AN032

SRD regulations for license-free transceiver operation in the 2.4 GHz band

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1 Keywords

- *CEPT recommendations*
- *ETSI standards*
- *FCC Part 15*
- *ARIB STD T-66*
- *R&TTE directive*
- *Type approval*
- *Equipment testing*

2 Introduction

International regulations and national laws regulate the use of radio receivers and transmitters. This document is a summary of the most important aspects of these regulations for license-free operation of radio receivers and transmitters in the worldwide 2.4 GHz band.

Although the operation of transceivers in the 2.4 GHz band is license-free, the final product itself has to be type approved. The type approval procedure will also be reviewed in this document.

Chipcon is a worldwide distributor of transceivers and transmitters that generally are designed to comply with the regulations discussed in this document. Please note that it is not the transceiver or transmitter itself that will need type approval, but rather the actual application or end product.

3 Regulation overview

The use of radio equipment in most European countries is regulated through the R&TTE directive. This directive defines the general requirements for radio operation. The actual standards to comply with are written by standardisation bodies like The European Conference of Postal and Telecommunications Administrations (CEPT) and the European Telecommunications Standards Institute (ETSI).
CEPT is an organ for the Post -Telephone –Telegraph (PTT) authorities in the European countries and has the responsibility for the allocation of frequencies and output power. This is described in the European Radiocommunications Committee (ERC) recommendation CEPT/ERC/70-03. In this document the regulations of the 2.4 GHz band is reviewed.

ETSI is developing standards for the testing and type approval of transmitters and receivers. Detailed specifications and test methods are outlined. Different frequency bands are covered by different standards. The 2.4 GHz ISM band is covered by the following standards:

- EN 300 440 covers 1 – 25 GHz.
- EN 300 328 covers the 2.4 GHz band.
- EN 300 761 covers a specific application in the 2.4 GHz band.

Equipment containing radio transmitters, transceivers or receivers must also obtain an EMC certificate based on the requirements outlined in EN 300 683 or EN 301 489-3.

In the United States the legal issues governing the manufacture and sale of RF products for unlicensed operation is regulated under the Federal Communications Commission (FCC) CFR47, Part 15. In this document we review the regulations for the 2.4 GHz band only.

In Japan compliance with ARIB STD T-66 needs to be obtained.

For equipment operating under the IEEE 802.15.4 standard, a good summary of relevant regulatory requirements can be found in annex F of the standard. The full standard can be downloaded from IEEE's web pages using this program: http://standards.ieee.org/getieee802/802.15.html.

Please note that the terms and conditions according to the following web site apply (http://standards.ieee.org/getieee802/terms.html).

This application note does not cover the rest of the world, but in general most countries seem to follow similar regulations as the USA, Europe and/or Japan.
In order to obtain a clear picture of the applicable rules and regulations a local governing body should always be contacted before development is started.
FCC maintains a list of PTT governing bodies:
http://www.fcc.gov/mb/audio/bickel/world-govt-telecom.html

This document contains information based on documents available from several telecommunication authorities and is believed to be correct. Chipcon is not responsible for any errors or changes that might occur. A local governing body should always be contacted before development starts, in order to have a clear picture of the applicable rules and regulations.

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4 Abbreviations

AC	Alternating Current
ARIB	Association of Radio Industries and Businesses
AVI	Automatic Vehicle Identification
BW	Bandwidth
CE	Conformité Européene (French), i.e. European Conformity
CEPT	European Conference of Postal and Telecommunications Administrations
CFR	Code of Federal Regulations
CISPR	International Special Committee on Radio Interference
CW	Continuous Wave
DC	Direct Current
DoC	Declaration of Conformity
DSSS	Direct Sequence Spread Spectrum
DUT	Device Under Test
ECC	Electronic Communications Committee
ECI	Equipment Class Identifier
EEA	European Economic Area
EIRP	Effective Isotropic Radiated Power
EM	Electromagnetic
EMC	Electromagnetic Compatibility
ERC	European Radiocommunications Committee
ERC/DEC	European Radiocommunications Committee/Decision
ERP	Effective Radiated Power
ESD	Electro Static Discharge
ETSI	European Telecommunications Standards Institute
EU	European Union
FCC	Federal Communications Commission
FHSS	Frequency Hopping Spread Spectrum
I/O	Input/Output
IEC	International Electrotechnical Commission
ISM	Industrial, Scientific and Medical
ITU	International Telecommunication Union
LAN	Local Area Network
kbps	kilobits per second
PTT	Post- Telephone -Telegraph
RBW	Resolution Bandwidth
RE	Radio Equipment
RF	Radio Frequency
RFID	Radio Frequency Identification
R&TTE	Radio and Telecommunications Terminal Equipment
SMA	Subminiature version A
SPD	Spectrum Power Density
SRD	Short Range Device
TCF	Technical Construction File
TDD	Time Division Duplex
VBW	Video Bandwidth

5 CEPT ERC RECOMMENDATION 70-03

A summary of the recommendation for the 2.4 GHz band Short Range Devices (SRD) is provided, based on the October 2004 edition of CEPT ERC Recommendation 70-03. The complete document can be downloaded from www.ero.dk. Direct links to documents and other useful links from CEPT can also be found at this site.

Class	Frequency band	Power EIRP*	Duty cycle	Channel spacing	Comments
1l	**2400 – 2483.5 MHz**	**10mW**	**No restriction.**	**No channel spacing specified**	Non-Specific Short Range Devices
3a	**2400 – 2483.5 MHz**	**100mW****	**No restriction.**	**No channel spacing specified.** Minimum data rate is 250 kbps.	Local Area Networks**
4a	**2446 – 2454 MHz**	**500mW**	**No restriction.**	**5 channels within the band.** Each 1.5 MHz wide.	Automatic Vehicle Identification (AVI) for railways. Transmitting only in presence of trains. Covered by EN 300 761
6a	**2400 – 2483.5 MHz**	**25mW**	**No restriction.**	**No channel spacing specified**	Equipment for detecting movement and alert.
11a	**2446 – 2454 MHz**	**500mW** **4W** (Only allowed inside buildings)	**Up to 100%** **< 15%** (Maximum duty cycle when operating above 500mW is 15%)	**No channel spacing specified**	RFID. Power levels above 500mW only allowed inside buildings. (FHSS should be used for output powers above 500mW). The duty cycle must be less than 15% within any 200ms period if the output power is above 500mW.

*EIRP = effective isotropic radiated power, see explanation below.
**For direct sequence spread spectrum (DSSS), the maximum spectrum power density (SPD) is limited to –20 dBW/MHz. For Frequency Hopping Spread Spectrum (FHSS) the SPD is limited to –10 dBW/100kHz.

Table 1: CEPT ERC Recommendation 70-03 for the 2.4 GHz frequency band

The 2.4 GHz band is covered by ERC decisions, which means that this is a harmonised band in most of Europe, see ERC/DEC/(01)05, ERC/DEC/(01)07 and ERC/DEC/(01)08. Being a harmonised band means that there is no need to notify the telecommunication authorities when introducing a product to the market in any EU/ECC country (as governed by Directive 1999/5/EC (R&TTE)) as long as the product is declared in compliance with the harmonised ETSI standards described below. The relevant standards are EN 300 440, EN 300 328 and EN 300 761 respectively. The equipment must also meet the spurious emission limits defined within ERC/REC 74-01 when tested as described in EN 300 440, EN 300 328 or EN 300 761.

5.1 Power

The Effective Isotropic Radiated Power (EIRP) is the apparent power transmitted towards the receiver assuming that the signal power is radiated equally in all directions, such as a spherical wave emanating from a point source. In other words, the transmitted signal power equals the arithmetic product of the power supplied to an antenna and its gain (dBi). Begin by testing the transmitter with a well defined dummy load and a calibrated power meter, or alternatively a spectrum analyser. Add the transmitter's output power (dBm) with the antenna gain (dBi) to obtain the EIRP.

EIRP must not be confused with ERP. By definition ERP is the abbreviation for Effective Radiated Power, i.e. the power directed in a given direction for a given antenna. It is the power supplied to an antenna multiplied by the antenna gain in a given direction, where the direction and type of reference antenna should be specified. If the direction is not specified, the direction of maximum gain is assumed. The antenna gain is most often the gain relative to a *half-wave dipole* (dBd) in a given direction. The half-wave dipole is 0 dBd, corresponding to 2.15 dBi. However, EIRP is more commonly used in microwave engineering.

5.2 Antenna

The antenna shall be an integral part of the product (no external antenna socket), or a dedicated antenna shall be used (type approved with the equipment). The dedicated antenna should be a permanently fixed antenna, or an antenna using an otherwise not commonly used connector. In the latter case the use of a reverse polarity SMA connector (not compatible with normal SMA connectors) is recommended.

5.3 Channel spacing

No specified channel spacing means that the entire frequency band can be used. However, the product can be designed to use appropriate channel widths and spacing inside this band as long as the overall requirement is met.

5.4 Licensing

If the product is approved according to the relevant requirements, no individual license is required to operate these products. See ERC decisions mentioned above, and national restrictions regarding exceptions.

5.5 Product marking

The product shall be marked indicating which class the equipment is designed for. For example non-specific SRDs in the 2.4 GHz band will be of class "1l".

5.6 Transmitter duty cycle

The transmitter duty cycle is defined as the ratio of the maximum "on" time, relative to a one-hour period. If message acknowledgement is required, the additional "on" time shall be included. In the 2.4 GHz band there is no duty cycle limits (except class 11a operating inside buildings with high output powers), and thus continuous transmission is allowed.

5.7 Special national restrictions

The national authorities have stated some restrictions to the implementation of the CEPT ERC Recommendation 70-03. Some of these are given below (as of October 2004). The national telecommunication authorities should be consulted for full details.

Croatia:
11a: Not implemented.

Czech Republic:
11a: Not implemented.

France:
3a: Outdoor use limited to 10mW EIRP within the band 2454-2483.5 MHz.
6a: Indoor use without restrictions. Outdoor use limited to 10mW EIRP within 2454 to 2483.5 MHz.
11a: Max EIRP 500mW.

Iceland:
4a: Not applicable.

Italy:
3a: If used outside of own premises general authorization is required.
4a: Not implemented.
11a: Not implemented.

Luxembourg:
3a: General authorization required for public service.

Malta:
4a: Not applicable.

Norway:
4a: Only 2447, 2448.5, 2450, 2451.5 and 2453 MHz allowed.

Poland:
11a: Limited to 100mW EIRP.

Portugal:
4a: Not implemented.

Romania:
1l: Secondary basis, individual license required
3a: On a secondary basis. Individual license required. T/R 22-06 not implemented (High Performance Radio Local Area Network, HIPERLAN).
4a: On a secondary basis. Individual license required.
6a: Not implemented.

Slovak Republic:
3a: Max 10 mW ERP (Military band).
4a: Not implemented (Military band).
11a: Not implemented (Military band).

Sweden:
4a: Not implemented (License required, military band).
11a: Limited to 25mW EIRP (Military band).

United Kingdom:
1l: Channel spacing > 20 MHz where justified by the modulation.
6a: Limited to 2445-2455 MHz.

6 R&TTE Directive

The Radio Equipment and Telecommunications Terminal Equipment (R&TTE) Directive, 1999/5/EC, introduced a self-declaration regime similar to that used for other European directives. The new directive, changing to self-declaration, makes the conformity assessment process quicker and more flexible, and takes radio and telecommunication equipment to the same level as other product types. Compliance is presumed when the manufacturer issues a Declaration of Conformity (DoC) and marks the product with the CE logo.

The R&TTE Directive applies throughout the European Union (EU) and the European Economic Area (EEA).

The Directive itself can be found in the European Law section of the European Union's web site: www.europa.eu.int/eur-lex/pri/en/oj/dat/1999/l_091/l_09119990407en00100028.pdf.

6.1 Essential requirements

The DoC shall declare that the essential requirements of the R&TTE Directive are met. The essential requirements for radio equipment (RE) can be summarized as follows:

- The RE shall effectively use the radio spectrum so as to avoid harmful interference
- The RE shall protect the health and safety of the user and others, including meeting the safety requirements of the Low Voltage Directive 73/23/EEC
- The RE shall be in compliance with the essential requirements of the EMC Directive 89/336/EEC

The Low Voltage and EMC directives are integrated into the new directive, so manufacturers only need to declare conformity with the new one. This approach makes the process easier, but it also means that manufacturers take even more responsibility for the conformity of their products, as there is no third party approval authority.

6.2 Routes to compliance

In order to obtain the CE marking, compliance with the R&TTE Directive must be demonstrated. There are three options for conformity assessment of radio equipment where a harmonised standard has been applied. These are given in the directive annexes III, IV and V:

- A conformity assessment procedure based on internal production control, and testing according to harmonised standards (annex III),
- As stated above but in addition a technical construction file (TCF, annex IV) is presented to and reviewed by a “notified body” appointed by the State.
- Based on full quality assurance by having a quality system (annex V) approved by a “notified body”. The quality system must contain elements for design, manufacture and final product inspection. The manufacturer must apply to the “notified body” to have an assessment carried out of the quality system, all documentation of the quality system and products intended for conformity must be included.

Manufacturers of SRDs in the license-free 2.4 GHz frequency range can chose to follow the procedure in annex III, when the apparatus conforms with harmonised standards. The applicable harmonised standards are EN 300 440 (Non-specific SRDs), EN 300 328 (Wideband transmission systems), EN 300 761 (AVI for train monitoring), EN 60950 (safety) and EN 301 489 (EMC).

A harmonised standard is one that has been published in the Official Journal of the European Communities. Please note that complying with a harmonised standard does not ensure that a product meets the essential requirements as described earlier, but it gives the manufacturer a presumption of conformity with the requirements.

The manufacturer declares compliance with a written DoC and by placing the CE Marking on the product. Both the equipment user and the member state shall be notified about the DoC, and the full technical documentation must be kept for 10 years after the last product was manufactured.

6.3 Equipment marking

The marking requirements are given in the R&TTE Directive's annex VII. They include CE marking, notified body number (if used), equipment class identifier (if defined, see below), manufacturers name, type batch and/or serial number.

6.4 Notification when using a non-harmonised band

Where radio equipment uses frequency bands which use is not harmonised throughout the EU, the manufacturer must notify Member State authorities at least four weeks before placing the product on the market. The product must then be marked with the class 2 Equipment Class Identifier (ECI) which is the alert symbol (exclamation mark, "!" inside a circle).

As per August 2004 the band 2400 – 2483.5 MHz is not yet fully harmonized. Bands 1l, 3a and 6a are "nearly harmonised", meaning that only one or two administrations within the EEA has not implemented the bands or have restrictions. Further information on harmonised bands can be found at www.ero.dk.

7 ETSI EN 300 440

The ETSI EN 300 440 specifies in detail the requirements and test methods to be used for license-free operated radio equipment under classes 1l, 6a and 11a. Equipment using FHSS under class 3a must be tested according to EN 300 328, and equipment intended specifically for train AVI under class 4a must be tested according to EN 300 761.
The following is a summary of the most important requirements in EN 300 440. The complete document can be downloaded from www.etsi.org (direct link to search site: http://pda.etsi.org/pda/queryform.asp).

7.1 Effective Isotropically Radiated Power (EIRP)

EIRP (as defined in section 5.1) limits apply to the peak power of the transmitter. EIRP shall be measured with a test signal applied as described in section 6.1 of EN 300 440.
If the equipment is equipped with a 50Ω connector the conducted peak power is measured at this connector and EIRP is calculated using the declared antenna gain.
If the equipment is not fitted with an antenna connector the EIRP is measured as defined in section 7.1.2 of the standard. Two measurement methods are used depending on the equipment to be tested. For non-spread spectrum equipment with –6dB bandwidth ≤ 20MHz and duty cycle > 50%, and for spread spectrum equipment with –6dB bandwidth ≤ 1 MHz, the measurement is performed according to section 7.1.2.1. For other transmitters the measurement is performed according to section 7.1.2.2.
The transmitter's maximum EIRP shall not exceed the values given in the ERC Recommendation 70-03.

7.2 Permitted range of operating frequencies

The occupied bandwidth for an operating frequency is defined by the –74.8 dBm/Hz power spectrum density (or –30 dBm if measured in a 30 kHz bandwidth).
The range of operating frequencies is limited so that the occupied bandwidth for any operating frequency falls within the allocated frequency given in ERC recommendation 70-03.
The measurements of operating frequency range are specified in sections 7.2.2 and 7.2.3 for the different transmitters.

7.3 Spurious emission in transmit mode

A spurious emission measurement is a measurement of unwanted emitted signals. The device under test (DUT) shall be measured without modulation applied operating at maximum specified output power. In equipment where modulation cannot be disabled, spurious emission shall be measured with modulation. If so, this must be noted in the test report. Spurious emission should also be measured in standby mode.
Spurious emission can be measured as power in a specified load, given an available antenna connector. In this case radiated spurious emission from cabinet and structure must also be measured.
If no antenna connector is available, both emissions from antenna and cabinet/structure are measured radiated.

For frequency hopping transmitters the measurement shall be performed using hop sequences containing the highest and lowest hop frequency, and using frequency hops with maximum change in frequency. If the highest and lowest hop frequencies are not contained in the same hop set, two measurements must be carried out. Then one test should include the highest hop frequency, and one test include the lowest.

The equipment shall be measured for unwanted emissions from 25 MHz to ten times the operating frequency, i.e. 25 GHz for the 2.4 GHz frequency band.

The measuring receiver is either a spectrum analyzer or a selective voltmeter. The transmitter shall be connected to the measuring receiver through a 50Ω power attenuator, and if necessary an appropriate filter to avoid overloading the receiver. Filter limitations are given in EN 300 440, section 7.3.3.

The measurement bandwidth (spectrum analyzer resolution bandwidth) shall be 100 – 120 kHz for frequencies below 1 GHz, and 1 MHz for frequencies above 1 GHz. This is according to CISPR 16-1. The specified bandwidth must be reduced if a sensitivity 6dB below the spurious emission limit cannot be achieved.

All spurious components except emission at the intended channel (carrier) shall be measured. The spurious emission requirement is given in table 2, and illustrated in figure 1 below.

State	47-74 MHz 87.5-118 MHz 174-230 MHz 470-862MHz	Other frequencies below 1000 MHz	Above 1000 MHz
Operating	4nW = -54dBm	250nW = -36dBm	1μW = -30dBm
Standby	2nW = -57dBm	2nW = -57dBm	20nW = -47dBm

Table 2: EN 300 440 spurious emission requirements

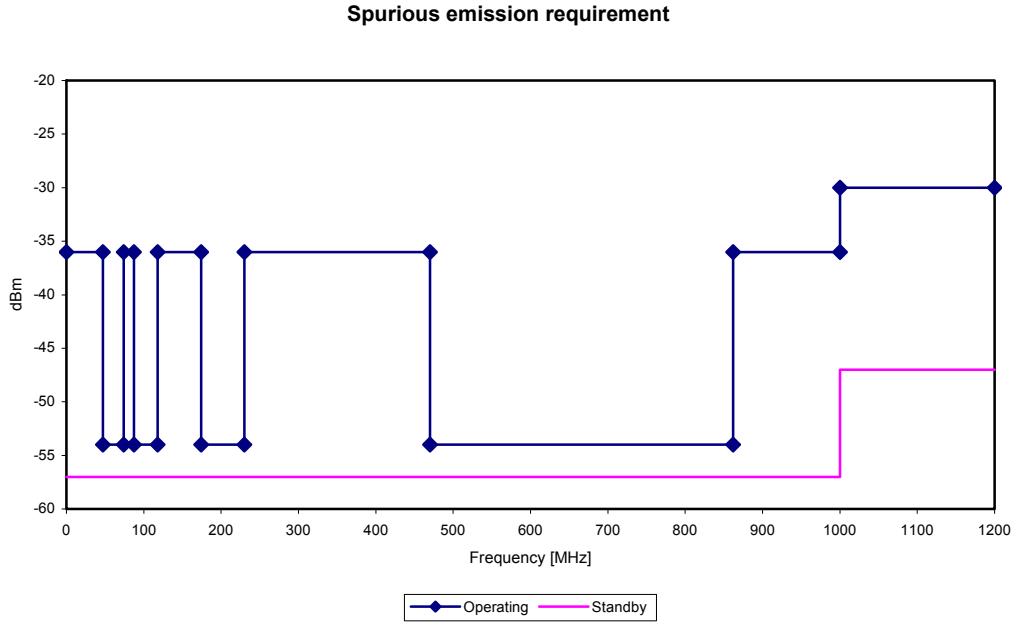

Figure 1: Spurious emission requirement (operating and standby)

7.4 Duty cycle

This requirement states that the transmitter on/off ratio shall be measured during a one hour period. As stated in the ERC/DEC 70-03E recommendation (see above) the only duty cycle limitation in the 2.4 GHz band applies for devices operating in class 11a with output powers between 500mW and 4W.

7.5 Additional FHSS requirements

FHSS modulation shall make use of at least 20 channels separated by the channel bandwidth as measured at 20dB below peak level. The dwell time per channel shall not exceed 0.4s. The maximum –20dBc bandwidth of a single channel shall not exceed 1 MHz when measured in a 100kHz bandwidth. During operation every channel shall be used at least once within a period of 4 times the dwell time per hop multiplied with the number of channels.
While the transmitter is performing hops between channels, the transmit power level shall be attenuated below the standby spurious emission level as given above.
FHSS systems in class 3a should be tested according to EN 300 328, see below.

7.6 Receiver regulations

Short Range Devices (SRDs) are divided into three equipment classes having different receive performance criteria. The classification is based upon the impact on persons in case the equipment does not operate as specified, as presented in section 4.1.1.

For “standard reliable SRD communication”, i.e. receiver class 3 (malfunction does not result in a physical risk to a person, or cause inconvenience that can not be simply overcome), the ETSI standard does not give any mandatory requirements to receiver selectivity or blocking (sections 8.1, 8.2, 8.3) for the SRD systems in the 2.4 GHz range.

For medium reliable SRD communication, i.e. receiver class 2 (malfunction does not result in a physical risk to a person, but may cause inconvenience that can not be simply overcome), the receiver operating in the 2.4 GHz band must also meet the blocking requirements given in table 3. The table lists the minimum level of an interfering signal at a given frequency offset the receiver must be able to endure, while receiving a wanted signal 3 dB above the sensitivity limit. Details of the measurement are described in section 8.3:

Frequency offset (MHz)	Limit
±5	-50 dBm
±10	-45 dBm
±20	-40 dBm
±50	-30 dBm

Table 3: EN 300 440 receiver class 2 blocking requirements

For “highly reliable SRD communication”, i.e. receiver class 1 (serving human life inherent systems), the receiver must meet additional selectivity requirements and stricter blocking requirements. Chipcon products operating in the 2.4 GHz band are not intended for class 1 operation. Details of the requirements can be found in sections 8.1, 8.2 and 8.3.

7.7 Receiver spurious radiation

For equipment with an integral antenna the radiated emission from the receiver shall be measured. Equipment with an external antenna connector shall be measured for both conducted spurious emission and cabinet radiation.

The equipment shall be measured for unwanted emissions from 25 MHz to ten times the carrier frequency, i.e. 25 GHz.

The radiation limits are given in table 4 below.

State	Below 1000 MHz	Above 1000 MHz
Receive	2nW = -57 dBm	20nW = -47 dBm

Table 4: EN 300 440 receiver spurious radiation requirements

8 ETSI EN 300 328

The ETSI EN 300 328 standard specifies in detail the requirements and test methods to be used for license-free operated radio equipment under class 3a, equipment using wideband modulation techniques (DSSS or FHSS). The following is a summary of the most important requirements. The complete document can be downloaded from www.etsi.org (direct link to search site: http://pda.etsi.org/pda/queryform.asp).

8.1 Modulation

The standard defines two categories of equipment based on modulation type:

- Frequency Hopping Spread Spectrum (FHSS)
- Direct Sequence Spread Spectrum (DSSS) and other digital modulation types.

Note that equipment using digital modulation types other than FHSS and DSSS are considered equivalent to DSSS when tested according to EN 300 328.

FHSS modulation shall make use of at least 15 non-overlapping channels, separated by the channel bandwidth as measured at 20dB below peak power. The dwell time per channel shall not exceed 0.4s, and every channel shall be occupied at least once during a period equal to 4 times the product of dwell time and the number of channels. Equipment that does not satisfy the above constraints is tested according to the requirements for DSSS systems.

8.2 Effective Isotropically Radiated Power (EIRP)

The maximum allowed radiated power (EIRP) is -10 dBW (100mW). This limit shall apply for any combination of power level and intended antenna.

8.3 Maximum spectral power density

The maximum spectral power density is defined as the highest power level in W/Hz generated by the transmitter within the power envelope.

Using FHSS the maximum spectral power density shall be –10dBW (100mW) per 100 kHz (EIRP).
Using other types of modulation the maximum spectral power density shall be –20dBW EIRP (10mW) per MHz.

8.4 Frequency range

The occupied bandwidth for a transmitted signal is defined by the power envelope limited by a spectral power density (EIRP) of –80 dBm/Hz. (Or –30 dBm if measured in a 100 kHz bandwidth).
The range of operating frequencies is limited so that the occupied bandwidth for any operating frequency falls within the allocated frequency range 2400 – 2483.5 MHz.

8.5 Transmitter and receiver spurious emission

The spurious emission is a measurement of unwanted emitted signals. The device shall be measured at maximum specified output power in transmit mode. Both narrowband and wideband emissions shall be measured. By narrowband emissions it is meant emissions that do not have a wideband modulated shape (for instance local oscillator leakage). For narrowband measurements the resolution bandwidth can be made as small as necessary to achieve a reliable result. Limits are shown in table 5 below.

Spur type	State	30 MHz – 1 GHz	1.8 – 1.9 GHz 5.15 – 5.3 GHz	Other frequencies 1 – 12.75 GHz
Narrowband	Operating TX	250 nW = -36 dBm	20 nW = -47 dBm	1 μW = -30 dBm
	Standby / RX	2 nW = -57 dBm	20 nW = -47 dBm	20 nW = -47 dBm
Wideband	Operating TX	-86 dBm/Hz (-36dBm if measured in a 100kHz BW)	-97 dBm/Hz (-47dBm if measured in a 100kHz BW)	-80 dBm/Hz (-30dBm if measured in a 100kHz BW)
	Standby / RX	-107 dBm/Hz (-57dBm if measured in a 100kHz BW)	-97 dBm/Hz (-47dBm if measured in a 100kHz BW)	-97 dBm/Hz (-47dBm if measured in a 100kHz BW)

Table 5: EN 300 328 spurious radiation requirements

9 ETSI EN 300 761

The ETSI EN 300 761 standard specifies in detail the requirements and test methods to be used for Short Range Devices used in Automatic Vehicle Identification (AVI) for railways in the 2.4 GHz band under class 4a. For information about regulations for this specific application please refer to the EN 300 761 standard, which can be downloaded from http://www.etsi.org (direct link to search site: http://pda.etsi.org/pda/queryform.asp).

10 ETSI EN 301 489

ETSI EN 301 489 is a series of harmonised standards on electromagnetic compatibility (EMC) and radio spectrum matters that can be used for testing of SRD transmitters and receivers. Part 3 has special relevance to SRDs. The complete documents can be downloaded from www.etsi.org. (Direct link to search site: http://pda.etsi.org/pda/queryform.asp).

The old EN 300 683 and the new EN 301 489 are both harmonised standards, meaning that both can be used to show compliance for SRDs. However, EN 300 683 will probably be obsolete by 2005, so it is recommended to follow EN 301 489. The main difference is that immunity testing is extended from 1 GHz to 2 GHz in the new standard.

The equipment shall be tested for both RF immunity and RF emission. The immunity testing characterizes the equipment's ability to withstand externally imposed electromagnetic radiation.

10.1 Test conditions

The frequencies at which SRDs are intended to operate are excluded from all the conducted and radiated RF immunity and emission tests for transmitters. No exclusion bands apply for receiver emission measurements.

For the 2.4GHz band there are no defined exclusion band for receiver immunity, since the immunity testing specifies an RF electromagnetic field in the 80 MHz to 2 000 MHz frequency range.

For transmitters operating in a channelised frequency band, the exclusion band is three times the maximum occupied bandwidth. For wideband transmitters the exclusion band is twice the intended operating band.

10.2 Performance criteria

Different performance criteria are defined for different types of equipment depending on the result of too low performance: 1) physical risk to persons or goods, 2) inconvenience to persons, which simply cannot be overcome by other means, and 3) inconvenience to persons which can simply be overcome by other means (e.g. manual) (refer to classifications in EN 300 220).

For type 1 and 2, there shall be no loss of functions during continuous phenomena, there may be loss of function during transient phenomena, but these shall be self-recoverable after the test. The performance requirement is stronger for type 1 than for type 2.

For type 3, there may be loss of function during transient or continuous phenomena, but this should be recoverable by the user. There shall be no degradation of performance after the test for any of the classes.

10.3 Emission and immunity tests

Several phenomena are to be tested. The applicability of the tests depends on the category of equipment usage: as base station, mobile or portable use.

For emission tests the phenomena are:

- Radiated emission (from enclosure)
- Conducted emission (DC power I/O and AC mains I/O)
- Harmonic current emission (AC mains input)
- Voltage fluctuations and flicker (AC mains input)
- Conducted emission (telecommunication port)

For immunity tests the phenomena are:

- RF EM field, 80-2000 MHz (at enclosure)
- Electrostatic discharge, ESD (at enclosure)
- Fast transients, common mode (signal, DC and AC ports)
- RF common mode, 0.15-80 MHz (signal, DC and AC ports)
- Transients and surges (DC input)
- Voltage dips and interrupts (AC input)
- Surges, common and differential mode (AC input)

For portable equipment these tests are applicable: Radiated emission, RF EM field immunity and ESD.

For mobile equipment these tests are applicable: Radiated and conducted emission, RF EM immunity, ESD, RF common mode, transients and surge.

For base stations all tests apply, except transients and surges at DC input.

10.4 Emission test limits

At 10 meter measuring distance the radiated emission test limits are as given in table 6 below.

Frequency range	Quasi-peak detector
30 – 230 MHz	30 dBμV/m
230 - 1000 MHz	37 dBμV/m

Table 6: EN 301 489 emission test limits

10.5 Immunity test limits

The test level for RF EM immunity shall be 3V/m (measured unmodulated), with 80% AM modulation at 1 kHz, performed over the frequency range 80 – 1000 MHz and 1400 – 2000 MHz (except exclusion bands). The test method shall be in accordance with EN 55022.

The ESD test limits are +/-4kV for contact discharge, and +/-8kV for air discharge. The ESD shall be applied to all surfaces, except the centre pin of shielded RF connectors (should be specified in the user documentation). The test method shall be in accordance with EN 61000-4-2.

11 FCC Code of Federal Regulations, Title 47, Part 15

In the United States the Federal Communications Commission (FCC) is responsible for the regulation of all RF devices. RF products intended for unlicensed operation is regulated by CFR 47, Part 15.
A product intended for unlicensed operation has to be subjected to compliance testing. If the product is approved the FCC will issue an identification number. The final product has to be marked with an FCC identification label (ref. CFR 47, Part 2.925, part 2.926 and part 15.19).

The specific frequency bands used for unlicensed radio equipment are regulated by section 15.247 and 15.249 for the 2.4 GHz band.

General rules for certification measurements are found in section 15.35. Restricted bands and general limits for spurious emissions are found in sections 15.205 and 15.209.

The entire CFR can be downloaded from the web at www.gpoaccess.gov/cfr/index.html.
Direct links to each section can be found at
www.access.gpo.gov/nara/cfr/waisidx_03/47cfr15_03.html.

The following table summarizes the regulations for unlicensed operation within the 2.4 GHz band.

Frequency band	Max Peak Output power	Duty cycle limits	Measurement method fundamental power	Spurious emissions
2400 – 2483.5 MHz **Part 15.247** (See limitations given below)	**1W** (FHSS with at least 75 hop channels, and other digital modulation systems) **0.125W** (FHSS systems with less than 75 hop channels) Output power delivered to antenna with maximum 6dBi antenna gain. Output power must be reduced for higher antenna gains. (See 15.247b.4) The spectral density of digital modulation systems (not including FHSS) shall not exceed 8dBm/3kHz. The minimum 6dB bandwidth of such systems is 500kHz.	**No restriction**	**Average detector**	In any 100kHz bandwidth outside the operating band the power level shall be at least 20dB below the level in the 100kHz bandwidth with the highest power level in the operating band. Attenuation below limits given in 15.209 is not required. In addition emission that fall within restricted bands (15.205) must meet general limits given in 15.209 and shown below.
2400 – 2483.5 MHz **Part 15.249**	**50mV/m at 3m = 0.75 mW (-1.25 dBm)** Frequency tolerance of carrier better than ± 0.001% for temperatures -20°C to +50°C with normal supply voltage, and supply voltages from 85 to 115% of normal supply at 20°C.	**No restriction**	**Average detector**	Max field strength of harmonics 500 μV/m at 3m =75nW Emissions outside specified band (except harmonics): The highest value of -50dBc or general limits given below (15.209). General emission limits (15.209): <200 μV/m at 3m below 960 MHz (-49.2 dBm), <500 μV/m at 3m above 960 MHz (-41.2 dBm).

Table 7: FCC CFR47 part 15 regulations for unlicensed operation in the 2.4 GHz band

11.1 Equipment classified under section 15.247

Section 15.247 did previously only cover equipment using spread spectrum modulation techniques, i.e. FHSS (Frequency Hopping Spread Spectrum) or DSSS (Direct Sequence Spread Spectrum). As of June 2002 section 15.247 were opened up to cover a wider class of equipment by replacing the term “DSSS” with the term “Digital modulation”, and removing the requirement of 10dB coding gain (processing gain).
As a result section 15.247 does now cover equipment using FHSS or other digital modulation techniques with 6dB bandwidth of at least 500 kHz (including DSSS).
FHSS equipment classified under 15.247 shall have hop channel frequencies separated by whichever is largest of 25kHz or the 20dB bandwidth of the hop channel. At least 15 non-

overlapping channels shall be used, and hop frequencies shall be selected in a pseudo-random order. Every channel shall be used equally on average, and the average dwell time shall not exceed 0.4 seconds within a period of 0.4 seconds times the number of channels. FHSS systems with less than 75 hop channels can employ intelligent hopping, e.g. adaptive frequency hopping.
SRD equipment used in the 2.4 GHz band that does not fall within the 15.247 definition is classified under section 15.249.

11.2 Measurement methods

Contrary to the European regulations the US regulations are in most cases specified in terms of field strength, not power. The field strength shall be measured at 3 meters from the device under test.

The field strength can be converted into an Effective Isotropic Radiated Power (EIRP) using the following formula:

$$P_{EIRP} = 10\log(1000\frac{E^2 r^2}{30}) \quad [dBm]$$

Where E is the field strength in V/m and r is the distance (radius) in m.

Furthermore, the type of detector and measurement bandwidth is specified. This can be very important (and useful) for averaging effects when using pulsed transmissions. Part 15.35 outlines the general rules: A CISPR quasi-peak detector shall be used below 1 GHz, and an averaging detector shall be used above 1 GHz.

The CISPR quasi-peak detector is defined in Publication 16 of the International Special Committee on Radio Interference (CISPR) of the International Electrotechnical Commission (IEC). The quasi-peak detector is a peak detector with an attack time of 1 ms, a decay time of 500 ms and a 6dB bandwidth of 120 kHz.

When using a regular spectrum analyser without the quasi-peak detector option, the peak detector option can be used instead. For continuous wave (CW) or narrowband signals (here meaning less than 120 kHz bandwidth), the result will be the same as for the quasi-peak detector. For pulsed transmissions it will be a worst-case scenario because the small averaging effect of the quasi-peak detector is not exploited. When performing peak detector measurements the spectrum analyser should be set up with resolution bandwidth (RBW) = 120 kHz, and video bandwidth (VBW) = 300 kHz, and the detector type selected shall be ‘peak’ (usually default). If RBW = 120 kHz is not available on the spectrum analyser, using the next higher resolution bandwidth (usually 300 kHz) is a conservative choice.

When using an averaging detector a minimum bandwidth of 1 MHz shall be employed, and the measurement time shall not exceed 100 ms. For pulsed transmissions the averaging shall be done over a complete pulse train, including blanking interval. If the transmitter operates for longer than 100ms the averaging shall be done over a 100ms interval where the field strength is at its highest. Due to the averaging detector pulsed transmissions are allowed higher peak fundamental, harmonic and spurious power. This is a benefit for duty-cycled transmissions.
When an averaging detector is called for, there is also a limit on emissions measured using a peak detector function with a limit 20 dB above the average limit. This will define the maximum output level for transmissions with very short active intervals (low duty cycle).
The exact method of calculating the average field strength shall be submitted with the application for certification, or retained in the measurement data file for equipment subject to notification or verification.

When using a regular spectrum analyzer one way of generating an approximate average detector is to use a video bandwidth much lower than the lowest expected modulation frequency. Keep in mind that the linearity of the spectrum analyzer may limit the accuracy of

this measurement. The spectrum analyzer should be set up with resolution bandwidth (RBW) = 1 MHz, and video bandwidth (VBW) = 10 Hz, and the detector type selected should be 'peak' (usually default).

Some more insight regarding practical measurements can also be gained by using the "knowledge database" maintained by the FCC Office Of Engineering & Technology. A search site is found at: http://gullfoss2.fcc.gov/prod/oet/cf/kdb/index.cfm

11.3 General spurious emission requirements

Spurious emissions are unwanted emissions outside the intended transmission band except for harmonics.

The limit applies for the emission from transmitters outside their operating frequency band. For receivers and transceivers in continuous receive mode, it also applies inside their operating band, as they are defined as non-intentional radiations. Transceivers employing Time Division Duplex (TDD) can be treated as transmitters, and the spurious emission requirement do not apply inside the transmission band.

The general spurious emission limits are given in 15.209. The limits are also shown in figure 2 for the frequency range 100 – 2000 MHz.

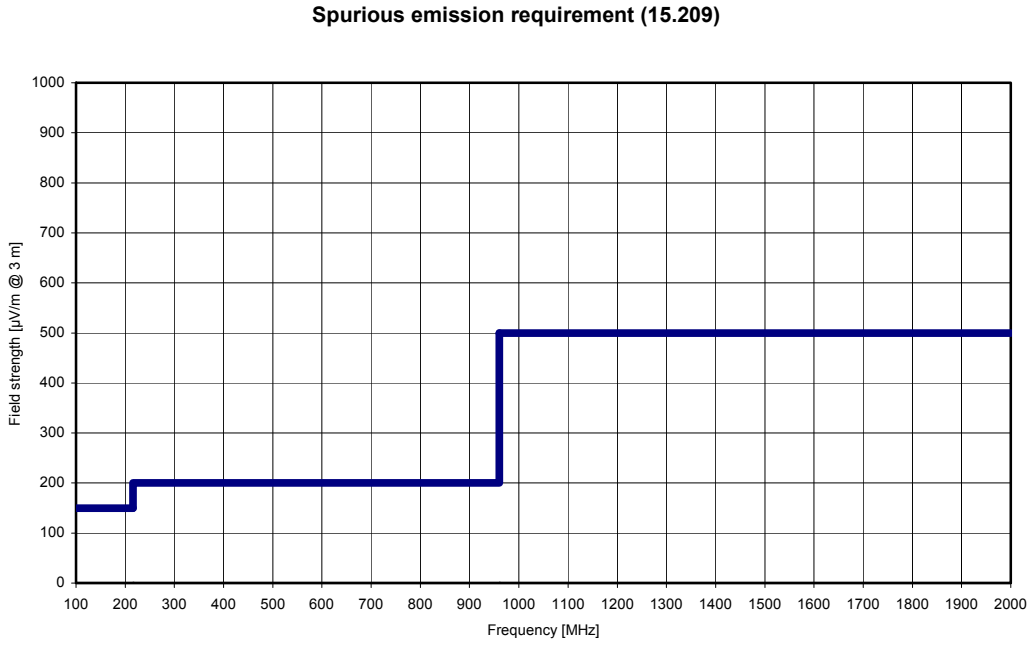

Figure 2: FCC part 15.209 spurious emission requirements

As mentioned in table 7 equipment classified according to part 15.247 are not required to meet the general spurious emission requirements, but rather a requirement relative to the intended transmission. However, equipment operating under part 15.247 must meet the general requirements for frequencies falling within the restricted bands described in part 15.205 and shown in table 8 below.

MHz	MHz	MHz	GHz
0.090-0.110	16.42-16.423	399.9-410	4.5-5.15
0.495-0.505	16.69475-16.69525	608-614	5.35-5.46
2.1735-2.1905	16.80425-16.80475	960-1240	7.25-7.75
4.125-4.128	25.5-25.67	1300-1427	8.025-8.5
4.17725-4.17775	37.5-38.25	1435-1626.5	9.0-9.2
4.20725-4.20775	73-74.6	1645.5-1646.5	9.3-9.5
6.215-6.218	74.8-75.2	1660-1710	10.6-12.7
6.26775-6.26825	108-121.94	1718.8-1722.2	13.25-13.4
6.31175-6.31225	123-138	2200-2300	14.47-14.5
8.291-8.294	149.9-150.05	2310-2390	15.35-16.2
8.362-8.366	156.52475-156.52525	2483.5-2500	17.7-21.4
8.37625-8.38675	156.7-156.9	2655-2900	22.01-23.12
8.41425-8.41475	162.0125-167.17	3260-3267	23.6-24.0
12.29-12.293	167.72-173.2	3332-3339	31.2-31.8
12.51975-12.52025	240-285	3345.8-3358	36.43-36.5
12.57675-12.57725	322-335.4	3600-4400	Above 38.6
13.36-13.41			

Table 8: FCC part 15.205 restricted bands of operation

11.4 Antenna restrictions

The transmitting device must be designed to ensure that no antenna other than that furnished by the responsible party shall be used with the device (section 15.203). Either the antenna must be integrated, permanently attached, or a unique connector must be used. The connector could be a reverse polarity SMA.

12 ARIB STD-T66

In Japan the unlicensed use of short range devices in the 2.4GHz ISM band is regulated by The Association of Radio Industries and Businesses (ARIB) standard STD-T66: “Second generation low power data communication system/Wireless LAN system”. The term “second generation” is included to distinguish these systems from existing equipment in the 2.471-2.497MHz band covered by ARIB standard RCR STD-33.

12.1 General conditions

The communication method is limited to digital signals (including spread spectrum). Communication is simplex, half-duplex or duplex. The main purpose of communication is transmission of digitized signals, and the allowed frequency band is 2.400 to 2.4835 GHz.

12.2 Transmitter parameters

Modulation is either spread spectrum (DSSS, FHSS or a hybrid of the two), or other digital modulation including amplitude modulation, frequency modulation, phase modulation or a mixture of these.

Average antenna power is limited to:

a) 3mW measured in a 1MHz bandwidth for FHSS or hybrid FHSS/DSSS systems using frequencies between 2.427and 2.47075 GHz.
b) 10mW measured in a 1MHz bandwidth for FHSS or hybrid FHSS/DSSS systems not using frequencies between 2.427and 2.47075 GHz.
c) 10mW measured in a 1MHz bandwidth for DSSS systems.
d) 10mW measured in a 1MHz bandwidth for systems not using spread spectrum.

Antenna power shall be within +20% and –80% of rated value.

Frequency tolerance shall be within ±50ppm of rated frequency.

Average power of spurious emissions (outside the specified 2.4 GHz band) provided through the antenna feed line shall be below:

a) 25mW (-16dBm) for 2.387GHz < f < 2.400GHz and 2.483 GHz < f < 2.4965 GHz.
b) 2.5mW (-26dBm) for 2.387 GHz > f and 2.4965GHz < f.

The spurious requirements are shown in figure 3.

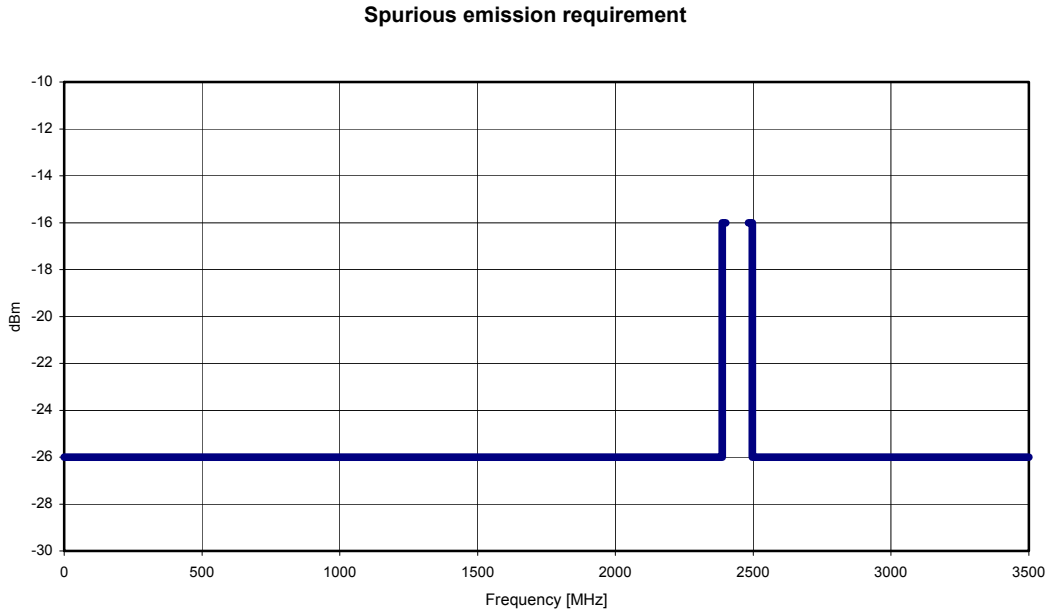

Figure 3: ARIB STD-T66 Spurious emission requirements

The required frequency bandwidth is limited by:
a) 83.5MHz for FHSS or hybrid FHSS/DSSS systems.
b) 26MHz in other systems.

The spreading bandwidth shall be 500kHz or more in spread spectrum systems. The spreading bandwidth is defined as the bandwidth containing 95% of the average radiated power.

The spreading factor (spreading bandwidth divided by frequency equivalent to transmission speed of modulating signal) shall be 5 or more.

The duration of power being emitted at a certain frequency in a FHSS or hybrid FHSS/DHSS system shall be 0.4 seconds or less.

12.3 Receiver parameters

Secondary emitted radiation is limited to 4nW (-54dBm) for frequencies below 1GHz and 20nW (-47dBm) for frequencies above 1GHz. When performing a conducted measurement the antenna load seen by the receiver shall have the same electrical properties as the receiving antenna.

Other receiver parameters are not specifically regulated.

12.4 Antenna

The antenna absolute gain shall be 2.14dB or less.
When EIRP is less than that of the maximal antenna power plus the 2.14dB antenna gain, the antenna gain can be increased to make up for the decline in EIRP.

12.5 Other parameters

ARIB STD T-66 does also specify requirements for control equipment (Section 3.4), connection of radio equipment to public telecommunication network (Section 3.5) and equipment housing (Section 3.7). Please refer to the ARIB standard for details.

13 General Information

13.1 Document History

Revision	Date	Description/Changes
1.0	2005-01-19	Initial release.

13.2 Disclaimer

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Compliance with regulations is dependent on complete system performance. It is the customer's responsibility to ensure that the system complies with regulations.

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