

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43

LoRaWAN 1.0.3 Regional Parameters
Copyright © 2018 LoRa Alliance, Inc. All rights reserved.

NOTICE OF USE AND DISCLOSURE

Copyright © LoRa Alliance, Inc. (2017). All Rights Reserved.

The information within this document is the property of the LoRa Alliance (“The Alliance”) and its use and disclosure are subject to LoRa Alliance Corporate Bylaws, Intellectual Property Rights (IPR) Policy and Membership Agreements.

Elements of LoRa Alliance specifications may be subject to third party intellectual property rights, including without limitation, patent, copyright or trademark rights (such a third party may or may not be a member of LoRa Alliance). The Alliance is not responsible and shall not be held responsible in any manner for identifying or failing to identify any or all such third party intellectual property rights.

This document and the information contained herein are provided on an “AS IS” basis and THE ALLIANCE DISCLAIMS ALL WARRANTIES EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO (A) ANY WARRANTY THAT THE USE OF THE INFORMATION HEREIN WILL NOT INFRINGE ANY RIGHTS OF THIRD PARTIES (INCLUDING WITHOUT LIMITATION ANY INTELLECTUAL PROPERTY RIGHTS INCLUDING PATENT, COPYRIGHT OR TRADEMARK RIGHTS) OR (B) ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, TITLE OR NON-INFRINGEMENT.

IN NO EVENT WILL THE ALLIANCE BE LIABLE FOR ANY LOSS OF PROFITS, LOSS OF BUSINESS, LOSS OF USE OF DATA, INTERRUPTION OF BUSINESS, OR FOR ANY OTHER DIRECT, INDIRECT, SPECIAL OR EXEMPLARY, INCIDENTAL, PUNITIVE OR CONSEQUENTIAL DAMAGES OF ANY KIND, IN CONTRACT OR IN TORT, IN CONNECTION WITH THIS DOCUMENT OR THE INFORMATION CONTAINED HEREIN, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH LOSS OR DAMAGE.

The above notice and this paragraph must be included on all copies of this document that are made.

LoRa Alliance, Inc.
2400 Camino Ramon, Suite 375
San Ramon, CA 94583

Note: All Company, brand and product names may be trademarks that are the sole property of their respective owners.



44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62

LoRaWAN™ 1.0.3 Regional Parameters

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

Authors:
LoRa Alliance Technical Committee Regional Parameters Workgroup

Revision: A
Date: July 2018
Status: Released

63 Contents

64	1	Introduction	7
65	1.1	Conventions	7
66	1.2	Quick cross reference table	7
67	2	LoRaWAN Regional Parameters	15
68	2.1	Regional Parameter Common Names	15
69	2.2	EU863-870MHz ISM Band	15
70	2.2.1	EU863-870 Preamble Format	15
71	2.2.2	EU863-870 ISM Band channel frequencies	15
72	2.2.3	EU863-870 Data Rate and End-device Output Power encoding	16
73	2.2.4	EU863-870 JoinAccept CFList	17
74	2.2.5	EU863-870 LinkAdrReq command	17
75	2.2.6	EU863-870 Maximum payload size	18
76	2.2.7	EU863-870 Receive windows	18
77	2.2.8	EU863-870 Class B beacon and default downlink channel	19
78	2.2.9	EU863-870 Default Settings	19
79	2.3	US902-928MHz ISM Band	21
80	2.3.1	US902-928 Preamble Format	21
81	2.3.2	US902-928 Channel Frequencies	21
82	2.3.3	US902-928 Data Rate and End-device Output Power encoding	22
83	2.3.4	US902-928 JoinAccept CFList	23
84	2.3.5	US902-928 LinkAdrReq command	23
85	2.3.6	US902-928 Maximum payload size	24
86	2.3.7	US902-928 Receive windows	25
87	2.3.8	US902-928 Class B beacon	25
88	2.3.9	US902-928 Default Settings	26
89	2.4	CN779-787 MHz ISM Band	27
90	2.4.1	CN779-787 Preamble Format	27
91	2.4.2	CN779-787 ISM Band channel frequencies	27
92	2.4.3	CN779-787 Data Rate and End-device Output Power encoding	27
93	2.4.4	CN779-787 JoinAccept CFList	28
94	2.4.5	CN779-787 LinkAdrReq command	29
95	2.4.6	CN779-787 Maximum payload size	29
96	2.4.7	CN779-787 Receive windows	30
97	2.4.8	CN779-787 Class B beacon and default downlink channel	30
98	2.4.9	CN779-787 Default Settings	30
99	2.5	EU433MHz ISM Band	32
100	2.5.1	EU433 Preamble Format	32
101	2.5.2	EU433 ISM Band channel frequencies	32
102	2.5.3	EU433 Data Rate and End-device Output Power encoding	32
103	2.5.4	EU433 JoinAccept CFList	33
104	2.5.5	EU433 LinkAdrReq command	34
105	2.5.6	EU433 Maximum payload size	34
106	2.5.7	EU433 Receive windows	35
107	2.5.8	EU433 Class B beacon and default downlink channel	35
108	2.5.9	EU433 Default Settings	35
109	2.6	AU915-928MHz ISM Band	37
110	2.6.1	AU915-928 Preamble Format	37
111	2.6.2	AU915-928 Channel Frequencies	37
112	2.6.3	AU915-928 Data Rate and End-point Output Power encoding	38
113	2.6.4	AU915-928 JoinAccept CFList	39
114	2.6.5	AU915-928 LinkAdrReq command	39
115	2.6.6	AU915-928 Maximum payload size	40

116	2.6.7	AU915-928 Receive windows	41
117	2.6.8	AU915-928 Class B beacon	41
118	2.6.9	AU915-928 Default Settings	42
119	2.7	CN470-510MHz Band	43
120	2.7.1	CN470-510 Preamble Format	43
121	2.7.2	CN470-510 Channel Frequencies.....	43
122	2.7.3	CN470-510 Data Rate and End-point Output Power encoding.....	44
123	2.7.4	CN470-510 JoinResp CFList.....	44
124	2.7.5	CN470-510 LinkAdrReq command	44
125	2.7.6	CN470-510 Maximum payload size	45
126	2.7.7	CN470-510 Receive windows	45
127	2.7.8	CN470-510 Class B beacon	46
128	2.7.9	CN470-510 Default Settings.....	47
129	2.8	AS923MHz ISM Band	48
130	2.8.1	AS923 Preamble Format.....	48
131	2.8.2	AS923 ISM Band channel frequencies	48
132	2.8.3	AS923 Data Rate and End-point Output Power encoding	49
133	2.8.4	AS923 JoinAccept CFList.....	50
134	2.8.5	AS923 LinkAdrReq command	50
135	2.8.6	AS923 Maximum payload size	50
136	2.8.7	AS923 Receive windows.....	51
137	2.8.8	AS923 Class B beacon and default downlink channel	52
138	2.8.9	AS923 Default Settings	52
139	2.9	KR920-923MHz ISM Band.....	53
140	2.9.1	KR920-923 Preamble Format	53
141	2.9.2	KR920-923 ISM Band channel frequencies.....	53
142	2.9.3	KR920-923 Data Rate and End-device Output Power encoding	54
143	2.9.4	KR920-923 JoinAccept CFList	55
144	2.9.5	KR920-923 LinkAdrReq command	55
145	2.9.6	KR920-923 Maximum payload size	56
146	2.9.7	KR920-923 Receive windows	56
147	2.9.8	KR920-923 Class B beacon and default downlink channel.....	57
148	2.9.9	KR920-923 Default Settings.....	57
149	2.10	IN865-867 MHz ISM Band	58
150	2.10.1	IN865-867 Preamble Format.....	58
151	2.10.2	IN865-867 ISM Band channel frequencies	58
152	2.10.3	IN865-867 Data Rate and End-device Output Power Encoding	58
153	2.10.4	IN865-867 JoinAccept CFList.....	59
154	2.10.5	IN865-867 LinkAdrReq command.....	60
155	2.10.6	IN865-867 Maximum payload size.....	60
156	2.10.7	IN865-867 Receive windows.....	61
157	2.10.8	IN865-867 Class B beacon and default downlink channel	61
158	2.10.9	IN865-867 Default Settings	62
159	2.11	RU864-870 MHz ISM Band.....	64
160	2.11.1	RU864-870 Preamble Format	64
161	2.11.2	RU864-870 ISM Band channel frequencies	64
162	2.11.3	RU864-870 Data Rate and End-device Output Power encoding	65
163	2.11.4	RU864-870 JoinAccept CFList.....	65
164	2.11.5	RU864-870 LinkAdrReq command	66
165	2.11.6	RU864-870 Maximum payload size	66
166	2.11.7	RU864-870 Receive windows	67
167	2.11.8	RU864-870 Class B beacon and default downlink channel	67
168	2.11.9	RU864-870 Default Settings.....	68

169	3	Revisions	69
170	3.1	Revision A.....	69
171	4	Bibliography.....	70
172	4.1	References	70
173	5	NOTICE OF USE AND DISCLOSURE	71
174			

175 Tables

176	Table 1: Channel Plan per Country	14
177	Table 2: EU863-870 synch words	15
178	Table 3: EU863-870 default channels	15
179	Table 4: EU863-870 JoinReq Channel List.....	16
180	Table 5: EU863-870 TX Data rate table	16
181	Table 6: EU863-870 TX power table	17
182	Table 7: EU863-870 ChMaskCntl value table	18
183	Table 8: EU863-870 maximum payload size	18
184	Table 9 : EU863-870 maximum payload size (not repeater compatible)	18
185	Table 10: EU863-870 downlink RX1 data rate mapping.....	19
186	Table 11: EU863-870 beacon settings	19
187	Table 12: US902-928 TX Data rate table	23
188	Table 13: US902-928 TX power table	23
189	Table 14: US902-928 ChMaskCntl value table	23
190	Table 15: US902-928 maximum payload size (repeater compatible).....	24
191	Table 16 : US902-928 maximum payload size (not repeater compatible)	25
192	Table 17: US902-928 downlink RX1 data rate mapping.....	25
193	Table 18: US902-928 beacon settings	25
194	Table 19: CN779-787 synch words	27
195	Table 20: CN779-787 JoinReq Channel List.....	27
196	Table 21: CN779-787 Data rate and TX power table.....	28
197	Table 22: CN779-787 ChMaskCntl value table.....	29
198	Table 23: CN779-787 maximum payload size	29
199	Table 24 : CN779-787 maximum payload size (not repeater compatible)	30
200	Table 25: CN779-787 downlink RX1 data rate mapping	30
201	Table 26: CN779-787 beacon settings.....	30
202	Table 27: EU433 synch words.....	32
203	Table 28: EU433 JoinReq Channel List	32
204	Table 29: EU433 Data rate and TX power table	33
205	Table 30: EU433 ChMaskCntl value table	34
206	Table 31: EU433 maximum payload size.....	34
207	Table 32 : EU433 maximum payload size (not repeater compatible).....	35
208	Table 33 : EU433 downlink RX1 data rate mapping	35
209	Table 34 : EU433 beacon settings	35
210	Table 35: AU915-928 Data rate table.....	38
211	Table 36 : AU915-928 TX power table	39
212	Table 37: AU915-928 ChMaskCntl value table	40
213	Table 38: AU915-928 maximum payload size	40
214	Table 39: AU915-928 maximum payload size (not repeater compatible)	41
215	Table 40 : AU915-928 downlink RX1 data rate mapping.....	41
216	Table 41 : AU915-928 beacon settings	41
217	Table 42: CN470-510 Data rate and TX power table.....	44
218	Table 43: CN470-510 ChMaskCntl value table.....	45
219	Table 44: CN470-510 maximum payload size	45

220	Table 45 : CN470-510 maximum payload size (not repeater compatible)	45
221	Table 46: CN470-510 downlink RX1 data rate mapping	46
222	Table 47 : CN470-510 beacon settings	46
223	Table 48: AS923 synch words	48
224	Table 49: AS923 default channels	48
225	Table 50: AS923 JoinReq Channel List	48
226	Table 51: AS923 Data rate table	49
227	Table 52: AS923 TxPower table	49
228	Table 53: AS923 ChMaskCntl value table	50
229	Table 54: AS923 maximum payload size	51
230	Table 55: AS923 maximum payload size (not repeater compatible)	51
231	Table 56 : AS923 beacon settings	52
232	Table 57: KR920-923 Center frequency, bandwidth, maximum EIRP output power table	53
233	Table 58: KR920-923 default channels	53
234	Table 59: KR920-923 JoinReq Channel List	54
235	Table 60: KR920-923 TX Data rate table	54
236	Table 61: KR920-923 TX power table	54
237	Table 62: KR920-923 ChMaskCntl value table	55
238	Table 63: KR920-923 maximum payload size	56
239	Table 64 : KR920-923 maximum payload size (not repeater compatible)	56
240	Table 65 : KR920-923 downlink RX1 data rate mapping	57
241	Table 66 : KR920-923 beacon settings	57
242	Table 67: IN865-867 synch words	58
243	Table 68: IN865-867 default channels	58
244	Table 69: IN865-867 JoinReq Channel List	58
245	Table 70: IN865-867 TX Data rate table	59
246	Table 71: IN865-867 TxPower table	59
247	Table 72: IN865-867 ChMaskCntl value table	60
248	Table 73: IN865-867 maximum payload size	61
249	Table 74 : IN865-867 maximum payload size (not repeater compatible)	61
250	Table 75: RU864-870 synch words	64
251	Table 76: RU864-870 default channels	64
252	Table 77: RU864-870 JoinReq Channel List	65
253	Table 78: RU864-870 TX Data rate table	65
254	Table 79: RU864-870 TX power table	65
255	Table 80: RU864-870 ChMaskCntl value table	66
256	Table 81: RU864-870 maximum payload size	67
257	Table 82 : RU864-870 maximum payload size (not repeater compatible)	67
258	Table 83: RU864-870 downlink RX1 data rate mapping	67
259	Table 84: RU864-870 beacon settings	67

260

261 **Figures**

262	Figure 1: US902-928 channel frequencies	21
263	Figure 2: AU915-928 channel frequencies	37
264	Figure 3: CN470-510 channel frequencies	43
265		

266 **1 Introduction**

267

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

272

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

278 **1.1 Conventions**

279

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

283

284 **1.2 Quick cross reference table**

285

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

289

290

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

291

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

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

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

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

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

331

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

332

Table 4: EU863-870 JoinReq Channel List

333 2.2.3 EU863-870 Data Rate and End-device Output Power encoding

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

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

338

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	

339

Table 5: EU863-870 TX Data rate table

340

341 EIRP¹ refers to the Equivalent Isotropically Radiated Power, which is the radiated output
 342 power referenced to an isotropic antenna radiating power equally in all directions and whose
 343 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

344
 345
 346
 347
 348 By default MaxEIRP is considered to be +16dBm. If the end-device cannot achieve 16dBm
 349 EIRP, the Max EIRP SHOULD be communicated to the network server using an out-of-band
 350 channel during the end-device commissioning process.
 351

352 2.2.4 EU863-870 JoinAccept CFList

353
 354 The EU 863-870 ISM band LoRaWAN implements an optional **channel frequency list** (CFList)
 355 of 16 octets in the JoinAccept message.

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

361

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

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

369 2.2.5 EU863-870 LinkAdrReq command

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

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

373

Table 7: EU863-870 ChMaskCntl value table

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

376 2.2.6 EU863-870 Maximum payload size

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

382

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	

383

Table 8: EU863-870 maximum payload size

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

386

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	

387

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

388 2.2.7 EU863-870 Receive windows

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

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

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

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

395

396 The RX2 receive window uses a fixed frequency and data rate. The default parameters are
 397 869.525 MHz / DR0 (SF12, 125 kHz)

398

399 2.2.8 EU863-870 Class B beacon and default downlink channel

400 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

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

402

403 The beacon frame content is:

404

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

405

406 The beacon default broadcast frequency is 869.525MHz.

407 The Class B default downlink pingSlot frequency is 869.525MHz

408

409 2.2.9 EU863-870 Default Settings

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

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

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

425 **2.3 US902-928MHz ISM Band**

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

428 **2.3.1 US902-928 Preamble Format**

429 The following synchronization words SHOULD be used:
 430

Modulation	Sync word	Preamble length
LORA	0x34	8 symbols

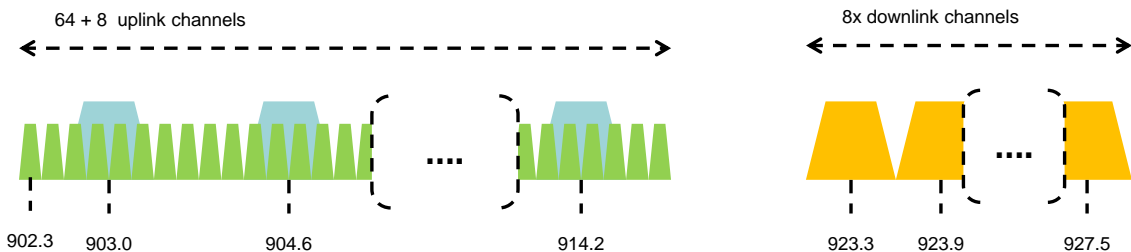
431

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

433 **2.3.2 US902-928 Channel Frequencies**

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

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



443
 444

Figure 1: US902-928 channel frequencies

445 915 MHz ISM band end-devices are required to operate in compliance with the relevant
 446 regulatory specifications, the following note summarizes some of the current (March 2017)
 447 relevant regulations.

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

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

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

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

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

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

471
 472 If using the over-the-air activation procedure, the end-device **SHALL** transmit the Join-
 473 request message on random 125 kHz channels amongst the 64 125kHz channels defined
 474 using **DR0** and on 500 kHz channels amongst the 8 500kHz channels defined using **DR4**.
 475 The end-device **SHALL** change channels for every transmission.

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

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

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

488 2.3.3 US902-928 Data Rate and End-device Output Power encoding

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

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

493

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

494

Table 12: US902-928 TX Data rate table

495

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

496

497

TXPower	Configuration (conducted power)
0	30 dBm – 2*TXpower
1	28 dBm
2	26 dBm
3..13
14	2 dBm
15	RFU

498

Table 13: US902-928 TX power table

499 2.3.4 US902-928 JoinAccept CFList

500

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

507

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>

508

509

510 2.3.5 US902-928 LinkAdrReq command

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

513

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

514

Table 14: US902-928 ChMaskCntl value table

515 If **ChMaskCntl** = 5 then the corresponding bits in the ChMask enable and disable a bank of 8
 516 125kHz channels and the corresponding 500kHz channel defined by the following calculation:
 517 [ChannelMaskBit * 8, ChannelMaskBit * 8 +7],64+ChannelMaskBit.

518

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

523

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

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

535 2.3.6 US902-928 Maximum payload size

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

541

542

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)

543

544

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

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

549

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)

550

551 2.3.7 US902-928 Receive windows

- 552
- 553 • 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.
 - 554 ○ RX1 Channel Number = Transmit Channel Number modulo 8
 - 555 • The RX1 window data rate depends on the transmit data rate (see Table 17 below).
 - 556 • The RX2 (second receive window) settings uses a fixed data rate and frequency.
 - 557 Default parameters are 923.3MHz / DR8
- 558

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

559

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

561

562 2.3.8 US902-928 Class B beacon

563 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

564

565 The downstream channel used for a given beacon is:

566
$$\text{Channel} = \left[\text{floor} \left(\frac{\text{beacon_time}}{\text{beacon_period}} \right) \right] \text{ modulo } 8$$

- 567 • whereby beacon_time is the integer value of the 4 bytes “Time” field of the beacon frame
- 568
- 569 • whereby beacon_period is the periodicity of beacons , 128 seconds
- 570 • whereby $\text{floor}(x)$ designates rounding to the integer immediately inferior or equal to x

571
572
573
574
575

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

576
577
578

The beacon frame content is:

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

579

580 2.3.9 US902-928 Default Settings

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

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

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

595

596 **2.4 CN779-787 MHz ISM Band**

 597 **2.4.1 CN779-787 Preamble Format**

598 The following synchronization words SHOULD be used :

599

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

600

Table 19: CN779-787 synch words

 601 **2.4.2 CN779-787 ISM Band channel frequencies**

602

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

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

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

607

608 • Minimum frequency : 779.5MHz

608 • Maximum frequency : 786.5 MHz

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

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

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

622

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			

623

Table 20: CN779-787 JoinReq Channel List

624

 625 **2.4.3 CN779-787 Data Rate and End-device Output Power encoding**

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

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

630

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

631

632

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

636

637 By default MAXEIRP is considered to be +12.15dBm. If the end-device cannot achieve
638 12.15dBm EIRP, the Max EIRP SHOULD be communicated to the network server using an
639 out-of-band channel during the end-device commissioning process.

640

641 2.4.4 CN779-787 JoinAccept CFList

642 The CN780 ISM band LoRaWAN implements an optional **channel frequency list** (CFList) of
643 16 octets in the JoinAccept message.

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

649

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

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

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

658 **2.4.5 CN779-787 LinkAdrReq command**

659

 660 The CN780 LoRaWAN only supports a maximum of 16 channels. When **ChMaskCntl** field is
 661 0 the ChMask field individually enables/disables each of the 16 channels.
 662

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

663

664

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

 667 **2.4.6 CN779-787 Maximum payload size**

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

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

674

675

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

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	

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

 680 **2.4.7 CN779-787 Receive windows**

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

 685

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

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

 687 The RX2 receive window uses a fixed frequency and data rate. The default parameters are
 688 786 MHz / DR0.

 689 **2.4.8 CN779-787 Class B beacon and default downlink channel**

690 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

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

692 The beacon frame content is:

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

693 The beacon default broadcast frequency is 785MHz.

694 The class B default downlink pingSlot frequency is 785MHz

695

 696 **2.4.9 CN779-787 Default Settings**

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

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

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

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

711 **2.5 EU433MHz ISM Band**

 712 **2.5.1 EU433 Preamble Format**

713 The following synchronization words SHOULD be used :

714

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

715

Table 27: EU433 synch words

 716 **2.5.2 EU433 ISM Band channel frequencies**

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

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

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

- 721
- Minimum frequency : 433.175 MHz
 - Maximum frequency : 434.665 MHz

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

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

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

736

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%

737

738

Table 28: EU433 JoinReq Channel List

 739 **2.5.3 EU433 Data Rate and End-device Output Power encoding**

 740 There is no dwell time limitation for the EU433 PHY layer. The **TxParamSetupReq** MAC
 741 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.

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

744

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 29: EU433 Data rate and TX power table

745

746

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

750

751 By default MAXEIRP is considered to be +12.15dBm. If the end-device cannot achieve
752 12.15dBm EIRP, the Max EIRP SHALL be communicated to the network server using an
753 out-of-band channel during the end-device commissioning process.

754

755

756 2.5.4 EU433 JoinAccept CFList

757

758 The EU433 ISM band LoRaWAN implements an optional **channel frequency list** (CFList) of
759 16 octets in the JoinAccept message.

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

765

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

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

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

774 **2.5.5 EU433 LinkAdrReq command**

 775 The EU433 LoRaWAN only supports a maximum of 16 channels. When **ChMaskCntl** field is
 776 0 the ChMask field individually enables/disables each of the 16 channels.

777

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

778

Table 30: EU433 ChMaskCntl value table

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

 781 **2.5.6 EU433 Maximum payload size**

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

787

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	

788

Table 31: EU433 maximum payload size

789

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

792

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	

793
 794

Table 32 : EU433 maximum payload size (not repeater compatible)
795 2.5.7 EU433 Receive windows

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

800

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

801

Table 33 : EU433 downlink RX1 data rate mapping

802 The RX2 receive window uses a fixed frequency and data rate. The default parameters are
 803 434.665MHz / DR0 (SF12, 125kHz).

804

805 2.5.8 EU433 Class B beacon and default downlink channel

806 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

807

Table 34 : EU433 beacon settings

808 The beacon frame content is:

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

809 The beacon default broadcast frequency is 434.665MHz.

810 The class B default downlink pingSlot frequency is 434.665MHz

811

812 2.5.9 EU433 Default Settings

813 The following parameters are recommended values for the EU433band.

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

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

829 **2.6 AU915-928MHz ISM Band**

830

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

833

834 **2.6.1 AU915-928 Preamble Format**

835 The following synchronization words SHOULD be used:

836

Modulation	Sync word	Preamble length
LORA	0x34	8 symbols

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

838 **2.6.2 AU915-928 Channel Frequencies**

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

840

841 • Upstream – 64 channels numbered 0 to 63 utilizing LoRa 125 kHz BW varying from
842 DR0 to DR5, using coding rate 4/5, starting at 915.2 MHz and incrementing linearly
843 by 200 kHz to 927.8 MHz

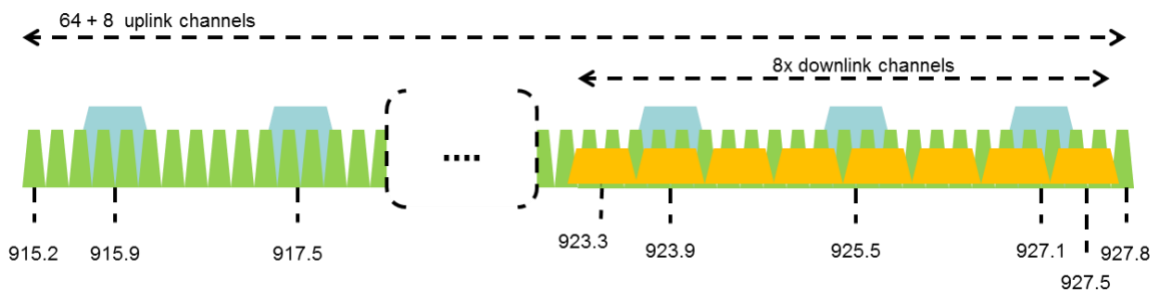
843

844 • Upstream – 8 channels numbered 64 to 71 utilizing LoRa 500 kHz BW at DR6
845 starting at 915.9 MHz and incrementing linearly by 1.6 MHz to 927.1 MHz

845

846 • Downstream – 8 channels numbered 0 to 7 utilizing LoRa 500 kHz BW at DR8 to
847 DR13) starting at 923.3 MHz and incrementing linearly by 600 kHz to 927.5 MHz

847



848

849

Figure 2: AU915-928 channel frequencies

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

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

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

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

860

861

862

863

864

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

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

871 2.6.3 AU915-928 Data Rate and End-point Output Power encoding

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

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

882
 883 The following encoding is used for Data Rate (**DR**) and End-point EIRP (**TXPower**) in the
 884 AU915-928 band:

885

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

886
 887
 888 DR6 is identical to DR12, DR8...13 MUST be implemented in end-devices and are reserved
 889 for future applications.
 890

891
 892
 893
 894

895

TXPower	Configuration (EIRP)
0	Max EIRP
1..14	Max EIRP – 2*TXPower
15	RFU

Table 36 : AU915-928 TX power table

896

897

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

901

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

906

907 2.6.4 AU915-928 JoinAccept CFList

908

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

915

916 2.6.5 AU915-928 LinkAdrReq command

917

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

919

920

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

921

Table 37: AU915-928 ChMaskCntl value table

 922 If **ChMaskCntl** = 5 then the corresponding bits in the ChMask enable and disable a bank of 8
 923 125kHz channels and the corresponding 500kHz channel defined by the following calculation:
 924 $[\text{ChannelMaskBit} * 8, \text{ChannelMaskBit} * 8 + 7], 64 + \text{ChannelMaskBit}$.

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

929

930 2.6.6 AU915-928 Maximum payload size

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

937

938

939

940

941

942

943

944

945

946

947

948

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	

949

950

Table 38: AU915-928 maximum payload size

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

953

954

955

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

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

958

DataRate	UplinkDwellTime=0		UplinkDwellTime=1	
	M	N	M	N
0	59	51	N/A	N/A
1	59	51	N/A	N/A

959
960
961
962
963
964
965
966
967
968
969
970

Table 39: AU915-payload size (not compatible)

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
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	

928 maximum repeater

971
972
973
974
975
976
977
978
979

2.6.7 AU915-windows

- The RX1 receive channel is a function of the upstream channel used to initiate the data exchange. The RX1 receive channel can be determined as follows.
 - RX1 Channel Number = 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

928 Receive

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

980
981

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

984

985 2.6.8 AU915-928 Class B beacon

986 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

987

988 The downstream channel used for a given beacon is:

989

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

- 990
- whereby beacon_time is the integer value of the 4 bytes “Time” field of the beacon frame
- 991
- whereby beacon_period is the periodicity of beacons , 128 seconds
- 992
- whereby $\text{floor}(x)$ designates rounding to the integer immediately inferior or equal to x
- 993
- 994

995 | Example: the first beacon will be transmitted on 923.3Mhz , the second
 996 | 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

999

1000

1001

The beacon frame content is:

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

1002

1003 2.6.9 AU915-928 Default Settings

1004 The following parameters are recommended values for the AU915-928 band.

- 1005 RECEIVE_DELAY1 1 s
- 1006 RECEIVE_DELAY2 2 s (MUST be RECEIVE_DELAY1 + 1s)
- 1007 JOIN_ACCEPT_DELAY1 5 s
- 1008 JOIN_ACCEPT_DELAY2 6 s
- 1009 MAX_FCNT_GAP 16384
- 1010 ADR_ACK_LIMIT 64
- 1011 ADR_ACK_DELAY 32
- 1012 ACK_TIMEOUT 2 +/- 1 s (random delay between 1 and 3 seconds)

1013 If the actual parameter values implemented in the end-device are different from those default
 1014 values (for example the end-device uses a longer RECEIVE_DELAY1 & 2 latency), those
 1015 parameters MUST be communicated to the network server using an out-of-band channel
 1016 during the end-device commissioning process. The network server may not accept
 1017 parameters different from those default values.

1018

1019 **2.7 CN470-510MHz Band**

1020 **2.7.1 CN470-510 Preamble Format**

1021 The following synchronization words SHOULD be used:

1022

Modulation	Sync word	Preamble length
LORA	0x34	8 symbols

1023 **2.7.2 CN470-510 Channel Frequencies**

1024

1025 In China, this band is defined by SRRC to be used for civil metering applications.

1026 The 470 MHz ISM Band SHALL be divided into the following channel plans:

1027

- 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.

1028

1029

1030

1031

1032

1033

1034

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.

1035

- 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

1036

1037

1038

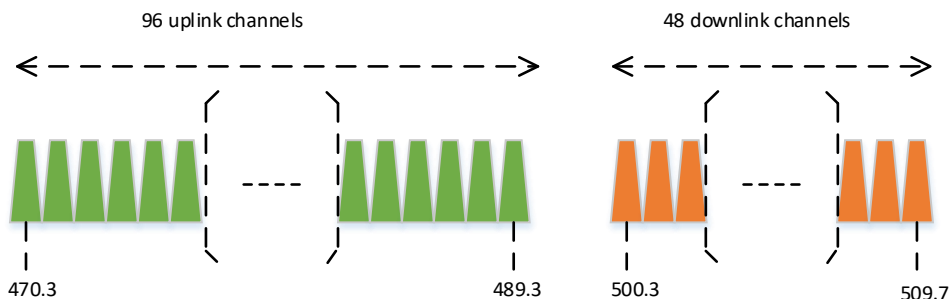


Figure 3: CN470-510 channel frequencies

1039

1040

1041

1042 The LoRaWAN can be used in the Chinese 470-510MHz band as long as

1043

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

1044

1045

1046

1047

1048 CN470-510 end-devices SHALL be capable of operating in the 470 to 510 MHz frequency
 1049 band and SHALL feature a channel data structure to store the parameters of 96 uplink
 1050 channels. A channel data structure corresponds to a frequency and a set of data rates usable
 1051 on this frequency.

1052 If using the over-the-air activation procedure, the end-device SHALL broadcast the JoinReq
 1053 message on a random 125 kHz channel amongst the 96 uplink channels defined using **DR5**
 1054 **to DR0**.

1055 Personalized devices SHALL have all 96 channels enabled following a reset.

1056

1057 2.7.3 CN470-510 Data Rate and End-point Output Power encoding

1058 There is no dwell time limitation for the CN470-510 PHY layer. The *TxParamSetupReq* MAC
 1059 command is not implemented by CN470-510 devices.

1060 The following encoding is used for Data Rate (DR) and End-point EIRP (TXPower) in the
 1061 CN470-510 band:

1062

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

1063

1064

1065 EIRP refers to the Equivalent Isotropically Radiated Power, which is the radiated output
 1066 power referenced to an isotropic antenna radiating power equally in all directions and whose
 1067 gain is expressed in dBi.

1068

1069 By default MaxEIRP is considered to be +19.15dBm. If the end-device cannot achieve
 1070 19.15dBm EIRP, the Max EIRP SHOULD be communicated to the network server using an
 1071 out-of-band channel during the end-device commissioning process.

1072

1073 2.7.4 CN470-510 JoinResp CFList

1074

1075 The CN470-510 LoRaWAN supports the use of the optional **CFList** appended to the
 1076 JoinResp message. If the **CFList** is not empty then the CFListType field SHALL contain the
 1077 value one (0x01) to indicate the CFList contains a series of ChMask fields. The ChMask
 1078 fields are interpreted as being controlled by a virtual ChMaskCntl that initializes to a value of
 1079 zero (0) and increments for each ChMask field to a value of five (5). (The first 16 bits
 1080 controls the channels 1 to 16, ..)

1081

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

1082 2.7.5 CN470-510 LinkAdrReq command

1083 For the CN470-510 version the **ChMaskCntl** field of the *LinkADRReq* command has the
 1084 following meaning:

1085

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

1086

Table 43: CN470-510 ChMaskCntl value table

1087 If the ChMask field value is one of the values meaning RFU, then end-device SHOULD reject
1088 the command and unset the “**Channel mask ACK**” bit in its response.

1089 2.7.6 CN470-510 Maximum payload size

1090 The maximum **MACPayload** size length (M) is given by the following table. It is derived from
1091 the maximum allowed transmission time at the PHY layer taking into account a possible
1092 repeater encapsulation. The maximum application payload length in the absence of the
1093 optional **FOpt** MAC control field (N) is also given for information only. The value of N might be
1094 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	

1095

Table 44: CN470-510 maximum payload size

1096 If the end-device will never operate with a repeater then the maximum application payload
1097 length in the absence of the optional **FOpt** control field SHOULD be:

1098

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	

1099

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

1100

1101 2.7.7 CN470-510 Receive windows

- 1102 • The RX1 receive channel is a function of the upstream channel used to initiate the
1103 data exchange. The RX1 receive channel can be determined as follows.
 - 1104 ○ RX1 Channel Number = Uplink Channel Number modulo 48, for example,
1105 when transmitting channel number is 49, the rx1 channel number is 1.
- 1106 • The RX1 window data rate depends on the transmit data rate (see Table below).
- 1107 • The RX2 (second receive window) settings uses a fixed data rate and frequency.
1108 Default parameters are 505.3 MHz / DR0

1109

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

1110

1111

1112 The allowed values for RX1DROffset are in the [0:5] range. Values in the range [6:7] are
 1113 reserved for future use.

1114 2.7.8 CN470-510 Class B beacon

1115 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

1116

1117

1118 The downstream channel used for a given beacon is:

$$1119 \text{ BeaconChannel} = \left[\text{floor} \left(\frac{\text{beacon_time}}{\text{beacon_period}} \right) \right] \text{ modulo } 8$$

- 1120 • whereby beacon_time is the integer value of the 4 bytes “Time” field of the beacon
- 1121 frame
- 1122 • whereby beacon_period is the periodicity of beacons , 128 seconds
- 1123 • whereby $\text{floor}(x)$ designates rounding to the integer immediately inferior or equal to x
- 1124

1125 | Example: the first beacon will be transmitted on 508.3Mhz, the second
 1126 | on 508.5MHz, the 9th beacon will be on 508.3Mhz again.

1127

1128

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

1129

1130

1131 The beacon frame content is:

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

1132

1133 2.7.9 CN470-510 Default Settings

1134 The following parameters are recommended values for the CN470-510 band.

1135	RECEIVE_DELAY1	1 s
1136	RECEIVE_DELAY2	2 s (MUST be RECEIVE_DELAY1 + 1s)
1137	JOIN_ACCEPT_DELAY1	5 s
1138	JOIN_ACCEPT_DELAY2	6 s
1139	MAX_FCNT_GAP	16384
1140	ADR_ACK_LIMIT	64
1141	ADR_ACK_DELAY	32
1142	ACK_TIMEOUT	2 +/- 1 s (random delay between 1 and 3 seconds)

1143 If the actual parameter values implemented in the end-device are different from those default
1144 values (for example the end-device uses a longer RECEIVE_DELAY1 & 2 latency), those
1145 parameters MUST be communicated to the network server using an out-of-band channel
1146 during the end-device commissioning process. The network server may not accept
1147 parameters different from those default values.

1148 **2.8 AS923MHz ISM Band**

 1149 **2.8.1 AS923 Preamble Format**

1150 The following synchronization words SHOULD be used:

1151

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

1152

Table 48: AS923 synch words

 1153 **2.8.2 AS923 ISM Band channel frequencies**

 1154 This section applies to regions where the frequencies [923...923.5MHz] are comprised in the
 1155 ISM band.

 1156 The network channels can be freely attributed by the network operator. However the two
 1157 following default channels MUST be implemented in every AS923MHz end-device. Those
 1158 channels are the minimum set that all network gateways SHOULD always be listening on.

1159

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%

1160

Table 49: AS923 default channels

 1161 Those default channels MUST be implemented in every end-device and cannot be modified
 1162 through the **NewChannelReq** command and guarantee a minimal common channel set
 1163 between end-devices and network gateways.

1164 AS923MHz ISM band end-devices should use the following default parameters

1165

- Default EIRP: 16 dBm

 1166 AS923MHz end-devices SHALL feature a channel data structure to store the parameters of
 1167 at least 16 channels. A channel data structure corresponds to a frequency and a set of data
 1168 rates usable on this frequency.

 1169 The following table gives the list of frequencies that SHALL be used by end-devices to
 1170 broadcast the JoinReq message.

1171

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%

1171

Table 50: AS923 JoinReq Channel List

1172

 1173 The default JoinReq Data Rate utilizes the range DR2-DR5 (SF10/125 kHz – SF7/125 kHz),
 1174 this setting ensures that end-devices are compatible with the 400ms dwell time limitation until
 1175 the actual dwell time limit is notified to the end-device by the network server via the MAC
 1176 command "TxParamSetupReq".

1177 The JoinReq message transmit duty-cycle SHALL follow the rules described in chapter

1178 “Retransmissions back-off” of the LoRaWAN specification document.
 1179

1180 **2.8.3 AS923 Data Rate and End-point Output Power encoding**

1181 The “TxParamSetupReq/Ans” MAC command MUST be implemented by the AS923 devices.
 1182 The following encoding is used for Data Rate (DR) in the AS923 band:

1183

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	

1184

Table 51: AS923 Data rate table

1185

1186 The TXPower table indicates power levels relative to the Max EIRP level of the end-device,
 1187 as per the following table:

1188

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

1189

1190

Table 52: AS923 TxPower table

1191 EIRP refers to the Equivalent Isotropically Radiated Power, which is the radiated output
 1192 power referenced to an isotropic antenna radiating power equally in all directions and whose
 1193 gain is expressed in dBi.

1194 By default Max EIRP SHALL be 16dBm. The Max EIRP can be modified by the network
 1195 server through the **TxParamSetupReq** MAC command and SHOULD be used by both the
 1196 end-device and the network server once **TxParamSetupReq** is acknowledged by the device
 1197 via **TxParamSetupAns**,

1198

1199 2.8.4 AS923 JoinAccept CFList

1200 The AS923 LoRaWAN implements an optional channel frequency list (CFList) of 16 octets in
1201 the JoinAccept message.

1202 In this case the CFList is a list of five channel frequencies for the channels two to six whereby
1203 each frequency is encoded as a 24 bits unsigned integer (three octets). All these channels are
1204 usable for DR0 to DR5 125 KHz LoRa modulation. The list of frequencies is followed by a
1205 single CFListType octet for a total of 16 octets. The CFListType SHALL be equal to zero (0)
1206 to indicate that the CFList contains a list of frequencies.

1207

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

1208 The actual channel frequency in Hz is 100 x frequency whereby values representing
1209 frequencies below 100 MHz are reserved for future use. This allows setting the frequency of
1210 a channel anywhere between 915 and 928MHz in 100 Hz steps. Unused channels have a
1211 frequency value of 0. The CFList is optional and its presence can be detected by the length of
1212 the join-accept message. If present, the CFList replaces all the previous channels stored in
1213 the end-device apart from the two default channels. The newly defined channels are
1214 immediately enabled and usable by the end-device for communication.

1215 2.8.5 AS923 LinkAdrReq command

1216 The AS923 LoRaWAN only supports a maximum of 16 channels. When **ChMaskCntl** field is
1217 0 the ChMask field individually enables/disables each of the 16 channels.

1218

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

1219

1220 If the ChMask field value is one of values meaning RFU, the end-device SHOULD reject the
1221 command and unset the “**Channel mask ACK**” bit in its response.

1222

1223 2.8.6 AS923 Maximum payload size

1224 The maximum **MACPayload** size length (M) is given by the following table for both dwell time
1225 configurations: No Limit and 400ms. It is derived from the PHY layer limitation depending on
1226 the effective modulation rate used taking into account a possible repeater encapsulation layer.

1227

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	

Table 54: AS923 maximum payload size

1228

 1229 If the end-device will never operate with a repeater then the maximum MAC payload length
 1230 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	

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

1231

 1232 The maximum application payload length in the absence of the optional **FOpt** control field (*N*)
 1233 is eight bytes lower than the MACPayload value in the above table. The value of *N* might be
 1234 smaller if the **FOpt** field is not empty.
 1235

1236 2.8.7 AS923 Receive windows

 1237 The RX1 receive window uses the same channel than the preceding uplink. The data rate is
 1238 a function of the uplink data rate and the RX1DROffset as following:

 1239 Downstream data rate in RX1 slot = $MIN(5, MAX(\text{MinDR}, \text{Upstream data rate} -$
 1240 $\text{Effective_RX1DROffset}))$

 1241 MinDR depends on the DownlinkDwellTime bit sent to the device in the **TxParamSetupReq**
 1242 command:

- 1243 • Case DownlinkDwellTime = 0 (No limit): MinDR = 0
- 1244 • Case DownlinkDwellTime = 1 (400ms): MinDR = 2

1245 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

 1246 Values in the [6:7] range allow setting the Downstream RX1 data rate higher than Upstream
 1247 data rate.

 1248 The RX2 receive window uses a fixed frequency and data rate. The default parameters are
 1249 923.2 MHz / DR2 (SF10/125KHz).

1250

 1251 **2.8.8 AS923 Class B beacon and default downlink channel**

1252 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

1253

Table 56 : AS923 beacon settings

1254 The beacon frame content is:

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

1255 The beacon default broadcast frequency is 923.4MHz.

1256 The class B default downlink pingSlot frequency is 923.4MHz

1257

 1258 **2.8.9 AS923 Default Settings**

1259 The following parameters are recommended values for the AS923MHz band.

1260	RECEIVE_DELAY1	1 s
1261	RECEIVE_DELAY2	2 s (MUST be RECEIVE_DELAY1 + 1s)
1262	JOIN_ACCEPT_DELAY1	5 s
1263	JOIN_ACCEPT_DELAY2	6 s
1264	MAX_FCNT_GAP	16384
1265	ADR_ACK_LIMIT	64
1266	ADR_ACK_DELAY	32
1267	ACK_TIMEOUT	2 +/- 1 s (random delay between 1 and 3 seconds)

1268 If the actual parameter values implemented in the end-device are different from those default
 1269 values (for example the end-device uses a longer RECEIVE_DELAY1 and
 1270 RECEIVE_DELAY2 latency), those parameters MUST be communicated to the network
 1271 server using an out-of-band channel during the end-device commissioning process. The
 1272 network server may not accept parameters different from those default values.

1273 **2.9 KR920-923MHz ISM Band**

 1274 **2.9.1 KR920-923 Preamble Format**

1275 The following synchronization words SHOULD be used:

1276

Modulation	Sync word	Preamble length
LORA	0x34	8 symbols

 1277 **2.9.2 KR920-923 ISM Band channel frequencies**

 1278 The center frequency, bandwidth and maximum EIRP output power for the South Korea
 1279 RFID/USN frequency band are already defined by Korean Government. Basically Korean
 1280 Government allocated LPWA based IoT network frequency band from 920.9 to 923.3MHz.

1281

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

1282

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

 1283 The three following default channels (922.1, 922.3 and 922.5MHz / DR0 to DR5) determined
 1284 by the network operator from the set of available channels as defined by the South Korean
 1285 regulation MUST be implemented in every KR920-923MHz end-device, and cannot be
 1286 alterable by the **NewChannelReq** command. Those channels are the minimum set that all
 1287 network gateways SHOULD always be listening on to guarantee a minimal common channel
 1288 set between end-devices and network gateways.

1289

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

1290

Table 58: KR920-923 default channels

 1291 In order to access the physical medium the South Korea regulations impose some restrictions.
 1292 The South Korea regulations allow the choice of using either a duty-cycle limitation or a so-
 1293 called Listen Before Talk Adaptive Frequency Agility (LBT AFA) transmissions management.
 1294 The current LoRaWAN specification for the KR920-923 ISM band exclusively uses LBT
 1295 channel access rule to maximize MACPayload size length and comply with the South Korea
 1296 regulations.

1297 KR920-923MHz ISM band end-devices SHALL use the following default parameters

- 1298 • Default EIRP output power for end-device(920.9~921.9MHz): 10 dBm
- 1299 • Default EIRP output power for end-device(922.1~923.3MHz): 14 dBm
- 1300 • Default EIRP output power for gateway: 23 dBm

1301 KR920-923MHz end-devices SHALL be capable of operating in the 920 to 923MHz frequency
 1302 band and SHALL feature a channel data structure to store the parameters of at least 16
 1303 channels. A channel data structure corresponds to a frequency and a set of data rates usable
 1304 on this frequency.

1305 The following table gives the list of frequencies that SHALL be used by end-devices to
 1306 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

1307 **Table 59: KR920-923 JoinReq Channel List**

1308 2.9.3 KR920-923 Data Rate and End-device Output Power encoding

1309 There is no dwell time limitation for the KR920-923 PHY layer. The *TxParamSetupReq* MAC
 1310 command is not implemented by KR920-923 devices.

1311 The following encoding is used for Data Rate (DR), and EIRP Output Power (TXPower) in the
 1312 KR920-923 band:

1313

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	

1314 **Table 60: KR920-923 TX Data rate table**

1315

1316

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

1317 **Table 61: KR920-923 TX power table**

1318

1319 EIRP refers to the Equivalent Isotropically Radiated Power, which is the radiated output
 1320 power referenced to an isotropic antenna radiating power equally in all directions and whose
 1321 gain is expressed in dBi.

1322

1323 By default MaxEIRP is considered to be +14dBm. If the end-device cannot achieve 14dBm
 1324 EIRP, the MaxEIRP SHOULD be communicated to the network server using an out-of-band
 1325 channel during the end-device commissioning process.

1326 When the device transmits in a channel whose frequency is <922MHz, the transmit power
 1327 SHALL be limited to +10dBm EIRP even if the current transmit power level set by the
 1328 network server is higher.

1329 **2.9.4 KR920-923 JoinAccept CFList**

1330 The KR920-923 ISM band LoRaWAN implements an optional **channel frequency list** (CFList)
 1331 of 16 octets in the JoinAccept message.

1332 In this case the CFList is a list of five channel frequencies for the channels three to seven
 1333 whereby each frequency is encoded as a 24 bits unsigned integer (three octets). All these
 1334 channels are usable for DR0 to DR5 125kHz LoRa modulation.

1335 The list of frequencies is followed by a single CFListType octet for a total of 16 octets. The
 1336 CFListType SHALL be equal to zero (0) to indicate that the CFList contains a list of
 1337 frequencies.

1338

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

1339 The actual channel frequency in Hz is 100 x frequency whereby values representing
 1340 frequencies below 100 MHz are reserved for future use. This allows setting the frequency of
 1341 a channel anywhere between 100 MHz to 1.67 GHz in 100 Hz steps. Unused channels have
 1342 a frequency value of 0. The **CFList** is optional and its presence can be detected by the length
 1343 of the join-accept message. If present, the **CFList** replaces all the previous channels stored
 1344 in the end-device apart from the three default channels. The newly defined channels are
 1345 immediately enabled and usable by the end-device for communication.

1346 **2.9.5 KR920-923 LinkAdrReq command**

1347 The KR920-923 LoRaWAN only supports a maximum of 16 channels. When **ChMaskCntl**
 1348 field is 0 the ChMask field individually enables/disables each of the 16 channels.

1349

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

1350
1351

1352 If the ChMaskCntl field value is one of values meaning RFU, the end-device SHOULD reject
 1353 the command and unset the “**Channel mask ACK**” bit in its response.

1354 2.9.6 KR920-923 Maximum payload size

1355 The maximum **MACPayload** size length (M) is given by the following table for the regulation
 1356 of dwell time; less than 4 sec with LBT. It is derived from limitation of the PHY layer depending
 1357 on the effective modulation rate used taking into account a possible repeater encapsulation
 1358 layer. The maximum application payload length in the absence of the optional **FOpt** control
 1359 field (N) is also given for information only. The value of N might be smaller if the **FOpt** field is
 1360 not empty:

1361

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	

1362

Table 63: KR920-923 maximum payload size

1363 If the end-device will never operate with a repeater then the maximum application payload
 1364 length in the absence of the optional **FOpt** control field SHOULD be:

1365

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	

1366

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

1367

1368 2.9.7 KR920-923 Receive windows

1369 The RX1 receive window uses the same channel than the preceding uplink. The data rate is
 1370 a function of the uplink data rate and the RX1DROffset as given by the following table. The
 1371 allowed values for RX1DROffset are in the [0:5] range. Values in the [6:7] range are reserved
 1372 for future use.

1373

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

1374 **Table 65 : KR920-923 downlink RX1 data rate mapping**

1375 The RX2 receive window uses a fixed frequency and data rate. The default parameters are
 1376 921.90MHz / DR0 (SF12, 125 kHz).

1377 **2.9.8 KR920-923 Class B beacon and default downlink channel**

1378 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

1379 **Table 66 : KR920-923 beacon settings**

1380

1381 The beacon frame content is:

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

1382 The beacon default broadcast frequency is 923.1MHz.

1383 The class B default downlink pingSlot frequency is 923.1MHz

1384

1385 **2.9.9 KR920-923 Default Settings**

1386 The following parameters are recommended values for the KR920-923Mhz band.

1387	RECEIVE_DELAY1	1 s
1388	RECEIVE_DELAY2	2 s (MUST be RECEIVE_DELAY1 + 1s)
1389	JOIN_ACCEPT_DELAY1	5 s
1390	JOIN_ACCEPT_DELAY2	6 s
1391	MAX_FCNT_GAP	16384
1392	ADR_ACK_LIMIT	64
1393	ADR_ACK_DELAY	32
1394	ACK_TIMEOUT	2 +/- 1 s (random delay between 1 and 3 seconds)

1395 If the actual parameter values implemented in the end-device are different from those default
 1396 values (for example the end-device uses a longer RECEIVE_DELAY1 and
 1397 RECEIVE_DELAY2 latency), those parameters MUST be communicated to the network
 1398 server using an out-of-band channel during the end-device commissioning process. The
 1399 network server may not accept parameters different from those default values.

1400

1401 **2.10 IN865-867 MHz ISM Band**

 1402 **2.10.1 IN865-867 Preamble Format**

1403 The following synchronization words SHOULD be used:

1404

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

1405

Table 67: IN865-867 synch words

 1406 **2.10.2 IN865-867 ISM Band channel frequencies**

1407 This section applies to the Indian sub-continent.

 1408 The network channels can be freely attributed by the network operator. However the three
 1409 following default channels MUST be implemented in every India 865-867MHz end-device.
 1410 Those channels are the minimum set that all network gateways SHOULD always be listening
 1411 on.

1412

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

1413

Table 68: IN865-867 default channels

 1414 End-devices SHALL be capable of operating in the 865 to 867 MHz frequency band and
 1415 should feature a channel data structure to store the parameters of at least 16 channels. A
 1416 channel data structure corresponds to a frequency and a set of data rates usable on this
 1417 frequency.

 1418 The first three channels correspond to 865.0625, 865.4025, and 865.985 MHz / DR0 to DR5
 1419 and MUST be implemented in every end-device. Those default channels cannot be modified
 1420 through the **NewChannelReq** command and guarantee a minimal common channel set
 1421 between end-devices and network gateways.

 1422 The following table gives the list of frequencies that SHALL be used by end-devices to
 1423 broadcast the JoinReq message. The JoinReq message transmit duty-cycle SHALL follow the
 1424 rules described in chapter "Retransmissions back-off" of the LoRaWAN specification
 1425 document.

1426

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

1427

Table 69: IN865-867 JoinReq Channel List

 1428 **2.10.3 IN865-867 Data Rate and End-device Output Power Encoding**

 1429 There is no dwell time or duty-cycle limitation for the INDIA 865-867 PHY layer. The
 1430 **TxParamSetupReq** MAC command is not implemented by INDIA 865-867 devices.

 1431 The following encoding is used for Data Rate (DR) and End-device Output Power (TXPower)
 1432 in the INDIA 865-867 band:

1433

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

1434

1435

1436 The TXPower table indicates power levels relative to the Max EIRP level of the end-device,
 1437 as per the following table:

1438

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

1439

1440

1441 EIRP refers to the Equivalent Isotropically Radiated Power, which is the radiated output power
 1442 referenced to an isotropic antenna radiating power equally in all directions and whose gain is
 1443 expressed in dBi.

1444 By default MaxEIRP is considered to be 30dBm. If the end-device cannot achieve 30dBm
 1445 EIRP, the Max EIRP SHOULD be communicated to the network server using an out-of-band
 1446 channel during the end-device commissioning process.

1447

1448 2.10.4 IN865-867 JoinAccept CFList

1449 The India 865-867 ISM band LoRaWAN implements an optional **channel frequency list**
 1450 (CFList) of 16 octets in the JoinAccept message.

1451 In this case the CFList is a list of five channel frequencies for the channels three to seven
 1452 whereby each frequency is encoded as a 24 bits unsigned integer (three octets). All these
 1453 channels are usable for DR0 to DR5 125kHz LoRa modulation.

1454 The list of frequencies is followed by a single CFListType octet for a total of 16 octets. The
 1455 CFListType SHALL be equal to zero (0) to indicate that the CFList contains a list of
 1456 frequencies.

1457

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

1458 The actual channel frequency in Hz is 100 x frequency whereby values representing
 1459 frequencies below 100 MHz are reserved for future use. This allows setting the frequency of
 1460 a channel anywhere between 100 MHz to 1.67 GHz in 100 Hz steps. Unused channels have
 1461 a frequency value of 0. The **CFList** is optional and its presence can be detected by the length
 1462 of the join-accept message. If present, the **CFList** replaces all the previous channels stored
 1463 in the end-device apart from the three default channels. The newly defined channels are
 1464 immediately enabled and usable by the end-device for communication.

1465 2.10.5 IN865-867 LinkAdrReq command

1466 The INDIA 865-867 LoRaWAN only supports a maximum of 16 channels. When **ChMaskCntl**
 1467 field is 0 the ChMask field individually enables/disables each of the 16 channels.

1468

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

1469

Table 72: IN865-867 ChMaskCntl value table

1470 If the ChMaskCntl field value is one of values meaning RFU, the end-device SHOULD reject
 1471 the command and unset the “**Channel mask ACK**” bit in its response.

1472 2.10.6 IN865-867 Maximum payload size

1473 The maximum **MACPayload** size length (*M*) is given by the following table. It is derived from
 1474 limitation of the PHY layer depending on the effective modulation rate used taking into account
 1475 a possible repeater encapsulation layer. The maximum application payload length in the
 1476 absence of the optional **FOpt** control field (*N*) is also given for information only. The value of
 1477 *N* might be smaller if the **FOpt** field is not empty:

1478

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	

1479

Table 73: IN865-867 maximum payload size

 1480 If the end-device will never operate with a repeater then the maximum application payload
 1481 length in the absence of the optional **FOpt** control field SHOULD be:

1482

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	

1483

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

1484 2.10.7 IN865-867 Receive windows

 1485 The RX1 receive window uses the same channel than the preceding uplink. The data rate is
 1486 a function of the uplink data rate and the RX1DROffset as given by the following table. The
 1487 allowed values for RX1DROffset are in the [0:7] range. Values in the [6:7] range allow setting
 1488 the Downstream RX1 data rate higher than Upstream data rate.

1489 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

 1490 Downstream data rate in RX1 slot = $MIN(5, MAX(0, Upstream\ data\ rate -$
 1491 $Effective_RX1DROffset))$

 1492 The RX2 receive window uses a fixed frequency and data rate. The default parameters are
 1493 866.550 MHz / DR2 (SF10, 125 kHz).

1494 2.10.8 IN865-867 Class B beacon and default downlink channel

1495 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

1496

1497 The beacon frame content is:

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

1498 The beacon default broadcast frequency is 866.550MHz.

1499 The class B default downlink pingSlot frequency is 866.550MHz

1500

1501 2.10.9 IN865-867 Default Settings

1502 The following parameters are recommended values for the INDIA 865-867MHz band.

1503

1504	RECEIVE_DELAY1	1 s
1505	RECEIVE_DELAY2	2 s (MUST be RECEIVE_DELAY1 + 1s)
1506	JOIN_ACCEPT_DELAY1	5 s
1507	JOIN_ACCEPT_DELAY2	6 s
1508	MAX_FCNT_GAP	16384
1509	ADR_ACK_LIMIT	64
1510	ADR_ACK_DELAY	32
1511	ACK_TIMEOUT	2 +/- 1 s (random delay between 1 and 3 seconds)

1512 If the actual parameter values implemented in the end-device are different from those default
1513 values (for example the end-device uses a longer RECEIVE_DELAY1 and
1514 RECEIVE_DELAY2 latency), those parameters MUST be communicated to the network
1515 server using an out-of-band channel during the end-device commissioning process. The
1516 network server may not accept parameters different from those default values.

1517

1518

1520 **2.11 RU864-870 MHz ISM Band**

 1521 **2.11.1 RU864-870 Preamble Format**

1522 The following synchronization words SHOULD be used:

1523

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

1524

Table 75: RU864-870 synch words

 1525 **2.11.2 RU864-870 ISM Band channel frequencies**

 1526 The network channels can be freely attributed by the network operator in compliance with the
 1527 allowed sub-bands defined by the Russian regulation. However the two following default
 1528 channels MUST be implemented in every RU864-870 MHz end-device. Those channels are
 1529 the minimum set that all network gateways SHOULD always be listening on.

1530

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%

1531

Table 76: RU864-870 default channels

 1532 RU864-870 MHz end-devices SHALL be capable of operating in the 864 to 870 MHz
 1533 frequency band and SHALL feature a channel data structure to store the parameters of at
 1534 least 8 channels. A channel data structure corresponds to a frequency and a set of data rates
 1535 usable on this frequency.

 1536 The first two channels correspond to 868.9 and 869.1 MHz / DR0 to DR5 and MUST be
 1537 implemented in every end-device. Those default channels cannot be modified through the
 1538 **NewChannelReq** command and guarantee a minimal common channel set between end-
 1539 devices and network gateways.

 1540 The following table gives the list of frequencies that SHALL be used by end-devices to
 1541 broadcast the JoinReq message. The JoinReq message transmit duty-cycle SHALL follow the
 1542 rules described in chapter "Retransmissions back-off" of the LoRaWAN specification
 1543 document.

1544

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

1545 **Table 77: RU864-870 JoinReq Channel List**

1546 **2.11.3 RU864-870 Data Rate and End-device Output Power encoding**

1547 There is no dwell time limitation for the RU864-870 PHY layer. The *TxParamSetupReq* MAC
 1548 command is not implemented in RU864-870 devices.

1549 The following encoding is used for Data Rate (DR) and End-device EIRP (TXPower) in the
 1550 RU864-870 band:

1551

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 78: RU864-870 TX Data rate table

1552

1553

1554 EIRP¹ refers to the Equivalent Isotropically Radiated Power, which is the radiated output
 1555 power referenced to an isotropic antenna radiating power equally in all directions and whose
 1556 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 79: RU864-870 TX power table

1557

1558

1559

1560

1561 By default MaxEIRP is considered to be +16dBm. If the end-device cannot achieve +16dBm
 1562 EIRP, the Max EIRP SHOULD be communicated to the network server using an out-of-band
 1563 channel during the end-device commissioning process.

1564

1565 **2.11.4 RU864-870 JoinAccept CFList**

1566

1567 The RU 864-870 ISM band LoRaWAN implements an optional **channel frequency list**
 1568 (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

1569 In this case the CFList is a list of five channel frequencies for the channels two to six whereby
 1570 each frequency is encoded as a 24 bits unsigned integer (three octets). All these channels are
 1571 usable for DR0 to DR5 125kHz LoRa modulation. The list of frequencies is followed by a single
 1572 CFListType octet for a total of 16 octets. The CFListType SHALL be equal to zero (0) to
 1573 indicate that the CFList contains a list of frequencies.

1574

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

1575 The actual channel frequency in Hz is 100 x frequency whereby values representing
 1576 frequencies below 100 MHz are reserved for future use. This allows setting the frequency of
 1577 a channel anywhere between 100 MHz to 1.67 GHz in 100 Hz steps. Unused channels have
 1578 a frequency value of 0. The **CFList** is optional and its presence can be detected by the length
 1579 of the join-accept message. If present, the **CFList** replaces all the previous channels stored
 1580 in the end-device apart from the two default channels. The newly defined channels are
 1581 immediately enabled and usable by the end-device for communication.

1582 2.11.5 RU864-870 LinkAdrReq command

1583 The RU864-870 LoRaWAN only supports a maximum of 16 channels. When **ChMaskCntl**
 1584 field is 0 the ChMask field individually enables/disables each of the 16 channels.
 1585

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

1586

Table 80: RU864-870 ChMaskCntl value table

1587 If the ChMaskCntl field value is one of values meaning RFU, the end-device SHOULD reject
 1588 the command and unset the “**Channel mask ACK**” bit in its response.

1589 2.11.6 RU864-870 Maximum payload size

1590 The maximum **MACPayload** size length (*M*) is given by the following table. It is derived from
 1591 limitation of the PHY layer depending on the effective modulation rate used taking into account
 1592 a possible repeater encapsulation layer. The maximum application payload length in the
 1593 absence of the optional **FOpt** control field (*N*) is also given for information only. The value of
 1594 N might be smaller if the **FOpt** field is not empty:
 1595

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	

1596

Table 81: RU864-870 maximum payload size

1597

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

1598

1599

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	

1600

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

1601

2.11.7 RU864-870 Receive windows

1602

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

1603

1604

1605

1606

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

1607

Table 83: RU864-870 downlink RX1 data rate mapping

1608

1609

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

1610

1611

1612

2.11.8 RU864-870 Class B beacon and default downlink channel

1613

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

1614

Table 84: RU864-870 beacon settings

1615

1616

The beacon frame content is:

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

1617 The beacon default broadcast frequency is 869.1 MHz.

1618 The class B default downlink pingSlot frequency is 868.9 MHz.

1619

1620 2.11.9 RU864-870 Default Settings

1621 The following parameters are recommended values for the RU864-870 MHz band.

1622	RECEIVE_DELAY1	1 s
1623	RECEIVE_DELAY2	2 s (MUST be RECEIVE_DELAY1 + 1s)
1624	JOIN_ACCEPT_DELAY1	5 s
1625	JOIN_ACCEPT_DELAY2	6 s
1626	MAX_FCNT_GAP	16384
1627	ADR_ACK_LIMIT	64
1628	ADR_ACK_DELAY	32
1629	ACK_TIMEOUT	2 +/- 1 s (random delay between 1 and 3 seconds)

1630 If the actual parameter values implemented in the end-device are different from those default
 1631 values (for example the end-device uses a longer RECEIVE_DELAY1 and
 1632 RECEIVE_DELAY2 latency), those parameters MUST be communicated to the network
 1633 server using an out-of-band channel during the end-device commissioning process. The
 1634 network server may not accept parameters different from those default values.

1635

1636 **3 Revisions**

1637 **3.1 Revision A**

- 1638 • Initial 1.0.3 revision, the regional parameters were extracted from the
- 1639 LoRaWANV1.0.3 revision A.
- 1640

1641 **4 Bibliography**

1642 **4.1 References**

1643

1644 [LORAWAN] LoRaWAN Specification, V1.0.3, the LoRa Alliance, January 2018.

1645 5 NOTICE OF USE AND DISCLOSURE

1646 Copyright © LoRa Alliance, Inc. (2015-2018). All Rights Reserved.

1647 The information within this document is the property of the LoRa Alliance (“The Alliance”) and its use and disclosure are
1648 subject to LoRa Alliance Corporate Bylaws, Intellectual Property Rights (IPR) Policy and Membership Agreements.

1649 Elements of LoRa Alliance specifications may be subject to third party intellectual property rights, including without
1650 limitation, patent, copyright or trademark rights (such a third party may or may not be a member of LoRa Alliance). The
1651 Alliance is not responsible and shall not be held responsible in any manner for identifying or failing to identify any or all such
1652 third party intellectual property rights.

1653 This document and the information contained herein are provided on an “AS IS” basis and THE ALLIANCE DISCLAIMS
1654 ALL WARRANTIES EXPRESS OR IMPLIED, INCLUDING BUT NOT LIMITED TO (A) ANY WARRANTY THAT
1655 THE USE OF THE INFORMATION HEREIN WILL NOT INFRINGE ANY RIGHTS OF THIRD PARTIES (INCLUDING
1656 WITHOUT LIMITATION ANY INTELLECTUAL PROPERTY RIGHTS INCLUDING PATENT, COPYRIGHT OR
1657 TRADEMARK RIGHTS) OR (B) ANY IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A
1658 PARTICULAR PURPOSE, TITLE OR NONINFRINGEMENT.

1659 IN NO EVENT WILL THE ALLIANCE BE LIABLE FOR ANY LOSS OF PROFITS, LOSS OF BUSINESS, LOSS OF
1660 USE OF DATA, INTERRUPTION OF BUSINESS, OR FOR ANY OTHER DIRECT, INDIRECT, SPECIAL OR
1661 EXEMPLARY, INCIDENTAL, PUNITIVE OR CONSEQUENTIAL DAMAGES OF ANY KIND, IN CONTRACT OR IN
1662 TORT, IN CONNECTION WITH THIS DOCUMENT OR THE INFORMATION CONTAINED HEREIN, EVEN IF
1663 ADVISED OF THE POSSIBILITY OF SUCH LOSS OR DAMAGE.

1664 The above notice and this paragraph must be included on all copies of this document that are made.

1665 LoRa Alliance, Inc.

1666 2400 Camino Ramon, Suite 375

1667 San Ramon, CA 94583

1668 *Note: All Company, brand and product names may be trademarks that are the sole property of their respective owners.*