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## **APPENDIX G – Bluetooth Specifications**



## Part A

# RADIO SPECIFICATION

## Core System Package [Controller volume]

### CONTENTS

<b>1 Scope .....</b>	<b>2</b>
<b>2 Frequency Bands and Channel Arrangement .....</b>	<b>3</b>
<b>3 Transmitter Characteristics.....</b>	<b>4</b>
3.1 Modulation Characteristics.....	5
3.2 Spurious Emissions.....	6
3.2.1 In-band spurious emission .....	6
3.3 Radio Frequency Tolerance .....	7
<b>4 Receiver Characteristics .....</b>	<b>8</b>
4.1 Actual Sensitivity Level .....	8
4.2 Interference Performance .....	8
4.3 Out-of-Band Blocking.....	9
4.4 Intermodulation Characteristics.....	9
4.5 Maximum Usable Level.....	10
4.6 Receiver Signal Strength Indicator.....	10
4.7 Reference Signal Definition.....	10
<b>5 Appendix A .....</b>	<b>11</b>
<b>6 Appendix B .....</b>	<b>13</b>

# 1 SCOPE

Bluetooth devices operate in the unlicensed 2.4 GHz ISM (Industrial Scientific Medical) band. A frequency hop transceiver is applied to combat interference and fading. A shaped, binary FM modulation is applied to minimize transceiver complexity. The symbol rate is 1 Ms/s. For full duplex transmission, a Time-Division Duplex (TDD) scheme is used. This specification defines the requirements for a Bluetooth radio.

Requirements are defined for two reasons:

- Provide compatibility between radios used in the system
- Define the quality of the system

The Bluetooth radio shall fulfil the stated requirements under the operating conditions specified in [Appendix A](#) and [Appendix B](#). The radio parameters shall be measured according to the methods described in the RF Test Specification.

This specification is based on the established regulations for Europe, Japan and North America. The standard documents listed below are only for information, and are subject to change or revision at any time.

## **Europe:**

Approval Standards: European Telecommunications Standards Institute, ETSI

Documents: EN 300 328, ETS 300-826

Approval Authority: National Type Approval Authorities

## **Japan:**

Approval Standards: Association of Radio Industries and Businesses, ARIB

Documents: ARIB STD-T66

Approval Authority: Ministry of Post and Telecommunications, MPT.

## **North America:**

Approval Standards: Federal Communications Commission, FCC, USA

Documents: CFR47, Part 15, Sections 15.205, 15.209, 15.247 and 15.249

Approval Standards: Industry Canada, IC, Canada

Documents: GL36

Approval Authority: FCC (USA), Industry Canada (Canada)

## 2 FREQUENCY BANDS AND CHANNEL ARRANGEMENT

The Bluetooth system operates in the 2.4 GHz ISM band. This frequency band is 2400 - 2483.5 MHz.

Regulatory Range	RF Channels
2.400-2.4835 GHz	$f=2402+k$ MHz, $k=0,\dots,78$

Table 2.1: Operating frequency bands

RF channels are spaced 1 MHz and are ordered in channel number  $k$  as shown in [Table 2.1](#). In order to comply with out-of-band regulations in each country, a guard band is used at the lower and upper band edge.

Lower Guard Band	Upper Guard Band
2 MHz	3.5 MHz

Table 2.2: Guard Bands

### 3 TRANSMITTER CHARACTERISTICS

The requirements stated in this section are given as power levels at the antenna connector of the Bluetooth device. If the device does not have a connector, a reference antenna with 0 dBi gain is assumed.

Due to difficulty in measurement accuracy in radiated measurements, systems with an integral antenna should provide a temporary antenna connector during type approval.

If transmitting antennas of directional gain greater than 0 dBi are used, the applicable paragraphs in EN 300 328, EN 301 489-17 and FCC part 15 shall be compensated for.

The device is classified into three power classes.

Power Class	Maximum Output Power (P <sub>max</sub> )	Nominal Output Power	Minimum Output Power <sup>1</sup>	Power Control
1	100 mW (20 dBm)	N/A	1 mW (0 dBm)	P <sub>min</sub> < +4 dBm to P <sub>max</sub> Optional: P <sub>min</sub> <sup>2</sup> to P <sub>max</sub>
2	2.5 mW (4 dBm)	1 mW (0 dBm)	0.25 mW (-6 dBm)	Optional: P <sub>min</sub> <sup>2</sup> to P <sub>max</sub>
3	1 mW (0 dBm)	N/A	N/A	Optional: P <sub>min</sub> <sup>2</sup> to P <sub>max</sub>

Table 3.1: Power classes

1. Minimum output power at maximum power setting.

2. The lower power limit P<sub>min</sub> < -30 dBm is suggested but is not mandatory, and may be chosen according to application needs.

Power class 1 device shall implement power control. The power control is used for limiting the transmitted power over +4 dBm. Power control capability under +4 dBm is optional and could be used for optimizing the power consumption and overall interference level. The power steps shall form a monotonic sequence, with a maximum step size of 8 dB and a minimum step size of 2 dB. A class 1 device with a maximum transmit power of +20 dBm shall be able to control its transmit power down to 4 dBm or less.

Devices with power control capability optimizes the output power in a physical link with LMP commands (see [Link Manager Protocol](#)). It is done by measuring RSSI and reporting back if the transmission power shall be increased or decreased if possible.

In a connection, the output power shall not exceed the maximum output power of power class 2 for transmitting packets if the receiving device does not support the necessary messaging for sending the power control messages, see Link Manager Protocol [Section 4.1.3 on page 211](#). In this case, the transmitting device shall comply with the rules of a class 2 or class 3 device.

If a class 1 device is paging or inquiring very close to another device, the input power can be larger than the requirement in [Section 4.5 on page 39](#). This can

cause the receiving device to fail to respond. It may therefore be useful to page at Class 2 or 3 power in addition to paging at power class 1.

### 3.1 MODULATION CHARACTERISTICS

The Modulation is GFSK (Gaussian Frequency Shift Keying) with a bandwidthbit period product  $BT=0.5$ . The Modulation index shall be between 0.28 and 0.35. A binary one shall be represented by a positive frequency deviation, and a binary zero shall be represented by a negative frequency deviation. The symbol timing shall be less than  $\pm 20$  ppm.

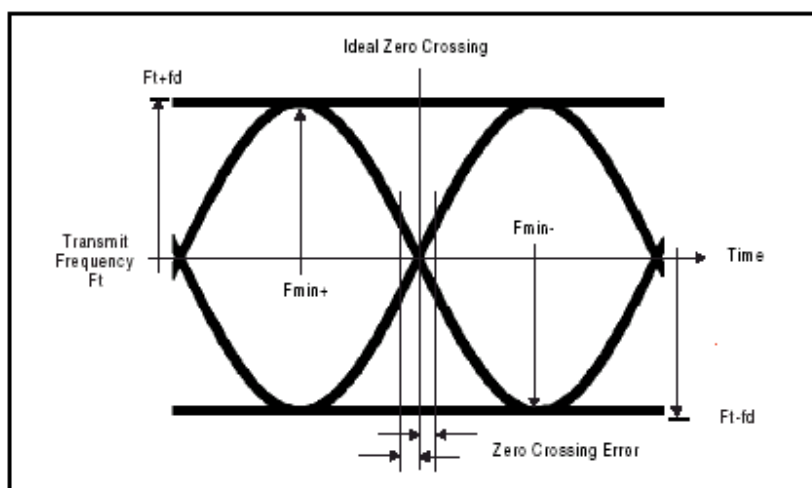


Figure 3.1: GFSK parameters definition.

For each transmission, the minimum frequency deviation,  $F_{min} = \min\{|F_{min+}|, |F_{min-}|\}$ , which corresponds to 1010 sequence shall be no smaller than  $\pm 80\%$  of the frequency deviation ( $f_d$ ) with respect to the transmit frequency  $F_t$ , which corresponds to a 00001111 sequence.

In addition, the minimum frequency deviation shall never be smaller than 115 kHz. The data transmitted has a symbol rate of 1 Ms/s.

The zero crossing error is the time difference between the ideal symbol period and the measured crossing time. This shall be less than  $\pm 1/8$  of a symbol period.

## 3.2 SPURIOUS EMISSIONS

In-band spurious emissions shall be measured with a frequency hopping radio transmitting on one RF channel and receiving on a second RF channel; this means that the synthesizer may change RF channels between reception and transmission, but always returns to the same transmit RF channel. There will be no reference in this document to out of ISM band spurious emissions; the equipment manufacturer is responsible for compliance in the intended country of use.

### 3.2.1 In-band spurious emission

Within the ISM band the transmitter shall pass a spectrum mask, given in [Table 3.2](#). The spectrum shall comply with the 20dB bandwidth definition in FCC part 15.247 and shall be measured accordingly. In addition to the FCC requirement an adjacent channel power on adjacent channels with a difference in RF channel number of two or greater is defined. This adjacent channel power is defined as the sum of the measured power in a 1 MHz RF channel. The transmitted power shall be measured in a 100 kHz bandwidth using maximum hold. The device shall transmit on RF channel M and the adjacent channel power shall be measured on RF channel number N. The transmitter shall transmit a pseudo random data pattern in the payload throughout the test.

Frequency offset	Transmit Power
$\pm 500$ kHz	-20 dBc
2MHz ( $ M-N  = 2$ )	-20 dBm
3MHz or greater ( $ M-N  \geq 3$ )	-40 dBm

Table 3.2: Transmit Spectrum mask.

**Note:** If the output power is less than 0dBm then, wherever appropriate, the FCC's 20 dB relative requirement overrules the absolute adjacent channel power requirement stated in the above table.

Exceptions are allowed in up to three bands of 1 MHz width centered on a frequency which is an integer multiple of 1 MHz. They shall comply with an absolute value of -20 dBm.

### 3.3 RADIO FREQUENCY TOLERANCE

The transmitted initial center frequency shall be within  $\pm 75$  kHz from  $F_c$ . The initial frequency accuracy is defined as being the frequency accuracy before any packet information is transmitted. Note that the frequency drift requirement is not included in the  $\pm 75$  kHz.

The limits on the transmitter center frequency drift within a packet are specified in [Table 3.3](#). The different packets are defined in the Baseband Specification.

Duration of Packet	Frequency Drift
Max length one slot packet	$\pm 25$ kHz
Max length three slot packet	$\pm 40$ kHz
Max length five slot packet	$\pm 40$ kHz
Maximum drift rate <sup>1</sup>	400 Hz/ $\mu$ s

Table 3.3: Maximum allowable frequency drifts in a packet.

1. The maximum drift rate is allowed anywhere in a packet.



## 4 RECEIVER CHARACTERISTICS

The receiver characteristics shall be measured using loopback as defined in [“Test Methodology” on page 233\[vol. 3\]](#).

The reference sensitivity level referred to in this chapter is -70 dBm.

### 4.1 ACTUAL SENSITIVITY LEVEL

The actual sensitivity level is defined as the input level for which a raw bit error rate (BER) of 0.1% is met. The receiver sensitivity shall be below or equal to -70 dBm with any Bluetooth transmitter compliant to the transmitter specification specified in [Section 3 on page 33](#).

### 4.2 INTERFERENCE PERFORMANCE

The interference performance on Co-channel and adjacent 1 MHz and 2 MHz shall be measured with the wanted signal 10 dB over the reference sensitivity level. For interference performance on all other RF channels the wanted signal shall be 3 dB over the reference sensitivity level. If the frequency of an interfering signal is outside of the band 2400-2483,5 MHz, the out-of-band blocking specification (see [Section 4.3 on page 38](#)) shall apply. The interfering signal shall be Bluetooth-modulated (see [section 4.7 on page 39](#)). The BER shall be  $\phi 0.1\%$  for all the signal-to-interference ratios listed in [Table 4.1](#):

Frequency of Interference	Ratio
Co-Channel interference, $C/I_{\text{co-channel}}$	11 dB
Adjacent (1 MHz) interference, $C/I_{1\text{MHz}}$	0 dB
Adjacent (2 MHz) interference, $C/I_{2\text{MHz}}$	-30 dB
Adjacent ( $\geq 3$ MHz) interference, $C/I_{\geq 3\text{MHz}}$	-40 dB
Image frequency Interference <sup>1 2</sup> , $C/I_{\text{image}}$	-9 dB
Adjacent (1 MHz) interference to in-band image frequency, $C/I_{\text{image}\pm 1\text{MHz}}$	-20 dB

Table 4.1: Interference performance

1. In-band image frequency

2. If the image frequency  $\neq n \cdot 1$  MHz, then the image reference frequency is defined as the closest  $n \cdot 1$  MHz frequency.

If two adjacent channel specifications from [Table 4.1](#) are applicable to the same channel, the more relaxed specification applies.

These specifications are only to be tested at nominal temperature conditions with a device receiving on one RF channel and transmitting on a second RF channel; this means that the synthesizer may change RF channels between reception and transmission, but always returns to the same receive RF channel.

RF channels where the requirements are not met are called spurious response RF channels. Five spurious response RF channels are allowed at RF channels with a distance of  $>2$  MHz from the wanted signal. On these spurious response RF channels a relaxed interference requirement  $C/I = -17$  dB shall be met.

### 4.3 OUT-OF-BAND BLOCKING

The out-of-band suppression (or rejection) shall be measured with the wanted signal 3 dB over the reference sensitivity level. The interfering signal shall be a continuous wave signal. The BER shall be  $<0.1\%$ . The out-of-band blocking shall fulfil the following requirements:

Interfering Signal Frequency	Interfering Signal Power Level
30 MHz - 2000 MHz	-10 dBm
2000 - 2399 MHz	-27 dBm
2484 - 3000 MHz	-27 dBm
3000 MHz - 12.75 GHz	-10 dBm

Table 4.2: Out-of-band suppression (or rejection) requirements.

24 exceptions are permitted which are dependent upon the given RF channel and are centered at a frequency which is an integer multiple of 1 MHz. For at least 19 of these spurious response frequencies, a reduced interference level of at least -50dBm is allowed in order to achieve the required BER=0.1% performance, whereas for a maximum of 5 of the spurious frequencies the interference level may be assumed arbitrarily lower.

### 4.4 INTERMODULATION CHARACTERISTICS

The reference sensitivity performance, BER = 0.1%, shall be met under the following conditions:

- . The wanted signal shall be at frequency  $f_0$  with a power level 6 dB over the reference sensitivity level.
- . A static sine wave signal shall be at a frequency  $f_1$  with a power level of -39 dBm.
- . A Bluetooth modulated signal (see [Section 4.7 on page 39](#)) shall be at  $f_2$  with a power level of -39 dBm.

Frequencies  $f_0$ ,  $f_1$  and  $f_2$  shall be chosen such that  $f_0=2f_1-f_2$  and  $f_2-f_1 = n \cdot 1$  MHz, where  $n$  can be 3, 4, or 5. The system shall fulfill at least one of the three alternatives ( $n=3,4$ , or 5).

### 4.5 MAXIMUM USABLE LEVEL

The maximum usable input level that the receiver operates at shall be greater than -20 dBm. The BER shall be less than or equal to 0.1% at -20 dBm input power.

#### **4.6 RECEIVER SIGNAL STRENGTH INDICATOR**

If a device supports Receive Signal Strength Indicator (RSSI) the accuracy shall be  $\pm 6$  dBm.

#### **4.7 REFERENCE SIGNAL DEFINITION**

A Bluetooth modulated interfering signal shall be defined as:

Modulation = GFSK

Modulation index =  $0.32 \pm 1\%$

BT =  $0.5 \pm 1\%$

Bit Rate = 1 Mbps  $\pm 1$  ppm

Modulating Data for wanted signal = PRBS9

Modulating Data for interfering signal = PRBS 15

Frequency accuracy better than  $\pm 1$  ppm.

## **5 APPENDIX A**

### **5.1 NOMINAL TEST CONDITIONS**

#### **5.1.1 Nominal temperature**

The nominal temperature conditions for tests shall be +15 to +35 °C. When it is impractical to carry out the test under this condition a note to this effect, stating the ambient temperature, shall be recorded. The actual value during the test shall be recorded in the test report.

#### **5.1.2 Nominal power source**

##### *5.1.2.1 Mains voltage*

The nominal test voltage for equipment to be connected to the mains shall be the nominal mains voltage. The nominal voltage shall be the declared voltage or any of the declared voltages for which the equipment was designed. The frequency of the test power source corresponding to the AC mains shall be within 2% of the nominal frequency.

##### *5.1.2.2 Lead-acid battery power sources used in vehicles*

When radio equipment is intended for operation from the alternator-fed leadacid battery power sources which are standard in vehicles, then the nominal test voltage shall be 1.1 times the nominal voltage of the battery (6V, 12V, etc.).

##### *5.1.2.3 Other power sources*

For operation from other power sources or types of battery (primary or secondary), the nominal test voltage shall be as declared by the equipment manufacturer. This shall be recorded in the test report.

## **5.2 EXTREME TEST CONDITIONS**

### **5.2.1 Extreme temperatures**

The extreme temperature range shall be the largest temperature range given by the combination of:

- . The minimum temperature range 0 °C to +35 °C
- . The product operating temperature range declared by the manufacturer.

This extreme temperature range and the declared operating temperature range shall be recorded in the test report.

### **5.2.2 Extreme power source voltages**

Tests at extreme power source voltages specified below are not required when the equipment under test is designed for operation as part of and powered by another system or piece of equipment. Where this is the case, the limit values of the host system or host equipment shall apply. The appropriate limit values shall be declared by the manufacturer and recorded in the test report.

#### *5.2.2.1 Mains voltage*

The extreme test voltage for equipment to be connected to an AC mains source shall be the nominal mains voltage  $\pm 10\%$ .

#### *5.2.2.2 Lead-acid battery power source used on vehicles*

When radio equipment is intended for operation from the alternator-fed lead-acid battery power sources which are standard in vehicles, then extreme test voltage shall be 1.3 and 0.9 times the nominal voltage of the battery (6V, 12V etc.)

#### *5.2.2.3 Power sources using other types of batteries*

The lower extreme test voltage for equipment with power sources using the following types of battery, shall be

- a) for Leclanche, alkaline, or lithium type battery: 0.85 times the nominal voltage of the battery
- b) for mercury or nickel-cadmium types of battery: 0.9 times the nominal voltage of the battery.

In both cases, the upper extreme test voltage shall be 1.15 times the nominal voltage of the battery.

#### *5.2.2.4 Other power sources*

For equipment using other power sources, or capable of being operated from a variety of power sources (primary or secondary), the extreme test voltages shall be those declared by the manufacturer. These shall be recorded in the test report.

## 6 APPENDIX B

The radio parameters shall be tested in the following conditions

### Parameter Temperature Power source

Parameter	Temperature	Power source
Output Power	ETC	ETC
Power control	NTC	NTC
Modulation index	ETC	ETC
Initial Carrier Frequency accuracy	ETC	ETC
Carrier Frequency drift	ETC	ETC
Conducted in-band spurious emissions	ETC	ETC
Radiated in-band emissions	NTC	NTC
Sensitivity	ETC	ETC
Interference Performance	NTC	NTC
Intermodulation Characteristics	NTC	NTC
Out-of-band blocking	NTC	NTC
Maximum Usable Level	NTC	NTC
Receiver Signal Strength Indicator	NTC	NTC

ETC = Extreme Test Conditions

NTC = Nominal Test Conditions