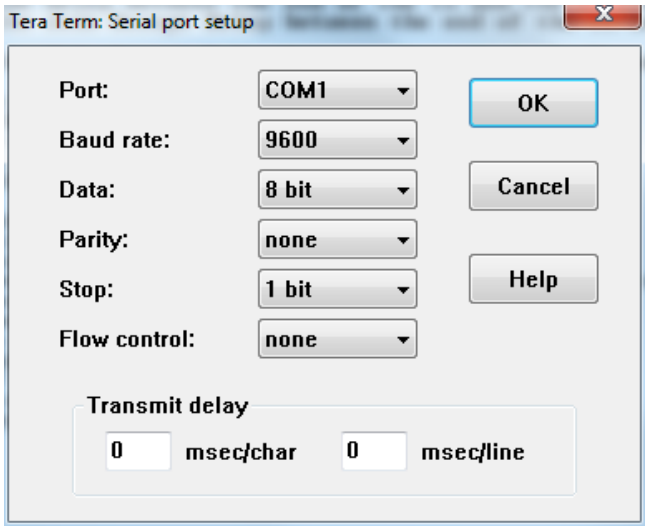
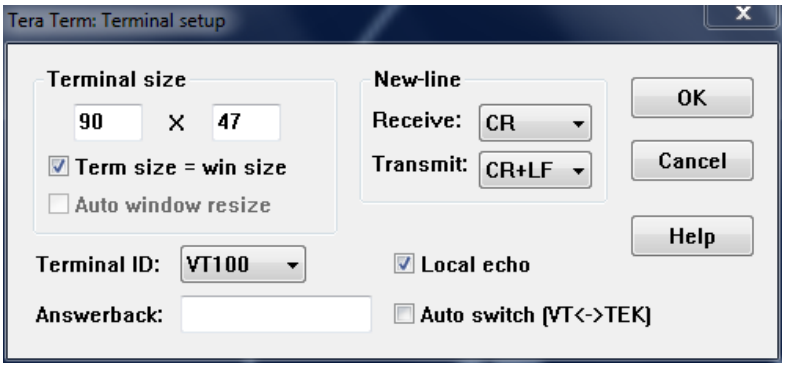


Figure 4. Tera Term terminal setup example



All the AT commands have a standard format as “AT+XXX”, with XXX denoting the command. There are four available command behaviors:

- **AT+XXX?** provides a short help of the given command, for example **AT+DEUI?**
- **AT+XXX** is used to run a command, such as **AT+JOIN**
- **AT+XXX=?** is used to get the value of a given command, for example **AT+CFS=?**
- **AT+XXX=<value>** is used to provide a value to a command, for example **AT+SEND=2:Hello**

The output of the commands is provided on the UART. The output format is as below:

`<value><CR><LF>`

`<CR><LF><Status<CR><LF>`

Note: <CR> stands for “carriage return” and <LF> stands for “line feed”

The <value><CR><LF> output is returned whenever the “help AT+XXX?” or the “get AT+XXX=?” commands are run.

When no value is returned, the <value><CR><LF> output is not returned at all.

Every command (except for ATZ used for MCU reset) returns a status string, which is preceded and followed by <CR><LF> in a .”`<CR><LF><Status<CR><LF>”` format. The possible status are:

- OK: command run correctly without error.
- AT_ERROR: generic error
- AT_PARAM_ERROR: a parameter of the command is wrong
- AT_BUSY_ERROR: the LoRa® network is busy, so the command could not completed
- AT_TEST_PARAM_OVERFLOW: the parameter is too long
- AT_NO_NETWORK_JOINED: the LoRa® network has not been joined yet
- AT_RX_ERROR: error detection during the reception of the command

More details on each command description and examples are described in the next part of this section. Note that each command preceded by # is the one provided by the host to the module. Then the return of the module is printed.

4.1 General commands

This section describes the commands related to “attention” help list, link control and CPU AT_Slave reset.

4.1.1 AT: attention

This command is used to check that the link is working properly (refer to *Table 2* for details).

Table 2. Link check command

Command	Input parameter	Return value	Return code
AT	-	-	OK

4.1.2 AT?: short help

This command provides short help for all the supported commands (refer to *Table 3* for details).

Table 3. Short help command

Command	Input parameter	Return value	Return code
AT?	-	AT+<CMD>?: help on <CMD AT+<CMD>: run <CMD> AT+<CMD>=<value>: set the value AT+<CMD>=?: get the value <followed by the help of all commands>	OK

4.1.3 ATZ: MCU reset

This command is used to trig a CPU reset of the B-L072Z-LRWAN1 Discovery board (refer to *Table 4* for details).

Table 4. MCU reset command

Command	Input parameter	Return value	Return code
ATZ?	-	ATZ: triggers a reset of the MCU	OK
ATZ	-	No return value and return code. The MCU is reset.	Void

4.2 Keys, IDs and EUIs management

This section gives description of the commands related to the activation of the end device.

4.2.1 AT+APPEUI: application identifier

This command allows the user to access the global application identifier (refer to *Table 5* for details).

Table 5. Application identifier command

Command	Input parameter	Return value	Return code
AT+APPEUI?	-	AT+APPEUI: get or set the application EUI	OK
AT+APPEUI=?	-	<8 hexa separated by:>	OK
AT+APPEUI= <Param>	<8 hexa separated by:>	-	OK / AT_PARAM_ERROR(1)
Example AT+APPEUI=	01:2:a:FB:A1:CD:4D:20:01 :02:30:40:5a:6b:7f:88	-	OK
Example AT+APPEUI=	01:2:a:FB:A1:CD:4D:20:01 :02:30:40:5a:6b:7f	-	AT_PARAM_ERROR(1)
Example AT+APPEUI=?	-	01:02:03:04:05:06:07:08	OK

1. AT_PARAM_ERROR is returned when setting a wrong or malformed value.

4.2.2 AT+APPKEY: application key

This command allows the user to access the application session key (refer to *Table 6* for details).

Table 6. Application key command

Command	Input parameter	Return value	Return code
AT+APPKEY?	-	AT+APPKEY: get or set the application key	OK
AT+APPKEY=?	-	<16 hexa separated by:>	OK
AT+APPKEY= <Param>	<16 hexa separated by:>	void	OK / AT_PARAM_ERROR(1)
Example AT+APPKEY=	01:2:a:FB:A1:CD:4D:20:0 1:02:30:40:5a:6b:7f:88	-	OK
Example AT+APPKEY=	01:2:a:FB:A1:CD:4D:20:0 1:02:30:40:5a:6b:7f	-	AT_PARAM_ERROR(1)
Example AT+APPKEY=?	-	2b:7e:15:16:28:ae:d2:a6:ab :f7:15:88:09:cf:4f:3c	OK

1. AT_PARAM_ERROR is returned when setting a wrong or malformed value.

4.2.3 AT+APPSKEY: application session key

This command allows the user to access the application session key (refer to *Table 7* for details).

Table 7. Application session key command

Command	Input parameter	Return value	Return code
AT+APPSKEY?	-	AT+APPSKEY: get or set the application session key	OK
AT+APPSKEY=?	-	<16 hexa separated by:>	OK
AT+APPSKEY=<Param>	<16 hexa separated by:>	void	OK / AT_PARAM_ERROR(1)
Example AT+APPSKEY=	01:2:a:FB:A1:CD:4D:20:01:02:30:40:5a:6b:7f:88	-	OK
Example AT+APPSKEY=	01:2:a:FB:A1:CD:4D:20:01:02:30:40:5a:6b:7f:	-	AT_PARAM_ERROR(1)
Example AT+APPSKEY=?	-	df:bb:02:df:30:eb:7e:07:52:c5:6d:8f:1d:e4:3f:37	OK

1. AT_PARAM_ERROR is returned when setting a wrong or malformed value.

4.2.4 AT+DADDR: device address

This command allows the user to access the device address (refer to *Table 8* for details).

Table 8. Device address command

Command	Input parameter	Return value	Return code
AT+DADDR?	-	AT+DADDR: get or set the device address	OK
AT+DADDR=?	-	<4 hexa separated by:>	OK
AT+DADDR=<Param>	<4 hexa separated by:>	-	OK / AT_PARAM_ERROR(1)
Example AT+DADDR=	01:2:a:FB:A1:CD:4D:20:01:02:30:40:5a:6b:7f:88	-	OK
Example AT+DADDR=?	11:22:33:44	11:22:33:44	OK

1. AT_PARAM_ERROR is returned when setting a wrong or malformed value.

4.2.5 AT+DEUI: device EUI

This command allows the user to access the global end-device ID (refer to *Table 9* for details).

Table 9. Device EUI command

Command	Input parameter	Return value	Return code
AT+DEUI?	-	AT+DEUI: get or set the device EUI	OK
AT+DEUI=?	-	<8 hexa separated by:>	OK
AT+DEUI=<Param>	<8 hexa separated by:>	-	OK / AT_PARAM_ERROR(1)
Example AT+DEUI=?	-	11:22:33:44:55:66:77:88	OK
Example AT+DEUI=	11:22:33:44:55:66:77:88	-	OK

1. AT_PARAM_ERROR is returned when setting a wrong or malformed value.

4.2.6 AT+NWKID: network ID

This command allows the user to access the network identifier (refer to *Table 10* for details).

Table 10. Network ID command

Command	Input parameter	Return value	Return code
AT+NWKID?	-	AT+NWKID: get or set the network ID	OK
AT+NWKID=?	-	<4 hexa separated by:>	OK
AT+DEUI=<Param>	<4 hexa separated by:>	-	OK / AT_PARAM_ERROR(1)
Example AT+DEUI=?	-	11:22:33:44:55:66:77:88	OK
Example AT+DEUI=	11:22:33:44:55:66:77:88	-	OK

1. AT_PARAM_ERROR is returned when setting a wrong or malformed value.

4.2.7 AT+NWKSKEY: network session key

This command allows the user to access the network session key (refer to *Table 11* for details).

Table 11. Network session key command

Command	Input parameter	Return value	Return code
AT+NWKSKEY?	-	AT+NWKSKEY: get or set the network session key	OK
AT+NWKSKEY=?	-	<16 hexa separated by:>	OK
AT+NWKSKEY=<Param>	<16 hexa separated by:>	-	OK / AT_PARAM_ERROR(1)
Example AT+NWKSKEY=	0:1:2:3:4:5:6:7:8:9:A:B:C:D:E:F	-	OK
Example AT+NWKSKEY=?	-	00:01:02:03:04:05:06:07:08:09:A:0B:0C:0D:0E:0F	OK

1. AT_PARAM_ERROR is returned when setting a wrong or malformed value.

4.3 Joining and sending data on LoRa® network

This section gives description of the commands related to the join procedure and to the data path.

4.3.1 AT+CFM: confirm mode

This command allows the user to access to the notification on received data coming from network (refer to *Table 12* for details).

Table 12. Confirm mode command

Command	Input parameter or Parmeter	Return value	Return code
AT+CFM?	-	AT+CFM: get or set the confirm mode (0-1)	OK
AT+CFM=?	-	0 or 1	OK
AT+CFM=<Param>	0 or 1	-	OK / AT_PARAM_ERROR(1)
Example AT+CFM=	1	-	OK
Example AT+CFM=?(2)	-	1	OK

1. AT_PARAM_ERROR is returned when setting a wrong or malformed value.
2. When the confirmation mode is 1, each sent message must be confirmed. AT+CFS=? allows to know whether the last sent message has been confirmed or not.

4.3.2 AT+CFS: confirm status

This command allows the user to access to the status of the last “SEND” command (refer to *Table 13* for details).

Table 13. Confirm status command

Command	Input parameter	Return value	Return code
AT+CFS?	-	AT+CFS: get the confirmation status of the last AT+SEND (0-1)	OK
AT+CFS=?	-	0 or 1	OK
Example AT+CFS=?	-	0	OK

4.3.3 AT+JOIN: join LoRa® network

This command does a join request to the network (refer to *Table 14* for details).

Table 14. Join LoRa® network command

Command	Input parameter	Return value	Return code
AT+JOIN?	-	AT+JOIN: join network	OK
AT+JOIN	Void	Void	OK/ AT_BUSY_ERROR(1)
Example AT+JOIN	-	-	OK

1. AT_BUSY_ERROR is returned when a joining process is already running.

This is an asynchronous command. OK means that the join is being run. The completion of the JOIN must be verified with AT+NJS=?.

4.3.4 AT+NJM: LoRa® network join mode

This command allows the user to access to the network join mode (refer to *Table 15* for details).

Table 15. LoRa® network join mode command

Command	Input parameter	Return value	Return code
AT+NJM?	-	AT+NJM: get or set the network join mode (0: ABP, 1: OTAA)	OK
AT+NJM	-		OK/
AT+NJM=<Input>	0 or 1	-	OK/ AT_PARAM_ERROR(1)
Example AT+NJM=?	-	0	OK

Table 15. LoRa® network join mode command (continued)

Command	Input parameter	Return value	Return code
Example AT+NJM=	1	-	OK
Example AT+NJM=	2	-	AT_PARAM_ERROR

1. AT_PARAM_ERROR is returned when setting a wrong or malformed value.

Note that AT+JOIN is required even in the case of an activation by personalization (for more details refer to document 1 of *Section 2: Reference documents*).

4.3.5 AT+NJS: LoRa® network join status

This command allows the user to access to the current status of the LoRa® link (refer to *Table 16* for details).

Table 16. LoRa® network join status command

Command	Input parameter	Return value	Return code
AT+NJS?	-	AT+NJS: get the join status	OK
AT+NJS=?	-	0 or 1	OK
Example AT+NJS=?	-	0 (network not joined)	OK
Example AT+NJS=?	-	1 (network joined)	OK

4.3.6 AT+RECV: last received text data

This command allows the user to access to the last received text data in raw format (refer to *Table 17* for details).

Table 17. Last received text data command

Command	Input parameter	Return value	Return code
AT+RECV?	-	AT+RECV: print the last received data in raw format	OK
AT+RECV=?	-	raw (string format)	OK
Example AT+RECV=?	-	45: hello world	OK

This command returns the last received data in a text form, along with the port on which it was received. The format of the output is:

```
<port>:<text data><CR><LF>
<CR><LF>OK<CR><LF>
```

When called twice, without new data received between the calls, the second AT+RECV=? returns an empty value as shown below:

```
45:<CR><LF>
<CR><LF>OK<CR><LF>
```

4.3.7 AT+RECVB: last received binary data

This command allows the user to access to the last received text data in binary format (refer to *Table 18* for details). In *Table 18* the binary data is received on the port 45.

Table 18. Last received binary data command

Command	Input parameter	Return value	Return code
AT+RECVB?	-	AT+RECVB: print the last received data in binary format (with hexadecimal values)	OK
AT+RECVB=?	-	<port>:<binary>,	OK
Example AT+RECVB=?	-	45:48656c6c6f20576f726c64	OK

4.3.8 AT+SEND: send text data

This command provides the way to send text data on a dedicated port number (refer to *Table 19* for details). In *Table 19* the text data is received on the port 12.

Table 19. Send text data command

Command	Input parameter	Return value	Return code
AT+SEND?	-	AT+SEND: send text data along with the application port	OK
AT+SEND=<input>	port text	-	OK/ AT_PARAM_ERROR(1)/ AT_BUSY_ERROR(2)/ AT_NO_NETWORK_JOINED(3)
Example AT+SEND=	12: hello world	-	OK

1. AT_PARAM_ERROR is returned when the setting does not have the correct format <port>:<text>, with <port> being a decimal value.
2. AT_BUSY_ERROR is returned when the previous send is not complete (send waiting for duty cycle, rx window not consumed…).
3. AT_NO_NETWORK_JOINED is returned when the network is not yet joined.

4.3.9 AT+SENB: send binary data

This command provides the way to send text data in binary format on a dedicated port number (refer to *Table 20* for details).

Each byte of the binary data is provided as two characters denoting the value in hexadecimal. Hence, the length of the binary data is always even.

In the example of *Table 20*, 8 bytes are sent on port 12: 0xab, 0xcd, 0xef, 0x0 (note that the example passes “01”, passing only “1” would fail), 0x23, 0x45, 0x67 and 0x89.

Table 20. send binary data command

Command	Input parameter	Return value	Return code
AT+SENDB?	-	AT+SENDB: send hexadecimal data along with the application port	OK
AT+SENDB=<input>	<port>:<binary>,	-	OK/ AT_PARAM_ERROR(1)/ AT_BUSY_ERROR(2)/ AT_NO_NETWORK_JOINED(3)
Example AT+SENDB=	12:abcdef0123456789	-	OK
Example AT+SENDB=	abcdef0123456789	-	AT_PARAM_ERROR

1. AT_PARAM_ERROR is returned when the setting has not the correct format <port>:<binary>, with <port> being a decimal value, and <binary> following hexadecimal format using 2 characters described above.
2. AT_BUSY_ERROR is returned when the previous send is not complete (send waiting for duty cycle, rx window not consumed…).
3. AT_NO_NETWORK_JOINED is returned when the network is not joined yet.

4.4 LoRa® network management

This section provides a set of commands for network management.

4.4.1 AT+ADR: adaptive rate

This command allows the user to access to the adaptive data rate (refer to *Table 21* for details). The default value of the ADR is 1 (enabled).

Table 21. Adaptive rate command

Command	Input parameter	Return value	Return code
AT+ADR?	-	AT+ADR: get or set the adaptive data rate setting (0: off, 1: on)	OK
AT+ADR=?	-	0 or 1	OK
AT+ADR=<Input>	0 or 1	-	OK/ AT_PARAM_ERROR(1)
Example AT+ADR=	0	-	OK
Example AT+ADR=?	-	0	OK

1. AT_PARAM_ERROR is returned when setting a wrong or malformed value.

4.4.2 AT+CLASS: LoRa® class

This command allows the user to access to the LoRaWAN™ class (refer to *Table 22* for details).

Table 22. LoRa® class command

Command	Input parameter	Return value(1)	Return code
AT+CLASS?	-	AT+CLASS: get or set the device class	OK
AT+CLASS=?	-	A, B, or C	OK
AT+CLASS=<Input>	A, B or C	-	OK/ AT_PARAM_ERROR(2)
Example AT+CLASS=?	-	A	-

1. Only class A is supported with this release version.
2. AT_PARAM_ERROR is returned when setting a wrong or malformed value.

4.4.3 AT+DCS: duty cycle settings

This command allows the user to access to the duty cycle parameter (refer to *Table 23* for details).

Table 23. Duty cycle settings command

Command	Input parameter	Return value	Return code
AT+DCS?	-	AT+DCS: get or set the ETSI duty cycle setting: 0=disable, 1=enable - only for testing (refer to document 2)	OK
AT+DCS?	-	0 or 1	OK
AT+DCS=<Input>	0 or 1	-	OK/ AT_PARAM_ERROR(1)
Example AT+DCS?	-	1	OK
Example AT+DCS=	1	-	OK

1. AT_PARAM_ERROR is returned when setting a wrong or malformed value.

4.4.4 AT+DR: data rate

This command allows the user to access to the data rate (refer to *Table 24* for details).

Table 24. Data rate command

Command	Input parameter	Return value	Return code
AT+DR?	-	AT+DR: get or set the data rate (0-7 corresponding to DR_X)<	OK
AT+DR=?	-	[0,1,2,3,4,5,6,7]	OK
AT+DR=<Input>	[0,1,2,3,4,5,6,7]	-	OK/ AT_PARAM_ERROR(1)
Example AT+DR=?	-	3	OK
Example AT+DR=	2	-	OK

1. AT_PARAM_ERROR is returned when setting a wrong or malformed value.

4.4.5 AT+FCD: frame counter downlink

This command allows the user to access to the frame counter downlink (refer to *Table 25* for details).

Table 25. Frame counter downlink command

Command	Input parameter	Return value	Return code
AT+FCD?	-	AT+FCD: get or set the downlink frame counter	OK
AT+FCD=?	-	<integer>	OK
AT+FCD=<input>	<integer>	-	OK/ AT_PARAM_ERROR(1)
Example AT+FCD=?	-	4294967295	OK
Example AT+FCD=<input>	10	-	OK

1. AT_PARAM_ERROR is returned when setting a wrong or malformed value.

4.4.6 AT+FCU: frame counter uplink

This command allows the user to access to the frame counter uplink (refer to *Table 26* for details).

Table 26. Frame counter uplink command

Command	Input parameter	Return value	Return code
AT+FCU?	-	AT+FCU: get or set the uplink frame counter	OK
AT+FCU=?	-	<integer>	OK
AT+FCU=<input>	<integer>	-	OK/ AT_PARAM_ERROR(1)
Example AT+FCU=?	-	4294967295	OK
Example AT+FCU=<input>	10	-	OK

1. AT_PARAM_ERROR is returned when setting a wrong or malformed value.

4.4.7 AT+JN1DL: join delay on RX window 1

This command allows the user to access to the join delay on RX window 1 (refer to *Table 27* for details).

Table 27. Join delay on RX window 1 command

Command	Input parameter	Return value	Return code
AT+JN1DL?	-	AT+JN1Dl: get or set the joint accept delay between the end of the Tx and the join Rx window 1 in ms	OK
AT+JN1DL=?	-	<integer>	OK/ AT_BUSY_ERROR(1)
AT+JN1DL=<input>	<integer>	-	OK/ AT_PARAM_ERROR(2) AT_BUSY_ERROR(1)
Example AT+JN1DL=?	-	5000	OK
Example AT+JN1DL=	10000	-	OK

1. AT_BUSY_ERROR is returned when a join or a send is being processed.
2. AT_PARAM_ERROR is returned when setting a wrong or malformed value.

4.4.8 AT+JN2DL: join delay on RX window 2

This command allows the user to access to the join delay on RX window 2 (refer to *Table 28* for details).

Table 28. Join delay on RX window 2 command

Command	Input parameter	Return value	Return code
AT+JN2DL?	-	AT+JN2DL: get or set the joint accept delay between the end of the Tx and the join Rx window 2 in ms	OK
AT+JN2DL=?	-	<integer>	OK/ AT_BUSY_ERROR(1)
AT+JN2DL=<input>	<integer>	-	OK/ AT_PARAM_ERROR(2) AT_BUSY_ERROR(1)
Example AT+JN2DL=?	-	6000	OK
Example AT+JN2DL=	20000	-	OK

1. AT_BUSY_ERROR is returned when a join or a send is being processed.
2. AT_PARAM_ERROR is returned when setting a wrong or malformed value.

4.4.9 AT+PNM: public network mode

This command allows the user to access to the public network mode (refer to *Table 29* for details).

Table 29. Public network mode command

Command	Input parameter	Return value	Return code
AT+PNM?	-	AT+PNM: get or set the public network mode (0:off, 1:on).	OK
AT+PNM=?	-	0 or 1	OK
AT+PNM=<input>	0 or 1	-	OK/ AT_PARAM_ERROR(1)
Example AT+PNM=?	-	0	OK
Example AT+PNM=	1	-	OK
Example AT+PNM=	2	-	AT_PARAM_ERROR(1)

1. AT_PARAM_ERROR is returned when setting a wrong or malformed value.

4.4.10 AT+RX1DL: delay of the received window 1

This command allows the user to access to the delay of the received window 1 (refer to *Table 30* for details).

Table 30. Delay of the received window 1 command

Command	Input parameter	Return value	Return code
AT+RX1DL?	-	AT+RX1DL: get or set the delay between the end of the Tx and the Rx window 1 in ms	OK
AT+RX1DL=?	-	<integer>	OK/ AT_BUSY_ERROR(1)
AT+RX1DL=<input>	<integer>	-	OK/ AT_PARAM_ERROR(2) AT_BUSY_ERROR(1)
Example AT+RX1DL=?	-	1000	OK
Example AT+RX1DL=	1500	-	OK

1. AT_BUSY_ERROR is returned when a join or a send is being processed.
2. AT_PARAM_ERROR is returned when setting a wrong or malformed value.

4.4.11 AT+RX2DL: delay of the received window 2

This command allows the user to access to the delay of the received window 2 (refer to *Table 31* for details).

Table 31. Delay of the received window 2 command

Command	Input parameter	Return value	Return code
AT+RX2DL?	-	AT+RX2DL: get or set the delay between the end of the Tx and the Rx window 2 in ms	OK
AT+RX2DL=?	-	<integer>	OK/ AT_BUSY_ERROR(1)
AT+RX2DL=<input>	<integer>	-	OK/ AT_PARAM_ERROR(2) AT_BUSY_ERROR(1)
Example AT+RX2DL=?	-	2000	OK
Example AT+RX2DL=	2500	-	OK

1. AT_BUSY_ERROR is returned when a join or a send is being processed.
2. AT_PARAM_ERROR is returned when setting a wrong or malformed value.

4.4.12 AT+RX2DR: data rate of the received window 2

This command allows the user to access to the data rate of received window 2 (refer to *Table 32* for details).

Table 32. Data rate of the received window 2 command

Command	Input parameter	Return value	Return code
AT+RX2DR?	-	AT+RX2DR: get or set the Rx2 window data rate (0-7) corresponding to DR_X	OK
AT+RX2DR=?	-	[0,1,2,3,4,5,6,7]	OK/ AT_BUSY_ERROR(1)
AT+RX2DR=<input>	[0,1,2,3,4,5,6,7]	-	OK/ AT_PARAM_ERROR(1) AT_BUSY_ERROR(2)
Example AT+RX2DR=?	-	6	OK
Example AT+RX2DR=	5	-	OK

1. AT_BUSY_ERROR is returned when a join or a send is being processed.
2. AT_PARAM_ERROR is returned when setting a wrong or malformed value.

4.4.13 AT+RX2FQ: frequency of the received window 2

This command allows the user to access to the frequency of the received window 2 (refer to *Table 33* for details).

Table 33. Frequency of the received window 2 command

Command	Input parameter	Return value	Return code
AT+RX2FQ?	-	AT+RX2FQ: get or set the Rx2 window frequency	OK
AT+RX2FQ=?	-	Frequency in Hz	OK/ AT_BUSY_ERROR(1)
AT+RX2FQ=869535000	Frequency in Hz	-	OK/ AT_PARAM_ERROR(2) AT_BUSY_ERROR(1)
Example AT+RX2FQ=?	-	869535000	OK
Example AT+RX2FQ=	869535000	-	OK

1. AT_BUSY_ERROR is returned when a join or a send is being processed.
2. AT_PARAM_ERROR is returned when setting a wrong or malformed value.

4.4.14 AT+TXP: transmit power

This command allows the user to access to the transmit power (refer to *Table 34* for details).

Table 34. Transmit power command

Command	Input parameter	Return value	Return code
AT+TXP?	-	AT+TXP: get or set the transmit power (0-5)	OK
AT+TXP=?	-	[0,1,2,3,4,5]	OK AT_PARAM_ERROR(1)
AT+TXP=<input>	[0,1,2,3,4,5]	-	OK AT_PARAM_ERROR(1)
Example AT+TXP=?	-	1	OK
Example AT+TXP=	4	-	OK

1. AT_PARAM_ERROR is returned when setting a wrong or malformed value.

4.5 Information

This section provides a set of commands for battery level, RF signal quality and FW version.

4.5.1 AT+BAT: battery level

This command allows the user to access to the battery level of the end-device (refer to *Table 35* for details).

Table 35. Battery level command

Command	Input parameter	Return value(1)	Return code
AT+BAT?	-	AT+BAT: get the battery level	OK
AT+BAT=?	-	[1, ...254]	OK
Example AT+BAT=?	-	254	OK

1. Battery level is from 1 to 254, 254 meaning it is fully charged.

4.5.2 AT+RSSI: RSSI on reception

This command allows the user to access to the RSSI on reception (refer to *Table 36* for details).

Table 36. RSSI on reception command

Command[1]	Input parameter	Return value	Return code
AT+RSSI?	-	AT+RSSI: get the RSSI of the last received packet	OK
AT+RSSI=?	-	integer	OK
Example AT+RSSI=?	-	-31	OK

1. At+RSSI=? provides a value in dBm.

4.5.3 AT+SNR: signal noise ratio

This command allows the user to access to the SNR of the last received packet (refer to *Table 37* for details).

Table 37. Signal noise ratio command

Command[1]	Input parameter	Return value	Return code
AT+SNR?	-	AT+SNR: get the SNR of the last received packet	OK
AT+SNR=?	-	integer	OK
Example AT+SNR=?	-	32	OK

1. At+SNR=? provides a value in dBm.

4.5.4 AT+VER: version of the firmware

This command allows the user to access to the version of the B-L072Z-LRWAN1 Discovery board firmware (refer to *Table 38* for details).

Table 38. Version of the firmware command

Command	Input parameter	Return value	Return code
AT+VER?	-	AT+VER: get the version of the AT_iSlave FW	OK
AT+VER=?	-	V.x.y	OK
Example AT+VER=?	-	1.0.0	OK

4.6 RF tests

This section provides a set of commands for the RF test management.

4.6.1 AT+TRSSI: Start Radio Frequency RSSI Tone test

This command allows the user to start the RF RSSI tone test (refer to *Table 39* for details).

Table 39. Start Radio Frequency RSSI Tone command

Command	Input parameter	Return value	Return code
AT+TRSSI?	-	AT+TRSSI: start RF RSSI tone test	OK
AT+TRSSI	Void	Void	OK AT_BUSY_ERROR
Example AT+TRSSI	-	-	OK

4.6.2 AT+TTONE: Start Radio Frequency Tone test

This command allows the user to start the RF tone test (refer to *Table 40* for details).

Table 40. Start Radio Frequency Tone test command

Command	Input parameter	Return value	Return code
AT+TTONE?	-	AT+TTONE: start RF tone test	OK
AT+TTONEI	Void	Void	OK AT_BUSY_ERROR
Example AT+TTONE	-	-	OK

4.6.3 AT+TTLRA: Start RF Tx LoRa® test

This command allows the user to start the RF Tx LoRa® test (refer to *Table 41* for details).

Table 41. Start RF Tx LoRa® test command

Command	Input parameter	Return value	Return code
AT+TTLRA?	-	AT+TTLRA: starts Tx LoRa® test	OK
AT+TTLRA	Void	Void	OK AT_BUSY_ERROR
Example AT+TTLRA	-	-	OK

4.6.4 AT+TRLRA: Start RF Rx LORA test

This command allows the user to start the RF Rx LoRa® test (refer to *Table 42* for details).

Table 42. Start RF Rx LoRa® test command

Command	Input parameter	Return value	Return code
AT+TRLRA?	-	AT+TRLRA: starts Rx LoRa® test	OK
AT+TRLRA	Void	Void	OK AT_BUSY_ERROR
Example AT+TRLRA	-	-	OK

4.6.5 AT+TCONF: Config LoRa® RF test

This command allows the user to access the LoRa® configuration test (refer to *Table 43* for details).

Table 43. Config LoRa® RF test command

Command	Input parameter	Return value	Return code
AT+TCONF?	-	AT+TCONF: configure LoRa® RF test	OK
AT+TCONF=?	Void	Void	OK AT_ERROR
AT+TCONF=<param>	Void	Void	OK AT_PARAM_ERROR
Example AT+TCONF?	-	Freq = 868 MHz Power = 14 dbm Bandwidth = 125 KHz SF = 12 CR = 4 / 8 LNA State = 0 PA boost state = 0	OK
Example AT+TCONF=	868:12:125:12:4 /8:0:0	-	OK
Example AT+TCONF=	868:12:**300**:12:4 /8:0:0	-	AT_PARAM_ERROR (error on bandwidth setting)

AT_PARAM_ERROR is returned when the setting does not have either the correct format (being a decimal value), or being outside the required set:

- Bandwidth = {125, 250, 500};
- SF = {7, 8, 9, 10, 11, 12};
- CR = {4/5, 4/6, 4/7, 4/8}.

4.6.6 AT+TOFF: Stop ongoing Radio Frequency test

This command allows the user to stop the ongoing RF test (refer to *Table 44* for details).

Table 44. Stop Radio Frequency test command

Command	Input parameter	Return value	Return code
AT+TOFF?	-	AT+TOFF: stop ongoing RF test	OK
AT+TOFF	Void	Void	OK

4.6.7 AT+CERTIF: Set the module in LoRaWAN™ Certification Mode

This command allows the user to start the RF Rx LoRa test (refer to *Table 45* for details).

Table 45. Set the module in LoRaWAN™ Certification Mode command

Command	Input parameter	Return value	Return code
AT+CERTIF?	-	AT+CERTIF: set the module in LoraWAN™ Certification Mode	OK
AT+CERTIF	Void	Void	OK AT_BUSY_ERROR

AT+CERTIF will put the timer to handler data transmission equal to 5 s.

5 Examples

This section provides some examples of join and send, receiving and confirmation of data.

5.1 Join and send

This example shows the complete join procedure and the way to send data on the LoRa® link.

```
# AT
<CR><LF>OK<CR><LF>
# AT+JOIN
<CR><LF>OK<CR><LF>
# AT+NJS=?
0<CR><LF>/* Network is not joined yet */
<CR><LF>OK<CR><LF>
/* wait for few seconds to wait for join to complete */
# AT+NJS=?
1<CR><LF>/* Network is now joined */
<CR><LF>OK<CR><LF>
/* now the network is joined, data can be sent */
# AT+SEND=50:Hello World/* Send text to port 50 */
<CR><LF>OK<CR><LF>
# AT+SENDB=60:0123 /* Send data (2 bytes: 0x01 and 0x23) on port 60 */
<CR><LF>OK<CR><LF>
/* Note that the result could be AT_BUSY_ERROR in case the previous send is
not completed, because of the duty cycle restriction, or because RX windows
are not completed */
```

5.2 Confirmation

This example shows how to transmit data on the LoRa® link. This example assumes that the network is already joined.

```
# AT+NJS=?
1<CR><LF>/* Network is already joined */
<CR><LF>OK<CR><LF>
# AT+CFM=?
0<CR><LF>/* Unconfirmed data */
<CR><LF>OK<CR><LF>
# AT+CFM=1
<CR><LF>OK<CR><LF>
# AT+CFM=?
0<CR><LF>/* Confirmed data */
<CR><LF>OK<CR><LF>
# AT+SEND=50:Hello World/* Send text to port 50 */
```

```
<CR><LF>OK<CR><LF>
# AT+CFS=?
0<CR><LF>/* Message is not confirmed yet */
<CR><LF>OK<CR><LF>
/* wait for few seconds to wait for the confirmation */
# AT+CFS=?
# AT+NJS=?
1<CR><LF>/* Network is already joined */
<CR><LF>OK<CR><LF>
# AT+CFM=?
0<CR><LF>/* Unconfirmed data */
<CR><LF>OK<CR><LF>
# AT+CFM=1
<CR><LF>OK<CR><LF>
# AT+CFM=?
0<CR><LF>/* Confirmed data */
<CR><LF>OK<CR><LF>
# AT+SEND=50:Hello World/* Send text to port 50 */
<CR><LF>OK<CR><LF>
# AT+CFS=?
0<CR><LF>/* Message is not confirmed yet */
<CR><LF>OK<CR><LF>
/* wait for few seconds to wait for the confirmation */
# AT+CFS=?
```

5.3 Receiving data

This example shows how to receive data on the LoRa® link, with the assumption that the network is already joined.

```
# AT+NJS=?
1<CR><LF>/* Network is already joined */
<CR><LF>OK<CR><LF>
# AT+RECV=?
0:<CR><LF>/* Nothing has been received */
<CR><LF>OK<CR><LF>
/* Server is sending Binary Data 0x01 0xA0 0x23 on port 20
   Need to send data to receive the one from the server */
# AT+SENDB=2:ab
<CR><LF>OK<CR><LF>
# AT+RECVB=?
0:<CR><LF>/* Nothing has been received yet */
<CR><LF>OK<CR><LF>
/* wait the received windows to complete */
# AT+RECVB=?
20:01a023<CR><LF> /* Message is now received */
<CR><LF>OK<CR><LF>
# AT+RECVB=?
20:<CR><LF>/* No new message received */
<CR><LF>OK<CR><LF>
```

6 Embedded software description

This section gives an overview of the firmware architecture of the B-L072Z-LRWAN1 Discovery board. To see the complete description of the LoRa® embedded expansion software implementation I-CUBE-LRWAN refer to document *2*.

6.1 Firmware overview

This overview refers to the software expansion for STM32Cube (see document *2*) and not to the specific implementation of the LoRa® technology. For more details on how to proceed with the specific LoRa® technology case refer to document *2*).

The AT command processing is found in the source files listed below:

- command.c: contains the definition and handlers of all the commands
- at.c: contains AT driver functions (basic action to provide what to whom)

6.2 Low layer driver

In order to reduce the size of the code, the HAL is not used in this project. Instead, the LL (low layer) drivers are used (refer to document *3* for more details). The LL drivers are designed to offer a fast light-weight and expert-oriented layer closer to the hardware than the HAL.

The LL drivers provide hardware services based on the available features of the STM32 peripherals. These services reflect exactly the hardware capabilities and provide one-shot operations that must be called following the programming model described in the specific microcontroller reference manual.

By using the LL drivers, the code is smaller than if the HAL was used. The drawback is that the code it is now more specific in below terms of supported MCUs and in terms of functionalities.

In terms of supported MCU, as the LL drivers fit on the MCU series, only the STM32L0 Series based MCU would be supported using LL in this implementation. In practical terms, as the example developed in this application note is using the STM32L0 Series devices, the proposed code is valid only for the products inside this series, and a different code must be developed for any application in a device other than the STM32L0 Series.

A specific example on the functionalities restrictions is the initialization of the GPIOs. In this case, if the user is using the HAL, the HAL_GPIO_Init() function is used. This function is able to initialize all the GPIOs for all the defined modes. However, in AT_Slave demonstrator, the used modes are only: GPIO_MODE_ANALOG, GPIO_MODE_INPUT, GPIO_MODE_IT_RISING, GPIO_MODE_OUTPUT_PP and GPIO_MODE_AF_PP. As per the AT_Slave demonstrator specificity, it is useless (and so it saves code size) to implement the GPIO mode in events, in falling IT and in open drain mode.

For more detailed information on the low layer driver, refer to document *3*.

6.3 LPUART

The AT commands are sent through an UART carrier. In order to optimize the low power, the LPUART of the B-L072Z-LRWAN1 Discovery board is used.

The AT_slave module executes two different tasks:

- LoRa® tasks: it manages the received windows, and it sends data
- Receives commands from the master that schedules LoRa® tasks, and then send back the requested value and the status of the command.

As the AT_slave is already executing the two tasks described above, the MCU is idle most of the time. The MCU remains waiting either for a command from the master or for a LoRa® task schedule.

So it is important to be in Stop Mode in order to optimize the low-level power of the MCU. As commands are received through the UART, the low power UART (LPUART) is being used, hence the communication transfer rate is limited to 9600 bauds.

The LPUART is initialized to be enabled in Stop Mode, and the wake up from Stop Mode is performed on a Start bit detection. The LPUART handler (vcom_IRQHandler()) enables RXNE (RX not empty) IT, so that when RXNE IT is raised, the character is read and stored in an internal circular buffer.

The buffer of read characters is then processed in the normal thread (not in the IT thread). A command is recognized when the new character received is <CR> or <LF>.

6.4 Compilation switches

This section lists the compilation switches provided to the user to control the compilation process.

Table 46 provides a summary of the main options for the application configuration.

Table 46. Compilation switch options

Switch option		Definition	Location
Bands	USE_BAND_868	Enable the EU band selection	Compiler option setting
	USE_BAND_433		
	USE_BAND_915		
Debug	DEBUG	Enable “Led on/off”	hw_conf.h
	TRACE	Enable “printf”	
Command	NO_HELP	Disable the short help on AT commands when using AT+<CMD>?	command.c

Note: When "printf" are enabled, the resulting commands may be interlaced with debug printf().

6.4.1 Debug switches

In \Projects\Multi\Applications\LoRa\AT_Slave\inc\hw_conf.h, the user can enable the debug mode and /or the trace mode by commenting out #define DEBUG/ #define TRACE.

The debug mode enables the DBG_GPIO_SET and DBG_GPIO_RST macros. This mode also enables the debugger mode even when the MCU goes in low power.

The trace mode enables the DBG_PRINTF macro.

Note: To do a true low power both the #define DEBUG and the #define TRACE must be commented out.

6.5 Footprint

The values in *Table 47* have been measured for the following configuration

- Compiler: Keil®
  - Optimization: optimized for size level 3
  - Debug option: off
  - Trace option: off

Table 47. AT_slave footprint

-	Flash memory (bytes)	RAM (bytes)	Description
AT_Slave	6324	395	LoRa® finite state machine (Lora.c)
LoRa® stack	30124	4389	LoRa® stack
Total	36448	4784	Total memory

7 Revision history

Table 48. Document revision history

Date	Revision	Changes
10-Jan-2017	1	Initial release.
25-Aug-2017	2	Updated document title and *Section 3: Overview*. Added *Section 4.6: RF tests* and its subsections. Updated *Figure 1: Terminal emulation mode*. Updated *Table 1: List of acronyms*. Minor text edits across the whole document.