**IEEE P802.15**

**Wireless Personal Area Networks**

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| Project | IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs) | |
| Title | **Frequency Regulations for IG-LPWA report** | |
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| Abstract | [Korean frequency regulations are added to 15-17-0528-00-lpwa-draft-ig-lpwa-report.] | |
| Purpose | [Description of what the author wants P802.15 to do with the information in the document.] | |
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Draft IG Low Power Wide Area Report

Date: 2017-xx-xx

# Abstract

# Table of Contents

[1 Introduction 4](#_Toc493057907)

[2 Technical Characteristics of Low Power Wide Area Networks 5](#_Toc493057908)

[Theoretical Bound on Maximum Payload Bit-Rate 6](#_Toc493057909)

[Technical Challenges of LPWAN 7](#_Toc493057910)

[3 Potential Use-Cases for Low Power Wide Area Networks 8](#_Toc493057911)

[Agriculture and Environmental 8](#_Toc493057912)

[Consumer/Medical 8](#_Toc493057913)

[Industrial 8](#_Toc493057914)

[Infrastructure 8](#_Toc493057915)

[Logistics 9](#_Toc493057916)

[Smart Building 9](#_Toc493057917)

[Smart City 9](#_Toc493057918)

[4 Frequency Regulation and Channel Models 10](#_Toc493057919)

[4.1 Frequency Regulation 10](#_Toc493057920)

[FCC (United States) 10](#_Toc493057921)

[ETSI (Europe) 11](#_Toc493057922)

[MOSI (Korea) 11](#_Toc493057922)

[4.2 Propagation Models for LPWAN 12](#_Toc493057923)

[Indoor Model 12](#_Toc493057924)

[Outdoor Urban Model / Outdoor Rural Model 13](#_Toc493057925)

[Outdoor Device-to-Device 13](#_Toc493057926)

[Thermal Noise 13](#_Toc493057927)

[4.3 Interference Channel Model 14](#_Toc493057928)

[4.4 Number of Active Users 17](#_Toc493057929)

[5 Use-Case Evaluation Process 20](#_Toc493057930)

[6 Analysis of Existing IEEE Standards / Candidate Technologies 22](#_Toc493057931)

[6.1 Suitability of Candidate Technologies 22](#_Toc493057932)

[6.2 Suitability Analysis of Existing IEEE Standards 25](#_Toc493057933)

[6.3 Qualitative Evaluation of Candidate Technologies 28](#_Toc493057934)

[6.4 Quantitative Evaluation of Candidate Technologies 29](#_Toc493057935)

[6.5 Evaluation Summary 30](#_Toc493057936)

[7 Summary and Recommendation for Future WG Activities 31](#_Toc493057937)

[Annex 32](#_Toc493057938)

[Literature 33](#_Toc493057939)

# 4 Frequency Regulation and Channel Models

For the evaluation process of different candidate technologies and existing IEEE standards it is essential to understand the achievable performance of these systems. In chapter 2 the theoretical bounds concerning the maximum payload bit-rate have already been discussed. This chapter adds additional aspects. First, this covers the frequency regulation that may vary significantly between different countries. Next, the channel models are defined that allow the prediction of the achievable transmit range in different scenarios. Finally, models for the interference and the channel use are presented.

## 4.1 Frequency Regulation

LPWAN systems may be either used in licensed or unlicensed frequency spectrum. Generally, licensed spectrum offers significant performance benefits, as it is typically under full control of the license owner. However, it is expected that most LPWAN systems will be operated in the license exempt frequency bands below 1 GHz. In order to guarantee a certain level of interoperability between users in these frequency bands, the responsible frequency regulation authorities have defined limitations to devices that are using these bands. These limitations refer to parameters such as the maximum transmit power, the used signal bandwidth or the duty cycle. The following sub-sections give a brief overview over the regulation in the United States and Europe.

### FCC (United States)

In the United States, the Federal Communications Commission (FCC) is the body responsible for implementing the frequency regulation rules. These rules are documented in Part 15 of Title 47 of the Code of Federal regulations [5]. Relevant for the license exempt sub-GHz bands 902 to 928 MHz are Part 15.247 (Frequency Hopping and Digitally Modulated Intentional Radiators) and Part 15.249 (General Non-Licensed Intentional Regulators).

Part 15.249 does not enforce any restrictions on devices operated in the 902 to 928 MHz band, e.g. on the bandwidth or the maximum transmit duration. However, Part 15.249 limits the maximum field strength to 50 mV/m in a distance of 3 m. This approximately results in an effective transmit power of -1 dBm [1], which may be too low for many applications.

In contrast, Part 15.247 allows for significantly higher transmit powers. However, it enforces additional rules that are mainly related to the mandatory use of frequency hopping.

**Frequency Hopping:** According to Part 15.247, systems with a 6 dB bandwidth of less than 500 kHz have to be treated as frequency hopping systems. These systems shall use at least 50 hopping channels, and the average time of occupancy per channel shall not be greater than 0.4 s within a 20 s period. If the 20 dB bandwidth of the hopping channels is 250 kHz or greater, the system shall use at least 25 hopping channels, and the average time of occupancy per channel shall not be greater than 0.4 s within a 10 s period.

**Transmit Power:** The electrical transmit power is limited to 1 W, and the ERP (Effective Radiated Power) is limited to 4 W. For frequency hopping systems with less than 50 channels these values have to be reduced to 0.25 W electrical power and 1 W ERP. Furthermore, non-frequency hopping signals shall not exceed a power spectral density of 8 dBm in any 3 kHz band.

### ETSI (Europe)

The European norm ETSI EN 300 220-2 [6, p. 20] lists the EU wide harmonized national radio frequency bands from 25 MHz to 1,000 MHz. The norm refers to these devices as “Short Range Devices” (SRD). Available frequencies for SRD are close to 27 MHz, 40 MHz, 169 MHz, 433 MHz, and between 863 and 870 MHz. Furthermore, local authorizes may allow additional frequencies, which a not EU wide harmonized. The main restrictions are related to the transmit power, the duty cycle, and the signal bandwidth.

**Transmit power:** The transmit power is limited to 10 mW or 25 mW ERP (Effective Radiated Power) in most SRD bands. The term ERP indicates that these values already include the antenna gain, which means that the maximum electrical power may be significantly lower. Only few frequency bands allow for a higher transmit power of 500 mW ERP, i.e. 169.400-169.475 MHz, and 869.400-869.650 MHz.

**Duty cycle:** The ETSI norm limits the channel occupancy of devices in most frequency bands. The duty cycle, i.e. the ratio expressed as a percentage of the cumulative duration of transmission within an observation interval in a given operational frequency band [7, p. 28]. The observation interval is normally defined as 1 h and typical duty cycles are between 0.1% and 10%. Thus, the cumulative duration is typically limited between 3.6 s and 360 s per hour, which may lead to restrictions in some LPWAN applications, especially for the base-stations. Thus, the transmission of a single packet low bit-rate LPWAN packet may be longer than the allowed duty cycle. Furthermore, the use of techniques such as frequency hopping does not increase the allowed transmission time if the hopping takes place in the same operational band, which will be the case for most applications. Only few operational bands do not have any duty cycle limitation, but they have additional restrictions with respect to the transmit power.

The operational bands between 863 and 870 MHz allows for so-called “polite spectrum access” as an alternative mode to the duty cycle operation. The exact definition of this mode is given in [7, p. 55]. This mode mainly adds a clear channel assessment with well-defined timing parameters before each transmission. However, also this mode defines a maximum cumulative on-time which is 100 s / 1 h within a h h200 kHz portion of the spectrum. This corresponds to a maximum duty cycle of 2.7% if only this portion of the spectrum is used. If also other portions of the spectrum are used, e.g. by means of frequency hopping, a duty cycle of more than 50% is feasible (e.g. hopping between 863 and 868 MHz).

**Bandwidth:** The maximum bandwidth depends on the used operational band. Most bands offer only a maximum signal bandwidth of few kHz. A higher signal bandwidth of more than 1 MHz is only available in the 434 MHz band. Furthermore, the band ranging from 863 to 870 MHz allows for a maximum signal bandwidth of 3 MHz. M

### MOSI (KOREA)

The sub-GHz band frequency, which can be used for LPWA without a license in Korea, follows the provisions of Ministry of Science and ICT (MOSI) of KOREA. So far, the 917 MHz band is the only Korean sub-GHz frequency band applies to traditional IEEE802 standards including IEEE802.15.4k. However, this regulation was amended in September 2016 by MOSI. The 262 MHz band and the 940 MHz band have been added under the revised regulations, and the specifications for the existing 917 MHz band have changed [29]. The three sub-GHz frequency bands can be used for LPWA applications. However, when using the existing IEEE802 standard or creating a new standard, it is necessary to change the 917 MHz band specification of the existing standard and newly add the new 262 MHz band and the 940 MHz band. The three bands have different regulations regarding Transmit Power Limit, Frequency Hopping, Duty cycle and LBT ATA.

**Transmit Power:** Currently, the 917 MHz band, which is currently used in the 802.15.4k standard [30], has a Transmit power limit of 3 mW to 25 mW depending on the 200 KHz unit channel of 917-923.5 MHz. Exceptionally, 200mW of radiated power of the 917 MHz band is allowed exclusively for outdoor fixed point-to-multipoint radio devices. The transmit power of up to 100mW and 200mW are allowed for the 262 MHz and the 940 MHz respectively.

**Frequency Hopping:** If more than 16 redundant channels are used, the 917 MHz band can be used for frequency hopping. The time limit per channel is limited to 0.4 sec.

**LBT ATA :** The 917 (917-923.5) MHz band can be used with an LBT ATA with a carrier sense of more than 5 ms. However, transmission is possible when the detected signal strength is less than -65 dBm, the transmission period is limited to less than 4 seconds, and the stop period of 50 ms or more should be applied.

**Duty cycle:** In the 917 MHz band, transmission is limited to within 2% for a 20-second period under 10 mW, 1% for a 40-second period between 10 and 25mW, within 0.5% for an 80-second period over 25mW. For the 262 MHz band, idle time is required after a transmission from a specific channel, and the sum of the continuous transmission time to the post stop time is limited to 1% or less. In the 940 MHz band, the occupancy time of a particular channel is limited to within 0.1% in any one hour.

Frequency Regulation Summary

The frequency regulation authorities enforce different frequency regulatory aspects. A system that may be used on a world-wise basis has to take the following aspects into account:

* Maximum transmit duration of 0.4 s within a 20 s period (10 s period for  some configurations), mandatory use of frequency hopping
* Limitation of duty cycle, which is especially critical for the LPWAN base-stations

# Literature

|  |  |
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| [29] | Tae-Joon Park, Hoyong Kang, Wun-Cheol Jeong, “Korean Frequency Regulations for LPWA,” 15-17/153r0, 2017. |
| [30] | Tae-Joon Park, Kyeseon Lee, Wun-Cheol Jeong, Eun-Hee Kim, “Proposal for Suitability Analysis of IG LPWA Report,” 15-17/0155r01, 2017. |