

Part A

RADIO SPECIFICATION



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1 SCOPE

The Bluetooth transceiver is operating in the 2.4 GHz ISM band. This specification defines the requirements for a Bluetooth transceiver operating in this unlicensed band.

Requirements are defined for two reasons:

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

The Bluetooth transceiver shall fulfil the stated requirements under the operating conditions specified in [Appendix A](#) and [Appendix B](#). The Radio parameters must 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 (except France and Spain):

Approval Standards: European Telecommunications Standards Institute, ETSI

Documents: ETS 300-328, ETS 300-339

Approval Authority: National Type Approval Authorities

France:

Approval Standards: La Reglementation en France por les Equipements fonctionnant dans la bande de frequences 2.4 GHz "RLAN-Radio Local Area Network"

Documents: SP/DGPT/ATAS/23, ETS 300-328, ETS 300-339

Approval Authority: Direction Generale des Postes et Telecommunications

Note: A new R&TTE EU Directive will be in effect by March 2000, with the consequence of manufactures declaration of conformity and free circulation of products within the EU.

Spain:

Approval Standards: Suplemento Del Numero 164 Del Boletin Oficial Del Estado (Published 10 July 91, Revised 25 June 93)

Documents: ETS 300-328, ETS 300-339

Approval Authority: Cuadro Nacional De Atribucion De Frecuencias

Japan:

Approval Standards: Association of Radio Industries and Businesses, ARIB

Documents: RCR STD-33A

Approval Authority: Ministry of Post and Telecommunications, MPT

Note: The Japanese rules are in revision and decision on the revision will take place in Q2 1999.

North Americas:

Approval Standards: Federal Communications Commission, FCC, USA

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

Approval Standards: Industry Canada, IC, Canada

Documents: GL36

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

2 FREQUENCY BANDS AND CHANNEL ARRANGEMENT

The Bluetooth system is operating in the 2.4 GHz ISM (Industrial Scientific Medicine) band. Although globally available, each country has specified a set of frequencies applicable for each country. In order to comply with each country's regulations the transceiver must use a specified frequency-hopping algorithm as specified in the [Baseband Specification](#).

Geography	Regulatory Range	RF Channels
USA	2.400-2.4835 GHz	$f=2402+k$ MHz, $k=0,\dots,78$
Europe (except Spain and France)	2.400-2.4835 GHz	$f=2402+k$ MHz, $k=0,\dots,78$
Spain ¹⁾	2.445-2.475 GHz	$f=2449+k$ MHz, $k=0,\dots,22$
France ¹⁾	2.4465-2.4835 GHz	$f=2454+k$ MHz, $k=0,\dots,22$
Japan ²⁾	2.471-2.497 GHz	$f=2473+k$ MHz, $k=0,\dots,22$

Table 2.1: Operating frequency bands

Note 1. A harmonisation process has been started to conform to same ISM band as rest of Europe.

Note 2. There is a proposal from ARIB to revise the Japanese ISM band to 2400-2483.5 MHz. A decision is expected in Q2 1999.

The channel spacing is 1 MHz. In order to comply with out-of-band regulations in each country, a guard band is used at the lower and upper band edge.

Geography	Lower Guard Band	Upper Guard Band
USA	2 MHz	3.5 MHz
Europe (except Spain and France)	2 MHz	3.5 MHz
Spain	4 MHz	26 MHz
France	7.5 MHz	7.5 MHz
Japan	2 MHz	2 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 equipment. If the equipment does not have a connector a reference antenna with 0 dBi gain is assumed.

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

If transmitting antennas of directional gain greater than 0 dBi are used, the applicable paragraphs in ETSI 300 328 and FCC part 15 must be compensated for.

The equipment is classified into three power classes.

Power Class	Maximum Output Power	Nominal Output Power	Minimum Output Power ¹⁾	Power Control
1	100 mW (20 dBm)	N/A	1 mW (0 dBm)	4 to +20 dBm -30 ²⁾ to 0 dBm, Optional
2	2.5 mW (4 dBm)	1 mW (0 dBm)	0.25 mW (-6 dBm)	-30 ²⁾ to 0 dBm, Optional
3	1 mW (0 dBm)	N/A	N/A	-30 ²⁾ to 0 dBm, Optional

Table 3.1: Power classes

Note 1. Minimum output power at maximum power setting.

Note 2. The lower range limit of -30 dBm is not mandatory and may be chosen according to application needs.

A power control is required for power class 1 equipment. The power control is used for limiting the transmitted power over 0 dBm. Power control capability under 0 dBm is optional and could be used for optimising 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 equipment with a maximum transmit power of +20 must be able to control its transmit power down to 4 dBm or less.

Equipment with power control capability optimizes the output power in a link with LMP commands (see [Link Manager Protocol](#)). It is done by measuring RSSI and report back if the power should be increased or decreased.

3.1 MODULATION CHARACTERISTICS

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

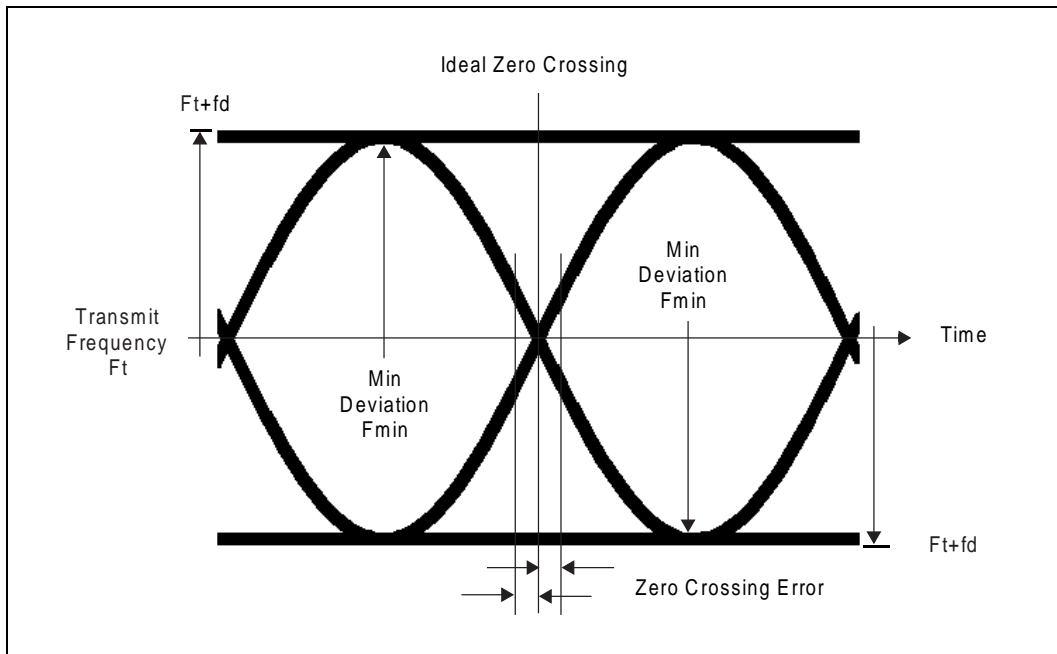


Figure 3.1: Figure 3-1 Actual transmit modulation.

For each transmit channel, the minimum frequency deviation (F_{min}) which corresponds to a 1010 sequence should be no smaller than $\pm 80\%$ of the frequency deviation (F_{t+fd}) which corresponds to a 00001111 sequence. In addition the minimum deviation shall never be smaller than 115 kHz.

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

The spurious emission, in-band and out-of-band, are measured with a frequency hopping transmitter hopping on a single frequency, meaning that the synthesiser must change frequency between receive slot and transmit slot, but always return to the same transmit frequency.

For USA the rules of the FCC parts 15.247, 15.249, 15.205 and 15.209 are applicable regulations. For Japan, RCR STD-33 and for Europe, ETSI 300 328 are applicable regulations.



3.2.1 In-band Spurious Emission

Within the ISM band the transmitter shall pass a spectrum mask, which is given by Table 3.2. The spectrum must comply with FCC’s 20-dB bandwidth definition stated below and should be measured accordingly. In addition to the FCC requirement an adjacent channel power on adjacent channels with a difference in channel number of two or greater an adjacent channel power is defined. This adjacent channel power is defined as the sum of the measured power in a 1 MHz channel. The transmitted power shall be measured in a 100 kHz bandwidth using maximum hold. The transmitter is transmitting on channel M and the adjacent channel power is measured on channel number N. The transmitter is sending a pseudo random data pattern throughout the test.

Frequency offset	Transmit Power
± 550 kHz	-20 dBc
$ M-N = 2$	-20 dBm
$ 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 is overruling the absolute adjacent channel power requirement stated in the above table.

“In any 100 kHz bandwidth outside the frequency band in which the spread spectrum 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. 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)).”

FCC Part 15.247c

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

3.2.2 Out-of-Band Spurious Emission

The measured power should be measured in a 100 kHz bandwidth.

Frequency Band	Operation mode	Idle mode
30 MHz - 1 GHz	-36 dBm	-57 dBm
1 GHz – 12.75 GHz	-30 dBm	-47 dBm
1.8 GHz – 1.9 GHz	-47 dBm	-47 dBm
5.15 GHz – 5.3 GHz	-47 dBm	-47 dBm

Table 3.3: Out-of-band spurious emission requirement

3.3 RADIO FREQUENCY TOLERANCE

The transmitted initial center frequency accuracy must be ± 75 kHz from F_c . The Initial frequency accuracy is defined as being the frequency accuracy before any information is transmitted. Note that the frequency drift requirement is not included in the ± 75 kHz.

The transmitter center frequency drift in a packet is specified in [Table 3.4](#). The different packets are defined in the Baseband Specification.

Type of Packet	Frequency Drift
One slot package	± 25 kHz
Three slot package	± 40 kHz
Five slot package	± 40 kHz
Maximum drift rate ¹⁾	400 Hz/ μ s

Table 3.4: Frequency drift in a package

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



4 RECEIVER CHARACTERISTICS

In order to measure the bit error rate performance; the equipment must have a “loop back” facility. The equipment sends back the decoded information. This facility is specified in the [Test Mode Specification](#).

The reference sensitivity level referred to in this chapter equals to -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 requirement for a Bluetooth receiver is an actual sensitivity level of -70 dBm or better. The receiver must achieve the -70 dBm sensitivity level with any Bluetooth transmitter compliant to the transmitter specification specified in [Section 3 on page 20](#).

4.2 INTERFERENCE PERFORMANCE

The interference performance on Co-channel and adjacent 1 MHz and 2 MHz are measured with the wanted signal 10 dB over the reference sensitivity level. On all other frequencies the wanted signal shall be 3 dB over the reference sensitivity level. The interfering signal shall be Bluetooth modulated (see [section 4.8 on page 27](#)). The BER shall be $\leq 0.1\%$. The signal to interference ratio shall be:

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

Table 4.1: Interference performance

Note 1. These specifications are tentative and will be fixed within 18 months after the release of the Bluetooth specification version 1.0. Implementations have to fulfill the final specification after a 3 years convergence period starting at the release of the Bluetooth specification version 1.0. During the convergence period, devices need to achieve a co-channel interference resistance of +14 dB, an ACI (@1MHz) resistance of +4 dB, Image frequency interference resistance of -6 dB and an ACI to in-band image frequency resistance of -16 dB.

Note 2. In-band image frequency

Note 3. If the image frequency $\neq n \cdot 1$ MHz, than the image reference frequency is defined as the closest $n \cdot 1$ MHz frequency.



These specifications are only to be tested at nominal temperature conditions with a receiver hopping on one frequency, meaning that the synthesiser must change frequency between receive slot and transmit slot, but always return to the same receive frequency.

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

4.3 OUT-OF-BAND BLOCKING

The Out of band blocking is 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 must fulfill the following requirements:

Interfering Signal Frequency	Interfering Signal Power Level
30 MHz - 2000 MHz	-10 dBm
2000 - 2400 MHz	-27 dBm
2500 – 3000 MHz	-27 dBm
3000 MHz – 12.75 GHz	-10 dBm

Table 4.2: Out of Band blocking requirements

24 exceptions are permitted which are dependent upon the given receive channel frequency and are centred at a frequency which is an integer multiple of 1 MHz. At 19 of these spurious response frequencies a relaxed power level -50 dBm of the interferer may be used to achieve a BER of 0.1% and at the remaining 5 spurious response frequencies the power level is arbitrary.

4.4 INTERMODULATION CHARACTERISTICS

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

- The wanted signal at frequency f_0 with a power level 6 dB over the reference sensitivity level.
- A static sine wave signal at f_1 with a power level of -39 dBm
- A Bluetooth modulated signal (see [Section 4.8 on page 27](#)) at f_2 with a power level of -39 dBm

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 must fulfil one of the three alternatives.

4.5 MAXIMUM USEABLE LEVEL

The maximum useable input level the receiver shall operate at shall be better than -20 dBm. The BER shall be less or equal to 0,1% at -20^* dBm input power.

4.6 SPURIOUS EMISSIONS

The spurious emission for a Bluetooth receiver shall not be more than:

Frequency Band	Requirement
30 MHz - 1 GHz	-57 dBm
1 GHz – 12.75 GHz	-47 dBm

Table 4.3: Out-of-band spurious emission

The measured power should be measured in a 100 kHz bandwidth.

4.7 RECEIVER SIGNAL STRENGTH INDICATOR (OPTIONAL)

A transceivers that wishes to take part in a power controlled link must be able to measure its own receiver signal strength and determine if the transmitter on the other side of the link should increase or decrease its output power level. A Receiver Signal Strength Indicator (RSSI) makes this possible.

The way the power control is specified is to have a golden receive power. This golden receive power is defined as a range with a low limit and a high limit. The RSSI must have a minimum dynamic range equal to this range. The RSSI must have an absolute accuracy of ± 4 dB or better when the receive signal power is -60 dBm. In addition a minimum range of 20 ± 6 dB, starting from -60 dB and up, must be covered (see Figure 4.1 on page 26).

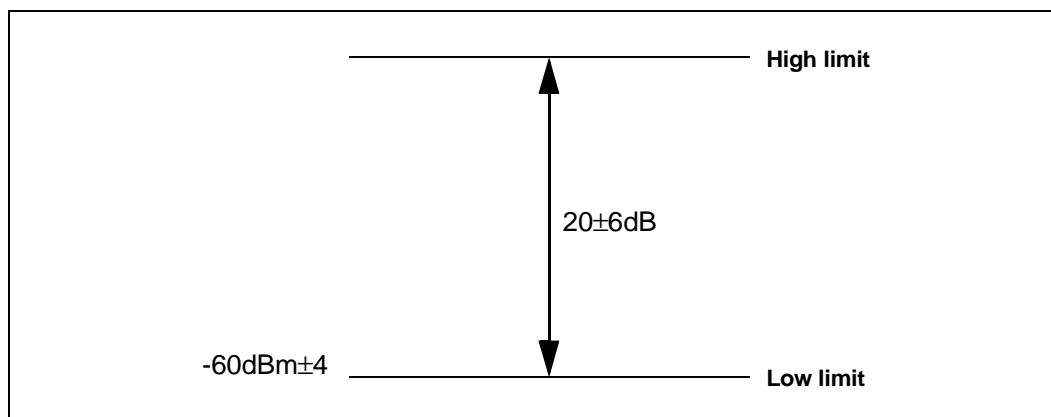


Figure 4.1: RSSI dynamic range and accuracy

4.8 REFERENCE INTERFERENCE-SIGNAL DEFINITION

A Bluetooth modulated interfering signal is defined as:

Modulation = GFSK

Modulation index = $0.32 \pm 1\%$

BT = $0.5 \pm 1\%$

Bit Rate = 1 Mbps ± 1 ppm

Modulating Data = PRBS9

Frequency accuracy better than ± 1 ppm.

5 Appendix A

5.1 NOMINAL TEST CONDITIONS (NTC)

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 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 on vehicles

When radio equipment is intended for operation from usual, alternator fed lead-acid battery power sources used on 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 is defined as 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 usual type of alternator fed lead-acid battery power source used on 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 Leclanché or lithium type battery : 0.85 times times the nominal voltage of the battery
- b) for the 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
Output Power	ETC	ETC
Power control	NTC	NTC
Modulation index	ETC	ETC
Initial Carrier Frequency accuracy	ETC	ETC
Carrier Frequency drift	ETC	ETC
In-band spurious emissions	ETC	ETC
Out-of-band Spurious Emissions	ETC	ETC
Sensitivity	ETC	ETC
Interference Performance	NTC	NTC
Intermodulation Characteristics	NTC	NTC
Out-of-band blocking	NTC	NTC
Maximum Useable Level	NTC	NTC
Receiver Signal Strength Indicator	NTC	NTC

ETC = Extreme Test Conditions

NTC = Nominal Test Conditions

