

AN001**SRD regulations for licence free transceiver operation**By P. M. Evjen

Keywords

- CEPT recommendations
- ETSI standards
- R&TTE directive
- Part 15 devices
- Type approval
- Equipment testing
- Operating frequency below 1GHz

Introduction

International regulations and national laws regulate the use of radio receivers and transmitters, including short-range devices (SRDs). This document is a summary of the most important aspects of these regulations for licence free operation for radio receivers and transmitters, for operation below 1GHz.

Although the operation of transceivers in certain frequency bands is licence free,

the product itself has to be type approved or meet certain requirements. The type approval procedures will also be reviewed in this document.

Chipcon is a worldwide distributor of transceiver chips designed to comply with the specifications discussed in this document.

Regulations overview

The use of radio equipment in the European Union (EU) is regulated through the R&TTE directive. This directive sets the general essential requirements. The actual standards to follow are written by standardisation bodies like CEPT and ETSI.

The CEPT is an organ for the PTT (post-telephone -telegraph) authorities in the European countries and is responsible for the use of frequencies and output power. This is described in the ERC recommendation CEPT/ERC/70-03. In the present document we review the regulations for the 433 MHz and the 868 MHz bands.

ETSI is working on standards for the conformity testing and for transmitters and receivers. Detailed specifications and testing methods are outlined. Several standards cover the different frequency ranges:

EN 300 220 covers 25 MHz – 1 GHz

EN 300 330 covers 9 kHz – 25 kHz

EN 300 440 covers 1 – 25 GHz

Radio transmitters and transceivers must also meet EMC requirements outlined in EN 300 683 or EN 301 489-3, as well as safety requirements.

In the United States the legal issues governing the manufacturing and sale of RF products for unlicensed operation is regulated under the FCC (Federal Communications Commission) CFR47, Part 15. In the present document we review the regulations for the 260-470 MHz and 902-928 MHz band.

This application note does not cover the rest of the world. The local governing body should always be contacted before development starts in order to have a clear picture of the local rules. FCC maintains a list of PTT governing bodies at 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.

CEPT ERC RECOMMENDATION 70-03E

A summary of the recommendations for the 433 MHz and 868 MHz band SRDs follows based on the February 2002 edition. The complete document can be downloaded from www.ero.dk. Direct links to documents and other useful links from CEPT can be found at <http://www.ero.dk/EROWEB/SRD/SRD-index.htm>.

Class	Frequency band	Power e.r.p.	Duty cycle (max)	Channel spacing	Comments
1e	433.050-434.790	10mW	10%	No channel spacing specified	Harmonised band
1e1	433.050-434.790	1mW -13dBm/10kHz	100%	No channel spacing specified	Audio and voice signals should be avoided
1e2	434.040-434.790	10mW	100%	25kHz	Audio and voice signals should be avoided
10c	863.000 –865.000	10mW	100%	200kHz	Consumer radio microphones
13a	863.000 –865.000	10mW	100%	No channel spacing specified (300kHz for analogue systems)	Wireless audio (cordless loudspeakers and headphones) Integrated antenna only
13b	864.800-865.000	10mW	100%	50kHz	Narrow band analogue voice
1f	868.000 - 868.600	25mW	1%	No channel spacing specified	
7a	868.600 - 868.700	10mW	0.1%	25kHz or 1 channel wideband	Alarms in general
1g	868.700 - 869.200	25mW	0.1%	No channel spacing specified	
7d	869.200 - 869.250	10mW	0.1%	25kHz	Social Alarms
7b	869.250 - 869.300	10mW	0.1%	25kHz	Alarms in general
1h	869.300 – 869.400	10mW	100%	25kHz	
1i	869.400 - 869.650	500mW	10%	25kHz. Or one broadband channel	
7c	869.650 - 869.700	25mW	10%	25kHz	Alarms in general
1k	869.700 - 870.000	5mW	100%	No channel spacing specified	

e.r.p. = effective radiated power

Alarm systems

Specific sub-bands are recommended exclusively for alarm systems (indicated in the rightmost column above).

Audio applications

Specific sub-bands are recommended for audio systems (indicated in the rightmost column above). We do not recommend the 433MHz band for such applications, even though a few national regulations still allow 100% duty cycle in this band.

Antenna

The antenna shall be an integrated 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 last case we recommend the use of a reversed polarity SMA.

Channel spacing

No specified channel spacing means that the whole 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 requirements are met.

Licensing

If the product is conforming to the relevant requirements, no license is required to operate these products.

Product marking

The product shall be marked indicating which class the equipment is designed for. For example, SRDs in the 433 MHz band could be "1e". Further instructions for marking are given in the R&TTE directive (see below).

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. *Advisory* limits are:

Duty cycle categories	Maximum "on" time [sec]	Minimum "off" time [sec]
0.1 %	0.72	0.72
1 %	3.6	1.8
10 %	36	3.6

Special national restrictions

The national authorities have stated some restrictions to the implementation of this recommendation. Some of these are given below. Please contact your national telecommunication authorities for full details, or see ERC/REC70-03E Appendix 3.

Estonia, Finland, Italy, Latvia, Luxembourg and United Kingdom:

Audio and voice are not allowed in the 433.050-434.790 MHz band.

France, The Netherlands:

No duty-cycle limit in the band 433.050-434.790 MHz.

Germany:

Audio and voice are not allowed in the 868.000-868.600, 868.700-869.200, 869.400-869.650 and 869.700 –870.000 MHz bands.

Sweden:

In the 433.050-434.790 MHz band 25mW is currently allowed.

R&TTE Directive

The Radio Equipment and Telecommunications Terminal Equipment (R&TTE) Directive, 1999/5/EEC, 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/en/lif/dat/1999/en_399L0005.html

Essential requirements

The DoC shall declare that the *essential requirements* of the directive are met. The essential requirements for radio equipment (RE) can be summarized as:

- 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 new 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.

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),
- based on a technical construction file (TCF, annex IV)
- based on full quality assurance by having an accredited quality system (annex V).

Most manufacturers of SRDs in the 25-1000 MHz range will follow the procedure in annex III, using harmonised standards. The applicable harmonised standards are EN 300 220 (for use of radio spectrum), 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. Note however that complying with a harmonised standard does not ensure that a product meets the essential requirements, 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. In addition the technical documentation must be kept for 10 years after the last product was manufactured.

Equipment marking

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

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 July 2003 only band, 1e (433.050 - 434.790 MHz, 10% duty cycle) is harmonised. Most bands at 868 – 870 MHz are “nearly harmonised”, meaning that only one or two administrations within EEA has not implemented the bands. Further information on harmonised bands can be found at www.ero.dk.

ETSI EN 300 220

The ETSI EN 300 220, which is a harmonised European Norm, specifies in detail the requirements and test methods to be used for declaration of conformity of licence-free operated radio equipment. The following is a summary of the most important requirements. The complete document can be downloaded from www.etsi.org.

One important thing to notice is the classification of receivers. Class 1 and 2 receivers refer to SRDs where mal-function may result in a physical risk to a person, or causing inconvenience to a person, which cannot simply be overcome by other means, respectively. Class 3 receiver equipment mal-function, could cause inconvenience to a person, which can simply be overcome by other means. Selectivity and blocking requirements are much stricter for class 1 and 2 than for class 3 (see below).

Frequency error (section 8.1)

The maximum frequency error depends on the type of use; base/mobile or portable, and of the channel separation. The requirement applies only when channel spacing is specified.

Frequency band	10/12.5kHz channel spacing	20/25 kHz channel spacing	Comment
300-500 MHz	1 / 1.5 / 2.5	2 / 2 / 2.5	Figures is in kHz for base/mobile/portable
500-1000MHz	N.A.	2.5 / 2.5 / 3	

Carrier power, conducted (section 8.2)

This requirement applies for equipment with external antenna connector. The maximum power depends on the equipment class. The maximum output power allowed is given by the ERC/DEC 70-03E recommendation (see above).

Effective radiated power (section 8.3)

This requirement applies for equipment with dedicated or integral antenna. The test method is different from equipment with external antenna connector, but the test limits are the same as above.

TX modulation (section 8.4)

This test applies to analogue speech systems only (FM and AM).

Adjacent channel power (section 8.5)

The adjacent channel power (ACP) test is applicable for equipment operating in bands with specified channel separation and bandwidths.

For 25 kHz channel spacing, which is the narrowest channel spacing used in the 868MHz band, the test receiver bandwidth and filter shape for the adjacent channel is specified as follows:

Offset kHz	Attenuation dB
6	-2
8	-6
9.25	-26
13.25	-90

There are special test instruments made for this kind of measurements, having the filter shape specified above, for example the Rhode & Swartz test receiver CMTA 84. However, a spectrum analyser can also be used, giving a somewhat "pessimistic" result, as the filters are normally not as steep as required. For 25 kHz channel spacing, the measurement bandwidth should be set to 16 kHz, at +/- 25 kHz offsets, in order to measure the upper and lower ACP

respectively. The test should be done using test modulation patterns D-M3 (package) or D-M2 (data stream).

The ACP requirement for 25kHz channel spacing is 200nW = -37dBm for normal test conditions, and 640nW = -32dBm for extreme test conditions.

Modulation bandwidth for wideband equipment (>25kHz) (section 8.6)

This test is applicable when no channel spacing is specified, or channel spacing is larger than 25kHz.

The latest version of the standard states that the test laboratory shall ensure that the spectrum analyser's span and bandwidth are sufficiently wide, and scan time sufficiently slow, to ensure that the emission and all its major modulation side bands are captured. A good starting point is to measure the power envelope with a spectrum analyser, RBW = 100 Hz, VBW = 10 kHz, using the maximum hold display function. The bandwidth is defined as the bandwidth of the power envelope where the power is above the required spurious level. The spurious level limit is 250nW = -36dBm.

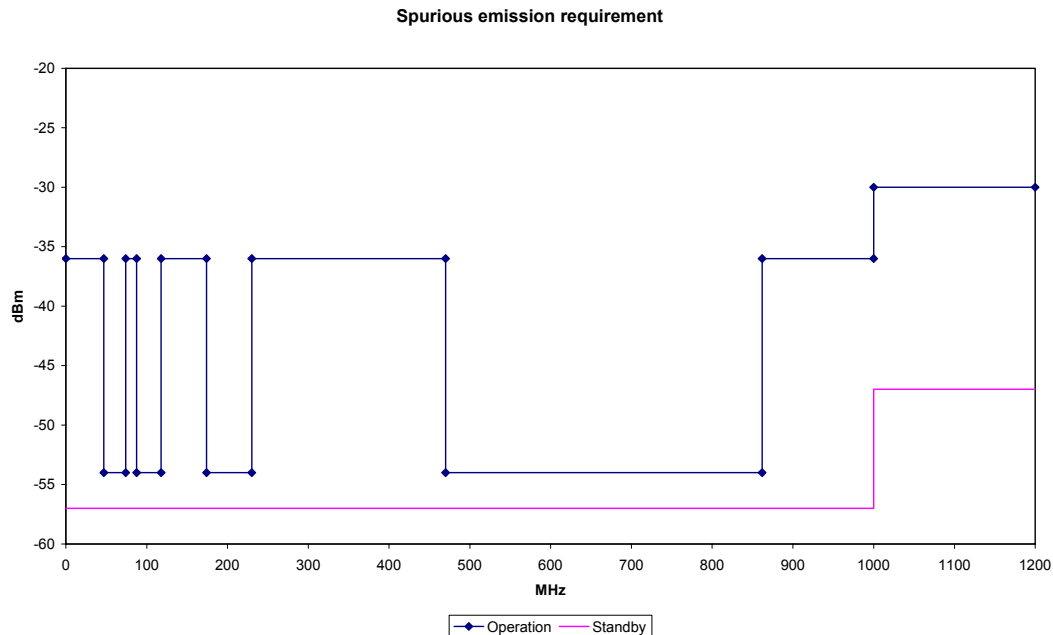
Spurious emission (section 8.7)

The spurious emission is a measurement of unwanted emitted signals. The device shall be measured without modulation applied.

If the carrier frequency is < 470 MHz the equipment shall be measured for unwanted emissions from 9 kHz to 4 GHz. If the carrier frequency is >470 MHz, the upper limit is 12.75 GHz. Measurements below 1 GHz shall be done with a quasi-peak detector, and a peak detector above 1 GHz. If using a spectrum analyser the bandwidth shall be 100 kHz.

All spurs except emission at the intended channel and the adjacent channels shall be measured. The requirements are given in the table, and illustrated in the figure below.

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



Frequency stability for low voltage battery operation (section 8.8)

This requirement applies for battery-operated equipment only.

The requirement is that when reducing the operating voltage to zero, the equipment should stay on the desired frequency, or cease to function altogether.

Duty cycle (section 8.9)

This requirement states the transmitter on/off ratio measured during 1 hr period. The duty cycle ratio for each frequency band is given by the ERC/DEC 70-03E recommendation (see above).

Receiver requirements (section 9.1 – 9.3)

Adjacent channel selectivity (section 9.1), adjacent band selectivity (section 9.2) requirements apply only to class 1 receivers. Blocking and desensitisation (section 9.3) requirement applies only to class 1 and 2 receivers. For class 3 receivers covering most SRDs, these requirements do not have to be met.

Receiver spurious radiation (section 9.4)

For equipment with 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.

If the carrier frequency is < 470 MHz the equipment shall be measured for unwanted emissions from 9kHz to 4 GHz. If the carrier frequency is >470 MHz, the upper limit is 12.75 GHz.

The radiation limit is given in the table below.

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

ETSI EN 301 489

The ETSI EN 301 489 is a series of harmonised standards on electromagnetic compatibility 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.

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, the EN 300 683 will probably be obsolete by 2005, so it is better to use the EN 301 489. The main difference is that immunity testing is extended to 2 GHz in the new standard.

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

Test conditions

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

The exclusion band for receiver immunity used in a channellised frequency band depends on the equipment class. The exclusion band is ± 10 MHz or $\pm 2\%$, ± 15 MHz or $\pm 5\%$, ± 15 MHz or $\pm 10\%$, whichever is greater, for equipment class 1, 2 and 3 respectively.

The exclusion band for wide band receiver immunity (i.e. not used in a channellised frequency band) is the band limit \pm the following extension values: ± 10 MHz or $\pm 2\%$, ± 15 MHz or $\pm 5\%$, ± 15 MHz or $\pm 10\%$, whichever is greater, for equipment class 1, 2 and 3 respectively.

For transmitters operating in a channellised frequency band, the exclusion band is three times the maximum occupied bandwidth. For wide-band transmitters the exclusion band is twice the intended operating band.

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.

Emission and immunity tests

Several phenomena are to be tested. The application of the tests depends on the equipment use: 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.

Emission test limits

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

Frequency range	Quasi-peak
30 – 230 MHz	30 dB μ V/m
230 - 1000 MHz	37 dB μ V/m

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 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).

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. CFR 47, Part 15, regulates RF products intended for unlicensed operation. A product intended for unlicensed operation has to be subject to compliance testing. If the product is approved, the FCC will issue an identification number. The final product has to be marked with a FCC identification label (ref. CFR 47, Part 2.925 and 2.926).

Section 15.231 for the 260-470 MHz band, and sections 15.247 and 15.249 for the 902-928 MHz band regulate the specific frequency bands used for unlicensed radio equipment.

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 CFR47 can be downloaded from the web at www.access.gpo.gov/nara/cfr. Direct links to each section can be found at http://www.access.gpo.gov/nara/cfr/waisidx_01/47cfr15_01.html.

The following table summarises the regulations for unlicensed operation below 1 GHz.

Frequency band	Output power	Duty cycle limits	Measurement method fundamental power	Spurious emissions
260 – 470 MHz (15.231), except: 240 – 285 MHz 322 – 335.4 MHz 399.9 – 410 MHz (15.205)	Frequency dependent, see text 6 mV/m at 3 m or -19.6 dBm EIRP* at 315 MHz 11mV/m at 3 m or -14 dBm EIRP* at 433 MHz	YES, see text	Average detector or CISPR quasi-peak detector (15.231)	<200 μV/m at 3 m below 960 MHz (-49.2 dBm), <500 μV/m at 3 m above 960 MHz (-41.2 dBm). Use quasi-peak detector below 1 GHz, and use averaging detector above 1 GHz. (15.35, 15.209)
902 – 928 MHz (15.249)	50mV/m at 3 m or -1 dBm EIRP*	NO	CISPR quasi-peak detector (15.35)	
902 – 928 MHz, spread spectrum (15.247)	0.5 W or 1 W depending on spreading technique plus a 6 dBi antenna	NO		

* The actual specification is limiting the field strength. Here the field strength is converted to dBm EIRP (Effective Isotropic Radiated Power).

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 equivalent Effective Isotropic Radiated Power (EIRP) using the following formula:

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

where E is the field strength in V/m and r is the distance 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 gives 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 an IF filter setting of 100 kHz.

Using a regular spectrum analyser without the quasi-peak detector option, a normal peak detector can be used instead. For continuous wave (CW) or narrow band 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. Doing 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 should be 'peak' (usually default). If RBW = 120 kHz is not available on the spectrum analyser, use 100 kHz.

The *averaging detector* shall employ a pre-detection minimum bandwidth of 1 MHz, and the measurement time shall be maximum 100 ms. Furthermore, 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.

Using a regular spectrum analyser, an average detector means using a video bandwidth much less than the resolution bandwidth. The spectrum analyser 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).

For pulsed transmissions the averaging detector therefore allows higher peak fundamental, harmonic and spurious power. This is a benefit for duty-cycled transmissions (pulse trains), and can be exploited in the 260 – 470 MHz band.

If the duty cycle factor of the periodic signal is known, measuring the peak value and adding a relaxation factor can determine the average value. The peak measurement should in this case be done using 1 MHz RBW and 1 or 3 MHz VBW. The relaxation factor is $20 \log (TX \text{ on-time}/100 \text{ ms})$ [dB].

General spurious emission requirements (15.209) and restricted bands (15.205)

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

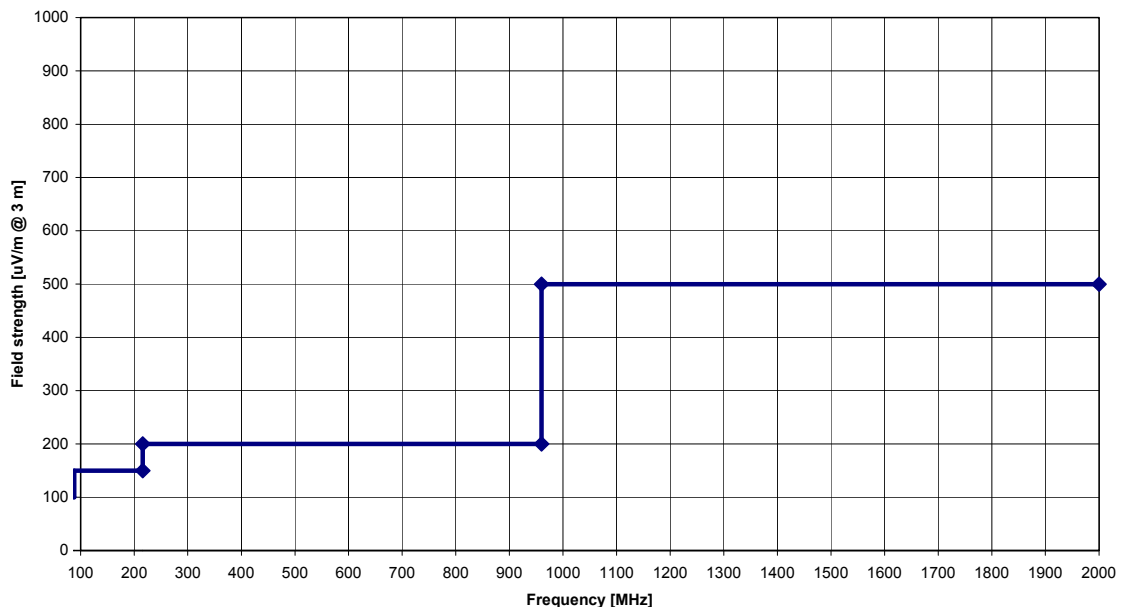
The limit applies for the emission of transmitters outside their operating frequency band. For receivers and transceivers in continuous receive mode, it applies also inside their operating band, as they are defined as non-intentional radiations. Transceivers doing Time Division Duplex (TDD) can be treated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

There are some restricted bands inside the 260-470 MHz band where only spur emissions are permitted (15.205). The field strength emission level in the restricted bands shall not exceed the limits given in the table below (15.209).

Restricted band	Quasi-peak detector measurement limit
240 – 285 MHz	200µV/m at 3 m distance
322 – 335.4 MHz	
399.9 - 410	

The general limits are given in 15.209 and shown in the graph below for 100 – 2000 MHz.

Spurious emission requirement (15.209)



The 260 – 470 MHz band (15.231)

For the 260-470 MHz band the FCC does not only regulate the fundamental power, harmonic levels and allowed bandwidth, but also considers the data being sent, and their intended function (15.231).

Under part 15.231 it is allowed to transmit

- control or command signals,
- recognition / ID codes
- radio control signals during emergencies.

It is not allowed to

- control toys
- do continuous transmissions such as voice or video

If the transmission is activated manually, the operation must cease within 5 seconds of switch being released. If the transmission is activated automatically, it must cease within 5 seconds of activation. Periodic transmissions at regular predetermined intervals are not permitted. However, periodic polling or supervision of transmitters used in security or safety applications are allowed if the periodic rate of transmission does not exceed one transmission of not more than one second duration per hour for each transmitter.

The maximum allowed fundamental field strength in the 260 – 470 MHz band is increasing proportional and linear to the operating frequency, starting at 3750 µV/m and ending at 12500 µV/m measured at 3 m distance. Since path loss (ref. Friis transmission equations) also increases in proportion to the frequency, the range performance will be equal across the band. This equation can be used to calculate the maximum field strength for a given frequency (µV/m at 3 m):

$$E = 41.6667 f - 7083.3333 \text{ } \mu\text{V/m, where } f \text{ is frequency in MHz}$$

In the restricted bands inside the 260-470 MHz band only spur emissions are permitted (15.205), as mentioned above.

The 15.231 calls explicitly for an *average detector* for fundamental power measurements, which is overruling the general statement in 15.35. However, the CISPR quasi-peak detector can be used as an alternative. The unwanted emissions below 1 GHz (as per 15.205 and 15.209) shall be measured using the CISPR quasi-peak detector. Above 1 GHz an averaging detector shall be used.

The maximum permitted unwanted emission level is 20 dB below the maximum permitted fundamental level.

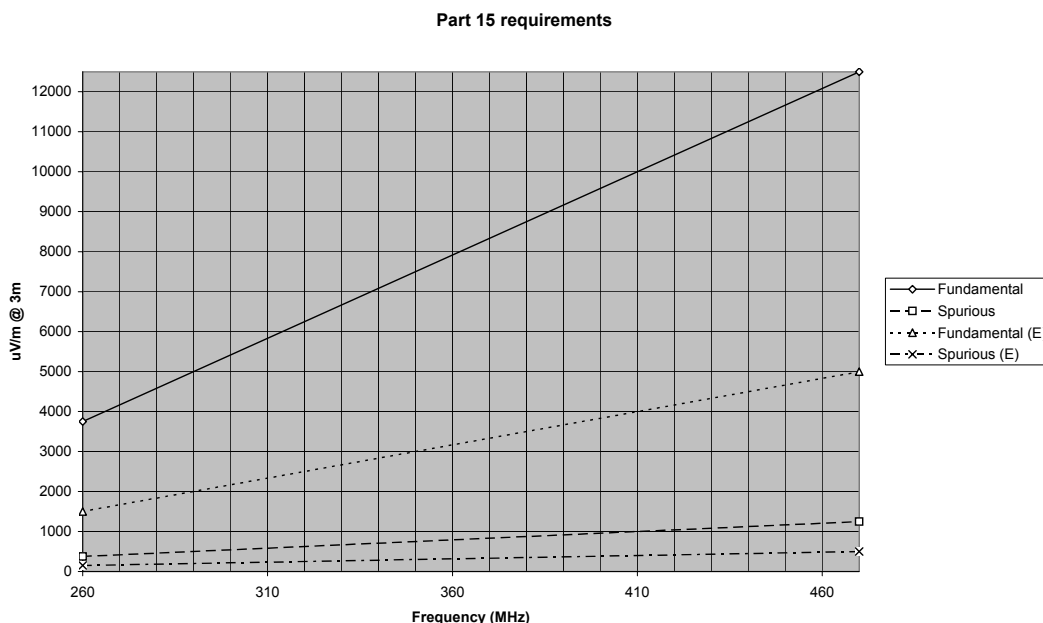
The bandwidth shall not be wider than 0.25% of the centre frequency. The bandwidth is determined at the points 20 dB down from the modulated carrier.

Devices may operate at a periodic rate exceeding that specified above, and may be employed for any type of operation, provided that (part 15.231 E):

- the fundamental field strength is reduced
- each transmission do not exceed 1 second
- minimum silent period is 30 times the duration of each transmission, but never less than 10 seconds
- The maximum fundamental field strength in the 260 – 470 MHz band is increasing proportional and linear to the operating frequency, starting at 1500 $\mu\text{V/m}$ and ending at 5000 $\mu\text{V/m}$ measured at 3 m distance, that is

$$E = 16.6667 f - 2833.3333 \text{ } \mu\text{V/m}, \text{ where } f \text{ is frequency in MHz}$$
- unwanted emission level is 20 dB below fundamental power

The field strength limits are illustrated in the figure below.



902 – 928 MHz band (15.247 and 15.249)

Most systems at 902 – 928 MHz are certified under Part 15.249. The regulations in this band are much simpler than for the 260 – 470 MHz band. There are no restrictions that limit the applications, the content or duration of a transmission. The freedom to send analogue voice and continuous data has made this band very popular and hence also congested.

For fundamental power the transmitter field strength is restricted to 50 mV/m at 3 meters distance (- 1 dBm EIRP) when spread spectrum is not used (15.249). The power shall be measured using a CISPR quasi-peak detector (15.35a).

Harmonics emission is restricted to 500 μ V/m at 3 meters distance (that is -40 dBc or -41 dBm). The power shall be measured using an average detector (15.35b), minimum 1 MHz bandwidth.

Spurious emission outside 902 - 928 MHz (other than harmonics) is set by the limit in 15.209, see above.

Frequency hopping systems (15.247a1) must use at least 50 hopping frequencies if the 20 dB bandwidth is < 250 kHz, having a duration of <0.4 s of a 20 s period, and maximum 1 W output power. For bandwidths >250kHz, at least 25 channels must be used, having a duration of <0.4 s of a 10 s period, and maximum 0.25 W output power. Maximum 20 dB bandwidth is 500 kHz.

Digital modulation systems (15.247a2) (for example direct sequence spread spectrum, DSSS) must have a minimum 6 dB bandwidth of 500 kHz, and maximum 1 W output power. Also the peak power spectral density shall not be greater than 8 dBm in any 3 kHz band (which is equivalent to 1W uniformly distributed over the 500 kHz bandwidth).

In addition to the maximum output power for spread spectrum systems (FH or digital modulation), an antenna with up to 6 dBi may be used.

Antenna restrictions

The transmitter 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.

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