PS01709

LoRaWAN Class A/B/C AT Command Specification

V1.2

Document information

Info	Content
Keywords	*LoRaWAN, AT Command, UART, USB, Class A/B/C*
Abstract	This document defines AT command format used by RisingHF LoRaWAN module

WARNING:

This document is only for AT modem of which version is higher than 3.1.0 (LoRaWAN A/B/C), for other version devices please refer to PS01509

Content

Tables

1 Introduction

RisingHF™ LoRaWAN™ modem is LoRaWAN compatible device, which supports flexible LoRaWAN communication. This document is intended to describe a command interface implementation of LoRaWAN Class A/B/C protocol. LoRaWAN protocol is available from LoRa Alliance, it is recommended to review LoRaWAN specification before using LoRaWAN modem.

1.1 Feature

- LoRaWAN R1.0.2B band plan:
  - EU868 US915 US915HYBRID CN779 EU433 AU915 AU915OLD CN470 AS923 KR920 IN865
- User defined band plan:
  - CN470PREQUEL STE920
- LoRaWAN Class A/B/C
- All LoRaWAN 1.0.2B Class A/B/C MAC command:
  - LinkCheckReq / LinkCheckAns
  - LinkADRReq / LinkADRAns
  - DutyCycleReq / DutyCycleAns
  - RXParamSetupReq / RXParamSetupAns
  - DevStatusReq / DevStatusAns
  - NewChannelReq / NewChannelAns
  - RXTimingSetupReq / RXTimingSetupAns
  - TxParamSetupReq / TxParamSetupAns
  - DlChannelReq / DlChannelAns
  - DeviceTimeReq / DeviceTimeAns
  - PingSlotInfoReq / PingSlotInfoAns
  - PingSlotChannelReq / PingSlotChannelAns
  - BeaconTimingReq / BeaconTimingAns
  - BeaconFreqReq / BeaconFreqAns
- LoRaWAN dynamic select Port Zero / FOpts to send uplink MAC command
- Flexible RXWIN2 configuration interface
- Configurable RXWIN1 channel frequency
- Possibility to enable full-duplex LoRaWAN system
- Maximum configurable 96 channels
- Maximum 255 bytes RF frame
- User configuration nonvolatile
- Numerous test commands (LoRa P2P, Class C downlink, Continuous Wave etc.)
- Flexible hexadecimal string parser
- Ultra-low power (1.4uA@3.3V 1.9uA@3.3 watchdog on)[1], intelligent auto low power mode
- Case insensitive commands
- 256 bytes EEPROM to save user data
- RTC time and supply voltage measurement

[1] UART interface modem only

- Power supply measurement
- AT+LOG to speed up development debugging
- Intelligent LoRaWAN beacon time auto correction
- Multicast for Class B and Class C mode
- Configurable leap seconds through AT command

1.2 Related Products

Part Number	Bootloader	Interface
RHF76-052DM	UART	UART
RHF76-052CL	UART	UART
RHF3M076B	USB	USB
RHF0M003-LF20	UART	UART
RHF0M003-HF20	UART	UART
RHF0M010-LF20	UART	UART
RHF0M010-HF20	UART	UART
RHF0M062-LF22	UART	UART
RHF0M062-HF22	UART	UART

Table 1-1 Related products list

2 Preface

2.1 Conventions

- Command is case insensitive;
- All commands have response;
- Command length never exceeds total 528 characters;
- One valid AT Command must end with '\n', "\r\n" is also valid;
- If command timeout feature is enabled, end '\n' will not be mandatory;
- <LF> means the newline character. <CR> means carriage return;
- Default UART[2] configuration "9600, 8, n,1" (8 bits data, no parity, 1 stop bit);

2.2 Symbols

- = --> Set value for command
- ? --> Query
- : --> Start a list input parameter
- + --> Prefix of command
- , --> Separator of parameters
- Space --> Empty character, could be used to format command

NOTE: You could use quote sign < " > to force input parameter with space, such as <AT+MSGHEX="AA BB CC DD EE">, then "AA BB CC DD EE" is treated as one parameter. But if you input command <AT+MSGHEX=AA BB CC DD EE>, "AA BB CC DD EE" will treated as 5 parameters, AT+MSGHEX returns error.

2.3 Format

All commands in this document are end with <CR><LF>. In order to facilitate the description, all <CR><LF> is intentionally omitted in this document.

2.3.1 Query

Use query command to check LoRaWAN modem configuration, such as channel configuration, ADR status, TX power, etc.

```
AT+COMMAND
AT+COMMAND?
AT+COMMAND=?
```

NOTE: Query format is available with every LoRaWAN supported command

2.3.2 Configure / Control

Uses configure/control command to set new configuration or control transaction.

```
AT+COMMAND=DATA
```

2.3.3 Return

Return data is in format like "+CMD: RETURN DATA"

```
+COMMAND: "RETURN DATA"
```

[2] ***RHF76-052AM*** *supports UART interface*
RHF3M076B *supports USB CDC interface of which UART configuration is unconcerned*

2.4 Error

Code	Comment
-1	Parameters is invalid
-10	Command unknown
-11	Command is in wrong format
-12	Command is unavailable in current mode (Check with "AT+MODE")
-20	Too many parameters. LoRaWAN modem support max 15 parameters
-21	Length of command is too long (exceed 528 bytes)
-22	Receive end symbol timeout, command must end with <LF>
-23	Invalid character received
-24	Either -21, -22 or -23

Table 2-1 Error code list

This error code list applies to all LoRaWAN supported command. User could refer to this list to know what is happening to LoRaWAN modem, when gets errors.

2.5 EEPROM

Items below will be synchronized to EEPROM of LoRaWAN modem once changed successfully, this makes LoRaWAN modem memorized, user doesn't need to reconfigure parameter after repower, LoRaWAN modem helps to keep it. If user wants to go back factory default configuration, refer to 4.21 FDEFAULT.

Item
Channel frequency, datarate range (up to 96 channels)
Datarate
TX power
ADR
RX Window2 frequency/datarate
RX Window1 frequency
Keys(NwkSkey, AppSkey, AppKey)
ID(DevAddr, DevEui, AppEui)
Port
Unconfirmed message repetition
Confirmed message retry
Mode[3]
LWABP/LWOTAA
Delay(RX1, RX2, JRX1, JRX2)
Multicast parameters (MC_DevAddr, MC_ NwkSkey, MC_ AppSkey)

Table 2-2 Memorized configuration

[3] Test mode is not stored; a reset during test mode makes modem switch back to previous mode.

3 Band Plans

RisingHF LoRaWAN Class A/B/C AT modem devices support:
LoRaWAN 1.0.2B Band Plans:

EU868 US915 US915HYBRID CN779 EU433 AU915 AU915OLD CN470 AS923 KR920 IN865

Customized band plans:

CN470PREQUEL STE920

Refer to LoRaWANRegionalParametersv1.0.2_final_1944_1.pdf for details.

3.1 Data Rate Scheme

DR	EU868	US915	US915 HYBRID	CN779	EU433	AU915	AU915OLD	CN470	AS923	KR920	IN865	CN470 PREQUEL	STE920
0	SF12/125	SF10/125	SF10/125	SF12/125	SF12/125	SF12/125	SF10/125	SF12/125	SF12/125	SF12/125	SF12/125	SF12/125	SF12/125
1	SF11/125	SF9/125	SF9/125	SF11/125	SF11/125	SF11/125	SF9/125	SF11/125	SF11/125	SF11/125	SF11/125	SF11/125	SF11/125
2	SF10/125	SF8/125	SF8/125	SF10/125	SF10/25	SF10/125	SF8/125	SF10/125	SF10/125	SF10/125	SF10/125	SF10/125	SF10/125
3	SF9/125	SF7/125	SF7/125	SF9/125	SF9/125	SF9/125	SF7/125	SF9/125	SF9/125	SF9/125	SF9/125	SF9/125	SF9/125
4	SF8/125	SF8/500	SF8/500	SF8/125	SF8/125	SF8/125	SF8/500	SF8/125	SF8/125	SF8/125	SF8/125	SF8/125	SF8/125
5	SF7/125	-	-	SF7/125	SF7/125	SF7/125	-	SF7/125	SF7/125	SF7/125	SF7/125	SF7/125	SF7/125
6	SF7/250	-	-	SF7/250	SF7/250	SF8/500	-	-	SF7/250	-	SF7/250	-	SF7/250
7	FSK	-	-	FSK	FSK	-	-	-	FSK	-	FSK	-	FSK
8	-	SF12/500	SF12/500	-	-	SF12/500	SF12/500	-	-	-		-	-
9	-	SF11/500	SF11/500	-	-	SF11/500	SF11/500	-	-	-		-	-
10	-	SF10/500	SF10/500	-	-	SF10/500	SF10/500	-	-	-		-	-
11	-	SF9/500	SF9/500	-	-	SF9/500	SF9/500	-	-	-		-	-
12	-	SF8/500	SF8/500	-	-	SF8/500	SF8/500	-	-	-		-	-
13	-	SF7/500	SF7/500	-	-	SF7/500	SF7/500	-	-	-		-	-
14	-	-	-	-	-		-	-	-	-		-	-
15	-	-	-	-	-		-	-	-	-		-	-

Table 3-1 Data Rate Scheme

RF Modulation	Indicative physical bit rate [bit/s]
LoRa SF12/125KHz	250
LoRa SF11/125KHz	440
LoRa SF10/125KHz	980
LoRa SF9/125KHz	1760
LoRa SF8/125KHz	3125
LoRa SF7/125KHz	5470
LoRa SF7/250KHz	11000
FSK 50kbps	50000
LoRa SF12/500KHz	980
LoRa SF11/500KHz	1760
LoRa SF10/500KHz	3900
LoRa SF9/500KHz	7000
LoRa SF8/500KHz	12500
LoRa SF7/500KHz	21900

Table 3-2 RF Modulation Bit Rate

3.2 Payload Length Limitation

Repeater mode is not supported.

DR	EU868	US915	US915 HYBRID	CN779	EU433	AU915	AU915OLD	CN470	AS923	KR920	IN865	CN470 PREQUEL	STE920
0	51	11	11	51	51	51	11	51	51	65	51	51	51
1	51	53	53	51	51	51	53	51	51	151	51	51	51
2	51	126	126	51	51	51	126	51	51	242	51	51	51
3	115	242	242	115	115	115	242	115	115	242	115	115	115
4	242	242	242	242	242	242	242	242	242	242	242	242	242
5	242	-	-	242	242	242	-	242	242	242	242	242	242
6	242	-	-	242	242	242	-	-	242	-	242	-	242
7	242	-	-	242	242		-	-	242	-	242	-	242
8	-	53	53	-	-	53	53	-	-	-		-	-
9	-	129	129	-	-	129	129	-	-	-		-	-
10	-	242	242	-	-	242	242	-	-	-		-	-
11	-	242	242	-	-	242	242	-	-	-		-	-
12	-	242	242	-	-	242	242	-	-	-		-	-
13	-	242	242	-	-	242	242	-	-	-		-	-
14	-	-	-	-	-		-	-	-	-		-	-
15	-	-	-	-	-		-	-	-	-		-	-

Table 3-3 Data Rate and Payload Length Map

3.3 TX Output Power Encoding[4]

TXPower	EU868	US915	US915 HYBRID	CN779	EU433	AU915	AU915OLD	CN470	AS923	KR920	IN865	CN470 PREQUEL	STE920
MaxEIRP	16	30	30	12.15[5]	12.15	30	30	19.15[6]	16	14	30	19.15	30
0~15	MaxEIRP – 2*TXPower												
0	16	30	30	12	12	30	30	20	16	14	30	20	20
1	14	28	28	10	10	28	28	18	14	12	28	18	18
2	12	26	26	8	8	26	26	16	12	10	26	16	16
3	10	24	24	6	6	24	24	14	10	8	24	14	14
4	8	22	22	4	4	22	22	12	8	6	22	12	12
5	6	20	20	2	2	20	20	10	6	4	20	10	10
6	4	18	18			18	18	8	4	2	18	8	8
7	2	16	16			16	16	6	2	0	16	6	6
8		14	14			14	14				14		
9		12	12			12	12				12		
10		10	10			10	10				10		
11-15													
TXPower Max	7	10	10	5	5	10	10	7	7	7	10	7	10
Default	1	8	8	0	0	8	8	0	0	1	8	0	4

Table 3-4 TX Power Table

[4] LoRaWAN V1.0.3 US915 / AU915 band supports TxPower maximum 15

[5] 12.15dBm is set to 12dBm, MaxEIRP Index 2

[6] 19.15dBm is converted to 20dBm, MaxEIRP Index 7

	EU868	US915	US915 HYBRID	CN779	EU433	AU915	AU915OLD	CN470	AS923	KR920	IN865	CN470 PREQUEL	STE920
MaxEIRP Index	5	13	13	2	2	13	13	7	5	4	13	7	13
MaxEIRP	16	30	30	12.15[7]	12.15	30	30	19.15[8]	16	14	30	19.15	30

Table 3-5 Default MaxEIRP Value and MaxEIRP Index Map

MaxEIRP Index	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
MaxEIRP	8	10	12	13	14	16	18	20	21	24	26	27	29	30	33	36

Table 3-6 MaxEIRP Table

TXPower is defined in LoRaWAN specification Mac command LinkADRReq chapter.

3.4 Channels

3.4.1 Default Uplink Channels

Band \ DR	0	1	2	3~95	Default Data Rate	Channel Numbers	Channel Numbers Max
EU868	868.1 DR0~DR5	868.3 DR0~DR5	868.5 DR0~DR5	-	0	3	16
US915	902.3 DR0~DR3	902.5 DR0~DR3	902.7 DR0~DR3	0~63 **902.3 + ch * 200000 DR0~DR3** 64~71 **903.0 + ch * 600000 DR4**	0	72	72
US915HYBRID	902.3 DR0~DR3	902.5 DR0~DR3	902.7 DR0~DR3	0~7 **902.3 + ch * 200000 DR0~DR3** 64 **903.0 + ch * 600000 DR4**	0	9	72
CN779	779.5 DR0~DR5	779.7 DR0~DR5	779.9 DR0~DR5	-	0	3	16
EU433	433.175 DR0~DR5	433.375 DR0~DR5	433.575 DR0~DR5	-	0	3	16
AU915	915.2 DR0~DR3	915.4 DR0~DR3	915.6 DR0~DR3	0~63 **915.2 + ch * 200000 DR0~DR5** 64~71 **915.9 + ch * 600000 DR6**	0	72	72
AU915OLD	915.2 DR0~DR3	915.4 DR0~DR3	915.6 DR0~DR3	0~63 **915.2 + ch * 200000 DR0~DR3** 64~71 **915.9 + ch * 600000 DR4**	0	72	72
CN470	470.3 DR0~DR5	470.5 DR0~DR5	470.7 DR0~DR5	200KHz channel space up to 95	0	96	96
AS923	923.2 DR0~DR5	923.4 DR0~DR5	-	-	2	2	16
KR920	922.1 DR0~DR5	922.3 DR0~DR5	922.5 DR0~DR5	-	0	3	16
IN865	865.0625 DR0~DR5	865.4025 DR0~DR5	865.985 DR0~DR5	-	0	3	16
CN470PREQUEL	471.5 DR0~DR5	471.7 DR0~DR5	471.9 DR0~DR5	200KHz channel space up to 7	0	8	16
STE920	922.0 DR0~DR5	922.2 DR0~DR5	922.4 DR0~DR5	200KHz channel space up to 7	0	8	16

Table 3-7 Default Uplink Channels

3.4.2 Downlink RXWIN1 Channels

Downlink Data Rate is defined by RX1DROffset.

Band \ CH	0~95
EU868	Same as uplink channels
US915	**923.3 + (ch % 8) * 0.6**
US915HYBRID	**923.3 + (ch % 8) * 0.6**
CN779	Same as uplink channels
EU433	Same as uplink channels
AU915	**923.3 + (ch % 8) * 0.6**
AU915OLD	**923.3 + (ch % 8) * 0.6**

[7] 12.15dBm is set to 12dBm, MaxEIRP Index 2

[8] 19.15dBm is converted to 20dBm, MaxEIRP Index 7

Band \ CH	0~95
CN470	500.3 + (ch % 48) * 0.2
AS923	Same as uplink channels
KR920	Same as uplink channels
IN865	Same as uplink channels
CN470PREQUEL	Same as uplink channels
STE920	Same as uplink channels

Table 3-8 Default Downlink RXWIN1 Channels

3.4.3 Downlink RXWIN2 Channel

Band\DR	Frequency/MHz	Data Rate
EU868	869.525	DR0
US915	923.3	DR8
US915HYBRID	923.3	DR8
CN779	786	DR0
EU433	434.665	DR0
AU915	923.3	DR8
AU915OLD	923.3	DR8
CN470	505.3	DR0
AS923	923.2	DR2
KR920	921.9	DR0
IN865	866.55	DR2
CN470PREQUEL	471.3	DR3
STE920	923.2	DR0

Table 3-9 Default RXWIN2 Configuration

3.4.4 Join Request Channels

Band	Channels
EU868	0-2
US915	All uplink channels
US915HYBRID	All uplink channels
CN779	0-2
EU433	0-2
AU915	All uplink channels
AU915OLD	All uplink channels
CN470	All uplink channels
AS923	0-1 (Fixed DR2)
KR920	0-2
IN865	0-2
CN470PREQUEL	0-7
STE920	0-7

Table 3-10 Join Request Channels

Note: Although the modem supports user to modify the default uplink channels, it does not encourage user to do so. If user need modify the default channels, please make sure gateway and server supports the selected channel.

3.5 Join Duty Cycle Limitation

The latest V2.1.x (or higher) firmware enables the global JoinReq duty cycle which applies below table[9].

Time	Range	Transmit time	DutyCycle
Aggregated during the first hour following power-up or reset	T0<t<T0+1	Transmit time < 36Sec	1%
Aggregated during the next 10 hours	T0+1<t<T0+11	Transmit time < 36Sec	0.1%
After the first 11 hours, aggregated over 24h	T0+11+N<t<T0+35+N (N>=0)	Transmit time < 8.7Sec per 24h	0.01%

Table 3-11 Join Duty Cycle

"AT+LW=JDC, OFF" command could be used to disable the feature if user need to disable the feature.

3.6 RX1DROffset Limitation

RX1DROffset	EU868	US915	US915 HYBRID	CN779	EU433	AU915	AU915OLD	CN470	AS923	KR920	IN865	CN470 PREQUEL	STE920
Min	0	0	0	0	0	0	0	0	0	0	0	0	0
Max	5	3	3	5	5	5	3	5	7	5	7	5	5

Table 3-12 RX1DROffset Range

Default RX1DROffset of all bands is 0.

3.6.1 EU868/EU434/CN470 /KR920/CN470PREQUEL/STE920

```
DR = MAX( UplinkChannelDaraRate - RX1DROffset, DR0)
```

3.6.2 US915/ US915HYBRID/AU915

```
DR = MAX( MIN( UplinkChannelDaraRate +10 - RX1DROffset, DR13 ), DR8 )
```

3.6.3 AS923

```
MIN( 5, MAX( MinDR, UplinkChannelDaraRate - Effective_RX1DROffset ) )
```

MinDR depends on the **DownlinkDwellTime** bit sent to the device in the **TxParamSetupReq** command:

- Case **DownlinkDwellTime** = 0 (No limit): **MinDR** = DR0
- Case **DownlinkDwellTime** = 1 (400ms): **MinDR** = DR2

RX1DROffset	0	1	2	3	4	5	6	7
Effective_RX1DROffset	0	1	2	3	4	5	-1	-2

Table 3-13 AS923 RX1DROffset Effective Table

3.6.4 IN865

```
MIN( 5, MAX( 0, UplinkChannelDaraRate - Effective_RX1DROffset ) )
```

RX1DROffset	0	1	2	3	4	5	6	7
Effective_RX1DROffset	0	1	2	3	4	5	-1	-2

Table 3-14 IN865 RX1DROffset Effective Table

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3.7 CFLIST

CFListType	EU868	US915	US915 HYBRID	CN779	EU433	AU915	AU915OLD	CN470	AS923	KR920	IN865	CN470 PREQUEL	STE920
ChId	3-7[10]	N/A	N/A	3-7	3-7	N/A	N/A	N/A	2-6	3-7	3-7	N/A	N/A
ChMask	N/A	0-71	0-71	N/A	N/A	0-71	N/A	0-95	N/A	N/A	N/A	N/A	N/A

Table 3-15 CFList Definition

LoRaWAN V1.0.3 US915 / US915 / CN470 supports to use CFLIST to management channel (ChMask).

3.8 LinkAdrReq

ChMaskCntl	EU868	US915	US915 HYBRID	CN779	EU433	AU915	AU915OLD	CN470	AS923	KR920	IN865	CN470 PREQUEL	STE920
0	0-15	0-15	0-15	0-15	0-15	0-15	0-15	0-15	0-15	0-15	0-15	0-15	0-15
1	RFU	16-31	16-31	RFU	RFU	16-31	16-31	16-31	RFU	RFU	RFU	16-31	RFU
2	RFU	32-47	32-47	RFU	RFU	32-47	32-47	32-47	RFU	RFU	RFU	32-47	RFU
3	RFU	48-63	48-63	RFU	RFU	48-63	48-63	48-63	RFU	RFU	RFU	48-63	RFU
4	RFU	**64-71**	**64-71**	RFU	RFU	**64-71**	**64-71**	64-79	RFU	RFU	RFU	64-79	RFU
5	RFU	8LSB CHBlk 0-7 8MSBs RFU[11]	8LSB CHBlk 0-7 8MSBs RFU	RFU	RFU	8LSB CHBlk 0-7 8MSBs RFU	RFU	80-95	RFU	RFU	RFU	80-95	RFU
6	All On	**0-63 on Mask 64-71**	**0-63 on Mask 64-71**	All On	All On	**0-63 on Mask 64-71**	**0-63 on Mask 64-71**	**All On**	All On	All On	All On	**All On**	All On
7	RFU	**0-63 off 64-71 Mask**	**0-63 off 64-71 Mask**	RFU	RFU	**0-63 off 64-71 Mask**	**0-63 off 64-71 Mask**	**RFU**	RFU	RFU	RFU	**RFU**	RFU

Table 3-16 LinkAdrReq ChMaskCntl Definition

3.9 Band Specific Limitation

3.9.1 US915/AU915/CN470 Channel Limitation

Under these modes, up to 72 (US915/AU915) or 96 (CN470) channels could be enabled. All these channels are not configurable with the default channels according to the definition of LoRaWAN 1.0.1. This means below commands will be invalid:

```
AT+CH=ch, freq, [drmin], [drmax]
AT+RXWIN1=ch, freq
```

To turn on/off channel, user need to use AT+CH=NUM or AT+CH=ch, ON/OFF command.

3.9.2 EU868 Duty Cycle Limitation

Only EU868 band need enable duty cycle limitation to comply with ETSI [EN300.220] standard. Band and limitation is defined as below.

Band Index	Frequencies(MHz)	Maximum Power	Duty Cycle	Band Width
g2	863.00 ~ 865.00	14dBm	0.1%	2MHz
g	865.00 ~ 868.00	14dBm	1%	3MHz

[10] Here has some difference from LoRaWAN specification use 4-8 to define, by which it assume first channel has index 1. RisingHF device use index 0 for the first channel.

[11] LoRaWAN V1.0.3 Only

Band Index	Frequencies(MHz)	Maximum Power	Duty Cycle	Band Width
g1	868.00 ~ 868.60	14dBm	1%	600KHz
g2	868.70 ~ 869.20	14dBm	0.1%	500KHz
g3	869.40 ~ 869.65	27dBm	10%	250KHz
g4	869.70 ~ 867.00	14dBm	1%	300KHz

Table 3-17 ETSI EU868 Regulation

3.9.3 CN799 Duty Cycle Limitation

Band Index	Frequencies(MHz)	Maximum Power	Duty Cycle	Band Width
g0	779.00 ~ 787.00	12.15dBm	1%	8MHz

Table 3-18 CN779 Duty Cycle Limitation

3.9.1 EU433 Duty Cycle Limitation

Band Index	Frequencies(MHz)	Maximum Power	Duty Cycle	Band Width
g0	433.175 ~ 434.665	12.15dBm	1%	1.5MHz

Table 3-19 EU433 Duty Cycle Limitation

3.9.2 AS923 Dwell Time Limitation

UplinkDwellTime, DownlinkDwellTime and MaxEIRP can be set configured through TxParamSetupReq / TxParamSetupAns MAC command.

DR \ DwellTime	UplinkDwellTime 0	UplinkDwellTime 1	DownlinkDwellTime 0	DownlinkDwellTime 1
0	51	N/A	51	N/A
1	51	N/A	51	N/A
2	51	11	51	11
3	115	53	115	53
4	242	125	242	125
5	242	242	242	242
6	242	242	242	242
7	242	242	242	242
8:15	RFU	RFU	RFU	RFU

Table 3-20 AS923 Dwell Time Limitation

3.9.3 KR920 Channels and TX Power Limitation

For KR920 band, only below channels are available.

Channel Frequency	920.9	921.1	921.3	921.5	921.7	921.9	922.1	922.3	922.5	922.7	922.9	923.1	923.3
Maximum EIRP output power	10	10	10	10	10	10	14	14	14	14	14	14	14

Table 3-21 KR920 Channel and TX power limitation

3.10 Band Frequency Range

Band	Start Channels	End Frequency	Band Width
EU868	863	870	7MHz
US915	902	928	26MHz
US915HYBRID	902	928	26MHz
CN779	799	787	8MHz
EU433	433.175	434.665	1.49MHz

Band	Start Channels	End Frequency	Band Width
AU915	915	928	13MHz
AU915OLD	915	928	13MHz
CN470	470	510	40MHz
AS923	902	928	26MHz
KR920	920.9	923.3	2.4MHz
IN865	865	867	2MHz
CN470PREQUEL	470	510	40MHz
STE920	920	925	26MHz

Table 3-22 Band Frequency Range

3.10.1 AS923 Region Limitation[12]

Country Name	Frequency Range
Brunei	923-925
Cambodia	923-925
Indonesia	923-925
Japan	920-928
Laos	923-925
New Zealand	915-928
Singapore	920-925
Taiwan	922-928
Thailand	920-925
Vietnam	920-925

Table 3-23 AS923 Region Limitation

3.11 Class B

3.11.1 Default Parameters

Band	Beacon Channel Number (ChannelNum)	Beacon Channel Frequency / MHz	Beacon Channel DataRate	Beacon Channel SF/BW	Ping Slot Channel Frequency / MHz	Ping Slot Channel Data Rate / MHz
EU868	1	869.525	DR3	SF9/125KHz	869.525	DR3
US915	8	923.3 + ch * 0.6	DR8	SF12/500KHz	923.3 + ch * 0.6	DR8
US915HYBRID	8	923.3 + ch * 0.6	DR8	SF12/500KHz	923.3 + ch * 0.6	DR8
CN779	1	785	DR3	SF9/125KHz	785	DR3
EU433	1	434.665	DR3	SF9/125KHz	434.665	DR3
AU915	8	923.3 + ch * 0.6	DR10	SF10/500KHz	923.3 + ch * 0.6	DR10
AU915OLD	8	923.3 + ch * 0.6	DR10	SF10/500KHz	923.3 + ch * 0.6	DR10
CN470	8	508.3 + ch * 0.2	DR2	SF10/125KHz	508.3 + ch * 0.2	DR2
AS923	1	923.4	DR3	SF9/125KHz	923.4	DR3
KR920	1	923.1	DR3	SF9/125KHz	923.1	DR3
IN865	1	865.55	DR4	SF8/125KHz	865.55	DR4
CN470PREQUEL	1	473	DR3	SF9/125KHz	473	DR3
STE920	1	923.4	DR3	SF9/125KHz	923.4	DR3

Table 3-24 Class B Default Parameters

Beacon channel index number at specified beacon time can be calculated with formula:

ch = floor(beacon_time/beacon_period) % ChannelNum

[12] Defined by LoRaWAN 1.0.2 Regional Parameter

3.11.2 Beacon Frame Content

LoRaWAN V102B and V103:

Band	Size	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
EU868	17	RFU		Time				CRC		GwSpecific							CRC							
US915	23	RFU						Time				CRC	GwSpecific							RFU				CRC
CN779	17	RFU		Time				CRC		GwSpecific							CRC							
EU433	17	RFU		Time				CRC		GwSpecific							CRC							
AU915	19	RFU					Time				CRC	GwSpecific						RFU	CRC					
CN470	19	RFU					Time				CRC	GwSpecific						RFU	CRC					
AS923	17	RFU		Time				CRC		GwSpecific							CRC							
KR920	17	RFU		Time				CRC		GwSpecific							CRC							
IN865	19	RFU			Time				CRC			GwSpecific						RFU	CRC					

Table 3-25 Beacon Format

LoRaWAN V102 (Time is in UTC epoch format)

Band	Size	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
EU868 V102	17	NetId				Time			CRC	GwSpecific							CRC							
US915 V102	19	NetId					Time				CRC	GwSpecific						RFU	CRC					

Table 3-26 Legacy EU868 and US915 Beacon Format

3.11.3 Periodicity

Periodicity is a very important Class B parameter to control ping slot numbers and ping slot timing. Periodicity is set to 5 by default. **AT+BEACON=periodicity** command can be used to configure periodicity.

Periodicity	Ping slot control	0	1	2	3	4	5	6	7
PingNb	Number of ping slots per beacon period.	128	64	32	16	8	4	2	1
PingPeriod	Period of the device receiver wake-up expressed in number of slots	32	64	128	256	512	1024	2048	4096
PingPeriodTime/s	Period of the device receiver wake-up expressed in seconds	0.96	1.92	3.84	7.68	15.36	30.72	61.44	122.88
PingOffset	Randomized offset computed at each beacon period start.	0-31	0-63	0-127	0-255	0-511	0-1023	0-2047	0-4095

Table 3-27 Class B Periodicity Table

4 Commands

Command	Description
AT	Test command
FDEFAULT	Factory data reset
RESET	Software reset
DFU	Force bootloader to enter dfu mode
LOWPOWER	Enter sleep mode
VER	Version[Major.Minor.Patch]
MSG	LoRaWAN unconfirmed data
MSGHEX	LoRaWAN unconfirmed data in hex
CMSG	LoRaWAN confirmed data
CMSGHEX	LoRaWAN confirmed data in hex
PMSG	LoRaWAN proprietary
PMSGHEX	LoRaWAN proprietary in hex
CH	LoRaWAN channel frequency
DR	LoRaWAN datarate
ADR	LoRaWAN ADR control
REPT	Unconfirmed message repetition
RETRY	Confirmed message retry
POWER	LoRaWAN TX power
RXWIN2	LoRaWAN RX window2
RXWIN1	LoRaWAN RX window1
PORT	LoRaWAN communication port
MODE	LWABP, LWOTAA, TEST
ID	LoRaWAN DevAddr/DevEui/AppEui
KEY	Set NWKSKEY/APPSKEY/APPKEY
CLASS	Choose LoRaWAN modem class(A/B/C)
JOIN	LoRaWAN OTAA JOIN
LW	LoRaWAN misc configuration (CDR, ULDL, NET, DC, MC, THLD)
BEACON	LoRaWAN Class B utilities
TEST	Send test serious command
UART	UART configure
DELAY	RX window delay
VDD	Get VDD
RTC	RTC time get/set
EEPROM	Write/Read EEPROM
WDT	Watchdog control
TEMP	Get Temperature
LOG	Log DEBUG/INFO/WARN/ERROR/FATAL/PANIC/QUIET

Table 4-1 Command List

4.1 AT

Use to test if connection of module is OK. This is a dummy command just like other common "AT modules"

Format:

```
AT
```

Return:

```
+AT: OK
```

4.2 VER

Check firmware version. Versioning rule refers to Semantic Versioning 2.0.0.

Format:

```
AT+VER
```

Return:

```
+VER: $MAJOR.$MINOR.$PATCH
+VER: 2.1.x
```

4.3 ID

Use to check the ID of the LoRaWAN module, or change the ID. ID is treated as big endian numbers.

Read ID Format:

```
AT+ID                    // Read all, DevAddr(ABP), DevEui(OTAA), AppEui(OTAA)
AT+ID=DevAddr            // Read DevAddr
AT+ID=DevEui             // Read DevEui
AT+ID=AppEui             // Read AppEui
AT+ID=DevAddr, "devaddr" // Set new DevAddr
AT+ID=DevEui, "deveui"   // Set new DevEui
AT+ID=AppEui, "appeui"   // Set new AppEui
```

Return:

```
+ID: DevAddr, xx:xx:xx:xx
+ID: DevEui[13], xx:xx:xx:xx:xx:xx:xx:xx
+ID: AppEui[14], xx:xx:xx:xx:xx:xx:xx:xx
```

Change end device address (**DEVADDR**)

```
AT+ID=DevAddr, “4 bytes length hex identifier”
eg: AT+ID=DevAddr, "01234567"
eg: AT+ID=DEVADDR, "01 23 45 67"
```

Return:

```
+ID: DevAddr, 01:23:45:67
```

Change device extended unique identifier (**DEVEUI**)

```
AT+ID= DevEui, “8 bytes length hex identifier (64bits)”
```

[13] DevEui which is supplied by RisingHF are derived from STM32's UUID, these EUIs are RisingHF unique is not standard IEEE EUI-64, , it is recommended to apply and use IEEE-EUI64.

[14] Default AppEui is **52:69:73:69:6E:67:48:46**

```
eg: AT+ID=DevEui, "0123456789ABCDEF"
eg: AT+ID=DEVEUI, "01 23 45 67 89 AB CD EF"
```

Return:

```
+ID: DevEui, 01:23:45:67:89:AB:CD:EF
```

Change device extended unique identifier (**APPEUI**)

```
AT+ID= AppEui, “8 bytes length hex identifier (64bits)”
eg: AT+ID=AppEui, "0123456789ABCDEF"
eg: AT+ID=APPEUI, "01 23 45 67 89 AB CD EF"
```

Return:

```
+ID: AppEui, 01:23:45:67:89:AB:CD:EF
```

4.4 RESET

Use to reset the module. If module returns error, then reset function is invalid.

Format:

```
AT+RESET
```

Return:

```
+RESET: OK
```

4.5 MSG

Use to send string format frame which is no need to be confirmed by the server.

Format:

```
AT+MSG="Data to send"
```

Return: *(Full return message)*

```
+MSG: Start
+MSG: FPENDING
+MSG: Link 20, 1
+MSG: ACK Received
+MSG: MULTICAST
+MSG: PORT: 8; RX: "12345678"
+MSG: RXWIN2[15], RSSI -106, SNR 4
+MSG: Done
```

Below return messages are optional, it is returned only in the cases that specified event occurs.

```
+MSG: FPENDING                    // Downlink frame FPENDING flag is set
+MSG: Link 20, 1                  // LinkCheckAns received
+MSG: ACK Received                // Downlink frame ACK flag is set
+MSG: MULTICAST                   // Downlink frame is multi cast message
+MSG: PORT: 8; RX: "12345678"     // Downlink message is received
+MSG: RXWIN2, RSSI -106, SNR 4    // Downlink frame signal strength
```

[15] **RXWIN2**: Message is received during RX Window2; **RXWIN1**: RX Window1; **RXWIN0**: Class C Extra RXWIN2.

4.5.1 LinkCheckReq

AT+MSG could be used to send LinkCheckReq mac command to check Link status between modem and server.

```
AT+MSG
+MSG: Start
+MSG: TX ""
+MSG: Link 20, 1
+MSG: RXWIN1, RSSI -93, SNR 6.25
+MSG: Done
```

From example above, the modem returns "***+MSG: Link 20, 1***" to host, it is in the format:

+MSG: Link Margin, GwCnt

The demodulation margin (***Margin***) is an 8-bit unsigned integer in the range of 0..254 indicating the link margin in dB of the last successfully received LinkCheckReq command.
A value of "0" means that the frame was received at the demodulation floor (0 dB or no margin) while a value of "20", for example, means that the frame reached the gateway 20 dB above the demodulation floor. Value "255" is reserved.

The gateway count (***GwCnt***) is the number of gateways that successfully received the last LinkCheckReq command.

4.5.2 Error Status

1. LoRaWAN transaction service is ongoing
   +MSG: LoRaWAN modem is busy
2. LoRaWAN modem is in OTAA mode and not joined a network
   +MSG: Please join network first
3. LoRaWAN modem already joined to a network previously
   +JOIN: Joined already

Note: use AT+JOIN=FORCE to force join if needed.

4. All configured channels are occupied by others.
   +MSG: No free channel -70

Note: use AT+LW=THLD to set a new threshold

5. There is no band available for the moment. The modem must stay silence for a while, because of local regulation rules or Join Request Duty Cycle
   +MSG: No band in 13469ms
6. Current DR set data rate is not supported
   +MSG: DR error

Note: use AT+DR=dr to set a new datarate

7. Current payload length is too long to send.
   +MSG: Length error N
   Note: N could be 0 or none zero value, if it returns 0, it means there is a pending Uplink MAC Command must be sent through Port 0. User need send a dummy MSG command "AT+MSG" to flush uplink MAC command.

It is recommended for use to run AT+LW=LEN command to get maximum available payload size. And make sure the next packet payload length is less than the available maximum payload length.
Note: use AT+LW=LEN command to get current available length.

4.6 CMSG

Use to send string format frame which must be confirmed by the server.

Format:

```
AT+CMSG="Data to send"
```

Return: *(Full return message)*

```
+CMSG: Start
+CMSG: Wait ACK
+CMSG: FPENDING
+CMSG: Link 20, 1
+CMSG: ACK Received
+CMSG: MULTICAST
+CMSG: PORT: 8; RX: "12345678"
+CMSG: RXWIN2[16], RSSI -106, SNR 4
+CMSG: Done
```

Below return messages are optional, it is returned only in the cases that specified event occurs.

```
+CMSG: FPENDING                    // Downlink frame FPENDING flag is set
+CMSG: Link 20, 1                  // LinkCheckAns received
+CMSG: ACK Received                // Downlink frame ACK flag is set
+CMSG: MULTICAST                   // Downlink frame is multi cast message
+CMSG: PORT: 8; RX: "12345678"     // Downlink message is received
+CMSG: RXWIN2, RSSI -106, SNR 4    // Downlink frame signal strength
```

4.7 MSGHEX

Use to send hex format frame which is no need to be confirmed by the server.

Format:

```
AT+MSGHEX="xx xx xx xx"
eg: AT+MSGHEX="12345678"
```

Return:

```
+MSGHEX: Start
+MSGHEX: Done
```

For detailed examples, please refer to MSG. MSG and MSGHEX are the same command except payload format.

4.7.1 Send Unconfirmed Message with Zero Length Payload

Format:

```
AT+MSGHEX
eg: AT+MSGHEX
```

Return:

```
+MSGHEX: Start
+MSGHEX: Done
```

[16] **RXWIN2**: Message is received during RX Window2; **RXWIN1**: RX Window1; **RXWIN0**: Class C Extra RXWIN2.

4.8 CMSGHEX

Use to send hex format frame which must be confirmed by the server.

Format:

```
AT+CMSGHEX="Data to send"
eg: AT+CMSGHEX="12345678"
```

Return:

```
+CMSGHEX: Start
+CMSGHEX: Wait ACK
+CMSGHEX: Done
```

For detailed examples, please refer to CMSG. CMSG and CMSGHEX are the same command except payload format.

4.8.1 Send Confirmed Message with Zero Length Payload

Format:

```
AT+CMSGHEX
eg: AT+CMSGHEX
```

Return:

```
+CMSGHEX: Start
+CMSGHEX: Wait ACK
+CMSGHEX: Done
```

4.9 PMSG

Use to send string format LoRaWAN proprietary frames.

Format:

```
AT+PMSG="Data to send"
eg: AT+PMSG="This is a string"
```

Return:

```
+PMSG: Start
+PMSG: Done
```

4.10 PMSGHEX

Use to send hex format LoRaWAN proprietary frames.

Format:

```
AT+PMSGHEX="Data to send"
eg: AT+PMSGHEX="AB CD"
```

Return:

```
+PMSGHEX: Start
+PMSGHEX: Done
```

4.11 PORT

Set PORT number which will be used by MSG/CMSG/MSGHEX/CMSGHEX command to send message, port number should range from 1 to 255. User should refer to LoRaWAN specification to choose port.

Format:

```
AT+PORT="port"                    // "port" should be 1~255
eg: AT+PORT=8                     // Set port to 8
eg: AT+PORT=?                     // Check current port
```

Return:

```
+PORT: 8                          // PORT query/set return
```

4.12 ADR

Set ADR function of LoRaWAN module.

Format:

```
AT+ADR="state"
eg: AT+ADR=ON                     // Enable ADR function
AT+ADR=OFF                        // Disable ADR function
AT+ADR=?                          // Check current ADR configuration
```

Return:

```
+ADR: ON                          // ADR query/set return
```

4.13 DR

Use LoRaWAN defined DRx to set datarate of LoRaWAN AT modem. Refer to **Chapter 3 Band Plans** about the detailed definition of LoRaWAN data rate.

4.13.1 Check and Set Data Rate

Format:

```
AT+DR               // Check current selected DataRate
AT+DR=drx           // "drx" should range 0~15
```

Return:

```
+DR: DR0
+DR: US915 DR0  SF10 BW125K
```

Return: *(ADR is functional)*

```
+DR: DR0 (ADR DR3)
+DR: US915 DR3  SF7  BW125K
+DR: US915 DR0  SF10 BW125K
```

4.13.2 Data Rate Scheme

Format:

```
AT+DR=band          // "band" could be band names defined in Chapter 3 Band Plans
AT+DR=SCHEME        // Check current band
```

Return: *(EU868)*

```
+DR: EU868
+DR: EU868 DR0  SF12 BW125K
+DR: EU868 DR1  SF11 BW125K
+DR: EU868 DR2  SF10 BW125K
+DR: EU868 DR3  SF9  BW125K
+DR: EU868 DR4  SF8  BW125K
```

```
+DR: EU868 DR5  SF7  BW125K
+DR: EU868 DR6  SF7  BW250K
+DR: EU868 DR7  FSK  50kbps
+DR: EU868 DR8  RFU
+DR: EU868 DR9  RFU
+DR: EU868 DR10 RFU
+DR: EU868 DR11 RFU
+DR: EU868 DR12 RFU
+DR: EU868 DR13 RFU
+DR: EU868 DR14 RFU
+DR: EU868 DR15 RFU
```

4.14 CH

4.14.1 Query Channel Configuration

Format:

```
AT+CH
AT+CH=ch
```

1. Check single channel frequency

```
eg: AT+CH=2
+CH: 2,868500000,DR0:DR5
```

2. Query all channels

```
AT+CH
```

Query All Channels Return Format:

```
+CH: TOTAL_CHANNEL_NUMBER; LCn,FREQn,DR_MINn,DR_MAXn; LCy,FREQy,DR_MINy,DR_MAXy; ...
LCz,FREQz,DR_MINz,DR_MAXz;
eg: +CH: 3; 0,868100000,DR0,DR5; 1,868300000,DR0,DR5; 2,868500000,DR0,DR5;
```

4.14.2 Add or Delete Channel

Set channel parameter of LoRaWAN modem, Set frequency zero to delete one channel.

Format:

```
AT+CH="chn", ["freq"], ["drmin"], ["drmax"]
// Change the chn channel frequency to "Freq"
// "freq" is in MHz.
// Available "drmin"/"drmax" range DR0 ~ DR15
```

1. Change channel CH3 frequency to 433.3MHz, datarate DR0~DR5

```
eg: AT+CH=3, 433.3, DR0, DR5
```

2. Delete channel CH3

```
eg: AT+CH=3, 0
```

3. Change channel CH0 frequency to 433.3MHz,DR7

```
eg: AT+CH=0, 433.3, DR7
```

4. Change channel CH3 frequency to 433.7MHz, datarate DR0~DR5

```
eg: AT+CH=3, 433.7, 0, 5
```

5. Change channel CH3 frequency to 433.7MHz, datarate DR7

```
eg: AT+CH=3, 433.7, DR7
```

6. Change channel CH3 frequency to 433.7MHz, with default datarate DR0~DR5

```
eg: AT+CH=?
eg: AT+CH=3, 433.7
// It is not recommended to use this command
```

Return:

```
+CH: 3,433700000,DR0:DR5
+CH: 3,433700000,DR1
```

4.14.3 Enable or Disable Channel

Format:

```
AT+CH=NUM
AT+CH=NUM, chm-chn, ..., chx-chy, chz
```

1. Check current enabled channels

```
eg: AT+CH=NUM
+CH: NUM, 0-7, 64
```

2. Enable and disable channels

```
eg: AT+CH=NUM, 0-5, 64    // Enable channel 0, 1, 2, 3, 4, 5 and 64, disable all others
+CH: NUM, 0-5, 64
```

Note: All channels should be controlled by a single command. The command operates all channels (0-95).

3. Enable single channel

```
eg: AT+CH=chn,ON
```

4. Disable single channel (channel is just masked, not deleted)

```
eg: AT+CH=chn,OFF
```

4.15 POWER

4.15.1 Set and Check Power

LoRaWAN TX power is controlled by internal TX power table, and also decided by hardware. Check TX power table to know what power could support.

Format:

```
AT+POWER
AT+POWER="pow"                    // Change LoRaWAN Tx Power
eg: AT+POWER=14                   // Change LoRaWAN AT module TX power to 14dBm
```

Return:

```
+POWER: 14
```

4.15.2 Force Set Power

This command can be used to set a fixed TX power for LoRaWAN modem, it will bypass LoRaWAN TX power table and LinkADRReq command.

Format:

```
AT+POWER=pow, FORCE
```

4.15.3 Power Table

This command can be used to check band specific power table.

Format:

```
AT+POWER=TABLE
+POWER: 30 28 26 24 22 20 18 16 14 12 10
```

4.16 REPT

Unconfirmed message repeats times.

Format:

```
AT+REPT="Repeat Times"    //Repeat times" should range 1~15
eg: AT+REPT=2             //Repeat 2 times
```

Return:

```
+REPT: 2
```

4.17 RETRY

Confirmed message retry times. Valid range 0~254, if retry times is less than 2, only one message will be sent. Random delay 3 - 10s between each retry (band duty cycle limitation has the priority)

Format:

```
AT+RETRY="Retry Times"    //Retry times" should range 0~15
eg: AT+RETRY=3            //Retry 2 times (3-1), if no ack receive
```

Return:

```
+RETRY: 3
```

4.18 RXWIN2

Set second RX window frequency and Data Rate. This command will change RXWIN2 configuration, which may cause downlink lost, if configuration is wrong.

Format:

```
AT+ RXWIN2                          // Query RX Window2 configuration
AT+RXWIN2=Frequency,DRx             // Set frequency and datarate
AT+RXWIN2=Frequency,SFx,BW          // Set RXWIN2 through SF and BW
eg: AT+RXWIN2=433.3,DR3             // Set RXWIN2 433.3MHz/DR3
eg: AT+RXWIN2=433.3,SF7,500         // Set RXWIN2 433.3MHz/SF7/BW500KHz
```

Return:

```
// General data rate
+RXWIN2: 433300000,DR5
// Customized RX Window2 data rate with spread factor and band width
+RXWIN2: 433000000,SF7,BW125K
```

From firmware 1.8.0, RXWIN2 command could support more flexible configuration. Both LoRaWAN defined data rate (combination of spread faction and band width) and LoRa defined spread factor and band width format are supported. User could set his RXWIN2 to any possible SF and BW scheme, which is a very useful function for LoRaWAN proof of concept.

4.19 RXWIN1

RXWIN1 command could be used to set customized RXWIN channel, each RXWIN channel maps to an uplink channel. When RXWIN1 is enabled, user need make sure every uplink channel has its own mapped RXWIN1 channel, or the modem may perform unexpected.

With this special RXWIN1 command, frequency shift between uplink and downlink becomes possible, then full-duplex is easy to achieve for the system if gateway supports.

a) Set RXWIN1

```
AT+RXWIN1=ch,freq
eg: AT+RXWIN1=0,868.9
```

Set none zero **freq** to overwrite default RXWIN1 channel frequency.

Set zero **freq** to use default frequency

b) Query RXWIN1 channel

```
AT+RXWIN1=ch
eg: AT+RXWIN1=0,868100000
```

c) Check RXWIN1

```
AT+RXWIN1
+RXWIN1: 3; 0,868100000; 1,868300000; 2,868500000;
```

AT+RXWIN1 and its subcommands always returns the channels which are enabled currently. If customized downlink channel is zero, then default downlink channels will be used.

4.20 KEY

Change LoRaWAN related AES-128 KEY. If wrong key is used, your LoRaWAN modem will be rejected by LoRaWAN server. Contact server administrator to know what key should use. All KEYs are unreadable for security, the one who forgets his KEY need rewrite with a new key.

Format:

Change network session key (NWKSKEY)

```
AT+KEY=NWKSKEY, “16 bytes length key”
eg: AT+KEY=NWKSKEY, "2B7E151628AED2A6ABF7158809CF4F3C"
eg: AT+KEY=NWKSKEY, "2B 7E 15 16 28 AE D2 A6 AB F7 15 88 09 CF 4F 3C"
```

Return:

```
+KEY: NWKSKEY 2B7E151628AED2A6ABF7158809CF4F3C
```

Change application session key (APPSKEY)

```
AT+KEY=APPSKEY, “16 bytes length key”
eg: AT+KEY=APPSKEY, "2B7E151628AED2A6ABF7158809CF4F3C"
eg: AT+KEY= APPSKEY, "2B 7E 15 16 28 AE D2 A6 AB F7 15 88 09 CF 4F 3C"
```

Return:

```
+KEY: APPSKEY 2B7E151628AED2A6ABF7158809CF4F3C
```

Change application session key (APPKEY)

```
AT+KEY=APPKEY, “16 bytes length key”
eg: AT+KEY=APPKEY, "2B7E151628AED2A6ABF7158809CF4F3C"
    AT+KEY= APPKEY, "2B 7E 15 16 28 AE D2 A6 AB F7 15 88 09 CF 4F 3C"
```

Return:

```
+KEY: APPKEY 2B7E151628AED2A6ABF7158809CF4F3C
```

4.21 FDEFAULT

Reset LoRaWAN AT modem to factory default configuration.

Format:

```
AT+FDEFAULT
AT+FDEFAULT=RISINGHF
```

Return:

```
+FDEFAULT: OK
```

Item	Value
Mode	LoRaWAN ABP
Channel	3 default channels 868.1MHz 868.3MHz 868.5MHz
Datarate Range	DR0 : DR5
Unconfirmed Message Repetition	1
Confirmed Message Retry	3
Port	8
Datarate	DR0
ADR	ON
Power	14dBm
RXWIN2	869.525MHz, DR0
RXWIN1 Delay	1s
RXWIN2 Delay	2s
JOIN ACCEPT RXWIN1 Delay	5s
JOIN ACCEPT RXWIN2 Delay	6s
Listen Before Talk Threshold	-85dBm
EU868 Duty Cycle Limitation	OFF
LoRaWAN Public Network	ON
NwkSKey	2B7E151628AED2A6ABF7158809CF4F3C
AppSKey	2B7E151628AED2A6ABF7158809CF4F3C
AppKey	2B7E151628AED2A6ABF7158809CF4F3C
AppEui	52:69:73:69:6e:67:48:46
Uplink Counter	1
Downlink Counter	0
Multicast	OFF

Table 4-2 Factory default configuration

NOTE: Customized modem may be precompiled to use a different factory default configuration. If any user has request, please contact RisingHF support@risinghf.com.

4.22 DFU

Use to enter DFU mode. If user need to enter DFU mode to update LoRaWAN modem firmware, then user should first send "AT+DFU=ON" command to enable firmware upgrade. Once DFU mode is on, user should repower LoRaWAN modem (unplug and plug back), after repowered LoRaWAN will enter DFU mode, user could use DfuSe tool to update the firmware. If user want to exit DFU mode without upgrade, user just need to repower again, LoRaWAN modem will exit DFU mode automatically.

For UART bootloader, "AT+DFU=ON" command will make device enter bootloader mode automatically. For USB bootloader, after "AT+DFU=ON" command, user need restart device manually.

Format:

```
AT+DFU="New state"
eg: AT+DFU=ON            // Enable DFU function
eg: AT+DFU=OFF           // Disable DFU function
AT+DFU=?                 // Check if DFU is enabled configuration
```

Return:

```
+DFU: ON
+DFU: OFF
```

Example:

```
+DFU: ON
```

Note: DFU mode is risky. Before updating, user must make sure the firmware is supplied by RisingHF, a wrong firmware may brick LoRaWAN modem.

4.23 MODE

Use to select work mode. LWABP[17], LWOTAA[18], TEST are supported. LoRaWAN modem can only work with one mode at a time. By default, LWABP is enabled, all test commands are unavailable, LoRaWAN will return error(-12) if it receives test command in non-test mode.

"AT+MODE" command will reset LoRaWAN stack when first enter LWABP/LWOTTA mode and reset LoRa chip when first enter test mode.

LWABP/LWOTAA mode status is remembered by LoRaWAN modem, each time LoRaWAN modem starts, it will enter previous working mode before reset or repower.

Format:

```
AT+MODE="mode"
eg: AT+MODE=TEST                // Enter TEST mode
eg: AT+MODE=LWOTAA              // Enter LWOTAA mode
eg: AT+MODE=LWABP               // Enter LWABP mode
```

Return

```
+MODE: LWABP                    // Enter LWABP mode successfully
+MODE: LWOTAA                   // Enter LWOTAA mode successfully
+MODE: TEST                     // Enter TEST mode successfully
```

4.24 JOIN

When OTAA mode is enabled, JOIN command could use to join a known network.

Format:

```
AT+JOIN
AT+JOIN=FORCE
```

[17] *LWABP is short for LoRaWAN Activation By Personalization. Check < LoRaWAN™ Specification> for details*

[18] *LWOTAA is short for LoRaWAN Over-The-Air-Activation.*

1. Join

```
eg: AT+JOIN                          // Send JOIN request
```

2. Disconnect with current network, force send one JOIN request

```
eg: AT+JOIN=FORCE
```

3. Returns
   a) Join successfully

```
+JOIN: Starting
+JOIN: NORMAL
+JOIN: NetID 000024 DevAddr 48:00:00:01
+JOIN: Done
```

   b) Join failed

```
+JOIN: Join failed
```

   c) Join process is ongoing

```
+JOIN: LoRaWAN modem is busy
```

4.24.1 Auto Join

Format:

```
AT+JOIN=period                  // period: 0 - 172800s, 0 to disable auto jioin.
AT+JOIN=FORCE
```

1. Enable auto Join 1min

```
eg: AT+JOIN=60
```

2. Disable auto join

```
eg: AT+JOIN=0
```

In auto join mode host could still detect below format URC message to know device is connected

```
+JOIN: NetID 000024 DevAddr 48:00:00:01
+JOIN: Done
```

4.25 BEACON

4.25.1 AT+BEACON

Set beacon and ping slot configuration

```
AT+BEACON=periodicity,[DRx],[psfreq],[DRx,bfreq]      // Set beacon configuration
// periodicity: pingSlotPeriod factor (pingSlotPeriod = 2^periodicity seconds)
//         DRx: Data rate
//      psfreq: Ping slot frequency
//       bfreq: Beacon frequency
//          []: The field is omissible with all appended fields
```

Query beacon and ping slot configuration

```
AT+BEACON
  +BEACON: periodicity,DRx,psfreq,DRx,bfreq
```

4.25.2 AT+BEACON=DMMUL

Dummy uplink control. Before switching to Class B mode, dummy uplink is supported by device to get configuration information. By default, dummy uplink is turned off.

AT+BEACON=DMMUL,num,period

num: 0 to disable, others to enable exact number of dummy uplinks, 0 ~ 255
period: uplink period, 5 ~ 17280s
AT+BEACON=DMMUL, 0, 15

4.25.3 AT+BEACON=INFO

Get beacon description information. Includes NetID, GatewayID, Gateway Coordinate

AT+BEACON=INFO

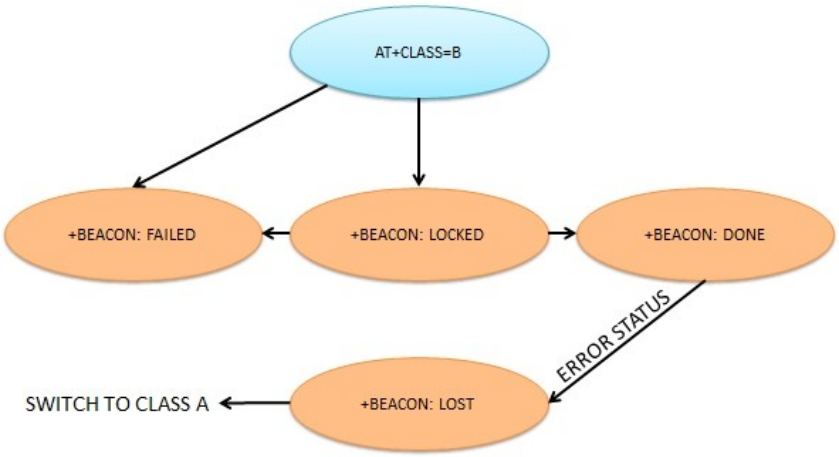
+BEACON: INFO, netid, gwid, longitude, latitude
netid: 3 bytes hex
gwid: 3 bytes hex
longitude: positive for east, negative for west. 123.124037 (East)
latitude: positive for north, negative for south. 89.002293 (North)

4.25.4 AT+BEACON=GWGPS

Get gateway GPS coordinate from last received beacon.

AT+BEACON=GWGPS
+BEACON: GWGPS, 123.124037, 89.002293
// 123.124037 Longitude (East)
// 89.002293 Latitude (North)

4.25.5 Switch to Class B mode



Command flow:

1. AT+CLASS=B
2. Wait +BEACON: LOCKED
3. Wait +BEACON: DONE
4. Device is now in Class B mode
5. When in Class B mode host should be responsible to monitor “+BEACON: LOST” event, when it occurs, which means device switch to Class A due to Beacon lost issue

6. If no beacon found during Class B switching process, “+BEACON: FAILED” is sent to host.
7. Current class mode is checkable through AT+CLASS command

Notification, will be triggered when the event occur.

```
+BEACON: LOCKED                    // Beacon found and synced
+BEACON: FAILED                    // Fail to switch to Class B
+BEACON: DONE                      // Success to switch to Class B
+BEACON: LOST                      // Beacon lost, switch back to Class A
```

4.25.5.1 ABP

Execute class switch AT command “AT+CLASS=B”, the modem will negotiate with server automatically.

```
AT+CLASS=B
```

When beacon is found, “+BEACON: LOCKED” message is notified.

```
+BEACON: LOCKED
```

When ping slot information is exchanged, “+BEACON: DONE” message is notified. At this time ping slots will be opened periodically

```
+BEACON: DONE
```

If there is not beacon is found in 128s, “+BEACON: FAILED” will be notified
If there is not beacon is found in 2 hour after beacon locked, “+BEACON: LOST” will be notified.

4.25.5.2 OTAA

Switch to OTAA mode.

```
AT+MODE=LWOTAA
```

Trigger AT+JOIN command to try to join the known LoRaWAN network.

```
AT+JOIN
```

Other information are the same as chapter 4.25.5.1 ABP.

4.26 CLASS

This command could enable LoRaWAN modem to work at different mode (Class A/B[19]/C). LoRaWAN modem works at class A mode when power on, user need manually switch mode to class B/C as needed.

Format:

```
eg: AT+CLASS=A                 // Enable Class A mode
eg: AT+CLASS=B                 // Enable Class B mode
eg: AT+CLASS=C                 // Enable Class C mode
```

Query class type:

```
AT+CLASS
```

[19] Class B is available in after 3.x.x version firmware

```
+CLASS: A
+CLASS: C
+CLASS: B
+CLASS: B (Sx)                  // Class B switching ongoing
```

4.26.1 Class C Downlink

Class C mode will reuse RXWIN2 configuration. Check with "AT+RXWIN2". If downlink is received, below message could be returned to host.

```
+MSG: FPENDING
+MSG: Link 20, 1
+MSG: ACK Received
+MSG: MULTICAST
+MSG: PORT: 8; RX: "12345678"
+MSG: RXWIN0, RSSI -106, SNR 4
+MSG: Done
```

4.26.2 Class B Downlink

Check with "AT+BEACON" current beacon and ping slot configuration. If downlink is received, below message could be returned to host. RXWIN3 stands for ping slot received packet.

```
+MSG: FPENDING
+MSG: Link 20, 1
+MSG: ACK Received
+MSG: MULTICAST
+MSG: PORT: 8; RX: "12345678"
+MSG: RXWIN3, RSSI -106, SNR 4
+MSG: Done
```

4.26.3 Class B Status

```
+CLASS: B (S0)                  // (Status 0, Beacon timing request)
+CLASS: B (S1)                  // (Status 1, Beacon searching)
+CLASS: B (S2)                  // (Status 2, Ping slot information request)
+CLASS: B (S3)                  // (Status 3, Failed)
+CLASS: B (S4)                  // (Status 4, Not synced)
+CLASS: B (S5)                  // (Status 5, Network not joined)
+CLASS: B (S6)                  // (Status 6, LoRaWAN is busy)
+CLASS: B (S7)                  // (Status 7, Send dummy uplink)
+CLASS: B                       // (Class B mode enabled)
```

4.27 DELAY

RX window delay configuration command. Supports configure RECEIVE_DELAY1, RECEIVE_DELAY2, JOIN_ACCEPT_DELAY1, JOIN_ACCEPT_DELAY2.

Command	Item	Comments
AT+DELAY=RX1, ms	RECEIVE_DELAY1	RX window 1 delay time
AT+DELAY=RX2, ms	RECEIVE_DELAY2	RX window 1 delay time
AT+DELAY=JRX1, ms	JOIN_ACCEPT_DELAY1	Join accept RX window 1 delay time
AT+DELAY=JRX2, ms	JOIN_ACCEPT_DELAY2	Join accept RX window 2 delay time

Table 4-3 LoRaWAN Delay Items

Format:

```
// Query delay settings
AT+DELAY
AT+DELAY?
AT+DELAY=?

// Set delay
AT+DELAY=RX1, 1000    // Unit: ms
AT+DELAY=RX2, 2000
AT+DELAY=JRX1, 5000
AT+DELAY=JRX2, 6000
```

Return:

```
+DELAY RX1, 1000
+DELAY RX2, 2000
+DELAY JRX1, 5000
+DELAY JRX2, 6000
```

4.28 LW

LW commands is a collection of several LoRaWAN control commands. Include CDR, ULDL, DC, NET, MC, THLD. BAT, TPS, SCR, JDC, LEN.

4.28.1 CDR

CDR command could be used to get current TX/RX available data rate range.

Format:

```
AT+LW=CDR, [ UL_DR_MIN, UL_DR_MAX, DL_DR_MIN, DL_DR_MAX ]
```

1. Check current datarate limitation

```
AT+LW=CDR
+LW: CDR, TXDR(0,7), RXDR(0,7)              //EU868
+LW: CDR, TXDR(0,4), RXDR(8,13)             //AU920
```

4.28.2 ULDL

Set and read uplink and downlink counter.

Format:

```
AT+LW=ULDL, UL_COUNTER, DL_COUNTER
```

1. Read counter

```
AT+LW=ULDL
+LW: ULDL 1, 0
```

2. Set counter

```
AT+LW=ULDL, 5, 10
+LW: ULDL 5, 10
```

4.28.3 DC

EU868 Duty Cycle limitation and LoRaWAN Transmit Duty Cycle control interface. This option is mandatory to be set to on, when using in Europe to follow ETSI regulation. And this command could

also be used to set a specify value for **MaxDCycle**, valid range 0 ~ 15. And the tansmit aggregated duty cycle is allowed by:

$$AggregatedDutyCylce = \frac{1}{2^{MaxDCycle}}$$

A value of 0 corresponds to “no duty cycle limitation” except the one set by the regional regulation.

MaxDCycle	$2^{MaxDCycle}$	Aggregated Duty Cycle
0	1	100.000%
1	2	50.000%
2	4	25.000%
3	8	12.500%
4	16	6.250%
5	32	3.125%
6	64	1.563%
7	128	0.781%
8	256	0.391%
9	512	0.195%
10	1024	0.098%
11	2048	0.049%
12	4096	0.024%
13	8192	0.012%
14	16384	0.006%
15	32768	0.003%

Table 4-4 Duty Cycle Control

Format:

```
AT+LW=DC, "ON/OFF"
AT+LW=DC, MaxDCycle
```

Return format:

```
+LW=DC, "ON/OFF", MaxDCycle
```

1. Check DC option

```
AT+LW=DC
+LW: DC, ON, 0            // EU868 Duty Cycle ON, MaxDCycle is 0
```

2. Set EU868 ETSI Duty Cycle on

```
AT+LW=DC, ON
+LW: DC, ON, 0            //
```

3. Set EU868 ETSI Duty Cycle off

```
AT+LW=DC, OFF
+LW: DC, OFF
```

4. Set LoRaWAN MaxDCycle

```
AT+LW=DC
+LW: DC, ON, 0     // EU868 Duty Cycle ON, MaxDCycle is 0
+LW: DC, OFF, 1    // EU868 Duty Cycle OFF or not in EU868 mode, MaxDCycle is 0
```

4.28.4 NET

This command is used to choose public LoRaWAN network or private network. Set ON to choose public network, set OFF to choose private network.

Format:

```
AT+LW=NET, "ON/OFF"
```

1. Check network type

```
AT+LW=NET
+LW: NET, ON
```

2. Set public network on

```
AT+LW=NET, ON
+LW: NET, ON
```

3. Set public network off

```
AT+LW=NET, OFF
+LW: NET, OFF
```

4.28.5 MC

MC command could enable an extra broadcast address for LoRaWAN modem. This command is useful when using Class B or C mode, to control a group of devices which has the same multi cast address at the same time to use a broadcast downlink command.

Format:

```
AT+LW=MC,["ON/OFF"],["DEVADDR"],["NWKSKEY"],["APPSKEY"],["COUNTER"]
```

1. Check multi cast status

```
AT+LW=MC
+LW: MC, OFF, 00cf3e72, 0
```

2. Set MC parameters

```
AT+LW=MC,ON,"11223344","2B7E151628AED2A6ABF7158809CF4F3C","2B7E151628AED2A6ABF7158809CF4F3C",0
+LW: MC, ON, 11223344, 0
```

Default MC_NWKSKEY and MC_APPSKEY both are ***2B7E151628AED2A6ABF7158809CF4F3C***.

4.28.6 THLD

Listen before talk threshold control, available value -1 ~ -140 (dBm).

Format:

```
AT+LW=THLD, thresh_hold
```

1. Check current threshold level

```
AT+LW=THLD
+LW: THLD, -90
```

2. Set new threshold

```
AT+LW=THLD, -85
+LW: THLD, -85
```

4.28.7 BAT

Set DevStatusReq/DevStatusAns battery level value. Available value 0 ~ 255

1. Check current threshold level

```
AT+LW=BAT
+LW: BAT, 255
```

2. Set new threshold

```
AT+LW=BAT, 100
```

```
+LW: BAT, 100
```

4.28.8 TPS

TPS command can be used to set default TX parameter. **UplinkDwellTime** and **DownlinkDwellTime** option is just for AS923. **MaxEIRP** is for all bands.

Format:

```
AT+LW=TPS
AT+LW=TPS, UplinkDwellTime, DownlinkDwellTime, MaxEIRP
UplinkDwellTime:     ON/OFF
DownlinkDwellTime:   ON/OFF
MaxEIRP:             0~15
```

Return:

```
+LW: TPS, UplinkDwellTime, DownlinkDwellTime, MaxEIRP
```

Example:

```
AT+LW=TPS, ON, ON, 7
+LW: TPS, ON, ON, 7
```

4.28.9 SCR

SCR (Sequence counter Checking Relaxed) command could be used to disable strict downlink frame counter checking. Which is useful for some application, especially in the case which server can't reset downlink counter automatically.

Format:

```
AT+LW=SCR
AT+LW=SCR, ON
AT+LW=SCR, OFF
```

Return

```
+LW: SCR, OFF
+LW: SCR, ON
```

NOTE: If SCR is enabled, there may be security issue, if some recorder downlink and replay back to your device.Be careful to use this command.
NOTE: If SCR is enabled by default since firmware v2.1.16, disable it if you need more security.

4.28.10 JDC

JDC command could be used to disable the JoinRequest duty cycle limitation.

Format:

```
AT+LW=JDC
AT+LW=JDC, OFF
AT+LW=JDC, ON
```

Return:

```
+LW: JDC, ON
+LW: JDC, OFF
```

4.28.11 CT

CT command can be used to enable or disable strict lorawan compliance test mode. When disabled AT modem will optimize several lorawan features to make it more usable for application. By default It is disabled.

Format:

```
AT+LW=CT
AT+LW=CT, ON
AT+LW=CT, OFF
```

Return:

```
+LW: CT, ON
+LW: CT, OFF
```

Index	Description
1	Downlink ACK of Confirmed uplink is no need to check, any valid downlink will terminate the confirmed downlink transaction.
2	When under ADR off mode, LinkAdrReq Datarate and TxPower configuration will be ignored and keep settings unchanged. And will reply always ACK
3	CN470/US915/AU915 band supports to use DlChannelReq command to configure downlink channel frequency
4	EU868 band is available to configure out of range channels to make customized band plans
5	

4.28.12 LEN

LEN command can be used to get maximum payload length which is supported to send according to current data rate.

Format:

```
AT+LW=LEN
```

Return:

```
+LW: LEN, 50
```

*Note: If "AT+LW=LEN" returns 0 length. User must send a dummy **AT+MSG** command to flush the internal MAC command buffer. And continue to send more data.*

4.28.13 VER

Note: don't change unless you know what you are doing.

Switch LoRaWAN protocol version.

Format:

```
AT+LW=VER, Vxx
```

Version	Description
V10	See V102
V101	See V102
V102	Legacy LoRaWAN 102, Class B beacon is in UTC epoch format, beacon timing will be influenced by leap second, class B of V102 is deprecated. Protocol: LoRaWAN102-20161012_1398_1.pdf Regional Parameter: LoRaWANRegionalParametersv1.0.2_final_1944_1.pdf
V102B	Default setting. LoRaWAN alliance recommended Class B protocol. Protocol: LoRaWAN1.0.2_classB_draft4-clean.pdf

	Regional Parameter: LoRaWANRegionalParametersv1.0.2_final_1944_1.pdf
V103	Latest LoRaWAN alliance v1.0.x protocol. Protocol: lorawan1.0.3_final.pdf Regional Parameter: LoRaWAN Reginal Parameters v1.0.3 revA.pdf
V102ALPHA	The only difference between V102ALPHA and V102B is V102B use DeviceTimeReq to sync time with NS, but V102ALPHA use BeaconTimingReq. Protocol: LoRaWAN102-20161012_1398_1.pdf + LoRaWAN1.1_draft_30.pdf (Class B Section) Regional Parameter: LoRaWANRegionalParametersv1.0.2_final_1944_1.pdf
V11	Not supported yet Protocol: LoRaWAN-v1.1.pdf(October 11, 2017) Regional Parameter: LoRaWAN-Regional-Parameters-v1.1rA.PDF(October 11, 2017)

Example:

```
AT+LW=VER,V102B
+LW: VER, V102B
```

4.28.14 DTR

Buffer DeviceTimeReq MAC command for AT modem, the MAC command will be sent in next LoRaWAN transaction controlled by command **MSG/CMSG/MSGHEX/CMSGHEX**

Format:

```
AT+LW=DTR
```

It is recommended to use MSGHEX and CMSGHEX to carry this command if there is no application payload to send.

4.28.15 LCR

Buffer LinkCheckReq MAC command for AT modem, the MAC command will be sent in next LoRaWAN transaction controlled by command **MSG/CMSG/MSGHEX/CMSGHEX**

Format:

```
AT+LW=LCR
```

It is recommended to use MSGHEX or CMSGHEX to carry this command if there is no application payload to send.

4.28.16 LDRO

This command could be used to configure Low Data Rate Optimize option. Which supports 3 status, AUTO, ON and OFF. Default mode is AUTO. (Note: this conjuration is not memorable, it is set to AUTO mode when power on or reset)

Format:

```
AT+LW=LDRO
AT+LW=LDRO,AUTO
AT+LW=LDRO,ON
AT+LW=LDRO,OFF
```

Example:

```
AT+LW=LDRO
+LW: LDRO, AUTO
```

AUTO mode: (LoRaWAN configuration)

Data Rate	Low Data Rate Optimize
SF11/BW125	ON
SF12/BW125	ON
SF12/BW250	ON
Others	OFF

Use in LoRaWAN mode:

1. Run **AT+LW=LDRO** command
2. It will effect in next transaction (Class A uplink and RX windows, or Class B beacon and ping windows)

Use in TEST mode:

1. Run **AT+LW=LDRO** command
2. Run "**AT+LW=RFCFG,freq,sf**" command to effect it.

Example:

1. **AT+MODE=TEST**
2. **AT+LW=LDRO,ON**
3. **AT+TEST=RFCFG,freq,sf,bw,….**
4. **AT+TEST=TXLRPKT** to send packet or **AT+TEST=RXLRPKT** to receive

Note: If LDRO option is not matched between TX and RX, then on receiver side it probably can't receive packet or receive damaged packet

4.28.17 DCMRX

DCMRX could be used to disable Confirmed Message RX window to speed up uplink period for Gateway or Server test purpose

Format:

AT+LW=DCMRX
AT+LW=DCMRX,ON
AT+LW=DCMRX,OFF

Example:

AT+LW=DCMRX
+LW: DCMRX, ON

4.28.18 DUMRX

DUMRX could be used to disable Unconfirmed Message RX window to speed up uplink period for through output uplinks to server in short time to optimize application power consumption and efficiency.

Format:

AT+LW=DUMRX
AT+LW=DUMRX,ON
AT+LW=DUMRX,OFF

Example:

AT+LW=DUMRX
+LW: DUMRX, ON

4.28.19 AFPACK

AFPACK could be enabled to make the AT modem Auto ACK FPending bit to ease the end-device design. When enabled device will wait to timeout if FPending bit is set

Format:

```
AT+LW=AFPACK
AT+LW=AFPACK,0                  // disable AFPACK function
AT+LW=AFPACK,1~172800           // enable AFPACK, and set timeout to N seconds
```

Example:

```
AT+LW=AFPACK
+LW: AFPACK, 0~172800
```

4.28.20 CHRB

CHRB can be set to enable or disable channel configuration roll back features. Channel roll back feature in standard LoRaWAN protocol could complex the server and end-device design and could lead to channel configuration non-synced issue. It is recommended to set CHRB OFF to disable channel roll back feature (Default setting).

Format:

```
AT+LW=CHRB
AT+LW=CHRB,OFF                  // disable AFPACK function
AT+LW=CHRB,ON                   // enable AFPACK, and set timeout to N seconds
```

Example:

```
AT+LW=CHRB
+LW: CHRB, OFF
```

4.29 WDT

WDT command can be used to turn on/off internal watchdog. The watchdog is on by default, this will enhance the module stability, especially under the condition of severe electromagnetic environment. After WDT is turned on, the sleep current will be increased by around 0.7uA.

Format:

```
AT+WDT
AT+WDT=ON
AT+WDT=OFF
```

Return:

```
+WDT: ON
+WDT: OFF
```

4.30 LOWPOWER[20]

Sleep command could be used to make modem enter sleep mode with ultra-low power consumption, check device datasheet to know detailed parameters. After device enters in sleep mode, host device could send any character to wakeup it, after this host should wait at least 5ms to send next commands, so that modem could get ready. A C code example is attached to show how to handle LOWPOWER mode.

[20] RHF76-052AM (UART enabled) supports this feature, RHF3M076B (USB enabled) doesn't support sleep mode.

During the LOWPOWER mode, level of UART RX pin must keep unchanged, any signal on UART RX pin will make modem exit LOWPOWER mode. When LOWPOWER mode is triggered, there are extra 30ms before modem really enter sleep mode, host device should use this time to de-initial its UART if it is needed.
It also supplies feature to set a lowpower alarm from 100ms to 129600000ms (36hrs).

Format:

```
eg: AT+LOWPOWER                    // Sleep until woke up by UART TX
eg: AT+LOWPOWER=1000[21]           // Sleep 1000ms until timeout
eg: AT+LOWPOWER=AUTOON             // Enter extremely low power mode
eg: AT+LOWPOWER=AUTOOFF[22]        // Exit extremely low power mode
                                   // Query symbol is not available
```

Return

```
+LOWPOWER: SLEEP                   // Enter SLEEP mode successfully
+LOWPOWER: WAKEUP                  // Modem is woke up.
```

Example:

```
AT+LOWPOWER=1000
+LOWPOWER: WAKEUP
```

Note: Extra 0x55 will be sent to host mcu to perform a wakeup signal for it, LoRaWAN AT Modem will wait for 15ms before sending “+LOWPOWER: WAKEUP” frame , host MCU could use this 15ms to initialize then to receive the WAKEUP frame.

C example:

```
printf("AT+LOWPOWER\r\n");// Set low-power mode
// ...
// HOST do other operation.
// ...
printf("A");              // Send any character to wake-up the modem
DelayMs(5);               // Wait modem ready
printf("AT+ID\r\n");      // New operation
```

4.30.1 Low Power Auto Mode

AT+LOWPOWER=AUTOON command could be used to enable extremely low power mode. In this mode modem will enter deep sleep mode when it is idle. The idle status means no ongoing receiving commands, no ongoing LoRaWAN service needed. If this mode is enabled, when sending commands to modem, at least four 0xFFs need to be added to the start of each AT command. At the same time, each return message is also added with four 0xFFs. The host mcu parser should be able to handle these wakeup characters.

.

Example to send AT+ID command with low power auto mode

0xFF	0xFF	0xFF	0xFF	‘A’	‘T’	‘+’	‘I’	‘D’	‘\r’	‘\n’

Use AT+LOWPOWER=AUTOOFF command to turn off low power auto mode, four 0xFFs are also needed to add to the start of the command.

[21] Available after v1.9.5

[22] It is better to use AT+LOWPOWER=AUTOOFF always with heading 0xFFs

FF	FF	FF	FF	A	T	+	L	O	W	P	O	W	E	R	=	A	U	T	O	O	F	F	\r	\n
FF	FF	FF	FF	61	74	2B	6C	6F	77	70	6F	77	65	72	3D	61	75	74	6F	6F	66	66	0D	0A

Below hex string equals to the table above, send it to modem in hex format could also disable the low power auto on feature.

FFFFFFFF61742B6C6F77706F7765723D6175746F6F66660D0A

C example:

```
uint8_t buf[256];
printf("AT+LOWPOWER=AUTOON\r\n");// Set low-power auto on mode
// ...
// HOST do other operation.
// ...
buf[0] = 0xFF;
buf[1] = 0xFF;
buf[2] = 0xFF;
buf[3] = 0xFF;
//DelayMs(5); // If user use higher baud rate than 9600, uncomment this line
sprintf(buf+4, "AT+MSG=\"string\"\r\n");
uart_putbuf(buf, strlen(buf+4)+4); // Send command to LoRaWAN modem
```

4.31 VDD

Get supply voltage, return value in unit 0.01V. Format:

AT+VDD

AT+VDD?

AT+VDD=?

Example:

AT+VDD

+VDD: 3.30V

4.32 TEMP

Get temperature, return value in unit °C. Format:

AT+TEMP

AT+TEMP?

AT+TEMP=?

Example:

AT+TEMP

+TEMP: 20.5

Note: Temperature command returns temperature sensed by on chip sensor which gives precision about +/-5°C in worst case, this feature provides a cheap temperature measurement solution for low precision application

4.33 RTC

Get real time from LoRaWAN modem. When modem is powered on, it always starts from 2000-01-01 00:00:00, user could set new time to modem to sync to the real time.

1. Check current time

```
AT+RTC
+RTC: 2000-01-01 01:00:28     // this means the modem has kept running for 1 hour
```

2. Set new time to "2016-06-14 18:16:11", this format is very critical, must keep the same format as “yyyy-MM-dd HH:mm:ss”, year must starts with 20xx.

```
AT+RTC="2016-06-14 18:16:11"
+RTC: 2016-06-14 18:16:11
```

3. Get time zone

```
AT+RTC=ZONE
+RTC: ZONE, +00:00
```

4. Set time zone

```
AT+RTC=ZONE, "+08:00"
+RTC: ZONE, +00:00
```

5. Get verbose RTC time

```
AT+RTC=FULL
+RTC: YY-MM-DD hh:mm:ss UTCshh:mm, epoch, age
UTCshh:mm: s -> -/+, hh -> hour, mm -> minute
epoch: GPS epoch (if LoRaWAN V102 is enabled it is in UTC epoch[23])
age: device start up age in second (AT+RESET / POWER ON / WDT Reset clears age to 0)
```

6. Check Leap seconds setting

```
AT+RTC=LEAPSEC
+RTC: LEAPSEC, 37
```

7. Set new leap seconds

```
AT+RTC=LEAPSEC,37
+RTC: LEAPSEC, 37
```

4.33.1 Time Synchronization

When modem is powered on, it always starts from 2000-01-01 00:00:00, there are 3 ways for user to sync real time:

- user could set new time to modem to sync to the real time.
- Use AT+LW=DTR command trigger DeviceTimeReq to sync time manually
  - LoRaWAN V102B or higher protocol
- In class B mode, time will be synchronized with beacon automatically

4.33.2 Leap second

Check http://www.ietf.org/timezones/data/leap-seconds.list to know the leap second list. As of this document (year 2017), there has been 37 leap seconds ever. The firmware has preset this value to calculate the UTC time. In the future, more leap seconds will occur, at that time user should update the leap second to real one so that AT+RTC command returns right time.

4.33.3 Time Zone

AT+RTC=ZONE command can be used to set time zone. Default set to UTC+00:00.

[23] UTC epoch is already deprecated by LoRa Alliance due to the leap second issue, however AT modem keeps this mode for users whose LoRaWAN server still doesn’t support GPS epoch

4.34 EEPROM

LoRaWAN Modem supports maximum 256 bytes to save user data. Format:

```
AT+EEPROM=ADDR
AT+EEPROM=ADDR,VAL
```

Return:

```
+EEPROM: ADDR, VAL
```

Both ADDR and VAL are in hex format. Valid range is 0x00 ~ 0xFF. Example:

```
AT+EEPROM=00, AB
+EEPROM: 00, AB
```

4.35 UART

4.35.1 TIMEOUT

LoRaWAN AT modem supports UART receive timeout feature, AT parser inside the modem start counts from first "AT" character is received, when counter overflows, a "Input timeout" event will be triggered. One message like below will be showed. Maximum timeout value is 300ms.

```
+INFO: Input timeout

AT+UART=TIMEOUT, 0              // Disable timeout feature
AT+UART=TIMEOUT, 1000           // Set timeout 1s feature
AT+UART=TIMEOUT                 // Get timeout value
```

4.35.2 BR

BR command could be used to set new baud rate. Available baud rate are 9600 14400 19200 38400 57600 76800 115200 and 230400. New baud rate will be validated after reset or repower.

Format:

```
AT+UART=BR
AT+UART=BR, br
```

Return:

```
+UART=BR, br
```

4.36 TEST

TEST command is not like other command, it is a serious command, includes several sub-commands, refer to table below. With test mode, user could do RF performance test quickly without any knowledge of LoRa chip. Commands which are related to RF configuration is disabled in test mode.

Sub-Command	Comment
STOP	Set LoRaWAN Modem to TEST stop mode
TXCW	Transmit continuous wave
TXCLORA	Transmit continuous LoRa signal
RFCFG	Set RF configuration in TEST mode
RXLRPKT	Continuous receive pure LoRa packet, print once there is new packet received
TXLRPKT	Send one HEX format packet out
TXLRSTR	Send one string format packet
RSSI	Get RSSI value of specified channel
LWDL	Send LoRaWAN downlink packet, useful tool to test CLASS C device

Table 4-5 TEST mode sub-command list

4.36.1 Help Information

```
      STOP -- AT+TEST=STOP
      HELP -- AT+TSET=HELP
       TXCW -- AT+TEST=TXCW
   TXCLORA -- AT+TEST=TXCLORA
     RFCFG -- AT+TEST=RFCFG,[F],[SF],[BW],[TXPR],[RXPR],[POW],[CRC],[IQ],[NET]
  RXLRPKT -- AT+TEST=RXLRPKT
  TXLRPKT -- AT+TEST=TXLRPKT,"HEX"
  TXLRSTR -- AT+TEST=TXLRSTR,"TEXT"
     RSSI -- AT+TEST=RSSI,F,[CNT]
     LWDL -- AT+TEST=LWDL,TYPE,DevAddr,"HEX",[FCNT],[FPORT],[FCTRL]
```

"[ ]" means the parameter is omissible together with parameters behind it

4.36.2 Enter TEST mode

Before use any TEST command, LoRaWAN should work in test mode, or error code -12 will be reported.

Command:

```
AT+MODE=TEST
```

Return:

```
+MODE: TEST                 // LoRaWAN modem enter TEST mode successfully
```

4.36.3 Query RF configuration

First thing after enter TEST mode should be check RF configuration.

Command:

```
AT+TEST=?                  // Query test mode and RF configuration
```

Return Error:

```
+TEST: ERROR(-12)
```

When come with ERROR(-12), user could try "AT+MODE=?" to check if LoRaWAN modem is in TEST mode, if not user should enter test mode first.

Return STOP:

```
+TEST: STOP
+TEST: RFCFG F:433300000, SF12, BW125K, TXPR:8, RXPR:8, POW:14dBm, CRC:ON, IQ:OFF,
NET:ON
```

Return TXLRPKT:

```
+TEST: TXLRPKT
+TEST: RFCFG F:433300000, SF12, BW125K, TXPR:8, RXPR:8, POW:14dBm, CRC:ON, IQ:OFF,
NET:ON
```

Return RXLRPKT:

```
+TEST: RXLRPKT
+TEST: RFCFG F:433300000, SF12, BW125K, TXPR:8, RXPR:8, POW:14dBm, CRC:ON, IQ:OFF,
NET:ON
```

Return TXCW:

```
+TEST: TXCW
+TEST: RFCFG F:433300000, SF12, BW125K, TXPR:8, RXPR:8, POW:14dBm, CRC:ON, IQ:OFF,
NET:ON
```

4.36.4 Set RF Configuration

RFCFG supports set frequency, SF, band width, TX preamble, RX preamble and TX power settings. TX and RX shares all configuration except "preamble length", user could choose different preamble length. For LoRa communication, it is strongly recommended to set RX preamble length longer than TX's. Bandwidth only supports 125KHz / 250KHz / 500KHz.

Depend on Semtech SX1276 (PA_BOOST/RFO) and design solution of RisingHF module, MAX output power of different band LoRaWAN modem could be different. Check below table about the details.

Device	Bootloader	Interface	LF Band[24]	HF Band[25]
RHF76-052AM	UART	UART	20dBm	14dBm
RHF76-052CM	UART	UART	-	20dBm
RHF76-052DM	UART	UART	20dBm	14dBm
RHF78-052AM	UART	UART	20dBm	-
RHF3M076B	USB	USB	20dBm	14dBm

Table 4-6 MAX output power of HF and LF band

Format:

"[ ]" means the parameter is omissible together with parameters after it

```
AT+TEST=RFCFG,[FREQUENCY],[SF],[BANDWIDTH],[TX PR],[RX PR],[TX POWER],[CRC],[IQ],[NET]
eg: AT+TEST=RFCFG,866,SF12,125,12,15,14,ON,OFF,OFF
FREQUENCY:      866MHz
SpreadFactor:   SF12
```

[24] LF Band: Frequency is less than 525MHz

[25] HF Band: Frequency is larger than 525MHz

```
BandWidth:        125KHz
TX Preamble:      12
RX Preamble:      15
Power:            14dBm
CRC:              ON
Inverted IQ:      OFF
Public LoRaWAN:   OFF
```

Return:

```
+TEST: RFCFG F:868100000, SF12, BW125K, TXPR:8, RXPR:8, POW:14dBm, CRC:ON, IQ:OFF, PNET:ON
```

4.36.5 TX LoRa Packet

After enter test mode, user could send LoRa packet through "AT+TEST=TXLRPKT" sub-command. The command format is like below:

```
AT+TEST=TXLRPKT, "HEX STRING"
```

Command sequence to send LoRa packet:

```
// Set test mode
AT+MODE=TEST
// Query test mode, check RF configuration
AT+TEST=?
// Set RF Configuration
AT+TEST=RFCFG,[FREQUENCY],[SF],[BANDWIDTH],[TXPR],[RXPR],[POW],[CRC],[IQ],[NET]
// Send HEX format packet
AT+TEST=TXLRPKT, "HEX String"
eg:AT+TEST=TXLRPKT, "00 AA 11 BB 22 CC"
// Send TEXT format packet
AT+TEST=TXLRSTR, "TEXT"
eg:AT+TEST=TXLRSTR, "LoRaWAN Modem"
```

Return:

```
+TEST: TXLRPKT “404EA99000800A00089F6E770959”
+TEST: TXLRSTR "LoRaWAN Modem"
+TEST: TX DONE
```

4.36.6 RX LoRa Packet

After enter test mode, user could enter LoRa packet continuous RX mode through RXLRPKT sub-command. Like below:

```
AT+TEST=RXLRPKT
```

Command sequence to receive LoRa packet:

```
// Set test mode
AT+MODE=TEST
// Query test mode, check RF configuration
AT+TEST=?
// Set RF Configuration
AT+TEST=RFCFG,[FREQUENCY],[SF],[BANDWIDTH], [TXPR],[RXPR],[POW],[CRC],[IQ],[NET]
// Enter RX continuous mode
```

```
AT+TEST=RXLRPKT
```

Return:

```
+TEST: LEN:250, RSSI:-106, SNR:10
+TEST: RX 404EA99000800A00089F6E770959
```

4.36.7 TX Continuous Wave

Before enable TXCW function, right frequency and TX power should be set. Format:

```
AT+TEST=TXCW
```

Return:

```
+TEST: TXCW
```

4.36.8 TX Continuous LoRa

Before enable TXCLORA function, right frequency and TX power should be set. Format:

```
AT+TEST= TXCLORA
```

Return:

```
+TEST: TXCLORA
```

4.36.9 RSSI

Read RSSI from a specified channel. Format:

```
AT+TEST = RSSI, frequency(MHz), [times]
```

Return:

```
+TEST: RSSI, average, maximum, minimum
```

4.36.10 LWDL

LWDL command is designed to test LoRaWAN modem CLASS C function. Use this command, user can easily send data to a working LoRaWAN Class C device.

```
AT+TEST = LWDL, TYPE, "DevAddr", "HEX STRING", [FCNT], [FPORT], [FCTRL]
FCNT: HEX
FPORT: Decimal
FCTRL: HEX
```

Return:

```
AT+TEST=LWDL,MSG,"009291ad","14 54 54 88 08 93 122 35", 1, 5, 00
+TEST: LWDL "A0AD919200000010005134D37EA53E3023A9F0125D234"
+TEST: LWDL TX DONE
```

Note: Must use AT+TEST=RFCFG command to set CRC OFF, IQ ON, NET ON before sending LoRaWAN downlink.

4.36.1 Beacon Sniffer

AT+TEST=BEACON command can be used to set AT modem into beacon sniffer mode, which could be useful for server and gateway designer to debug beacon timing.

Format:

```
AT+TEST=BEACON
+TEST: BEACON
```

When beacon is received one beacon message is returned to host controller.

```
+TEST: BEACON, ms, payload, rssi, snr, ticks, vdd, temp
      ms: beacon received time in ms
 payload: hex string
    rssi: unit dBm
     snr: unit dB
   ticks: unit 8192Hz
     vdd: unit 0.01V
    temp: unit 0.01°C
```

Before use Beacon, user also need use AT+TEST=RFCFG command to set CRC OFF, IQ OFF, NET ON, and use AT+DR=band to select correct band, use AT+LW=VER command to select correct LoRaWAN protocol.

Command flow to sniff EU868 beacon:

```
AT+DR=EU868
AT+LW=VER,102B
AT+MODE=TEST
AT+TEST=RFCFG, 869.525, SF9, 125, 8, 8, 20, OFF, OFF, ON
AT+TEST=BEACON
+TEST: BEACON, 232509, 0000804D67475A2800000000000000000000, -66, 5, 1905042, 320, 2197
+TEST: BEACON, 232509, 0000804D67475A2800000000000000000000, -66, 5, 1905042, 320, 2197
+TEST: BEACON, 360509, 0000004E674732AC000000000000000000, -66, 5, 2953807, 319, 2187
+TEST: BEACON, 488510, 0000804E67470A7100000000000000000000, -66, 5, 4002572, 319, 2223
+TEST: BEACON, 616511, 0000004F6747029B000000000000000000, -66, 4, 5051336, 319, 2223
+TEST: BEACON, 744512, 0000804F67473A4600000000000000000000, -66, 5, 6100101, 319, 2205
```

Note: For beacon frequency hopping band like US915/CN470/AU915, BEACON sniffer mode can only sniff a single selected channel.

4.37 LOG

LOG command is for user debugging purpose, after log is enabled, AT modem will returns extra log message to host controller, check these log could help user locate issue quickly when it happens. Log is turned by default.

Format:

```
AT+LOG=level       // DEBUG/INFO/WARN/ERROR/FATAL/PANIC/QUIET
```

Enable log:

```
AT+LOG=DEBUG
```

Disable log:

```
AT+LOG=QUIET
```

Note: if log is enabled it will takes extra energy, for low power application it is recommended to turn off log.

5 Class A/B/C and A/C Different Command

Class A/B/C(v3.1.x) firmware is designed to be backward compatible with Class A/C firmware (v2.1.x), and add new commands to support LoRaWAN class B.

Command
AT+LW=VER
AT+LW=DTR
AT+LW=LCR
AT+LW=LDRO
AT+LW=DCMRX
AT+LW=DUMRX
AT+LW=AFPACK
AT+LW=CHRB
AT+JOIN=time
AT+CMSGHEX (send empty payload)
AT+MSGHEX (send empty payload)
AT+RTC=ZONE
AT+RTC=LEAPSEC
AT+RTC=FULL
AT+TEMP
AT+CLASS=B
AT+BEACON
AT+BEACON=GWGPS
AT+BEACON=INFO
AT+BEACON=DMMUL
AT+TEST=BEACON
AT+LOG

Revision

V1.2 2018-12-15
+ Added V1.0.3 support
+ Added AT+LW=DCMRX
+ Added AT+LW=DUMRX
+ Added AT+LW=AFPACK
+ Added AT+LW=CHRB
+ Added AT+JOIN=time (auto sendding JoinRequest)
+ Added new part number:
  RHF76-052CL
  RHF0M003-LF20
  RHF0M003-HF20
  RHF0M010-LF20
  RHF0M010-HF20
  RHF0M062-LF22
  RHF0M062-HF22
+ AT+MSGHEX and AT+CMSGHEX to send empty payload packet
+ Fixed various typos
+ Sync LoRaWAN at modem 3.5.x

V1.1 2018-03-15
+ Added AT+LW=LDRO
+ Sync version 3.2.2

V1.0 2017-12-22
+ Extract AT command from PS01509 v4.4
+ Added AT+LW=VER
+ Added AT+LW=DTR
+ Added AT+LW=LCR
+ Added AT+RTC=ZONE
+ Added AT+RTC=LEAPSEC
+ Added AT+RTC=FULL
+ Added AT+TEMP
+ Added AT+CLASS=B
+ Added AT+BEACON
+ Added AT+TEST=BEACON
+ Added AT+LOG
+ Added Class B band plan description

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