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BLUETOOTH LOW ENERGY REGULATORY ASPECTS

ABSTRACT: This white paper contains Guidelines regarding regulatory issues for *Bluetooth* low energy devices.

Revision History		
Revision	**Date**	**Description**
0.1	14 May 2007	Initial Draft.
0.2	21 May 2007	Edits of the ETSI part
0.3	23 May 2007	Addition of Power density TC.
0.4	30 May 2007	Addition of Immunity test requirements
0.5d1	1 Jun 2007	Added: “Section 7 Regulatory Aspects on Dual mode devices” Editorials: · Editorial Global replace of WiBree for LE Bluetooth · Added “Definitions and Abbreviations” · Added rationale for LE Bluetooth as “DSSS” w.r.t FCC regulation
0.6	14 Jun 2007	Removal of Section 7 Addition of JRL part
0.7d1	11 Oct 2007	Addition of Annex C
0.7d2	16 Oct 2007	Editorial adjustments
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09d1	22 Nov 2008	Additional assessment results from Telefication assessment of the conditions in China, South Korea and Taiwan
09d2	16 Nov 2008	Editorial merge of Telefication results with past 07d12
09d3	24 Feb 2009	Limitations of scope; consistent with “Disclaimer and Copyright notice” added. Clarifications from Telefication added Added 5.1.5.1 on CCC Added clarification in 5.2.5 regarding BR/EDR on modulation vs to applicable to Bluetooth LE in China Added clarification in 5.4.6 on difference in spectral density test results between South Korean and ETSI test standards Added clarification in 5.8.5 regarding the carrier frequency tolerance for China.
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Contents

1. Introduction

This paper is a summary of the regulatory requirements for the *Bluetooth*® low energy (LE) transceiver. These requirements have implications for the *Bluetooth* LE physical and link layers.

This document covers regulations for United States, Europe, Japan, Korea, China, and Taiwan. The regulatory reference documents listed in this paper are subject to change or revision at any time.

Further restrictions on use may be applied in certain environments, such as on board of aircraft (for instance, during takeoff and landing) where it may be expected that the *Bluetooth* LE transceiver can be turned off. Note that this and other similar scenarios are outside the scope of this white paper. For this reason, observe that the *Bluetooth* Copyright and disclaimer notice that appears in every *Bluetooth* specification includes further instructions to this effect per the following excerpt:

> **Examples of such laws and regulatory controls include, but are not limited to, airline regulatory controls, telecommunications regulations, technology transfer controls and health and safety regulations. Each Member is solely responsible for the compliance by their Bluetooth® Products with any such laws and regulations and for obtaining any and all required authorizations, permits, or licenses for their Bluetooth® Products related to such regulations within the applicable jurisdictions. Each Member acknowledges that nothing in the Specification provides any information or assistance in connection with securing such compliance, authorizations or licenses.**

2. Regulatory References

Related regulatory reference documents are:

[1] FCC Code of Federal Regulations, Title 47, Part 15
http://www.fcc.gov/oet/info/rules/part15/part15-5-4-07.pdf

[2] ETSI EN 300 328 : Electromagnetic compatibility and Radio spectrum Matters (ERM); Wideband transmission systems; Data transmission equipment operating in the 2,4 GHz ISM band and using wide band modulation techniques; Harmonized EN covering essential requirements under article 3.2 of the R&TTE Directive

[3] Final draft ETSI EN 301 489

[4] Japanese regulations

a. Japanese Radio Law, Article 4.3, Article 3.28, Article 3.29, Article 3.38
第 2 章 無線局の免許 第 4 条の 3
第 3 章 無線設備 第 28 条 (電波の質)
第 3 章 無線設備 第 29 条 (受信設備の条件)
第 3 章 無線設備 第 29 条 (その他の技術基準)

i. Radio Equipment Regulations,
Article 1.2.5, Article 1.2.6, Article 1.2.7, Article 2.1.14, Article 3.24, Article 5.9.4
Article 4.17.49.20.1.HO(1), Article 4.17.49.20.1.HO(2)

無線設備規則
第一章 総則 第二節 電波の質(第五条—第七条）
第二章 送信設備 第一節 通則(第十四条）
第三章 受信設備（第二十四条）
第一章 総則 第五節 混信防止機能(第九条の四）
第四章 業務別又は電波の型式及び周波数帯別による無線設備の条件 第四 節の十七 小電力データ通信システムの無線局の無線設備（第四十九条の二十）

ii. Radio Law Enforcement Regulations, Article 2.1.6.2, Article 2.1.6.4.4.1, Article 2.1.6.7

電波法施行規則
第二章 無線局 第一節 通則 第六条の二
第二章 無線局 第一節 通則 第六条の四の四の一
第二章 無線局 第一節 通則 第六条の七

b. Telecommunication Business Law
Telecommunication circuit connection Terminal and Other Equipment Regulation, Article 9

電気通信事業法
端末設備等規則 第 3 章 安全性等 第 9 条 端末設備内において電波を使用する端末設備

c. *Announcement of the Ministry of Post and Telecommunications*
No.424 of 1994, No.757 of 1999

総務省告示 1994 年 No.424, 1999 年 No.757

[5] Taiwan:
Low Power 0002 (LP0002), 29 August, 2007 revised
Low-power Radio-frequency Devices Technical Regulations
http://www.ncc.gov.tw/english/

[6] Korea:
Rules on Radio Equipment 2008-116, September 11, 2008
http://www.rra.go.kr/eng/index.jsp

[7] China
MIIT regulation [2002]353
http://www.srrc.org.cn/
http://www.miit.org.cn/

Note: Any regulations quoted in this white paper are for information; the authoritative documents are the current original versions from the applicable agencies in the original languages.

3. Definitions and Abbreviations

DSSS	Direct-Sequence Spread Spectrum
FCC	Federal Communications Commission
FHSS	Frequency-Hopping Spread Spectrum
JRL	Japanese Radio Law
MIIT (China)	Ministry of Industry and Information Technology
KCC (Korea)	Korea Communications Commission
NCC (Taiwan)	National Communications Commission

4. Link Layer

4.1 FCC

In FCC Title 47, Part 15 [1], there are no direct requirements set for the link layer.

Section 15.5 requires that the transceiver not cause harmful interference and be capable of accepting interference from other radiating systems. The *Bluetooth* LE transceiver is designed to fulfill these requirements. This requirement is more relevant for the physical layer, but the process for avoiding interfering channels is defined in the *Bluetooth* LE link layer specification.

> *15.5(b) Operation of an intentional, unintentional, or incidental radiator is subject to the conditions that no harmful interference is caused and that interference must be accepted that may be caused by the operation of an authorized radio station, by another intentional or unintentional radiator, by industrial, scientific and medical (ISM) equipment, or by an incidental radiator.*

4.2 ETSI

ETSI EN 300 328 [2] set requirements for Wide Band Data Transmission equipment which is used in wireless local area networks. Examples of Wide Band Data Transmission equipment are IEEE 802.11, RLANs, *Bluetooth* wireless technologies, and ZigBee.

Chapter 4.3.5 Medium access protocol requires that the transceiver have a link layer in order to share the spectrum with other wireless devices.

> *§ 4.3.5.1 Definition*
>
> *A medium access protocol is a mechanism designed to facilitate spectrum sharing with other devices in a wireless network.*
>
> *§ 4.3.5.2 Requirement*
>
> *A medium access protocol shall be implemented by the equipment.*

4.3 JRL

A medium access protocol shall be implemented in the equipment *(Radio Equipment Regulations, Article 4.17.49.20)*

*無線設備規則 第四節の十七 小電力データ通信システムの無線局の無線設備 (第四十九条の二十)*Interference prevention requirements for the Link Layer are defined in the *Radio Equipment Regulations, Article 5.9.4*

無線設備規則 第五節 混信防止機能 (第九条の四)

5) For specified low-power radio stations (which refer to radio stations prescribed in Article 6.4 item 2 of the Enforcement Regulations; this also applies hereafter) using emissions of a frequency in a range of higher than 73.6 MHz to 1,260 MHz or from 2,400 MHz to 2,483.5 MHz :

(a) The interference prevention function prescribed in Article 6.2 item 3) of the Enforcement Regulations, if the specified low-power radio stations are connected to a telecommunication circuit

(b) The interference prevention function prescribed in Article 6.2 item 3) or 4) of the Enforcement Regulations, if the specified low-power radio stations are not connected to a telecommunication circuit

According to Telefication[1], an identification of the sending and receiving equipment by their MAC address is considered as a valid implementation of this requirement, provided that the receiving equipment only accepts messages from a known transmitter and vice versa. The presence of encryption techniques is in line, but above, what is minimally required.

4.4 TAIWAN

There are no direct requirements regarding the link layer.

In Low Power 0002 (LP0002), 29 August, 2007 (revised), the following requirement is to be found regarding harmful interference in clause 2.6

> *2.6 The operation of the low-power radio-frequency devices is subject to the conditions that no harmful interference is caused. The user must stop operating the device immediately should harmful interference is caused and shall not resume until the condition causing the harmful interference has been corrected.*
>
> *Moreover, the interference must be accepted that may be caused by the operation of an authorized communications, or ISM equipment.*

4.5 CHINA

There are no direct requirements regarding the link layer.

In the MIIT regulation [2002]353 the following statement can be found:

五、**在**该频段内的无线电台站之间产生干扰，**原**则上不受保护，应自行**解决或**协商解决。为便于协调而需查找干扰源，**可**请当地无线电管理机**构**协助查找。

5) *The frequencies on which these radio stations operate are, in principle, not protected, against harmful interference. If harmful interference occurs it should be resolved or settled through consultation. In order to facilitate coordination and to find the sources of interference, local radio management institutions must be consulted to help to resolve the problem.*

4.6 KOREA

There are no direct requirements regarding the link layer.

The radio equipment must be marked with a warning that the device cannot be used for life saving applications since there is a risk of harmful interference by other radio transmitters/services.

[1] Telefication is a Conformity Assessment Body (CAB) under the Japanese law. Most radio equipment intended for use in Japan requires approval and falls under the requirements of the Japanese Radio Law). The Mutual Recognition Agreement EU – Japan enables appointed Certification Bodies in the European Union to grant approval for certain Radio Equipment enabling fast access to the Japanese market.

5. Physical Layer

5.1 FREQUENCY BAND

5.1.1 FCC

In FCC Title 47, Section 15.247 the frequency band is defined to be 2400-2483.5 MHz.

5.1.2 ETSI

In ETSI EN 300 328 the frequency band is defined to be 2400-2483.5 MHz.

5.1.3 JRL

In the *Radio Equipment Regulations,* the frequency band is defined to be 2400-2483.5 MHz.

無線設備規則 第四節の十七 小電力データ通信システムの無線局の無線設備 (第四十九条の二十)

5.1.4 TAIWAN

In Low Power 0002 (LP0002), 29 August, 2007 (revised), clause 3.10.1 (1)(1.10) the frequency band is defined to be 2400-2483.5 MHz.

5.1.5 CHINA

In the MIIT regulation [2002]353 the frequency band is defined to be 2400-2483.5 MHz.

5.1.5.1 CCC (CHINA COMPULSORY CERTIFICATION MARK) REQUIREMENTS

Starting from May 1, 2003, certain types of products defined by the CCC-catalogue, either marketed by domestic manufacturers or imported must obtain the certificate for compulsory product certification (hereinafter referred to as the New Certificate) and shall apply for China Compulsory Certification mark (hereinafter referred to as the New Mark) before they are imported or marketed. The CCC scheme is not applicable to all kinds of electronic equipment.

According to Telefication, RF low power transmitters/devices are outside of the scope of the CCC certification scheme. In the case of *Bluetooth* BR/EDR, *Bluetooth* LE, and WiFi and (as examples) the CCC certification scheme is not compulsory.

5.1.6 KOREA

In the Rules on Radio Equipment 2008-116, September 11, 2008, the frequency band is defined to be 2400-2483.5 MHz.

5.2 MODULATION

5.2.1 FCC

FCC classifies *Bluetooth* BR/EDR as a FHSS system; however, *Bluetooth* LE does not fulfill these requirements[2]. Instead, FCC classifies *Bluetooth* LE as a system using *digital modulation techniques*.

> *15.247(a)(2): Systems using digital modulation techniques may operate in the 902 - 928 MHz, 2400 - 2483.5 MHz, and 5725 - 5850 MHz bands. The minimum 6 dB bandwidth shall be at least 500 kHz.*

5.2.2 ETSI

ETSI classifies *Bluetooth* BR/EDR as an FHSS system; however, *Bluetooth* LE does not fulfill the FHSS requirements in clause 4.2.1. Instead, ETSI classifies *Bluetooth* LE as a system using DSSS modulation.

[2] Frequency hopping spread spectrum systems (FHSS) in the 2400-2483.5 MHz are in FCC 15.247(1) (iii) required to a) use at least 15 channels and b) when hopping, the transmission also must comply with a 0.4 second/channel maximum dwell time.

§ 4.2.2: For the purposes of the present document, other forms of modulation which do not satisfy the constraints of the specification given in clause 4.2.1, shall be considered equivalent to DSSS modulation. Systems using these other forms of modulation shall be considered equivalent to DSSS systems and shall be tested according to the requirements for DSSS modulation.

5.2.3 JRL

In the *Radio Equipment Regulations Article 49.20* [4], requirements for the modulation are presented

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> *The radio equipment of a radio station of a low-power data communication system shall comply with the conditions in the items below according to the classification provided below:*
>
> *1) The radio equipment that uses emissions of a frequency from 2,400 MHz to 2,483.5 MHz:*
>
> *c. The modulation method shall be one of the items below.*
>
> *(1) Orthogonal frequency division multiplexing (OFDM) or spread spectrum method*
>
> *(2) Digital modulation method other than (1) above*
>
> *d. The spread spectrum method shall be the direct spread method, frequency hopping method, or a combination of the direct spread method and frequency hopping method, or a combination of OFDM and frequency hopping method.*

Although *Bluetooth* LE uses frequency hopping method during the communication, it is not defined as a system using the frequency hopping method according to *Radio Equipment Regulations, Article 4.17.49.20*.

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> *j. The frequency retention time in the frequency hopping method shall be 0.4 second or less. For the radio equipment that uses the frequency hopping method excluding a combination of the spread spectrum method and OFDM, the total sum of the frequency retention time in any frequency within the time obtained by multiplying the diffusion rate by 0.4 second shall be 0.4 second or shorter.*

Thus according to JRL, every frequency hopping system shall have channel dwell time ≤ 0.4 s. In *Bluetooth* LE, the dwell time can be > 0.4 s depending on the advertising or the connection interval for a single "hop". In comparison to *Bluetooth* BR/EDR, JRL will therefore not categorize *Bluetooth* LE as a frequency hopping system.

Instead, JRL classifies *Bluetooth* LE as a system using *"Digital modulation method other than orthogonal frequency division multiplexing (OFDM) or spread spectrum method"* [3]. This categorization is equal to the JRL categorization utilized with for example ZigBee and IEEE 802.11a (with DFS and carrier sensing). These systems are always seeking for a suitable frequency band, to reduce interference in the environment and to improve the effective throughput.

5.2.4 TAIWAN

The NCC in Taiwan classifies *Bluetooth* BR/EDR as a FHSS system; however, *Bluetooth* LE does not fulfill these requirements[4]. Instead, NCC classifies *Bluetooth* LE as a system using *digital modulation techniques*.

3.10.1 Type of device: Intentional radiators employing frequency hopping spread spectrum or digital modulation techniques.

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[3] Informally also called a *"frequency changing system"*

[4] Frequency hopping spread spectrum systems (FHSS) in the 2400-2483.5 MHz are in Low Power 0002 (LP0002), clause 3.10 (3.10.1)(6)(6.1.2), required to a) use at least 15 channels and b) when hopping, the transmission also must comply with a 0.4 second/channel maximum dwell time.

(1) Frequency bands:

(1.10) 2400 -2483.5 MHz

(1.11) 5725.0-5850.0MHz

3.10.1(6)(6.2) Digital modulation techniques system:

(6.2.1) For digitally modulated systems, the minimum 6dB bandwidth shall be at least 500 kHz."

5.2.5 CHINA

The MIIT regulation [2002]353 does not specify any specific requirement for types of modulation. Generic terms as wireless LAN and *Bluetooth* are being used instead.

*2.4GHz 频段作为无线局域网、**无**线接入系统、蓝牙技术设备、**点**对点或点对多点扩频通信系统等各类无线电台站的共用频段。*

(2) The 2.4 GHz band can be used by devices as wireless LAN, wireless access systems, Bluetooth technology and equipment.

According to Telefication, this shall mean requirements as for *Bluetooth* BR/EDR on modulation also apply to *Bluetooth* LE.

5.2.6 KOREA

In the Rules on Radio Equipment 2008-116, September 11, 2008, the following translated table is given with the possibilities for allowable modulation types in the 2.4 GHz band.

Frequency (MHz)	Radio Wave Type	Remarks
2400 - 2483.5 5725 - 5825	F(G,D)1(2,7)C(D,E,F,W) A2(7,9)F(W) F9W	The Radio equipment must have a label in a visible location to indicate that the equipment has a possibility of interfering with other devices during operation. Radio equipment manufacturer and set-up company need to announce to operators and users through user's manual that the equipment cannot serve as human safety-related devices because of the possibility of interference. Radio equipment can have receiving functionality for channel searching in 5829Mhz ~5850Mhz

Furthermore, in the Rules on Radio Equipment 2008-116, September 11, 2008, the allowable modulation methods are stated as being DSSS, FHSS and OFDM types of modulation. The minimum 6dB bandwidth is specified as being 500 kHz.

2. 직접시퀀스 확산스펙트럼방식(DSSS), 첩 확산스펙트럼방식(CSS)을 사용하는 것(주파수도약확산스펙트럼방식(FHSS)과 복합적으로 이용하는 것 포함) 또는 직교주파수분할 다중방식(OFDM)을 사용하는 것

점유주파수대폭	전력밀도	공중선 절대이득	비고
0.5㎒ 이상 26㎒ 이하	10㎽/㎒ 이하	6dB 이하 (다만, 고정형 점대점 통신용 무선설비는 20 dB 이하일 것[주2)])	전력밀도는 평균치이며, 공중선 절대이득이 기준치를 초과한 경우에 초과한 값만큼 전력밀도가 저감할 것
26㎒ 초과 40㎒ 이하	5㎽/㎒ 이하		
40㎒ 초과 60㎒ 이하[주1)]	0.1㎽/㎒ 이하	6dB 이하	

라. 호핑채널은 중첩되지 않는 15개 이상일 것

바. 하나의 호핑채널에서의 체류시간(Dwell Time)은 0.4 초 이내일 것

Translation follows:

2) It uses Direct Sequence Spread Spectrum Method (DSSS), Chip Spread Spectrum Method (CSS) (include Frequency Hoping Spread Spectrum Method (FHSS) and its complex Method) OR Orthogonal Frequency Division Multiplexing.

Occupied Bandwidth	Electric Power Density	Absolute Antenna Gain	Remark
0.5MHz ≤ OBW ≤ 26MHz	Below 10mW/MHz	Below 6 dB (but, the fixed radio device for point to point should be less than 20dB)	The power density value is the AVR. If antenna gain is over the limit, the power density should be decreased same as exceeded value.
26MHz < OBW ≤ 40MHz	Below 5mW/MHz		
40MHz < OBW ≤ 60MHz	Below 0.1mW/MHz	Below 6dB	

3) Channel hopping should be more than 15 channels that do not overlap each other.

4) Dwell time on one among hopping channels should be below 0.4 second

Frequency hopping spread spectrum systems (FHSS) in the 2400-2483.5 MHz are required to use at least 15 channels and when hopping, the transmission also must comply with a 0.4 second/channel maximum dwell time.

5.3 MAXIMUM CONDUCTED OUTPUT POWER

5.3.1 FCC

FCC Title 47, Section 15.247 requires that the maximum conducted output power not exceed 1 W when using antennas with directional gains that do not exceed 6 dBi. For antennas exceeding 6 dBi, output power is limited according dBi value.

> *15.247(b)(3) For systems using digital modulation in the 902–928 MHz, 2400–2483.5 MHz, and 5725–5850 MHz bands: 1 Watt. As an alternative to a peak power measurement, compliance with the one Watt limit can be based on a measurement of the maximum conducted output power. Maximum Conducted Output Power is defined as the total transmit power delivered to all antennas and antenna elements averaged across all symbols in the signaling alphabet when the transmitter is operating at its maximum power control level. Power must be summed across all antennas and antenna elements. The average must not include any time intervals during which the transmitter is off or is transmitting at a reduced power level. If multiple modes of operation are possible (e.g., alternative modulation methods), the maximum conducted output power is the highest total transmit power occurring in any mode.*

5.3.2 ETSI

ETSI limits total maximum transmission power to 100 mW. However, for the DSSS the spectral density is limited to 10 mW/MHz. Thus, the maximum output power for *Bluetooth* LE is limited to 10 mW.

> *§ 4.3.1 the equivalent isotropic radiated power (EIRP) shall be equal to or less than -10 dBW (100 mW). This limit shall apply for any combination of power level and intended antenna assembly.*
>
> *§ 4.3.2 For wide band modulations other than FHSS (e.g. DSSS, OFDM, etc.), the maximum EIRP spectral density is limited to 10 mW per MHz.*

5.3.3 JRL

JRL limits the output power to 10 mW.

> *Radio Equipment Regulations Article 4.17.49.20.1.HO: The antenna power of the transmitting equipment other than that stated in (1) And (2) above shall be 10 mW or less.*

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Note that the antenna power requirements are “absolute;” i.e., they are never allowed to have a higher value. Related to the rated power —as defined separately by the approval holder—there is also a second requirement that is related to the deviation of the actual power from the rated power. For the deviation from the rated power, the following tolerance scheme is applicable:

> For the 2.4 GHz bands: +20% and –80%[5]

This means that with a Rated power of 8.3 mW/MHz, it is allowed to cover the tolerance field from 1.66 mW/MHz up to 10 mW/MHz. [6]

5.3.4 TAIWAN

In Low Power 0002 (LP0002), 29 August, 2007 (revised), clause 3.10.1(2)(2.3) the peak conducted output power shall not exceed 1 W when using antennas with directional gains that do not exceed 6 dBi:

> *(2.3) For systems using digital modulation in the 2400-2483.5MHz, and 5725-5850MHz bands: below 1 Watt.*
>
> *In addition to the peak output power described in Appendix 2 for measurement, the maximum conducted output power may also be used. Maximum Conducted Output Power is defined as the average of all symbols of the signaling alphabet delivered to all antennas and antenna when the transmitter is operating at its maximum power level. The average must not include any time intervals during which the transmitter is off or is transmitting at a reduced power level. If multiple modes of operation are possible (e.g. alternative modulation methods), the maximum conducted output power is the highest total transmit power occurring in any mode.*

Furthermore, clause 3.10.1(3)(3.2) states a limitation on the maximum peak output power when using antennas having a gain over 6 dBi:

> *(3.2) In addition to Section 3.1, for systems employing transmitting antenna with directional gain greater than 6dBi, the peak conducted output power from the intentional radiator shall be reduced by the amount in dB that exceeds 6dBi.*

5.3.5 CHINA

The MIIT regulation [2002]353 specify the following maximum allowable output power levels (EIRP):

(一) 等效全向辐射功率(EIRP)：
天线增益＜10dBi 时：≤100 mW 或≤20 dBm；
天线增益≥10dBi 时：≤500 mW 或≤27 dBm

The maximum allowable output power level (EIRP), while using antenna gains of less than 10 dBi is 100 mW/20 dBm (EIRP).

The maximum allowable output power level (EIRP), while using antenna gains of more than, or equal to, 10 dBi is 500 mW/27 dBm (EIRP).

5.3.6 KOREA

See power spectral density.

5.4 POWER SPECTRAL DENSITY

5.4.1 FCC

FCC Title 47, Section 15.247 requires that the conducted power spectral density not be greater than 8 dBm in any 3 kHz band.

[5] Note that tolerance in the 5 *GHz bands i: +50% and –50%*
[6] ….and a Rated Power of 6,6 mW/MHz covers the field from 3.3 mW/MHz up to 9.9 mW/MHz (for the 5 GHz band)

15.247(e) For digitally modulated systems, the power spectral density conducted from the intentional radiator to the antenna shall not be greater than 8 dBm in any 3 kHz band during any time interval of continuous transmission. This power spectral density shall be determined in accordance with the provisions of paragraph (b) of this section. The same method of determining the conducted output power shall be used to determine the power spectral density.

5.4.2 ETSI

ETSI requires that the maximum spectral density is 10 mW per MHz.

§ 4.3.2.2 for wide band modulations other than FHSS (e.g. DSSS, OFDM, etc.), the maximum EIRP spectral density is limited to 10 mW per MHz.

5.4.3 JRL

No requirements set by the JRL.

5.4.4 TAIWAN

In Low Power 0002 (LP0002), 29 August, 2007 (revised), clause 3.10(3.10.1)(6)(6.2)(6.2.2), the maximum level of the conducted peak power spectral density is defined as being:

> *(6.2.2) For digitally modulated systems, the peak power spectral density conducted from the intentional radiator to the antenna shall not be greater than 8dBm in any 3kHz band during any time interval of continuous transmission.*

5.4.5 CHINA

The MIIT regulation [2002]353 specify the following maximum level of the power spectral density (EIRP):

1. ***最大功率****谱密度：*
   直接序列*扩频或其它工作方式：*
   天*线增益＜10dBi 时：≤10 dBm / MHz(EIRP)；*
   天*线增益≥10dBi 时：≤17 dBm / MHz(EIRP)；*
2. *跳频工作方式：*
   天线增益＜10dBi 时：≤20 dBm / MHz(EIRP)；
   天线增益≥10dBi 时：≤27 dBm / MHz(EIRP)

The maximum level of the power spectral density (EIRP) for direct sequence spread spectrum systems, while using antenna gains of less than 10 dBi is 10 dBm/MHz (EIRP).

The maximum level of the power spectral density (EIRP) for direct sequence spread spectrum systems, while using antenna gains of more than, or equal to, 10 dBi is 17 dBm/MHz (EIRP).

The maximum level of the power spectral density (EIRP) for frequency hopping systems, while using antenna gains of less than 10 dBi is 20 dBm/MHz (EIRP).

The maximum level of the power spectral density (EIRP) for frequency hopping systems, while using antenna gains of more than, or equal to, 10 dBi is 27 dBm/MHz (EIRP).

5.4.6 KOREA

In the Rules on Radio Equipment 2008-116, September 11, 2008, the maximum level of power density is defined as 10 mW/MHz (for antennas having a gain of less than 6 dBi).

Occupied Bandwidth	Electric Power Density	Absolute Antenna Gain	Remark
0.5MHz ≤ OBW ≤ 26MHz	Below 10mWMHz	Below 6dB (but, the fixed radio device for point to point should be less than 20dB)	The power density value is the AVR, if antenna gain is over the limit, the power density should be decreased same as exceeded value
26MHz < OBW ≤ 40MHz	Below 5mWMHz		
40MHz < OBW ≤ 60MHz	Below 0.1mWMHz	Below 6dB	

Note that the test requirements differ slightly between ETSI and the South Korean tests. The measurement results obtained by the Korean test method will exceed the values measured in accordance with EN 300 328.

How much higher the measurement results will be implementation dependent. In the EU the comparable requirement is "Maximum spectral power density" (stated in EN 300 328). In the EN 300 328 the maximum spectral density is measured while using a power meter which indicates the power/MHz. The power meter measures average power (just as when determining the radiated output power when the method conducted output power + peak antenna gain is being used).

In South Korea the measurement method is slightly different. Maximum spectral power density in dBm/MHz is measured as PEAK power density (on a spectrum analyzer).

5.5 MINIMUM MODULATION BANDWIDTH

5.5.1 FCC

FCC Title 47, Section 15.247 requires that the minimum 6dB bandwidth be at least 500 kHz.

15.247(a)(2) Systems using digital modulation techniques may operate in the 902–928 MHz, 2400–2483.5 MHz, and 5725–5850 MHz bands. The minimum 6 dB bandwidth shall be at least 500 kHz.

5.5.2 ETSI

No requirement set by ETSI.

5.5.3 JRL

According to *Radio Equipment Regulations Article 6* [4] the permissible values for a bandwidth occupied by emissions shall be as stipulated in Table 2. However, the requirement for *Bluetooth* LE is presented in the sub-claim that relates to Table 2 (table is marked as I in Roman numeral).

無線設備規則 第二節 電波の質 第六条 (占有周波数帯幅の許容値)

> *XXX. Notwithstanding the values prescribed in I to IV, the tolerance for the occupied bandwidth of the radio equipment of radio stations of low-power data-based communication systems shall be as follows.*
>
> *1) Radio equipment which uses emissions of a frequency from 2,400 MHz to 2,483.5 MHz or from 2,471 MHz to 2,497 MHz.*
>
> *2) Radio equipment that uses 2,400 MHz or higher to 2,483.5 MHz and uses the frequency hopping method, direct spread method, and a combination of the frequency hopping method and direct spread method, or a combination of QFDM and the frequency hopping method 83.5 MHz.*
>
> *3) Radio equipment that uses methods other than those specified in (1) above 26 MHz.*

In summary, the occupied bandwidth shall be ≤ 26 MHz. The bandwidth occupied by *Bluetooth* LE will be defined by JRL as the channel bandwidth.

According to JRL 49.20 h, the diffusion bandwidth[7] of the radio equipment that uses the spread spectrum method shall be at least 500 kHz.

Testing of *Bluetooth* LE can be done against article 49.20 [4] where the channels Low, Middle, High will be under test.

5.5.4 TAIWAN

In Low Power 0002 (LP0002), 29 August, 2007 (revised), clause 3.10(3.10.1)(6)(6.2)(6.2.1), the minimum 6dB bandwidth is defined as being 500 kHz.

(6.2.1) For digitally modulated systems, the minimum 6dB bandwidth shall be at least 500 kHz.

5.5.5 CHINA

The MIIT regulation [2002]353 does not specify a minimum modulation bandwidth.

5.5.6 KOREA

In the Rules on Radio Equipment 2008-116, September 11, 2008, the minimum 6dB bandwidth is specified as being 500 kHz.

5.6 SPURIOUS CONDUCTED EMISSIONS

5.6.1 FCC

FCC Title 47, Section 15 requires that all harmonics and spurs be at least 20 dB below the highest emission level in the operational band. In addition, restricted band requirements in Section 15.205 shall be fulfilled.

> *15.247(d) In any 100 kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20 dB below that in the 100 kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement, provided the transmitter demonstrates compliance with the peak conducted power limits. If the transmitter complies with the conducted power limits based on the use of RMS averaging over a time interval, as permitted under paragraph (b)(3) of this section, the attenuation required under this paragraph shall be 30 dB instead of 20 dB. Attenuation below the general limits specified in §15.209(a) is not required. In addition, radiated emissions which fall in the restricted bands, as defined in §15.205(a), must also comply with the radiated emission limits specified in §15.209(a) (see §15.205(c)).*

5.6.2 ETSI

ETSI requires that spectral density of harmonics and spurs be below -30 dBm when in any 100 kHz band. There are also more specific requirements for transmitter and receiver as defined in chapter 4.3.6 and 4.3.7.

> *§ 4.3.3 The frequency range of the equipment is determined by the lowest and highest frequencies occupied by the spectrum envelope.*
>
> *fH is the highest frequency of the spectrum envelope: it is the frequency furthest above the frequency of maximum power where the EIRP spectral density drops below the level of -80 dBm/Hz (-30 dBm if measured in a 100 kHz bandwidth).*
>
> *fL is the lowest frequency of the spectrum envelope; it is the frequency furthest below the frequency of maximum power where the EIRP spectral density drops below the level of -80 dBm/Hz (or -30 dBm if measured in a 100 kHz bandwidth).*
>
> *For a given operating frequency, the width of the spectrum envelope is (fH - fL). In equipment that allows adjustment or selection of different operating frequencies, the power envelope takes up different positions in the allocated band. The frequency range is determined by the lowest value*

[7] A frequency bandwidth with an upper frequency limit and lower frequency limit such that each of the mean powers radiated above the upper frequency limit and below the lower frequency limit is equal to 5% of the total mean power radiated.

of fL and the highest value of fH resulting from the adjustment of the equipment to the lowest and highest operating frequencies.

5.6.3 JRL

The requirements according to *Radio Equipment Regulations Article 7* are the following:

無線設備規則 第二節 電波の質 第七条 (スプリアス発射又は不要発射の強度の許容値)

The permissible values for the intensity of spurious emissions or unwanted emissions shall be as stipulated in Table 3.

Requirements for *Bluetooth* LE are defined in the sub-claim 24.

24) Notwithstanding the values prescribed in 2 and 18, the permissible value of the unwanted emission intensity of the transmitting equipment of specified low-power radio stations which use emissions of a frequency of 2,400 MHz or higher but no more than 2,483.5 MHz and which use the frequency hopping method, and the transmission equipment at radio stations of low-power data communication systems that use emissions of a frequency of 2,400 MHz or higher but no more than 2,483.5 MHz shall be as follows:

Frequency band	Permissible value of unwanted emission intensity
Lower than 2,387 MHz, and higher than 2,496.5 MHz	The mean power in any 1 MHz bandwidth is 2.5 μW or lower.
2,387 MHz or higher but lower than 2,400 MHz and higher than 2,483.5 MHz but no more than 2,496.5 MHz	The mean power in any 1 MHz bandwidth is 25 μW or lower.

5.6.4 TAIWAN

In Low Power 0002 (LP0002), 29 August, 2007 (revised), clause 3.10(3.10.1)(5), the maximum level of spurious conducted emission is defined as follows:

In any 100kHz bandwidth outside the frequency band in which the spread spectrum or digitally modulated intentional radiator is operating, the radio frequency power that is produced by the intentional radiator shall be at least 20dB below that in the 100kHz bandwidth within the band that contains the highest level of the desired power, based on either an RF conducted or a radiated measurement. If the transmitter measurement is based on the peak conducted output power, as permitted under paragraph 3.10.1 (2) (2.3) of this section, the attenuation required under this paragraph shall be 30dB instead of 20dB. In addition, radiated emissions which fall in section 2.7 the restricted bands must also comply with the radiated emission limit specified in section 2.8.

5.6.5 CHINA

The MIIT regulation [2002]353 does specify the following limits for the levels of radiated emissions.

- *(四) 带外发射功率(在 2.4-2.4835GHz 频段以外)：*
  ≤-80 dBm / Hz (EIRP)。
- *(五) 杂散发射(辐射)功率(对应载波±2.5 倍信道带宽以外)：*
  ≤-36 dBm / 100 kHz (30 - 1000 MHz)；
  ≤-33 dBm / 100 kHz (2.4 - 2.4835 GHz)；
  ≤-40 dBm / 1 MHz (3.4 - 3.53 GHz)；
  ≤-40 dBm / 1 MHz (5.725 - 5.85 GHz)；
  ≤-30 dBm / 1 MHz (其它 1 - 12.75 GHz)

MIIT requires that spectral density of harmonics and spurious emissions shall be below the levels as listed above when measured in either a 100 kHz band or 1 MHz band, depending on the frequency range to be tested for spurious emissions.

There are also specific requirements for the frequency range of operation in MIIT regulation [2002]353:

The frequency range of the equipment is determined by the lowest and highest frequencies occupied by the spectrum envelope.

fH is the highest frequency of the spectrum envelope: it is the frequency furthest above the frequency of maximum power where the EIRP spectral density drops below the level of -80 dBm/Hz.

fL is the lowest frequency of the spectrum envelope; it is the frequency furthest below the frequency of maximum power where the EIRP spectral density drops below the level of -80 dBm/Hz.

5.6.6 KOREA

The Rules on Radio Equipment 2008-116, September 11, 2008, specifies the following limits for the levels of conducted emissions.

Unwanted emission outside the frequency band should be below -30dBm with the 100KHz resolution bandwidth measurement at the one except the frequency band

다. 불요발사는 제1호의 규정에 의한 주파수대역 밖의 주파수에서 100㎑ 분해대역폭으로 측정하였을 때 -30dBm 이하일 것

5.7 SECONDARY RADIATED EMISSION FOR RECEIVING EQUIPMENT

5.7.1 FCC

No requirement set by FCC.

5.7.2 ETSI

No requirement set by ETSI.

5.7.3 JRL

The limit on secondary emissions radiated from the receiving equipment is defined in the sub-claim of the Radio Equipment Regulations Article 3.24

無線設備規則 第三章 受信設備 第二十四条 (副次的に発する電波等の限度)

2) *Notwithstanding the provisions of the preceding paragraph, the limit on the secondary emissions radiated from the receiving equipment at a specified low-power radio station which uses emissions of a frequency from 2,400 MHz to 2,483.5 MHz, at a premises radio station which uses emissions of a frequency in the range higher than 2,425 MHz to 2,475 MHz and uses a frequency hopping system, at the radio station of a low-power data communication system, and at a premises radio station using the 19 GHz band, shall be as stipulated in the following table:*

Frequency band	Limit on secondary radiated emissions
Lower than 1 GHz	4 nW or lower
1 GHz or higher to lower than 10 GHz	20 nW or lower
10 GHz or higher	20 nW or lower

5.7.4 TAIWAN

No requirement set by NCC.

5.7.5 CHINA

No requirement set by MIIT.

5.7.6 KOREA

No requirement set by KCC.

5.8 FREQUENCY TOLERANCE

5.8.1 FCC

No requirement set by FCC.

5.8.2 ETSI

No requirement set by ETSI.

5.8.3 JRL

JRL requires that the frequency tolerance of the transmitting equipment is at least 50 ppm.

Radio Equipment Regulations, Article 2.5, Table 1 (Relevant information shown in the table below)

無線設備規則 第二節 電波の質 第五条 (周波数の許容偏差) 別表第一号

Frequency band	Radio station	Tolerance of frequency (other than those to which Hz or kHz is added are indicated in %)
7 Higher than 470 MHz to 2,450 MHz	… 10 Radio stations of low-power data-based communication systems	50
8 Higher than 2,450 MHz to 10,500 MHz	… 6 Radio stations of low-power data-based communication systems (1) Those which use emissions of a frequency of: 5,180 MHz, 5,200 MHz, 5,220 MHz, 5,240 MHz, 5,260 MHz, 5,280 MHz, 5,300 MHz or 5,320 MHz indoors, or those which use emissions of a frequency of 5,180 MHz, 5,200 MHz, 5,220 MHz or 5,240 MHz in aircraft (2) Those which use emissions of other frequencies …	20 50

5.8.4 TAIWAN

No requirement set by NCC.

5.8.5 CHINA

MIIT regulation [2002]353 requires that the frequency tolerance of the transmitting equipment is 20 ppm. Frequency tolerance here is really (carrier tolerance) which is defined as the frequency tolerance between nominal carrier frequency and the ‘’wanted” carrier frequency under normal voltage and normal temperature condition.

(三) 载频容限：20 ppm

(3) Channel tolerance: 20 ppm

5.8.6 KOREA

In the Rules on Radio Equipment 2008-116, September 11, 2008, in 2.2), the frequency tolerance requirement is set to 50 ppm.

주파수허용편차는 ± 50 × 10^{-6} 이하일 것

Frequency tolerance: Under ± 50 × 10^{-6}

6. Immunity Tests

There are no requirements for compliance with immunity to RF electromagnetic fields in Taiwan, China and Korea.

ETSI recommends a number of immunity test cases outlined in Table 2 of ref. [3]. Below is a short summary of these requirements, which *Bluetooth* LE must fulfill:

6.1 RF ELECTROMAGNETIC FIELD

This test assesses the ability of the Equipment Under Test (EUT) to operate as intended in the presence of a radio frequency electromagnetic field disturbance.

For details of this test, please refer to clause 9.2 of [3].

6.2 ELECTROSTATIC DISCHARGE

This test assesses the ability of the EUT to operate as intended in the event of an electrostatic discharge.

For details of this test, please refer to clause 9.3 of [3].

7. Conclusion

With consideration to the regulatory requirements stipulated by FCC, ETSI, and JRL, the *Bluetooth* LE system must fulfill at least the following requirements:

1) System shall not cause harmful interference. (Section 4.1)
2) System shall be capable of operating while subject to interference from other radiating systems. (Section 4.1)
3) System shall have a mechanism designed to facilitate spectrum sharing with other devices in a wireless network. (Section 4.2)
4) Maximum output power is 10 mW/MHz. (Section 5.3)
5) Minimum 6dB bandwidth shall be at least 500 kHz. (Section 5.2.1 and 5.5.4)
6) Tolerance of frequency per FCC, ETSI, JRL, KCC, and NC is ±50x10-6 (Section 5.8.3). Tolerance of frequency per MIIT is ±20x10-6 (Section 5.8.5).

8. Annex A: Reference Summary

The following table summarizes all references within the various Regulatory specifications along with the related clause within the *Bluetooth* Core Specification v4.0.

	Test Item	FCC	ETSI	JRL	LE
Link Layer	Non-Harmful Interference	47 Part 15.5(b)			NA
	Medium Access Control	NA	EN 300 328 4.3.5.2		NA
	Controlling equipment (Interference prevention function)	NA	NA	Radio Law Enforcement Regulations Article 6-2 Radio Equipment Regulations Article 9-4	NA
	Telecommunications circuit connection	NA	NA	Terminal and Other Equipment Regulations Article 9, Announcement of the Ministry No.424 of 1994, No,757 of 1999	N/A
Physical Layer	Frequency Band	Part 15.247 (2)	4.3.3	Radio Law Enforcement Regulations Article 6	PART C: PHYSICAL LAYER §1 & 3.3.1 LE spec
	Modulation	DSSS	DSSS	Other Radio system Radio Equipment Regulations Article 49.20.1.C.2	Part D- Table 12-RF Spec
	Maximum Conducted OUTPUT Power	§15.247(b) (3) (3)	4.3.1		1.1 Table 7; 3.1
	Maximum Transmit Power (Antenna Power)	15.247 (iii)-2-b-3	4.3.1	Radio Equipment Regulations Article 49.20.1.E.3	3.1

	Test Item	FCC	ETSI	JRL	LE
	Minimum Bandwidth	§15.247; 15.247(a) (2)	NA	NA	3.3.1
	Spurious Conducted Emissions	§15.247; 15.205.; 15.247(d)15.247 (b) (3),§15.209(a); §15.205(c)	4.3.6; 4.3.7;4.3.3		3.3.3 & Table 6
	Frequency Tolerance	NA	NA	Radio Equipment Regulations Article 5, Attached Table No.1)	3.4
	Spurious emission intensity	NA	4.3.6.2 Table 3	Radio Equipment Regulations Article 7	3.3.2
	Maximum spectral Power density	NA	4.3.2; 5.7.3		
	Secondary radiated emission for Receiving equipment	NA	NA	Radio Equipment Regulations Article 24	
	Tolerance for antenna Power	NA	NA	Radio Equipment Regulations Article 14	
	Permissible value for occupied bandwidth	NA	NA	Radio Equipment Regulations Article 6, Attached Table No.2	

9. Annex B: Recommended Regulatory Test Cases

9.1 LIST OF FCC TEST CASES

- Maximum conducted output power
- Power spectral density
- Minimum bandwidth
- Spurious conducted emissions

9.2 LIST OF ETSI REQUIRED TEST CASES

The ETSI requirement for *Bluetooth* LE is identical to those stated for *Bluetooth* BR/EDR. In practice, the following engineering evidences must be provided for *Bluetooth* LE:

- Output Power
- TX Output Spectrum- Frequency range
- Out of Band spurious emissions
- RF Electromagnetic Field
- Electrostatic discharge

9.3 LIST OF JAPANESE RADIO LAW TEST CASES

- Antenna power
- Frequency tolerance
- Permissible value for occupied bandwidth
- Spurious emission intensity
- Secondary radiated emission for Receiving equipment

10. Annex C: FCC Interpretation

10.1 FCC 15.247

Bluetooth LE has been designed to operate as a Digital Transmissions Systems (DTS) under section 15.247. Over time, section 15.247 has been modified, thus allowing a different kind of modulation for *Bluetooth* LE in comparison to *Bluetooth* BR/EDR.

The following interpretation is given in FCC response with publication number 453039.

Before the recent changes to the spread spectrum rules, there were two major types of spread spectrum systems: direct sequence and frequency hopping spread spectrum (FHSS). These two distinct systems were required to comply with separate rule requirements. The new rules, however, allow manufacturers more flexibility and are not as limiting. **The new rules provide more flexibility for manufacturers by eliminating the requirement to employ direct sequence modulation techniques along with their associated requirement to comply with a minimum processing gain. Instead, manufacturers may now employ wideband digital modulation under the new rules for Digital Transmissions Systems (DTS).**

The only requirement in Section 15.247 for the digitally modulated system, in addition to emission limits that are the same as for the frequency hopping systems employing at least 75 hopping channels, is that the 6 dB bandwidth shall be at least 500 kHz.

> *(a)(2) Systems using digital modulation techniques may operate in the 902 - 928 MHz, 2400 - 2483.5 MHz, and 5725 - 5850 MHz bands. The minimum 6 dB bandwidth shall be at least 500 kHz.*

Measurement of digital transmission systems operating under Section 15.247 is explained in the FCC response with the publication number 558074.

During the work of scoping the original *Bluetooth* LE specification, several questions regarding FCC requirements for operation as Digital Transmissions Systems (DTS) were inquired from the FCC, and no further restrictions were found. These are the two most significant questions and their corresponding answers:

1) Under Section 15.247 may a DTS system “advertise” its presence by first transmitting a digitally modulated signal sequentially on three different channels? For example, the first packet would be transmitted at channel 1, the second at channel 12, and the third on channel 24. Would such an approach need to comply with the frequency hopping provisions of Section 15.247? If pseudo-random channel selection is required to operate under Section 15.247, may such a system operate without pseudo-random channel selection under Section 15.249?

   FCC: No, the described devices still falls under DTS rules; though total transmitter power and other limits still apply when multiple channels are in use.

2) FCC Publication 45039 from OET’s Knowledge Database discusses the operation of a hybrid system under Section 15.247 that would have aspects of a digital transmission system (DTS) and a frequency hopping spread spectrum (FHSS) system. The interpretation in publication 45039 says that “there is no minimum number of hopping channels associated with this type of hybrid system.” Would this interpretation support a hybrid DTS/FHSS system in which there are three hopping channels accessed on a pseudorandom basis?

   FCC: To be categorized under the hopping system the system has to meet all the requirements under 15.247(a), otherwise, a system is usually filed under DTS rules.

It is required that the device operating under 15.247 rules shall use at least 15 non-overlapping channels, but *Bluetooth* LE uses only three channels in the advertising mode and thus the system shall be filed under DTS rules.

10.2 HYBRID SYSTEMS

During the process of defining the correlation between FCC Rules and *Bluetooth* LE was a study of whether *Bluetooth* LE could be filed under 15.247(f) hybrid systems. The definition of "hybrid spread spectrum systems" in Section 2.1 (terms and definitions) of the FCC rules is:

> *"Hybrid spread spectrum systems are those which use combinations of two or more types of direct sequence, frequency hopping, time hopping and pulsed FM modulation in order to achieve their wide occupied bandwidths."*

Thus, these rules are not usable for *Bluetooth* LE, because of the wide occupied bandwidth is achieved with the modulation.

10.3 FCC 15.249

Another FCC study was the filing of *Bluetooth* LE under FCC 15.249. These rules allow for flexibility in implementing low power short-range radio systems. The rules do not restrict frequency band usage as much as in FCC 15.247. In line with FCC 15.249, the system may either be frequency hopping or stationary. The problem is that although *Bluetooth* LE is considered a low duty cycle system, the allowable transmission power would be too limited. The output power limits for the FCC 15.249 are:

- Maximum average transmission power -1.25 dB (radiated measurement)
- Maximum peak power +18.75 dBm (peak field strength of any emission shall not exceed the maximum permitted average limits by more than 20 dB under any condition of modulation.)

The measurement setup defined in ANSI C63.4-1992 (shown in Figure 1), decreases the calculated average radiated power from the device. The maximum allowed field intensity at a distance of 3 meters is 50 mV/m. There are two reasons why the actual output power is less than a direct conversion from the field strength to the conducted power.

- The measurement is performed to strongest polarization and direction. Non-directional applications must therefore assume an average antenna gain in their link budget calculations; therefore 2-4dBs are lost depending on antenna pattern.
- Measurement shall be performed with a reflective floor. Maximum signal can be 6 dB more than direct signal alone.

Thus, due to ground plane reflection and antenna, the average radiated power can be only ~-10 dBm

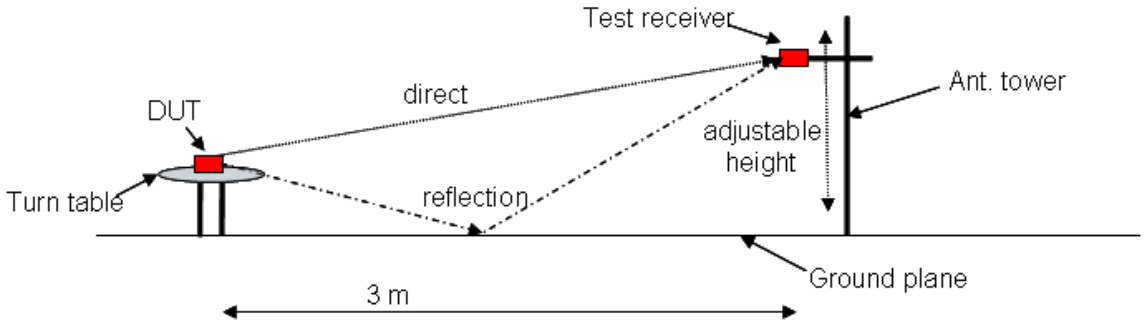

Figure 1: ANSI C63.4-1992 measurement setup

On the other hand, the average radiated power can be increased with duty cycle factor correction:

> *If the dwell time per channel of the hopping signal is less than 100 ms, then the reading may be adjusted by a "duty cycle correction factor", derived from 20log(dwell time/100 ms). FCC 15.249(e)*

However, as the maximum duty cycle depends on the dwell time, devices should use different output power levels depending on current dwell time and number of used channels. For example, for the continuous advertising mode, the output power would be below 0 dBm and it depends on the number of used advertising channels.