

1
2 **LoRaWAN Regional Parameters**

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LoRaWAN™ Regional Parameters

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1 Introduction

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This document describes the LoRaWAN™ regional parameters for different regulatory regions worldwide. This document is a companion document to the protocol specification document, LoRaWAN Specification [LORAWAN], starting with version 1.0.2 of the specification. Separating the regional parameters from the protocol specification allows the addition of new regions to the former without impacting the latter document.

2 LoRaWAN Regional Parameters

2.1 EU 863-870MHz ISM Band

2.1.1 EU863-870 Preamble Format

The following synchronization words should be used:

Modulation	Sync word	Preamble length
LORA	0x34	8 symbols
GFSK	0xC194C1	5 bytes

Table 1: EU863-870 synch words

2.1.2 EU863-870 ISM Band channel frequencies

This section applies to any region where the ISM radio spectrum use is defined by the ETSI [EN300.220] standard.

The network channels can be freely attributed by the network operator. However the three following default channels must be implemented in every EU868MHz end-device. Those channels are the minimum set that all network gateways should always be listening on.

Modulation	Bandwidth [kHz]	Channel Frequency [MHz]	FSK Bitrate or LoRa DR / Bitrate	Nb Channels	Duty cycle
LoRa	125	868.10 868.30 868.50	DR0 to DR5 / 0.3-5 kbps	3	<1%

Table 2: EU863-870 default channels

In order to access the physical medium the ETSI regulations impose some restrictions such maximum time the transmitter can be on or the maximum time a transmitter can transmit per hour. The ETSI regulations allow the choice of using either a duty-cycle limitation or a so-called **Listen Before Talk Adaptive Frequency Agility** (LBT AFA) transmissions management. The current LoRaWAN specification exclusively uses duty-cycled limited transmissions to comply with the ETSI regulations.

EU868MHz ISM band end-devices should use the following default parameters

- Default ERP: 14 dBm

EU868MHz end-devices should be capable of operating in the 863 to 870 MHz frequency band and should feature a channel data structure to store the parameters of at least 16 channels. A channel data structure corresponds to a frequency and a set of data rates usable on this frequency.

The first three channels correspond to 868.1, 868.3, and 868.5 MHz / DR0 to DR5 and must be implemented in every end-device. Those default channels cannot be modified through the **NewChannelReq** command and guarantee a minimal common channel set between end-devices and network gateways.

The following table gives the list of frequencies that should be used by end-devices to broadcast the JoinReq message. The JoinReq message transmit duty-cycle shall follow the

1 rules described in chapter “Retransmissions back-off” of the LoRaWAN specification
 2 document.

Modulation	Bandwidth [kHz]	Channel Frequency [MHz]	FSK Bitrate or LoRa DR / Bitrate	Nb Channels
LoRa	125	868.10 868.30 868.50	DR0 – DR5 / 0.3-5 kbps	3

4 **Table 3: EU863-870 JoinReq Channel List**

5 **2.1.3 EU863-870 Data Rate and End-device Output Power encoding**

6 There is no dwell time limitation for the EU863-870 PHY layer. The *TxParamSetupReq*
 7 MAC command does not have to be implemented by EU863-870 devices.

8 The following encoding is used for Data Rate (DR) and End-device Output Power (TXPower)
 9 in the EU863-870 band:

DataRate	Configuration	Indicative physical bit rate [bit/s]
0	LoRa: SF12 / 125 kHz	250
1	LoRa: SF11 / 125 kHz	440
2	LoRa: SF10 / 125 kHz	980
3	LoRa: SF9 / 125 kHz	1760
4	LoRa: SF8 / 125 kHz	3125
5	LoRa: SF7 / 125 kHz	5470
6	LoRa: SF7 / 250 kHz	11000
7	FSK: 50 kbps	50000
8..15	RFU	

11 **Table 4: TX Data rate table**

TXPower	Configuration (ERP)
0	20 dBm
1	14 dBm
2	11 dBm
3	8 dBm
4	5 dBm
5	2 dBm
6..15	RFU

13 **Table 5: TX power table**

15 **2.1.4 EU863-870 JoinAccept CFList**

16

17 The EU 863-870 ISM band LoRaWAN implements an optional **channel frequency list**
 18 (CFList) of 16 octets in the JoinAccept message.

1 In this case the **CFList** is a list of five channel frequencies for the channels four to eight
 2 whereby each frequency is encoded as a 24 bits unsigned integer (three octets). All these
 3 channels are usable for DR0 to DR5 125kHz LoRa modulation. The list of frequencies is
 4 followed by a single RFU octet for a total of 16 octets.

5

Size (bytes)	3	3	3	3	3	1
CFList	Freq Ch4	Freq Ch5	Freq Ch6	Freq Ch7	Freq Ch8	RFU

6 The actual channel frequency in Hz is 100 x frequency whereby values representing
 7 frequencies below 100 MHz are reserved for future use. This allows setting the frequency of
 8 a channel anywhere between 100 MHz to 1.67 GHz in 100 Hz steps. Unused channels have
 9 a frequency value of 0. The **CFList** is optional and its presence can be detected by the
 10 length of the join-accept message. If present, the **CFList** replaces all the previous channels
 11 stored in the end-device apart from the three default channels as defined in Chapter **Error!**
 12 **Reference source not found..** The newly defined channels are immediately enabled and
 13 usable by the end-device for communication.

14 2.1.5 EU863-870 LinkAdrReq command

15 The EU863-870 LoRaWAN only supports a maximum of 16 channels. When **ChMaskCntl**
 16 field is 0 the ChMask field individually enables/disables each of the 16 channels.

17

ChMaskCntl	ChMask applies to
0	Channels 1 to 16
1	RFU
..	..
4	RFU
5	RFU
6	All channels ON The device should enable all currently defined channels independently of the ChMask field value.
7	RFU

18

Table 6: ChMaskCntl value table

19 If the ChMaskCntl field value is one of values meaning RFU, the end-device should reject
 20 the command and unset the “**Channel mask ACK**” bit in its response.

21 2.1.6 EU863-870 Maximum payload size

22 The maximum **MACPayload** size length (M) is given by the following table. It is derived from
 23 limitation of the PHY layer depending on the effective modulation rate used taking into
 24 account a possible repeater encapsulation layer. The maximum application payload length in
 25 the absence of the optional **FOpt** control field (N) is also given for information only. The
 26 value of N might be smaller if the **FOpt** field is not empty:

27

DataRate	M	N
0	59	51
1	59	51
2	59	51
3	123	115
4	230	222
5	230	222

6	230	222
7	230	222
8:15	Not defined	

Table 7: EU863-870 maximum payload size

If the end-device will never operate with a repeater then the maximum application payload length in the absence of the optional **FOpt** control field should be:

DataRate	M	N
0	59	51
1	59	51
2	59	51
3	123	115
4	250	242
5	250	242
6	250	242
7	250	242
8:15	Not defined	

Table 8 : EU863-870 maximum payload size (not repeater compatible)

2.1.7 EU863-870 Receive windows

The RX1 receive window uses the same channel than the preceding uplink. The data rate is a function of the uplink data rate and the RX1DROffset as given by the following table. The allowed values for RX1DROffset are in the [0:5] range. Values in the [6:7] range are reserved for future use.

RX1DROffset Upstream data rate	0	1	2	3	4	5
	Downstream data rate in RX1 slot					
DR0	DR0	DR0	DR0	DR0	DR0	DR0
DR1	DR1	DR0	DR0	DR0	DR0	DR0
DR2	DR2	DR1	DR0	DR0	DR0	DR0
DR3	DR3	DR2	DR1	DR0	DR0	DR0
DR4	DR4	DR3	DR2	DR1	DR0	DR0
DR5	DR5	DR4	DR3	DR2	DR1	DR0
DR6	DR6	DR5	DR4	DR3	DR2	DR1
DR7	DR7	DR6	DR5	DR4	DR3	DR2

The RX2 receive window uses a fixed frequency and data rate. The default parameters are 869.525 MHz / DR0 (SF12, 125 kHz)

2.1.8 EU863-870 Default Settings

The following parameters are recommended values for the EU863-870MHz band.

RECEIVE_DELAY1	1 s
RECEIVE_DELAY2	2 s (must be RECEIVE_DELAY1 + 1s)
JOIN_ACCEPT_DELAY1	5 s
JOIN_ACCEPT_DELAY2	6 s
MAX_FCNT_GAP	16384

- 1 ADR_ACK_LIMIT 64
- 2 ADR_ACK_DELAY 32
- 3 ACK_TIMEOUT 2 +/- 1 s (random delay between 1 and 3 seconds)
- 4 If the actual parameter values implemented in the end-device are different from those default
- 5 values (for example the end-device uses a longer RECEIVE_DELAY1 and
- 6 RECEIVE_DELAY2 latency), those parameters must be communicated to the network
- 7 server using an out-of-band channel during the end-device commissioning process. The
- 8 network server may not accept parameters different from those default values.
- 9

2.2 US 902-928MHz ISM Band

2.2.1 US902-928 Preamble Format

The following synchronization words should be used:

Modulation	Sync word	Preamble length
LORA	0x34	8 symbols

LoRaWAN does not make use of GFSK modulation in the US902-928 ISM band.

2.2.2 US902-928 Channel Frequencies

The 915 MHz ISM Band shall be divided into the following channel plans.

- Upstream – 64 channels numbered 0 to 63 utilizing LoRa 125 kHz BW varying from DR0 to DR3, using coding rate 4/5, starting at 902.3 MHz and incrementing linearly by 200 kHz to 914.9 MHz
- Upstream – 8 channels numbered 64 to 71 utilizing LoRa 500 kHz BW at DR4 starting at 903.0 MHz and incrementing linearly by 1.6 MHz to 914.2 MHz
- Downstream – 8 channels numbered 0 to 7 utilizing LoRa 500 kHz BW at DR8 to DR13) starting at 923.3 MHz and incrementing linearly by 600 kHz to 927.5 MHz

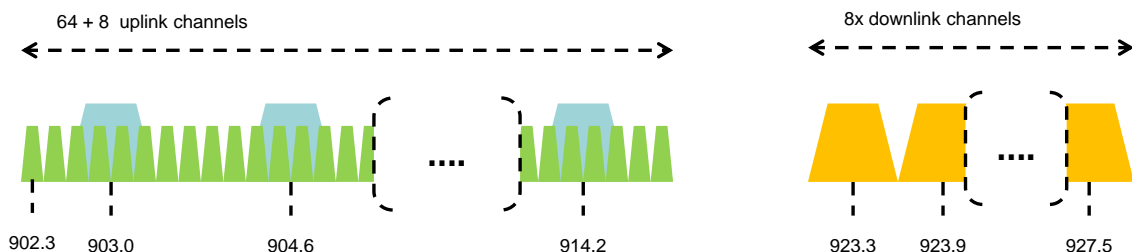


Figure 1: US902-928 channel frequencies

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1915 MHz ISM band end-devices should use the following default parameters:

- Default radiated transmit output power: 20 dBm
 - Devices, when transmitting with 125 kHz BW may use a maximum of +30 dBm. The transmission shall never last more than 400 ms.
 - Devices, when transmitting with 500 kHz BW may use a maximum of +26 dBm

US902-928 end-devices should be capable of operating in the 902 to 928 MHz frequency band and should feature a channel data structure to store the parameters of 72 channels. A channel data structure corresponds to a frequency and a set of data rates usable on this frequency.

If using the over-the-air activation procedure, the end-device should broadcast the JoinReq message alternatively on a random 125 kHz channel amongst the 64 channels defined using **DR0** and a random 500 kHz channel amongst the 8 channels defined using **DR4**. The end-device should change channel for every transmission.

Personalized devices shall have all 72 channels enabled following a reset.

2.2.3 US902-928 Data Rate and End-device Output Power encoding

FCC regulation imposes a maximum dwell time of 400ms on uplinks. The **TxParamSetupReq** MAC command does not have to be implemented by US902-928 devices.

The following encoding is used for Data Rate (**DR**) and End-device Output Power (**TXPower**) in the US902-928 band:

DataRate	Configuration	Indicative physical bit rate [bit/sec]
0	LoRa: SF10 / 125 kHz	980
1	LoRa: SF9 / 125 kHz	1760
2	LoRa: SF8 / 125 kHz	3125
3	LoRa: SF7 / 125 kHz	5470
4	LoRa: SF8 / 500 kHz	12500
5:7	RFU	
8	LoRa: SF12 / 500 kHz	980
9	LoRa: SF11 / 500 kHz	1760
10	LoRa: SF10 / 500 kHz	3900
11	LoRa: SF9 / 500 kHz	7000
12	LoRa: SF8 / 500 kHz	12500
13	LoRa: SF7 / 500 kHz	21900
14:15	RFU	

Table 9: TX Data rate table

Note: DR4 is purposely identical to DR12, DR8..13 must be implemented in end-devices and are reserved for future applications

TXPower	Configuration
0	30 dBm – 2*TXpower
1	28 dBm
2	26 dBm
3 : 9
10	10 dBm
11:15	RFU

Table 10: TX power table

2.2.4 US902-928 JoinAccept CFList

The US902-928 LoRaWAN does not support the use of the optional **CFList** appended to the JoinAccept message. If the **CFList** is not empty it is ignored by the end-device.

2.2.5 US902-928 LinkAdrReq command

For the US902-928 version the **ChMaskCntl** field of the **LinkADRReq** command has the following meaning:

ChMaskCntl	ChMask applies to
0	Channels 0 to 15
1	Channels 16 to 31
..	..
4	Channels 64 to 71
5	RFU
6	All 125 kHz ON ChMask applies to channels 64 to 71
7	All 125 kHz OFF ChMask applies to channels 64 to 71

Table 11: ChMaskCntl value table

If **ChMaskCntl** = 6 then 125 kHz channels are enabled, if **ChMaskCntl** = 7 then 125 kHz channels are disabled. Simultaneously the channels 64 to 71 are set according to the **ChMask** bit mask. The DataRate specified in the command need not be valid for channels specified in the ChMask, as it governs the global operational state of the end-device.

Note: FCC regulation requires hopping over at least 50 channels when using maximum output power. It is possible to have end-devices with less channels (at least six 125 kHz channels) when limiting the end-device transmit power to 21 dBm.

Note: A common network server action may be to reconfigure a device through multiple LinkAdrReq commands in a contiguous block of MAC Commands. For example to reconfigure a device from 64 channel operation to the first 8 channels could contain two LinkAdrReq, the first (ChMaskCntl = 7) to disable all 125kHz channels and the second (ChMaskCntl = 0) to enable a bank of 8 125kHz channels.

2.2.6 US902-928 Maximum payload size

The maximum **MACPayload** size length (M) is given by the following table. It is derived from the maximum allowed transmission time at the PHY layer taking into account a possible repeater encapsulation. The maximum application payload length in the absence of the optional **FOpt** MAC control field (N) is also given for information only. The value of N might be smaller if the **FOpt** field is not empty:

DataRate	M	N
0	19	11
1	61	53
2	133	125
3	250	242
4	250	242
5:7	Not defined	
8	41	33
9	117	109
10	230	222
11	230	222
12	230	222
13	230	222
14:15	Not defined	

1 **Table 12: US902-928 maximum payload size (repeater compatible)**

 2 The greyed lines correspond to the data rates that may be used by an end-device behind a
 3 repeater.

 4 If the end-device will never operate under a repeater then the maximum application payload
 5 length in the absence of the optional **FOpt** control field should be:
 6

DataRate	<i>M</i>	<i>N</i>
0	19	11
1	61	53
2	133	125
3	250	242
4	250	242
5:7	Not defined	
8	61	53
9	137	129
10	250	242
11	250	242
12	250	242
13	250	242
14:15	Not defined	

 7 **Table 13 : US902-928 maximum payload size (not repeater compatible)**

 8 **2.2.7 US902-928 Receive windows**

- 9
- 10 The RX1 receive channel is a function of the upstream channel used to initiate the data exchange. The RX1 receive channel can be determined as follows.
 - 11 ○ RX1 Channel Number = Transmit Channel Number modulo 8
 - 12 • The RX1 window data rate depends on the transmit data rate (see Table 14 below).
 - 13 • The RX2 (second receive window) settings uses a fixed data rate and frequency.
- 14 Default parameters are 923.3MHz / DR8
-
- 15

Upstream data rate RX1DROffset	Downstream data rate			
	0	1	2	3
DR0	DR10	DR9	DR8	DR8
DR1	DR11	DR10	DR9	DR8
DR2	DR12	DR11	DR10	DR9
DR3	DR13	DR12	DR11	DR10
DR4	DR13	DR13	DR12	DR11

 16 **Table 14: Data rate mapping**

 17 The allowed values for RX1DROffset are in the [0:3] range. Values in the range [4:7] are
 18 reserved for future use.

 19 **2.2.8 US902-928 Default Settings**

20 The following parameters are recommended values for the US902-928 band.

21	RECEIVE_DELAY1	1 s
22	RECEIVE_DELAY2	2 s (must be RECEIVE_DELAY1 + 1s)
23	JOIN_ACCEPT_DELAY1	5 s
24	JOIN_ACCEPT_DELAY2	6 s
25	MAX_FCNT_GAP	16384
26	ADR_ACK_LIMIT	64

- 1 ADR_ACK_DELAY 32
- 2 ACK_TIMEOUT 2 +/- 1 s (random delay between 1 and 3 seconds)
- 3 If the actual parameter values implemented in the end-device are different from those default
- 4 values (for example the end-device uses a longer RECEIVE_DELAY1 & 2 latency), those
- 5 parameters must be communicated to the network server using an out-of-band channel
- 6 during the end-device commissioning process. The network server may not accept
- 7 parameters different from those default values.
- 8

1 2.3 China 779-787MHz ISM Band

2 2.3.1 CN779-787 Preamble Format

3 The following synchronization words should be used :

Modulation	Sync word	Preamble length
LORA	0x34	8 symbols
GFSK	0xC194C1	5 bytes

5 **Table 15: CN779-787 synch words**

6 2.3.2 CN779-787 ISM Band channel frequencies

8 The LoRaWAN can be used in the Chinese 779-787MHz band as long as the radio device
9 ERP is less than 10mW (or 10dBm).

10 The end-device transmit duty-cycle should be lower than 1%.

11 The LoRaWAN channels center frequency can be in the following range:

- 12 • Minimum frequency : 779.5MHz
- 13 • Maximum frequency : 786.5 MHz

14 CN780MHz end-devices should be capable of operating in the 779 to 787 MHz frequency
15 band and should feature a channel data structure to store the parameters of at least 16
16 channels. A channel data structure corresponds to a frequency and a set of data rates
17 usable on this frequency.

18 The first three channels correspond to 779.5, 779.7 and 779.9 MHz with DR0 to DR5 and
19 must be implemented in every end-device. Those default channels cannot be modified
20 through the **NewChannelReq** command and guarantee a minimal common channel set
21 between end-devices and gateways of all networks. Other channels can be freely distributed
22 across the allowed frequency range on a network per network basis.

23 The following table gives the list of frequencies that should be used by end-devices to
24 broadcast the JoinReq message The JoinReq message transmit duty-cycle shall follow the
25 rules described in chapter “Retransmissions back-off” of the LoRaWAN specification
26 document.

Modulation	Bandwidth [kHz]	Channel Frequency [MHz]	FSK Bitrate or LoRa DR / Bitrate	Nb Channels	Duty cycle
LoRa	125	779.5 779.7 779.9 780.5 780.7 780.9	DR0 – DR5 / 0.3-5 kbps	6	<0.1%

28 **Table 16: CN780 JoinReq Channel List**

1 2.3.3 CN779-787 Data Rate and End-device Output Power encoding

2 There is no dwell time limitation for the CN779-787 PHY layer. The *TxParamSetupReq*
 3 MAC command does not have to be implemented by CN779-787 devices.

4 The following encoding is used for Data Rate (DR) and End-device Output Power (TXPower)
 5 in the CN780 band:

DataRate	Configuration	Indicative physical bit rate [bit/s]	TXPower	Configuration
0	LoRa: SF12 / 125 kHz	250	0	10 dBm
1	LoRa: SF11 / 125 kHz	440	1	7 dBm
2	LoRa: SF10 / 125 kHz	980	2	4 dBm
3	LoRa: SF9 / 125 kHz	1760	3	1 dBm
4	LoRa: SF8 / 125 kHz	3125	4	-2 dBm
5	LoRa: SF7 / 125 kHz	5470	5	-5 dBm
6	LoRa: SF7 / 250 kHz	11000	6..15	RFU
7	FSK: 50 kbps	50000		
8..15	RFU			

6 **Table 17: Data rate and TX power table**

7 2.3.4 CN779-787 JoinAccept CFList

8 The CN780 ISM band LoRaWAN implements an optional **channel frequency list** (CFList) of
 9 16 octets in the JoinAccept message.

10 In this case the CFList is a list of five channel frequencies for the channels four to eight
 11 whereby each frequency is encoded as a 24 bits unsigned integer (three octets). All these
 12 channels are usable for DR0 to DR5 125kHz LoRa modulation. The list of frequencies is
 13 followed by a single RFU octet for a total of 16 octets.

Size (bytes)	3	3	3	3	3	1
CFList	Freq Ch4	Freq Ch5	Freq Ch6	Freq Ch7	Freq Ch8	RFU

15 The actual channel frequency in Hz is 100 x frequency whereby values representing
 16 frequencies below 100 MHz are reserved for future use. This allows setting the frequency of
 17 a channel anywhere between 100 MHz to 1.67 GHz in 100 Hz steps. Unused channels have
 18 a frequency value of 0. The **CFList** is optional and its presence can be detected by the
 19 length of the join-accept message. If present, the **CFList** replaces all the previous channels
 20 stored in the end-device apart from the three default channels as defined in Chapter 6.

21 The newly defined channels are immediately enabled and usable by the end-device for
 22 communication.

2.3.5 CN779-787 LinkAdrReq command

The CN780 LoRaWAN only supports a maximum of 16 channels. When **ChMaskCntl** field is 0 the ChMask field individually enables/disables each of the 16 channels.

ChMaskCntl	ChMask applies to
0	Channels 1 to 16
1	RFU
..	..
4	RFU
5	RFU
6	All channels ON The device should enable all currently defined channels independently of the ChMask field value.
7	RFU

Table 18: ChMaskCntl value table

If the ChMask field value is one of values meaning RFU, then end-device should reject the command and unset the “**Channel mask ACK**” bit in its response.

2.3.6 CN779-787 Maximum payload size

The maximum **MACPayload** size length (M) is given by the following table. It is derived from limitation of the PHY layer depending on the effective modulation rate used taking into account a possible repeater encapsulation layer. The maximum application payload length in the absence of the optional **FOpt** control field (N) is also given for information only. The value of N might be smaller if the **FOpt** field is not empty:

DataRate	M	N
0	59	51
1	59	51
2	59	51
3	123	115
4	230	222
5	230	222
6	250	242
7	230	222
8:15	Not defined	

Table 19: CN780 maximum payload size

If the end-device will never operate with a repeater then the maximum application payload length in the absence of the optional **FOpt** control field should be:

DataRate	M	N
0	59	51
1	59	51
2	59	51
3	123	115
4	250	242
5	250	242
6	250	242
7	250	242

8:15	Not defined
------	-------------

Table 20 : CN780 maximum payload size (not repeater compatible)

2.3.7 CN779-787 Receive windows

The RX1 receive window uses the same channel than the preceding uplink. The data rate is a function of the uplink data rate and the RX1DROffset as given by the following table. The allowed values for RX1DROffset are in the [0:5] range. Values in the range [6:7] are reserved for future use

RX1DROffset Upstream data rate	0	1	2	3	4	5
	Downstream data rate in RX1 slot					
DR0	DR0	DR0	DR0	DR0	DR0	DR0
DR1	DR1	DR0	DR0	DR0	DR0	DR0
DR2	DR2	DR1	DR0	DR0	DR0	DR0
DR3	DR3	DR2	DR1	DR0	DR0	DR0
DR4	DR4	DR3	DR2	DR1	DR0	DR0
DR5	DR5	DR4	DR3	DR2	DR1	DR0
DR6	DR6	DR5	DR4	DR3	DR2	DR1
DR7	DR7	DR6	DR5	DR4	DR3	DR2

The RX2 receive window uses a fixed frequency and data rate. The default parameters are 786 MHz / DR0.

2.3.8 CN779-787 Default Settings

The following parameters are recommended values for the CN779-787MHz band.

RECEIVE_DELAY1	1 s
RECEIVE_DELAY2	2 s (must be RECEIVE_DELAY1 + 1s)
JOIN_ACCEPT_DELAY1	5 s
JOIN_ACCEPT_DELAY2	6 s
MAX_FCNT_GAP	16384
ADR_ACK_LIMIT	64
ADR_ACK_DELAY	32
ACK_TIMEOUT	2 +/- 1 s (random delay between 1 and 3 seconds)

If the actual parameter values implemented in the end-device are different from those default values (for example the end-device uses a longer RECEIVE_DELAY1 and RECEIVE_DELAY2 latency), those parameters must be communicated to the network server using an out-of-band channel during the end-device commissioning process. The network server may not accept parameters different from those default values.

1 2.4 EU 433MHz ISM Band

2 2.4.1 EU433 Preamble Format

3 The following synchronization words should be used :

Modulation	Sync word	Preamble length
LORA	0x34	8 symbols
GFSK	0xC194C1	5 bytes

5 **Table 21: EU433 synch words**

6 2.4.2 EU433 ISM Band channel frequencies

7 The LoRaWAN can be used in the ETSI 433-434 MHz band as long as the radio device ERP
8 is less than 10 mW (or 10 dBm).

9 The end-device transmit duty-cycle should be lower than 1%¹.

10 The LoRaWAN channels center frequency can be in the following range:

- 11 • Minimum frequency : 433.175 MHz
- 12 • Maximum frequency : 434.665 MHz

13 EU433 end-devices should be capable of operating in the 433.05 to 434.79 MHz frequency
14 band and should feature a channel data structure to store the parameters of at least 16
15 channels. A channel data structure corresponds to a frequency and a set of data rates
16 usable on this frequency.

17 The first three channels correspond to 433.175, 433.375 and 433.575 MHz with DR0 to DR5
18 and must be implemented in every end-device. Those default channels cannot be modified
19 through the **NewChannelReq** command and guarantee a minimal common channel set
20 between end-devices and gateways of all networks. Other channels can be freely distributed
21 across the allowed frequency range on a network per network basis.

22 The following table gives the list of frequencies that should be used by end-devices to
23 broadcast the JoinReq message. The JoinReq message transmit duty-cycle shall follow the
24 rules described in chapter “Retransmissions back-off” of the LoRaWAN specification
25 document.

26

Modulation	Bandwidth [kHz]	Channel Frequency [MHz]	FSK Bitrate or LoRa DR / Bitrate	Nb Channels	Duty cycle
LoRa	125	433.175 433.375 433.575	DR0 – DR5 / 0.3-5 kbps	3	<1%

27

Table 22: EU433 JoinReq Channel List

¹ The EN300220 ETSI standard limits to 10% the maximum transmit duty-cycle in the 433MHz ISM band. The LoRaWAN requires a 1% transmit duty-cycle lower than the legal limit to avoid network congestion.

2.4.3 EU433 Data Rate and End-device Output Power encoding

There is no dwell time limitation for the EU433 PHY layer. The **TxParamSetupReq** MAC command does not have to be implemented by EU433 devices.

The following encoding is used for Data Rate (DR) and End-device Output Power (TXPower) in the EU433 band:

DataRate	Configuration	Indicative physical bit rate [bit/s]	TXPower	Configuration
0	LoRa: SF12 / 125 kHz	250	0	10 dBm
1	LoRa: SF11 / 125 kHz	440	1	7 dBm
2	LoRa: SF10 / 125 kHz	980	2	4 dBm
3	LoRa: SF9 / 125 kHz	1760	3	1 dBm
4	LoRa: SF8 / 125 kHz	3125	4	-2 dBm
5	LoRa: SF7 / 125 kHz	5470	5	-5 dBm
6	LoRa: SF7 / 250 kHz	11000	6..15	RFU
7	FSK: 50 kbps	50000		
8..15	RFU			

Table 23: Data rate and TX power table

2.4.4 EU433 JoinAccept CFList

8

9

10

11

The EU433 ISM band LoRaWAN implements an optional **channel frequency list** (CFList) of 16 octets in the JoinAccept message.

12

13

14

15

In this case the CFList is a list of five channel frequencies for the channels four to eight whereby each frequency is encoded as a 24 bits unsigned integer (three octets). All these channels are usable for DR0 to DR5 125 kHz LoRa modulation. The list of frequencies is followed by a single RFU octet for a total of 16 octets.

16

Size (bytes)	3	3	3	3	3	1
CFList	Freq Ch4	Freq Ch5	Freq Ch6	Freq Ch7	Freq Ch8	RFU

17

18

19

20

21

22

The actual channel frequency in Hz is 100 x frequency whereby values representing frequencies below 100 MHz are reserved for future use. This allows setting the frequency of a channel anywhere between 100 MHz to 1.67 GHz in 100 Hz steps. Unused channels have a frequency value of 0. The **CFList** is optional and its presence can be detected by the length of the join-accept message. If present, the **CFList** replaces all the previous channels stored in the end-device apart from the three default channels as defined in Chapter 6.

23

24

The newly defined channels are immediately enabled and usable by the end-device for communication.

2.4.5 EU433 LinkAdrReq command

26

27

28

The EU433 LoRaWAN only supports a maximum of 16 channels. When **ChMaskCntl** field is 0 the ChMask field individually enables/disables each of the 16 channels.

ChMaskCntl	ChMask applies to
0	Channels 1 to 16
1	RFU
..	..

ChMaskCntl	ChMask applies to
4	RFU
5	RFU
6	All channels ON The device should enable all currently defined channels independently of the ChMask field value.
7	RFU

Table 24: ChMaskCntl value table

1

2 If the ChMask field value is one of the values meaning RFU, then end-device should reject
3 the command and unset the “**Channel mask ACK**” bit in its response.

4 2.4.6 EU433 Maximum payload size

5 The maximum **MACPayload** size length (M) is given by the following table. It is derived from
6 limitation of the PHY layer depending on the effective modulation rate used taking into
7 account a possible repeater encapsulation layer. The maximum application payload length in
8 the absence of the optional **FOpt** control field (N) is also given for information only. The
9 value of N might be smaller if the **FOpt** field is not empty:

10

DataRate	M	N
0	59	51
1	59	51
2	59	51
3	123	115
4	230	222
5	230	222
6	230	222
7	230	222
8:15	Not defined	

Table 25: EU433 maximum payload size

11

12 If the end-device will never operate with a repeater then the maximum application payload
13 length in the absence of the optional **FOpt** control field should be:

14

DataRate	M	N
0	59	51
1	59	51
2	59	51
3	123	115
4	250	242
5	250	242
6	250	242
7	250	242
8:15	Not defined	

Table 26 : EU433 maximum payload size (not repeater compatible)

15

16

17 2.4.7 EU433 Receive windows

18 The RX1 receive window uses the same channel than the preceding uplink. The data rate is
19 a function of the uplink data rate and the RX1DROffset as given by the following table. The

1 allowed values for RX1DROffset are in the [0:5] range. Values in the range [6:7] are
 2 reserved for future use.

3
 4
 5
 6
 7

RX1DROffset	0	1	2	3	4	5
Upstream data rate	Downstream data rate in RX1 slot					
DR0	DR0	DR0	DR0	DR0	DR0	DR0
DR1	DR1	DR0	DR0	DR0	DR0	DR0
DR2	DR2	DR1	DR0	DR0	DR0	DR0
DR3	DR3	DR2	DR1	DR0	DR0	DR0
DR4	DR4	DR3	DR2	DR1	DR0	DR0
DR5	DR5	DR4	DR3	DR2	DR1	DR0
DR6	DR6	DR5	DR4	DR3	DR2	DR1
DR7	DR7	DR6	DR5	DR4	DR3	DR2

Table 27 : EU43 RX1DROffset

8
 9
 10

11 The RX2 receive window uses a fixed frequency and data rate. The default parameters are
 12 434.665MHz / DR0 (SF12, 125kHz)

13 2.4.8 EU433 Default Settings

14 The following parameters are recommended values for the EU433band.

- 15 RECEIVE_DELAY1 1 s
- 16 RECEIVE_DELAY2 2 s (must be RECEIVE_DELAY1 + 1s)
- 17 JOIN_ACCEPT_DELAY1 5 s
- 18 JOIN_ACCEPT_DELAY2 6 s
- 19 MAX_FCNT_GAP 16384
- 20 ADR_ACK_LIMIT 64
- 21 ADR_ACK_DELAY 32
- 22 ACK_TIMEOUT 2 +/- 1 s (random delay between 1 and 3 seconds)

23
 24
 25
 26
 27
 28
 29
 30
 31
 32

If the actual parameter values implemented in the end-device are different from those default values (for example the end-device uses a longer RECEIVE_DELAY1 & 2 latency) , those parameters must be communicated to the network server using an out-of-band channel during the end-device commissioning process. The network server may not accept parameters different from those default values.

1 2.5 Australia 915-928MHz ISM Band

2 2.5.1 AU915-928 Preamble Format

3 The following synchronization words should be used:

4

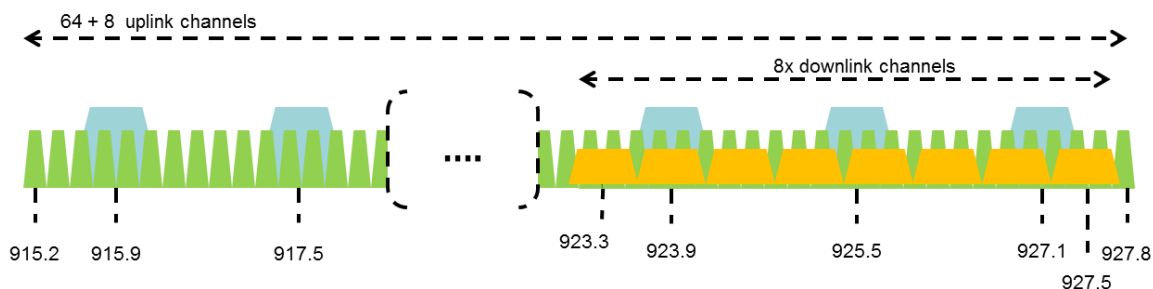
Modulation	Sync word	Preamble length
LORA	0x34	8 symbols

5 LoRaWAN does not make use of GFSK modulation in the AU915-928 ISM band.

6 2.5.2 AU915-928 Channel Frequencies

7 The AU ISM Band shall be divided into the following channel plans.

- 8 • Upstream – 64 channels numbered 0 to 63 utilizing LoRa 125 kHz BW varying from
- 9 DR0 to DR3, using coding rate 4/5, starting at 915.2 MHz and incrementing linearly
- 10 by 200 kHz to 927.8 MHz
- 11 • Upstream – 8 channels numbered 64 to 71 utilizing LoRa 500 kHz BW at DR4
- 12 starting at 915.9 MHz and incrementing linearly by 1.6 MHz to 927.1 MHz
- 13 • Downstream – 8 channels numbered 0 to 7 utilizing LoRa 500 kHz BW at DR8 to
- 14 DR13) starting at 923.3 MHz and incrementing linearly by 600 kHz to 927.5 MHz
- 15



16
17

Figure 2: AU915-928 channel frequencies

18 AU ISM band end-devices should use the following default parameters:

- 19 • Default radiated transmit output power: 20 dBm
 - 20 ○ All Devices may use a maximum of +30 dBm.
 - 21 ○ Devices, when transmitting with 125 kHz BW must frequency hop using a
 - 22 minimum of 20 channels. . The transmission shall never last more than 400
 - 23 ms.
 - 24 ○ Devices, when transmitting with 500 kHz BW may use a maximum of
 - 25 +26 dBm

26 AU915-928 end-devices should be capable of operating in the 915 to 928 MHz frequency

27 band and should feature a channel data structure to store the parameters of 72 channels. A

28 channel data structure corresponds to a frequency and a set of data rates usable on this

29 frequency.

30 If using the over-the-air activation procedure, the end-device should broadcast the JoinReq

31 message alternatively on a random 125 kHz channel amongst the 64 channels defined using

32 **DR0** and a random 500 kHz channel amongst the 4 channels defined using **DR4**. The end-

33 device should change channel for every transmission.

34 Personalized devices shall have all 72 channels enabled following a reset.

1 2.5.3 AU915-928 Data Rate and End-point Output Power encoding

2 The *TxParamSetupReq* MAC command does not have to be implemented by AU915-928
3 devices.

4

5 The following encoding is used for Data Rate (DR) and End-point Output Power (TXPower)
6 in the AU915-928 band:

7

DataRate	Configuration	Indicative physical bit rate [bit/sec]
0	LoRa: SF10 / 125 kHz	980
1	LoRa: SF9 / 125 kHz	1760
2	LoRa: SF8 / 125 kHz	3125
3	LoRa: SF7 / 125 kHz	5470
4	LoRa: SF8 / 500 kHz	12500
5:7	RFU	
8	LoRa: SF12 / 500 kHz	980
9	LoRa: SF11 / 500 kHz	1760
10	LoRa: SF10 / 500 kHz	3900
11	LoRa: SF9 / 500 kHz	7000
12	LoRa: SF8 / 500 kHz	12500
13	LoRa: SF7 / 500 kHz	21900
14:15	RFU	

8

Table 28: AU915 Data rate table

TXPower	Configuration
0	30 dBm – 2*TXpower
1	28 dBm
2	26 dBm
3 : 9
10	10 dBm
11:15	RFU

9

Table 29 : AU915 TX power table

10

11 DR4 is identical to DR12, DR8...13 must be implemented in end-devices and are reserved
12 for future applications.

13 2.5.4 AU915-928 JoinAccept CFList

14 The AU915-928 LoRaWAN does not support the use of the optional **CFList** appended to the
15 JoinAccept message. If the **CFList** is not empty it is ignored by the end-device.

16 2.5.5 AU915-928 LinkAdrReq command

17 For the AU915-928 version the **ChMaskCntl** field of the *LinkADRReq* command has the
18 following meaning:

19

20

ChMaskCntl | **ChMask applies to**

ChMaskCntl	ChMask applies to
0	Channels 0 to 15
1	Channels 16 to 31
..	..
4	Channels 64 to 71
5	RFU
6	All 125 kHz ON ChMask applies to channels 64 to 71
7	All 125 kHz OFF ChMask applies to channels 64 to 71

Table 30: ChMaskCntl value table

1
2 If **ChMaskCntl** = 6 (resp 7) then 125 kHz channels are enabled (resp disabled).
3 Simultaneously the channels 64 to 67 are set according to the **ChMask** bit mask.

4 **Note:** ACMA regulation requires hopping over at least 20 channels
5 when using channels that do not meet a minimum 6 dB bandwidth of
6 500 kHz.

7 2.5.6 AU915-928 Maximum payload size

8 The maximum **MACPayload** size length (M) is given by the following table. It is derived from
9 the maximum allowed transmission time at the PHY layer taking into account a possible
10 repeater encapsulation. The maximum application payload length in the absence of the
11 optional **FOpt** MAC control field (N) is also given for information only. The value of N might
12 be smaller if the **FOpt** field is not empty:

DataRate	M	N
0	19	11
1	61	53
2	134	126
3	250	242
4	250	242
5:7	Not defined	
8	41	33
9	117	109
10	230	222
11	230	222
12	230	222
13	230	222
14:15	Not defined	

Table 31: AU915-928 maximum payload size

14
15
16 The greyed lines correspond to the data rates that may be used by an end-device behind a
17 repeater.

18
19 If the end-device will never operate with a repeater then the maximum application payload
20 length in the absence of the optional **FOpt** control field should be:

21

1
2

DataRate	<i>M</i>	<i>N</i>
0	19	11
1	61	53
2	134	126
3	250	242
4	250	242
5:7	Not defined	
8	61	53
9	137	129
10	250	242
11	250	242
12	250	242
13	250	242
14:15	Not defined	

 3 **Table 32: AU915-928 maximum payload size (not repeater compatible)**

 4 **2.5.7 AU915-928 Receive windows**

- 5
- 6 • The RX1 receive channel is a function of the upstream channel used to initiate the data exchange. The RX1 receive channel can be determined as follows.
 - 7 ○ RX1 Channel Number = Transmit Channel Number modulo 8
 - 8 • The RX1 window data rate depends on the transmit data rate (see Table 14 below).
 - 9 • The RX2 (second receive window) settings uses a fixed data rate and frequency. Default parameters are 923.3Mhz / DR8
- 10

11

Upstream data rate RX1DROffset	Downstream data rate			
	0	1	2	3
DR0	DR10	DR9	DR8	DR8
DR1	DR11	DR10	DR9	DR8
DR2	DR12	DR11	DR10	DR9
DR3	DR13	DR12	DR11	DR10
DR4	DR13	DR13	DR12	DR11

 12 **Table 33: AU RX1DROffset**

13 The allowed values for RX1DROffset are in the [0:3] range. Values in the range [4:7] are reserved for future use.
 14

 15 **2.5.8 AU915-928 Default Settings**

16 The following parameters are recommended values for the AU915-928 band.

17	RECEIVE_DELAY1	1 s
18	RECEIVE_DELAY2	2 s (must be RECEIVE_DELAY1 + 1s)
19	JOIN_ACCEPT_DELAY1	5 s
20	JOIN_ACCEPT_DELAY2	6 s
21	MAX_FCNT_GAP	16384
22	ADR_ACK_LIMIT	64
23	ADR_ACK_DELAY	32
24	ACK_TIMEOUT	2 +/- 1 s (random delay between 1 and 3 seconds)

25 If the actual parameter values implemented in the end-device are different from those default values (for example the end-device uses a longer RECEIVE_DELAY1 & 2 latency), those parameters must be communicated to the network server using an out-of-band channel
 26
 27

- 1 during the end-device commissioning process. The network server may not accept
- 2 parameters different from those default values.
- 3

1 2.6 CN 470-510MHz Band

2 2.6.1 CN470-510 Preamble Format

3 The following synchronization words should be used:

4

Modulation	Sync word	Preamble length
LORA	0x34	8 symbols

5 2.6.2 CN470-510 Channel Frequencies

6

7 In China, this band is defined by SRRC to be used for civil metering applications.

8 The 470 MHz ISM Band shall be divided into the following channel plans:

- 9
- 10 • Upstream – 96 channels numbered 0 to 95 utilizing LoRa 125 kHz BW varying from DR0 to DR5, using coding rate 4/5, starting at 470.3 MHz and incrementing linearly by 200 kHz to 489.3 MHz.

11

12

13 Channel Index 6 to 38 and 45 to 77 are mainly used by China Electric
 14 Power. In the areas where these channels are used by China Electric
 15 Power, they should be disabled.

16

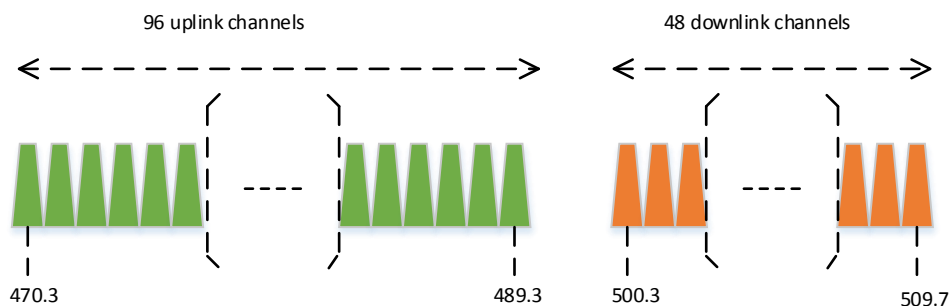
- 17 • Downstream – 48 channels numbered 0 to 47 utilizing LoRa 125 kHz BW varying from DR0 to DR5, using coding rate 4/5, starting at 500.3 MHz and incrementing linearly by 200 kHz to 509.7 MHz

18

19

20

21



22

23

Figure 3: CN470-510 channel frequencies

24 The LoRaWAN can be used in the Chinese 470-510MHz band as long as

- 25 • The radio device EIRP is less than 50mW (or 17dBm).
- 26 • The transmission never lasts more than 5000 ms.

27

28

29 CN470 MHz band end-devices should use the following default parameters:

- 30 • Default radiated transmits output power: 14 dBm.

31

32 CN470-510 end-devices should be capable of operating in the 470 to 510 MHz frequency
 33 band and should feature a channel data structure to store the parameters of 96 uplink
 34 channels. A channel data structure corresponds to a frequency and a set of data rates
 35 usable on this frequency.

1 If using the over-the-air activation procedure, the end-device should broadcast the JoinReq
 2 message on a random 125 kHz channel amongst the 96 uplink channels defined using **DR5**
 3 **to DR0**.

4 Personalized devices shall have all 96 channels enabled following a reset.

5

6 **2.6.3 CN470-510 Data Rate and End-point Output Power encoding**

7 There is no dwell time limitation for the CN470-510 PHY layer. The *TxParamSetupReq*
 8 MAC command does not have to be implemented by CN470-510 devices.

9 The following encoding is used for Data Rate (**DR**) and End-point Output Power (**TXPower**)
 10 in the CN470-510 band:

11

DataRate	Configuration	Indicative physical bit rate [bit/sec]	TXPower	Configuration
0	LoRa: SF12 / 125 kHz	250	0	17 dBm
1	LoRa: SF11 / 125 kHz	440	1	16 dBm
2	LoRa: SF10 / 125 kHz	980	2	14 dBm
3	LoRa: SF9 / 125 kHz	1760	3	12 dBm
4	LoRa: SF8 / 125 kHz	3125	4	10 dBm
5	LoRa:SF7 / 125 kHz	5470	5	7 dBm
6:15	RFU		6	5 dBm
			7	2 dBm
			8...15	RFU

12

Table 34: CN470 Data rate and TX power table

13 **2.6.4 CN470-510 JoinResp CFList**

14 The CN470-510 LoRaWAN does not support the use of the optional **CFList** appended to the
 15 JoinAccept message. If the **CFList** is not empty it is ignored by the end-device.

16 **2.6.5 CN470-510 LinkAdrReq command**

17 For the CN470-510 version the **ChMaskCntl** field of the *LinkADRReq* command has the
 18 following meaning:

19

ChMaskCntl	ChMask applies to
0	Channels 0 to 15
1	Channels 16 to 31
2	Channels 32 to 47
3	Channels 48 to 63
4	Channels 64 to 79
5	Channels 80 to 95
6	All channels ON The device should enable all currently defined channels independently of the ChMask field value.
7	RFU

20

Table 35: CN470 ChMaskCntl value table

21 If the ChMask field value is one of the values meaning RFU, then end-device should reject
 22 the command and unset the “**Channel mask ACK**” bit in its response.

2.6.6 CN470-510 Maximum payload size

The maximum **MACPayload** size length (M) is given by the following table. It is derived from the maximum allowed transmission time at the PHY layer taking into account a possible repeater encapsulation. The maximum application payload length in the absence of the optional **FOpt** MAC control field (N) is also given for information only. The value of N might be smaller if the **FOpt** field is not empty:

DataRate	M	N
0	59	51
1	59	51
2	59	51
3	123	115
4	230	222
5	230	222
6:15	Not defined	

Table 36: CN470-510 maximum payload size

2.6.7 CN470-510 Receive windows

- The RX1 receive channel is a function of the upstream channel used to initiate the data exchange. The RX1 receive channel can be determined as follows.
 - RX1 Channel Number = Uplink Channel Number modulo 48, for example, when transmitting channel number is 49, the rx1 channel number is 1.
- The RX1 window data rate depends on the transmit data rate (see Table Table 37: CN470-510 Data rate offset below).
- The RX2 (second receive window) settings uses a fixed data rate and frequency. Default parameters are 505.3 MHz / DR0

RX1DROffset	0	1	2	3	4	5
Upstream data rate	Downstream data rate in RX1 slot					
DR0	DR0	DR0	DR0	DR0	DR0	DR0
DR1	DR1	DR0	DR0	DR0	DR0	DR0
DR2	DR2	DR1	DR0	DR0	DR0	DR0
DR3	DR3	DR2	DR1	DR0	DR0	DR0
DR4	DR4	DR3	DR2	DR1	DR0	DR0
DR5	DR5	DR4	DR3	DR2	DR1	DR0

Table 37: CN470-510 Data rate offset

The allowed values for RX1DROffset are in the [0:3] range. Values in the range [4:7] are reserved for future use.

2.6.8 CN470-510 Default Settings

The following parameters are recommended values for the CN470-510 band.

RECEIVE_DELAY1	1 s
RECEIVE_DELAY2	2 s (must be RECEIVE_DELAY1 + 1s)
JOIN_ACCEPT_DELAY1	5 s
JOIN_ACCEPT_DELAY2	6 s

- | | | |
|---|---------------|--|
| 1 | MAX_FCNT_GAP | 16384 |
| 2 | ADR_ACK_LIMIT | 64 |
| 3 | ADR_ACK_DELAY | 32 |
| 4 | ACK_TIMEOUT | 2 +/- 1 s (random delay between 1 and 3 seconds) |
- 5 If the actual parameter values implemented in the end-device are different from those default
6 values (for example the end-device uses a longer RECEIVE_DELAY1 & 2 latency), those
7 parameters must be communicated to the network server using an out-of-band channel
8 during the end-device commissioning process. The network server may not accept
9 parameters different from those default values.

1 2.7 AS923MHz ISM Band

2 2.7.1 AS923 Preamble Format

3 The following synchronization words should be used:

Modulation	Sync word	Preamble length
LORA	0x34	8 symbols
GFSK	0xC194C1	5 bytes

5 **Table 38: AS923 synch words**

6 2.7.2 AS923 ISM Band channel frequencies

7 This section applies to regions where the frequencies [923...923.5MHz] are comprised in the
8 ISM band, which is the case for the following countries:

- 9 ❖ Brunei [923-925 MHz]
- 10 ❖ Cambodia [923-925 MHz]
- 11 ❖ Hong Kong [920-925 MHz]
- 12 ❖ Indonesia [923-925 MHz]
- 13 ❖ Japan [920-928 MHz]
- 14 ❖ Laos [923-925 MHz]
- 15 ❖ New Zealand [915-928 MHz]
- 16 ❖ Singapore [920-925 MHz]
- 17 ❖ Taiwan [922-928 MHz]
- 18 ❖ Thailand [920-925 MHz]
- 19 ❖ Vietnam [920-925 MHz]

20 The network channels can be freely attributed by the network operator. However the two
21 following default channels must be implemented in every AS923MHz end-device. Those
22 channels are the minimum set that all network gateways should always be listening on.

Modulation	Bandwidth [kHz]	Channel Frequency [MHz]	FSK Bitrate or LoRa DR / Bitrate	Nb Channels	Duty cycle
LoRa	125	923.20 923.40	DR0 to DR5 / 0.3-5 kbps	2	< 1%

24 **Table 39: AS923 default channels**

25 Those default channels must be implemented in every end-device and cannot be modified
26 through the **NewChannelReq** command and guarantee a minimal common channel set
27 between end-devices and network gateways.

28 AS923MHz ISM band end-devices should use the following default parameters

- 29 • Default ERP: 14 dBm

1 AS923MHz end-devices should feature a channel data structure to store the parameters of
 2 at least 16 channels. A channel data structure corresponds to a frequency and a set of data
 3 rates usable on this frequency.

4 The following table gives the list of frequencies that should be used by end-devices to
 5 broadcast the JoinReq message.

Modulation	Bandwidth [kHz]	Channel Frequency [MHz]	FSK Bitrate or LoRa DR / Bitrate	Nb Channels	Duty cycle
LoRa	125	923.20 923.40	DR2	2	< 1%

6 **Table 40: AS923 JoinReq Channel List**

7 The default JoinReq Data Rate is DR2 (SF10/125KHz), this setting ensures that end-devices
 8 are compatible with the 400ms dwell time limitation until the actual dwell time limit is notified
 9 to the end-device by the network server via the MAC command “TxParamSetupReq”.

10 The JoinReq message transmit duty-cycle shall follow the rules described in chapter
 11 “Retransmissions back-off” of the LoRaWAN specification document.

12

13 2.7.3 AS923 Data Rate and End-point Output Power encoding

14 The following encoding is used for Data Rate (DR) in the AS923 band:

15

DataRate	Configuration	Indicative physical bit rate [bit/s]
0	LoRa: SF12 / 125 kHz	250
1	LoRa: SF11 / 125 kHz	440
2	LoRa: SF10 / 125 kHz	980
3	LoRa: SF9 / 125 kHz	1760
4	LoRa: SF8 / 125 kHz	3125
5	LoRa: SF7 / 125 kHz	5470
6	LoRa: SF7 / 250 kHz	11000
7	FSK: 50 kbps	50000
8..15	RFU	

16 **Table 41: Data rate table**

17

18 The TXPower table indicates power levels relative to the Max ERP level of the end-device,
 19 as per the following table:

20

TXPower	Configuration
0	Max ERP
1	Max ERP – 2dB
2	Max ERP – 4dB
3	Max ERP – 6dB
4	Max ERP – 8dB
5	Max ERP – 10dB
6..15	RFU

21 **Table 42: TxPower table**

22

1

2 2.7.4 AS923 JoinAccept CFList

3 The AS923 LoRaWAN implements an optional channel frequency list (CFList) of 16 octets in
4 the JoinAccept message.

5 In this case the CFList is a list of five channel frequencies for the channels three to seven
6 whereby each frequency is encoded as a 24 bits unsigned integer (three octets). All these
7 channels are usable for DR0 to DR5 125 KHz LoRa modulation.

Size (bytes)	3	3	3	3	3	1
CFList	Freq Ch3	Freq Ch4	Freq Ch5	Freq Ch6	Freq Ch7	RFU

8 The actual channel frequency in Hz is 100 x frequency whereby values representing
9 frequencies below 100 MHz are reserved for future use. This allows setting the frequency of
10 a channel anywhere between 915 and 928MHz in 100 Hz steps. Unused channels have a
11 frequency value of 0. The CFList is optional and its presence can be detected by the length
12 of the join-accept message. If present, the CFList replaces all the previous channels stored
13 in the end-device apart from the two default channels as defined in Chapter 1.7.2. The newly
14 defined channels are immediately enabled and usable by the end-device for communication.

15 2.7.5 AS923 LinkAdrReq command

16 The AS923 LoRaWAN only supports a maximum of 16 channels. When **ChMaskCntl** field is
17 0 the ChMask field individually enables/disables each of the 16 channels.

18

ChMaskCntl	ChMask applies to
0	Channels 1 to 16
1	RFU
..	..
4	RFU
5	RFU
6	All channels ON The device should enable all currently defined channels independently of the ChMask field value.
7	RFU

19

Table 43: ChMaskCntl value table

20 If the ChMask field value is one of values meaning RFU, the end-device should reject the
21 command and unset the “**Channel mask ACK**” bit in its response.

22

23 2.7.6 AS923 Maximum payload size

24 The maximum **MACPayload** size length (*M*) is given by the following table for both dwell
25 time configurations: No Limit and 400ms. It is derived from the PHY layer limitation
26 depending on the effective modulation rate used taking into account a possible repeater
27 encapsulation layer.

28

DataRate	Uplink MAC Payload Size (M)	Downlink MAC Payload Size (M)
-----------------	------------------------------------	--------------------------------------

	UplinkDwellTime = 0	UplinkDwellTime = 1	DownlinkDwellTime = 0	DownlinkDwellTime = 1
0	59	N/A	59	N/A
1	59	N/A	59	N/A
2	59	19	59	19
3	123	61	123	61
4	230	133	230	134
5	230	250	230	250
6	230	250	230	250
7	230	250	230	250
8:15	RFU		RFU	

Table 44: AS923 maximum payload size

If the end-device will never operate with a repeater then the maximum MAC payload length should be:

DataRate	Uplink MAC Payload Size (M)		Downlink MAC Payload Size (M)	
	UplinkDwellTime = 0	UplinkDwellTime = 1	DownlinkDwellTime = 0	DownlinkDwellTime = 1
0	59	N/A	59	N/A
1	59	N/A	59	N/A
2	59	19	59	19
3	123	61	123	61
4	250	133	250	134
5	250	250	250	250
6	250	250	250	250
7	250	250	250	250
8:15	RFU		RFU	

Table 45: AS923 maximum payload size (not repeater compatible)

The maximum application payload length in the absence of the optional **FOpt** control field (M) is eight bytes lower than the MACPayload value in the above table. The value of N might be smaller if the **FOpt** field is not empty.

2.7.7 AS923 Receive windows

The RX1 receive window uses the same channel than the preceding uplink. The data rate is a function of the uplink data rate and the RX1DROffset as following:

Downstream data rate in RX1 slot = $MIN(5, MAX(\text{MinDR}, \text{Upstream data rate} - \text{Effective_RX1DROffset}))$

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

- Case DownlinkDwellTime = 0 (No limit): MinDR = 0
- Case DownlinkDwellTime = 1 (400ms): MinDR = 2

The allowed values for RX1DROffset are in the [0:7] range, encoded as per the below table:

RX1DROffset (Coded value)	0	1	2	3	4	5	6	7
Effective_RX1DROffset	0	1	2	3	4	5	-1	-2

Values in the [6:7] range allow setting the Downstream RX1 data rate higher than Upstream data rate.

1 The RX2 receive window uses a fixed frequency and data rate. The default parameters are
 2 923.2 MHz / DR2 (SF10/125KHz).

3

4 **2.7.8 AS923 Default Settings**

5 The following parameters are recommended values for the AS923MHz band.

6	RECEIVE_DELAY1	1 s
7	RECEIVE_DELAY2	2 s (must be RECEIVE_DELAY1 + 1s)
8	JOIN_ACCEPT_DELAY1	5 s
9	JOIN_ACCEPT_DELAY2	6 s
10	MAX_FCNT_GAP	16384
11	ADR_ACK_LIMIT	64
12	ADR_ACK_DELAY	32
13	ACK_TIMEOUT	2 +/- 1 s (random delay between 1 and 3 seconds)

14 If the actual parameter values implemented in the end-device are different from those default
 15 values (for example the end-device uses a longer RECEIVE_DELAY1 and
 16 RECEIVE_DELAY2 latency), those parameters must be communicated to the network
 17 server using an out-of-band channel during the end-device commissioning process. The
 18 network server may not accept parameters different from those default values.

19

20 **2.8 South Korea 920-923MHz ISM Band**

21 **2.8.1 KR920-923 Preamble Format**

22 The following synchronization words should be used:

23

Modulation	Sync word	Preamble length
LORA	0x34	8 symbols

24

Table 46 :KR920-923 synch words

25 **2.8.2 KR920-923 ISM Band channel frequencies**

26 The center frequency, bandwidth and maximum EIRP output power for the South Korea
 27 RFID/USN frequency band are already defined by Korean Government. Basically Korean
 28 Government allocated LPWA based IoT network frequency band from 920.9 to 923.3MHz.

29

Center frequency (MHz)	Bandwidth (kHz)	Maximum EIRP output power (dBm)	
		For end-device	For gateway
920.9	125	10	23
921.1	125	10	23
921.3	125	10	23
921.5	125	10	23
921.7	125	10	23
921.9	125	10	23
922.1	125	14	23
922.3	125	14	23
922.5	125	14	23

922.7	125	14	23
922.9	125	14	23
923.1	125	14	23
923.3	125	14	23

1 **Table 47: Center frequency, bandwidth, maximum EIRP output power table**

2 The three following default channels (922.1, 922.3 and 922.5MHz / DR0 to DR5) determined
 3 by the network operator from the set of available channels as defined by the South Korean
 4 regulation must be implemented in every KR920-923MHz end-device, and cannot be
 5 alterable by the **NewChannelReq** command. Those channels are the minimum set that all
 6 network gateways should always be listening on to guarantee a minimal common channel
 7 set between end-devices and network gateways.

Modulation	Bandwidth [kHz]	Channel Frequency [MHz]	FSK Bitrate or LoRa DR / Bitrate	Nb Channels
LoRa	125	922.10 922.30 922.50	DR0 to DR5 / 0.3-5 kbps	3

8 **Table 48: KR920-923 default channels**

9
 10 In order to access the physical medium the South Korea regulations impose some
 11 restrictions. The South Korea regulations allow the choice of using either a duty-cycle
 12 limitation or a so-called Listen Before Talk Adaptive Frequency Agility (LBT AFA)
 13 transmissions management. The current LoRaWAN specification for the KR920-923 ISM
 14 band exclusively uses LBT channel access rule to maximize MACPayload size length and
 15 comply with the South Korea regulations.

16 KR920-923MHz ISM band end-devices should use the following default parameters

- 17 • Default EIRP output power for end-device(920.9~921.9MHz): 10 dBm
- 18 • Default EIRP output power for end-device(922.1~923.3MHz): 14 dBm
- 19 • Default EIRP output power for gateway: 23 dBm

20 KR920-923MHz end-devices should be capable of operating in the 920 to 923MHz
 21 frequency band and should feature a channel data structure to store the parameters of at
 22 least 16 channels. A channel data structure corresponds to a frequency and a set of data
 23 rates usable on this frequency.

24 The following table gives the list of frequencies that should be used by end-devices to
 25 broadcast the JoinReq message.

Modulation	Bandwidth [kHz]	Channel Frequency [MHz]	FSK Bitrate or LoRa DR / Bitrate	Nb Channels
LoRa	125	922.10 922.30 922.50	DR0 to DR5 / 0.3-5 kbps	3

26 **Table 49: KR920-923 JoinReq Channel List**

28 2.8.3 KR920-923 Data Rate and End-device Output Power encoding

29 There is no dwell time limitation for the KR920-923 PHY layer. The **TxParamSetupReq**
 30 MAC command does not have to be implemented by the KR920-923 devices.

1

2 The following encoding is used for Data Rate (DR), corresponding Configurations and
 3 maximum EIRP Output Power (TXPower) in the KR920-923 band:

4

DataRate	Configuration	Indicative physical bit rate [bit/s]
0	LoRa: SF12 / 125 kHz	250
1	LoRa: SF11 / 125 kHz	440
2	LoRa: SF10 / 125 kHz	980
3	LoRa: SF9 / 125 kHz	1760
4	LoRa: SF8 / 125 kHz	3125
5	LoRa: SF7 / 125 kHz	5470
6..15	RFU	

5

Table 50: TX Data rate table

6

TXPower	Configuration, max EIRP allowed
0	20 dBm
1	14 dBm
2	10 dBm
3	8 dBm
4	5 dBm
5	2 dBm
6	0 dBm
7..15	RFU

7

Table 51: TX power table

8

9 2.8.4 KR920-923 JoinAccept CFList

10 The KR920-923 ISM band LoRaWAN implements an optional **channel frequency list**
 11 (CFList) of 16 octets in the JoinAccept message.

12 In this case the CFList is a list of five channel frequencies for the channels four to eight
 13 whereby each frequency is encoded as a 24 bits unsigned integer (three octets). All these
 14 channels are usable for DR0 to DR5 125kHz LoRa modulation. The list of frequencies is
 15 followed by a single RFU octet for a total of 16 octets.

16

Size (bytes)	3	3	3	3	3	1
CFList	Freq Ch4	Freq Ch5	Freq Ch6	Freq Ch7	Freq Ch8	RFU

17 The actual channel frequency in Hz is 100 x frequency whereby values representing
 18 frequencies below 100 MHz are reserved for future use. This allows setting the frequency of
 19 a channel anywhere between 100 MHz to 1.67 GHz in 100 Hz steps. Unused channels have
 20 a frequency value of 0. The **CFList** is optional and its presence can be detected by the
 21 length of the join-accept message. If present, the **CFList** replaces all the previous channels
 22 stored in the end-device apart from the three default channels as defined in Chapter 8.7.2.
 23 The newly defined channels are immediately enabled and usable by the end-device for
 24 communication.

1 2.8.5 KR920-923 LinkAdrReq command

2 The KR920-923 LoRaWAN only supports a maximum of 16 channels. When **ChMaskCntl**
 3 field is 0 the ChMask field individually enables/disables each of the 16 channels.

4

ChMaskCntl	ChMask applies to
0	Channels 1 to 16
1	RFU
..	..
4	RFU
5	RFU
6	All channels ON The device should enable all currently defined channels independently of the ChMask field value.
7	RFU

5

Table 52: ChMaskCntl value table

6 If the ChMaskCntl field value is one of values meaning RFU, the end-device should reject
 7 the command and unset the “**Channel mask ACK**” bit in its response.

8 2.8.6 KR920-923 Maximum payload size

9 The maximum **MACPayload** size length (M) is given by the following table for the regulation
 10 of dwell time; less than 4 sec with LBT. It is derived from limitation of the PHY layer
 11 depending on the effective modulation rate used taking into account a possible repeater
 12 encapsulation layer. The maximum application payload length in the absence of the optional
 13 **FOpt** control field (N) is also given for information only. The value of N might be smaller if
 14 the **FOpt** field is not empty:

15

DataRate	M	N
0	73	65
1	159	151
2	250	242
3	250	242
4	250	242
5	250	242
6:15	Not defined	

16

Table 53: KR920-923 maximum payload size

17 2.8.7 KR920-923 Receive windows

18 The RX1 receive window uses the same channel than the preceding uplink. The data rate is
 19 a function of the uplink data rate and the RX1DROffset as given by the following table. The
 20 allowed values for RX1DROffset are in the [0:5] range. Values in the [6:7] range are
 21 reserved for future use.

22

RX1DROffset Upstream data rate	0	1	2	3	4	5
	Downstream data rate in RX1 slot					
DR0	DR0	DR0	DR0	DR0	DR0	DR0
DR1	DR1	DR0	DR0	DR0	DR0	DR0
DR2	DR2	DR1	DR0	DR0	DR0	DR0

RX1DROffset Upstream data rate	0	1	2	3	4	5
	Downstream data rate in RX1 slot					
DR3	DR3	DR2	DR1	DR0	DR0	DR0
DR4	DR4	DR3	DR2	DR1	DR0	DR0
DR5	DR5	DR4	DR3	DR2	DR1	DR0

1

2 The RX2 receive window uses a fixed frequency and data rate. The default parameters are
3 921.90MHz / DR0 (SF12, 125 kHz)

4 **2.8.8 KR920-923 Default Settings**

5 The following parameters are recommended values for the KR920-923Mhz band.

6 RECEIVE_DELAY1	1 s
7 RECEIVE_DELAY2	2 s (must be RECEIVE_DELAY1 + 1s)
8 JOIN_ACCEPT_DELAY1	5 s
9 JOIN_ACCEPT_DELAY2	6 s
10 MAX_FCNT_GAP	16384
11 ADR_ACK_LIMIT	64
12 ADR_ACK_DELAY	32
13 ACK_TIMEOUT	2 +/- 1 s (random delay between 1 and 3 seconds)

14 If the actual parameter values implemented in the end-device are different from those default
15 values (for example the end-device uses a longer RECEIVE_DELAY1 and
16 RECEIVE_DELAY2 latency), those parameters must be communicated to the network
17 server using an out-of-band channel during the end-device commissioning process. The
18 network server may not accept parameters different from those default values.

19

20

1 **3 Revisions**

2 **3.1 Revision 1.0**

- 3 • Initial revision, the regional parameters were extracted from the LoRaWANV1.0.1
- 4 and the Asia/PAC regional cluster definition was added
- 5 • The ADR command for the US902-928 physical layer was amended to include ADR
- 6 MAC command blocks
- 7 • Added KR920-923 frequency band support
- 8 • Modified EU868 PHY layer power limit from 14dBm EIRP to 14dBm ERP
- 9

1 **4 Bibliography**

2 **4.1 References**

3

4 [LORAWAN] LoRaWAN Specification, V1.0.2, the LoRa Alliance, October 2016.

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