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LoRaWAN 1.0.3 Regional Parameters

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LoRaWAN™ 1.0.3 Regional Parameters

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This document is a companion document to the LoRaWAN 1.0.3 protocol specification

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LoRa Alliance Technical Committee Regional Parameters Workgroup

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268 **1 Introduction**

269

270 This document describes the LoRaWAN™ regional parameters for different regulatory regions
271 worldwide. This document is a companion document to the LoRaWAN 1.0.3 protocol
272 specification [LORAWAN]. Separating the regional parameters from the protocol specification
273 allows addition of new regions to the former without impacting the latter document.

274

275 It must be noted here that, regardless of the specifications provided, at no time is any LoRa
276 equipment allowed to operate in a manner contrary to the prevailing local rules and regulations
277 where it is expected to operate. It is the responsibility of the LoRa device to insure that
278 compliant operation is maintained without any outside assistance from a LoRa network or any
279 other mechanism.

280 **1.1 Conventions**

281

282 The key words "MUST", "MUST NOT", "REQUIRED", "SHALL", "SHALL NOT", "SHOULD",
283 "SHOULD NOT", "RECOMMENDED", "MAY", and "OPTIONAL" in this document are to be
284 interpreted as described in RFC 2119.

285

286 **1.2 Quick cross reference table**

287

288 In order to support the identification of LoRaWAN channel plans for a given country, the table
289 below provides a quick reference of suggested channel plans listed in priority order for each
290 country.

291

292

Country name	Band / channels	Channel Plan
Afghanistan		None
Albania	433.05 - 434.79 MHz	EU433
	863 - 873 MHz	EU863-870
	918 - 921 MHz	Other
Algeria	433.05 - 434.79 MHz	EU433
	870-876MHz	Other
	880-885MHz	Other
	915 - 921 MHz	Other
	925 - 926 MHz	Other
Andorra	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870
Armenia	863 - 870 MHz	EU863-870
	433.05 - 434.79 MHz	EU433
Argentina	902 - 928 MHz (915-928 MHz usable)	AU915-928, US902-928
Austria	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870
Australia	915 - 928 MHz	AU915-928, AS923
Azerbaijan	433.05 - 434.79 MHz	EU433
	863 - 868 MHz	Others
Bahrain	862 - 870MHz	EU863-870
Bangladesh	433.05 - 434.79 MHz	EU433
	818 - 824 MHz	Other
	863 - 869 MHz	EU863-870
	925.0 - 927.0 MHz	Other
Belarus	433.05 - 434.79 MHz	EU433
	864.4 - 868.6 MHz	EU863-870
	869-869.2MHz	EU863-870
Belgium	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870
Burma (Myanmar)	433 - 435 MHz	EU433
	866 - 869MHz	EU863-870
	919 - 923 MHz	Other
Bolivia	915 - 930 MHz	AU915-928, AS923
Bosnia and Herzegovina	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870
Botswana		None
Brazil	902 - 907.5 MHz	Other
	915 - 928 MHz	AU915-928
	433 - 435 MHz	EU433
Brunei Darussalam	866 - 870 MHz	EU863-870
	920 - 925 MHz	AS923

	433 - 435 MHz	EU433
Bulgaria	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870
Cambodia	866 - 869 MHz	EU863-870
	923 - 925 MHz	AS923
Cameroon		None
Canada	902 - 928 MHz	US902-928, AU915-928
Chile	902 - 928 MHz (915-928MHz usable)	AU915-928, AS923, US902-928
China	920.5 - 924.5 MHz	AS923
	779 - 787 MHz	CN779-787
	470 - 510 MHz	CN470-510
	433.05 - 434.79 MHz	EU433
	314-316 MHz	Other
	430 - 432 MHz	Other
	840 - 845 MHz	Other
Colombia	902 - 928 MHz	AU915-928, US902-928
Congo Rep.		None
Costa Rica	920.5 - 928 MHz	AS923
Croatia	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870
Cuba	433.05 - 434.79 MHz	EU433
	915 - 921 MHz	Other
Cyprus	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870
Czech Republic	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870
Denmark	433.05 - 434.79 MHz	EU433
	863 - 873 MHz	EU863-870
	918 - 921 MHz	Other
Dominican Republic	915 - 928 MHz	AU915-928
Ecuador	902 - 928 MHz	AU915-928, US902-928, AS923
Egypt	433.05 - 434.79 MHz	EU433
	863 - 876 MHz	EU863-870
Estonia	433.05 - 434.79 MHz	EU433
	863 - 873 MHz	EU863-870
	918 - 921 MHz	Other
Finland	433.05 - 434.79 MHz	EU433
	863 - 873 MHz	EU863-870
France	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870
Georgia		None
Germany	433.05 - 434.79 MHz	EU433

	863 - 870 MHz	EU863-870
Ghana		None
Greece	433.05 - 434.79 MHz	EU433
	868 - 870 MHz	EU863-870
Guatemala	902 - 928 MHz (915-928 MHz usable)	AU915-928, AS923, US902-928
Haiti		None
Honduras	915-928 MHz	AU915-928
Hong Kong	433.05 - 434.79 MHz	EU433
	865 - 868 MHz	Other
	920 - 925 MHz	AS923
Hungary	433.05 - 434.79 MHz	EU433
	863 - 873 MHz	EU863-870
	918 - 921 MHz	Other
Iceland	433.05 - 434.79 MHz	EU433
	863 - 873 MHz	EU863-870
India	865 - 867 MHz	IN765-867
Indonesia	923 - 925 MHz	AS923
Iraq		None
Iran	433.05 - 434.79 MHz	EU433
	863 - 873 MHz	EU863-870
	915 - 918 MHz	Other
Ireland	433.05 - 434.79 MHz	EU433
	863 - 873 MHz	EU863-870
	918 - 921 MHz	Other
Israel	433.05 - 434.79 MHz	EU433
	915 - 917 MHz	Other
Italy	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870
Ivory Coast		None
Jamaica	902 - 928 MHz (915-928 MHz usable)	AU915-928, US902-928
Japan	920.6 - 928.0 MHz (steps of 200kHz)	AS923
	920.8 - 927.8 MHz (steps of 600kHz)	AS923
Jordan	865 - 868 MHz	Other
Kazakhstan	433.05 - 434.79 MHz	EU433
Kenya		None
Korea (DPR)		None
Kuwait	433.05 - 434.79 MHz	EU433
Kyrgyz Republic		None
Laos	433 - 435 MHz	EU433
	862 - 875 MHz	EU863-870
	923 - 925 MHz	AS923
Latvia	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870

Lebanon	433 - 435 MHz	EU433
	862 - 870 MHz	EU863-870
Liechtenstein	433.05 - 434.79 MHz	EU433
	863 - 873 MHz	EU863-870
Libya		None
Lithuania	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870
Luxembourg	433.05 - 434.79 MHz	EU433
	863 - 873 MHz	EU863-870
	918 - 921 MHz	Other
Macao		None
Macedonia, FYR	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870
Malaysia	433 - 435 MHz	EU433
	919 – 924 MHz	AS923
Maldives		None
Malta	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870
Mauritius		None
Mexico	902 - 928 MHz	US902-928, AU915-928
Moldova	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870
Mongolia		None
Montenegro	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870
Morocco	433.05 - 434.79 MHz	EU433
	867.6 - 869 MHz	EU863-870
Netherlands	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870
New-Zealand	915 - 928 MHz	AS923, AU915-928
	819 - 824 MHz	Other
	864 - 870MHz	EU863-870
	433.05 - 434.79 MHz	EU433
Nicaragua	902 - 928 MHz (915-928 MHz usable)	AU915-928, US902-928
Nigeria	863 - 870 MHz	EU863-870
Norway	433.05 - 434.79 MHz	EU433
	863 - 873 MHz	EU863-870
	918 - 921 MHz	Other
Oman	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870
Pakistan	433.05 - 434.79 MHz	EU433
	865 - 869 MHz	EU863-870
	900 - 925 MHz	AS923

Panama	902 - 928 MHz	AU915-928, US902-928, AS923
Paraguay	433.05 - 434.79 MHz	EU433
	915 - 928 MHz	AU915-928, AS923
Peru	915 - 928 MHz	AU915-928, AS923
Papua New Guinea	915 - 925 MHz	AU915-928
Philippines	915 - 918 MHz	Other
	868 – 869.2 MHz	EU863-870
	869.7 - 870 MHz	EU863-870
	433.05 - 434.79 MHz	EU433
Poland	433.05 - 434.79 MHz	EU433
	863 - 873 MHz	EU863-870
	918 - 921 MHz	Other
Portugal	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870
Qatar	433.05 - 434.79 MHz	EU433
	868 - 868.6 MHz	EU863-870
	868.7 - 869.2 MHz	EU863-870
	869.4 - 869.65 MHz	EU863-870
	869.7 - 870 MHz	EU863-870
Romania	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870
Russian federation	866 - 868 MHz (Licensed)	RU864-870
	864 - 865 MHz	RU864-870
	868.7 - 869.2 MHz	RU864-870
	433.075 - 434.75 MHz	EU433
	916 - 921 MHz (Licensed)	Other
Salvador	915-928	AU915-928, AS923
Saudi Arabia	863 - 870 MHz	EU863-870
	433.05 - 434.79 MHz	EU433
Senegal		None
Serbia	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870
Singapore	920 - 925 MHz	AS923
	433.05 - 434.79 MHz	EU433
	866 - 869 MHz	EU863-870
Slovak Republic	433.05 - 434.79 MHz	EU433
	863 - 873 MHz	EU863-870
	918 - 921 MHz	Other
Slovenia	433.05 - 434.79 MHz	EU433
	863 - 873 MHz	EU863-870
	918 - 921 MHz	Other
South Africa	433.05 - 434.79 MHz	EU433
	865 – 868.6 MHz	EU863-870

	868.7 – 869.2 MHz	EU863-870
	869.4 – 869.65 MHz	EU863-870
	869.7 – 870 MHz	EU863-870
	915 - 921 MHz	Other
South Korea	917 - 923.5 MHz	KR920-923
Spain	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870
Sri Lanka	433.05 - 434.79 MHz	EU433
Sudan		None
Sweden	433.05 - 434.79 MHz	EU433
	868 - 870 MHz	EU863-870
Switzerland	433.05 - 434.79 MHz	EU433
	863 - 873 MHz	EU863-870
Syrian Arab Rep.		None
Taiwan	920 - 925 MHz	AS923
Tajikistan		None
Tanzania		None
Thailand	433.05 - 434.79 MHz	EU433
	920 - 925 MHz	AS923
Trinidad and Tobago		None
Tunisia	433.05 - 434.79 MHz	EU433
	868 – 868.6 MHz	EU863-870
	868.7 – 869.2 MHz	EU863-870
	869.4 – 869.65 MHz	EU863-870
	869.7 – 870 MHz	EU863-870
Turkey	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870
Turkmenistan		None
Uganda	433.05 - 434.79 MHz	EU433
	865 - 867.6 MHz	Other
	869.25 - 869.7 MHz	Other
	923 - 925 MHz	AS923
Ukraine	433.05 - 434.79 MHz	EU433
	863 - 865 MHz	EU863-870
	868 - 868.6 MHz	EU863-870
United Arab Emirates	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870
	870 - 875.8 MHz	Other
	915 - 921 MHz	Other
United Kingdom	433.05 - 434.79 MHz	EU433
	863 - 873 MHz	EU863-870
	918 - 921 MHz	Other
United States	902 - 928 MHz	US902-928, AU915-928

Uruguay	902 - 928 MHz (915 - 928 MHz usable)	AU915-928, AS923, US902-928
Uzbekistan	433.05 - 434.79 MHz	EU433
Venezuela	922 - 928 MHz	AS923
Vietnam	433.05 - 434.79 MHz	EU433
	863 - 870 MHz	EU863-870
	918 - 923 MHz	Other
Yemen, Rep.		None
Zimbabwe		None

Table 1: Channel Plan per Country

293

2 LoRaWAN Regional Parameters

2.1 Regional Parameter Common Names

In order to support the identification of LoRaWAN channel plans referenced by other specification documents, the table below provides a quick reference of common channel plans listed for each formal plan name.

Channel Plan	Common Name
EU863-870	EU868
US902-928	US915
CN779-787	CN779
EU433	EU433
AU915-928	AU915
CN470-510	CN470
AS923	AS923
KR920-923	KR920
IN865-867	IN865
RU864-870	RU864

2.2 EU863-870MHz ISM Band

2.2.1 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 2: EU863-870 synch words

2.2.2 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 3: 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

317 hour. The ETSI regulations allow the choice of using either a duty-cycle limitation or a so-
 318 called **Listen Before Talk Adaptive Frequency Agility** (LBT AFA) transmissions
 319 management. The current LoRaWAN specification exclusively uses duty-cycled limited
 320 transmissions to comply with the ETSI regulations.

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

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

329 The following table gives the list of frequencies that SHALL be used by end-devices to
 330 broadcast the JoinReq message. The JoinReq message transmit duty-cycle SHALL follow the
 331 rules described in chapter "Retransmissions back-off" of the LoRaWAN specification
 332 document.
 333

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

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

335 2.2.3 EU863-870 Data Rate and End-device Output Power encoding

336 There is no dwell time limitation for the EU863-870 PHY layer. The **TxParamSetupReq** MAC
 337 command is not implemented in EU863-870 devices.

338 The following encoding is used for Data Rate (DR) and End-device EIRP (TXPower) in the
 339 EU863-870 band:

340

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	

341 **Table 5: EU863-870 TX Data rate table**

342

343 EIRP¹ refers to the Equivalent Isotropically Radiated Power, which is the radiated output
 344 power referenced to an isotropic antenna radiating power equally in all directions and whose
 345 gain is expressed in dBi.

TXPower	Configuration (EIRP)
0	Max EIRP
1	Max EIRP – 2dB
2	Max EIRP – 4dB
3	Max EIRP – 6dB
4	Max EIRP – 8dB
5	Max EIRP – 10dB
6	Max EIRP – 12dB
7	Max EIRP – 14dB
8..15	RFU

Table 6: EU863-870 TX power table

346
347
348
349
350
351
352
353

By default MaxEIRP is considered to be +16dBm. If the end-device cannot achieve 16dBm EIRP, the Max EIRP SHOULD be communicated to the network server using an out-of-band channel during the end-device commissioning process.

354 2.2.4 EU863-870 JoinAccept CFList

355

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

358 In this case the CFList is a list of five channel frequencies for the channels three to seven
 359 whereby each frequency is encoded as a 24 bits unsigned integer (three octets). All these
 360 channels are usable for DR0 to DR5 125kHz LoRa modulation. The list of frequencies is
 361 followed by a single CFListType octet for a total of 16 octets. The CFListType SHALL be equal
 362 to zero (0) to indicate that the CFList contains a list of frequencies.

363

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

364 The actual channel frequency in Hz is 100 x frequency whereby values representing
 365 frequencies below 100 MHz are reserved for future use. This allows setting the frequency of
 366 a channel anywhere between 100 MHz to 1.67 GHz in 100 Hz steps. Unused channels have
 367 a frequency value of 0. The **CFList** is optional and its presence can be detected by the length
 368 of the join-accept message. If present, the **CFList** SHALL replace all the previous channels
 369 stored in the end-device apart from the three default channels. The newly defined channels
 370 are immediately enabled and usable by the end-device for communication.

371 2.2.5 EU863-870 LinkAdrReq command

372 The EU863-870 LoRaWAN only supports a maximum of 16 channels. When **ChMaskCntl**
 373 field is 0 the ChMask field individually enables/disables each of the 16 channels.
 374

¹ ERP = EIRP – 2.15dB; it is referenced to a half-wave dipole antenna whose gain is expressed in dBd

ChMaskCntl	ChMask applies to
0	Channels 0 to 15
1	RFU
..	..
4	RFU
5	RFU
6	All channels ON The device SHALL enable all currently defined channels independently of the ChMask field value.
7	RFU

375

Table 7: EU863-870 ChMaskCntl value table

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

378 2.2.6 EU863-870 Maximum payload size

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

384

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	

385

Table 8: EU863-870 maximum payload size

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

388

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	

389

Table 9 : EU863-870 maximum payload size (not repeater compatible)

390 2.2.7 EU863-870 Receive windows

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

393 allowed values for RX1DROffset are in the [0:5] range. Values in the [6:7] range are reserved
 394 for future use.
 395

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

396 **Table 10: EU863-870 downlink RX1 data rate mapping**

397

398 The RX2 receive window uses a fixed frequency and data rate. The default parameters are
 399 869.525 MHz / DR0 (SF12, 125 kHz)

400

401 2.2.8 EU863-870 Class B beacon and default downlink channel

402 The beacons SHALL be transmitted using the following settings

DR	3	Corresponds to SF9 spreading factor with 125 kHz BW
CR	1	Coding rate = 4/5
Signal polarity	Non-inverted	As opposed to normal downlink traffic which uses inverted signal polarity

403 **Table 11: EU863-870 beacon settings**

404

405 The beacon frame content is:

406

Size (bytes)	2	4	2	7	2
BCNPayload	RFU	Time	CRC	GwSpecific	CRC

407

408 The beacon default broadcast frequency is 869.525MHz.

409 The Class B default downlink pingSlot frequency is 869.525MHz

410

411 2.2.9 EU863-870 Default Settings

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

413	RECEIVE_DELAY1	1 s
414	RECEIVE_DELAY2	2 s (MUST be RECEIVE_DELAY1 + 1s)
415	JOIN_ACCEPT_DELAY1	5 s
416	JOIN_ACCEPT_DELAY2	6 s
417	MAX_FCNT_GAP	16384
418	ADR_ACK_LIMIT	64
419	ADR_ACK_DELAY	32
420	ACK_TIMEOUT	2 +/- 1 s (random delay between 1 and 3 seconds)

421 If the actual parameter values implemented in the end-device are different from those default
422 values (for example the end-device uses a longer RECEIVE_DELAY1 and
423 RECEIVE_DELAY2 latency), those parameters **MUST** be communicated to the network
424 server using an out-of-band channel during the end-device commissioning process. The
425 network server may not accept parameters different from those default values.
426

427 **2.3 US902-928MHz ISM Band**

428 This section defines the regional parameters for the USA, Canada and all other countries
 429 adopting the entire FCC-Part15 regulations in 902-928 ISM band.

430 **2.3.1 US902-928 Preamble Format**

431 The following synchronization words SHOULD be used:
 432

Modulation	Sync word	Preamble length
LORA	0x34	8 symbols

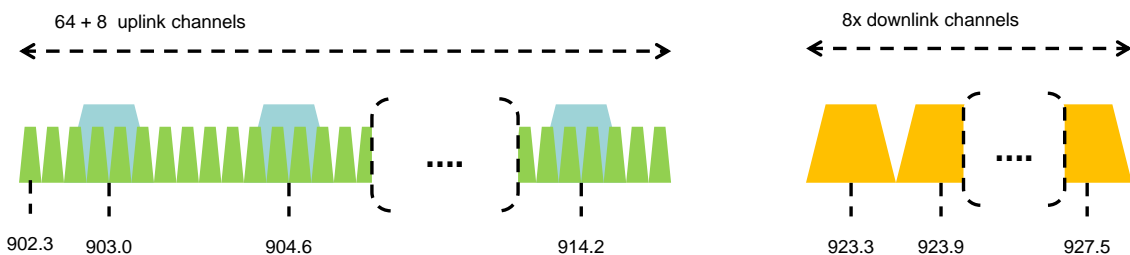
433

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

435 **2.3.2 US902-928 Channel Frequencies**

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

- 437 • Upstream – 64 channels numbered 0 to 63 utilizing LoRa 125 kHz BW varying from
 438 DR0 to DR3, using coding rate 4/5, starting at 902.3 MHz and incrementing linearly
 439 by 200 kHz to 914.9 MHz
- 440 • Upstream – 8 channels numbered 64 to 71 utilizing LoRa 500 kHz BW at DR4
 441 starting at 903.0 MHz and incrementing linearly by 1.6 MHz to 914.2 MHz
- 442 • Downstream – 8 channels numbered 0 to 7 utilizing LoRa 500 kHz BW at DR8 to
 443 DR13, starting at 923.3 MHz and incrementing linearly by 600 kHz to 927.5 MHz
 444



445
 446

Figure 1: US902-928 channel frequencies

447 915 MHz ISM band end-devices are required to operate in compliance with the relevant
 448 regulatory specifications, the following note summarizes some of the current (March 2017)
 449 relevant regulations.

450 Frequency-Hopping, Spread-Spectrum (FHSS) mode, which requires
 451 the device transmit at a measured conducted power level no greater
 452 than +30 dBm, for a period of no more than 400 msec and over at least
 453 50 channels, each of which occupy no greater than 250 kHz of
 454 bandwidth.

455 Digital Transmission System (DTS) mode, which requires that the
 456 device use channels greater than or equal to 500 kHz and comply with
 457 a conducted Power Spectral Density measurement of no more than +8
 458 dBm per 3 kHz of spectrum. In practice, this limits the conducted output
 459 power of an end-device to +26 dBm.

460 Hybrid mode, which requires that the device transmit over multiple
 461 channels (this may be less than the 50 channels required for FHSS
 462 mode, but is recommended to be at least 4) while complying with the
 463 Power Spectral Density requirements of DTS mode and the 400 msec

464 dwell time of FHSS mode. In practice this limits the measured
 465 conducted power of the end-device to 21 dBm.

466 Devices which use an antenna system with a directional gain greater
 467 than +6 dBi, but reduce the specified conducted output power by the
 468 amount in dB of directional gain over +6 dBi.

469 US902-928 end-devices **MUST** be capable of operating in the 902 to 928 MHz frequency band
 470 and **MUST** feature a channel data structure to store the parameters for 72 channels. This
 471 channel data structure contains a list of frequencies and the set of data rates available for
 472 each frequency.

473
 474 If using the over-the-air activation procedure, the end-device **SHALL** transmit the Join-
 475 request message on random 125 kHz channels amongst the 64 125kHz channels defined
 476 using **DR0** and on 500 kHz channels amongst the 8 500kHz channels defined using **DR4**.
 477 The end-device **SHALL** change channels for every transmission.

478 For rapid network acquisition in mixed gateway channel plan environments, the device
 479 **SHOULD** follow a random channel selection sequence which efficiently probes the octet
 480 groups of eight 125 kHz channels followed by probing one 500 kHz channel each pass.
 481 Each consecutive pass **SHOULD NOT** select a channel that was used in a previous pass,
 482 until a Join-request is transmitted on every channel, after which the entire process can
 483 restart.

484 Example: First pass: Random channel from [0-7], followed by [8-15]... [56-63], then 64
 485 Second pass: Random channel from [0-7], followed by [8-15]... [56-63], then
 486 65
 487 Last pass: Random channel from [0-7], followed by [8-15]... [56-63], then 71

488 Personalized devices **SHALL** have all 72 channels enabled following a reset and shall use the
 489 channels for which the device's default data-rate is valid.

490 **2.3.3 US902-928 Data Rate and End-device Output Power encoding**

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

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

495

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
--------	-----

496

Table 12: US902-928 TX Data rate table

497

498

499

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

TXPower	Configuration (conducted power)
0	30 dBm – 2*TXpower
1	28 dBm
2	26 dBm
3..15

500

Table 13: US902-928 TX power table

501 2.3.4 US902-928 JoinAccept CFList

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509

The US902-928 LoRaWAN supports the use of the optional **CFList** appended to the JoinResp message. If the **CFList** is not empty then the **CFListType** field SHALL contain the value one (0x01) to indicate the **CFList** contains a series of ChMask fields. The ChMask fields are interpreted as being controlled by a virtual ChMaskCntl that initializes to a value of zero (0) and increments for each ChMask field to a value of four (4). (The first 16 bits controls the channels 0 to 15, ..)

Size (bytes)	[2]	[2]	[2]	[2]	[2]	[2]	[3]	[1]
CFList	<i>ChMask0</i>	<i>ChMask1</i>	<i>ChMask2</i>	<i>ChMask3</i>	<i>ChMask4</i>	RFU	RFU	<i>CFListType</i>

510

511

512 2.3.5 US902-928 LinkAdrReq command

513

514

515

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	8LSBs controls Channel Blocks 0 to 7 8MSBs are 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

516

Table 14: US902-928 ChMaskCntl value table

517

518

519

520

If **ChMaskCntl** = 5 then the corresponding bits in the ChMask enable and disable a bank of 8 125kHz channels and the corresponding 500kHz channel defined by the following calculation: $[\text{ChannelMaskBit} * 8, \text{ChannelMaskBit} * 8 + 7], 64 + \text{ChannelMaskBit}$.

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

525

526 **Note:** FCC regulation requires hopping over at least 50 channels when
 527 using maximum output power. It is possible to have end-devices with
 528 less channels when limiting the end-device conducted transmit power to
 529 21 dBm.

530 **Note:** A common network server action may be to reconfigure a device
 531 through multiple **LinkAdrReq** commands in a contiguous block of MAC
 532 Commands. For example to reconfigure a device from 64 channel
 533 operation to the first 8 channels could contain two **LinkAdrReq**, the first
 534 (**ChMaskCntl** = 7) to disable all 125kHz channels and the second
 535 (**ChMaskCntl** = 0) to enable a bank of 8 125kHz channels.
 536

537 2.3.6 US902-928 Maximum payload size

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

543

544

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	

Table 15: US902-928 maximum payload size (repeater compatible)

545

546

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

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

551

DataRate	M	N
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	

Table 16 : US902-928 maximum payload size (not repeater compatible)

552

553 2.3.7 US902-928 Receive windows

- 554
- 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 = Transmit Channel Number modulo 8
 - The RX1 window data rate depends on the transmit data rate (see Table 17 below).
 - The RX2 (second receive window) settings uses a fixed data rate and frequency. Default parameters are 923.3MHz / DR8
- 555
- 556
- 557
- 558
- 559
- 560

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

Table 17: US902-928 downlink RX1 data rate mapping

561

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

563

564 2.3.8 US902-928 Class B beacon

565 The beacons SHALL BE transmitted using the following settings:

DR	8	Corresponds to SF12 spreading factor with 500kHz bw
CR	1	Coding rate = 4/5
Signal polarity	Non-inverted	As opposed to normal downlink traffic which uses inverted signal polarity
frequencies	923.3 to 927.5MHz with 600kHz steps	Beaconing is performed on the same channel that normal downstream traffic as defined in the Class A specification

Table 18: US902-928 beacon settings

566

567 The downstream channel used for a given beacon is:

568
$$\text{Channel} = \left[\text{floor} \left(\frac{\text{beacon_time}}{\text{beacon_period}} \right) \right] \text{ modulo } 8$$

- whereby beacon_time is the integer value of the 4 bytes “Time” field of the beacon frame
 - whereby beacon_period is the periodicity of beacons , 128 seconds
 - whereby floor(x) designates rounding to the integer immediately inferior or equal to x
- 569
- 570
- 571
- 572
- 573

574
575
576
577

Example: the first beacon will be transmitted on 923.3Mhz , the second on 923.9MHz, the 9th beacon will be on 923.3Mhz again.

Beacon channel nb	Frequency [MHz]
0	923.3
1	923.9
2	924.5
3	925.1
4	925.7
5	926.3
6	926.9
7	927.5

578
579
580

The beacon frame content is:

Size (bytes)	5	4	2	7	3	2
BCNPayload	RFU	Time	CRC	GwSpecific	RFU	CRC

581

582 **2.3.9 US902-928 Default Settings**

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

584 RECEIVE_DELAY1 1 s
 585 RECEIVE_DELAY2 2 s (MUST be RECEIVE_DELAY1 + 1s)
 586 JOIN_ACCEPT_DELAY1 5 s
 587 JOIN_ACCEPT_DELAY2 6 s
 588 MAX_FCNT_GAP 16384
 589 ADR_ACK_LIMIT 64
 590 ADR_ACK_DELAY 32
 591 ACK_TIMEOUT 2 +/- 1 s (random delay between 1 and 3 seconds)

592 If the actual parameter values implemented in the end-device are different from those default
 593 values (for example the end-device uses a longer RECEIVE_DELAY1 & 2 latency), those
 594 parameters MUST be communicated to the network server using an out-of-band channel
 595 during the end-device commissioning process. The network server may not accept
 596 parameters different from those default values.
 597

598 2.4 CN779-787 MHz ISM Band

599 2.4.1 CN779-787 Preamble Format

600 The following synchronization words SHOULD be used :
601

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

602 **Table 19: CN779-787 synch words**

603 2.4.2 CN779-787 ISM Band channel frequencies

604

605 The LoRaWAN can be used in the Chinese 779-787MHz band as long as the radio device
606 EIRP is less than 12.15dBm.

607 The end-device transmit duty-cycle SHOULD be lower than 1%.

608 The LoRaWAN channels center frequency MAY be in the following range:

- 609 • Minimum frequency : 779.5MHz
- 610 • Maximum frequency : 786.5 MHz

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

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

620 The following table gives the list of frequencies that SHALL be used by end-devices to
621 broadcast the JoinReq message The JoinReq message transmit duty-cycle SHALL follow the
622 rules described in chapter "Retransmissions back-off" of the LoRaWAN specification
623 document.

624

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

625 **Table 20: CN779-787 JoinReq Channel List**

626

627 2.4.3 CN779-787 Data Rate and End-device Output Power encoding

628 There is no dwell time limitation for the CN779-787 PHY layer. The **TxParamSetupReq** MAC
629 command is not implemented by CN779-787 devices.

630 The following encoding is used for Data Rate (DR) and End-device EIRP (TXPower) in the
 631 CN780 band:

632

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

Table 21: CN779-787 Data rate and TX power table

633

634

635 EIRP refers to the Equivalent Isotropically Radiated Power, which is the radiated output
 636 power referenced to an isotropic antenna radiating power equally in all directions and whose
 637 gain is expressed in dBi.

638

639 By default MAXEIRP is considered to be +12.15dBm. If the end-device cannot achieve
 640 12.15dBm EIRP, the Max EIRP SHOULD be communicated to the network server using an
 641 out-of-band channel during the end-device commissioning process.

642

643 2.4.4 CN779-787 JoinAccept CFList

644 The CN780 ISM band LoRaWAN implements an optional **channel frequency list** (CFList) of
 645 16 octets in the JoinAccept message.

646 In this case the CFList is a list of five channel frequencies for the channels three to seven
 647 whereby each frequency is encoded as a 24 bits unsigned integer (three octets). All these
 648 channels are usable for DR0 to DR5 125kHz LoRa modulation. The list of frequencies is
 649 followed by a single CFListType octet for a total of 16 octets. The CFListType SHALL be equal
 650 to zero (0) to indicate that the CFList contains a list of frequencies.

651

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

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

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

660 **2.4.5 CN779-787 LinkAdrReq command**

661

 662 The CN780 LoRaWAN only supports a maximum of 16 channels. When **ChMaskCntl** field is
 663 0 the ChMask field individually enables/disables each of the 16 channels.
 664

ChMaskCntl	ChMask applies to
0	Channels 0 to 15
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 22: CN779-787 ChMaskCntl value table

665

666

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

 669 **2.4.6 CN779-787 Maximum payload size**

 670 The maximum **MACPayload** size length (M) is given by the following table. It is derived from
 671 limitation of the PHY layer depending on the effective modulation rate used taking into account
 672 a possible repeater encapsulation layer. The maximum application payload length in the
 673 absence of the optional **FOpt** control field (N) is also given for information only. The value of
 674 N MAY be smaller if the **FOpt** field is not empty:
 675

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 23: CN779-787 maximum payload size

676

677

 678 If the end-device will never operate with a repeater then the maximum application payload
 679 length in the absence of the optional **FOpt** control field SHOULD be:
 680

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	

681 **Table 24 : CN779-787 maximum payload size (not repeater compatible)**

 682 **2.4.7 CN779-787 Receive windows**

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

 687

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

 688 **Table 25: CN779-787 downlink RX1 data rate mapping**

 689 The RX2 receive window uses a fixed frequency and data rate. The default parameters are
 690 786 MHz / DR0.

 691 **2.4.8 CN779-787 Class B beacon and default downlink channel**

692 The beacons SHALL be transmitted using the following settings

DR	3	Corresponds to SF9 spreading factor with 125 kHz BW
CR	1	Coding rate = 4/5
Signal polarity	Non-inverted	As opposed to normal downlink traffic which uses inverted signal polarity

 693 **Table 26: CN779-787 beacon settings**

694 The beacon frame content is:

Size (bytes)	2	4	2	7	2
BCNPayload	RFU	Time	CRC	GwSpecific	CRC

695 The beacon default broadcast frequency is 785MHz.

696 The class B default downlink pingSlot frequency is 785MHz

697

 698 **2.4.9 CN779-787 Default Settings**

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

700	RECEIVE_DELAY1	1 s
701	RECEIVE_DELAY2	2 s (MUST be RECEIVE_DELAY1 + 1s)
702	JOIN_ACCEPT_DELAY1	5 s
703	JOIN_ACCEPT_DELAY2	6 s
704	MAX_FCNT_GAP	16384
705	ADR_ACK_LIMIT	64
706	ADR_ACK_DELAY	32

707 ACK_TIMEOUT 2 +/- 1 s (random delay between 1 and 3 seconds)

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

713 **2.5 EU433MHz ISM Band**

714 **2.5.1 EU433 Preamble Format**

715 The following synchronization words SHOULD be used :
716

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

717 **Table 27: EU433 synch words**

718 **2.5.2 EU433 ISM Band channel frequencies**

719 The LoRaWAN can be used in the ETSI 433-434 MHz band as long as the radio device EIRP
720 is less than 12.15dBm.

721 The end-device transmit duty-cycle SHALL be lower than 10%¹

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

- 723 • Minimum frequency : 433.175 MHz
- 724 • Maximum frequency : 434.665 MHz

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

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

734 The following table gives the list of frequencies that SHALL be used by end-devices to
735 broadcast the JoinReq message. The JoinReq message transmit duty-cycle SHALL follow the
736 rules described in chapter “Retransmissions back-off” of the LoRaWAN specification
737 document.

738

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%

739 **Table 28: EU433 JoinReq Channel List**

740

741 **2.5.3 EU433 Data Rate and End-device Output Power encoding**

742 There is no dwell time limitation for the EU433 PHY layer. The **TxParamSetupReq** MAC
743 command is not implemented by EU433 devices.

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.

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

746

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

747 **Table 29: EU433 Data rate and TX power table**

748

749 EIRP refers to the Equivalent Isotropically Radiated Power, which is the radiated output
750 power referenced to an isotropic antenna radiating power equally in all directions and whose
751 gain is expressed in dBi.

752

753 By default MAXEIRP is considered to be +12.15dBm. If the end-device cannot achieve
754 12.15dBm EIRP, the Max EIRP SHALL be communicated to the network server using an
755 out-of-band channel during the end-device commissioning process.

756

757

758 2.5.4 EU433 JoinAccept CFList

759

760 The EU433 ISM band LoRaWAN implements an optional **channel frequency list** (CFList) of
761 16 octets in the JoinAccept message.

762 In this case the CFList is a list of five channel frequencies for the channels three to seven
763 whereby each frequency is encoded as a 24 bits unsigned integer (three octets). All these
764 channels are usable for DR0 to DR5 125 kHz LoRa modulation. The list of frequencies is
765 followed by a single CFListType octet for a total of 16 octets. The CFListType SHALL be equal
766 to zero (0) to indicate that the CFList contains a list of frequencies.

767

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

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

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

776 **2.5.5 EU433 LinkAdrReq command**

 777 The EU433 LoRaWAN only supports a maximum of 16 channels. When **ChMaskCntl** field is
 778 0 the ChMask field individually enables/disables each of the 16 channels.
 779

ChMaskCntl	ChMask applies to
0	Channels 0 to 15
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

 780 **Table 30: EU433 ChMaskCntl value table**

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

 783 **2.5.6 EU433 Maximum payload size**

 784 The maximum **MACPayload** size length (*M*) is given by the following table. It is derived from
 785 limitation of the PHY layer depending on the effective modulation rate used taking into account
 786 a possible repeater encapsulation layer. The maximum application payload length in the
 787 absence of the optional **FOpt** control field (*N*) is also given for information only. The value of
 788 *N* might be smaller if the **FOpt** field is not empty:
 789

DataRate	<i>M</i>	<i>N</i>
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	

 790 **Table 31: EU433 maximum payload size**

 791
 792 If the end-device will never operate with a repeater then the maximum application payload
 793 length in the absence of the optional **FOpt** control field SHOULD be:
 794

DataRate	<i>M</i>	<i>N</i>
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	

795
 796

Table 32 : EU433 maximum payload size (not repeater compatible)
797 2.5.7 EU433 Receive windows

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

802

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

803

Table 33 : EU433 downlink RX1 data rate mapping

804 The RX2 receive window uses a fixed frequency and data rate. The default parameters are
 805 434.665MHz / DR0 (SF12, 125kHz).

806

807 2.5.8 EU433 Class B beacon and default downlink channel

808 The beacons SHALL be transmitted using the following settings

DR	3	Corresponds to SF9 spreading factor with 125 kHz BW
CR	1	Coding rate = 4/5
Signal polarity	Non-inverted	As opposed to normal downlink traffic which uses inverted signal polarity

809

Table 34 : EU433 beacon settings

810 The beacon frame content is:

Size (bytes)	2	4	2	7	2
BCNPayload	RFU	Time	CRC	GwSpecific	CRC

811 The beacon default broadcast frequency is 434.665MHz.

812 The class B default downlink pingSlot frequency is 434.665MHz

813

814 2.5.9 EU433 Default Settings

815 The following parameters are recommended values for the EU433band.

816	RECEIVE_DELAY1	1 s
817	RECEIVE_DELAY2	2 s (MUST be RECEIVE_DELAY1 + 1s)
818	JOIN_ACCEPT_DELAY1	5 s
819	JOIN_ACCEPT_DELAY2	6 s
820	MAX_FCNT_GAP	16384

821	ADR_ACK_LIMIT	64
822	ADR_ACK_DELAY	32
823	ACK_TIMEOUT	2 +/- 1 s (random delay between 1 and 3 seconds)
824		
825	If the actual parameter values implemented in the end-device are different from those default	
826	values (for example the end-device uses a longer RECEIVE_DELAY1 & 2 latency) , those	
827	parameters MUST be communicated to the network server using an out-of-band channel	
828	during the end-device commissioning process. The network server may not accept	
829	parameters different from those default values.	
830		

831 **2.6 AU915-928MHz ISM Band**

832

833 This section defines the regional parameters for Australia and all other countries whose ISM
834 band extends from 915 to 928MHz spectrum.
835

836 **2.6.1 AU915-928 Preamble Format**

837 The following synchronization words SHOULD be used:
838

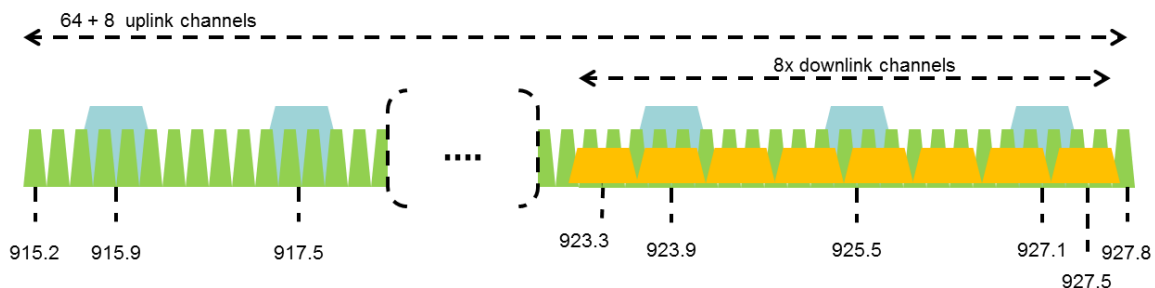
Modulation	Sync word	Preamble length
LORA	0x34	8 symbols

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

840 **2.6.2 AU915-928 Channel Frequencies**

841 The AU ISM Band SHALL be divided into the following channel plans.

- 842 • Upstream – 64 channels numbered 0 to 63 utilizing LoRa 125 kHz BW varying from
843 DR0 to DR5, using coding rate 4/5, starting at 915.2 MHz and incrementing linearly
844 by 200 kHz to 927.8 MHz
- 845 • Upstream – 8 channels numbered 64 to 71 utilizing LoRa 500 kHz BW at DR6
846 starting at 915.9 MHz and incrementing linearly by 1.6 MHz to 927.1 MHz
- 847 • Downstream – 8 channels numbered 0 to 7 utilizing LoRa 500 kHz BW at DR8 to
848 DR13) starting at 923.3 MHz and incrementing linearly by 600 kHz to 927.5 MHz
849



850
851

Figure 2: AU915-928 channel frequencies

852 AU ISM band end-devices may use a maximum EIRP of +30 dBm.

853 AU915-928 end-devices SHALL be capable of operating in the 915 to 928 MHz frequency
854 band and SHALL feature a channel data structure to store the parameters of 72 channels. A
855 channel data structure corresponds to a frequency and a set of data rates usable on this
856 frequency.

857 If using the over-the-air activation procedure, the end-device SHALL broadcast the JoinReq
858 message alternatively on a random 125 kHz channel amongst the 64 channels defined using
859 **DR2** and a random 500 kHz channel amongst the 8 channels defined using **DR6**. The end-
860 device SHOULD change channel for every transmission.

861 Personalized devices SHALL have all 72 channels enabled following a reset.

862

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

867 AU915-928 end-devices MUST consider UplinkDwellTime = 1 during
 868 boot stage until reception of the **TxParamSetupReq** command.
 869 AU915-928 end-devices MUST always consider DownlinkDwellTime =
 870 0, since downlink channels use 500KHz bandwidth without any dwell
 871 time limit.
 872

873 2.6.3 AU915-928 Data Rate and End-point Output Power encoding

874 The “TxParamSetupReq/Ans” MAC commands MUST be implemented by AU915-928
 875 devices.

876 If the field UplinkDwellTime is set to 1 by the network server in the
 877 **TxParamSetupReq** command, AU915-928 end-devices SHALL adjust
 878 the time between two consecutive uplink transmissions to meet the local
 879 regulation. Twenty seconds (20s) are recommended between 2 uplink
 880 transmissions when UplinkDwellTime = 1 but this value MAY be
 881 adjusted depending on local regulation.
 882 There is no such constraint on time between two consecutive
 883 transmissions when UplinkDwellTime = 0.

884
 885 The following encoding is used for Data Rate (**DR**) and End-point EIRP (**TXPower**) in the
 886 AU915-928 band:

887

DataRate	Configuration	Indicative physical bit rate [bit/sec]
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: SF8 / 500 kHz	12500
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 35: AU915-928 Data rate table

888
 889 DR6 is identical to DR12, DR8...13 MUST be implemented in end-devices and are reserved
 890 for future applications.
 891
 892
 893
 894
 895
 896

897

TXPower	Configuration (EIRP)
0	Max EIRP
1..15	Max EIRP – 2*TXPower

Table 36 : AU915-928 TX power table

898

899

900 EIRP refers to the Equivalent Isotropically Radiated Power, which is the radiated output
 901 power referenced to an isotropic antenna radiating power equally in all directions and whose
 902 gain is expressed in dBi.

903

904 By default MaxEIRP is considered to be +30dBm. The Max EIRP can be modified by the
 905 network server through the **TxParamSetupReq** MAC command and SHOULD be used by
 906 both the end-device and the network server once **TxParamSetupReq** is acknowledged by
 907 the device via **TxParamSetupAns**.

908

909 2.6.4 AU915-928 JoinAccept CFList

910

911 The AU915-928 LoRaWAN supports the use of the optional **CFList** appended to the
 912 JoinResp message. If the **CFList** is not empty then the CFListType field SHALL contain the
 913 value one (0x01) to indicate the CFList contains a series of ChMask fields. The ChMask
 914 fields are interpreted as being controlled by a virtual ChMaskCntl that initializes to a value of
 915 zero (0) and increments for each ChMask field to a value of four(4). (The first 16 bits
 916 controls the channels 1 to 16, ..)

Size (bytes)	[2]	[2]	[2]	[2]	[2]	[2]	[3]	[1]
CFList	ChMask0	ChMask1	ChMask2	ChMask3	ChMask4	RFU	RFU	CFListType

917

918 2.6.5 AU915-928 LinkAdrReq command

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

921

922

ChMaskCntl	ChMask applies to
0	Channels 0 to 15
1	Channels 16 to 31
..	..
4	Channels 64 to 71
5	8LSBs controls Channel Blocks 0 to 7 8MSBs are 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 37: AU915-928 ChMaskCntl value table

923

924 If **ChMaskCntl** = 5 then the corresponding bits in the ChMask enable and disable a bank of 8
 925 125kHz channels and the corresponding 500kHz channel defined by the following calculation:
 926 [ChannelMaskBit * 8, ChannelMaskBit * 8 + 7], 64+ChannelMaskBit.

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

931

932 2.6.6 AU915-928 Maximum payload size

933 The maximum **MACPayload** size length (M) is given by the following table for both uplink
 934 dwell time configurations: No Limit and 400ms. It is derived from the maximum allowed
 935 transmission time at the PHY layer taking into account a possible repeater encapsulation. The
 936 maximum application payload length in the absence of the optional **FOpt** MAC control field
 937 (N) is also given for information only. The value of N might be smaller if the **FOpt** field is not
 938 empty:

939

940

941

942

943

944

945

946

947

948

949

950

951

952

DataRate	UplinkDwellTime=0		UplinkDwellTime=1	
	M	N	M	N
0	59	51	N/A	N/A
1	59	51	N/A	N/A
2	59	51	19	11
3	123	115	61	53
4	230	222	133	125
5	230	222	250	242
6	230	222	250	242
7	Not defined		Not defined	
8	41	33	41	33
9	117	109	117	109
10	230	222	230	222
11	230	222	230	222
12	230	222	230	222
13	230	222	230	222
14:15	Not defined		Not defined	

Table 38: AU915-928 maximum payload size

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

955 For AU915-928, **DownlinkDwellTime** MUST be set to 0 (no limit). The
 956 400ms dwell time MAY only apply to uplink channels depending on the
 957 local regulations.

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

960

DataRate	UplinkDwellTime=0		UplinkDwellTime=1	
	M	N	M	N
0	59	51	N/A	N/A
1	59	51	N/A	N/A
2	59	51	19	11
3	123	115	61	53
4	250	242	133	125
5	250	242	250	242
6	250	242	250	242

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968
969
970
971
972

7	Not defined		Not defined	
8	61	53	61	53
9	137	129	137	129
10	250	242	250	242
11	250	242	250	242
12	250	242	250	242
13	250	242	250	242
14:15	Not defined		Not defined	

Table 39: AU915-payload size (not

compatible)

928 maximum repeater

973 2.6.7 AU915-928 Receive windows

- 974 • The RX1 receive channel is a function of the upstream channel used to initiate the
- 975 data exchange. The RX1 receive channel can be determined as follows.
- 976 ○ RX1 Channel Number = Transmit Channel Number modulo 8
- 977 • The RX1 window data rate depends on the transmit data rate (see Table 17 below).
- 978 • The RX2 (second receive window) settings uses a fixed data rate and frequency.
- 979 Default parameters are 923.3Mhz / DR8
- 980

Upstream data rate RX1DROff set	Downstream data rate					
	0	1	2	3	4	5
DR0	DR8	DR8	DR8	DR8	DR8	DR8
DR1	DR9	DR8	DR8	DR8	DR8	DR8
DR2	DR10	DR9	DR8	DR8	DR8	DR8
DR3	DR11	DR10	DR9	DR8	DR8	DR8
DR4	DR12	DR11	DR10	DR9	DR8	DR8
DR5	DR13	DR12	DR11	DR10	DR9	DR8
DR6	DR13	DR13	DR12	DR11	DR10	DR9

Table 40 : AU915-928 downlink RX1 data rate mapping

981
982

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

985

986 2.6.8 AU915-928 Class B beacon

987 The beacons are transmitted using the following settings:

DR	8	Corresponds to SF12 spreading factor with 500kHz bw
CR	1	Coding rate = 4/5
Signal polarity	Non-inverted	As opposed to normal downlink traffic which uses inverted signal polarity
frequencies	923.3 to 927.5MHz with 600kHz steps	Beaconing is performed on the same channel that normal downstream traffic as defined in the Class A specification

Table 41 : AU915-928 beacon settings

988

989 The downstream channel used for a given beacon is:

990
$$\text{Channel} = \left[\text{floor} \left(\frac{\text{beacon_time}}{\text{beacon_period}} \right) \right] \text{ modulo } 8$$

- 991
- 992
- 993
- 994
- 995
- whereby beacon_time is the integer value of the 4 bytes “Time” field of the beacon frame
 - whereby beacon_period is the periodicity of beacons , 128 seconds
 - whereby $\text{floor}(x)$ designates rounding to the integer immediately inferior or equal to x

996

997

998

999

Example: the first beacon will be transmitted on 923.3Mhz , the second on 923.9MHz, the 9th beacon will be on 923.3Mhz again.

Beacon channel nb	Frequency [MHz]
0	923.3
1	923.9
2	924.5
3	925.1
4	925.7
5	926.3
6	926.9
7	927.5

1000

1001

1002

The beacon frame content is:

Size (bytes)	3	4	2	7	1	2
BCNPPayload	RFU	Time	CRC	GwSpecific	RFU	CRC

1003

1004 2.6.9 AU915-928 Default Settings

1005 The following parameters are recommended values for the AU915-928 band.

1006	RECEIVE_DELAY1	1 s
1007	RECEIVE_DELAY2	2 s (MUST be RECEIVE_DELAY1 + 1s)
1008	JOIN_ACCEPT_DELAY1	5 s
1009	JOIN_ACCEPT_DELAY2	6 s
1010	MAX_FCNT_GAP	16384
1011	ADR_ACK_LIMIT	64
1012	ADR_ACK_DELAY	32
1013	ACK_TIMEOUT	2 +/- 1 s (random delay between 1 and 3 seconds)

1014 If the actual parameter values implemented in the end-device are different from those default

1015 values (for example the end-device uses a longer RECEIVE_DELAY1 & 2 latency), those

1016 parameters MUST be communicated to the network server using an out-of-band channel

1017 during the end-device commissioning process. The network server may not accept

1018 parameters different from those default values.

1019

1020 **2.7 CN470-510MHz Band**

1021 **2.7.1 CN470-510 Preamble Format**

1022 The following synchronization words SHOULD be used:

1023

Modulation	Sync word	Preamble length
LORA	0x34	8 symbols

1024 **2.7.2 CN470-510 Channel Frequencies**

1025

1026 In China, this band is defined by SRRC to be used for civil metering applications.

1027 The 470 MHz ISM Band SHALL be divided into the following channel plans:

1028

- 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.

1029

1030

1031

1032

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

1033

1034

1035

1036

- 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

1037

1038

1039

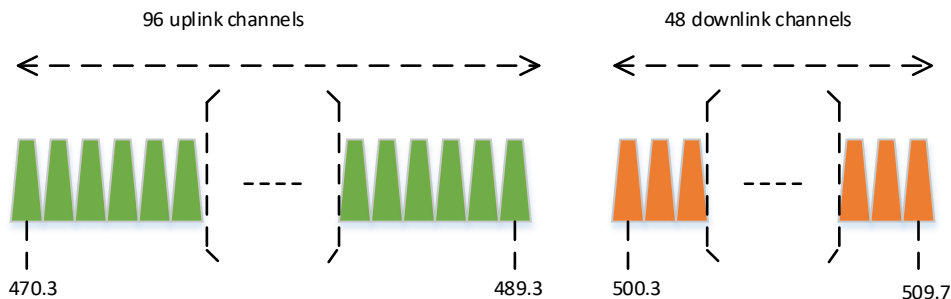


Figure 3: CN470-510 channel frequencies

1040

1041

1042

1043 The LoRaWAN can be used in the Chinese 470-510MHz band as long as

1044

- The radio device EIRP is less than 19.15dBm
- The transmission never lasts more than 5000 ms.

1045

1046

1047

1048

1049 CN470-510 end-devices SHALL be capable of operating in the 470 to 510 MHz frequency band and SHALL feature a channel data structure to store the parameters of 96 uplink channels. A channel data structure corresponds to a frequency and a set of data rates usable on this frequency.

1050

1051

1052

1053 If using the over-the-air activation procedure, the end-device SHALL broadcast the JoinReq message on a random 125 kHz channel amongst the 96 uplink channels defined using **DR5 to DR0**.

1054

1055

1056 Personalized devices SHALL have all 96 channels enabled following a reset.

1057

1058 **2.7.3 CN470-510 Data Rate and End-point Output Power encoding**

1059 There is no dwell time limitation for the CN470-510 PHY layer. The *TxParamSetupReq* MAC
1060 command is not implemented by CN470-510 devices.

1061 The following encoding is used for Data Rate (**DR**) and End-point EIRP (**TXPower**) in the
1062 CN470-510 band:

1063

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

Table 42: CN470-510 Data rate and TX power table

1064

1065

1066 EIRP refers to the Equivalent Isotropically Radiated Power, which is the radiated output
1067 power referenced to an isotropic antenna radiating power equally in all directions and whose
1068 gain is expressed in dBi.

1069

1070 By default MaxEIRP is considered to be +19.15dBm. If the end-device cannot achieve
1071 19.15dBm EIRP, the Max EIRP SHOULD be communicated to the network server using an
1072 out-of-band channel during the end-device commissioning process.

1073

1074 **2.7.4 CN470-510 JoinResp CFList**

1075

1076 The CN470-510 LoRaWAN supports the use of the optional **CFList** appended to the
1077 JoinResp message. If the **CFList** is not empty then the CFListType field SHALL contain the
1078 value one (0x01) to indicate the CFList contains a series of ChMask fields. The ChMask
1079 fields are interpreted as being controlled by a virtual ChMaskCntl that initializes to a value of
1080 zero (0) and increments for each ChMask field to a value of five (5). (The first 16 bits
1081 controls the channels 1 to 16, ..)

1082

Size (bytes)	[2]	[2]	[2]	[2]	[2]	[2]	[3]	[1]
CFList	ChMask0	ChMask1	ChMask2	ChMask3	ChMask4	ChMask5	RFU	CFListType

1083 **2.7.5 CN470-510 LinkAdrReq command**

1084 For the CN470-510 version the **ChMaskCntl** field of the *LinkADRReq* command has the
1085 following meaning:

1086

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

1087

Table 43: CN470-510 ChMaskCntl value table

1088 If the ChMask field value is one of the values meaning RFU, then end-device SHOULD reject
 1089 the command and unset the “**Channel mask ACK**” bit in its response.

1090 2.7.6 CN470-510 Maximum payload size

1091 The maximum **MACPayload** size length (M) is given by the following table. It is derived from
 1092 the maximum allowed transmission time at the PHY layer taking into account a possible
 1093 repeater encapsulation. The maximum application payload length in the absence of the
 1094 optional **FOpt** MAC control field (N) is also given for information only. The value of N might be
 1095 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	

1096

Table 44: CN470-510 maximum payload size

1097 If the end-device will never operate with a repeater then the maximum application payload
 1098 length in the absence of the optional **FOpt** control field SHOULD be:

1099

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

1100

Table 45 : CN470-510 maximum payload size (not repeater compatible)

1101

1102 2.7.7 CN470-510 Receive windows

- 1103 • The RX1 receive channel is a function of the upstream channel used to initiate the
 1104 data exchange. The RX1 receive channel can be determined as follows.
 - 1105 ○ RX1 Channel Number = Uplink Channel Number modulo 48, for example,
 1106 when transmitting channel number is 49, the rx1 channel number is 1.
- 1107 • The RX1 window data rate depends on the transmit data rate (see Table below).
- 1108 • The RX2 (second receive window) settings uses a fixed data rate and frequency.
 1109 Default parameters are 505.3 MHz / DR0

1110

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 46: CN470-510 downlink RX1 data rate mapping

1111

1112

1113 The allowed values for RX1DROffset are in the [0:5] range. Values in the range [6:7] are
1114 reserved for future use.

1115 2.7.8 CN470-510 Class B beacon

1116 The beacons are transmitted using the following settings:

DR	2	Corresponds to SF10 spreading factor with 125kHz bw
CR	1	Coding rate = 4/5
Signal polarity	Non-inverted	As opposed to normal downlink traffic which uses inverted signal polarity
frequencies	508.3 to 509.7MHz with 200kHz steps	

Table 47 : CN470-510 beacon settings

1117

1118

1119 The downstream channel used for a given beacon is:

$$1120 \text{ BeaconChannel} = \left[\text{floor} \left(\frac{\text{beacon_time}}{\text{beacon_period}} \right) \right] \text{ modulo } 8$$

- 1121 • whereby beacon_time is the integer value of the 4 bytes "Time" field of the beacon frame
- 1122
- 1123 • whereby beacon_period is the periodicity of beacons , 128 seconds
- 1124 • whereby $\text{floor}(x)$ designates rounding to the integer immediately inferior or equal to x
- 1125

1126 | Example: the first beacon will be transmitted on 508.3Mhz, the second
1127 | on 508.5MHz, the 9th beacon will be on 508.3Mhz again.

1128

1129

Beacon channel nb	Frequency [MHz]
0	508.3
1	508.5
2	508.7
3	508.9
4	509.1
5	509.3
6	509.5
7	509.7

1130

1131

1132 The beacon frame content is:

Size (bytes)	3	4	2	7	1	2
BCNPayload	RFU	Time	CRC	GwSpecific	RFU	CRC

1133

1134 2.7.9 CN470-510 Default Settings

1135 The following parameters are recommended values for the CN470-510 band.

1136	RECEIVE_DELAY1	1 s
1137	RECEIVE_DELAY2	2 s (MUST be RECEIVE_DELAY1 + 1s)
1138	JOIN_ACCEPT_DELAY1	5 s
1139	JOIN_ACCEPT_DELAY2	6 s
1140	MAX_FCNT_GAP	16384
1141	ADR_ACK_LIMIT	64
1142	ADR_ACK_DELAY	32
1143	ACK_TIMEOUT	2 +/- 1 s (random delay between 1 and 3 seconds)

1144 If the actual parameter values implemented in the end-device are different from those default
1145 values (for example the end-device uses a longer RECEIVE_DELAY1 & 2 latency), those
1146 parameters MUST be communicated to the network server using an out-of-band channel
1147 during the end-device commissioning process. The network server may not accept
1148 parameters different from those default values.

1149 2.8 AS923MHz ISM Band

1150 2.8.1 AS923 Preamble Format

1151 The following synchronization words SHOULD be used:

1152

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

1153

Table 48: AS923 synch words

1154 2.8.2 AS923 ISM Band channel frequencies

1155 This section applies to regions where the frequencies [923...923.5MHz] are comprised in the
1156 ISM band.

1157 The network channels can be freely attributed by the network operator. However the two
1158 following default channels MUST be implemented in every AS923MHz end-device. Those
1159 channels are the minimum set that all network gateways SHOULD always be listening on.

1160

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%

1161

Table 49: AS923 default channels

1162 Those default channels MUST be implemented in every end-device and cannot be modified
1163 through the **NewChannelReq** command and guarantee a minimal common channel set
1164 between end-devices and network gateways.

1165 AS923MHz ISM band end-devices should use the following default parameters

- 1166 • Default EIRP: 16 dBm

1167 AS923MHz end-devices SHALL feature a channel data structure to store the parameters of
1168 at least 16 channels. A channel data structure corresponds to a frequency and a set of data
1169 rates usable on this frequency.

1170 The following table gives the list of frequencies that SHALL be used by end-devices to
1171 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 to DR5	2	< 1%

1172

Table 50: AS923 JoinReq Channel List

1173

1174 The default JoinReq Data Rate utilizes the range DR2-DR5 (SF10/125 kHz – SF7/125 kHz),
1175 this setting ensures that end-devices are compatible with the 400ms dwell time limitation until
1176 the actual dwell time limit is notified to the end-device by the network server via the MAC
1177 command "TxParamSetupReq".

1178 The JoinReq message transmit duty-cycle SHALL follow the rules described in chapter

1179 “Retransmissions back-off” of the LoRaWAN specification document.
 1180

1181 **2.8.3 AS923 Data Rate and End-point Output Power encoding**

1182 The “TxParamSetupReq/Ans” MAC command MUST be implemented by the AS923 devices.
 1183 The following encoding is used for Data Rate (DR) in the AS923 band:

1184

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	

Table 51: AS923 Data rate table

1185

1186

1187 The TXPower table indicates power levels relative to the Max EIRP level of the end-device,
 1188 as per the following table:

1189

TXPower	Configuration (EIRP)
0	Max EIRP
1	Max EIRP – 2dB
2	Max EIRP – 4dB
3	Max EIRP – 6dB
4	Max EIRP – 8dB
5	Max EIRP – 10dB
6	Max EIRP – 12dB
7	Max EIRP – 14dB
8..15	RFU

Table 52: AS923 TxPower table

1190

1191

1192 EIRP refers to the Equivalent Isotropically Radiated Power, which is the radiated output
 1193 power referenced to an isotropic antenna radiating power equally in all directions and whose
 1194 gain is expressed in dBi.

1195 By default Max EIRP SHALL be 16dBm. The Max EIRP can be modified by the network
 1196 server through the **TxParamSetupReq** MAC command and SHOULD be used by both the
 1197 end-device and the network server once **TxParamSetupReq** is acknowledged by the device
 1198 via **TxParamSetupAns**,

1199

1200 2.8.4 AS923 JoinAccept CFList

1201 The AS923 LoRaWAN implements an optional channel frequency list (CFList) of 16 octets in
 1202 the JoinAccept message.

1203 In this case the CFList is a list of five channel frequencies for the channels two to six whereby
 1204 each frequency is encoded as a 24 bits unsigned integer (three octets). All these channels are
 1205 usable for DR0 to DR5 125 KHz LoRa modulation. The list of frequencies is followed by a
 1206 single CFListType octet for a total of 16 octets. The CFListType SHALL be equal to zero (0)
 1207 to indicate that the CFList contains a list of frequencies.

1208

Size (bytes)	3	3	3	3	3	1
CFList	Freq Ch2	Freq Ch3	Freq Ch4	Freq Ch5	Freq Ch6	CFListType

1209 The actual channel frequency in Hz is 100 x frequency whereby values representing
 1210 frequencies below 100 MHz are reserved for future use. This allows setting the frequency of
 1211 a channel anywhere between 915 and 928MHz in 100 Hz steps. Unused channels have a
 1212 frequency value of 0. The CFList is optional and its presence can be detected by the length of
 1213 the join-accept message. If present, the CFList replaces all the previous channels stored in
 1214 the end-device apart from the two default channels. The newly defined channels are
 1215 immediately enabled and usable by the end-device for communication.

1216 2.8.5 AS923 LinkAdrReq command

1217 The AS923 LoRaWAN only supports a maximum of 16 channels. When **ChMaskCntl** field is
 1218 0 the ChMask field individually enables/disables each of the 16 channels.

1219

ChMaskCntl	ChMask applies to
0	Channels 0 to 15
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 53: AS923 ChMaskCntl value table

1220

1221 If the ChMask field value is one of values meaning RFU, the end-device SHOULD reject the
 1222 command and unset the “**Channel mask ACK**” bit in its response.

1223

1224 2.8.6 AS923 Maximum payload size

1225 The maximum **MACPayload** size length (*M*) is given by the following table for both dwell time
 1226 configurations: No Limit and 400ms. It is derived from the PHY layer limitation depending on
 1227 the effective modulation rate used taking into account a possible repeater encapsulation layer.

1228

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	133
5	230	250	230	250
6	230	250	230	250
7	230	250	230	250
8:15	RFU		RFU	

1229

Table 54: AS923 maximum payload size

1230 If the end-device will never operate with a repeater then the maximum MAC payload length
1231 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	133
5	250	250	250	250
6	250	250	250	250
7	250	250	250	250
8:15	RFU		RFU	

1232

Table 55: AS923 maximum payload size (not repeater compatible)

1233 The maximum application payload length in the absence of the optional **FOpt** control field (N)
1234 is eight bytes lower than the MACPayload value in the above table. The value of N might be
1235 smaller if the **FOpt** field is not empty.
1236

1237 2.8.7 AS923 Receive windows

1238 The RX1 receive window uses the same channel than the preceding uplink. The data rate is
1239 a function of the uplink data rate and the RX1DROffset as following:

1240 Downstream data rate in RX1 slot = $MIN(5, MAX(\text{MinDR}, \text{Upstream data rate} -$
1241 $\text{Effective_RX1DROffset}))$

1242 MinDR depends on the DownlinkDwellTime bit sent to the device in the **TxParamSetupReq**
1243 command:

- 1244 • Case DownlinkDwellTime = 0 (No limit): MinDR = 0
- 1245 • Case DownlinkDwellTime = 1 (400ms): MinDR = 2

1246 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

1247 Values in the [6:7] range allow setting the Downstream RX1 data rate higher than Upstream
1248 data rate.

1249 The RX2 receive window uses a fixed frequency and data rate. The default parameters are
1250 923.2 MHz / DR2 (SF10/125KHz).

1251

 1252 **2.8.8 AS923 Class B beacon and default downlink channel**

1253 The beacons SHALL be transmitted using the following settings

DR	3	Corresponds to SF9 spreading factor with 125 kHz BW
CR	1	Coding rate = 4/5
Signal polarity	Non-inverted	As opposed to normal downlink traffic which uses inverted signal polarity

1254

Table 56 : AS923 beacon settings

1255 The beacon frame content is:

Size (bytes)	2	4	2	7	2
BCNPayload	RFU	Time	CRC	GwSpecific	CRC

1256 The beacon default broadcast frequency is 923.4MHz.

1257 The class B default downlink pingSlot frequency is 923.4MHz

1258

 1259 **2.8.9 AS923 Default Settings**

1260 The following parameters are recommended values for the AS923MHz band.

1261	RECEIVE_DELAY1	1 s
1262	RECEIVE_DELAY2	2 s (MUST be RECEIVE_DELAY1 + 1s)
1263	JOIN_ACCEPT_DELAY1	5 s
1264	JOIN_ACCEPT_DELAY2	6 s
1265	MAX_FCNT_GAP	16384
1266	ADR_ACK_LIMIT	64
1267	ADR_ACK_DELAY	32
1268	ACK_TIMEOUT	2 +/- 1 s (random delay between 1 and 3 seconds)

1269 If the actual parameter values implemented in the end-device are different from those default
 1270 values (for example the end-device uses a longer RECEIVE_DELAY1 and
 1271 RECEIVE_DELAY2 latency), those parameters MUST be communicated to the network
 1272 server using an out-of-band channel during the end-device commissioning process. The
 1273 network server may not accept parameters different from those default values.

1274 **2.9 KR920-923MHz ISM Band**

 1275 **2.9.1 KR920-923 Preamble Format**

1276 The following synchronization words SHOULD be used:

1277

Modulation	Sync word	Preamble length
LORA	0x34	8 symbols

 1278 **2.9.2 KR920-923 ISM Band channel frequencies**

 1279 The center frequency, bandwidth and maximum EIRP output power for the South Korea
 1280 RFID/USN frequency band are already defined by Korean Government. Basically Korean
 1281 Government allocated LPWA based IoT network frequency band from 920.9 to 923.3MHz.

1282

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

1283

Table 57: KR920-923 Center frequency, bandwidth, maximum EIRP output power table

 1284 The three following default channels (922.1, 922.3 and 922.5MHz / DR0 to DR5) determined
 1285 by the network operator from the set of available channels as defined by the South Korean
 1286 regulation MUST be implemented in every KR920-923MHz end-device, and cannot be
 1287 alterable by the **NewChannelReq** command. Those channels are the minimum set that all
 1288 network gateways SHOULD always be listening on to guarantee a minimal common channel
 1289 set between end-devices and network gateways.

1290

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

1291

Table 58: KR920-923 default channels

 1292 In order to access the physical medium the South Korea regulations impose some restrictions.
 1293 The South Korea regulations allow the choice of using either a duty-cycle limitation or a so-
 1294 called Listen Before Talk Adaptive Frequency Agility (LBT AFA) transmissions management.
 1295 The current LoRaWAN specification for the KR920-923 ISM band exclusively uses LBT
 1296 channel access rule to maximize MACPayload size length and comply with the South Korea
 1297 regulations.

1298 KR920-923MHz ISM band end-devices SHALL use the following default parameters

- 1299
- Default EIRP output power for end-device(920.9~921.9MHz): 10 dBm
 - 1300 • Default EIRP output power for end-device(922.1~923.3MHz): 14 dBm
 - 1301 • Default EIRP output power for gateway: 23 dBm

1302 KR920-923MHz end-devices SHALL be capable of operating in the 920 to 923MHz frequency
 1303 band and SHALL feature a channel data structure to store the parameters of at least 16
 1304 channels. A channel data structure corresponds to a frequency and a set of data rates usable
 1305 on this frequency.

1306 The following table gives the list of frequencies that SHALL be used by end-devices to
 1307 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

1308 **Table 59: KR920-923 JoinReq Channel List**

1309 2.9.3 KR920-923 Data Rate and End-device Output Power encoding

1310 There is no dwell time limitation for the KR920-923 PHY layer. The *TxParamSetupReq* MAC
 1311 command is not implemented by KR920-923 devices.

1312 The following encoding is used for Data Rate (DR), and EIRP Output Power (TXPower) in the
 1313 KR920-923 band:

1314

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	

1315 **Table 60: KR920-923 TX Data rate table**

1316

1317

TXPower	Configuration (EIRP)
0	Max EIRP
1	Max EIRP – 2dB
2	Max EIRP – 4dB
3	Max EIRP – 6dB
4	Max EIRP – 8dB
5	Max EIRP – 10dB
6	Max EIRP – 12dB
7	Max EIRP – 14dB
8..15	RFU

1318 **Table 61: KR920-923 TX power table**

1319

1320 EIRP refers to the Equivalent Isotropically Radiated Power, which is the radiated output
 1321 power referenced to an isotropic antenna radiating power equally in all directions and whose
 1322 gain is expressed in dBi.

1323

1324 By default MaxEIRP is considered to be +14dBm. If the end-device cannot achieve 14dBm
 1325 EIRP, the MaxEIRP SHOULD be communicated to the network server using an out-of-band
 1326 channel during the end-device commissioning process.

1327 When the device transmits in a channel whose frequency is <922MHz, the transmit power
 1328 SHALL be limited to +10dBm EIRP even if the current transmit power level set by the
 1329 network server is higher.

1330 2.9.4 KR920-923 JoinAccept CFList

1331 The KR920-923 ISM band LoRaWAN implements an optional **channel frequency list** (CFList)
 1332 of 16 octets in the JoinAccept message.

1333 In this case the CFList is a list of five channel frequencies for the channels three to seven
 1334 whereby each frequency is encoded as a 24 bits unsigned integer (three octets). All these
 1335 channels are usable for DR0 to DR5 125kHz LoRa modulation.

1336 The list of frequencies is followed by a single CFListType octet for a total of 16 octets. The
 1337 CFListType SHALL be equal to zero (0) to indicate that the CFList contains a list of
 1338 frequencies.

1339

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

1340 The actual channel frequency in Hz is 100 x frequency whereby values representing
 1341 frequencies below 100 MHz are reserved for future use. This allows setting the frequency of
 1342 a channel anywhere between 100 MHz to 1.67 GHz in 100 Hz steps. Unused channels have
 1343 a frequency value of 0. The **CFList** is optional and its presence can be detected by the length
 1344 of the join-accept message. If present, the **CFList** replaces all the previous channels stored
 1345 in the end-device apart from the three default channels. The newly defined channels are
 1346 immediately enabled and usable by the end-device for communication.

1347 2.9.5 KR920-923 LinkAdrReq command

1348 The KR920-923 LoRaWAN only supports a maximum of 16 channels. When **ChMaskCntl**
 1349 field is 0 the ChMask field individually enables/disables each of the 16 channels.

1350

ChMaskCntl	ChMask applies to
0	Channels 0 to 15
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 62: KR920-923 ChMaskCntl value table

1351

1352

1353 If the ChMaskCntl field value is one of values meaning RFU, the end-device SHOULD reject
 1354 the command and unset the “**Channel mask ACK**” bit in its response.

1355 **2.9.6 KR920-923 Maximum payload size**

1356 The maximum **MACPayload** size length (M) is given by the following table for the regulation
 1357 of dwell time; less than 4 sec with LBT. It is derived from limitation of the PHY layer depending
 1358 on the effective modulation rate used taking into account a possible repeater encapsulation
 1359 layer. The maximum application payload length in the absence of the optional **FOpt** control
 1360 field (N) is also given for information only. The value of N might be smaller if the **FOpt** field is
 1361 not empty:

1362

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	

1363

Table 63: KR920-923 maximum payload size

1364 If the end-device will never operate with a repeater then the maximum application payload
 1365 length in the absence of the optional **FOpt** control field SHOULD be:

1366

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

1367

Table 64 : KR920-923 maximum payload size (not repeater compatible)

1368

1369 **2.9.7 KR920-923 Receive windows**

1370 The RX1 receive window uses the same channel than the preceding uplink. The data rate is
 1371 a function of the uplink data rate and the RX1DROffset as given by the following table. The
 1372 allowed values for RX1DROffset are in the [0:5] range. Values in the [6:7] range are reserved
 1373 for future use.

1374

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

1375 **Table 65 : KR920-923 downlink RX1 data rate mapping**

1376 The RX2 receive window uses a fixed frequency and data rate. The default parameters are
 1377 921.90MHz / DR0 (SF12, 125 kHz).

1378 **2.9.8 KR920-923 Class B beacon and default downlink channel**

1379 The beacons SHALL be transmitted using the following settings

DR	3	Corresponds to SF9 spreading factor with 125 kHz BW
CR	1	Coding rate = 4/5
Signal polarity	Non-inverted	As opposed to normal downlink traffic which uses inverted signal polarity

1380 **Table 66 : KR920-923 beacon settings**

1381

1382 The beacon frame content is:

Size (bytes)	2	4	2	7	2
BCNPayload	RFU	Time	CRC	GwSpecific	CRC

1383 The beacon default broadcast frequency is 923.1MHz.

1384 The class B default downlink pingSlot frequency is 923.1MHz

1385

1386 **2.9.9 KR920-923 Default Settings**

1387 The following parameters are recommended values for the KR920-923Mhz band.

1388	RECEIVE_DELAY1	1 s
1389	RECEIVE_DELAY2	2 s (MUST be RECEIVE_DELAY1 + 1s)
1390	JOIN_ACCEPT_DELAY1	5 s
1391	JOIN_ACCEPT_DELAY2	6 s
1392	MAX_FCNT_GAP	16384
1393	ADR_ACK_LIMIT	64
1394	ADR_ACK_DELAY	32
1395	ACK_TIMEOUT	2 +/- 1 s (random delay between 1 and 3 seconds)

1396 If the actual parameter values implemented in the end-device are different from those default
 1397 values (for example the end-device uses a longer RECEIVE_DELAY1 and
 1398 RECEIVE_DELAY2 latency), those parameters MUST be communicated to the network
 1399 server using an out-of-band channel during the end-device commissioning process. The
 1400 network server may not accept parameters different from those default values.

1401

1402 **2.10 IN865-867 MHz ISM Band**

 1403 **2.10.1 IN865-867 Preamble Format**

1404 The following synchronization words SHOULD be used:

1405

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

1406

Table 67: IN865-867 synch words

 1407 **2.10.2 IN865-867 ISM Band channel frequencies**

1408 This section applies to the Indian sub-continent.

 1409 The network channels can be freely attributed by the network operator. However the three
 1410 following default channels MUST be implemented in every India 865-867MHz end-device.
 1411 Those channels are the minimum set that all network gateways SHOULD always be listening
 1412 on.

1413

Modulation	Bandwidth [kHz]	Channel Frequency [MHz]	FSK Bitrate or LoRa DR / Bitrate	Nb Channels
LoRa	125	865.0625 865.4025 865.985	DR0 to DR5 / 0.3-5 kbps	3

1414

Table 68: IN865-867 default channels

 1415 End-devices SHALL be capable of operating in the 865 to 867 MHz frequency band and
 1416 should feature a channel data structure to store the parameters of at least 16 channels. A
 1417 channel data structure corresponds to a frequency and a set of data rates usable on this
 1418 frequency.

 1419 The first three channels correspond to 865.0625, 865.4025, and 865.985 MHz / DR0 to DR5
 1420 and MUST be implemented in every end-device. Those default channels cannot be modified
 1421 through the **NewChannelReq** command and guarantee a minimal common channel set
 1422 between end-devices and network gateways.

 1423 The following table gives the list of frequencies that SHALL be used by end-devices to
 1424 broadcast the JoinReq message. The JoinReq message transmit duty-cycle SHALL follow the
 1425 rules described in chapter "Retransmissions back-off" of the LoRaWAN specification
 1426 document.

1427

Modulation	Bandwidth [kHz]	Channel Frequency [MHz]	FSK Bitrate or LoRa DR / Bitrate	Nb Channels
LoRa	125	865.0625 865.4025 865.9850	DR0 – DR5 / 0.3-5 kbps	3

1428

Table 69: IN865-867 JoinReq Channel List

 1429 **2.10.3 IN865-867 Data Rate and End-device Output Power Encoding**

 1430 There is no dwell time or duty-cycle limitation for the INDIA 865-867 PHY layer. The
 1431 **TxParamSetupReq** MAC command is not implemented by INDIA 865-867 devices.

 1432 The following encoding is used for Data Rate (DR) and End-device Output Power (TXPower)
 1433 in the INDIA 865-867 band:

1434

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	RFU	RFU
7	FSK: 50 kbps	50000
8..15	RFU	

Table 70: IN865-867 TX Data rate table

1435

1436

1437

1438

1439

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

TXPower	Configuration (EIRP)
0	Max EIRP
1	Max EIRP – 2dB
2	Max EIRP – 4dB
3	Max EIRP – 6dB
4	Max EIRP – 8dB
5	Max EIRP – 10dB
6	Max EIRP – 12dB
7	Max EIRP – 14dB
8	Max EIRP – 16dB
9	Max EIRP – 18dB
10	Max EIRP – 20dB
11..15	RFU

Table 71: IN865-867 TxPower table

1440

1441

1442

1443

1444

EIRP refers to the Equivalent Isotropically Radiated Power, which is the radiated output power referenced to an isotropic antenna radiating power equally in all directions and whose gain is expressed in dBi.

1445

1446

1447

1448

By default MaxEIRP is considered to be 30dBm. If the end-device cannot achieve 30dBm EIRP, the Max EIRP SHOULD be communicated to the network server using an out-of-band channel during the end-device commissioning process.

1449

2.10.4 IN865-867 JoinAccept CFList

1450

1451

The India 865-867 ISM band LoRaWAN implements an optional **channel frequency list** (CFList) of 16 octets in the JoinAccept message.

1452

1453

1454

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

1455 The list of frequencies is followed by a single CFListType octet for a total of 16 octets. The
 1456 CFListType SHALL be equal to zero (0) to indicate that the CFList contains a list of
 1457 frequencies.

1458

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

1459 The actual channel frequency in Hz is 100 x frequency whereby values representing
 1460 frequencies below 100 MHz are reserved for future use. This allows setting the frequency of
 1461 a channel anywhere between 100 MHz to 1.67 GHz in 100 Hz steps. Unused channels have
 1462 a frequency value of 0. The **CFList** is optional and its presence can be detected by the length
 1463 of the join-accept message. If present, the **CFList** replaces all the previous channels stored
 1464 in the end-device apart from the three default channels. The newly defined channels are
 1465 immediately enabled and usable by the end-device for communication.

1466 2.10.5 IN865-867 LinkAdrReq command

1467 The INDIA 865-867 LoRaWAN only supports a maximum of 16 channels. When **ChMaskCntl**
 1468 field is 0 the ChMask field individually enables/disables each of the 16 channels.

1469

ChMaskCntl	ChMask applies to
0	Channels 0 to 15
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

1470

Table 72: IN865-867 ChMaskCntl value table

1471 If the ChMaskCntl field value is one of values meaning RFU, the end-device SHOULD reject
 1472 the command and unset the “**Channel mask ACK**” bit in its response.

1473 2.10.6 IN865-867 Maximum payload size

1474 The maximum **MACPayload** size length (*M*) is given by the following table. It is derived from
 1475 limitation of the PHY layer depending on the effective modulation rate used taking into account
 1476 a possible repeater encapsulation layer. The maximum application payload length in the
 1477 absence of the optional **FOpt** control field (*N*) is also given for information only. The value of
 1478 *N* might be smaller if the **FOpt** field is not empty:

1479

DataRate	<i>M</i>	<i>N</i>
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	

1480

Table 73: IN865-867 maximum payload size

1481 If the end-device will never operate with a repeater then the maximum application payload
 1482 length in the absence of the optional **FOpt** control field SHOULD be:
 1483

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	

1484

Table 74 : IN865-867 maximum payload size (not repeater compatible)

1485 2.10.7 IN865-867 Receive windows

1486 The RX1 receive window uses the same channel than the preceding uplink. The data rate is
 1487 a function of the uplink data rate and the RX1DROffset as given by the following table. The
 1488 allowed values for RX1DROffset are in the [0:7] range. Values in the [6:7] range allow setting
 1489 the Downstream RX1 data rate higher than Upstream data rate.

1490 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

1491 Downstream data rate in RX1 slot = $MIN(5, MAX(0, \text{Upstream data rate} -$
 1492 $\text{Effective_RX1DROffset}))$

1493 The RX2 receive window uses a fixed frequency and data rate. The default parameters are
 1494 866.550 MHz / DR2 (SF10, 125 kHz).

1495 2.10.8 IN865-867 Class B beacon and default downlink channel

1496 The beacons are transmitted using the following settings

DR	4	Corresponds to SF8 spreading factor with 125 kHz BW
CR	1	Coding rate = 4/5
Signal polarity	Non-inverted	As opposed to normal downlink traffic which uses inverted signal polarity

1497

1498 The beacon frame content is:

Size (bytes)	1	4	2	7	3	2
BCNPayload	RFU	Time	CRC	GwSpecific	RFU	CRC

1499 The beacon default broadcast frequency is 866.550MHz.

1500 The class B default downlink pingSlot frequency is 866.550MHz

1501

1502 2.10.9 IN865-867 Default Settings

1503 The following parameters are recommended values for the INDIA 865-867MHz band.

1504

1505	RECEIVE_DELAY1	1 s
1506	RECEIVE_DELAY2	2 s (MUST be RECEIVE_DELAY1 + 1s)
1507	JOIN_ACCEPT_DELAY1	5 s
1508	JOIN_ACCEPT_DELAY2	6 s
1509	MAX_FCNT_GAP	16384
1510	ADR_ACK_LIMIT	64
1511	ADR_ACK_DELAY	32
1512	ACK_TIMEOUT	2 +/- 1 s (random delay between 1 and 3 seconds)

1513 If the actual parameter values implemented in the end-device are different from those default
1514 values (for example the end-device uses a longer RECEIVE_DELAY1 and
1515 RECEIVE_DELAY2 latency), those parameters MUST be communicated to the network
1516 server using an out-of-band channel during the end-device commissioning process. The
1517 network server may not accept parameters different from those default values.

1518

1519

1520

1521 **2.11 RU864-870 MHz ISM Band**

 1522 **2.11.1 RU864-870 Preamble Format**

1523 The following synchronization words SHOULD be used:

1524

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

1525

Table 75: RU864-870 synch words

 1526 **2.11.2 RU864-870 ISM Band channel frequencies**

 1527 The network channels can be freely attributed by the network operator in compliance with the
 1528 allowed sub-bands defined by the Russian regulation. However the two following default
 1529 channels MUST be implemented in every RU864-870 MHz end-device. Those channels are
 1530 the minimum set that all network gateways SHOULD always be listening on.

1531

Modulation	Bandwidth [kHz]	Channel Frequency [MHz]	FSK Bitrate or LoRa DR / Bitrate	Nb Channels	Duty cycle
LoRa	125	868.9 869.1	DR0 to DR5 / 0.3-5 kbps	2	<1%

1532

Table 76: RU864-870 default channels

 1533 RU864-870 MHz end-devices SHALL be capable of operating in the 864 to 870 MHz
 1534 frequency band and SHALL feature a channel data structure to store the parameters of at
 1535 least 8 channels. A channel data structure corresponds to a frequency and a set of data rates
 1536 usable on this frequency.

 1537 The first two channels correspond to 868.9 and 869.1 MHz / DR0 to DR5 and MUST be
 1538 implemented in every end-device. Those default channels cannot be modified through the
 1539 **NewChannelReq** command and guarantee a minimal common channel set between end-
 1540 devices and network gateways.

 1541 The following table gives the list of frequencies that SHALL be used by end-devices to
 1542 broadcast the JoinReq message. The JoinReq message transmit duty-cycle SHALL follow the
 1543 rules described in chapter "Retransmissions back-off" of the LoRaWAN specification
 1544 document.

1545

Modulation	Bandwidth [kHz]	Channel Frequency [MHz]	FSK Bitrate or LoRa DR / Bitrate	Nb Channels
LoRa	125	868.9 869.1	DR0 – DR5 / 0.3-5 kbps	2

1546

Table 77: RU864-870 JoinReq Channel List

 1547 **2.11.3 RU864-870 Data Rate and End-device Output Power encoding**

 1548 There is no dwell time limitation for the RU864-870 PHY layer. The *TxParamSetupReq* MAC
 1549 command is not implemented in RU864-870 devices.

 1550 The following encoding is used for Data Rate (DR) and End-device EIRP (TXPower) in the
 1551 RU864-870 band:

1552

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	

1553

Table 78: RU864-870 TX Data rate table

1554

 1555 EIRP¹ refers to the Equivalent Isotropically Radiated Power, which is the radiated output
 1556 power referenced to an isotropic antenna radiating power equally in all directions and whose
 1557 gain is expressed in dBi.

TXPower	Configuration (EIRP)
0	Max EIRP
1	Max EIRP – 2dB
2	Max EIRP – 4dB
3	Max EIRP – 6dB
4	Max EIRP – 8dB
5	Max EIRP – 10dB
6	Max EIRP – 12dB
7	Max EIRP – 14dB
8..15	RFU

1558

Table 79: RU864-870 TX power table

1559

1560

1561

 1562 By default MaxEIRP is considered to be +16dBm. If the end-device cannot achieve +16dBm
 1563 EIRP, the Max EIRP SHOULD be communicated to the network server using an out-of-band
 1564 channel during the end-device commissioning process.

1565

 1566 **2.11.4 RU864-870 JoinAccept CFList**

1567

 1568 The RU 864-870 ISM band LoRaWAN implements an optional **channel frequency list**
 1569 (CFList) of 16 octets in the JoinAccept message.

¹ ERP = EIRP – 2.15dB; it is referenced to a half-wave dipole antenna whose gain is expressed in dBd

1570 In this case the CFList is a list of five channel frequencies for the channels two to six whereby
 1571 each frequency is encoded as a 24 bits unsigned integer (three octets). All these channels are
 1572 usable for DR0 to DR5 125kHz LoRa modulation. The list of frequencies is followed by a single
 1573 CFListType octet for a total of 16 octets. The CFListType SHALL be equal to zero (0) to
 1574 indicate that the CFList contains a list of frequencies.

1575

Size (bytes)	3	3	3	3	3	1
CFList	Freq Ch2	Freq Ch3	Freq Ch4	Freq Ch5	Freq Ch6	CFListType

1576 The actual channel frequency in Hz is 100 x frequency whereby values representing
 1577 frequencies below 100 MHz are reserved for future use. This allows setting the frequency of
 1578 a channel anywhere between 100 MHz to 1.67 GHz in 100 Hz steps. Unused channels have
 1579 a frequency value of 0. The **CFList** is optional and its presence can be detected by the length
 1580 of the join-accept message. If present, the **CFList** replaces all the previous channels stored
 1581 in the end-device apart from the two default channels. The newly defined channels are
 1582 immediately enabled and usable by the end-device for communication.

1583 **2.11.5 RU864-870 LinkAdrReq command**

1584 The RU864-870 LoRaWAN only supports a maximum of 16 channels. When **ChMaskCntl**
 1585 field is 0 the ChMask field individually enables/disables each of the 16 channels.
 1586

ChMaskCntl	ChMask applies to
0	Channels 0 to 15
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 80: RU864-870 ChMaskCntl value table

1587

1588 If the ChMaskCntl field value is one of values meaning RFU, the end-device SHOULD reject
 1589 the command and unset the “**Channel mask ACK**” bit in its response.

1590 **2.11.6 RU864-870 Maximum payload size**

1591 The maximum **MACPayload** size length (*M*) is given by the following table. It is derived from
 1592 limitation of the PHY layer depending on the effective modulation rate used taking into account
 1593 a possible repeater encapsulation layer. The maximum application payload length in the
 1594 absence of the optional **FOpt** control field (*N*) is also given for information only. The value of
 1595 N might be smaller if the **FOpt** field is not empty:
 1596

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	

1597

Table 81: RU864-870 maximum payload size

1598 If the end-device will never operate with a repeater then the maximum application payload
 1599 length in the absence of the optional **FOpt** control field SHOULD be:

1600

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	

1601

Table 82 : RU864-870 maximum payload size (not repeater compatible)

1602 **2.11.7 RU864-870 Receive windows**

1603 The RX1 receive window uses the same channel as the preceding uplink. The data rate is a
 1604 function of the uplink data rate and the RX1DROffset as given by the following table. The
 1605 allowed values for RX1DROffset are in the [0:5] range. Values in the [6:7] range are reserved
 1606 for future use.
 1607

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

1608

Table 83: RU864-870 downlink RX1 data rate mapping

1609

1610 The RX2 receive window uses a fixed frequency and data rate. The default parameters are
 1611 869.1MHz / DR0 (SF12, 125 kHz)

1612

1613 **2.11.8 RU864-870 Class B beacon and default downlink channel**

1614 The beacons SHALL be transmitted using the following settings

DR	3	Corresponds to SF9 spreading factor with 125 kHz BW
CR	1	Coding rate = 4/5
Signal polarity	Non-inverted	As opposed to normal downlink traffic which uses inverted signal polarity

1615

Table 84: RU864-870 beacon settings

1616

1617 The beacon frame content is:

Size (bytes)	2	4	2	7	2
BCNPayload	RFU	Time	CRC	GwSpecific	CRC

1618 The beacon default broadcast frequency is 869.1 MHz.

1619 The class B default downlink pingSlot frequency is 868.9 MHz.

1620

1621 **2.11.9 RU864-870 Default Settings**

1622 The following parameters are recommended values for the RU864-870 MHz band.

1623	RECEIVE_DELAY1	1 s
1624	RECEIVE_DELAY2	2 s (MUST be RECEIVE_DELAY1 + 1s)
1625	JOIN_ACCEPT_DELAY1	5 s
1626	JOIN_ACCEPT_DELAY2	6 s
1627	MAX_FCNT_GAP	16384
1628	ADR_ACK_LIMIT	64
1629	ADR_ACK_DELAY	32
1630	ACK_TIMEOUT	2 +/- 1 s (random delay between 1 and 3 seconds)

1631 If the actual parameter values implemented in the end-device are different from those default
 1632 values (for example the end-device uses a longer RECEIVE_DELAY1 and
 1633 RECEIVE_DELAY2 latency), those parameters MUST be communicated to the network
 1634 server using an out-of-band channel during the end-device commissioning process. The
 1635 network server may not accept parameters different from those default values.

1636

1637 **3 Revisions**

1638 **3.1 Revision A**

- 1639 • Initial 1.0.3 revision, the regional parameters were extracted from the
1640 LoRaWANV1.0.3 revision A.
1641

1642 **4 Bibliography**

1643 **4.1 References**

1644

1645 [LORAWAN] LoRaWAN Specification, V1.0.3, the LoRa Alliance, January 2018.

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